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COST-EFFECTIVENESS OF FLIGHT SIMULATORS FOR MILITARY TRAINING

Volume II:

Estimating Costs of Training in Simulators and Aircraft

Joseph String
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August 1977

Prepared for

Office of the Director of Defense Research and Engineering

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION

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(U) Flight simulators cost less to operate than do aircraft; estimates range from 5 to 20 percent. Many studies have shown that skills learned in flight simulators can be performed successfully in aircraft, i.e., the use of flight simulators for training purposes saves flight time. The critical issue is whether the amount of flight time saved by the use of simulators is worth their cost. The cost-effectiveness of flight simulators for training has been demonstrated only in

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a few recent studies which report that the procurement cost of simulators can be amortized in a few years. Current R&D about flight simulators centers about the need for motion and wide angle visual display systems. Flight simulators have achieved their greatest use by the military so far in undergraduate flight training. Their greatest potential for future savings lies in transition and continuation training which account for the major costs of military flying. Consistent methods of data collection and cost estimating, not now available, are needed to evaluate the cost-effectiveness of alternative flight training programs, including the use of various types of simulators, part-task trainers, new instructional strategies, and the like. The report provides a preliminary cost model which identifies the data needed to develop cost estimates for use in cost-effectiveness analyses of flight training.

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400 Army-Navy Drive, Arlington, Virginia 22202

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ABBREVIATIONS

A/C	Aircraft
AFLC	Air Force Logistics Command
AFR	Air Force Regulation
AGE	Aerospace ground equipment
AIR	Designation of an office within the Naval Air Systems Command
ALC	Air Logistics Center
AN	Army/Navy; prefix to numbers identifying equipment in a common numbering system
AR	Army Regulation
ASARC	Army Systems Acquisition Review Council
ASW	Anti-submarine warfare
BOIP	Basis of issue plan
BOS	Base operating support
BY	Budget year
CGI	Computer generated imagery
CNAL	Commander, Naval Air Atlantic
CNAP	Commander, Naval Air Pacific
CNATRA	Chief of Naval Air Training
CNET	Chief of Naval Education and Training
CNETS	Service Division, Chief of Naval Education and Training

CNO	Chief of Naval Operations
CTEA	Cost and training effectiveness evaluation
CY	Current year
DASC	Department of the Army System Coordinator
DCS	Deputy Chief of Staff
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DP	Development proposal
DSARC	Defense Systems Acquisition Review Council
FM	Field manual
FOCA	Field Operating Cost Agency
FY	Fiscal year
IOC	Initial operational capability
IOT&E	Initial operational test and evaluation
M/D/S	Mission, Design, and Series (of an aircraft)
MILCON	Military construction
MILPERS	Military personnel
NATOPS	Naval Air Training and Operating Procedures Standarization
NAVAIR	Naval Air Systems Command
NAVOP	Designation of an office under the Chief of Naval Operations
NTEC	Naval Training Equipment Center
O&M	Operations and maintenance
O&S	Operations and support

OFT	Operational flight trainer
OPNAV	Designation of an officer under the Chief of Naval Operations and identification of materials (instructions, etc.) originating within offices of the Chief of Naval Operations
OR	Operational requirement
OSD	Office of the Secretary of Defense
OT&E	Operational test and evaluation
PCS	Permanent change of station
PEM	Program element monitor
PFT	Program flying training
PME	Prime mission equipment
PMTRADE	Program Manager, Training Devices
POL	Petroleum, oil, and lubricants
POM	Program Objective Memorandum
PY	Prior year
RDT/E	Research, development, test, and evaluation
ROC	Required operational capability
SAR	Selected Acquisition Report
SECNAVINSTR	Secretary of the Navy Instruction
SPO	System Project Office
STEP	Special Training Equipment Program: System Training Equipment Program
TAC	Tactical Air Command
TAD	Temporary additional duty
TAEG	Training Analysis and Evaluation Group
TAERS/TAMS	Army Integrated Equipment Record Maintenance Management System/Army Maintenance Management System

TDA	Tables of distribution and allowance
TDY	Temporary duty
T/M/S	Type, model, series (of an aircraft)
TOE	Tables of organization and equipment
u.e.	Unit equipment
USAF	United States Air Force

I. INTRODUCTION

A. BACKGROUND

This volume is part of a study on R&D related to the cost-effectiveness of flight simulators for military training. It is concerned particularly with a review of the methods and data needed to estimate the costs of flight training in simulators and in aircraft.

The cost-estimating methodology is set in the context of a weapon system model; that is, it addresses training for one type of aircraft. However, it can be expanded to incorporate a number of aircraft types simultaneously within the same basic estimating structure. Procedures for estimating costs of flying and simulation are developed to permit a trade-off between the two. Again, the model can be expanded, within its basic structure, to permit assessments of trade-offs among other training modes and devices, e.g., classroom training, part-task trainers and the like.

The remainder of this chapter presents a short discussion of cost/effectiveness analysis as a tool for assisting in comparisons among alternatives. This is followed by six chapters. The first discusses the nature, extent and costs of flying for training purposes and derives definitions of flight training and flight training costs that are used through the remainder of the paper. The next three chapters are devoted to discussions of the nature and role of simulators in training programs and discussions of simulator program and cost information developed throughout the services and available to service headquarters and DoD components. The final two chapters present the cost-estimating method (model) and assess the data required for its implementation in terms of availability and sources.

In no sense can this analysis of the costs of flight training be considered complete or exhaustive. It is an initial attempt to analyze an extensive and intricate problem. Further work by the DoD and the services would be required before it could be implemented.

Basic considerations surrounding the role of flight simulators (and extendable to considerations of other training equipments and resources) have been developed from traditional economic analysis. A model has been formulated that emphasizes analyses of cost trade-offs between flight and simulation of flight. Formulation of the model has served to identify the general types of data that would be required for its implementation; availability of these types of data has been investigated for each of the three services. The model is neither sufficiently detailed nor complete to serve as an analytical tool, and it was not intended for that purpose. Rather, it provides a first approximation, or strawman, for guiding further development of analytical methods and data-collection systems along the road to internal service capabilities for assessing the cost impacts of proposed training program changes.

B. COST/EFFECTIVENESS ANALYSIS

Systems analysis is a generally accepted technique for assisting decision makers by examining and comparing alternatives (i.e., policies or objectives), ways of achieving them, and their implications in terms of costs and benefits for effectiveness. Cost/effectiveness analysis is a form of systems analysis in which alternative ways of achieving a given objective(s) are examined in terms of their costs and in terms of how effective each is in satisfying the objective.

This analytical technique was introduced into DoD in 1961 by Messrs. McNamara, Hitch, and Enthoven. The technique is well-documented in the literature and will not be elaborated on further here, except for a brief review of the key concept of economic efficiency.[1]

The basis of cost/effectiveness analysis lies in the well-defined concept of economic efficiency (or efficient allocation of resources). The criterion of efficiency may be stated in terms of satisfying either of two equivalent conditions, (1) to minimize economic cost for a given (objective) level of production or performance effectiveness, and (2) to maximize performance effectiveness or produce for a given level of economic cost.[2] Obviously, if neither the level of cost nor level of product (the scale of operations) is fixed, there will be numerous combinations of the two satisfying these conditions with no unambiguous way to determine which one is "best".

To provide definitive comparisons between alternatives, analyses invariably assume that either cost or effectiveness is fixed, thereby setting the scale of operation. Two assumptions have been made in this study. The first is that all costs are measurable in dollars. The second is that training effectiveness can be assessed and that equally effective training programs can be designed. These permit the study to concentrate on conventional cost analysis procedures.

[1]For example, see:

1. Hitch, Charles J. and McKean, Roland N., The Economics of Defense in the Nuclear Age, Harvard University Press, Cambridge, 1960.
2. Quade, E.S. and Boucher, W.I., Editors, Systems Analysis and Policy Planning, Applications in Defense, American Elsevier Publishing Company, Inc. New York, 1968.
3. Goldman, Thomas A., Editor, Cost-Effectiveness Analysis, New Approaches in Decision-Making, Washington Operations Research Council, Frederick A. Praeger, Publishers, New York, 1967.
4. Fisher, Gene H., Cost Considerations in Systems Analysis, American Elsevier Publishing Company, Inc., New York, 1974.

[2]A further discussion of conditions for efficient allocation of resources may be found in Appendix A.

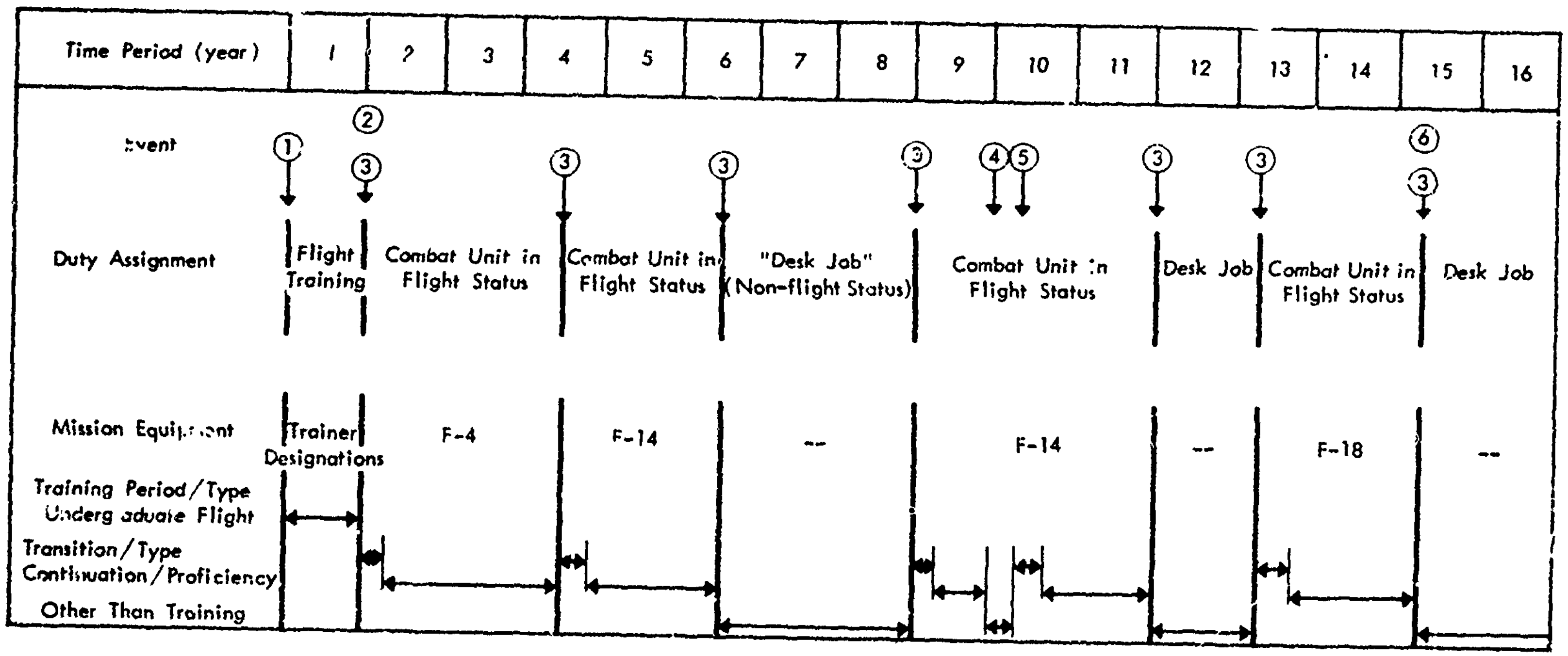
II. NATURE AND EXTENT OF FLIGHT TRAINING

A. THE NATURE OF FLYING FOR TRAINING

During periods of peacetime, the principal function of military forces including the air arms of the three services) is to maintain a continuous capability of engaging in combat. From this reasoning, one can derive a definition for and measure the extent of peacetime military flying for training. Some level of flight activity can be associated with the administration and support of the military establishment in general (including the development and maintenance of combat capability of nonflying forces). Examples include industrial fund flying, weapons development and test, airborne alert, and command support. This peacetime operational flying appears to account for something less than 20 percent of the total hours and closer to 10 percent of variable flying cost.

The remainder of peacetime flying can be supported only on the basis of training of personnel (both ground and flight crew) assigned to aviation units. Within this statement lies the rationale adopted in this paper for defining flight training and for measuring both its extent and cost. Assume two conditions, (1) that all flight crew personnel come to the services (i.e., off the street) fully trained for all combat missions and, (2) that retention of these skills is perfect. The difference in flying levels that would be observed in this hypothetical world and what is actually observed is ideally defined as flight crew training. The difference in military budgets that would be observed in this hypothetical world and what is actually observed is ideally defined as the cost of flight crew training. These ideal definitions provide rules for associating observed flying with training or with operations and for associating incurred costs with the training function.

In fact, the overwhelming majority of personnel come to the service with no flying skill, and, once learned, these skills must be continuously reinforced to be retained. In addition, no person is ever trained for all combat missions, and stands to receive additional training with each duty station reassignment. Figure 1 displays a possible (simplified) set of duty assignments for one individual during his service career. According to this definition of training, he spends the majority of his time in one of three distinct kinds of training administered by three distinct organizations. His initial training is conducted by organizations whose only mission is to impart general flight (including non-pilot) training to wholly unskilled personnel, employing aircraft that have no other mission. "Undergraduate" training is unique in the sense that an individual passes through it only once in his career, so long as he remains in the same flying specialty (pilot, navigator, etc.). Each time he is assigned to flight duty in a different type of aircraft (or loses "currency" by not having flown that aircraft for some period of time) he must enter training to qualify (or requalify) for that type of aircraft. The "transition" or "type" training is provided by organizations whose primary peacetime assignment is training but whose personnel and equipments are qualified for and assigned to combat mobilization billets. That is, they are a part of the combat-ready forces. (These two organizations comprise the formal flight training system, and generally conduct their operations at bases whose primary assignments are flight training.) The maintenance of combat proficiency is the function of "continuation training"--flying and other training activities by personnel



Events:
1. Enter Flight Training
2. Complete Undergraduate Training
3. Rotation (Permanent Duty)
4. Temporary Duty, Non-Flight Status
5. Return to Permanent Duty
6. Permanent Removal from Flight Status (Overage, Medical, Etc.)

Figure 1. HYPOTHETICAL SEQUENCE OF DUTY ASSIGNMENTS

who (once qualified) are assigned to organizations with primary mission of "combat in the event of conflict". Where such organizations have no operational mission during peacetime the total flying time logged must be considered as training. On the basis of the aircraft to which this individual is assigned the total of his flight status time and the total of his flying hours must be considered training.

B. EXTENT AND COST OF FLYING FOR TRAINING

The following examples have been developed from Air Force and Navy data to provide the reader with a perspective of the proportion of total flying time and cost that is incurred for training. In both cases, the figures pertain only to the active elements of the service and only for fixed-wing aircraft. The Navy data were prepared under the ground rule that helicopter training would be provided by the Army, but there is uncertainty about whether the Air Force data were prepared under a similar assumption.

1. Air Force

Relative amounts of the aircraft inventory, flying time, and variable costs of flying that can be associated with Air Force training are shown in Table 1. The inventories and flying hours are derived from the projection for fiscal year 1981 in USAF Program, Aerospace Vehicles and Flying Hours by M/D/S, Vol. 1 (PA 78-POM), dated 7 May 1976, Secret. Aircraft held in small numbers were not included in the tally. The omitted flying hours and costs amount to less than one percent of the fixed-wing totals.

The estimates of variable flying cost are in terms of 1977 dollars and are based on information contained in USAF Cost and Planning Factors (AFR 173-10). For all aircraft they include costs of POL consumption, base maintenance materials, that

Table 1. USAF: RELATIVE FLYING HOURS AND VARIABLE FLYING COST, BY FUNCTION

	Cost/ Flying Hour, Dollars	Percent of Total		
		Inventory	Flying Hours	Cost
Undergraduate training	398	17	24	9
Transition training	1165	14	10	11
Mission-Not Industrial Funded	1424	53	40	54
Mission-Industrial Funded	1202	9	18	21
Support	513	7	8	4
TOTAL		100	100	100

Totals may not add due to rounding.

Source: USAF Program, Aerospace Vehicles and Flying Hours, Vol. 1, by M/D/S, PA FY-78-POM, 7 May 1976 (Secret).

USAF Cost and Planning Factors (AFR 173-10) (Confidential).

portion of depot maintenance considered to vary with flying hours, and replenishment spares. In addition, base maintenance labor has been included for aircraft employed in undergraduate flight training.

The significant feature is that approximately 80 percent of all flying time and 85 percent of variable flying costs can be associated with flight crew training based on the definition adopted in this paper. (One-half of industrial fund flying and all the support category has been assumed necessary for support and administration of the peacetime force; the remainder is considered to be for the purpose of training.) The relative cost of undergraduate flying is surprisingly low compared with the attention it has received in discussions of training costs and simulator usage. From this data, per-flying-hour costs of combat aircraft are over three times higher than those of trainers. This raises two questions about current training programs and simulator proposals: the first is the relative cost/effectiveness of investing in simulation for undergraduate training vis-a-vis transition and continuation training. The second concerns the relative cost/effectiveness of utilizing small aircraft (like current trainer designations) in continuation training programs.

2. Navy

Comparable Navy information (Table 2) was extracted from the Aircraft Program Data File (APDF) as it existed during January 1977. This material contains estimates of flying costs as well as inventory and flying hour data, but the structure or composition of the costs is unknown, except for the fact that they have been adjusted to hypothesized 1978 cost levels. These estimates are significantly higher than Navy per-flying-hour costs shown in other documentation (notably the OP-20 and Flying Hour Cost Reports).

Table 2. U.S. NAVY, RELATIVE FLYING HOURS AND VARIABLE FLYING COST, BY FUNCTION

	Cost/ Flying Hour, Dollars	Percent of Total		
		Inventory	Flying Hours	Cost
Undergraduate Training	222	18	22	9
Transition Training	704	13	13	15
Mission	730	57	53	67
Support	420	12	13	9
TOTAL		100	100	100

Totals may not add due to rounding.

Source: Aircraft Program Date File (APDF) January 1977 (Secret).

If it is assumed that only flying in the support category is necessary to operation and administration of the peacetime force, 85 percent of all flying time and 90 percent of variable flying costs can be considered as incurred because of training requirements.

Inventory and flying hour detail (by aircraft type) is shown in Appendix D. Since these data are classified, Appendix D has been published under separate cover.

C. FLIGHT TRAINING COSTS

Ignoring, for the time being, simulators as an item of special interest in this study, Table 3 displays the types of activities and costs involved in flight training.[1] This set of cost elements emphasizes conventional thinking about flight training--the high cost and special nature of flying is pointed up by its separate treatment, while all other direct requirements are grouped under one heading.

The discussion of the nature of flight training (above) identified three different levels of flight training as a function of prior aviator skill and mission readiness. This stratification has implications for which of the costs incurred by training organizations are logically chargeable to the training function. Undergraduate flight training is conducted by organizations whose aircraft inventories and personnel have no other mission. That is, the assets associated with undergraduate training do not have prior or additional assignments to peacetime support of the forces or to combat missions in the event of hostilities. As such, all costs incurred on their

[1]This table is put forth as a general hypothesis rather than as an immutable, complete, or precise set of rules for estimating cost. Organizational and accounting differences between the services and, possibly, between different units of the same service imply a degree of adaptability in defining cost elements and in associating costs with training activities.

Table 3. REPRESENTATIVE COST ELEMENTS

Cost Element	Notes
Academic Training	
Operations	
Pay & Allowances	
Instructors	1
Instructional Support Personnel	2
Training Device Maintenance	2
Training Materials	2
Investment	
Training Device Procurement	2
Flying Training	
Operations	
Instructor Pay & Allowances	1
Munitions Expended	
Variable Aircraft Flying Costs	
Base Maintenance Labor	
Base Maintenance Materials	3
Depot Maintenance & Modification	
Investment	
Aircraft Attrition & Procurement	4
Student Pay & Allowances	
Training Support	
Operations	
Pay & Allowances	
Unit Command/Admin./Operations	5
Base Oper./Medical Support Pers.	6
Facilities Maintenance Material	
Investment	
Training Program Development	

Notes:

1. Where instructor personnel engage in more than one type of training (academic and flight) a basis for allocation, e.g., time spent between them, is required.
2. All instructional support personnel and training devices (other than aircraft) are assumed to be associated only with school-house training.
3. Consists of aircraft replenishment spares, other aircraft maintenance materials, and POL. Costs of these requirements are considered wholly a function of flying hours.
4. Applicable only to new (yet to be procured) aircraft. Either, but not both, procurement or attrition would be applicable.
5. To the extent that a portion of unit command/operations personnel is identifiable with training.
6. BOS support required for incremental personnel associated with the training function (including students).

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behalf, including training base support and administration, are correctly a cost of training.[1] Looked at in another light, in that hypothetical world in which all personnel come to the services fully trained, the undergraduate flight training organizations themselves (including all personnel and equipment assigned), would be superfluous.

Since transition training organizations have prior combat mobilization assignments, they would exist in the absence of a training mission with close to their present complement of personnel and equipment. That is, qualified pilots (the instructors), aircraft maintenance personnel, unit command and operations personnel, and their associated support personnel would be required due to the mobilization assignment, and cost of these personnel are incurred to maintain the combat capability of the organization rather than training. Costs associated with training are limited to the (variable) costs of flying time; student pay and allowances; the costs of equipments, materials, and personnel associated with training devices and support of the instructional program (and their associated base support personnel). When one compares transition and combat unit training there is little difference with regard to costs. The only discernable difference is that in combat organizations there are no students, per se, and no evidence of a group of persons dedicated to the direct support of training other than those associated with the operation and maintenance of equipments held solely for training.

In addition to the types of costs chargeable to the training function the natures of undergraduate, transitional, and continuation training differ in a way that affects the way in which costs are estimated. This difference is essentially in

[1]Flight training bases may provide services to tenant organizations with either peacetime support or combat mission assignments. In either case the direct costs of these units and some share of base operating overhead cannot be considered a cost of undergraduate training.

who is trained and the purpose of the training and is most easily seen in comparison of undergraduate and continuation training.

Undergraduate is strictly individual training in basic flight skills applicable across a range of aircraft types. The training for the different skills (pilot, navigator, etc.) typically occur at training bases specializing in only one skill (crew seat). Each student progresses through the same syllabus without restricting his options in terms of aircraft to which he may later be assigned.[1] The cost of training for a particular crew seat is estimated without reference to the training programs or training rates for other crew seats or to the crew requirements of different combat aircraft.

Continuation training, on the other hand, is for the purpose of training a crew (as a team) in the skills necessary to execute combat missions in a particular aircraft model. The training base (normally an operational base housing a wing or squadron) is predominantly associated with one aircraft model and, for other than single-place aircraft, a collection of crew-seat skills. Flying for training involves a total crew; non-flying training may be particularized by crew seat. The result is that the unit for which training costs are estimated must be the complete crew, but the estimating process requires separate estimates for those training regimes common to the crew and those unique to each crew seat.

Transition training contains a mixture of elements from undergraduate and continuation. It has a principal purpose of training individuals to mission readiness in a particular model aircraft. For multi-seat aircraft, the different crew seats will

[1]Navy pilot training does introduce an element of specialization in undergraduate training. After an initial period in which all students follow the same curriculum they will specialize in one of three major aircraft lines—jet, propeller, or helicopter. This essentially introduces a two-step training process, each step of which may have to be estimated seperately to develop a total training cost estimate.

be trained at the same locations using syllabi that prescribe activities common across crew positions and activities that are unique to one position. As a typical example, training for a two-place aircraft will require some pilot training sorties in which the rear seat will be occupied by an instructor and some sorties in which it will be occupied by a student (say a radar-navigator). The joint syllabus might specify the following sorties:

	Student Pilot	Student Radar-Navigator
With Instructor	80	50
With Student	30	30

This complicates the process of estimating costs as the estimates must be based on one of two assumptions.

1. The basic unit trained is the complete crew (pilot and radar-navigator).
2. The basic unit trained is the individual (pilot or radar-navigator), and the costs of joint activities are to be pro-rated to each.

Neither assumption is really satisfactory. So long as the numbers of each crew seat to be trained (per unit of time) are equal either assumption will work as well. However, there is no justification for assuming they will always be equal, and unequal numbers will involve some additional cost--either in terms of additional flying, and hence training expense, or in terms of delays in the training for one crew seat with a resulting mismatch in the number of mission-qualified pilots and radar-navigators. The cost associated with a mismatch in qualified crew members cannot be measured in dollars. The allocation of the cost of the additional flying would either be quite complex or arbitrary.

The cost-element listing displayed in Table 3, and supplemented to account for the differences between the various levels of training is shown in Table 4. Those costs that are not applicable to a given level of training have been shaded. The different training levels are physically separated in the table to emphasize that each level represents a distinct and, to some extent, different cost-estimating process.[1]

Note that no provision is made for costs of "full crew" training activities at the transition level. As discussed above, this is consistent with an assumption that costs of flight involving students with different crew specialities will be pro-rated to each It is no more than an arbitrary choice for purposes of displaying Table 4. Whether associating costs with full crew training is appropriate or not will depend upon the nature of the training program assumed (or given).

---

[1]In truth, continuation and transition training requirements cannot be divorced as completely as would seem to be indicated when interest is centered on the costs of training devices and simulators or on the cost trade-offs between simulation and flight. So long as the same simulator models are employed at both levels, the net trade-offs can be determined only by considering the joint impact of their use at both levels.

Table 4. REPRESENTATIVE COST ELEMENTS BY LEVEL OF TRAINING

	Undergraduate	Transition By Seat			Continuation By Seat			Continuation Full Crew
		1	2	. . .	1	2	. . .	
Academic Training								
Operations								
Pay & Allowances								
Instructors								
Instructional Support Personnel								
Training Device Maintenance								
Training Materials								
Investment								
Training Device Procurement								
Flying Training								
Operations								
Instructor Pay & Allowances								
Munitions Expended								
Variable Aircraft Flying Costs								
Base Maintenance Labor								
Base Maintenance Materials[1]								
Depot Maintenance & Mod.								
Investment								
Aircraft Attrition & Procurement								
Student Pay & Allowances								
Training Support								
Operations								
Pay & Allowances								
Unit Command/Admin./Operations								
Base Oper./Medical Support Pers.								
Facilities Maintenance Material								
Investment								
Training Program Development								

[1]Includes POL, replenishment spares, other base materials.

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III. THE ROLE OF SIMULATORS IN FLIGHT TRAINING

At present, DoD has a large number of options open in developing a comprehensive policy for incorporating simulators into flight training programs for both existing and new models of aircraft. On a per-hour basis, costs of flying are several times the costs of simulators, and current inventory holdings seem to barely scratch the surface of their potential use. The procurement and use of simulators in flight training programs raises four basic questions:

1. *What Kind* of simulators are to be procured and employed and in what mix? The range of "what kind" encompasses both the menu of flight functions to be learned through simulation and the physical and performance characteristics of simulator hardware. Should individual simulators be designed for limited functions (part task and procedures trainers; target tracking, refueling, etc.) or for a broad range of functions (generally associated with weapon system or mission simulators)? What features are to be incorporated into the hardware and by using what technologies? For example, to what extent should simulators employ visual systems; where should visual systems use computer generated imagery, camera model boards, etc.; in terms of the learning tasks addressed and subsystems employed, where should simulator hardware be simple and cheap and where should it be sophisticated and expensive?

2. *How much* simulation is to be incorporated into training programs and on what time schedule? This question addresses the magnitude of expenditures for simulator hardware and operations over time. How many simulators of each kind should be

procured? How much should each be utilized in training programs --in terms of operating hours or the proportion of requisite flying skills to be learned through simulation? What should be the timing of budget allocations for simulator procurement and operations?

3. *Who gets* simulator training or where are simulators to be used? Given a simulator budget, the resources made available must be distributed between the different levels of training (undergraduate to combat unit) and among the different types and models of aircraft (and crew position for multi-seat models). In addition to "how much" the distribution problem must also address "when". In what order or sequence is simulation training to be made available across the different training levels and aircraft models? There is a further question, of smaller scope, associated with allocation. Given the allocation among aircraft models, how are resources to be distributed as to geographic location and command (for widely held aircraft)?

4. *What portion* of simulator resources are to be allocated to simulator development? How much should be spent for what new simulator capabilities and when should it be spent?

All aspects of these questions apply to program formulation at higher echelons (DoD and Service headquarters) and a limited set of them at an individual aircraft type or weapon system level. The different levels cannot be separated in any real sense however, since policies formulated at the DoD and service-wide levels will limit the solutions that can be developed at lower echelons. In any case, these four questions exhaust the relevant considerations of simulator use and will be answered in some fashion, regardless of what policies are finally adopted. At the extreme, a policy of not employing any simulation is tantamount to the answer "none" to all of the above questions. Whether such questions are explicitly addressed or not, any other policy implicitly devotes a portion of available (training) resources to simulation in a particular pattern that describes who, what, how many, and when.

A. COST ELEMENTS FOR PROCURING AND OPERATING SIMULATORS

Particular interest in the costs of simulators is quite recent, and as a result little in the way of an historical cost base has been developed. Further, the technological characteristics of simulators have changed to the point where the validity of historical data developed as little as 10 years ago is open to serious question. The section presents a short discussion of a cost structure based on logical considerations of the physical configuration of simulators and organizational arrangements of the services rather than on analysis of historical records.

1. Procurement Costs

Simulators consist of definite subsystems, often associated with a single dominant technology, and a listing of these major components provides definitive guidance for estimating procurement costs. A telling argument for this point is that simulators are often contracted (or subcontracted) along such a subsystem line. In addition, a frequent practice is to procure initially a simulator with limited features and later to add additional elements that correspond to the subsystem structure (e.g., visual or motion systems).

It should be noted, however, that a single subsystem structure will not be universally applicable for a number of reasons. For one, a complete simulator may not contain all possible subsystems. Procedures and part-task trainers frequently include neither visual nor motion capabilities, while weapon system and operational flight trainers may be anticipated to contain one or both. A second reason is that the applicable structure can be expected to vary with the level of technology incorporated into the device. With a camera model visual system, computation hardware will likely be a distinct subsystem controlling cockpit instruments, cockpit motion, and TV gantry movement as an integrated operation. On the other hand, the computational requirements associated with computer-generated imagery (CGI) may be sufficiently great that it would be best implemented by a devoted computer with software linkage to a second computer controlling other computational requirements. In this case, computational costs might be best estimated by considering each as a separate subsystem or by considering visual display and computation equipment as a single subsystem. A third reason is that an appropriate subsystem structure as well as the estimating approach may differ, depending upon where in the development/acquisition process a simulator is. In an early conceptual phase, where major configuration features and performance characteristics are yet to be determined, a parametric approach is generally indicated for estimating costs. Here the appropriate subsystem structure may differ significantly from that suited for engineering estimates typical of later stages of the process after configuration and performance parameters have been fairly well set.

The structure shown in Table 5 is presented as one amenable to parametric estimates at early stages in system development where major configuration trade-offs are of particular interest. Note that all computational capability is grouped into two closely related systems (hardware and software). Recognizing that other subsystems contribute to the net computational load, whether costs are better estimated by defining one or a number of computational subsystems would appear to depend upon alternative configuration proposals to be investigated. The principal advantage of the grouping lies in the simpler descriptions of other subsystems that it affords. The subsystem structure shown in Table 6 has been suggested by the Air Force Simulator Systems Project Office. Considering the nature of

Table 5. SUBSYSTEM STRUCTURE SUGGESTED FOR PARAMETRIC ESTIMATES

Subsystem	Comments
Cockpit (or Cab)	Possibly a nose section of the aircraft itself complete except for instruments and controls.
Flight Instruments	Not included in cockpit system since the instruments and controls may be specifically tailored for simulation (e.g., digital driven where flight vehicle instruments are analog).
Mission Instruments/Displays	Defined separately to permit identification of high-cost mission-peculiar items that represent a significant increase in cost over "typical" instrument requirements, e.g., radar land mass simulator.
Computational Hardware	May be better handled as a number of distinct or second level subsystems. Candidates for separate definitions would be special or unusual computational capabilities, e.g., extended record/playback.
Computational Software	
Visual Sensors/Displays	
Motion Platform/	
Other Motion Cueing Devices	G-Suits, G-Seats, etc.
Control System	Instructor and operation controls, panels, etc.
Installation and Facilities Construction/Modification	Probably cannot be estimated by generalized relationships--dependent upon availability of existing structures with suitable environmental systems, electric service, weight bearing, flooring, etc.

Table 6. SUBSYSTEM STRUCTURE SUGGESTED BY AIR FORCE SIMULATOR SYSTEM PROJECT OFFICE

Subsystem	Comments
Cockpit (or Cab)	Possibly a nose section of the aircraft itself, including functional flight and navigation instruments, dynamic control loading, and some weapon functions. Provides data processing and flight equations needed to simulate flight and to control the instruments and other subsystems that may be added to the simulator.
Motion Cueing	Platform, G-Suit, G-Seat, Harness, etc.
Visual	TV map-board, film, GCI, domes, etc.
Sensors	Air-to-Air radar, landmass radar, etc.
Instructional Features	Instructor's console, performance measurement, malfunction insertion, automatic demonstration, etc.
Installation and Facilities Construction/Modification	Same as Table 5.

this office, it would appear to be applicable at later stages in system development as system configuration alternatives are narrowed and engineering estimates become relevant in working toward RFP formulation and contract selection.

2. Operating Costs

Simulator operating costs are comprised of two identifiable elements. The first, variable operating cost (utilities, maintenance materials, etc.), by definition, varies directly and linearly with the number of operating hours. The second is that element of operating costs that is fixed per unit of time (year, etc.) such as would be associated with maintenance and operations crews. (Crew cost is incurred because a simulator is operated but is conceptually independent of how many hours it is operated). In assessing simulator costs, particularly when the assessment involves comparisons between simulators, between simulation and flying, or between alternative training programs, interest will center on the cost per unit of use (e.g., operating hours), and fixed operating cost per hour is an inverse function of hours operated per time period (week, month, etc.).[1]

These two types of operating costs combine into a simple relation for estimating total simulator operating costs associated with a training program. For each simulator model employed the total is the sum of total hours utilized times variable (hourly) operating cost and total inventory time fixed operating cost. Although the relation is conceptually simple determination (or estimation) of both variable and fixed operating costs appears to be beyond the current data bases of the

[1]Adaptability and the impact of scale of operations blur the conceptual neatness. Increasing the number of simulators operated at a given location may imply a less than proportionate increase in the number of operations crews required; maintenance crew size may be partially adjustable to actual hours logged, and the extent of adjustment can be expected to increase with the passage of time, etc.

services. The requirements for and availability of simulator cost information are discussed in the chapters that follow.

On the basis of the discussion in this section, Table 4 may be modified to incorporate explicit considerations of simulator costs. The expanded set of cost elements is shown in Table 7.

Table 7. REPRESENTATIVE COST ELEMENTS OF FLIGHT AND SIMULATOR TRAINING--BY LEVEL OF TRAINING

	Undergraduate	Transition	Continuation	
		By Seat	By Seat	Full Crew
		1 | 2 | . . .	1 | 2 | . .	
Academic Training				
Operations				
Pay & Allowances				
Instructors				
Instructional Support Personnel				
Training Device Maintenance				
Training Materials				
Investment				
Training Device Procurement				
Flying Training				
Operations				
Instructor Pay & Allowances				
Munitions Expended				
Variable Aircraft Flying Costs				
Base Maintenance Labor				
Base Maintenance Materials[1]				
Depot Maintenance & Mod.				
Investment				
Aircraft Attrition & Procurement				
Simulation Training				
Operations				
Instructor Pay & Allowances				
Student TAD/TDY				
Simulation Costs				
Simulation Operations Labor				
Base Maintenance Labor				
Base Maintenance Materials				
Depot Maintenance & Mod.				
Investment				
Simulator Procurement[2]				
Student Pay & Allowances				
Training Support				
Operations				
Pay & Allowances				
Unit Command/Admin./Operations				
Base Oper./Medical Support Pers.				
Facilities Maintenance Material				
Investment				
Training Program Development				

[1] Includes POL, replenishment spares, other base materials.

[2] Includes directed development.

7-1-75-16

IV. RECURRING SIMULATOR PROGRAM AND COST INFORMATION

This and the following chapter contain (respectively) discussions of simulator information reporting and study requirements levied by the Department of Defense and military department headquarters. These are distinct requirements serving separate purposes, and the sources of information and formats in which each is presented may be quite different. In each case, however, the information should provide inputs for assessing cost tradeoffs (between different simulators and between simulation and flight) and for estimating costs of hypothesized training programs.

Reporting system requirements typically specify precisely the information to be reported, its format, and the frequency of submission (annually at a minimum). A further requirement is that when the information contains projections of future activities it shall be consistent with approved programs. The Department of Defense has levied a requirement on each of the services for annual documentation of their planned simulator programs (including both procurement and utilization schedules). The nature of this requirement and the response of each service is discussed below. In addition, the Air Force has revised and expanded its own periodic reporting requirements, and this is also discussed.

A. THE DEPARTMENT OF DEFENSE REQUIREMENT

This has become generally known as the 'POM backup material.' The requirement has been in effect for three budget cycles and represents the bulk of such information available. It is set out in the Special Analyses section of Part 2 of DoD Manual 7110-1-M. The reporting instructions are reproduced as Appendix B, and the reporting format is shown in Tables 8, 9, and 10. Exhibit ST-1 (Table 8) is a service-wide summary. Exhibit ST-2 (Table 9), a summary by w apon system, is submitted for each aircraft type employing simulators in its training program. Exhibit ST-3 (Table 10) provides detailed back-up to the weapon system summary. Paragraphs 1 through 5.A are submitted for each major type of simulator used in each aircraft training program. Paragraph 5.B (submitted once for each aircraft type) stratifies a portion of training device detail according to the level of training supported.

The instructions for completing the forms are contained in Appendix B. Note that what is requested is primarily information rather than historical data. Since this is the case, there is little way to verify what is presented. Note also that the instructions lend themselves to a variety of interpretations. There is evidence that they have been interpreted differently by the service components and that a significant amount of the information requested has not been supplied as a result of the ambiguity.

B. AIR FORCE

The Air Force is currently implementing (or planning to implement) several actions that should have a significant impact on the quantity and quality of training device data generated. In addition to extending data collected, reporting procedures will be more formalized, permitting tracking of data sources and consistency. Currently, the POM backup is eclectic and it is not evident that data from various sources is coordinated. For several items, alternative sources are available, and some level of duplication may persist when planned reporting systems are implemented.

Table 8. SIMULATOR DATA REPORTING FORMAT - EXHIBIT ST-1 (OVERVIEW)

	FY-PY	FY-CY	FY-BY	FY-BY+1	FY-BY+2	FY-BY+3	FY-BY+4
1. Resource Overview							
Funding: $(M)							
By Appropriation:							
RDT&E							
Memorandum Entry:							
Investment							
Operating							
Procurement							
O&M							
MILCON							
MILPERS							
Memorandum Entry:							
Investment							
Operating							
Total							

	FY-PY	FY-CY	FY-BY	FY-BY+1	FY-BY+2	FY-BY+3	FY-BY+4
2. Utilization Overview							
By Function (A/C Hours/Training Device Hours)							
Transition							
Combat Unit							
Proficiency							
Other							
Undergraduate (Flight)							

(Identify the source documents used to supply the information in this section, and the criteria (codes) used to segregate the data by function.)

EXHIBIT ST-1

Table 9. SIMULATOR DATA REPORTING FORMAT - EXHIBIT ST-2 (WEAPON SYSTEM SUMMARY)

1. Weapon System or Major Device Type Nomenclature: ____________________.

	FY-PY	FY-CY	FY-BY	FY-BY+1	FY-BY+2	FY-BY+3	FY-BY+4
2. Aircraft Data: (as appropriate)							
A. Inventory							
B. Utilization							
(1) Hours/Year							
(2) Hrs/Aircraft/Yr							

C. Cost

(1) Cost/Flying Hour ($)__________ (2) Fuel Consumption/Hr. (gals)__________

(3) Initial Aircraft Acquisition Cost_____ (4) Year Delivered (IOC)__________

(5) Expected Life__________

	FY-PY	FY-CY	FY-BY	FY-BY+1	FY-BY+2	FY-BY+3	FY-BY+4
3. Training Devices Data.							
A. Inventory by Device(s) Category (Nomenclature)							
•							
•							
B. Utilization by Device(s) Category (Hours/Year) (Identify simulation training provided by contract as a separate line entry)							
•							
•							
C. Current Year Cost by Device(s) Category (Cost/Device Hour) ________.							
•							
•							

EXHIBIT ST-2

Table 10. SIMULATOR DATA REPORTING FORMAT - EXHIBIT ST-3 (TRANING DEVICE DETAIL)

1. **Aircraft Nomenclature:**__________ 2. Device(s) Nomenclature:__________

3. **Simulator(s)/Device(s) Description:** (Include characteristics such as visual, degrees of motion, substitution rate, etc of each device type if more than one is to be included on this Exhibit. Also identify major equipment contractors).

4. **Resource Data:**

	FY-PY	FY-CY	FY-BY	FY-BY+1	FY-BY+2	FY-BY+3	FY-BY+4
RDT&E(Qty/$M)							
Procurement(Qty/$M)							
O&M ($M)							
Memorandum Entries:							
Non-Personnel ($M)							
Civilian ($M)							
Civilian Manyears							
MILCON ($M) (Support these entries with a list of projects and their locations.)							
MILPER ($M) (Include only those personnel directly related to training, operations, and maintenance of the device.)							
Memorandum Entry:							
Officer & Enlisted Manyears							
Total ($M)							
Simulator(s)/Device(s) inventory							
Gains							
Losses							
Net							

5. Operational Data:

A. Costs

(1) Aircraft--
- (a) Total Cost/Flying Hour________
- (b) Fuel Consumption/Hour________

(2) Training Device--
- (a) Cost/Device(s) Hour ________
- (b) Initial Device Acquisition Cost____
- (c) Year Delivered________
- (d) Design Life________

EXHIBIT ST-3

Table 10. CONTINUED

5. B. Utilization -	FY-PY	FY-CY	FY-BY	FY-BY+1	FY-BY+2	FY-BY+3	FY-BY+4
(1) Transition (CCTS/TT/RS):							
(a) A/C Inventory							
(b) Flying Hours							
(c) A/C Utilization (Fly Hr/A/C)							
(d) Training Device Hours							
(e) Estimated A/C Flying Hours replaced by Device Hours							
(f) Ratio-Trng Device Hours to Flying Hours (e/b+e)							
(g) Transition Pilot Training Load							
(h) Ratio-Total Pilots Transitioned to A/C Inventory (g/a)							
(2) Combat Unit:							
(a) A/C Inventory (UE)							
(b) Flying Hours							
(c) A/C Utilization (Flying Hrs/A/C)							
(d) Training Device Hours							
(e) Estimated A/C Flying Hours replaced by Device Hours							
(f) Ratio-Trng Device Hours to Flying Hours (e/b+e)							
(3) Proficiency:							
(a) A/C Inventory							
(b) Flying Hours							
(c) Training Device Hours							

EXHIBIT ST-3 (Cont'd)

Table 10. CONTINUED

5. B. Utilization -	FY-PY	FY-CY	FY-BY	FY-BY+1	FY-BY+2	FY-BY+3	FY-BY+4
(3) Proficiency:							
(d) Estimated A/C Flying Hours replaced by Device Hours							
(e) Ratio Device Hours to Flying Hours (d/b+d)							
(4) Other:							
(a) A/C Inventory							
(b) Flying Hours							
(c) Training Device Hours							
(d) Estimated A/C Flying Hours replaced by Device Hours							
(e) Ratio Device Hours to Flying Hours (d/b+d)							
(5) Undergraduate Flight:							
(a) A/C Inventory (UE)							
(b) Flying Hours							
(c) Training Device Hours							
(d) Estimated A/C Flying Hours replaced by Device Hours							
(e) Ratio-Training Device Hours to Flying Hours (d/b+d)							
(f) Average Student Load							
(g) Ratio-Avg Student Load to A/C Inventory (f/a)							

EXHIBIT ST-3 (Cont'd)

1. Current POM Backup Data

The material is assembled and printed by the Director of Budget, Air Force Comptroller, from sources described below. Training device inventory, utilization, and displaced flying hour projections are provided by the Directorate of Operations and Readiness, DCS for Plans and Operations for all simulators except those employed by the Air Training Command (ATC). Similar information for ATC training is provided by Director of Personnel Programs, DCS Personnel. These offices have direct cognizance over the location of simulator inventories and obtain planned utilization and displaced flying hours from surveys of field commanders. The inventory information is published in the "Special Training Equipment Program" (STEP), and the utilization and displaced flying hour information is published in the PA-CMD-2 (one volume of the Air Force P-series of planning documents). These documents are mutually consistent, are consistent with the POM, and project over the same horizon as the POM. Historical utilization data are available in the "World-Wide Trainer Equipment Inventory, Utilization Status Report" (RCS, HAF-DPP(M) 7103).

Projections of yearly O&S costs (Paragraph 4 of Form ST-3) are obtained from field surveys conducted by the Director of Budget, Air Force Comptroller but the cost-per-hour estimates contained in Paragraph 5.A.2 of the same form are obtained from the Directorate of Management Analysis.[1]

The Management Analysis estimates are based on collection of historical data and, hence, are provided only for currently deployed devices. It was not possible to verify coordination between the O&S projections obtained by field survey and the historical data provided by Management Analysis, nor between the O&S cost and

[1]Although it is not noted as such, the cost per hour rates include only base level costs. The data developed by Management Analysis is discussed below.

utilization rate projections (provided by the Directorate of Operations and Readiness.

Procurement costs cited in Paragraphs 4 and 5.A.2 (Form ST-3) were obtained from the Directorate of Development and Acquisition of DCS Research and Development for devices not yet procured and from DCS Systems and Logistics for those currently in the inventory. In the case of existing equipment, contract records were used, but how these data were interpreted to arrive at "initial device acquisition cost" is not known. They are not, however, based on contracted studies or estimates provided by the simulator system project office.

2. New or Developing Data Sources

The Comptroller of the Air Force and the Air Force Logistics Command have initiated a two-part program to collect simulator operating cost data on a recurring basis. Base-level costs are being collected through the establishment of cost centers codes (ledger accounts) for simulators. The base-level system has been initiated and forms the basis for the cost-per-operating hour developed by the Directorate of Management Analysis. Development of depot cost reporting has been assigned by AFLC to Warner-Robins Air Logistics Center for computer system costs and to Ogden ALC for all other costs. To date, the system has not been implemented.

The Directorate of Management Analysis has received one or two years of simulator base operating cost and utilization data. Some general characteristics of the data received are shown in Table 11. Which simulator models represent one year of data and which two are now known. The data received consists of man-years (that does not include instructor time), utilization, materials, and utilities costs. Man-year data were converted to personnel costs through factors contained in USAF Planning Factors (AFR 173-10). Since these data originate at individual operating bases, separate reports would have been received for each

Table 11. SIMULATOR BASE-LEVEL DATA REPORTED

Number of Simulator Models Reported	35
Number of Simulators Reported	197
Number of Simulators per Model: Range	1 to 19
Number of Simulators per Model: Average	5.6
Average Weekly Utilization Hours, by Model: Range	22 to 99
Average Cost Per Hour by Model: Range	42 to 245

Data Items Reported: Number of Simulators
Utilized Hours (Year)
Man-Years: Officer
Enlisted
Civilian
Supplies Cost
TDY Cost
Utilities Cost
Equipment Cost

Derived Personnel Costs: Pay & Allowances: Military
Civilian
Base Operating Support
Medical
PCS
Personnel Acquisition
Training

Note: In addition to the numbers above, information was received on three procedures trainers, 71 T-37 simulators (Model T-4), and 80 T-38 trainers (Models T-7/T-26).

location of each simulator model. Considering the number of individual simulators reported and the number of individual reports likely to have been received, the data set should represent a variety of equipment characteristics and a variety of utilization rates. It is rather early to assess the validity and sufficiency of data reported, but, on the surface, it appears to provide a basis for estimating operating costs on the basis of physical and performance parameters and utilization rates.

A second source of new data is the planned revision of STEP. Responsibility for this program rests with Directorate of Operations and Readiness, DCS Plans and Operations. The name is to be changed to "System Training Equipment Program," and the format is to be expanded and published in two parts. Part 1 will contain estimated acquisition costs and a narrative description of each simulator model's characteristics.[1] Part 2 will contain inventory and utilization projections. The system is to be automated with periodic reports distributed by DCS Plans and Programs and Resources. Utilization rates will be coordinated with the PA-CMD-2. Part 2 was released in July 1977.

Later versions of Part 1 may also contain projections of estimated operating costs. Should this come to pass, the estimates will be developed in conjunction with the Comptroller of the Air Force but not through the Directorate of Management Analysis. This has some logic, since STEP is a projection while the Management Analysis effort is concerned only with historical data. However, the Management Analysis project should result in estimating relationships that would provide the basis for

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[1]The only general source of physical characteristics currently available is Standard Aircraft Flight Simulator Characteristics (Orange Book). The material it contains is generally limited to statements of facility requirements of different simulator models (floor space, size, weight, power requirements, etc.).

new equipment estimates, and some of the same simulator models will undoubtedly be contained in both the projections and in the current operations data. How these would be coordinated cannot be answered at present.

C. NAVY

The Navy POM backup material (at least the simulator data items) are pretty well centralized within three small offices of the Aviation Manpower and Training Division of the Deputy CNO for Air Warfare (NAVOP 59). (The data associated with aircraft and flying hours originates the Aviation Programs Division of Deputy CNO for Air Warfare, NAVOP 51.)

The Navy has incorporated the ST series data displays as an integral part of their own training device management process. In addition, these displays come close to exhausting the simulator data developed within the Navy. At the same time, this makes it a rather simple process to describe how the POM is put together and next to impossible to describe how the data is developed.

The actual production (printing) of the ST forms is automated. The formatting and printing, along with calculation of some of the values, was programmed under contract by a local company. It is bound into what is called the Black Book and, together with program and hardware descriptions, forms a basis for program management and the baseline for developing the following year's submission.

The same office that is responsible for preparing the Black Book (Aviation Training Device Requirements Branch of the Aviation Manpower and Training Division of Deputy CNO for Air Warfare, NAVOP 596) is also responsible for Navy Department-level funding of training device procurement, for monitoring items out on contract, and for device deployment. As a result, the inventory projections are developed as a part of normal operations.

Device Utilization is a combination of survey of operating commands and the application of a utilization standard. Total utilization is arbitrarily set at 80 hours per week (except for procedures trainers where the standard is 40 hours) less an allowance for unscheduled maintenance. The unscheduled maintenance allowance varies with type of simulator but never exceeds 700 hours per year.

Fleet readiness squadrons (transition training) are assigned a first priority for simulator time, and estimates of their requirements are developed from a survey of the training units by the Tactical Air and Air ASW Training Branches of the Aviation Manpower and Training Division (NAVOP 593 and 594). Projected utilization by combat units is taken as the difference between the total available (based on the 80-hour-week standard) and that claimed by the replacement air groups.

Projections of displaced flying hours are developed in a fashion somewhat similar to utilization. Fleet readiness squadrons are surveyed by NAVOP 593 and 594. Displaced flying hours are credited to fleet units by the application of standard factors--although the factors are not hard and fixed. No displacement is allowed for utilization of part task and procedures trainers. Substitution rates for other devices average two simulation hours for one flight hour. However, for each simulator, the actual rate allowed is partially subjective and based on case by case evaluation of individual simulators--configuration and features, fidelity of response, etc. Total displaced hours projected for fleet units are the product of the calculated substitution rates and the utilization hours allowed after deducting the claims of replacement air groups. As they are physically located within 25 feet of one another, communication between NAVOP 593/594 and NAVOP 596 is informal. Utilization and displaced hours projections are transmitted to NAVOP 596 through personal contact.

The cost projections contained in Paragraph 4 of Form ST-3 are derived from at least three sources. The Navy has formulated its simulator programs so that RDT&E is applicable only to technology development efforts. Procurement cost projections are available within NAVOP 596 as a product of their principal missions. These costs represent amortization of initial procurement costs (typically over a 10-year period) and unamortized expenditures for major modifications, depot, and contractor maintenance.

Projections of O&M, military, and civilian personnel, and construction costs along with manning levels are developed by the Weapons Training Division of the Assistant Commander for Logistics/Fleet Support of the Naval Air Systems Command (AIR 413) from information supplied by other commands. Records of materials costs are maintained by the Naval Training Equipment Center (NTEC) and the Service Division of the Chief of Naval Education and Training (CNETS) as well as AIR-413 itself. Personnel man-year projections are made by simulator holding commands on the basis of anticipated usage and manning and workloads standards formulated by the Aviation and Manpower Programs Branch of the Deputy CNO for Air Warfare--NAVOP 597. Manning levels are converted to personnel costs by AIR 413. Costs of military construction are provided by the Naval Facilities Engineering Command from statements of facilities requirements provided by AIR 413. The projected costs are made available to NAVOP 596 in an informal manner--rather than as the result of an identifiable and formal reporting requirement. Cost per device hour (Paragraph 5.A.2 of Form ST-3) is a calculated value based on the O&M and military personnel projections in Paragraph 4 and projected utilization rather than data developed through operational experience. As a result, it is directly proportional to utilization.

Descriptive information (requested in Paragraph 3 of ST-3) is gathered into a separate volume. It is based on material extracted from the Directory of Naval Training Devices published by the Electronic Supply Office.

D. ARMY

The Army simulator program differs significantly from either those of the Navy or Air Force. The aircraft inventory is dominated by rotary wing craft, and roughly 75 percent consists of two models (both small--the UH-1 and OH-58). All newly graduated pilots are assigned field unit duty in one of these two, and the UH-1 is the basic vehicle for undergraduate training.

Understandably, the simulator program has centered on the UH-1 flight simulator (the model 2B24), and it will account for close to 90 percent of simulator cockpits planned to be available in fiscal year 1981. Currently, the total Army inventory consists of approximately one-third of a planned buy of 29 model 2B24 complexes (with four cockpits each) and six simple cockpit procedures trainers (model 2C35).[1] Two to three years operating experience has been gained with the 2B24, but all other information contained in the POM back-up materials is wholly estimated.

The Army has established the Office Program Manager for Training Devices (PM TRADE) with the contract, funding, and monitoring functions normally associated with project offices.[2]

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[1]IOT&E of simulator prototypes for the CH-47 and AH-1 prototypes is scheduled to begin during calendar 1977 and the Army is planning to modify some number of model 2B12 general procedures trainers to a generalized helicopter configuration.

[2]In contrast with Air Force practice, training device funding is separated from weapon procurement, permitting the program manager independence in technological and scheduling decisions.

Its charter specifies that this office will manage all contracts on a life-cycle design-to-cost philosophy, will monitor both procurement and operating costs, and will provide all life-cycle cost estimates through completion of program acquisition. PMTRADE, then, becomes the repository (if not the original source) of all data contained in the POM materials, at least through a program's acquisition phase.[1] Once fielded in operating units, data is developed and reported by the owning organizations. Note that at any time during a system's life-cycle special studies may be initiated by any organization with authority for its design, procurement, or use with the resulting data becoming the property of the initiator. All cost data, regardless of source, are monitored at Department of the Army level at two points. Procurement cost and delivery information flows to the Department of the Army System Coordinator (DACS) for aviation training devices in the Aviation Systems Division of the DCS for Research, Development and Acquisition. Operating cost information flows to the Requirements Division of the Requirements Directorate, DCS for Operations and Plans.

Simulator inventory deployment, utilization, and flying hour substitution information emanates from two sources within the Army Staff, depending upon whether devices are deployed to formal training establishments or field (combat) units. For field units, deployment of devices and the establishment of utilization and substitution rates rests with the Combat Division of the Requirements Directorate of DCS for Operations and Plans. Deployment is based on "basis of issue plans" (BIOP). The only firm plan at this date is for the UH-1 flight simulator, and this was issued in the form of the Army message (really a

[1]A special consideration is involved in the UH-1 simulator operating costs. All maintenance on fielded complexes has been performed under a single maintenance contract that has been renewed on an annual basis. Contract provisions and incurred costs are a joint responsibility of the program manager and the Aviation Systems Command.

series of messages, since it has been updated numerous times). Utilization standards are issued from this office, also in the form of a message, on the basis of an Army Regulation setting maximum levels of substitution between flight and simulation and prior field experiments. This regulation (Army Aviation: General Provisions and Flight Regulations--AR 95-1) is currently under review and revised substitution levels can be expected on the basis of current field testing.[1]

All formal Army aviation training is conducted at Ft. Rucker; the 2B24 prototype and first five production articles were deployed there. Device utilization is based on projected training loads and syllabus requirements, all of which are furnished to the Training Division of the Directorate of Military Personnel Management, DCS for Personnel. Substitution of flying hours is based on a ratio of one to one established through testing with the prototype unit at Ft. Rucker. These data elements for both the field units and Ft. Rucker are consolidated and submitted in the POM back-up.

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[1]Since this information was first gathered, AR 95-1 has been reissued, dated 15 January 1977, providing for an annual minimum simulator training requirement at a considerably higher level than the annual maximum specified in the previous AR 95-1 version.

V. COST/EFFECTIVENESS STUDIES SUPPORTING SIMULATOR PROCUREMENT PROPOSALS

The ultimate requirement for cost/effectiveness analyses of military systems lies in the guidance contained in Department of Defense Instruction (DODI) 7041.3, *Economic Analysis and Program Evaluation for Resource Management*. Its specifications have been implemented in each of the three services by the issuance of an instruction that, in effect, does no more than paraphrase the initial instruction.[1] Each of the Services, though, had previously or has since issued instructions that, in total, spell out procedures for satisfying the DoD requirement. The remainder of this chapter discusses the nature of DODI 7041.3 and the services' responses in the area of flight simulators.

A. THE NATURE OF DOD INSTRUCTION

DODI 7041.3 is a statement of overall policy with regard to analyses and specifically sets a broad scope of applicability. It expressly identifies both new and on-going projects as candidates for analysis. For new projects, analyses are to be made before program on-set (i.e., before resources are committed.) For on-going programs, analyses are to be performed whenever certain broad conditions are recognized. (Specifically mentioned are changes in program scale, changes in target performance parameters, changes in study assumptions, and the appearance of new alternatives.) What comprises a project is not expressly defined, and an exemplary listing of candidates,

[1]For example, the DoD Instruction is implemented in the Navy through SECNAVINSTR 7000.14B. This instruction consists of a two page introduction with DODI 7041.3 forming an enclosure.

shown in an enclosure, includes activities ranging from new weapon procurements and force structure trade-offs to changes in support facility (supply, maintenance depots, etc.) procedures or organization. Since one alternative to a proposal (whether it be a new weapon, a change in a training program, or whatever) is to continue the current system, anything different may be considered as a candidate for analysis.

This broad range of application may be contrasted with the almost total absence of specifics regarding the nature and conduct of studies. Nine elements of a "complete analysis" are identified and discussed individually.[1] However, the discussion is prefaced and the qualification that it represents only general, rather than specific, guidelines and explicitly notes that it is "not always feasible to conduct...(analyses)...on the basis outlined herein; therefore it will be necessary to determine locally..." discrete areas and priorities of analysis and the analytical approach, level of detail, sophistication, and amount of resources devoted to studies. This general nature is exacerbated by noting that evaluations are not required "when it can be shown the ... (cost of) ... the analysis would not be worth ... (its) ... benefits" and that the "method of documentation ... will usually vary from one study to another."

These qualifications have been incorporated into the restatements of the instruction by the individual services and have had a telling impact on the kinds of evaluations made in support of relatively small procurements--like past simulator buys. Automatic submission of studies to DoD is not a requirement. "Review of analyses at the OSD level will be made on a selective basis considering time and staffing constraints ...

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[1]The identification of objectives, assumptions, constraints on solutions, and alternative systems; the estimation and analysis of costs, benefits, and uncertainties; the analysis of sensitivities; and the ranking of alternatives.

Project officers and managers should be prepared to demonstrate the cost-effectiveness ... and to submit detailed analyses in support of budget estimates, as provided in ... DoD Manual 7110-1-M, *Department of Defense Budget Guidance Manual* ..." (see Chapter IV, above).

B. SERVICE RESPONSE TO DODI 7041.3

For major procurements (as defined in DoD Directive 5000.1), extensive study efforts can be expected, since they are, in effect, singled out for intensive review and since DSARC review and SAR reporting requirements must also be satisfied. However, the costs typically associated with simulator procurements are many times smaller than the dollar thresholds defining major programs. In like manner, the interest in detailed review should seem in proportion to a program's budgetary impact. In fact, it would appear that evaluations in the sense of DODI 7041.3 to support past simulator procurements have been rare. (The information reported in response to the Budget Guidance Manual--the "ST" forms--falls far short of a literal interpretation of the provisions of DODI 7041.3, and the requirement has existed for only three budget cycles.) The high interest and increased budget requests surrounding simulation during the past several years is bringing a change in this respect. Each of the services is preparing or implementing plans for more extensive evaluation and reporting of simulator utilization and configuration proposals. However, little in the way of concrete results is currently evident, and the remainder of this chapter primarily investigates the current rather than proposed practices.

1. Air Force

DODI 7041.3 has been implemented in the Air Force through Air Force Regulation (AFR) 178-1. Economic analyses of eight major simulator programs has recently been directed by Headquarters, USAF, and these will be the first studies undertaken specifically to satisfy AFR 178-1 at that level.[1] Considering the size of the Air Force simulator inventory and the magnitude of the program proposed in its master plan, this can only be surprising.

The lack of prior studies may be explained, in part, by the combined impact of the wording of AFR 178-1, the character of the simulator program, and the USAF system for processing system proposals. According to AFR 178-1 the Directorate of Management Analysis of the USAF Comptroller is the office of primary responsibility for compliance and coordination of studies but has no explicit study review authority, except for programs subject to DSARC approval (major systems in the sense of DODD 5000.1--Major Systems Acquisitions). Primary responsibility for determining when analyses are required (as well as for their receipt, review, and approval) rests with other USAF Headquarters offices. As a result, varying standards of analysis may result and studies accepted as economic analyses that were not specifically undertaken for that purpose and do not contain all its required elements. One case in point is a study of simulators for the A-10 system performed by the A-10 SPO and TAC Headquarters. Although representing one of the most complete studies found, it will not satisfy the current study requirement.

Concerning the character of the Air Force simulator program, the present master plan identifies 45 distinct simulator programs applicable to 21 mission aircraft types and to

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[1]The studies are for the following systems; instrument flight system trainer for undergraduate pilot training, C-130 mission flight simulator, B-52 instructional system, KC-135 instructional system, F-15 mission simulator, F-16 mission simulator, and A-10 mission simulator.

undergraduate training.[1] Approximately 90 percent of the investment cost projected is associated with eight aircraft types and undergraduate training. The current study requirements include seven of these aircraft and one type of simulator associated with undergraduate training.[2]

All but two of these simulator programs are either associated with major weapon procurement programs (currently in or yet to enter their acquisition phases) or represent major procurements and would be subject to DSARC approval. Analyses that satisfy the DSARC reviews appear to have been considered as satisfying the general requirement for economic analysis as well. In this sense, DODI 7041.3 is adhered to, but under a different guise. Note, however, that DSARC reviews of weapon procurements should concentrate on the PME while giving only minor attention to relatively small contract items such as training equipment. Here, an explicit requirement for analyses of the associated simulators represents new or additional material required by the DSARC process.

The initiation and processing of proposals for new capabilities and equipments follows the Required Operational Capability (ROC) process implemented by Air Force Regulation 57-1. The basic composition of a ROC is no more than a "statement of need" identifying a deficiency or threat and a "statement of operational capability," including a proposed operational concept to satisfy the need. The ROC may also (optionally) include statements of preferred or alternative solutions and expanded

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[1]The current master plan was published in December 1975 and is presently considered obsolete. A reissue is planned for September 1977. The reissue will involve some change in format as well as an updating of program proposals and estimates of simulator program costs and savings.

[2]The eighth program displayed a poor pay-off potential in the master plan, is currently not proposed for funding, and probably will not be included in the master plan revision. Other undergraduate simulators included in the master plan also displayed poor payoff potentials, but whether they will be included in the master plan revision is not known.

rationale that contain estimates of proposed system characteristics, quantities, costs, and criteria of effectiveness. Costs and effectiveness are specifically noted with the statement "if...reason for submitting the ROC is to achieve...reduction in the cost...economic justification and amortization figures should be presented..."

ROCs are formally submitted to USAF Headquarters by the major commands. Their processing is the cognizance of the Directorate of Operational Requirements of the DCS for Research and Development. This processing involves a sequence of reviews and approvals from a number of Headquarters offices (including the Directorate of Management Analysis) and the Air Force systems and logistics commands and serves as a vehicle for successively refining and clarifying the nature of the deficiency (or threat) and for evolving the equipment (or operational) concepts proposed for satisfying the deficiency before funding is requested. The focal point for simulator ROCs stated that studies are always performed somewhere along this processing stream, but that the process is informal. They may be contracted by the Directorate of Operational Requirements or they may be levied on the proposing major command, and AFR 57-1 prescribes no format that they must satisfy.

The Air Force must feel that such studies are consistent with the DODI requirements for economic analysis--that analyses are not automatically submitted, but that managers should be prepared to demonstrate cost and effectiveness and to submit detailed supporting analysis. Whether or not the analyses supporting ROCs do satisfy the provisions of DODI 7041.3 would depend upon their completeness, and this may vary widely from one case to another. The few observed do. In any event, analyses are performed, but not ones that can be explicitly identified with the DoD instruction.

2. Navy

Discussions with Naval personnel within the Office of the Chief of Naval Operations (OP 596) and at the Naval Air Systems Command (AIR 413) indicates that three time periods are relevant in considering the Navy's evaluations of flight simulators; prior to the fiscal year (FY) 1975 submission, from the FY 1975 submission to the present, and subsequent submissions.

FY 1975 marks the first time submission of the "ST" forms was specified in the Budget Guidance Manual. It also appears to mark a date when some changes in personnel and organization occurred in the Naval Air Systems Command office with cognizance over simulator procurements. No evidence of analyses being performed before that date has been found, even though the formal review process for approval of procurement proposals appears to have been the same as at present. Personnel currently assigned to this office of NAVAIR and to the Aviation Manpower and Training Division (Deputy CNO for Air Warfare) have been unable to shed any light on studies from this earlier period.

At the current time short studies (four or five pages) are routinely submitted as backup to budget requests, although it is uncertain whether an evaluation (of a given simulator) is submitted only at the first request for funding or annually until procurement is completed. The Assistant Secretaries of Defense, Comptroller and Manpower and Reserve Affairs are recipients, as are a number of offices within the Navy Headquarters establishment.

Two things should be noted about these evaluations. The first is that they do not appear to satisfy the requirements of DODI 7041.3 with regard to evaluation of alternatives. The only alternative to the proposed configuration that is recognized is no simulator. The second is that all the information they contain would be included in the Statement of Operational

Requirement (OR) and the Development Proposal (DP) that form a part of the internal Navy review process prior to requests for research and development funding. This process is described in OPNAV Instruction 5000.42 (Weapon Systems Selection and Planning) that, incidentally, makes no reference to DODI 7041.3.

These studies contain terse statements of simulator purpose, capability, and IOC in a requirements section. This is followed by a benefit/cost analysis section listing assumptions regarding simulator procurement and operations costs, aircraft flying hour cost, and flying hour substitution. Little information is provided in the way of data sources or estimating rationale. The final section consists of two tables showing expected net savings (discounted) over a 10-year period. A copy of one study supporting the FY 1978 budget request is contained in Appendix C.

The Navy is currently evaluating its simulator program management procedures, and it may be anticipated that one result will be to place an increased emphasis on evaluation and documentation of future program proposals. As a part of this effort, the Navy will publish its Aviation Simulator Master Plan in two phases. Volume I of the Phase I report (recently published) describes the Navy program management structure. Volume II (to be published) will contain an evaluation of the management system. The Phase II report will propose corrective actions to deficiencies identified during Phase I and present a draft master plan. It is here that the anticipated emphasis on evaluation and documentation should appear.

3. Army

As noted in Chapter IV, the Army presents a different picture than the Navy or Air Force. At this writing, the Army operates one model of simulator (the 2B24 for simulation of the UH-1) and has just begun operational test and evaluations (OT&E) of prototype simulators for the CH-47 and AH-1. In each of these cases, it has been Army practice to conduct extensive testing of one prototype before committing to procurement for inventory. In the case of the model 2B24 the program was initiated before 1970. The prototype was delivered and entered into IOT&E during Fiscal Year 1971. Six more units were delivered in FY 1974 and FY 1975. The testing of these units resulted in the formulation and verification of a training plan on which a Basis of Issue Plan (BOIP) was formulated. The first formal economic analysis (formal in the sense of satisfying DODI 7041.3) was published at this time as back-up to the BOIP.

Tentative BOIPs have been issued for both the CH-47 and AH-1 flight simulators, and preliminary economic analyses have been performed. At completion of OT&E a final Cost and Training Effectiveness Analysis (CTEA) will be issued along with a revised BOIP, and a formal economic analysis performed for review by the Army System Acquisition Review Council (ASARC). It is only at this point that funds will be committed to procurement for inventory. This practice points up the fact that, although extensive prototype testing should pay handsome dividends in terms of a configuration selection and BOIP, it is also a time-consuming process. (Delivery of the last buy of an anticipated 29 2B24 units is not planned until FY 1980). To the extent that there is an urgency in getting simulators on-line to displace flying hours, the extensive testing can be considered to add to program costs. There is a hint that the Army recognizes some problems with this practice and that it will make some changes in future programs in order to field operational units more expeditiously.

C. IMPACT OF COST ASSUMPTIONS ON STUDIES

The cost-effectiveness studies reviewed (whether or not they purported to satisfy the requirements of DODI 7041.3) are basically rather straightforward statements of the cost impacts of substituting simulator for flying hours in a manner that would leave unchanged the level and composition of skills learned. The crucial variables for such analyses are limited to the rates at which simulator times may be substituted for flying time and the ratio of (hourly) costs of the two.

Unfortunately, the cost of a flying hour is ambiguous. It can be, and has been, defined in a number of ways, and the range of flying hour costs that result from the different definitions is large. Further, definitions of flying hour costs are rarely provided in studies. The material below presents alternative flying hour cost estimates for the P-3C gathered from different official sources and the impact of adopting these different estimates on the results of a Training Analysis and Evaluation Group (TAEG) study of a P-3C simulator.

A related type of problem regarding simulator operating costs is also discussed. Here the problem revolves around assumptions regarding attainable utilization levels and the manner in which costs change with changes in utilization. Explicit evidence of an impact on the studies reviewed was not discernable in their documentation. However, the potential exists, and its magnitude on study conclusions might equal that of the variations in flying hour cost definitions.

1. The Structure of Aircraft Systems' Costs

Not all military costs can be associated with individual weapon systems or program elements (for example, costs of higher echelon military headquarters and overhead costs of central supply establishments). Costs that can be associated with individual systems are relevant for life cycle cost and cost/effectiveness studies and can be grouped into two categories. The first consists of those that are incurred due to the existence of a weapon system in the force. The second consists of costs whose magnitudes vary with the manner in which systems are deployed and operated in the peacetime environment.

A categorization of costs applicable to estimating the life-cycle costs of aircraft systems is shown in Table 12. The operating cost elements are a rearrangement of those employed by the Navy Resource Model (NARM). The level of fixed operating costs are estimated on a basis of the number of aircraft assigned operating units. Variable operating costs are estimated on the basis of hours flown by these aircraft under peacetime conditions.[1]

Which of these elements would be applicable to a system study would depend upon the ground rules or assumptions lying behind the study. For example, in comparing two hypothetical or new aircraft systems, all elements would be relevant since no costs have been incurred (or sunk). That is, all costs associated with one system would be avoided should the other be the "winner". Should the study be between an existing aircraft system and a new one (proposed as a replacement) R&D and procurement costs would not be relevant to the current sytem since they would not be avoided if it were, in fact, replaced.

In evaluating the benefits to be derived from simulation, criteria must be developed for distinguishing between those cost elements that are relevant from those that are not, and these criteria result in different sets of relevant elements from one study to another. If squadron manning levels would not change with the introduction of simulators, personnel costs would be an irrelevant cost element. Should a study concern

[1]Where personnel costs are based on the number of aircraft in inventory it would be assumed that the operating units are manned at levels sufficient to perform their combat missions rather than at levels designed to support peacetime operations.

Table 12. CATEGORIES OF COST

Investment Costs

Aircraft Research and Development
Aircraft Program Procurement

Fixed Operating Costs

Direct Military Personnel[1]
Indirect Military Personnel[2]
Standard Depot Level Maintenance (SDLM)
Logistics Support
Base Operations Material and Contract Labor
Training Material
Medical Material and Contract Labor
Recruiting
Temporary Additional Duty (TAD)

Variable Operating Costs

Aircraft POL
Base and Intermediate Level Maintenance Material
Replenishment Spares
Aircraft Engine Overhaul
Aircraft Component Overhaul

[1]Includes basic pay; allowances for subsistence, quarters, and clothing, hazardous duty pay; employer (Navy) Social Security contribution, permanent change of station (PCS) moves, and other pay and allowance items.

[2]Includes personnel associated with base operations, medical and health services, training, recruiting and examining, and transient personnel.

a new aircraft system (one yet to be procured, like the F-16) the use of simulation should result in a smaller number of aircraft required for transition training. If aircraft assigned to transition training had no combat mobilization assignments so that a smaller number of aircraft would be required, in total, the smaller buy would represent a cost reduction resulting from simulation, so that aircraft procurement costs would be a relevant cost element.

Unfortunately, neither the assumptions necessary for separating relevant and irrelevant cost elements nor the composition of flying hours costs were made explicit in any of the economic and cost/effectiveness analyses available to this study. Since flying hour costs vary widely as a function of the cost elements assumed relevant, the impact on assessment of simulator proposals is major. This is shown below in terms of variations in P-3C flying hour costs found in official documents and the impact on evaluation of the model 2F87F OFT.

2. Impact of Flying Hour Cost Variations in Assessment of the P-3C OFT

Six different P-3C flying hour cost levels were found in four Navy data compilations and one simulator study as shown in Table 13. The cost structure was explicit for three of these levels and is shown in Table 14. (In the case of the Navy Program Factors Manual, total operating costs were used as a base since this value was used in the Training Analysis and Evaluation Group (TAEG) report that is discussed below.) The values shown from the OP-20, Flying Hour Cost Report, and the Aircraft Program Data File seem to have the same composition. The Flying Hour Cost Report is based on FY 1976 actuals, and the OP-20 report cost per hour values appear to be based on Cost Report materials. The Aircraft Program Data File value reflects two years of anticipated escalation. In the case of the NAVAIR analysis of the 2F87F, no explanation is available

Table 13. P-3C COSTS PER FLYING HOUR AND SOURCES

Cost Per Flying Hour (Dollars)	Source
2284	Navy Program Factors Manual, Chief of Naval Operations (OPNAV-90P-02), 1 July 1976, FOUO.
1255 (Replacement Air Groups) 795 (Fleet Squadrons)	Cost Effectiveness Analysis, Procurement to Provide P-3C Aircrew Trainer 2F87F OFT, Naval Air Systems Command (Air 413), 5 January 1977.
602	Aircraft Program Data File (ADPF), Chief of Naval Operations (OPNAV 511), January 1977, Secret.
446 (Atlantic Fleet) 418 (Pacific Fleet)	Flying Hour Cost Report (line printer listing), Chief of Naval Operations (OPNAV 511), August 1976.
433	OP 20 Report (line printer listing), Chief of Naval Operations (OPNAV 57C), September 1976.

Table 14. STRUCTURE OF P-3C FLYING HOUR COSTS

	Basis of Estimate, Per Year	Navy Program Factors Manual (Atlantic Fleet Readiness Squadrons)	2F87F OFT Cost Effectiveness Analysis (Fleet Squadrons)	Flying Hour Cost Report (Average of Atlantic & Pacific Fleets)
Flying Hours Per Year		429		
Fixed Operating Costs				
Direct Military Personnel	Aircraft	330,000		
Indirect Military Personnel	"	202,000		
Standard Depot Level Maintenance (SDLM)	"	67,000		
Logistics Support	"	61,000		
Base Operations Material & Contract Labor	"	15,000		
Training Material	"	6,000		
Medical Material & Contract Labor	"	12,000		
Recruiting	"	3,000		
Temporary Additional Duty (TAD)	"	3,000		
Variable Operating Costs				
Aircraft POL	Flying Hour	288	386	288
Base & Intermediate Level Maintenance Material	"	110	159	133
Replenishment Spares	"	84	84	13
Aircraft Engine Overhaul	"	25	23	
Aircraft Component Overhaul	"	143	143	
Operating Costs Per Flying Hour		2,284	795	434

for the higher POL costs or for the higher costs associated with replacement air group training. In the latter case a likely reason is to assume a decrease in aircraft maintenance and operation personnel requirements. This would be justified on logical grounds only in the case that replacement air group aircraft and personnel do not have combat mobilization assignments so that personnel allowances could actually be decreased.

The total operating cost level developed from the Navy Program Factors Manual ($2284/flying hour) is of special interest since it was this value that was used in the TAEG Report No. 42 (*Training Effectiveness Evaluation of Device 2F87F, P-3C Operational Flight Trainer*) discussed in Chapter IV and Table 10 of Volume I of this study. The table is repeated here as Table 15. The large cost decreases claimed by the TAEG report would be logical only if it were assumed that the 2.8 aircraft released from this assignment (7.0 - 4.2) were 1) deactivated and all the personnel required for their operation and maintenance released from Naval service or 2) reassigned to other peacetime missions that *would have been* pursued by the procurement of 2.8 additional aircraft and the personnel necessary for their operation if the 2F87F OFT had not been procured.

It is only under one of these assumptions that the $2284 can be considered as the incremental decrease in costs associated with use of the simulator, and it is only the incremental changes in cost that are relevant for comparing with the ratio at which simulator and aircraft hours may be substituted for assessing the efficiency of simulator utilization. If the two assumptions above could not be accepted (or confirmed) some other value for variable flying hour cost--for example, the $650 shown in the Navy Program Factors Manual--would be required for a logically consistent evaluation. This presents a quite different picture of attractiveness of the 2F87F.

Table 15. COSTS OF TRAINING 200P-3C PILLOTS PER YEAR UNDER TWO SYLLABI (TAEG Report No. 42)

Device	Hours Required Per Student	Total Device Hours Per Year*	Operating Cost/ Hr**	Total Cost/ Yr**	No. of Devices Needed	Present Value (Each)
Control Group (N-16)						
CPT (2C45)	13	1,300	$ 104	$ 135K	1	$ 1,390K
OFT (2F69D)	9	900	134	121	1	1,396
P-3C	15	3,000	2,284	6,853	7	13,700
Total	37			$7,109K		
Experimental Group (N-27)						
CPT (2C45)	16	1,600	104	166K	1	1,390
OFT (2F87F)	24	2,400	144	346	1	4,225
P-3C	9	1,800	2,284	4,112	4.2	13,700
Total	49			$4,624K		

*For 200 pilots/yr

**Includes maintenance and support costs of two students and one instructor; availability of devices assumed as shown (P-3C hours based on actual utilization):

CPT 3000 hrs per yr (12 x 5 x 50)
2F69D 3000 hrs per yr (12 x 5 x 50)
2F87F 4000 hrs per yr (16 x 5 x 50)
P-3C 428 hrs per yr (35.7 x 12)

Table 16 displays the impact of using the other flying hour costs given in Navy source documents where impact is measured in terms of changes in the device amortization period. The TAEG study assumed a useful life of the simulator to be 10 years. On this basis, the efficiency of simulation is marginal at variable flying hour costs in the neighborhood of $550 to $600.

3. Simulator Operating Costs

A similar problem arises regarding the variable costs of simulation that is well illustrated by current Air Force practice. The effective utilization of simulators is determined by two factors; the proportion of time a simulator is available for use (up-time) and the demand for simulator time (student load times simulator hours per student). Base level simulator operating and cost data collected by the Directorate of Management Analysis, Comptroller of the Air Force indicates an average utilization of approximately 40 hours per week while Air Force policy has set 80 hours as a standard or target.[1] The data collected by the Directorate was organized into the categories shown in Table 17.

The problem arises in that the total of these simulator costs have been considered as fixed and independent of the number of hours used. While some of the elements may be truly fixed (or fixed within ranges of utilization) it is impossible to justify that all or even the majority are fixed for all usage levels. If the (hypothetical) per hour costs at 80 hour utilization rates are used in analyses or used as a basis for estimating operating costs of proposed simulator configurations, the result will be arbitrarily low values favoring

[1]Each of the services has postulated utilization rate standards between 60 and 80 hours per week.

Table 16. IMPACT ON P-3C TRAINING COSTS OF ALTERNATIVE FLYING HOUR COST ASSUMPTIONS (Thousands of Dollars)

Source of Flying Hour Cost Assumption	Item	Control Group	Experimental Group	Cost Difference	Amortization Period (Years)
TAEG Report No. 42 (Navy Program Factors Manual)	Cost Per Flying Hour	2,284	2,284		
	Annual Flying Cost	6,853	4,112		
	Annual Training Device Cost	256	512		
	Annual Total Cost	7,109	4,624	2,485	1.7
NAVAIR Cost Effectiveness Analysis Readiness Group	Cost Per Flying Hour	1,255	1,255		
	Annual Flying Cost	3,765	2,259		
	Annual Training Device Cost	256	512		
	Annual Total Cost	4,021	2,771	1,250	3.4
NAVAIR Cost Effectiveness Analysis; Fleet Squadron	Cost Per Flying Hour	795	795		
	Annual Flying Cost	2,385	1,431		
	Annual Training Device Cost	256	512		
	Annual Total Cost	2,641	1,943	698	6.1
Aircraft Program Data File	Cost Per Flying Hour	602	602		
	Annual Flying Cost	1,806	1,084		
	Annual Training Device Cost	256	512		
	Annual Total Cost	2,062	1,596	466	9.1
OP-20 and Flying Hour Cost Reports	Cost Per Flying Hour	433	433		
	Annual Flying Cost	1,299	779		
	Annual Training Device Cost	256	572		
	Annual Total Cost	1,555	1,291	264	16.0

Table 17. AIR FORCE SIMULATOR OPERATING COST CATEGORIES

Military Pay and Allowances[1]
Civilian Pay and Allowances[1]
Temporary Duty
Permanent Change of Station Moves
Personnel Acquisition and Training
Base Operating Support Personnel (Cost)
Medical
Supplies
Equipment (Minor)
Utilities

[1]Includes only simulation maintenance and operations personnel. Costs of students, instructors, and other instructional support personnel are ignored.

extensive simulator usage. In the light of the recent USAF utilization, base-level costs could be understated by up to one-half.

A further point is that these values are averages and averages are irrelevant in setting limits to efficient usage. Determination of the limits is developed in Appendix A on the basis of equality in the ratios of *incremental* or marginal learning to cost. Learning substitution rates between simulation and flight are expected to be nonlinear and to increase as simulation is increasingly substituted for flight. (That is, as simulation is increasingly substituted for flight a greater amount of simulation time will be required to substitute for one hour of flight.) The implication of zero variable operating costs of simulators (and ignoring costs associated with instructor and student time) is that increasing the levels of utilization of (existing) simulators will continue to be efficient so long as any learning results.[1]

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[1]Increasing rates of substitution are equivalent to convexity of "product isoquants" as defined in Appendix A (see Figure A-2).

$$L = f(A,S);$$

where L = learning
A = aircraft hours
S = simulator hours

The slope of the product isoquant, at any point is defined as the relative learning transfer rate and is equal to the value,

$$\frac{\partial L/\partial S}{\partial L/\partial A}$$

Sufficient conditions for convexity are that

$$\partial L/\partial S > 0 \text{ and } \partial L/\partial A > 0;$$

$$\partial^2 L/\partial S^2 < 0 \text{ and } \partial^2 L/\partial S^2 < 0.$$

Then, given the cost function

$$C = (\alpha A + \psi) + (\beta S + \delta);$$

(footnote continued on next page)

where C = total cost

α = incremental aircraft operating cost

β = incremental simulator operating cost

ψ = fixed aircraft operating cost

δ = fixed simulator operating cost

(A and S as above)

The slope of the budget-line (Appendix A, Figure A-1) is

$$\frac{\partial C/\partial S}{\partial C/\partial A},$$

and

$$\frac{\partial C}{\partial A} > \frac{\partial C}{\partial S} > 0, \quad \frac{\partial^2 C}{\partial A^2} = \frac{\partial^2 C}{\partial S^2} = 0$$

Beyond some point of simulator utilization

$$\frac{\partial L/\partial S}{\partial L/\partial A} \not> \frac{\partial C/\partial S}{\partial C/\partial A}.$$

However, if $\partial C/\partial S = 0$, efficient simulator utilization will continue to the point where $\partial C/\partial S = 0$.

VI. GENERALIZED MODEL FOR ESTIMATING TRAINING COSTS

This chapter describes, in general terms, the structure of a model for estimating costs of flight training. It is important to note that its purpose is not to set out a complete set of procedures or specifications to follow in making estimates.[1] Rather, it is a general framework composed with two limited purposes in mind. First, it should provide a simplified picture of the sources and structure of training costs. Second, it is intended as a general framework for identifying and assessing data requirements. Three considerations were instrumental in shaping its development.

1. The model should emphasize the differences in estimating costs of different training modes and equipments.
2. It should provide a single estimating structure for all levels of flight training (undergraduate, transition, and continuation).
3. This basic structure should be capable of addressing a wide (but unspecified) range of questions associated with training and the use of training equipments. That is, it should become a generally applicable estimating tool through only extensions or minor changes.

Since the model is put forth as an explanatory device, it contains a number of gross simplifications over what would be found in a model specifically to be used to estimate training program costs. Some of these simplifications have been

[1]Incompleteness of the model is easy to recognize. Relationships are specified in general terms and sometimes do not include the functional form. The specification of cost elements is probably incomplete for many particular study questions. Hopefully, it captures the general nature of flight training and the primary drivers of training cost.

discussed above and some more will be discussed below. There is one, however, that deserves discussion at this point.

The model is cast in that timeless static context typically associated with life-cycle cost estimates of individual weapon systems. The costs estimated are limited to system-unique (or training-program-unique) development and investment requirements and steady-state annual operating costs. As a result, the model displays no sensitivity to the timing of costs or to budget implications of program alternatives. Further, it is incapable of addressing inter-weapon system or service-wide impacts. The importance of these interactions for both the development of training programs and simulator development policies was discussed above. These are pertinent topics, and their absence represents a significant shortcoming of the model as it is currently described. However, it should be noted that the model can be expanded without changing its general nature to incorporate both time and the interrelationships between training programs and impacts of alternative overall simulator policies. That is, the structure is consistent with time-phased force structure cost estimating. The fact that its explanation is not cast in this light is one of convenience. The introduction of time and numbers of training programs (like weapon systems) involves a cumbersome and repetitive computational notation that would detract from its real purpose--that of explaining the general structure of training cost estimating and identifying data requirements.

The three sections of this chapter that follow discuss three distinct stages of the estimating process. The first is determination of training loads--the number of individuals or crews to be trained per time period (say, one year). This is a quite straightforward process and its discussion consists of little more than the set of mathematical relations by which loads may be determined.

The second stage consists of determining what is called the level of training activities. Training programs are generally described in terms of the number of classroom hours, flying hours, etc., that each student must engage in. The term "activity level" refers to the total classroom hours, flying hours, etc., per time period implied by the training load when one accounts for class size (for academic training), aircraft flying hours, by aircraft type, per credited student flying hour[1], etc. Determination of activity levels is not straightforward, and, indeed, it is not obvious that is amenable to modeling in the strict sense of being reducible to mathematical relationships. As a result, no set of relationships has been attempted. Instead, a discussion of the modeling problems is presented in Section B, below.

Once the level of training activities has been determined (by whatever means), the estimation of cost is conceptually straightforward. The final section of this chapter *assumes* that three key parameters describing training activity levels can be determined and goes on to set out mathematical relations by which total training activity and training costs may be estimated.

A. DETERMINATION OF TRAINING LOADS

The ultimate determinant of training loads is the force level (number of UE aircraft) or combat and support systems. Since continuation and transition training are wholly associated with one aircraft model, the determination of loads for both is a transition and continuation training function of this force level. On the other hand, undergraduate flight training is

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[1]Differences between aircraft flying hours and credited student flying hours result from such causes as instructors flying in chase aircraft, students occupying more than one seat of multi-seat aircraft, unsatisfactory student performance requiring reflys of training missions.

common across aircraft types, and undergraduate training loads must be determined by reference to the force levels of all aircraft types or must be assumed.[1]

Determination of training loads for continuation and transition training is shown in Figure 2 and the following relations. The continuation training load for one type of aircraft for one year is determined as follows:

For complete crews,

$$CL = (FL) \cdot (CR)$$

and, additionally, for each crew set (i),

$$CN_i = (CL) \cdot (CC_i)$$

where CC_i: Crew Composition; Number per Crew, Crew Seat i

CL: Number of Full Crews

CN_i: Number of Crew Required, Seat i

CR: Crew Ratio

FL: Force Level, number of UE Aircraft

Required outputs of transitional training arise from the combining of reassignment rates and number of assigned crews;

$$TO_i = (RR) \cdot (CN_i)$$

but the effective training load must account for trainee attrition (or wash-out). Assuming attritions occur linearly across the training period;[2]

$$TL_i = TO_i / \left(1 - \frac{TA_i}{2}\right) = (RR) \cdot (CN_i) / \left(1 - \frac{TA_i}{2}\right)$$

[1]The Navy system of pilot specialization during undergraduate training requires a further specification. Each of the three specialties (jet, propeller, helicopter) represent a separate track during some portion of undergraduate training.

[2]The impact of the linear attrition assumption in effective load is accounted for by a halving of the attrition rate.

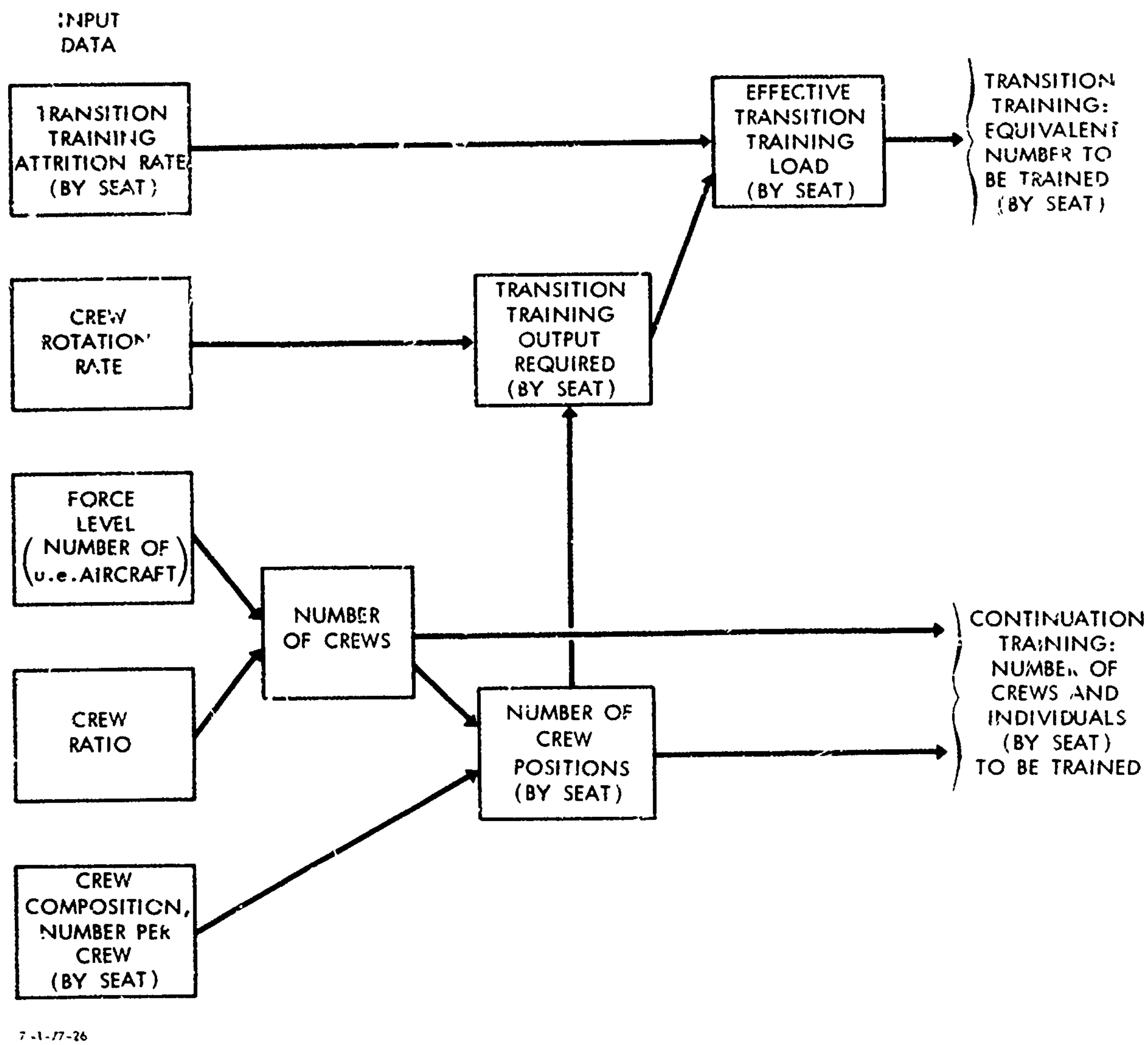

Figure 2. DETERMINATION OF CONTINUATION AND TRANSITION TRAINING LOADS

where RR: Crew Rotation (Transfer) Rate

TA_i: Transition Training Attrition Rate, Seat i

TL_i: Effective Transition Training Load, Seat i

TO_i: Transition Training Output Required, Seat i

If loads for undergraduate training are not assumed they may be developed according to Figure 3 and the relationships that follow. The contribution of each aircraft type to undergraduate training loads is the result of the numbers of persons required to occupy each crew seat and what will be called "flight crew attrition"--the loss of personnel qualified for flight operations. In addition to retirement and resignation associated with normal personnel attrition, it includes disqualification from flight status for such reasons as age, grade, and physical causes. Similar to transition training, the effective undergraduate training load includes allowances for training received by those who subsequently attrit from the training program.

$$UO_i = (DR_i) \cdot (TCN_i)$$

$$UL_i = UO_i / \left(1 - \frac{UA_i}{2}\right)$$

where DR_i: Flight Status Disqualification (Attrition) Rate, Crew Seat i

TCN_i: Total Number of Crew Required Across all Aircraft Types, Seat i

UA_i: Undergraduate Training Attrition Rate, Seat i

UL_i: Effective Undergraduate Training Load, Seat i

UO_i: Undergraduate Training Output Requirement, Seat i

These relationships present a highly simplified picture of what is, in fact, a complex process. As a result, they ignore

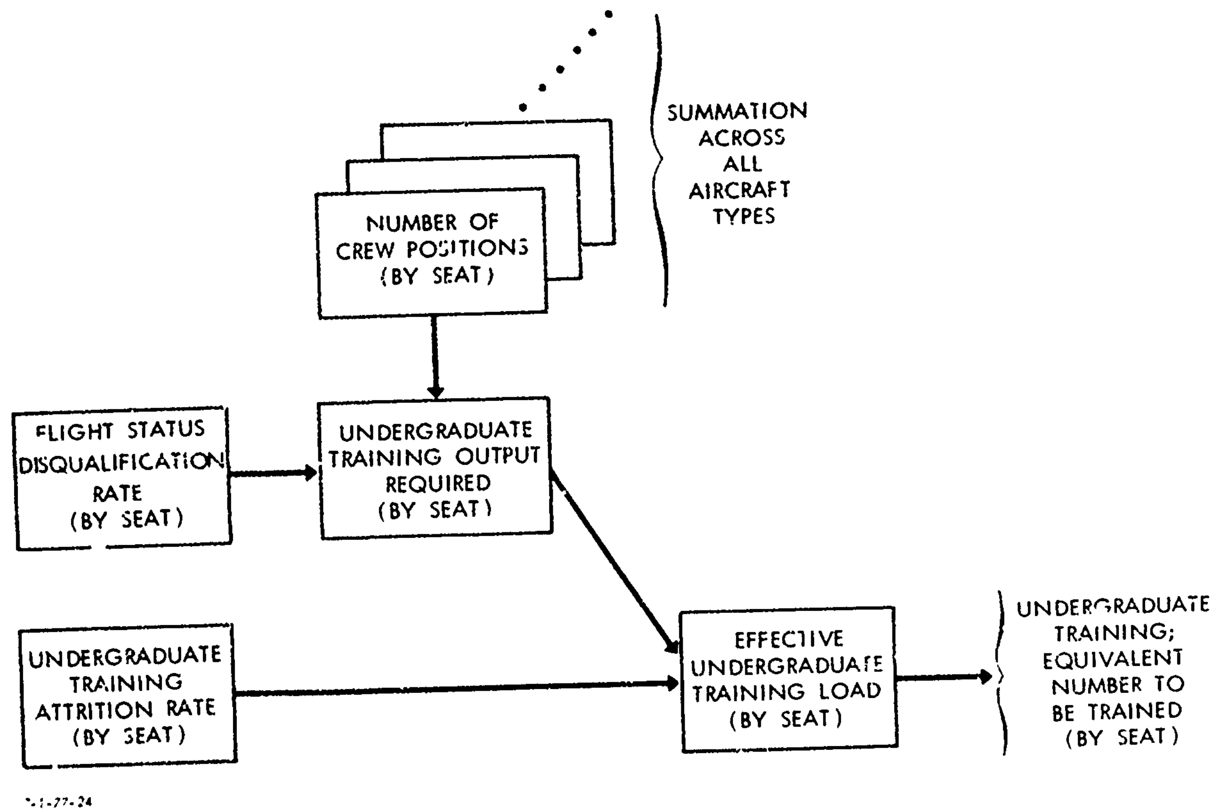

Figure 3. DETERMINATION OF UNDERGRADUATE TRAINING LOADS

a large number of factors that impact on actual assignment of personnel and training loads. Figures 2 and 3 and the relations ignore requirements for training undergraduate and transition instructors. Determination of these loads is relatively simple, but their conversions to training activities and costs is complex, since it would include activities required of regular students plus activities unique to the instructor curricula. In addition, requalification after "loss of currency" is not considered in determining transition training loads. These and other complications can be introduced at the expense of computational complexity to expand the range of questions that can be addressed and the fidelity and completeness of analysis. However, the simply derived impacts are useful for a number of purposes, and such refinements do little to change the basic process by which loads and costs are determined.

B. DETERMINATION OF TRAINING ACTIVITY LEVELS

Ideally, for each training course resulting in qualification for one crew seat in one aircraft type, a listing could be made of all activities (lectures, training device sessions, flying sorties, etc.) and each could be associated with a purpose or skill learned. These might then be grouped according to resource used (aircraft type, lecturer, etc.) and skill learned, be quantified, and be summarized as in Table 18. The totals thus derived would serve as basic inputs to estimation of both training cost and training effectiveness for one or a group of individuals. However, single training activities contribute to the learning of several skills and prevent one-to-one associations of the two. This is primarily a problem in training program design--translating required flight skills into a set of training activities that satisfy the requirements, in total. This translation is the essence of syllabi development, and their organization reflects the absence of one-to-one relations between what is done and what is learned. Individual

Table 18. IDEAL ASSOCIATION BETWEEN ACTIVITIES AND PROFICIENCY GAINED

Activity	Hours	Proficiency
Sortie	Aircraft #1	Skill 1
1	---	---
2	---	---
3	---	---
Sortie	Aircraft #1	Skill 2
1	---	---
2	---	---
Sortie	Aircraft #2	Skill 1
1	---	---
2	---	---
Session 1	Simulator #1	Skill 1
1	---	---
2	---	---
3	---	---
Session	Simulator #1	Skill 2
1	---	---
2	---	---
Lecture		Skill 1
1	---	---
2	---	---
3	---	---
Lecture		Skill 2
1	---	---
2	---	---

Summary

Total Flying Hours:	Aircraft #1	---
	Aircraft #2	---
Total Simulator Hrs:	Simulator #1	---
Total Lecture Hours:		---

		---

training activities (aircraft sorties, training device sessions, lectures, etc.) are specified and associated with maneuvers to be performed, subjects to be covered, etc., and frequently with the time required by each. Syllabi (and other program documentation), then, serve as a bridge for combining training curricula with student loads to develop statements of total training activity rates that provide the basis for estimating training costs (Figure 4). However, problems exist in this conversion, and their nature is explained below in two contexts. The first applies to training programs for all aircraft and pertains to the way syllabi materials are written. The second is methodological and is applicable only to multi-seat aircraft.

All Aircraft: Estimates of costs are generally based on utilization of equipment and personnel, and program specifications must be translatable into statements of utilization, not just events. For example, the cost of an aircraft sortie depends, in part at least, on the duration of the sortie. Syllabi appear generally to be written in a manner that does not permit quantifying of all requirements. Student sorties may require chase aircraft that are not noted by aircraft type. At advanced training levels (especially continuation training) requirements may be specified in maneuvers to be successfully performed without specifying the number of sorties and flying hours involved. Academic requirements generally do not specify class sizes and instructor requirements. Since various syllabi are written differently there can be no general rules formulated for converting these requirements into quantities whose costs can be estimated.

Personnel newly assigned to a weapon system come to that assignment with wide differences in experience in both general flight proficiency and the particular skills required by that mission. Compare, for example, a pilot transferred from F-4 to F-14 aircraft with a pilot who has just completed undergraduate training and is assigned to F-14. To accommodate the two,

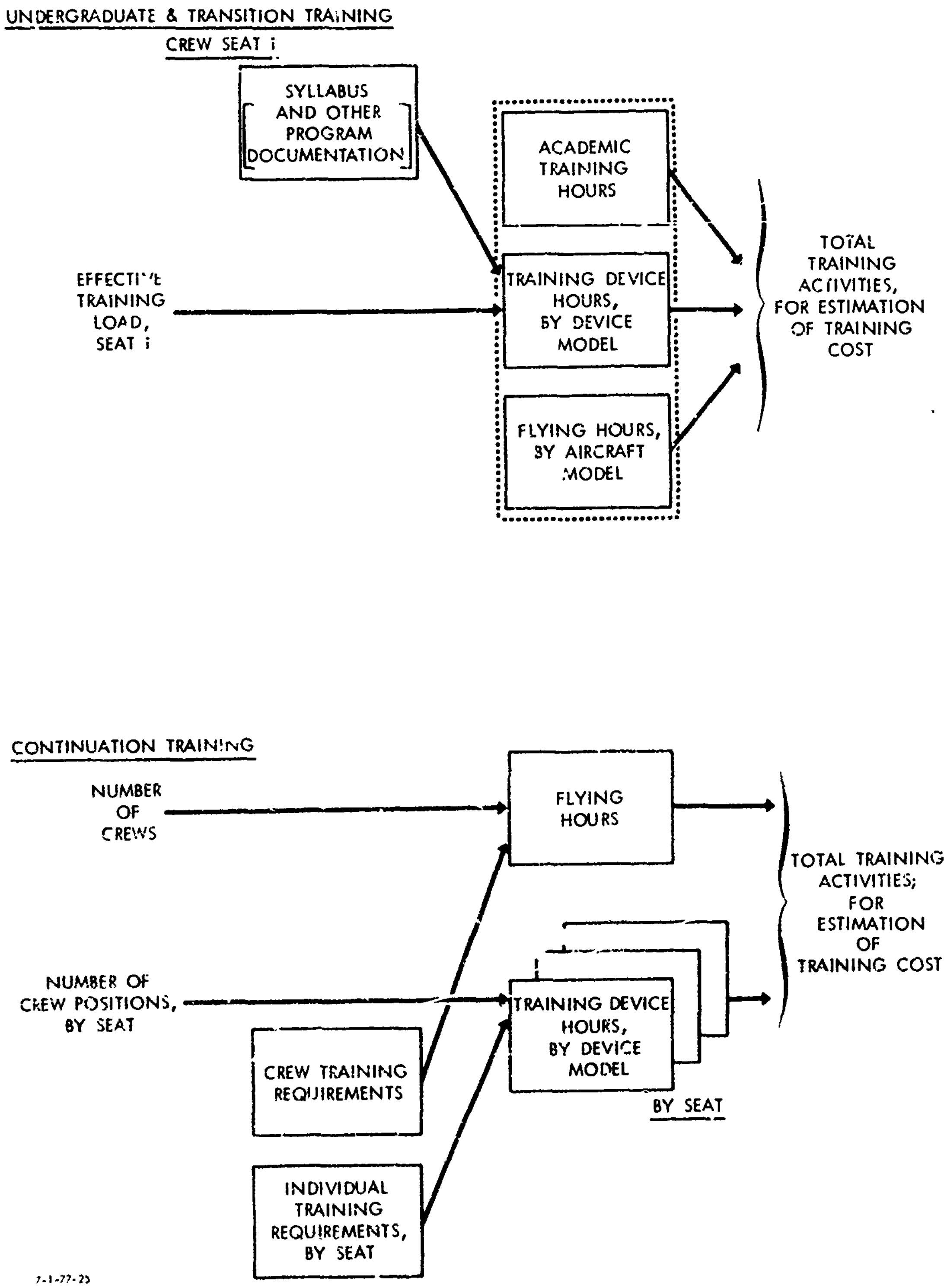

Figure 4. TRANSLATION OF SYLLABUS AND STUDENT LOAD INTO ACTIVITY RATES

transition training syllabi may consist of several sections, each partially tailored to account for differences in experience and specifying different levels of training activities. The average training received depends upon the particular experience mix of the input load, and its estimation is quite complex.

Multi-Place Aircraft: Both transition and proficiency training programs for multi-seat aircraft are really collections of separate programs. As an example, consider the current syllabus for the F-14 transition training program (Table 19). Individual training classes include both pilot and flight officer students. One document specifies the training for both seats, although the training schedules differ for candidates for each seat. Hence, it is not possible to distinguish between training sessions applicable to only one seat and common training sessions. Some flying activities require a student pilot and instructor flight officer, others a student in both seats. Equal numbers of student pilots and flight officers appear to be anticipated since the pilot syllabus stipulates the same number of flying hours to be flown with a student flight officer as the flight officer syllabus does to be flown with a student pilot. Syllabus detail provides short (four or five word) descriptions of each academic and simulator session and each flight sortie (for each category of pilot and NFO.) These descriptions, though, are the same for both pilot and NFO sections and are not sufficient to convey the full purposes of the sessions. Instructor guides or similar material must amplify on these points, but none are referenced in the syllabus bibliography.

Table 20 illustrated three problems concerning multi-seat aircraft training. (1) What happens if training loads of the two seats are not the same? (2) What if the average experience (and hence hours required) between the two differ? (3) Is the full 30-hour requirement (for newly graduated) really training for both seats? (That is, maybe flight officer training is productive for only 20 hours, and the remaining 10 are really

Table 19. F-14 SYLLABUS SUMMARY

	Category	Course Duration (Weeks)	Hours: Lecture / Test	Hours: Physical	Hours: Self Study	Hours: Seminar / Laboratory	Simulator Sorties Hours: OFT 2F95	Simulator Sorties Hours: Mission 15C9	Simulator Sorties Hours: WST 2F95 15C9	Replacement Pilot Flight Sorties / Hours	Replacement NFO Flight Hours Included	Replacement NFO Flight Sorties/Hours	Replacement Pilot Flight Hours Included	Instructor Flight Hours	Aircraft Hours: F-14*	Aircraft Hours: TA-4	Aircraft Hours: F-5	Aircraft Hours: A-4
Pilot	Category I	26	79.0	76.0	37.0	130.5	16/22.5	6/6.0	1/2.0	82/96.2	9.3			104.0	89.6	18.8	3.8	17.3
	Category II	26	79.0	76.0	37.5	129.5	17/22.5	6/6.0	1/2.0	70/78.6	9.8***			77.3	74.0	10.3	3.8	13.3
	Category III	19	79.0	76.0	32.0	114.0	6/5.0	-/-	2/2.0	46/54.5	9.3			48.7	47.8	9.3	2.7	3.8
	Category IV	6	79.0	76.0	23.0	55.5	9/13.5	-/-	-/-	6/10.0	-			10.0	10.0	-	-	-
	Average - Class of 7**	23.1	79.0	76.0	36.0	125.5	13.4/18.4	4.3/4.3	1.3/1.3	68.3/76.8	9.1			80.6	73.2	13.7	3.5	12.3
NFO	Category I	26	79.0	76.0	37.0	142.0	-/-	30/30.0	1/2.0			58/71.0	9.3	65.2	65.6	13.2	3.8	5.6
	Category II	26	79.0	76.0	38.0	139.5	-	30/30.0	1/2.0			50/60.2	9.3	54.0	56.6	7.3	2.8	5.2
	Category III	19	79.0	76.0	35.0	140.5	-/-	18/18.0	-/-			42/47.3	9.3	35.9	43.7	7.3	2.8	3.8
	Category IV	6	79.0	76.0	22.0	66.5	-/-	8/8.0	-/-			3/5.4	-	5.4	5.4	--	-	-
	Average - Class of 7**	23.1	79.0	76.0	36.7	140.9	-/-	26.6/26.6	0.7/1.4			51.1/61.1	9.3	53.6	56.8	9.8	3.2	5.0

*All F-14 hours accrue overhead flying - 25 percent, in addition to hours shown

**Three Category I students and two each Category II and Category IV

***This number seems to be in error

Table 20. SYLLABUS FLYING TIME

Crew Composition	Pilot Hours	Flight Officer Hours
New Graduates		
Student and Instructor	80	50
Two Students	30	30
Experienced Crew		
Student and Instructor	55	40
Two Students	20	20

for the benefit of pilots). Answers here require more than the information contained in syllabi. These questions appear fairly well avoided by considering the crew as the receiving entity for continuation training, but it may be a major consideration for assessing transition training.

C. ESTIMATION OF TRAINING COSTS

The material below presents a method (functional forms and relationships) for estimating training costs. The individual forms and relationships shown apply to estimates of training for one crew seat in one model of aircraft. As noted before, exceptions are that undergraduate training is not particularized to one aircraft,[1] and continuation training at (combat unit level) is associated with the total crew. Total training costs associated with one combat aircraft model would require replication of the estimating process for all crew seats at the transition level and for those training activities other than flight at the continuation level. Estimates of total training costs across a group of aircraft models would require replication of the estimating process for each seat of each aircraft model.

The relations and forms shown should be considered as exemplary only; that is, of the type that might be expected but not verifiable on the basis of data currently available to the author. The relationships, individually and in total, are straw men formulated as vehicles for shedding light on what data is required, what is available, and what has to be developed; for assessing the logic and feasibility of the estimating process; and for judging the scope of problems involved in assessing alternative training systems. In several cases, alternative estimating variables and forms are suggested. No

[1]The Navy practice of partial specialization for undergraduate pilots has been ignored since it does not change the basic flow of requirements but complicates its explanation.

judgements are made as to which are better or more applicable; each is logical, and the "best" may lie in differences in organization and accounting between the services.

Several simplifying assumptions were discussed above. They are reiterated here and several others are noted.

1. Regarding personnel composition, all instructors are assumed to be rated officers. This would be true in training for crew seats occupied by officers. In the case of crew seats occupied by enlisted personnel, the instructor cadre would probably be some mix of officers and enlisted. Further, instructional support, maintenance (both aircraft and simulator), and simulator operations personnel are assumed to be wholly enlisted. No provision has been made for civilian personnel.

2. The whole area of proficiency flying has been ignored. This is really another level of training. The determination of training loads would be considerably different, but once obtained, estimating its cost would be similar to continuation training flying.

3. The mix of varying experience levels of crew undergoing transition training has not been considered. The impact of the mix on formulation of syllabus requirements has been discussed above.

4. Requirements for instructor training have not been included. The complexity this introduces in the determination of training loads was discussed above.

5. Training programs for different crew seats of the same aircraft model are specified in the same or in different, but coordinated, syllabi. Individual training exercises may involve varying combinations of crew members (seats). For example, continuation training may impose differing numbers of flight hours or sorties on different crew members so that some flights are made with less than full crews; this can be accommodated in estimating training costs by considering the full crew as the entity receiving training. As a second example, some simulation training sessions (for a large aircraft) may include all crew members except the pilot and co-pilot; other sessions may include only the pilot and co-pilot. The same conditions may be encountered in transition training flying. It is simply assumed that syllabus requirements associated with an aircraft can be adjusted to allow costs to be estimated by seat and total crew, as required.

6. Training for small Navy aircraft will necessarily require carrier operations. Since the only purpose of carriers is air combat capability, their total cost of operation must be a cost of flight training. This opens a whole new and large area of data requirements and estimating relationships that have not been included in the discussion.

7. Finally, no costs of military construction have been included. Where the total size of military forces remains rather constant, construction is a relatively small element in total military expenditures. This is not to say that construction costs to house a simulator will always be minor in relation to the initial cost of the simulator. However, in relation to the life-cycle costs (or life-cycle training costs) of the system the simulator supports, construction costs can be anticipated as a minor item. In the second place, construction costs will, in large part, depend upon conditions such as deployment patter[illegible] that cann[illegible] be meaningfully formulated in a gener[illegible] [illegible]del.

Prior to estimating costs, estimates must be made of the level of training activities associated with the assumed training loads and the physical quantities of equipments and manpower they imply. As will be noted below, this encompasses the bulk of the estimating burden.[1] Table 21 provides an overview of the training activity levels and physical requirements applicable to each level of training, based on the discussions contained in Sections A and B above. The shaded areas (or cells) indicate requirements that are not applicable to a given training level. Table 22 is a companion to Table 21. It is identical to Table 7, with one exception. Several different aircraft and simulator models may be in[illegible]d in a training program and Table 22 makes note of this. The remainder of this section is devoted to explanations of the individual relationships comprising the model. These explanations are organized by paragraph, arranged numerically, and the column titled "paragraph" in Tables 21 and

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[1]The problems associated with translating syllabus specifications into activity levels has been discussed in the introduction to this chapter and in Section B, above. In this section it is simply assumed that three activity-level parameters (classroom hours, flying hours by aircraft model, and simulator hours by model) are known.

Table 21. REPRESENTATIVE ACTIVITY LEVELS AND PHYSICAL REQUIREMENTS

	Paragraph	Undergraduate	Transition By Seat 1	Transition By Seat 2	Transition By Seat . . .	Continuation By Seat 1	Continuation By Seat 2	Continuation By Seat . . .	Full Crew
Training Activity Levels									
Academic Training Hours	3								
Aircraft Utilization*	1								
Simulator Utilization*	2								
Equipment Requirements									
Aircraft*	4								
Simulators*	5								
Personnel Requirements (Man Years)									
Instructors	6								
Flight Instructors*	8	**		**					
Simulation Instructors*	7								
Instructional Support Personnel	9								
Aircraft Maintenance Personnel*	10	**		**					
Simulator Operations Personnel*	11								
Simulator Maintenance Personnel*	12								
Command/Administration Personnel	13								
Base Operating/Medical Personnel	14								

* Determined for each aircraft/simulator model.

** Army training units are organized according to Tables of Distribution and Allowance (TDA). As such the units, themselves, do not have standing mobilization assignments. This does not preclude individual personnel and equipment items from having such assignments (to combat or TOE units), including those employed in undergraduate training programs. The definition of training and training costs given in Chapter 2 implies that where these assignments are made the pay and allowances of instructor and aircraft maintenance personnel are costs of readiness rather than training. Where personnel do not have such assignments their associated costs are properly training costs. The pattern of shaded areas above assumes personnel assigned to transition training organizations have mobilization assignments, while personnel assigned to undergraduate training organizations do not.

Table 22. REPRESENTATIVE APPLICABLE COST ELEMENTS

	Paragraph(s)	Undergraduate	Transition By Seat 1	Transition By Seat 2	Transition By Seat . . .	Continuation By Seat 1	Continuation By Seat 2	Continuation By Seat . . .	Continuation Full Crew
Academic Training									
Operations									
Pay & Allowances									
Instructors	6,15	††		††					
Instructional Support Personnel	9,15								
Training Device Maintenance	16								
Training Materials	17								
Investment									
Training Device Procurement	25								
Flying Training									
Operations									
Instructor Pay & Allowances	8,15	††		††					
Munitions Expended	18								
Variable Aircraft Flying Costs*									
Base Maintenance Labor	10,15	††		††					
Base Maintenance Materials**	1,19								
Depot Maintenance & Mod.	1,20								
. . .									
Investment									
Aircraft Attrition or Procurement*	1,26								
. . .									
Simulation Training									
Operations									
Instructor Pay & Allowances	7,15	††		††					
Student TAD/TDY	23								
Simulation Costs*									
Simulation Operations Labor	11,15								
Base Maintenance Labor	12,15								
Base Maintenance Materials	2,5,21								
Depot Maintenance & Mod.	2,5,22								
. . .									
Investment									
Simulator Procurement*,†	5,27								
. . .									
Student Pay & Allowances	15								
Training Support									
Operations									
Pay & Allowances									
Unit Command, Admin./Operations	13,15								
Base Oper./Medical Support Pers.	14,15								
Facilities Maintenance Material	6-14,24								
Investment									
Training Program Development	28								

*Repeat section for each aircraft/simulation model.

**Includes POL, replenishment spares, other base material.

†Includes directed development.

††Army training units are organized according to Tables of Distribution and Allowance (TDA). As such units, themselves, do not have standing mobilization assignments. This does not preclude individual personnel and equipment items from having such assignments (to combat or TOE units), including those employed in undergraduate training programs. The definition of training and training costs given in Chapter 2 implies that where these assignments are made the pay and allowances of instructor and aircraft maintenance personnel (and certain aircraft operating costs) are costs of readiness rather than training. Where personnel do not have such assignments their associated costs are properly training costs. The pattern of shaded areas above assumes personnel assigned to transition training organizations have mobilization assignments, while personnel assigned to undergraduate training organizations do not.

22 keys the relationships relevant for estimating each requirement and cost.

1. Total flying hours per year, in the aircraft model trained for (i), and each other aircraft model used in the training program (j, k...).

Undergraduate and transition training:

Aircraft model trained for:

$$FHT_i = (ESL)(FHS_i+FHO_i)(1+FNPF)$$

Other aircraft models:

$$FHT_j = (ESL)(FHS_j+FHO_j)(1+FNPF)$$

$$FHT_k = (ESL)(FHS_k+FHO_i)(1+FNPF)$$

Continuation Training:

$$FHT_i = (NAC_i)(FHS_i+FHO_i)(1+FNPF)$$

Where:

ESL: Effective student load (equilavent students per time period--year).

FHO_i: Other syllabus flying hours, by aircraft model i, associated with student training but flown by other than students.

FHS_i: Student syllabus flying hours, by aircraft model i.

FHT_i: Total aircraft utilization, flying hours per year for aircraft model i.

FNPF: Nonproductive flying time factor, accounting for all flying time above that stipulated by the syllabus. Nonproductive flying time is primarily associated with student and equipment failures but also includes diverse other reasons (for example, weather, accidents).

NAC_i: Number of aircrews assigned to combat units, aircraft model i.

2. Total simulator hours per year for each model simulator (i) used in the training program.

$$SHT_i = (ESL)(SSH_i)(1+SNPS)$$

Where: ESL: Effective student load (equilavent students per time period--year).

SHT_i: Total simulator utilization hour. per year for simulator model i.

SNPS: Nonproductive simulation time factor, accounting for simulator time above and beyond that required by the syllabus. Nonproductive time is associated primarily with student and equipment failure.

SSH_i: Student syllabus hours, simulation training portion with simulator i (device hours per student).

3. Total academic hours per year for all students.

$$AHT = (ESL)(ASH)$$

Where: AHT: Total academic hours per year. (This is the total student man-hours spent in academic instruction.)

ASH: Student syllabus hours, academic training portion (class, laboratory, etc. hours).

ESL: Effective student load (equilavent students per time period--year).

4. Number of aircraft required by the training program; of the aircraft model trained for (i), and each other aircraft model used in the training program (j, k...).

Aircraft model trained for:

$$AIR_i = FHT_i/AUR_i$$

Other aircraft models:

$$AIR_j = FHT_j/AUR_j$$

$$AIR_k = FHT_k/AUR_k$$

Where: AIR_i: Aircraft inventory required, aircraft model i.

AUR_i: Aircraft utilization rate per aircraft flying hours per year for aircraft model i.

FHT_i: Total aircraft utilization, flying hours per year for aircraft model i.

Aircraft utilization is taken here as a given customary or typical value. It might also be treated as a variable determined by intensity of maintenance (affecting turnaround time) and the number of hours per day flight operations are conducted.

5. Number of simulators required for each simulator model (i) used in the training program.

$$SIR_i = SHT_i/SUR_i$$

Where: SHT_i: Total simulator utilization hours per year for simulator model i.

SIR_i: Simulator inventory requirement, simulator model i.

SUR_i: Simulator utilization rate per simulator, hours per year for each simulator of model i.

Simulator utilization might also be treated as a variable, and determination of the number required could be a complex process. For example, a minimum deployment requirement such as one per wing would determine both utilization and a minimum number required and considerably more program specification.

6. Academic instructor man-years.

The number of classes per year is determined by:

$$(ESL)/(ACS)$$

Instructor class hours per year is determined by:

$$(AHT)/(ACS)$$

Instructor duty hours per class hour is determined by:

$$(1+ADH)$$

One instructor man-year is set at:

$$(ODHO)(ROMY)$$

So that academic instructor man-years expended are:

$$AIMY = \left(\frac{ESL}{ACS}\right) \frac{(ASH)(1+ADH)}{(ODHO)(ROMY)}$$

Where:
- ACS: Class size, academic training portion (students/class).
- ADH: Instructor primary duty hours per class hour, academic instruction portion.
- AHT: Total academic hours per year. (This is the total student man-hours spent in academic instruction.)
- AIMY: Instructor man-years academic training portion.
- ODHO: Officer availability factor.
- ROMY: Officer duty hours per man-year.

7. Simulator instructor man-years, for each simulator model (i) used in the training program.

Simulator instructor man-hours per student is determined by:

$$(SSH_i)(SCS_i)(1+SNPI)(1+SDH)$$

So that total simulator instructor man-years expended are:

$$SIMY_i = (ESL)\frac{(SSH_i)(SCS_i)(1+SNPI)(1+SDH)}{(ODHO)(ROMY)}$$

Where:

- ESL: Effective student load (equivalent students per time period--year).
- SCS_i: Instructor crew size simulation training with simulator i.
- SDH: Instructor primary duty hours per student simulator hour, simulation training portion.
- $SIMY_i$: Instructor man-years simulator training, simulator model i.
- SNPI: Instructors' nonproductive training time factor --simulation training.
- SSH_i: Student syllabus hours, simulation training portion with simulator i (device hours per student).
- ODHO: Officer availability factor.
- ROMY: Officer duty hours per man-year.

8. Flight instructor man-years associated with each aircraft model (i) in which students are trained.

Flight instructor man-hours required per student are set at:

$$(FHS_i)(1+FHI+FCH)(1+FNPI)(1+FDH)$$

So that total instructor man-years expended are:

$$FIMY_i = (ESL)\frac{(FHS_i)(1+FHI+FCH)(1+FNPI)(1+FDH)}{(ODHO)(ROMY)}$$

Where: ESL: Effective student load (equilavent students per time period--year).

FCH: Instructor student contact hours (spent in other than flying) per student flight hour, flight instruction.

FDH: Factor for instructor primary duty hours per student contact hour, flying training.

FHI: Average instructor flying hours per student flying hour, flying training with aircraft model i.

FHS_i: Student syllabus flying hours, by aircraft model i.

$FIMY_i$: Instructor man-years flight training portion with aircraft model i.

FNPI: Instructors' nonproductive training time factor other than flying--flight training.

ODHO: Officer availability factor.

ROMY: Officer duty hours per man-year.

9. Instructional support personnel (man-years per year).

$$ISP=f(AIMY,ESL)$$

Where: AIMY: Instructor man-years academic training portion.

ESL: Effective student load (equivalent students per time period--year).

ISP: Instructional support personnel required (man-years).

Instructional support personnel are defined as enlisted personnel providing direct support to the training program in such areas as maintenance and operation of libraries, maintenance of student records, and curriculum materials and training supplies.

10. Aircraft maintenance personnel associated with each aircraft model (i) used in the training program.

$$AMP_i = (FHT_i)\frac{(MMHA_i)(MPT)(1+MSP)}{(NEMY)(ODHE)}$$

Where: AMP_i: Aircraft base maintenance man-years, aircraft model i.

FHT_i: Total aircraft utilization, flying hours per year for aircraft model i.

$MMHA_i$: Aircraft maintenance man-hours flying hour, aircraft model i.

MPT: Direct maintenance productive time factor.

MSP: Indirect maintenance personnel factor--the ratio of direct maintenance personnel to indirect personnel (such as supervisory, tool crib and maintenance, etc.).

NEMY: Non-rated enlisted duty hours per man-year.

ODHE: Enlisted personnel availability factor.

Note that maintenance personnel required is adjusted to account for idle or non-productive time (part and tool availability) and for maintenance support (tool crib, supply personnel, etc.).

11. Simulator operations personnel associated with each simulator model (i) used in the training program.

Set SCR_i as the number of simulator operations crews required for each simulator fielded, based on the number of shifts operated.

If $$\frac{SUR_i}{(NEMY)(ODHE)} \leq 1 \quad \text{then} \quad SCR_i=1$$

$$1 < \frac{SUR_i}{(NEMY)(ODHE)} \leq 2 \qquad SCR_i=2$$

$$\frac{SUR_i}{(NEMY)(ODHE)} > 2 \qquad SCR_i=3$$

and $$SOP_i = (SOS_i)(SIR_i)(SCR_i)$$

Where: NEMY: Non-rated enlisted duty hours per man-year.

ODHE: Enlisted personnel availability factor.

SCR_i: Number of simulator operations crews required, simulator model i.

SOS_i: Simulator operator crew size simulation training with simulator i.

SIR_i: Simulator inventory required, simulator model i.

SOP_i: Simulator operations man-years, simulator model i.

SUR_i: Simulator utilization rate per simulator, hours per year for each simulator of model i.

12. Simulator maintenance personnel associated with eac simulator model (i) used in the training program.

$$SMP_i = (SHT_i) \frac{(MMHS_i)(MPT)(1+MSP)}{(NEMY)(ODHE)}$$

Where: NEMY: Non-rated enlisted duty hours per man-year.

ODHE: Enlisted personnel availability factor.

$MMHS_i$: Simulator maintenance man-hours per flying hour, simulator model i.

MPT: Direct maintenance productive time factor.

MSP: Indirect maintenance personnel factor--the ratio of direct maintenance personnel to indirect personnel (such as supervisory, tool crib and maintenance, etc.)

SHT_i: Total simulator utilization, hours per year for simulator model i.

SMP_i: Simulator base maintenance man-years, simulator model i.

13. Unit command/administration personnel.

$$CAO = (CAOP) \cdot f\left(ESL, \sum_i FIMY_i + \sum_i SIMY_i + AIMY\right)$$

$$CAE = \frac{(1-CAOP)}{CAOP}(CAO)$$

Where: AIMY: Instructor man-years academic training.

CAE: Training unit command/administration enlisted personnel requirement.

CAO: Training unit command/administration officer personnel requirement (assumed to be all rated).

CAOP: Training unit command/administration personnel officer ratio.

ESL: Effective student load (equivalent students per time period--year).

$FIMY_i$: Instructor man-years flight training portion with aircraft model i.

$SIMY_i$: Instructor man-years simulator training, simulator model i.

This is assumed to be some function of the level of training activity as measured by either the student load or the total number of instructors required (or both).

14. Base operating/medical support personnel.

$$BOSO = (BOS)(BORA)\left[\sum_i (FIMY_i + AMP_i) + \sum_i (SIMY_i + SOP_i + SMP_i) + AIMY + ISP + ESL + CAO + CAE\right]$$

$$BOSE = \frac{(1-BORA)}{BORA} \cdot (BOSO)$$

Where: AIMY: Instructor man-years academic training portion.

AMP_i: Aircraft base maintenance man-years, aircraft model i.

BORA: Base operating/medical support personnel, officer ratio.

BOS: Base operating/medical support personnel rate (base support personnel as a fraction of training personnel).

BOSE: Base operating/medical support enlisted personnel requirement.

BOSO: Base operating/medical support officer personnel requirement.

CAE: Training unit command/administration enlisted personnel requirement.

CAO: Training unit command/administration officer personnel requirement (assumed to be all rated).

ESL: Effective student load (equivalent students per time period--year).

$FIMY_i$: Instructor man-years flight training portion with aircraft model i.

ISP: Instructional support personnel required (man-years).

$SIMY_i$: Instructor man-years simulator training, simulator model i.

SMP_i: Simulator base maintenance man-years, simulator model i.

SOP_i: Simulator operations man-years, simulator model i.

15. Pay and allowances of personnel. Pay and allowances of personnel associated with ten different functions encompassed by the training program are grouped together here.

Students:

$$PAST = (ESL)(PRST)(DTP)$$

(The appropriate pay and allowance rate will vary with the level of training and whether the seat trained for is occupied by officer or enlisted personnel.)

Flight instructors:

$$PAFI = \sum_i (FIMY)(PRRO)$$

(Flight instructor pay and allowances is the total across all aircraft models employed in the training program.)

Simulator instructors:

$$PASI = \sum_i (SIMY_i)(PRRO)$$

(This is a total across all simulator models used in the training program.)

Academic instructors:

$$PAAI = (AIMY)(PRRO)$$

Instructional support personnel:

$$PAIS = (ISP)(PREN)$$

Aircraft maintenance personnel:

$$PAAM_i = (AMP_i)(PREN)$$

(Stratified according to aircraft model i.)

Simulator maintenance personnel:

$$PASM_i = (SMP_i)(PREN)$$

(Stratified according to simulator model i.)

Simulator operations personnel:

$$PASO_i = (SOP_i)(PREN)$$

(Stratified according to simulator model i.)

Training unit command/administration personnel:

$$PACA - (CAO)(PRRO) + (CAE)(PREN)$$

Base operating/medical support personnel:

$$PAOB = (BOSO)(PRNO) + (BOSE)(PREN)$$

Where:

AIMY: Instructor man-years academic training portion.

AMP_i: Aircraft base maintenance man-years, aircraft model i.

BOSE: Base operating/medical support enlisted personnel requirement.

BOSO: Base operating/medical support officer personnel requirement.

CAE: Training unit command/administration enlisted personnel requirement.

CAO: Training unit command/administration officer personnel requirement.

DTP: Duration of training program. (Proportion of a year.)

ESL: Effective student load (equivalent students per time period--year).

FIMY: Instructor man-years flight training portion.

ISP: Instructional support personnel required.

PAAI: Pay and allowances of academic instructors.

$PAAM_i$: Pay and allowances of aircraft maintenance personnel associated with aircraft model i.

PACA: Pay and allowances of training unit command/ administration personnel.

PAFI: Pay and allowances of flight instructors.

PAIS: Pay and allowances of instructional support personnel.

PAOB: Pay and allowances of base operating/medical support personnel.

PASI: Pay and allowances of simulator instructors.

$PASM_i$: Pay and allowances of simulator maintenance personnel associated with simulator model i.

PASO: Pay and allowances of simulator operations personnel.

PAST: Pay and allowances of students.

PREN: Pay and allowance rate--enlisted.

PRNO: Pay and allowance rate--non-rated officer.

PRRO: Pay and allowance rate--rated officers.

PRST: Pay and allowance rate--students.

$SIMY_i$: Instructor man-years simulator training, simulator model i.

SMP_i: Simulator base maintenance man-years, simulator model i.

SOP_i: Simulator operations man-years, simulator model i.

16. Cost of training device maintenance and replacement.

$$TDMC = f(ESL, TDI)$$

Where: ESL: Effective student load (equivalent student per time period--year).

TDI: Inventory value of unspecified training devices (or value per student enrolled).

TDMC: Cost of training device maintenance and replacement.

(In the context of this paragraph training devices are defined as relatively small or low value devices normally associated with academic training and that may be of general use in a number of training programs. They are not the large complex devices though capable of replacing flying time that are normally associated with the term "simulator". Maintenance requirements would logically be related to the value of the inventory required for training and the amount of use they receive--approximated by the effective student load.)

17. Cost of expended training materials.

$$TMC = (ESL)(TMS)$$

Where: ESL: Effective student load (equivalent student per time period--year).

TMC: Cost of expended training materials.

TMS: Per student cost of training materials consumed.

18. Cost of training munitions expended.

$$TMUN = (ESL)(MUNS)$$

Where: ESL: Effective student load (equivalent student per time period--year).

MUNS: Syllabus allowance of training munitions per student.

TMUN: Cost of training munitions expended.

19. Aircraft base maintenance material cost, aircraft model i.

$$AMTL_i = (AFHC_i)(FHT_i)$$

Where: $AFHC_i$: Aircraft base maintenance material cost per flying hour, aircraft model i.

$AMTL_i$: Aircraft base maintenance material cost, aircraft model i.

FHT_i: Total aircraft utilization, flying hours per year for aircraft model i.

(Consisting of POL, replenishment spares, and other base maintenance materials.)

20. Aircraft depot maintenance cost, aircraft model i.

Transition and continuation training

$$ADM_i = (ADFH_i)(FHT_i)$$

Undergraduate training

$$ADM_i = (ADFH_i)(FHT_i) + (ADUE_i)(AIR_i)$$

Where: $ADFH_i$: Aircraft depot maintenance cost per flying hour, aircraft model i.

ADM_i: Aircraft depot maintenance cost, aircraft model i.

ADUE: Aircraft depot maintenance cost per u.e., aircraft model i. (That portion of depot cost that is independent of the level of flying hours).

AIR_i: Aircraft inventory required, aircraft model i.

FHT_i: Total aircraft utilization, flying hours per year for aircraft model i.

(Aircraft depot maintenance cost is generally considered to be composed of two components--those costs that are a function of the existence of aircraft in the inventory and those costs that are a function of the number of flying hours. Both components are considered applicable to undergraduate training, but only the latter to transitional and continuation training.)

21. Simulator base maintenance material cost, simulator model i.

$$SMTL_i = (SVMC_i)(SHT_i) + (SFMC_i)(SIR_i)$$

Where: $SFMC_i$: Simulator fixed base maintenance material cost, simulator model i.

SHT_i: Total simulator utilization, hours per year for simulator model i.

SIR_i: Simulator inventory required, simulator model i.

$SMTL_i$: Simulator base maintenance material cost, simulator model i.

$SVMC_i$: Simulator variable base maintenance material cost, simulator model i. (This is considered to include supplies, utilities, and other services).

(Both simulator base material and depot costs, below, are considered to vary with the number of simulators fielded and the total hours they are operated.)

22. Simulator depot maintenance and modification cost, simulator model i.

$$SDM_i = (SVDC_i)(SHT_i) + (SFDC_i)(SIR_i)$$

Where: SDM_i: Simulator depot maintenance and modification cost, simulator model i.

$SFDC_i$: Simulator fixed depot maintenance cost, simulator model i.

SHT_i: Total simulator utilization, hours per year for simulator model i.

SIR_i: Simulator inventory required, simulator model i.

$SVDC_i$: Simulator variable depot maintenance cost, simulator model i.

(Simulator depot maintenance does not necessarily imply that work is physically performed at depot locations. For large fixed simulators work would generally be performed in the field by travelling depot or contractor teams).

23. Cost of student (and instructor) temporary duty for simulator training.

$$TMPD = \left[(DAY)(PERD)(ESL) + (TRIP)(CPT)\right] (1+INSR)$$

Where: CPT: Cost per round trip for simulator training.

DAY: Student days of temporary duty (for simulator training, per student).

ESL: Effective student load (equivalent students per time period--year).

INSR: Simulator training travel--student/instructor ratio.

PERD: Temporary duty per diem rate.

TMPD: Cost of student temporary duty for simulator training.

TRIP: Number of trips required (per year) for simulator training, per student.

(At least three simulator deployment strategies may be followed: 1. each training base has its own complement of simulators; 2. mobil simulators travel to student locations; and 3. students travel to simulator locations for training. Which of these three is efficient will depend, among other things, on the level of simulator utilization. The first strategy will maximize the number of simulators and their attendent procurement and operations costs. The last will minimize the number of simulators (subject to some maximum utilization rate) at the expense of student and instructor travel. The strategy assumed will simultaneously impact on simulator procurement costs (paragraph 27), simulator utilization (paragraph 5) and this relation.

24. Cost of facilities maintenance materials.

$$FMM = (FMF)\left[\sum_i (FIMY_i + AMP_i) + \sum_i (SIMY_i + SOP_i + SMP_i) + AIMY + ISP + ESL + CAO + CAE + BOSO + BOSE\right]$$

Where: AIMY: Instructor man-years academic training portion.

AMP_i: Aircraft base maintenance man-years, aircraft model i.

BOSE: Base operating/medical support enlisted personnel requirement.

BOSO: Base operating/medical support officer personnel requirement.

CAE: Training unit command/admin. enlisted personnel requirement.

CAO: Training unit command/administration officer personnel requirement (assumed to be all rated.)

ESL: Effective student load (equivalent students per time period--year).

FIMY: Instructor man-years flight training portion.

FMF: Facilities maintenance materials factor.

FMM: Cost of facilities maintenance materials.

ISP: Instructional support personnel required.

$SIMY_i$: Instructor man-years simulator training, simulator model i.

SMP_i: Simulator base maintenance man-years, simulator model i.

SOP_i: Simulator operations man-years, simulator model i.

(This is a conventional formulation for an item of rather minor costs.)

The previous 24 paragraphs have been concerned only with levels of training activities and recurring (i.e., annual) operating costs. The form of these relationships would remain essentially the same whether costs were estimated for a single aircraft type or for many simultaneously. The following four paragraphs are concerned with one-time or investment costs. Here the manner in which costs are determined, and their interpretation, might differ significantly.

Indeed, the exact meaning of investment costs for a single aircraft is open to question. What investment cost are relevant to the particular problem addressed? Are capital items properly amortized over a system's life-cycle and added to operating costs or should they be considered a one-time outlay and sunk? What is appropriate depends upon study context and differs from case to case.

The relationships given below are generally appropriate to the single-aircraft approach. The way they are written is consistent with the assumption that investment is a one-time expenditure and separately identified rather than being amortized and charged year by year to system operations.

25. Cost of training device procurement.

$$TDPC = f(ESL)$$

$$TDPC = f(TDI)$$

Where: ESL: Effective student load (equivalent students per time period--year).

TDI: Inventory value of unspecified training devices (or value per student enrolled.)

TDPC: Training device procurement cost.

(Currently available data appears to shed little or no light on training device inventories. Were lists of device inventories available they might be used directly, as in the second relationship. They might also provide the basis for developing a general relationship based on numbers of students, as in the first relationship.)

26. Cost of aircraft procurement/attrition, aircraft model i.

$$ACPA_i = (FHT_i)(ACAR_i)(ACUC_i)$$

$$ACPA_i = (AIR_i)(ACUC_i)$$

Where: $ACAR_i$: Aircraft attrition rate, aircraft model i.

$ACPA_i$: Aircraft procurement/attrition cost, aircraft model i.

AIR_i: Aircraft inventory required, aircraft model i.

$ACUC_i$: Aircraft unit procurement cost, aircraft model i.

FHT_i: Total aircraft utilization, flying hours per year for aircraft model i.

(Costs of both attrition and procurement are relevant only to aircraft systems for which acquisition has not been completed. Aircraft used in continuation and transition training generally have mobilization assignments, and the appropriate cost would be limited to aircraft lost during training that are, therefore, not available for mobilization. Since aircraft with training missions only would not be procured except for that mission the full cost of the total buy is a proper cost even though they are not wholly consumed during the model time horizon).

27. Cost of simulator procurement, simulator model i.

$$SIP_i = (SIR_i)(SIUC_i)$$

Where: SIP_i: Simulator procurement cost, simulator model i.

SIR_i: Simulator inventory required, simulator model i.

$SIUC_i$: Simulator unit procurement cost, simulator model i.

28. Cost of training program development.

$$TPD = \overline{TPD}$$

Where: TPD: Training program development cost.

(For the purposes of this paper, costs of program development are taken as given.)

VII. INFORMATION SOURCES AND AVAILABILITY

This chapter addresses the availability and sources of information that may provide inputs to the model described in Chapter VI. In no way can this examination be considered exhaustive. Reflecting upon the scope of the topic and the resources available for the project, it was decided early-on to consider only information that is either systematically reported or generally available to military department headquarters. Within this constraint, there is undoubtedly a large volume of data that might provide useful inputs that could not be investigated. Still larger volumes of potentially useful data certainly reside within operating commands that could not be investigated, and here, neither uniformity in what is collected nor consistency in how it is treated can be counted on. Properly addressing this mass of information can only be accomplished by an extensive effort.

A second impact of the short time frame is that the model could not be modified from its initial formulation according to the results of this limited data search. A normal sequence in such a project is to formulate a first approximation model to serve two purposes; first, to serve as a framework for an initial evaluation of data, and second, to provide an explicit vehicle for assessing the logic and propriety of the estimating methodology in the light of data found available. Data evaluation can be expected to identify deficiencies in and indicate changes to the model. (Some data elements may simply not be available. Others may be accessible, but their formats may be inconsistent with the model. New or unanticipated sources and forms of data may be uncovered that permit expansion or refinement of the estimating process.) This is an iterative process, but, to date, nothing more than the first go-around has been accomplished--the initial formulation and first data search within the limited domain of headquarters offices.

Note that this chapter is formatted as a series of reference tables rather than text. The input elements of the model have been gathered into seven categories, and each comprises a separate section, as follows:

At the beginning of each section is a table listing each item and referencing (by service and training level) a paragraph within the section at which its discussion is to be found. A sample is shown in Table 23. The shaded cells denote that, within the model assumptions, a datum is not applicable to a given service and training level. The letter 'A' denotes that a datum is wholly a study assumption; that is, service management and data systems are irrelevant in formulating its value. A question mark (?) indicates that the information is considered relevant; intuitively it is felt that appropriate or limiting values could be developed from current service accounting or information systems, but no hint of where or how to develop it was gleaned from this study. The letter 'U' indicates a datum that, although relevant, does not appear to be available from current accounting and

Table 23. TRAINING LOAD CATEGCRY

Variable Name	Description	Army Under Graduate	Army Transition	Army Continuation	Navy Under Graduate	Navy Transition	Navy Continuation
CC_i	Crew composition (number per full crew), crew seat i.			1			
CR	Crew ratio (crews per u.e. aircraft).			3			
DR_i	Flight status disqualification rate, crew seat i.			6			
FL	Force level (number of u.e. aircraft).			8			
RR	Aircrew rotation/reassignment rate.			9			
TA_i	Transition training attrition rate, seat i.		10				
UA_i	Undergraduate training attrition rate, crew seat i.	10					

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information systems. (Wherever convenient the discussion has been consolidated across data elements, service, and training level.)

A. TRAINING LOAD INFORMATION (Table 24)

The relationships developed in Section C of Chapter VI employ two basic training load parameters; ESL (effective student load) and NAC_i (number of aircrews assigned to combat units, aircraft i). The input items shown in Table 24 allow for the derivation of their values as described in Section A of Chapter VI. However, between Sections A and C the symbols by which these two parameters are identified differ, since different relationships are used to estimate student load according to level of training. The reconciliation between the different symbology is as follows:

Relationship	Section C	Section A
Number of Aircrews	NAC_j	$CL = (FL)(CR)$
Student load - c[illegible]ation training	ESL	$CN_i = (FL)(CR)(CC_i)$
Student load - transition training	ESL	$TL_i = (RR)(FL)(CR)(CC_i)/(1 - \frac{TA_i}{2})$
Student load - undergraduate training		$UL_i = (DR_i) \sum_j \left[(FL_a)(CR_a)(CC_{j,i})\right] / \left(1 - \frac{UA_i}{2}\right)$

Note subscript nomenclature
- j: aircraft model
- i: crew seat

1. The only crew rating in Army avaiation is pilot, and the number of pilots per crew for all existing aircraft types is given in the Army Aviation Planning Manual (FM 101-20). For future buys this information could be obtained from the system

Table 24. TRAINING LOAD CATEGORY

Variable Name	Description	Army			Navy			Air Force		
		Under Graduate	Transition	Continuation	Under Graduate	Transition	Continuation	Under Graduate	Transition	Continuation
CC_i	Crew composition (number per full crew), crew seat i.			1			2			2
CR	Crew ratio (crews per u.e. aircraft).			3			4			5
DR_i	Flight status disqualification rate, crew seat i.			6			7			6
FL	Force level (number of u.e. aircraft).			8			8			8
RR	Aircrew rotation/reassignment rate.			9			9			9
TA_i	Transition training attrition rate, seat i.		10			11			12	
UA_i	Undergraduate training attrition rate, crew seat i.	10			13			12		

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coordinators in the Aviation Systems Division of DCS Research, Development, and Acquisition.

2. For Navy and Air Force systems this information is found in USAF Cost and Planning Factors (AFR 173-10) and the Navy volumes of Standard Aircraft Characteristics. Two problems should be recognized with these sources. In the case of the Air Force, information is given in terms of officer and enlisted only rather than crew specialty and may not be complete as to aircraft model. In the case of the Navy, the information is not given for some aircraft. This can't be considered a serious problem, as crew composition is in the nature of "common knowledge", certainly obtainable from any squadron operating the aircraft. For new aircraft, information would be obtainable from program monitors (at headquarters levels) or from system project offices (USAF Aeronautical Systems Division and Naval Air Systems Command).

3. Army aviation units are not manned in terms of crew ratios, however a proxie could be developed from Tables of Organization and Equipment (TOE), at alternative strength levels.

4. Crew ratios, by aircraft model, are developed by the Aviation Program Manpower, Tactical Air Training, and Air ASW Training Branches of the Aviation Manpower and Training Division, Deputy CNO for Air Warfare (NAVOP 597, 593, and 594). They are transmitted to other Naval offices by way of letter only.

5. USAF crew ratio standards, by aircraft type and command, are given in the same table of USAF Cost and Planning Factors (AFR 173-10) as crew compositions. Since this table is updated at irregular intervals, it may present problems of timeliness (as well as completeness); a better source would be the headquarters of major operating commands.

6. Information on flight status disqualification rates could not be found; however, general rates of officer personnel turnover are given in the Army Force Planning Cost Handbook (Directorate of Cost Analysis, Comptroller of the Army) and USAF Cost and Planning Factors (AFR 173-10). Personnel in the Army Directorate of Cost Analysis expressed a belief that they would not be significantly different and the general rate would serve as an acceptable lower bound.

7. Similar to the Army and Air Force, the Navy appears to keep no formal records of flight status disqualification. However, individuals in the Aviation Manpower and Training Division (Deputy CNO for Air Warfare) develop insights into the problem as a result of their normal workload. The pattern of loss they project is not simple--being tied to obligated service, promotion z[illegible], and rank.

. Force level projections for all three services are made for seven to fifteen years into the future. In the case of the Navy and Air Force, the projections are stratified by aircraft type and program element and show both inventory and flying hour projections. The Navy projection is published as the Aircraft Program Data File in the form of a line-printer output by the Aviation Programs Division of Deputy CNO for Air Warfare (OPNAV 511). The Air Force projection is published as the 'PA'--one of the formal P series of Air Force Planning documents. The Army projection resides in a computer data file that is part of the "Structure and Composition" subsystem of the Army 'Force Accounting System' maintained by the Force Accounting System Division of DCS for Operations and Plans. The format of this projection is uncertain, since the material was not available to this study.

9. Rotation rate has some characteristics of program assumptions. The services have general guidelines on rotation, but actual assignment durations may be quite different, and

vary over time. Further, the reasons for variation can be many--ranging from overall budget considerations to individual skill and experience levels. The only written information found was a listing of recommended first tour lengths for fiscal year 1977 for Navy pilots and flight officers (contained in a letter from the Aviation Manpower Programs Branch, Aviation Manpower and Training Division--OPNAV 59). The recommended tour lengths appeared to be a secondary consideration to maintaining criteria experience mixes by aircraft and squadron type.

10. Army training attrition for undergraduate training (experience and projections) may be found in two sources. The first is a report (Form 886 Service Training Report) transmitted monthly from all training establishments to the Training and Doctrine Command where it is consolidated and passed on to the Director of Military Personnel Management, DCS Personnel, Headquarters, Department of the Army. It provides student inputs and outputs stratified by training course and personnel category (officer, warrant, enlisted), from which attrition rates can be developed. The second source is budget submission materials containing the same information items projected over a three-year time horizon and submitted to the same office. (The Army appears to experience insignificant attrition for transition training.)

11. Attrition associated with transition training is reported to the tactical and ASW Air Training Branches of the Aviation Manpower and Training Division (Deputy CNO for Air Warfare) on a monthly basis, along with other data. This information does not appear to be published in any other form.

12. Air Force student attrition for all training (by installation, school, and course) is reported annually to the Directorate of Management Analysis, Comptroller of the Air Force. Reporting of incurred training costs (along with

specification of reporting formats) is a requirement of Air Force Regulation 173-7, Formal Training Course Cost Report.

13. Undergraduate flight training attrition factors are developed by the Commander of Naval Aviation Training. This, along with other training cost data, is used for justification of budget submission, but it is informally passed on to the Undergraduate Flight Training Branch of the Aviation Manpower and Training Division, Deputy CNO for Air Warfare (OPNAV 591).

B. SYLLABUS INFORMATION (Table 25)

Syllabus is used here as a general term to include all written materials that specify or describe training program events, evaluation criteria, performance standards, etc. Documents serving this function are associated with a number of different names such as phase manuals, mission guides, training manuals. They are also frequently identified simply as numbered manuals, directives, regulations, etc. and are difficult to identify in publication indexes. (Indeed, many such sources are not identified in standard publication indexes.)

Documentation is extensive for a given training program, and considering the number of flight training programs, the total of syllabus type publications might fill a fair-sized library. This project could hope for no more than a light sampling of existing documentation. In fact, they proved to be generally unavailable at headquarters levels, and the sample actually obtained (primarily from the field) cannot be considered as adequate for anything but rudimentary generalizations. From this small sample, though, it appears that formats have not been standardized (with the possible exception of Army material) with respect to either what information constitutes a training program specification or how it is organized.

Table 25. SYLLABUS CATEGORY

Variable Name	Description	Army Under Graduate	Army Transi- tion	Army Continu- ation	Navy Under Graduate	Navy Transi- tion	Navy Continu- ation	Air Force Under Graduate	Air Force Transi- tion	Air Force Continu- ation
ACS	Class size, academic training portion.	1	1		1	1		1	1	
ASH	Student syllabus hours, academic training portion.	2	2		2	2		2	2	
DAY	Student days of temporary duty (for simulator training).		A	A		A	A		A	A
DTP	Duration of Training Program (fraction of a year).	2	2		2	2		2	2	
FHO_i	Other syllabus flying hours, by aircraft model (i, j, k...).	2	2		2	2	?	2	2	?
FHS_i	Student syllabus flying hours, by aircraft model (i, j, k...).	2	2	3	2	2	3	2	2	3
FNPF	Non-productive flying time factor.	2	2	?	2	2	?	2	2	?
INSR	Simulator training travel--student/instructor ratio.	A	A		A	A		A	A	
MUNS	Syllabus allowance of training munitions per student.	2	2	3	2	2	3	2	2	3
SNPS	Non-productive simulation time factor.	?	?	?	?	?	?	?	?	?
SSH_i	Student syllabus hours, simulation training.	2	2	3	2	2	3	2	2	3
TRIP	Number of trips required for simulator training.		A	A		A	A		A	A

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1. Class size refers to the number of students in a classroom at one time--rather than the size of an entry class (the number beginning training on the same date). The intent is to measure the instructor resources expended per student--similar to an average student/instructor ratio. In either case, syllabus materials are generally silent. The only exception in the syllabi received was for the F-14, that showed a maximum class size (although this appeared to refer to the size of the entry class).

Planned Air Force and Navy entry class sizes, by date of entry, for periods of roughly a year are published in other documents for undergraduate and transition training. The Air Force projections are contained in "Program Flying Training" (PFT) volumes developed by the Air Training Command and the operating major commands. Navy projections are developed at Headquarters by Deputy CNO for Air Warfare (OPNAV 591, 593, 594) and distributed in the form of OPNAVNOTEs or letters. How well this information can be translated into class sizes (in the sense of instructor/student ratios) is questionable. However, considering the centralized nature of all Army flight training and the centralized command structure of Navy and Air Force undergraduate training, it is felt that class size data should be available from Ft. Rucker, Air Training Command, and Commander, Naval Eduction and Training (or Commander, Naval Air Training).

2. Syllabi for formal training courses (undergraduate and transition) uniformly contain statements of course hour requirements. Flying hours were shown in all syllabi seen. However, in some cases only student hours were shown and in others instructor hours (chase aircraft, etc.) were included. In all cases, though, syllabi provided statements of academic hours, simulator hours, and training program duration.

Actual flying hours expended above those specified as the standard for student instruction are generally classified as overhead flying. Requirements for overhead flying arise from a number of sources, including student reflies, instructor currency, equipment check-out, and mission abort (from any cause). The Navy closely monitors overhead flight and, especially, that portion due to student failure and mission aborts. In one case, the F-14, both the level and a percentage breakout of overhead flight was contained in the syllabus. Overhead flight rates for undergraduate training are included in the information normally reported to the Undergraduate Flight Training Branch of the Aviation Manpower and Training Division, Deputy CNO for Air Warfare (OPNAV 591).

For the Army and Air Force, overhead flying information is very sketchy, although intuitively it must be closely tracked and available somewhere. A single total for overhead flying, by training course, can be developed for Air Force single-seat training by comparing the syllabus standard with the actual hours logged and number of graduates as reported on Air Force Form 611 (a requirement specified in Air Force Regulation 173-7, Formal Training Course Cost Report).

Munition expenditures appear to be a standard syllabus specification for Army and Air Force training. However, it was not included in the Navy syllabi available.

3. Documentation of continuation training requirements is normally associated with publications designated as instructions, regulations, etc., rather than syllabi or training programs. In addition, they do not approach documentation of undergraduate or transition training in terms of completeness or formality. The only document found addressing Army continuation flying is Army Regulation 95-1 (Army Aviation: General Provisions and Flight Regulations). It is not specific, by aircraft type, but is undergoing a revision and expansion that will recognize differences by aircraft mission. The current regulation specifies

annaul and semi-annual maximum and minimum flying hours for the following flight categories; total, night, instrument, and tactical. The only other flight requirements it contains is a listing of maneuvers to be performed (and the number of times each shall be performed) within the minimum and maximum times allowed. The Army has permitted a maximum of 10 flight hours per year to be substituted by simulator time, although the impact of this is uncertain since the Army simulator program is just getting started.[1] With this sketchy requirement there is no way to determine requirements for training munitions.

Navy continuation flying is outlined in general terms in OPNAV Instruction 3710.7H (NATOPS General Flight and Operating Instructions). Further requirements are developed by the fleet commanders. For the Atlantic Fleet, CNAL Instruction C3500.42B levies monthly flying hour requirements according to type of squadron (attack, patrol, etc.) and deployment phase. For the Pacific Fleet, CNAP Instruction C3500.4D references syllabi developed by squadron or base level units to be followed by type of squadron, along with specific requirements for fighter and attack squadrons. No examples of these syllabi were obtained, and it is unknown whether simulator or munition requirements have been documented for either the Atlantic or Pacific Fleet programs.

Air Force continuation training is documented in the '51 series manuals by aircraft type. These are issued by the operating major commands and there appears to be little in the way of common format between the commands. Two examples were obtained. In one case, the manual gave only references to training courses. It is assumed that these course references also identify

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[1]Since this information was first gathered, AR 95-1 has been reissued with an effective date of 15 January 1977, providing for an annual minimum simulator training requirement at a considerably higher level than the annual maximum specified in the previous AR 95-1 version.

documents, but this could not be determined from the way the manual was written. This appears to be a case where one has to know the system to make sense out of it, and this project did not permit that kind of time. The second manual is written in terms of sortie standards (for both aircraft and simulators) but provides little description of the purpose of the sorties. For aircraft with short flight durations (as was this case), a sortie may closely equate to flying hours, but this can hardly be assumed as a general rule.

In the case of both the Air Force and the Navy, total programmed flying hours may be obtained from the basic planning documents (the PA in the Air Force case and the P-20 report for the Navy). This data might be reduced to approximate hours per crew through a knowledge of crew ratios, support aircraft requirements, etc. Although these hours include a mix of purposes for flying, it might prove to be the better data available.

As with the Navy, there were no data uncovered to shed light on munitions requirements.

C. AIRCRAFT INFORMATION (Table 26)

Aircraft information is pretty well centralized in two publications, one for Army systems and one for Air Force systems. For the Army, the primary reference is Field Manual 101-20 (United States Army Aviation Planning Manual). The primary source of Air Force information is Air Force Regulation 173-10 (USAF Cost and Planning Factors). Information on Navy systems is spread over a number of sources.

The information contained in FM 101-20 is complete in the sense that it pertains to all Army systems currently in the inventory. However, it provides no projections or estimates of future system characteristics, and it provides only general

Table 26. AIRCRAFT CATEGORY

Variable Name	Description	Army Under-Graduate	Army Transition	Army Continuation	Navy Under Graduate	Navy Transition	Navy Continuation	Air Force Under Graduate	Air Force Transition	Air Force Continuation
$ACAR_i$	Aircraft attrition rate, aircraft model i.	1	1	1	1	1	1	1	1	1
$ACUC_i$	Aircraft unit procurement cost, aircraft model i.	2	2	2	2	2	2	2	2	2
$ADUE_i$	Aircraft depot maintenance cost per u.e., aircraft model i.	3	3		5			9		
$ADFH_i$	Aircraft depot maintenance cost per flying hour, aircraft model i.	3	3	3	5	5	5	9	9	9
$AFHC_i$	Aircraft base maintenance material cost per flying hour, aircraft model i.	3	3	3	6	6	6	9	9	9
AUR_i	Aircraft utilization rate per aircraft (flying hours per year) for aircraft model i.	4	4	4	7	7	7	10	10	10
$MMHA_i$	Aircraft maintenance man-hours flying hour, aircraft model i.	3	3		8			11		

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factors by aircraft model. (That is, no distinctions are made on the basis of mission or unit assignment.)[1] With one exception the Navy data is similar--historical information on all current aircraft models is available. The one exception concerns aircraft inventory and utilization where projections for up to 10 years in the future by model and mission are available in the Aircraft Program Data File (APDF). The information contained in AFR 173-10 is neither complete with regard to aircraft models covered nor limited to historical data. Particular emphasis is given to first line combat mission aircraft and incorporates estimates of operating cost factors for aircraft where future procurement is anticipated. This impacts on aircraft used in undergraduate training and training support roles. Several aircraft are completely missing and data is typically incomplete on others.

1. Aircraft attrition rates (historical) may prove useful in developing analogies for estimating anticipated attrition of new models. Navy and Air Force data is shown in terms relating attrition to flying hour levels--AFR 173-10 for Air Force systems and through the Aviation Safety Coordinator (NAVOP-05F) located under the Assistant Chief of Naval Operation for Air Warfare. Army attrition data is related to inventory holding rather than flying-hour levels. Army personnel state that their comparisons indicate use of flying hours (instead of or in addition to inventory levels) yields no improvements in predicability.

2. Each of the services maintain acquisition program monitors at headquarters levels that can provide current procurement cost estimates through liaison with system project offices. For Army systems, these are the Department of the Army System Coordinators (DASC) located within the Aviation Systems Division

[1] Since Army aviation training is centrally located (Ft. Rucker, Ala.) differences between training and combat units might be relatively easy to ascertain.

of the DCS for Research, Development, and Acquisition. For Navy systems, they are called program coordinators and located in the Aviation Plans and Requirement Division of the Deputy CNO for Air Warfare. Air Force Program Element Monitors (PEM) are within the Directorate of Development and Acquisition under DCS Research and Development.

3. Maintenance costs and man-hour requirements at all maintenance levels are published in FM 101-20. These data are developed by the Directorate of Cost Analysis of the Comptroller of the Army. Since FM 101-20 is published irregularly, the Cost Analysis Directorate personnel provide a better source of current information. There are two uncertainties involved in the application of these data. First, both depot cost and base level material cost may exclude avionics and armament systems, and base maintenance labor definitely excludes these systems. Other tables in the manual list costs for these systems at all levels of maintenance, but according to end-item designation (such as AN number) rather than aircraft model. As a result, resort to listings of typical avionics and armament suites, also shown in FM 101-20, would be required to determine total maintenance costs. Second, although depot maintenance cost is nominally stated in terms of "per-flying-hour", it is actually based on the assumption of 5-year overhaul cycles. This raises a question of whether depot costs should be considered dependent upon flying hours or inventories, and there is no good answer.

4. FM 101-20 provides flying-hour levels by aircraft model, but no distinction is made between aircraft held in combat organizations and the training establishment. From the POM back-up material discussed in Chapter 2, there is reason to believe that differences may be significant. Historical flying hour data by both model and command (that would separate training from operations) can be obtained from the *Army Aviation Status Report* (or Gold Book--issued monthly by the Aviation

Logistics Office, DCS for Logistics). However, each issue contains a single month's data, and a considerable effort would be involved in verifying such a difference.

5. Naval aircraft depot maintenance costs are reported annually in the *Industrial Performance Summary for Naval Air Rework Facilities*. For a number of reasons, this data does not provide useable inputs for estimating training costs. Engine rework costs, by engine model, are reported separately from airframe cost, by aircraft model. Costs of component and accessory rework (that appear to account for a significant share of depot workloads) are reported in separate reports, and then only by national stock number. The Navy is currently developing a system for associating components with aircraft model, but even if this system becomes a reporting norm, extensive data analysis would still be required before total rework could be estimated by aircraft model. Further, rework planning and reporting is predicated on criteria time intervals between overhaul. There appears to be no way to associate incurred costs with flying hours without extensive analysis of additional data sources.

6. Base maintenance materials cost, aircraft inventory, and flying hours are reported monthly (with annual summaries) by aircraft model and program element in the *Flying Hour Cost Report*. It is available only in the form of a line-printer output from the Aviation Program Divisions of the Deputy CNO for Air Warfare (NAVOP 511).

7. Historical flying-hour rates are contained in the Flying Hour Cost Report (see 6., above). Projections of future flying rates can be obtained from two sources. The first is a line-printer output called the P-20 Report produced by the Aviation Program Division of the Deputy CNO for Air Warfare. This report is tied to the Five-Year Defense Plan and includes the current year actuals and four or five years of projected rates by aircraft model and program element. The second source is the Aircraft Program Data File--also a line-printer output produced by the Aviation Program Division. It provides essentially the same information, but for a period extending 11 years into the future.

8. So far as could be determined, there is no data available, Navy-wide, concerning maintenance man-hours. However, the Commander of Naval Education and Training (CNET) or the Commander of Naval Air Training (CNATEA) appears to have developed factors relating incremental student loads to incremental manpower requirements associated with undergraduate flight training. These are part of what is called "CNET factors" and are used by CNET or CNATRA in preparing budget estimates. Aircraft maintenance manpower estimates are relevant only for undergraduate training, and the factors should be worth further investigation as a source of field-developed information.

9. AFR 173-10 lists depot maintenance costs (on both a flying hour and inventory basis) and base maintenance material costs (on a flying hour basis) for the bulk of Air Force combat aircraft. For those aircraft not listed (primary trainer designations and mission support aircraft) no comparable information source was found.

10. Two sources of utilization rate information are available. AFR 173-10 lists flying hour levels of 'typical' combat squadrons for a selected number of widely held aircraft. A more encompassing, and apparently accurate source is the Air

Force 'PA' document--one of the P series of formal planning documents. This document lists all aircraft in the inventory from the current year through six years into the future. Among other things, the PA lists number of u.e. aircraft and flying hours by calendar quarter for each mission and holding command for each aircraft model/series planned for the inventory for the seven year period.

11. No general source of maintenance manpower information was found; however, it must be available somewhere within the Air Force, since maintenance labor costs per flying hour are contained in AFR 173-10 for the widely held mission aircraft. As with other data items, this does not indicate that data is collected on training and support aircraft relevant for undergraduate training costs.

D. SIMULATOR INFORMATION (Table 27)

The paucity of simulator data has been discussed in Chapters 3 and 4. This section looks at the same problem, but from the viewpoint of data directed toward the estimating model.

1. The Air Force appears to be the only service collecting operating cost data in a manner consistent with the development of cost factors and estimating relationships, and the effort so far is limited to base level costs. The current sample (collected by the Directorate of Management Analysis and described in Chapter 4) may be adequate for an initial formulation, but as far as can be determined, the data has not been analyzed in this light. Further, there appears to have been no headway made in developing depot-level data.

The Army, with only one operational model fielded in small numbers, has not had the chance to develop any significant data base. This is emphasized by the fact that maintenance

Table 27. SIMULATOR CATEGORY

Variable Name	Description	Army			Navy			Air Force		
		Under Graduate	Transition	Continuation	Under Graduate	Transition	Continuation	Under Graduate	Transition	Continuation
$MMHS_i$	Simulator maintenance man-hours per operating hour, simulator model i.	1	1	1	1	1	1	1	1	1
SCS_i	Instructor crew size simulation training, simulator i.	2	2		2			2		
$SFDC_i$	Simulator fixed depot maintenance cost, simulator model i.	1	1	1	1	1	1	1	1	1
$SFMC_i$	Simulator fixed base maintenance material cost, simulator model i.	1	1	1	1	1	1	1	1	1
$SIUC_i$	Simulator unit procurement cost, simulator model i.	3	3	3	3	3	3	3	3	3
SOS_i	Simulator operations crew size, simulator model i.	2	2	2	2	2	2	2	2	2
SUR_i	Simulator utilization rate, model i.	4	4	4	4	4	4	4	4	4
$SVDC_i$	Simulator variable depot maintenance cost, simulator model i.	1	1	1	1	1	1	1	1	1
$SVMC_i$	Simulator variable base maintenance material cost, simulator model i.	1	1	1	1	1	1	1	1	1

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has been performed on contract (what would normally be base and depot functions), and the cost records resulting may not be consistent with in-house accounting practices. One study of experienced operating costs has been performed (under the auspices of the Program Manager for Training Devices), but its documentation is not sufficient.

(Whether the Navy is recording simulator operating costs in a manner that permits identification of costs with utilization is not known. In any case, it would require contacting Air 413 and Chief of Naval Education and Training.)

2. Crew size requirements have been ignored in developing data sources, since they would appear to fall out of configuration and operating descriptions of particular devices and, hence, be readily obtainable.

3. Bearing in mind that only new or projected equipment buys are relevant, the available data base appears rather sparse. Technology and design capabilities pretty well invalidate costs of older equipments as predictors of current generation device costs. One characteristic of simulators helps in this respect, that is, their distinctive subsystem composition. Simulator capabilities can evolve through major modification of subsystems or of simply adding subsystems that were not part of original configurations. Indeed, the Navy has adopted this approach, and each modification adds something to a subsystem data base. Headquarters' offices for the Army and Air Force are only program monitors and detailed information may only exist in field establishments. For Army systems, the Aviation Systems Division of DSC for Research Development and Acquisition acts as monitor with procurement responsibility resting with the Program Monitor for Training Devices (PMTRADE) located at the Army Training Devices Agency, Orlando, Fla. Program monitors for Air Force systems are in the Directorate of Development and Acquisition, DCS Research and Development. Procurement responsibility may

rest either with the Simulation System Program Office or the System Program Offices for the associated weapon system. Whichever, the program offices are located at Aviation Systems Division Headquarters. In the case of Navy systems, procurement responsibility rests with the Aviation Training Requirement Branch, Aviation Manpower and Training Division, Deputy CNO for Air Warfare.

4. Simulator utilization rate (as used here) connotes either a target level or maximum attainable for determining a number of simulators required (or the minimum number required). In this respect, it has more the characteristics of a study assumption than a datum. (Historical utilization rates are functions of training loads and syllabi requirements as well as simulator availability.) Both the Army and Navy have established such target rates and employed them in program justifications. The target rate for the Navy--80 hours per week, less varying allowances for unscheduled maintenance--is spelled out in their POM backup documentation. The Army rate is set at 95 percent of 80 hours, but, as best as can be determined, it is not a published figure. Where available, actual utilizations are quite different, and appear to be of no value in setting the target levels. (As examples, the Air Force has experienced a range of 22 to 99 hours--see Table 11.) During a period that corresponds roughly with Fiscal 1976, the Army attained an average of 72 hours at Ft. Campbell and half that much at Ft. Rucker.

E. TRAINING-PECULIAR PERSONNEL FACTORS (Table 28)

The basic information from which such factors could be developed must be available at the base level to support justification of personnel authorizations, at all levels of training for each service. However, surprisingly little appears to be available at headquarters levels. The majority of material

Table 28. PERSONNEL, TRAINING-PECULIAR CATEGORY

Variable Name	Description	Army			Navy			Air Force		
		Under Graduate	Transi-tion	Continu-ation	Under Graduate	Transi-tion	Continu-ation	Under Graduate	Transi-tion	Continu-ation
ADH	Instructor primary duty hours per class hour, academic instruction.	2	2		2			2		
CAØP	Training unit command/administration personnel officer ratio.	3	3		3	3		3	3	
FCH	Instructor student contact hours per student flight hours.	1	1		1			1		
FDH	Factor for instructor primary duty hours per student contact hour, flying training.	1	1		1			1		
FHI	Average instructor flying hours per student flying hour, flying training.	1	1		1			1		
FNPI	Instructors' non-productive training time factor--flight training.	1	1		1			1		
ØDHE	Enlisted personnel availability factor.	4	4	4	4	4	4	4	4	4
ØDHØ	Officer availability factor.	4	4		4			4		
SDH	Instructor primary duty hours per student simulator hour, simulation training.	1	1		1			1		
SNPI	Instructors' non-productive training time factor--simulation training.	1	1		1			1		

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found pertains to Navy undergraduate training as part of the "CNET Factors". This information is developed and used by Commander, Naval Education and Training (and Commander, Naval Air Training) and is transmitted to Navy Department level in the form of worksheets rather than formal reports. Evidence that the required raw information is available at base level within the Air Force can be seen in the reports specified in the Formal Training Course Cost Report (AFR 173-7). However, this is a complex system and the way in which the basic data might be used in development of factors is not understood.

1. These six elements characterize the requirements levied on flight and simulation instructors' time. The Navy has used similar data to derive levels of student flying and simulation hours associated with an undergraduate instructor man-year. The resulting levels are included in the CNET Factors material sent to the Undergraduate Flight Training Branch, Aviation Manpower and Training Division, Deputy CNO for Air Warfare (NAVOP 591). In addition, these materials include an explanation of the way man-year standards are derived. No comparable information was found for either Army or Air Force training.

2. No information was found regarding expenditure of instructors' time in academic instruction. Since the Navy does include flight and simulation instructor time requirements in the CNET Factors it is hard to understand why the same information is not tabulated in this case, see paragraph 1, above.

3. Training-overhead personnel and the ratio between officers and enlisted are tabulated for Air Force training in the Formal Training Course Cost Report (AFR 173-7). However, neither the definition nor way in which the personnel count is developed can be determined from the reporting instructions. The Navy "CNET Factors" are concerned only with direct training

personnel (with overhead being an unconsidered base level from which their planning begins). No material was found concerning Army training

4. All services keep some track of primary duty time, but it does not appear to be generally documented information. The proportion of duty time personnel expend directly in the training function should be well known at training bases, although it may be rather variable by base. The Navy gives a value for officers in the "CNET Factors" (see paragraphs at the beginning of this section) but is silent with regard to enlisted personnel. No information, other than for Naval officers, was discovered.

F. GENERAL PERSONNEL INFORMATION (Table 29)

Intuitively, it should seem that general personnel data should be easy to find. Unfortunately, this is not the case, and the reasons for it can only be guessed at. An apparent first reason is that the services are organized and managed through quite different systems, and no single set of model relationships may be applicable to all three. Starting with just one set, as was done here, could make appropriate or applicable data hard to recognize, even though found. An understanding of how training units operate within the management structures of their particular service seems necessary, and this may only be possible through field-level investigations. A second, and more damaging, reason may be that some of this information is simply not required for budget justification and day-to-day management, and the cost of developing the data is simply considered too high. (Relevant examples may be the Army experience with the TAERS/TAMMS systems and the Field Operating Cost Agency - FOCA.)

1. Base operating personnel is defined in this paper as those base-level persons providing general support to a

Table 29. PERSONNEL, GENERAL CATEGORY

Variable Name	Description	Army			Navy			Air Force		
		Under Graduate	Transi-tion	Continu-ation	Under Graduate	Transi-tion	Continu-ation	Under Graduate	Transi-tion	Continu-ation
BØRA	Base operating/medical support per-sonnel, officer ratio.	1	1	1	1	1	1	1	1	1
BØS	Base operating/medical support per-sonnel rate	1	1	1	1	1	1	1	1	1
FMF	Facilities maintenance materials factor.	2	2	2	2	2	2	2	2	2
MPT	Direct maintenance productive time factor.	3	3	3	3	3	3	3	3	3
MSP	Indirect maintenance personnel factor.	4	4	4	4	4	4	4	4	4
NEMY	Non-rated enlisted duty hours per man-year.	5	5	5	5	5	5	5	5	5
PERD	Temporary duty per diem rate.		6	6		6	6		6	6
PREN	Pay and allowance rate--enlisted.	7	7	7	7	7	7	7	7	7
PRNØ	Pay and allowance rate--non-rated officer.	7	7	7	7	7	7	7	7	7
PRRØ	Pay and allowance rate--rated officers.	7	7		7			7		
PRST	Pay and allowance rate--students.	7	7		7	7		7	7	
RØMY	Officer duty hours per man-year.	5	5		5			5		

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training installation--that is, they are directly involved neither in providing or administering training services nor in maintenance of equipment integral to the training program. (Medical personnel are really a particular category of base operating support personnel.) The term "base operating personnel does not appear to be employed by the Navy, and no other term describing this function was found. As a result, there is no hint of whether such data might be developed without detailed analysis of personnel authorizations at training bases.

Both the Army and Air Force employ the term, but in widely different contexts. The definition given above is close to Air Force usage, but that service does not appear to have developed relations that tie support personnel requirements to direct personnel. USAF Cost and Planning Factors (AFR 173-10) does give BOS personnel levels (including splits between officer and enlisted) for selected "typical" squadrons. However, no explanation of how the levels are derived is given--only that the information is provided by the Director of Manpower and Organization, DCS Programs and Resources. One report required by the Formal Training Course Cost Report (AFR 173-7) contains a listing of personnel assigned to training bases, by function, one of which is base support. In Army usage, base operations or support is associated wholly with the operations and maintenance appropriation--necessarily excluding all military personnel. Separation of direct from support personnel at training installations (organized under Tables of Distribution and Allowance) or at unit installations (those organized under Tables of Organization and Equipment) appears possible only by analysis of assigned personnel.

2. Facilities maintenance material is defined to include materials used in providing medical, transportation, etc., services as well as materials used in maintaining real property. Both the Air Force and the Army provide per-man factors. The

Air Force giving separate factors for medical, base operations, real property maintenance, and vehicular equipment support in USAF Cost and Planning Factors Manual (AFR 173-10). The Army (in the Army Force Planning Cost Handbook) displays per-man factors for a number of elements stratified by DoD major program. Among them are included base operations, administration, medical other personnel support, and transportation. The total between the two are roughly comparable, but no attempt was made to determine if the components of the totals were defined in a consistent manner. No information of this type was found for the Navy. In addition, the Army factors are general across all types of units, and its seems unlikely that differences in support requirements between aviation and other units could be developed.

3. No substantive information was found for any service. The Army has periodically made special studies of maintenance time, but these have been generally oriented towards ground forces, and no recent studies were found. For the Air Force and the Navy, there is no indication that the problem has been investigated through either sampling studies or general reporting requirements. This in no way indicates that such efforts have not been undertaken by operating commands or individual unit commanders, but obtaining references to them would be difficult.

4. The Air Force has traditionally employed a 10-percent factor for what is called chief of maintenance and a 10-percent factor for AGE maintenance. What is included in these two categories is unknown, and recent editions of the Cost and Planning Factors (AFR 173-10) make no mention of them. The Directorate of Cost Analysis, Army Comptroller, currently employs a 40-percent factor to cover all maintenance overhead. Use of the 40-percent value, however, is not documented in any publication, and the basis upon which it was derived is unknown. No comparable allowances were found for Navy maintenance.

5. There appear to be no service-wide standards for duty hours, and it's understandable how they could vary between locations, across time, and with individual duty assignments. In conversations with military personnel they appear to think in terms of a 40-hour week. Whether they are simply expressing the convention of civilian labor or are reflecting their own recent experience is unknown. This is probably a datum best handled as a study assumption.

6. This is simply the DoD-wide standard rate. It is included here only because it was called out in Chapter VI.

7. All service components are required to submit military pay and allowance rates to DoD on an annual basis. The rates are then published in DoD Handbook 7220.9H, Accounting Guidance Handbook. Separate displays are given for each service, and within each service separate rates are given for basic pay, allowance for quarters, incentive pay, and other personnel expenses for each officer and enlisted grade.

Several problems may be involved in using the DoD published data directly for estimating training costs. First, the items tabulated may not exhaust all considered by the model to constitute military pay. For example, as formulated in Chapter VI, military pay and allowances, is intended to include permanent change in station (PCS), accession and separation costs, and possibly, other items. One would have to ascertain which of these types of costs were included in the other personnel expenses category and adjust the rates used so that they would be consistent with the model's usage. Second, pay rates are not aggregated across grade levels requiring additional information about the grade composition of training personnel. Third, there is no distinction made in the incentive pay category between the different incentive categories. Since flight pay is the dominant incentive pay of concern here, additional information would be required.

The Air Force (in Cost and Planning Factors) and the Army (in Army Force Cost Planning Handbook) provide more complete shred-outs of military pay rates, also providing averages for groups of ranks. Any points of inconsistency between the rates included in these publications and the DoD Handbook are not known.

G. OTHER INFORMATION (Table 30)

This is a catch-all category for items that did not fit comfortably in the other seven. It is only incidental that, for all practical purposes, no information appears to be available for any of the types of data shown. There is not even a satisfactory definition of unspecified training devices adopted. Larger items, like carrels, can neatly be classed as training devices. But in moving down the scale of size and cost there is a question of where one item is simply general (or organizational) equipment rather than a training device. How would items such as 35mm slide projectors, tables, syllabi, etc. be classified? In addition, how far down this scale is it appropriate, in terms of cost, to try and ferret out information? The same question can be asked in regard to training consumables. Is it worth the cost of finding out what it costs to provide students with pencils, pads of paper, etc., and can one ever define a point that demarks what is worth the cost from what isn't.

1. The Navy has performed some studies of training consumables and training aid requirements for technical training courses. Typically, the scope of the training studied is one short duration course at one location with average student loads in the range of 25 to 50 and teaching staffs of five to ten. This is a far different level of requirements than would be associated with flight training.

Table 30. MISCELLANEOUS/OTHER CATEGORY

Variable Name	Description	Army			Navy			Air Force		
		Under Graduate	Transi-tion	Continu-ation	Under Graduate	Transi-tion	Continu-ation	Under Graduate	Transi-tion	Continu-ation
CPT	Cost per round trip for simulator training.		A	A		A	A		A	A
TDI	Inventory value of unspecified training devices.	?	?	?	1	1	?	?	?	?
TMS	Per student cost of training materials consumed.	U	U	U	1	1	U	U	U	U
TPD	Assumed or given training program development cost.	U	U	U	U	U	U	U	U	U

7-11-77-2

REFERENCES

Browning, Robert F., Ryan, Leonard E., Scott, Paul G., Smode, Alfred F. *Training Effectiveness Evaluation of Device 2F87F, P-3C Operational Flight Trainer, TAEG Report No. 42*, Training Analysis and Evaluation Group, January 1977, Unclassified.

Chief of Naval Operations (OPNAV 90P), *Navy Program Factors Manual*, POM 78, 1 July 1976, FOUO.

Chief of Naval Operations (OPNAV 51C1), OP-20 Report (line printer output), 15 September 1976, Unclassified.

Chief of Naval Operations (OPNAV 511), *Flying Hour Cost Report*, (line printer output), August 1976, Unclassified.

Chief of Naval Operations, *Weapon System Selection and Planning*, OPNAVINST 5000.42A, 3 March 1976, Unclassified.

Department of Defense, *Economic Analysis and Program Evaluation*, (DODI 7041.3), 18 October 1972, Unclassified.

Department of Defense, *Department of Defense Budget Guidance Manual*, DoD 7110-1-M, Unclassified.

Headquarters, U.S. Air Force, Comptroller of the Air Force, Directorate of Management Analysis, Unpublished simulator base operating cost information for fiscal year 1976, Undated.

Headquarters, U.S. Air Force, *Required Operational Capabilities (ROCs)*, AF Regulation 57-1, 30 May 1975, Unclassified.

Headquarters, U.S. Air Force, *Economic Analysis and Program Evaluation for Resource Management*, AF Regulation 178-1, 28 December 1973, Unclassified.

U.S. Air Force, Aeronautical Systems Division, *Air Force Master Plan--Simulators for Aircrew Training*, December 1975, FOUO.

Appendix A

CONDITIONS FOR EFFICIENT ALLOCATION

Appendix A

CONDITIONS FOR EFFICIENT ALLOCATION

The graphic derivation of conditions for efficient allocation of resources is given below. Two simplifying assumptions are adopted.

1. There are only two inputs to the production process, labeled "simulator hours" and "aircraft hours". (Simulator hours and aircraft hours are further assumed to be ultimate inputs--or ones that can be made available only through fixed proportions of other inputs.

2. The ratio of the costs of the two inputs is constant, regardless of the quantities of each employed.[1]

Aircraft hours cost three times that of simulator hours. For a fixed total cost, then, the aircraft could be flown for 200 hours, the simulator could be operated for 600 hours, or they could be flown/operated in innumerable combinations so long as three times the number of aircraft hours plus the number of simulator hours equalled 600. This is the budget constraint line C_1 in Figure A-1. The slope of C_1 reflects the three-to-one ratio of input prices. Budget constraint line C_2 is necessarily parallel to C_1 and represents a different and smaller budget. All larger budgets are described by budget constraint lines above and to the right of C_1.

Line P_1 in Figure A-2 traces all alternative combinations of aircraft hours and simulator hours that result in an equal

[1]This is tantamount to assuming competitive market conditions and to denying discontinuities or economies of scale for the input mix.

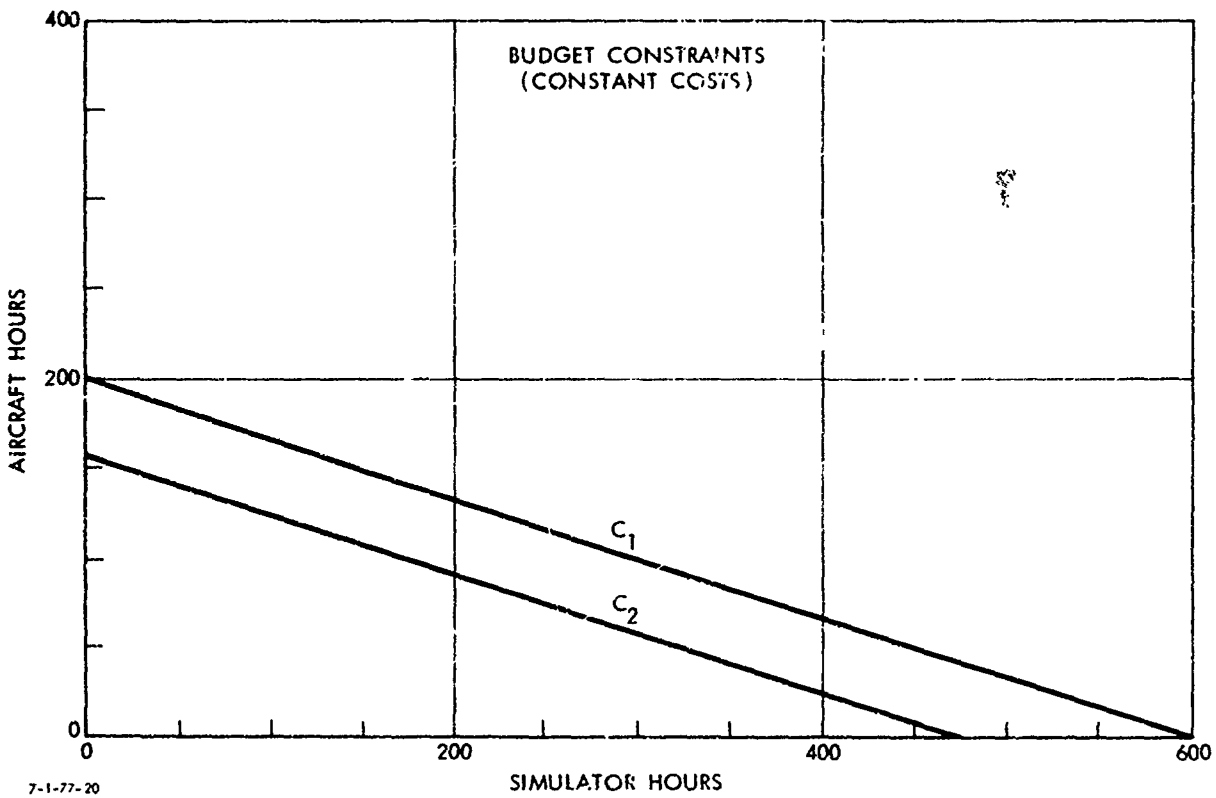

Figure A-1. BUDGET CONSTRAINT LINES

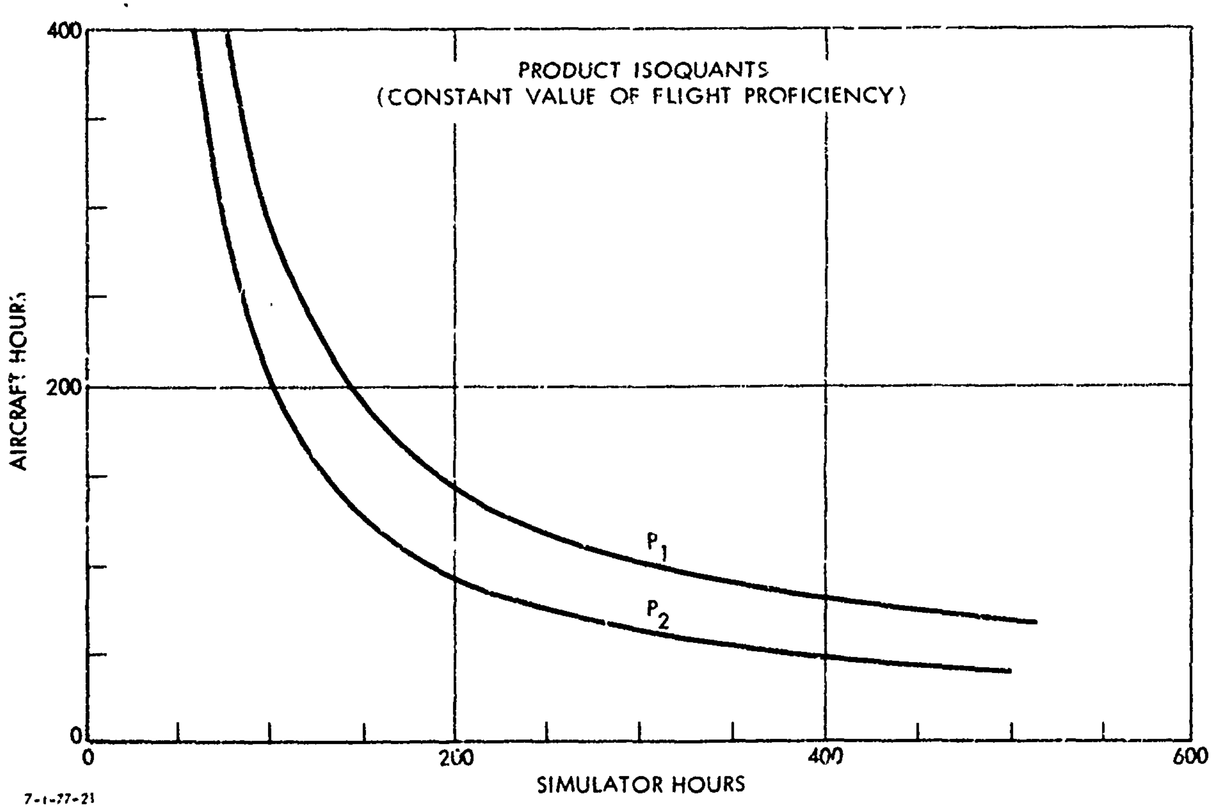

Figure A-2. PRODUCT ISOQUANT LINES

value of output or product--the level or value of flight proficiency produced. Product isoquant P_2 represents a different and small value of output. All higher levels of output are described by product isoquants above and to the right of P_1. At any point on P_1 the slope is the rate at which aircraft hours and simulator hours can be substituted for each other so as to leave the value of flight proficiency produced unchanged (the rate of input substitution at the margin of usage). Continuous convexity from the origin is consistent with universally observed phenomena and is logically based on two assertions.

1. In any production process, each input will be first applied where it generates the greatest relative quality of output. Thus, when a simulator is introduced into a training program it will be used first for those learning tasks where its output, relative to that of other training inputs, is greatest. In the table below, the simulator would first be used for task #1, second for task #5, and last for task #4.

Task #	Utilization Hours to Learn By:	
	Simulation	Flying
1	2	6
2	15	5
3	10	2
4	6	1
5	4	4

2. In any production process (flight proficiency, in this case), as successively greater quantities of one input (aircraft hours, for example) are employed, with all other inputs (simulator hours, for example) being held constant, the resulting increments in output will decrease after some point. (The classical statement of diminishing returns or variable proportions.)

These two are independent of each other, and either is sufficient for convexity. Where flight proficiency consists of learning a number of tasks, both assertions are operative. Where it consists of learning only one task, only the second assertion is relevant.

The budget constraints and product isoquants are combined in Figure A-3. The point of tangency of P_1 and C_1 (M_1) describes a unique combination of aircraft hours and simulator hours that maximizes the value of product for cost C_1 or, alternatively, that minimizes the cost of attaining a value of product equal to P_1. That is, no other equal cost mix of aircraft and simulator hours (point on C_1) will result in a higher value of product. Similarly, there is no other combination of aircraft and simulator hours that can yield the same level of flight proficiency at an equal or lower cost. At this point, the marginal rate of substitution of inputs with respect to the value of output (the slope of P_1) is equal to the ratio of costs of the inputs (the slope of C_1).

For each alternative budget level (C_2), there is an associated combination of aircraft and simulator hours (M_2) that maximizes the value of flight proficiency attained (P_2). M_1 and M_2 are two points on the line M (Figure A-4) tracing the path of all efficient (minimum costs) combinations of aircraft and simulator hours (inputs) for attaining alternative levels of flight proficiency (output).

The example above, couched in terms of two inputs and a single output, may be expanded to encompass any number of potential inputs to the training process. Letting the term "marginal product" (MP) denote the additional product (flight proficiency) resulting from the addition of one unit of a given input (e.g., simulation hour, flight hour, class hour) and "C" denote the cost per unit of that input, then, a necessary and sufficient condition for efficient allocation of resources is that the ratio of marginal product to unit cost be equal for all inputs at the margin of usage.

$$\frac{MP_1}{C_1} = \frac{MP_2}{C_2} = \ldots \frac{MP_3}{C_3}$$

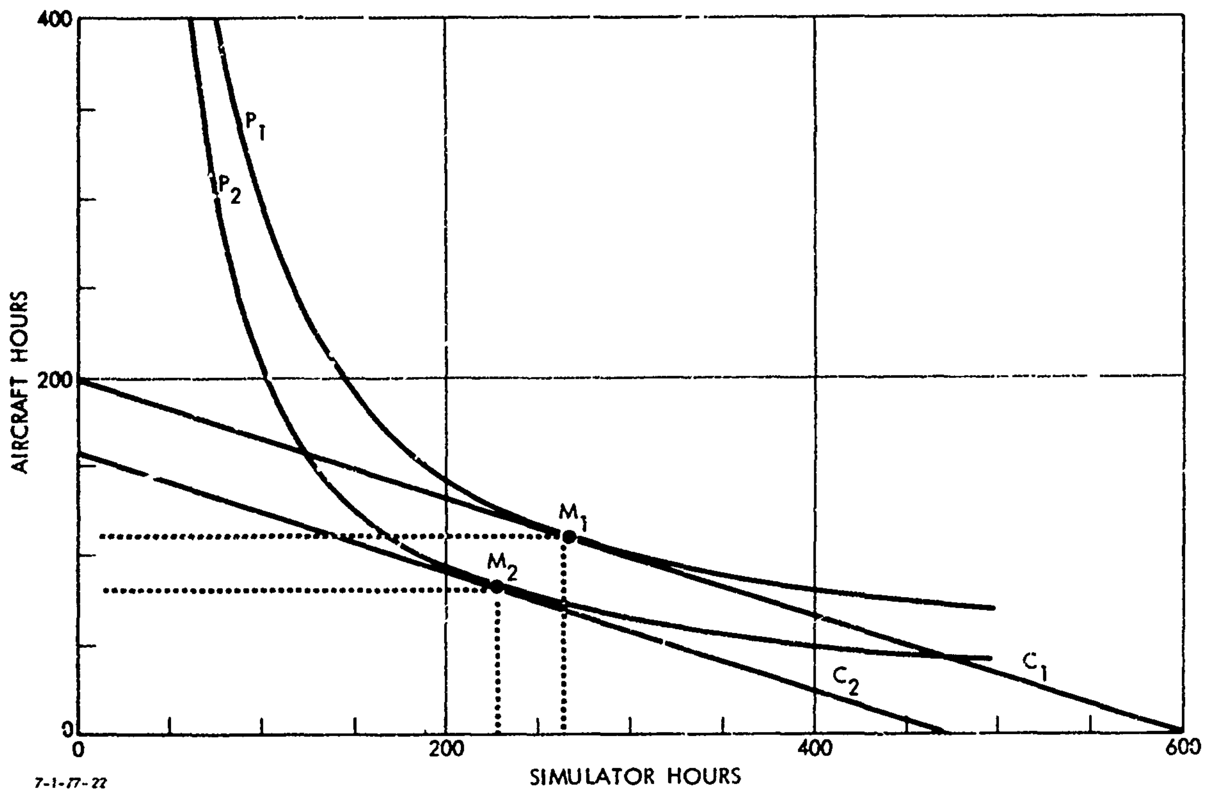

Figure A-3. EFFICIENT INPUT MIXES

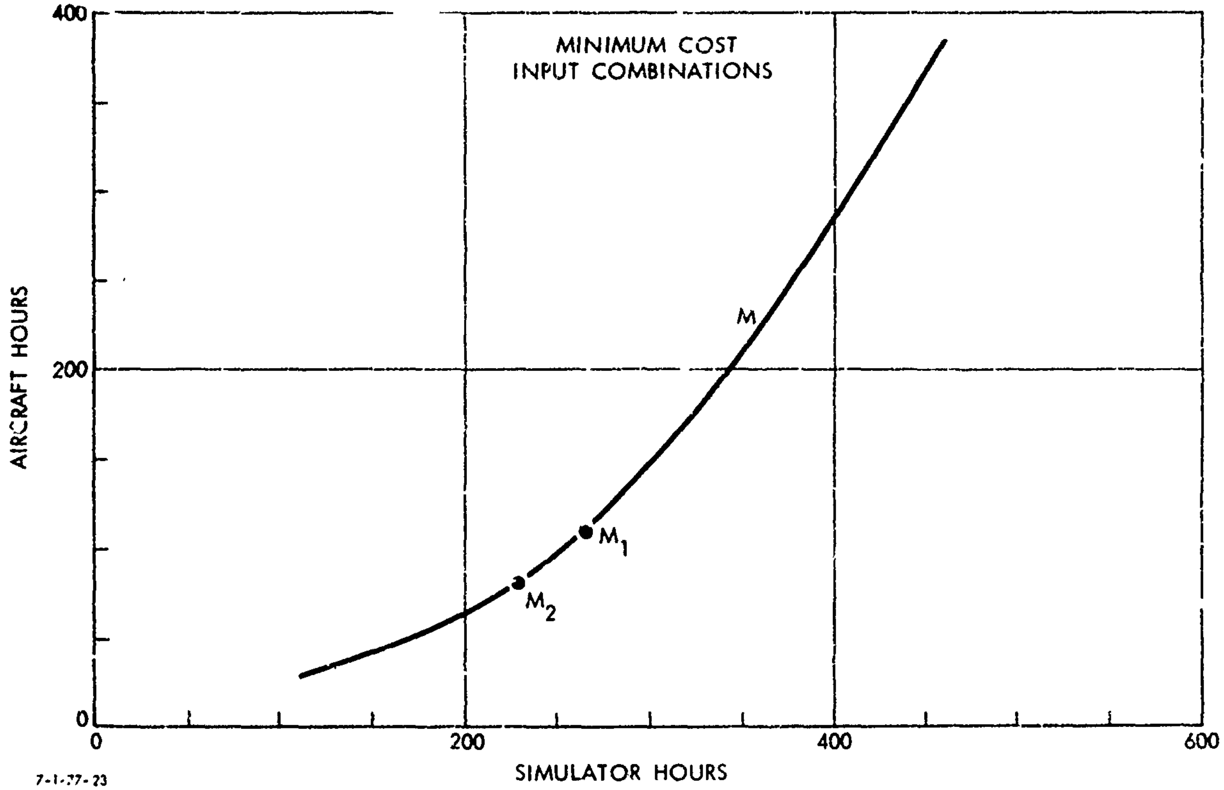

Figure A-4. PATH OF ALL EFFICIENT INPUT MIXES

This formulation sheds light on the basic problem of program design. To wit, for flight training, what is the efficient mix of all input resources that maximizes the value of training for a given level of cost (or minimizes the cost of a given level of training)? In this light, all potential inputs are competitors, and none are inherently inferior or superior to others--training devices of all varieties (carrels, procedures trainers, part-task trainers, mission trainers, ...), instrumented aircraft, uninstrumented aircraft, and human resources (instructors, instructional support personnel, ...). Further, all inputs are substitutable in variable proportions; the preferred or efficient proportions being determined by the relative costs and productivities of each competitor.

This formulation permits expanding the scope of questions of efficiency. The purpose of training for a particular aircraft type is the defense capability embodied in the weapon system employing that aircraft, and the question of efficient allocation encompasses all inputs to the weapon system--of which training is just one. Similarly, total defense capability consists of the individual capabilities embodied in the numerous weapon systems comprising the force structure, and questions of efficient allocation cut across weapon system and service lines. In these larger arenas, necessary conditions for efficient allocation of resources are expressed by the following two statements.

1. For each DoD activity (weapon system, training establishment command, etc.) taken separately, the incremental (present) value of defense capability resulting from an extra dollar spent on any input resource will just equal that resulting from an extra dollar spent on any other input.

2. For all DoD elements (or all elements of one service), taken together, the incremental present value of defense capability resulting from an extra dollar spent on any input resource will just equal that resulting from an extra dollar spent on any other resource.

The first is a necessary condition for efficiency within a single force element and in no way requires reference to outside factors--that are taken as given. Cast in the context of this study, it could read "for each aircraft type the present value of additional defense capability received from spending an additional dollar on flight simulation would just equal the value received by spending an additional dollar on flying." Similar equalities would simultaneously hold for all other tradeoffs, both larger and smaller in scope (i.e., between training and hardware, flight training vs. maintenance training, between part-task and full-mission simulators, between different features or configurations of a simulator, etc.). Whenever and wherever equality is not met the total defense capability obtained could be increased by changing the input mix (e.g., substituting a dollar spent on flight training for a dollar spent on hardware--or visa versa).

The second condition expands the scope of inquiry to the DoD (or Service-wide) level where the set of relevant trade-offs is broader (aircraft vs. ships, F-16 vs. F-18), and some aspects of DoD efficient allocation directly impact on and change the conditions for efficient allocation within individual weapon systems, commands, etc. That is, even though all equalities were to be satisfied within each aircraft type, weapon system, or command (internally or taken one at a time), this is not sufficient to insure efficient allocation on a DoD-wide basis (across all aircraft, etc. taken as a group). A particularly visibile example is the question of cost reductions or other benefits accruing to force elements from investments in technological development. A current issue in simulation is the potential net value of large-capacity, high-resolution, computer-generated imagery. Its development to the point of general availability will require a sizeable investment of both money and time, but, once brought to this point, it could be applied to a number of training programs for recurring production costs of the equipment. It is questionable whether the development and procurement cost would ever be justified on the basis of its potential payoff within the training program of a single aircraft system. It is necessarily less of a question when the costs are compared with the aggregate payoff potential across several aircraft systems (F-16 and A-10).

An implication arising from this reasoning is that planning for and assessment of simulation, either for one aircraft type or on a DoD-wide basis, must consider all other aspects of flight training. Further, planning and evaluation of individual programs (i.e., by aircraft type) necessarily falls short of addressing the range of relevant questions unless it is cast in a context of a total (and preferably dynamic) DoD training program--one that is formulated in a manner that expressly permits intersystem and interservice comparability and aggregation. That is, a requirement for evaluating cost and effectiveness of simulators in flight training is formalizing (or modeling) a set of procedures for estimating total cost and effectiveness of flight training at individual system, service, and DoD levels.

APPENDIX B

INSTRUCTIONS FOR PREPARATION OF POM BACK-UP

PART II - BUDGET FORMULATION

Section 10 - Special Analyses

Chapter 2B13 - Simulator and Training Device Programs

2B13.1 Purpose

A. This chapter provides instructions for preparation and submission of data needed for review of each DoD Component's budget requirements for simulators and training devices. At this time, the review will be limited to the flight simulator/training device category of equipment as defined in paragraph 2B13.3.A.1.

B. Paragraph 2B13.3.B. identifies the programs for which exhibits must be submitted.

2B13.2 Submission Requirements

A. Components will segregate their submissions by Active, National Guard, and Reserve as applicable. Each section will contain the following exhibits and information in support of budget estimates:

1. Exhibit ST-1, Component Flight Training Device Overview.

2. Exhibit ST-2, Component Flight Training Device Summary by Weapon System or Major Device Type. Exhibit ST-2 is intended to summarize the detail presented in the Exhibits ST-3 relating to a given weapon system. When identifying the individual training devices in paragraph 3.A. of Exhibit ST-2, devices that have similar capabilities or serve a common purpose may be combined in a single line entry. The same device(s) must be used in 3.B. and C. Grouping of devices by cost/device hour is permissible whenever such aggregation does not distort significant relationships.

3. Exhibit ST-3, Component Flight Training Device Detail. Submit a separate exhibit for each training device category as identified on Exhibit ST-2 for each Weapon System or Major Device Type. Section 5.B. of this exhibit is intended to consolidate training device utilization and substitution data for all devices which support a given weapon system. Training device hours and estimated flying hours replaced must be displayed by device type or group of devices as used in section 3 of each ST-2.

4. In addition, each component should append information briefs to each Exhibit ST-2, to explain and justify the budget estimates of the individual devices used to support the weapon system. New devices or existing devices that are expanding or contracting should be covered in more detail than those mature devices that are still required but are experiencing little or no ch e from a manpower or cost viewpoint. The briefs s' ald include but not be limited to a statement of the budget estimate's content, purpose, specific programs and activities. Further, for the operations and military personnel appropriations, explain the reasons for significant changes (+ or -) from the current year to the budget year, also identify any contracts related to the operation, maintenance, or training effort. For RDT&E, procurement and military construction, briefly explain the reasons for the budget requirements.

5. The cost/flying hour and cost/device hour figures shown in the exhibits should be based on common cost elements to facilitate comparison. Each component will submit a display of those cost e' ents and their contribution to the total cost per hour figures. Aircraft cost/flying hour figures should include only those cost elements which vary with adjustments in peacetime flying hour changes.

B. Twelve sets of the above material are required. Each set will be stapled or bound separately. The Exhibit ST-3's dealing with a given weapon system will be located immediately after the Exhibit ST-2 for that weapon system.

2B13.3 Preparation of Material

A. The following definitions apply for the purposes of preparing the above exhibits:

1. Flight Simulator/Training Device - A device used to give mental and/or physical existence to, and relate, the situations encountered and tasks performed by aircrew members in the performance of their required duties. These devices would include but not be limited to such equipment normally referred to as simulators (flight and mission), part task trainers, and cockpit procedures trainers. Devices such as classroom and maintenance trainers should be excluded.

2. Flying Hours - Aircraft flying hour totals should agree with the budget data supporting the DoD flight hour program. Aircraft flight hours include all flight operations

associated with the aircraft inventory of each section of the exhibit, not just those programmed for training.

3. Training Device Hours - Include only those training device hours which are required for the purpose of providing valid flight training, i.e., maintenance hours or time used for visitor demonstrations, for example, should be excluded.

4. Estimated Aircraft Flying Hours Replaced by Device Hours - The estimated aircraft flying hours that would have been required were the simulator not available.

5. Proficiency - All data included in the proficiency section of each exhibit will conform in meaning with the definitions as contained in DoD Directive 1340.4.

B. Flight simulator/training device exhibits will be submitted for those aircraft systems which have training device Research and Development or Procurement costs which exceed $0.5 million in any one year. Appropriate exhibits should also be sumitted for any other aircraft systems which have annual operation and maintenance costs which exceed $5 million. In addition, exhibits should also be submitted for any other flight training devices for which procurement costs exceed $0.5 million.

APPENDIX C

COST EFFECTIVENESS ANALYSIS

PROCUREMENT TO PROVIDE P-3C AIRCREW TRAINING

2F87F OFT

NAVAL AIR SYSTEMS COMMAND

WASHINGTON, DC

JANUARY 5,1977

I. PROPOSED PROCUREMENT

2F87(F) OFT with visual system.

II. REQUIREMENT

A. General. The proposed procurement is required to provide a media for P-3C flightcrew training in ASW tactics on the P-3C update II aircraft.

B. Specification of Requirements

1. Capability. The trainer will be required to provide 16 hrs/day, 5 days/week, 50 weeks/year training to support six squadrons of aircraft. No capability currently exists to provide the required training.

2. Location and Dates

(a) The procurement is required and planned for the Naval Air Station at Brunswick, Maine.

(b) Operating capability is required by FY1980. This requires funding and full production (service use) in FY 1978.

3. Source of Requirement. The requirement for the training capability was specified by CNO letter, Ser. 596/116664 dated 19 Dec 1975.

III. BENEFIT/COST ANALYSIS

A. Costs:

1. Capital Inventment - An estimated $6.5M is required to procure the 2F87(F) OFT with visual system to meet the specified training requirements. This estimate is based on current industry costs for similar procurements.

2. Mods/Updates - Annual estimated requirements for modification/updates are based on experience and are shown in Fig.1.

3. O&M - Twelve additional civilian or military personnel positions are required. No additional nonpersonnel operations and maintenance expense are anticipated. An average cost of $14,000 was used per civilian/military personnel position required.

4. MILCON - Facilities will be provided by Military Construction Project Number p-106 estimated at $1,400,000.

B. BENEFITS

1. Flight Hour Substitution - Expendables/Maintenance

Aircraft Cost/Flt Hour (Source: Navy Program Factors Manual)

POL Cost/Flt. Hr	$385.45
Organ. & Inter. Maint/Flt Hr	158.90
Component Rework	143.12
Replenishment Spares	84.40
Engine Overhaul	23.17
	$795.04

Flt Hr Substitution (Source: CNO OP-59, straightlined after FY82)

FY 78	0
FY 79	75
FY 80	457
FY 81	2065
FY 82-88	3421

Cost Savings = (Cost/Flt Hr) X (Flt Hr Substitution)

2. Flight Hour Substitution - Depreciation

Aircraft Acquisition Cost (Source: Budget Exhibit) $8.280M

Aircraft Service Life (Source: Budget Exhibit) 15 years

Depreciation (Annual at straight-line rate) .552M

$$\text{Depreciation Savings} = (\text{Depreciation/AC}) \times (\# \text{ AC}) \times \frac{(\text{Flt Hr Sub})}{(\text{Flt Hrs} + \text{Flt Hr Sub})}$$

3. Accident Reduction

An extimated monetary loss for damage to aircraft due to pilot error accidents was set at $50/Flt Hours.

$$\text{Accident Reduction Savings} = \frac{\$ \text{ Loss}}{\text{Flt Hour}} \times \text{Flt Hour Substitution}$$

IV. OTHER FACTORS CONSIDERED

The proposed procurement provides emergency training capability which is impossible or unsafe to conduct in the aircraft. Tnis training benefit is not reduceable to monetary quantities.

ECONOMIC ANALYSIS

			P-3C		DFT	2F87F						
	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	TOTAL
COSTS												
CAPITAL INVESTMENT	6.500	0.000	0.000	0.000	0.000	[illegible]	[illegible]	0.000	0.000	0.000	0.000	6.500
MODS/UPDATES	0.000	0.200	0.200	0.200	0.200	0.200	[illegible]	0.200	0.200	0.200	0.200	2.000
O&M-CIVPERS	0.000	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	1.680
O&M-MILPERS	0.000	0.000	0.000	0.000	0.000	[illegible]	0.000	0.000	0.000	0.000	0.000	0.000
O&M NONPERS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MILCON	1.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.400
TOTAL	7.900	0.368	0.368	0.368	0.368	[illegible]	[illegible]	0.368	0.368	0.368	0.368	11.580
PRESENT VALUE	7.900	0.347	0.327	0.309	0.291	0.274	0.259	0.244	0.230	0.217	0.205	10.608
BENEFITS												
FLT HR SUBSTITUTION	0.000	0.059	0.363	1.641	2.719	2.719	2.719	2.719	2.719	2.719	2.719	21.103
EXPENDABLES/MAINTENANCE												
FLT HR SUBSTITUTION	0.000	0.048	0.311	1.493	2.613	2.752	2.930	3.183	3.323	2.879	2.613	22.149
DEPRECIATION												
ACCIDENT REDUCTION	0.000	0.003	0.023	0.103	0.171	0.171	0.171	0.171	0.171	0.171	0.171	1.327
TOTAL	0.000	0.111	0.697	3.238	5.503	5.643	5.821	6.074	6.214	5.770	5.503	44.573
PRESENT VALUE	0.000	0.105	0.621	2.720	4.359	4.215	4.103	4.039	3.896	3.415	3.071	30.548
NET BENEFITS	-7.900	- 0.241	0.293	2.411	4.067	3.940	3.844	3.794	3.665	3.198	2.865	19.940

P-3C OFT

ACQUISITION COST = $6,480,000   COST/FLYING HOUR(RAG/FLEET) = $1,255 / $795   COST/DEVICE HOUR = $115.43

YEAR	FLT HOUR SUBSTITUTION RAG	FLEET	TRAINING DEVICE UTILIZATION
0	0	0	0
1	47	28	300
2	388	69	3600
3	384	1081	3600
4	2191	1230	3600
5	2191	1230	3600
6	2191	1230	3600
7	2191	1230	3600
8	2191	1230	3600
9	2191	1230	3600
10	2191	1230	3600
11	2191	1230	3600
12	2191	1230	3600
13	2191	1230	3600
14	2191	1230	3600
15	2191	1230	3600

YEAR   O = UNIT COST - ((A(I)*(COST/FLYING HOUR(RAG)) + (A1(I)*(COST/FLYING HOUR(FLEET)) - B(I)*(COST/DEVICE HOUR))

YEAR		DISCOUNTED SAVINGS	CUM DISCOUNTED SAVINGS
1	O = $6,480,000 - (47 * 1255 + 28 * 795 - 300 * 115) O = $6,480,000 - - 22642	21,360	- 21,360
2	O = $6,502,642 - (388 * 1255 + 69 * 795 - 3600 * 115) O = $6,502,642 - 126247	112,359	90,999
3	O = $6,376,395 - (384 * 1255 + 1081 * 795 - 3600 * 115) O = $6,376,395 - 1678767	1,409,492	1,500,492
4	O = $4,697,628 - (2191 * 1255 + 1230 * 795 - 3600 * 115) O = $4,697,628 - 3312007	2,623,440	4,123,932
5	O = $1,385,621 - (2191 * 1255 + 1230 * 795 - 3600 * 115) O = $1,385,621 - 3312007	2,475,002	6,598,935