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Effects on A-6E bombardier/navigator flight training with the introduction of device 2F114 A-6E weapons system trainer.

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THESIS

EFFECTS ON A-6E BOMBARDIER/NAVIGATOR FLIGHT TRAINING
WITH THE INTRODUCTION OF DEVICE 2F114,
A-6E WEAPON SYSTEM TRAINER

by

John Richard Tindle

March 1979

Thesis Advisor: D. E. Neil

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As weapon systems grow increasingly complex and sophisticated, the training requirements for operator personnel become correspondingly more demanding. This increase in training requirements, coupled with increased operational costs, necessitates the use of simulators as an integral part of many training programs. With the introduction of device 2F114, A-6E Weapon System Trainer, the A-6 community will have a state-of-the-art simulator to employ

in their training programs. Along with new devices, training programs must become more responsive to factors influencing training effectiveness and transfer of training. This report explores factors influencing simulator training effectiveness, and compares them with factors incorporated in device 2F114 and proposed training syllabi. Appendix B, "Alternatives in Bombardier/Navigator Training," identifies syllabus flights that have the potential to be substituted by the A-6E Weapon System Trainer.

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Effects on A-6E Bombardier/Navigator Flight Training with the Introduction of Device 2F114, A-6E Weapon System Trainer

by

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ABSTRACT

As weapon systems grow increasingly complex and sophisticated, the training requirements for operator personnel become correspondingly more demanding. This increase in training requirements, coupled with increased operational costs, necessitates the use of simulators as an integral part of many training programs. With the introduction of device 2F114, A-6E Weapon System Trainer, the A-6 community will have a state-of-the-art simulator to employ in their training programs. Along with new devices, training programs must become more responsive to factors influencing training effectiveness and transfer of training. This report explores factors influencing simulator training effectiveness, and compares them with factors incorporated in device 2F114 and proposed training syllabi. Appendix B, "Alternatives in Bombardier/Navigator Training," identifies syllabus flights that have the potential to be substituted by the A-6E Weapon System Trainer.

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I. INTRODUCTION

The replacement of the A-6A aircraft by more advanced modifications, such as the A-6E and A-6E Carrier Airborne Inertial Navigation System (CAINS) aircraft, resulted in a reduction of feasible Bombardier/ Navigator (B/N) flight training devices. The A-6A Weapons System Trainer (WST), device 2F67, could no longer adequately train replacement B/N's, due to the disparity bewteen the A-6A system and newer modifications. Device 2F114, A-6E WST, is designed to fill this training void, and provide the A-6 community with a state-of-the-art aircraft simulator.

The purpose of this report is to forecast possible effects the A-6E WST will have on B/N flight training programs. Through analysis of proposed training programs and training features incorporated in the A-6E WST, estimates of training effectiveness and efficiency were developed. These estimates are based on previous studies in transfer of training, and factors influencing simulator training effectiveness. Finally, possible training alternatives, and their effects, are examined.

A. BACKGROUND

Simulation, the technique of reproducing or imitating some system operation in a controlled environment, is an area in which there has recently been considerable advancement. This is quite apparent when observing the development of flight simulator use in aircrew training programs. These modern devices represent specific aircraft counterparts, and imitate or duplicate features of the actual flight platform for the expressed purpose of ground training of specific skills required in the aircraft mission environment. The flight simulator of today is the one

training device most like the aircraft, and is the most capable of representing aircraft operation [Erickson, et al, 1972].

The concept of simulation as a means to enhance a flight training syllabus is not new. As early as 1910, crude ground flight trainers were used in pilot training in England, and by 1917 the French had developed a ground trainer that incorporated noise fidelity, artificial "feel" in controls, and a simple visual system [Valverde, 1973]. In the United States, simulator development progressed more slowly. It was not until 1929, when Edwin A. Link developed his first trainer, that significant strides were made in flight simulation in the United States. Link trainers, in fact, were the first to find their way into systematic flight training programs [Adams, 1973]. By World War II, Link trainers were being used extensively in civil aviation, and had begun to be adopted by the military. From these meager beginnings, simulators have developed into precisely engineered devices with complex visual and motion systems, capable of realistically reproducing cockpit instrument indications and aerodynamic responses for nearly all flight situations.

Despite significant advancement in simulator design and capabilities, the role of the device in many training programs has not changed. Far too often, simulator training is only an adjunct to training, rather than being an integral part, thus reducing training and cost effectiveness of the device. There is little evidence in most military flight training programs that simulators have led to reduced training costs. In fact, in some programs, the use of a flight simulator only increased the cost of an already expensive program, without demonstrating any transfer of training benefits [Isley, Caro, and Jolley, 1968; Jolley and Caro, 1970; Caro and Prophet, 1973].

As a result of training programs in the commercial aviation industry, a new role is emerging for simulators in military flight training programs. This role can be characterized by emphasis upon simulators as primary vehicles for training. This shift in training from the aircraft to simulator, although a major departure from tradition, is not the most important aspect of the emerging role. Training programs have become more responsive to mission requirements, and the goals of training are being viewed in terms of objective performance measurement rather than in terms of flight hours logged [Caro and Prophet, 1973].

B. WHY SIMULATION?

A number of factors have contributed to the emerging role of simulators in military flight training. Generally, this role has developed through an increasing awareness of simulator capabilities, and several basis disadvantages to the use of operational training. When used as an integral part of a flight training program, simulators can minimize the time spent in the aircraft learning skills and procedures which can be trained more safely and efficiently in the less expensive ground environment. The simulator also provides a learning environment in which stress and workload can be controlled to meet the requirements necessary for developing particular flight skills [Erickson, et al, 1972].

1. Policy Guidance

Several studies have been developed which offer guidance with respect to the issue of flight simulator use in military training. This guidance supports the integration of simulators into flight training programs, and development of improved simulators to replace maximum amounts of training currently performed in aircraft. In 1973,

the Office of Management and Budget reported that, based on the experience of commercial aviation and the manned space program, the military could substitute simulators for flight training and reap substantial economic benefits [Orlansky and String, 1978]. The policy of the Department of Defense is reflected in a planning goal of a 25 percent reduction in aircraft training hours by fiscal year 1981, while maintaining the current level of training effectiveness [Hearing Before the Subcommittee on Research and Development of the Committee on Armed Services, 1976]. In order to achieve the effectiveness required through simulation, training program design must become more responsive to simulator capabilities.

2. Costs

The major advantage claimed for the use of simulators is that of reduced costs when compared to their counterpart aircraft, while maintaining required levels of training effectiveness. The complexities of current and future aircraft and weapons systems are driving cost per flying hour to such a level that all but mission related flight is prohibitively expensive [Micheli, 1972]. Limitations in oil supplies and rapidly escalating fuel costs are definitely a contributing factor [Orlansky and String, 1978].

Simulator hourly operating costs are less than in the corresponding aircraft for all but a few cases. In fact, studies indicate programs where costs for simulator training are ten times less than in the aircraft [Roscoe, 1974; Hopkins, 1975; Diehl and Ryan, 1977]. Simulators should not only cost less to operate and maintain, but should also require less down time as a result of malfunction [Hopkins, 1975]. The use of simulators in training reduces other training costs, such as nonrecoverable weapons systems, and target and weapon range costs.

By reducing flight hours, service life of the aircraft may also be extended. Finally, ecological costs, such as atmospheric pollution, can be reduced by substituting simulator hours for flight hours where feasible.

3. Safety

There is little doubt that simulators provide a safer environment for training than aircraft in the operational environment. The use of simulators permits control over a wide variety of malfunctions, and allows the crew to experience the consequences, up to the point of catastrophe, of incorrect performance. Simulators allow training in unusual aircraft configurations and attitudes, while avoiding the risk of accidents, and provide the opportunity to train emergency procedures which would be too dangerous to teach in flight.

4. Flexibility and Repeatability

Simulators provide a flexibility in training that cannot be duplicated by aircraft. For example, simulator use is independent of weather or time of day. Availability of aircraft, target areas, and airspace would no longer be a problem in performing missions. Simulator "flights" are made without impact on populated areas, which has become a problem in recent years [Orlansky and String, 1978]. Additionally, simulators can be used in part-task or specialized subsystem roles, which adds to their flexibility.

Simulators also provide a repeatability in training that cannot always be assured in aircraft. Initial and subsequent conditions can be controlled, which allows repeatability of specific sequences in flight. The simulated mission may be interrupted at any time for discussion and evaluation, providing immediate feedback to the trainee. This "freeze" capability allows the trainee to correct errors

immediately, thus reinforcing the learning situation [Williges, Roscoe and Williges, 1973].

5. Efficiency/Effectiveness of Simulators

Simulators can provide more efficient training than aircraft [Hopkins, 1975]. Initial conditions can be inserted for teaching specific tasks, without requiring the performance of all the mission phases that would normally proceed them in flight [Hopkins, 1975]. Thus, for a given amount of time, the simulator can provide more training of the specific skills desired. Additionally, safety and flexibility features, which have been previously discussed, enhance the efficiency of simulators in flight training.

Simulators can, and should, provide effective training. Training effectiveness implies that the device has some demonstrable effect on trainee performance. The key issue here, is whether skills learned in the simulator carry-over to the aircraft, a concept known as transfer of training. A number of variables have been shown to affect transfer, and will be discussed in a subsequent section. At this point, however, it should be noted that studies have shown that the manner in which a device is used in a training program may influence learning and transfer to a greater degree than device design [Micheli, 1972; Caro and Prophet, 1973; Povenmire and Roscoe, 1973; Valverde, 1973; Caro, 1973; Roscoe, 1974; Hopkins, 1975]. This would indicate that the introduction of any new device into a training program must be carefully developed to insure positive transfer and to achieve maximum effectiveness.

C. A-6E AIRCRAFT AND ITS MISSION

The A-6E Intruder is a two place (side-by-side), subsonic, twin engine jet aircraft designed for all-weather attack. Using a sophisticated navigation and attack system, the aircraft can accurately deliver a wide variety of weapons without the crew ever having visually acquired the ground or the target. It is the only carrier-based aircraft capable of penetrating enemy defenses at night, or in any weather, to detect, identify and attack fixed or moving targets. The aircraft is designed for extremely low level penetration, yet is capable of long range strikes approaching 600 nautical miles in radius.

With emphasis on reduction of flight hours, an efficient means of training and maintaining pilot and bombardier/navigator (B/N) proficiency is necessary. Since the A-6 mission demands close crew coordination, reductions in actual flight time may well have a disastrous effect on the ability of flight crews to perform their complex mission. The introduction of device 2F114, A-6E Weapons System Trainer (WST), is intended to provide a suitable training platform which can enhance readiness and fleet squadron training programs.

II. STATEMENT OF PROBLEM

A. PROBLEM STATEMENT

Since the introduction of the A-6 aircraft in the early 1960's, a need has existed for a safe, yet realistic environment in which to train replacement pilots and B/N's. Until now, most training has been obtained only in flight, in either the A-6E aircraft or the TC-4C aircraft. The TC-4C is a modified Gulfstream aircraft that is equipped with an A-6 radome, and an A-6E configured cockpit in the cabin, and is presently the primary device used in B/N training. The ground simulator used in training, Device 2F67, A-6A WST, is two aircraft modifications behind the current model A-6 aircraft, the A-6E Carrier Airborne Inertial Navigation System (CAINS). Due to these modifications, the A-6A WST has become primarily used as an emergency procedures trainer.

With increased emphasis on simulation, two A-6E WST's were developed to simulate specific aerodynamic performance, flight characteristics, and weapon system operation of the A-6E CAINS aircraft. Like the aircraft, the WST is capable of accepting the next generation modification, the Target Recognition Attack Multisensor (TRAM), and should therefore not lose training value like the A-6A WST. The first device is scheduled for delivery to Attack Squadron Forty-Two (VA-42) at NAS Oceana, Virginia, while Attack Squadron One Twenty Eight (VA-128) at NAS Whidbey Island, Washington will receive the second device. Delivery of both devices should occur in mid-1979.

Justification for procurement of the A-6E WST was for a device which could train crewmembers in the most realistic, cost-effective

manner. The problem that must be addressed, then, is how will the addition of this device into proposed training programs actually effect B/N flight training? This report will attempt to focus upon factors that influence training effectiveness and compare them to elements that have been, or have been proposed to be incorporated in the A-6E WST. By examining A-6 B/N flight training from a human factors standpoint, a realistic determination of the effects of the device can be made.

B. TRANSFER OF TRAINING

The theory behind effectiveness of any type training is concerned with the concept of transfer, and training effectiveness is usually expressed as a measure of transfer of training. Transfer of Training may be defined as the degree to which practive (learning) in a trainer or simulator carries-over or effects performance in an operational situation [Micheli, 1972]. Transfer of training is positive when a training situation aids subsequent performance, negative when it hinders that performance, and zero when no effect occurs.

1. Concept of Transfer

The basic concept behind transfer is analogy. What has been learned in a ground simulator will transfer to flight when there are similarities between past and present situations such that useful analogies can be made [Gregory, 1976].

Various theories of transfer have been proposed, but two general theories in particular have been employed in simulator design. The first major formulation was the concept of identical elements, proposed by E. L. Thorndike in 1924. He proposed that transfer from one situation to another occurred if there were identical elements in the

two situations. This concept has been employed by proponents of extremely high fidelity devices, where fidelity may be defined as features of the aircraft and its environment that are included in simulator design, and the extent to which features represent or duplicate real-world counterparts [Caro, 1976]. The thought here is that high fidelity devices will necessarily yield high transfer, although a direct casual relationship between fidelity of the training device and its transfer effectiveness has not yet been documented [Finnegan, 1977]. The other theory involving transfer of training is based on: (a) The degree of similarity of difference between the nature of the stimuli and of the responses, (b) the task on which the initial learning takes place, and (c) the task to which the learning is to be transferred [Muckler, et al, 1959]. This theory would imply that transfer is greatest when the stimulus and response of the transfer task is the same as in the initial learning task [McCormick, 1970]. This indicates that the device itself does not effect transfer as much as does the manner in which the training is presented.

In an article on simulation, Adams [1972] stated:

> "I would not consider the money being spent on flight simulators as staggering if we knew much about their training value, which we do not. We build flight simulators as realistic as possible, which is consistent with the identical elements theory of transfer of Thorndike, but the approach is also a coverup for our ignorance about transfer because in our doubts we have made costly devices as realistic as we can in hopes of gaining as much transfer as we can. In these affluent times, the users have been willing to pay the price, but the result has been an avoidance of the more challenging questions of how the transfer might be accomplished in other ways or whether all that complexity is really necessary."

The fundamental issue that Adams was raising, was that there had been significant development of hardware as the principal focus in flight training, but training itself had been ignored as a significant factor. Muckler, Nygaard, O'Kelly and Williams [1959] identified instructional techniques and ability as important variables in simulator transfer of training. Prophet [1966] stated that the simulator itself was only a vehicle in the training program, and was less important than the instructor and the content of the training program. Micheli [1972] concludes:

> "... that training effectiveness is more a function of the manner in which the trainer is used than the fidelity of the trainer."

A number of studies have been done since that time which combine the elements of both theories, indicating that fidelity of the simulator does effect transfer, but only within a greater context of the entire training program [Gagne, 1962; Micheli, 1972; Povenmire and Roscoe, 1973; Caro and Prophet, 1973; Valverde, 1973; Caro, 1973; Williges, Roscoe and Williges, 1973; Blaiwes, Puig and Ryan, 1973; Roscoe, 1974; Hopkins, 1975; Caro, 1976; Caro, 1977; Finnegan, 1977]. Fidelity is a factor that influences transfer of training, but instructional quality, attitudes, training objectives, and training program design and content all affect transfer to some degree.

2. Measurement of Transfer

In order to study the factors that influence transfer of training in a flight syllabus, some measurement device is necessary. A common measure is needed in order to compare transfer from various studies with different types of simulators, training programs, level of pilot skill, and so on. In a recent report by Diehl and Ryan [1977]

discussing current simulator substitution practices, three formulae are presented which currently are used to describe the relationship between simulator use and flight hours. It might be noted, however, that in transfer of training experiments, student performance (mission effectiveness) is usually defined in subjective, ambiguous, nonstandard terms [Diehl and Ryan, 1977]. Thus, when comparing performance between new and old programs, if a trainee "successfully" completes the program, mission effectiveness (for the individuals involved) is generally assumed equal. These formulae give indices of effectiveness and efficiency of a training program to substitute simulator hours for flight hours, while maintaining the required level of mission effectiveness.

The first measure is Percent Flight Syllabus Reduction (Percent Savings):

$$\text{Percent Savings} = \frac{\text{Original flight hours} - \text{New flight hours}}{\text{Original flight hours}} \times 100$$

This measure expresses the simulators overall ability to reduce the amount of flight time needed in the training program, and is directly related to simulator <u>effectiveness</u>. The larger the number, the more effective the simulator is in the syllabus. If more simulator time is needed to complete the given syllabus, percent savings will be a negative number.

The second measure is known as the Flight Substitution Ratio (FSR):

$$\text{FSR} = \frac{\text{New simulator hours} - \text{Original simulator hours}}{\text{Original flight hours} - \text{New flight hours}}$$

FSR indicates the <u>efficiency</u> of the simulator, by expressing the increase in simulator time to a decrease in flight time needed in a training syllabus. FSR expresses the rate at which simulator time replaces

flight time. The smaller the value of a positive FSR, the more effective the simulator is in replacing flight hours. A negative FSR is possible under two conditions; when the simulator is used effectively and both flight and simulator hours are reduced, or when increased simulator hours correspond to an increase in flight hours.

The final measure, known as the Transfer Effectiveness Ratio (TER), was developed by Roscoe [1971]. This measure has become widely used in transfer of training experiments, and is expressed:

$$TER = \frac{Yc - Y_e}{X_e}$$

where Y_c = flight hours in the control group or old program
Y_e = flight hours in the experimental group or new program
x_e = simulator hours in experimental group or new program

Another form of this equation is used when there were simulator hours in the old training program. This report will use the form:

$$TER = \frac{\text{Original flight hours - New flight hours}}{\text{New simulator hours - Original simulator hours}}$$

This ratio is essentially the reciprocal of FSR, and therefore only the FSR will be calculated in this report.

Although all these measures have been used in development of training programs where control and experimental groups of trainees were formed to measure actual transfer, these measures can also be used to calculate ratios between existing and proposed programs. This is the case with the A-6E WST, since no actual measurement can be made at this time.

III. METHODOLOGY

A. PROCEDURE

The methodology used in this forecast of A-6E WST effects on B/N training was based on an extensive literature review. This review concentrated upon the factors that could be associated with simulator training effectiveness, transfer of training, and effectiveness measurement. The A-6E WST was then evaluated in terms of its fidelity, and role in proposed A-6 readiness squadron training syllabi. By using indices, such as the FSR, the effectiveness of the simulator program could then be estimated.

Through analysis of training effectiveness factors and elements incorporated in the A-6E WST, which are detailed in subsequent sections of this report, substitution of particular syllabus flights by simulator missions was examined. This substitution should allow the WST to be introduced into training syllabi as an integral, cost-effective component. The FSR was again calculated, using the substitution effects as a basis. Comparisons were then made with previous estimates.

B. MODEL FORMULATION

The model used to examine simulator effectiveness in both readiness squadron syllabi was hybrid in nature, and was based on a technique proposed by Jeantheau [1971] and later described by Caro [1976 and 1977]. The model considers simulator fidelity, and requires an analysis of the training program in which the simulator is to be operated.

The model consists of three distinct phases:

(1) Analytic study of the simulator in terms of fidelity and elements incorporated that affect transfer of training.

(2) Analytic study of the training syllabus in which the simulator is to be employed, again examining transfer of training factors and measurement of effectiveness.

(3) Comparison of proposed programs with alternative approaches that include substitution of flight time where feasible.

This hybrid model is especially suited for estimation, since control and experimental groups are not necessary. Phase I of the model is based on the identical elements theory of Thorndike and Osgood's [1953] assumptions concerning the relationship between stimulus similarity, response similarity, and transfer of training. Phase II of the model involves the manner in which the simulator is incorporated into the training program. It can determine whether the training program is well designed, directed toward attainment of training objectives, and employs modern or innovative training techniques [Caro, 1977]. The combination of the first two phases results in a qualitative assessment of simulator training effectiveness. Only after the device is in operation can a more precise transfer of training model be employed to project quantitative assessment. Phase III of the model allows comparison of alternatives which may produce more effective methods for use of the device in a training syllabus.

C. DIFFICULTIES IN STUDY

A study of this nature does contain some inherent disadvantages. The available information concerning the factors that influence simulator training effectiveness and transfer of training was found to be quite limited. Only recently it appears has this area received specific attention, and the influence of some factors identified has

only been hypothesized. Definitive data could seldom be found in the literature which would permit quantitative assessment of the influence of suspected factors, and differences in study methodologies made conclusions difficult to generalize. Results from several transfer of training studies concerning simulator effectiveness have ended in a great deal of contradiction. As discussed by Valverde [1973], the reasons for such disparity may be due to variables not assessed in some experiments. The problems involved in identifying factors that influence simulator training effectiveness cannot be overcome easily, since suspected factors can seldom be examined in isolation [Caro, 1977]. As a result, information presented regarding the influences that contribute to simulator effectiveness are, in most cases, suggestive in nature and based on experience of the author as a former B/N Training Officer, and on the amount of quantifiable research that has been accomplished.

IV. RESULTS OF PREVIOUS STUDIES

A. CONCLUSIONS FROM SIMULATOR STUDIES

As a result of previous simulator effectiveness studies, a number of conclusions germane to this forecast have been identified. Although the following conclusions are general in nature, their applicability has been shown for a number of more specialized studies. These general conclusions are based on a review of thirty training evaluation studies [Micheli and Puig, 1972], a review of flight simulator transfer of training studies [Valverde, 1973], a report concerning simulator substitution practices [Diehl and Ryan, 1977], and conclusions from the Ninth Training and Personnel Conference, which addressed cost effectiveness of flight simulators for military training [Orlansky and String, 1978].

Basic conclusions that have been developed for simulator training inclde:

(1) Substantial amounts of flight time can be substituted by simulator hours in flight training programs.

(2) Crews who learn skills in a simulator need less time to master those skills in the aircraft than do those crews who have not received simulator instruction.

(3) Simulators have been shown to be effective for training crewmenbers of varying experience and expertise; for training in a variety of aircraft; and for training a number of flight tasks. Simulators have proven most effective for procedural and instrument flying tasks.

(4) The level of simulation and type of device influence transfer. Devices having high-fidelity motion systems, for example, achieve higher flight syllabus reductions than devices without such systems.

(5) Careful specification of both trainer and operational tasks are necessary if transfer is to occur. Additionally, measures of performance must be specified for effectiveness evaluations.

(6) When part-task trainers are utilized in conjunction with flight simulators, higher flight syllabus reductions and better flight substitution ratios are achieved.

(7) How a device is used may influence learning and transfer to a greater degree than trainer design. In fact, greater flight syllabus reductions, and more efficient flight substitution ratios were achieved in training syllabi that tailored the program to the simulator.

Although these conclusions are by no means exhaustive, they do indicate the applicability of simulator use in flight training programs.

B. PERFORMANCE OF SIMULATORS AS TRAINING DEVICES

The use of simulators as integral portions of flight training programs has become increasingly common. This fact is most evidenced by the success of simulators in commercial aviation. The airlines conduct over 75 percent of their flight training in simulators, with the trend towards only simulator training in the future [Orlansky and String, 1978]. Eleven airlines accomplish proficiency checks entirely in flight simulators, a practice approved by the Federal Aviation Administration (FAA) [Orlansky and String, 1978]. Further evidence of the transfer and substitutability of flight training by simulators, is NASA's Apollo Program, in which 100 percent of the training was conducted in simulators. This figure might be somewhat misleading, since personnel used for training were very experienced and individuals in the program could be considered part of a highly selective group. Notwithstanding, studies indicate sufficient evidence that simulators are also effective in neophyte pilot training [Micheli, 1972].

Simulator use in military programs has, thus far, proven less effective than in commercial and general aviation programs

[Diehl and Ryan, 1977]. This may be, in part, related to the relatively recent expansion of simulator use in military flight training programs.

The Army, utilizing the Synthetic Flight Training System, has developed a number of optimal programs for specific helicopters, and appears to have achieved high effectiveness and efficiency in military simulator training. The Air Force currently has an extensive research program utilizing the Advanced Simulator for Undergraduate Pilot Training (ASUPT) [Woodruff, 1976], while the Navy is presently involved with a major study concerned with optimizing simulator utilization in flight training [Havens, 1978]. With this momentum towards greater simulator use, and increasing awareness of the factors that influence simulator effectiveness, military training programs should become more responsive to incorporating simulators into well-designed, cost-effective training syllabi.

V. FACTORS INFLUENCING SIMULATOR TRAINING EFFECTIVENESS

A. INTRODUCTION

There is no question that simulator use in military flight training has increased dramatically in the last few years. However, the question becomes, how effective is this training, and how do we make simulator training more effective? The goal here is to achieve effective flight training through simulation rather than merely more extensive use of simulators. As discussed by Caro [1976 and 1977], the previous assumption has been that all simulators and training programs have been optimally designed, thus effectiveness would only depend upon how much the device was used. Several recent studies have shown this assumption is not necessarily true [Isley, Caro and Jolley, 1968; Jolley and Caro, 1970; Caro, Isley and Jolley, 1973]. Studies such as these have shown that it does not matter how much a simulator is used; rather it is the manner in which it is used, that effects transfer of training.

The following discussion will attempt to call attention to some particular factors which influence simulator training effectiveness. Although these factors do not by any means exhaust all possible influences on simulator training, they do represent those factors which are most prevalent in studies of simulator effectiveness [Muckler, et al, 1959; Gagne, 1962; Smode, Gruber, and Ely, 1963; Prophet, Caro and Hall, 1971; Micheli, 1972; Caro and Prophet, 1973; Roscoe, 1973; Valverde, 1973; Caro, 1973; Roscoe, 1974; Hopkins, 1975; Caro, 1976; Bushnell, et al, 1976; Caro, 1977].

B. SIMULATOR DESIGN

The characteristics of the simulator itself will, of course, contribute to the effectiveness of the training program. There are two basic design issues which effect simulator training effectiveness; fidelity of simulation, and design for training [Caro, 1977]. Fidelity refers to whether features of the aircraft and its operating environment are included in simulator design, and the accuracy with which design features represent or duplicate their real-world counterparts. Design for training may be defined as the inclusion of features in the simulator that facilitate training, but which do not resemble the features or environment of the aircraft being simulated. An additional design issue discussed by Williges, Roscoe, and Williges [1973], is that of degree of simulation. Degree of simulation refers to the inclusion of design features such as motion, extracockpit visual cues, and part-task versus whole-task representation, and is effectively a unification of fidelity and design for training.

1. Fidelity of Simulation

The concept of fidelity of simulation can be considered analogous to duplication, in that, fidelity is usually equated to the physical correspondence between the simulator and its counterpart aircraft. High fidelity can yield high training effectiveness, however the demand for high fidelity can be directly related to the rapidly escalating cost to purchase, maintain, and operate flight simulators [Finnegan, 1977]. This relationship is indicated in Figure 1, which repeats a figure used by Orlansky and String [1977]. Obviously, some trade-off between fidelity and cost effectiveness is needed with the current reduction of fiscal expenditures. It appears

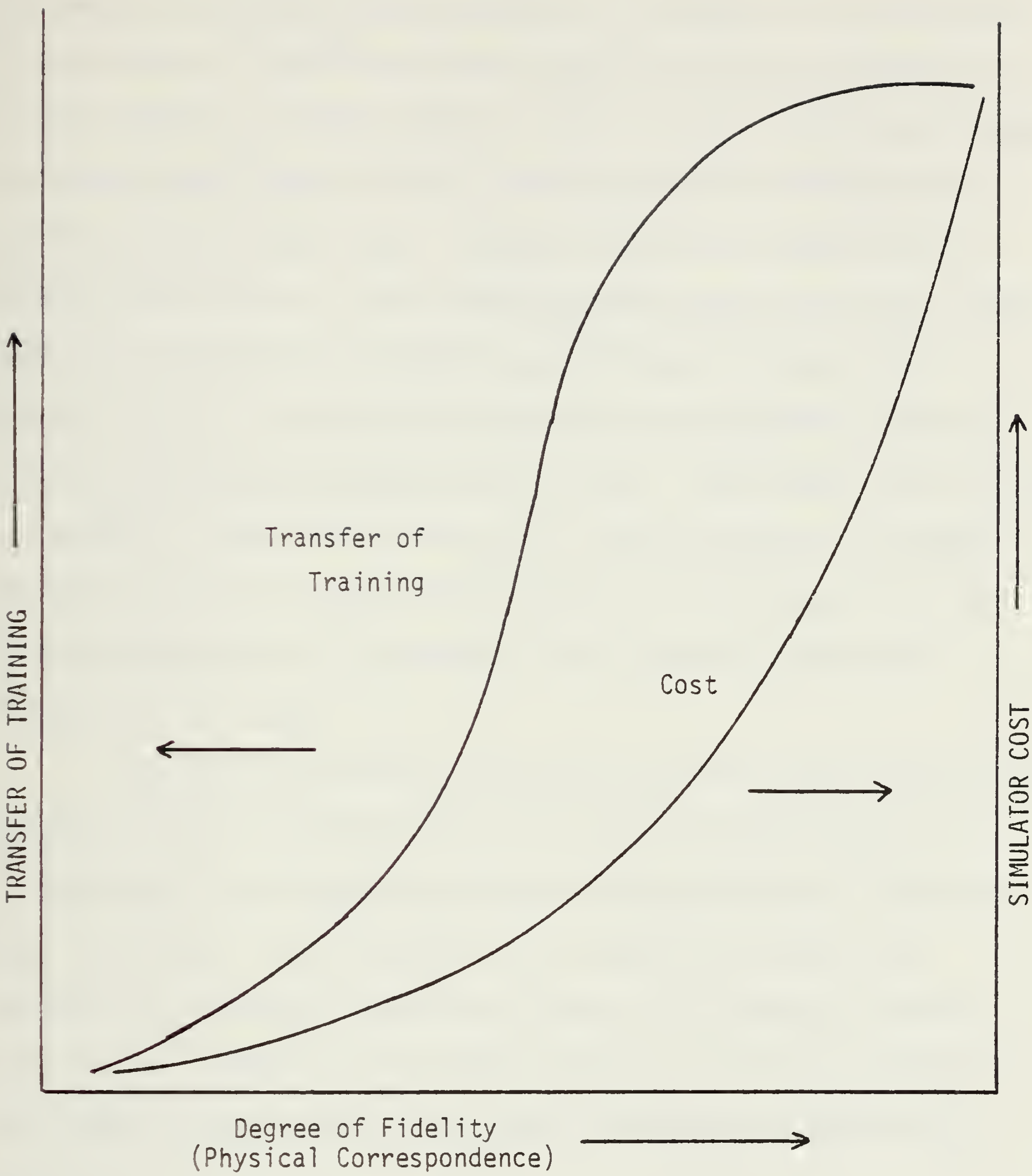

Figure 1. Cost, Fidelity and Transfer of Training Curves
Source: Orlansky and String [1977]

the amount and type of fidelity needed in a simulator will be related to the mission of the aircraft being simulated, and the intended use of the simulator. To date, however, there has been insufficient research to examine which types of fidelity have demonstrable training value and which do not [Caro, 1976]. Several studies have shown that low fidelity devices can, in fact, achieve higher transfer than more complex devices, at significantly reduced costs [Prophet and Boyd, 1970; Micheli, 1972]. This fact may be explained by an expanded concept of fidelity emphasized by Smode and Hall [1975]. They suggest that fidelity has meaning in terms of the process and realism necessary to promote learning, as well as physical relationships. This concept is similar to the relationship of psychological versus physical simulation [Muckler, et al, 1959].

Caro [1977] discusses one particular problem with fidelity. Lags between an aircraft modification and the time the modification is incorporated in the simulator may well influence simulator effectiveness in two ways. First, certain skills cannot be trained, and secondly the differences between the aircraft and simulator detract from simulator training, and reduces its perceived value by trainees. The latter is the case with the current A-6 simulator, device 2F67, A-6A WST.

As discussed earlier, several recent studies have shown that fidelity may not be as important to training effectiveness as once thought. It may be more a motivational influence [Muckler, et al, 1959; Williges, Roscoe, and Williges, 1973; Hopkins, 1975; Caro, 1977]. Although fidelity still tends to influence training effectiveness, more profound results can be achieved in other areas.

2. Motion Fidelity

Not much appears to be known about the influence of motion on simulator training effectiveness. In a Naval pilot training study three reasons were given for the incorporation of motion cues in flight simulators [Erickson, Simpson and Stark, 1972]. First, reaction time is shorter for proprioceptive that visual stimuli. Secondly, motion cues require less focusing of attention than other type cues. Finally, motion cues are timely, whereas there may be a lag in cockpit instruments. With increased technology, motion fidelity has become a major portion of flight simulators. The motion system that appears to be gaining the most acceptance is the six degree-of-freedom system, which provides motion about six axes; pitch, roll, yaw, lateral, longitudinal, and heave.

Gundry [1976] discusses two distinct types of motion; maneuver motion, and disturbance motion. Maneuver motion results from a pilot initiated change in motion of the aircraft to achieve a different heading, altitude, or attitude. Disturbance motion results from turbulance, or a failure of a component of airframe, equipment, or engines, which then results in an unexpected change in aircraft motion. All simulators that have motion systems provide maneuver motion. Gundry explores the types of motion further and indicates disturbance motion may be more important than maneuver motion, and disturbance motion need only be simulated at a fairly rudimentary level, especially when atmospheric turbulance is simulated.

A number of conflicting studies compound the problem even further [Puig, Harris and Regan, 1978]. Many early studies favor the effects of cockpit motion cues [Hunter, 1968; Cohen, 1970; Caro,

Jolley, Isley and Wright, 1972; Williges and Roscoe, 1973; Jacobs and Roscoe, 1975]. Other studies report that no specific conclusions can be drawn with respect to cockpit motion [Jacobs, Williges and Roscoe, 1973; Williges, Roscoe and Williges, 1973; Koonce, 1974; Gundry, 1975]. Still newer studies indicate that simulator motion does not aid simulator effectiveness [Hopkins, 1974; Roscoe, 1974; Woodruff, 1976; Martin and Waag, 1978; Cyrus, 1978].

At the present time, the role of motion in simulator training effectiveness and efficiency cannot be positively ascertained, but the trend indicates motion is not as critical a factor as once imagined. Motion systems do represent a significant portion of simulator procurement and operating costs, and do not contribute significantly to military simulator training effectiveness [Orlansky and String, 1977]. Simulator motion may act as a motivational variable, however. Hopkins [1975] states:

> "Pilots love to fly. If they can't fly in the air, they want to experience the closest thing to it on the ground."

Motion may allow the pilot to fly the simulator more accurately, and to "feel better" about flying in a simulator, but the real issue is whether the tasks learned in the simulator can be transferred to the aircraft. In this respect, motion systems have not as yet proven conclusively that the high fidelity incorporated in new devices is actually needed.

3. <u>G-Systems</u>

A g-system has been added to many simulators as a supplement to motion systems. It is a device used to provide simulation of sustained linear accelerations by such means as tightening harnesses

and inflating bladders in the seat bottom and back, or the g-suit of the crewmembers [Erickson, et al, 1972]. As in the case of motion systems, g-systems allow the trainee to "feel" like he is actually flying the aircraft. In normal or aerobatic maneuvers which involve positive and negative g forces, the degree of force sensed may provide some control cues. However, despite several studies in this area, as in the case of motion systems, no significant conclusions can be drawn [Puig, Regan and Harris, 1978]. G-systems can provide a motivational variable, but to what extent they aid in simulator efficiency and effectiveness has yet to be determined.

4. Handling Characteristics

The manner in which the simulator handles as compared to the aircraft being simulated has also been considered a factor in simulator effectiveness. The resistance of flight controls to crew inputs may provide data on the flight status of the aircraft. The simulation of control feel, and control/display interactions should be consistent with the indications encountered in flight. There exist strong opinions by crewmenbers that a simulator must feel like the aircraft, in order to have training effectiveness. This point, however, is not necessarily the case [Caro, 1976]. Simulators can be effective as long as the correspondence between the aircraft and devices are within reasonable limits. When this correspondence is gross, as in the case where the simulator would climb when forward pressure was applied to the control stick, simulator effectiveness would definitely suffer [Caro, 1976]. Caro [1977] concludes:

> "Thus, although in the extreme case simulator response characteristics unlike those of the aircraft can produce negative transfer of training, there is little evidence that the simulator must precisely duplicate the feel of the aircraft in order to be effective."

It should be noted, however, that as in the case of motion, pilots have resisted and most likely will continue to resist using simulators that do not feel like the aircraft.

5. Visual Fidelity

There is more known about the influence of visual displays upon simulator training effectiveness that motion systems. As in the case of motion systems, there exists a variety of alternatives for visual imagery; from relatively simple and inexpensive to extremely complex and costly. The alternative chosen will, of course, depend upon the visual tasks that are required to complete the mission. To assess the adequacy of a visual simulation system, the visual cue requirements essential to teaching those operations must be determined [Roscoe, 1974]. Specific tasks which require visual systems for military training are; take-off and landing, air-to-air combat, air-to-ground attack, carrier landing and aerial refueling [Orlansky and String, 1977]. Other tasks germane to the A-6 aircraft and its mission include low level navigation and formation flight. The type of visual system needed to develop those skills that are relevant to the A-6 mission can be extracted form an article by Morris and Matthews [1976]. They conclude that these skills require a wrap-around real-time visual presentation of at least 180 degrees by 60 degrees and must contain high picture content and resolution for visual low level navigation.

There are three basic visual systems in use today. These are model board, computer-generated imagery (CGI), and film. A model board system is based on a physical, scaled-down world. An optical probe and television camera mounted on a gantry moves over the model, as if it were an aircraft, and the crew sees a postion of the model as the aircraft maneuvers. Since this system is limited by size and optical distortion, these systems are being replaced by CGI systems. CGI systems store scenic content in digital form and calculate visual perspective for each television frame based on the instantaneous eye-point position and orientation of the aircraft in three-dimensional space. The simulated area can be very large, and this system has the ability to follow aircraft position and attitude in space. A CGI system with wide angle field of view produces a realistic impression of movement through space. Orlansky and String [1977] report a case where experienced pilots did not notice when platform motion was ceased during a demonstration flight with a wide angle CGI system. Film systems consist of photographed images of some flight path, usually an approach and landing. The optical system is moved by deviations from the normal flight path. Since these are very limited in field and maneuvering flexibility, it is doubtful that new systems of this type will be procurred [Orlansky and String, 1977].

The literature shows that even the simplest of visual displays has training value, although specific empirical evidence of visual display effectiveness is lacking. As in the case of motion systems, specific visual tasks must be subjected to research in order that meaningful data is obtained.

Visual systems are demonstrably more costly than motion systems, and the utility of flight simulators will depend critically

on their contribution to a wide variety of training tasks [Orlansky and String, 1977]. Visual systems, depending on their type, can add from $ .3 million to $4.5 million to the cost of a flight simulator. These systems can easily be the most expensive component of a modern flight simulator and could account for 50 to 60 percent of procurement costs. Development of visual systems must therefore be influenced by what is actually needed in the display. Since only selected visual cues are needed for specific tasks, and all visual cues are not required to perform every flying maneuver, the complete external visual environment does not need to be reproduced in a flight simulator [Williges, Roscoe, and Williges, 1973]. Given this constraint, an extra-cockpit visual display can be effective, and possibly the only way to present visual information needed for many operational tasks.

6. <u>Sound Fidelity</u>

Sound fidelity is another attempt to make the simulator more like the aircraft being simulated. As in the case of motion fidelity and handling characteristics, sound fidelity can act as a motivational variable, allowing the crew to feel like they are flying in an aircraft. However, background noises can be beneficial for training. Experienced pilots seem to hear when some component is not functioning properly. Stewart and Wainstein [1970] discuss a TWA study on sound fidelity that indicated sound inputs provide important cues for pilots. Erickson, et al [1972] state:

> "Aural cues to all systems operations, including aerodynamic sounds, communications, and systems actuation, are essential in flight simulation."

The modest cost of such systems and the training effectiveness which these systems provide, allows use of sound fidelity in some form in all modern simulators.

7. Design for Training

Features related to design for training are primarily concerned with application of principles of learning. These features include freeze capabilities, adaptive training, prompting and cueing, performance recording and playback, performance measurement, and instructor station controls and displays [Caro, 1977]. These factors have been shown to improve learning conditions and facilitate the attainment of training objectives [Prophet, Caro and Hall, 1971]. The use of these features is especially important for objective performance measurement and feedback. These tools can be of significant importance in simulator training programs, since they can enhance the device's capabilities and apply the knowledge we have of conditions that influence human learning.

Design for training emphasizes the trend away from perfect physical fidelity. Design features, in conjunction with well developed training programs, have been shown to be extremely important for transfer of training. This trend has been possible because of studies in human learning, although this research is far from being complete. Current devices are not perfect duplicates of their counterpart aircraft, because the aircraft is a relatively poor learning environment, and not necessarily training effective. The most important consideration for simulators, is the transfer to real tasks [Muckler, et al, 1959; Caro, 1973; Valverde, 1973; Blaiwes, Puig, and Regan 1973].

C. TRAINING PROGRAM

Training program design is an area which has received attention only recently, but has been shown to be the key to achieving simulator training efficiency. Although there is an increasing emphasis on the effective use of simulators, current instances can be cited of training programs in which these devices are misused or used inefficiently [Caro, 1976]. Caro and Prophet [1973] discuss several features of modern simulator training programs which are essential ingredients for effective and efficient training - better simulators, clearly defined program content, and well qualified instructors. Although these basic ingredients are required, more is needed to constitute a training program. Caro and Prophet [1973] define a training program as:

> "... the manner in which the well qualified instructor uses the appropriately designed simulator to establish the clearly defined course content within the skills repertoire of the trainee."

In design of any training program, it must be remembered that the goal is efficient development of trainee skills. This section will highlight those factors which have been shown capable of accomplishing this goal.

1. General Training and Management Features

Significant groundwork in the area of simulator training has been accomplished at the HummRRO Aviation Division, Fort Rucker, Alabama. In their work with Army and Coast Guard aviation simulator training programs, they have designed programs to take maximum advantage of the capability of the simulator, in light of current knowledge of conditions that foster human learning. Studies by Caro [1973], and Caro and Prophet [1973] outline some of the more important considerations when

designing programs. These include:

(1) Training programs have been organized around functional context, that is, sets of meaningful, purposeful, mission modules.

(2) All aspects of training are paced and redundant to the rate of learning of each student.

(3) Sequencing of instruction to assure students are taught prerequisite knowledge and skills before training new sets of skills.

(4) Minimizing overtraining as much as possible in bringing a student to the required skill level.

(5) Efficiently using personnel resources and instructors in training.

(6) Use of simulators in crew training and peer training roles.

(7) If possible, train in low to medium fidelity devices or less expensive equipment.

(8) State all training goals in objective, measurable terms which relate to trainee performance.

(9) Features of modern simulators allow precise and immediate feedback to the student.

These techniques can be employed with almost any training device, and form the basis of a sound training program. Their addition can definitely enhance the efficiency of a simulator training program.

2. <u>Instructional Sequence</u>

The sequencing of simulator and aircraft training has been suggested as a factor in simulator training effectiveness. Studies have suggested that switching from aircraft to the simulator reduces performance in the simulator on subsequent sessions, which results in training inefficiency. It appears likely that training in the aircraft, before deriving full benefit of the simulator in developing specific skills, would tend to reduce the overall efficiency of the simulator training program [Bushnell, et al, 1976]. Valverde [1973] cites

specific studies which favored the concept of block simulator instruction over alternating sequence of instruction. Block instruction consists of performing all the simulator training before advancing to the aircraft, and usually results in higher levels of effectiveness from the simulator training program [Reid, Hagin and Coats, 1970; Caro, 1977].

3. Program Content

The content of the training program is an obvious influence on the effectiveness of the simulator. For example, subject matter in a simulator program must be appropriate for the features of the simulator. This includes the reduction of non-usable information which would only detract from transfer of training. The manner in which the simulator is used in the program can also be of significance. A dynamic flight simulator that is used only as a procedures trainer is not being used effectively. Caro [1977] suggested that simulator training, when presented in the context of a simulated mission, rather than to some abstract training exercise, tends to be more effective. Evidence supports this theory, in that, material learned in a meaningful context will be forgotten less quickly [Jenkins, 1974].

One particular pitfall when adding a simulator to a training program, is to treat the simulator like an aircraft. Examples of this would be to fly long missions in a simulator, or waiting to debrief the mission until after it is completed, rather than taking advantage of the device's freeze capability. Although treating the simulator like an aircraft shows a favorable attitude towards simulator use, training effectiveness may be reduced since it preserves the disadvantages of the aircraft as a training vehicle [Caro, 1977]. Training program content is an important variable in simulator training

effectiveness, yet is not difficult to develop when the skills to be trained are well defined, and the simulator is used efficiently.

D. PERSONNEL

The personnel that use the simulator will definitely influence the effectiveness of the device. Two groups, the instructors and the trainees, are involved in simulator training. Both groups can influence effectiveness differently, due to prior experience and qualifications, as well as other factors such as stress, motivation, and fatigue. These factors can become quite complex, and can cause differing results in transfer of training studies [Caro, 1976]. Since personnel factors can be so diverse, this effort will only attempt to identify findings from earlier studies.

1. Trainees

Several factors attributed to flight trainees have been identified which may influence simulator training effectiveness. These include; experience level, proficiency, aptitude and attitude.

The level of experience or trainee skill has been questioned as an influence to simulator effectiveness. It has been suggested that simulators provide adequate training in the manned space program and commercial airlines, where trainees are very experienced, but cannot be so effective in training less experienced military trainees. Granted the skill levels of these two groups are quite different, however the tasks they train are also far from identical. The training they receive will not be the same, if the training program has been designed effectively. In fact, the experimental evidence does not support the concept that trainee experience affects simulator training effectiveness when isolated from other factors. Micheli [1972], in a

review of number of transfer of training studies concludes that simulators can be equally effective for all levels of trainee experience.

Proficiency at the time of simulator training may have an effect on training effectiveness. Studies have shown that less training value may be derived for pilots who fly operational missions daily than those who are less proficient [Caro, 1977]. In the case of readiness squadron training, all fleet replacement B/N's are maintained at approximately the same proficiency level to aid in training standardization.

Student aptitudes have also been discussed as factors in simulator training effectiveness. Aptitudes are most commonly defined in terms of efficiency of task learning, and thus, high aptitude students tend to acquire a given set of skills either more rapidly, or to a higher degree, than trainees with low aptitude. High aptitude students will require less time to learn a task in a training program which involves fixed performance levels, and will learn more tasks in a program which involves a fixed amount of simulator training. A well designed simulator program will be equally effective for both high and low aptitude students, with the higher aptitude students requiring less training time. Therefore, although high aptitude trainees learn more efficiently, in a properly designed training program, aptitude per se will not be an important factor in simulator training effectiveness [Caro, 1976].

The attitude of the trainee is extremely important for simulator training effectiveness. In an extensive review of transfer of training studies, Valverde [1973] concludes that motivation and attitude of the student toward the simulator may affect his learning of the specified

tasks. With simulators being introduced as integral parts of basic flight training programs, students are now able to view the advantages and importance of simulators in learning the skills necessary to fly in aircraft. Hopefully, this will foster good attitudes towards simulator use.

2. Instructors

No matter how much effort has been placed in constructing a well-defined, meaningful simulator training program, the effectiveness can be totally destroyed by neglecting the instructors who are to implement the program. Instructor biases, attitudes, and motivation all effect the transfer of training in simulator programs [Valverde, 1973]. Studies in this area have shown that the instructors attitude of the device is reflected in the attitude of the student. This would indicate that instructor selection and training is an important factor for positive transfer of training to occur. Not only is instructor attitude important, but instruction techniques and program objectives also effect transfer. Nonstandardization in administration of the training program can result in ineffective training [Caro, 1976]. The instructor must present those objectives which develop the skills necessary to perform in the aircraft.

Certain behaviors that have been attributed to effective simulator instructors were noted by Caro in a study analyzing Air Force simulator training effectiveness [1977]. These include:

(1) The best instructors do not try to teach all they know about the system and its components, but teach only what is needed to know to fulfill the mission.

(2) Good instructors simulate the actual flight environment as much as possible, such as radio communications and flight procedures.

(3) Good instructors let the trainee progress further before hitting the "freeze" button.

(4) Good instructors are tuned to the needs of the student and are willing to assist with their expertise. Poor instructors are usually interested in getting through the syllabus requirements.

Although there are certainly more factors that could be identified, these appear to form a basis common to better instructors.

The ratio of instructor to student is another consideration. That is, should the simulator instructor also be a flight instructor? Studies indicate that there is an apparent increase in effectiveness when a single instructor teaches both simulator and aircraft phases of a training program [Caro, 1976; Miller, 1978]. Besides being more cost-effective, in that fewer total instructors are needed, instructors are then more aware of the total training program. Instructors who teach in both environments are also better prepared, since they have knowledge of the aircraft and its mission, as well as the capabilities and limitations of the simulator.

Finally, instructors must be equally prepared for their job. Instructors must be aware of all the capabilities of the device. An instructor preparatory course in simulator operation is an ideal way demonstrate the device's capabilities, and also remove any reluctance the instructor may have in flying the simulator. Instructors must be shown that simulators have unique training value, and are not just designed to reduce flight time. A well-structured instructor program could aid in standardization of training procedures. Finally, these programs have been shown to influence instructor opinions concerning simulator training.

E. ATTITUDES AND EXPECTATIONS

A problem that often accompanies the introduction of new training equipment is the misuse, partial use, or non-use of that equipment. Although reasons such as design or equipment shortcomings are common, the user attitudes may also play a significant role in nonacceptance of simulators for flight training. Students who have undergone basic training with new and well designed simulator programs show favorable attitudes towards the use of simulators [Caro, 1977]. These attitudes might enhance simulator efficiency. Although early studies dismiss the effects of attitude on the effectiveness of a simulator as measured by transfer, they do indicate that attitudes do affect the efficiency of the training. More recent studies indicate an interrelationship exists between specific system attitudes and performance [Abrams, et al, 1977]. In any case, favorable attitudes do at least increase simulator use, which may be a step in the right direction.

There does appear to be a relationship between simulator design, or fidelity, and attitudes. As early as 1959, Muckler suggested that fidelity is a motivational variable. The more the simulator looks, acts, and feels like an aircraft, the more the trainee is convinced of the benefits of the simulator. In a circular fashion, simulator design is then influenced by these attitudes. Williges, Roscoe and Williges [1973] noted this phenomenon, in that, decisions to add expensive simulator motion systems were generally determined by pilot's attitudes. Attitudes and performance also share this commonality. The better the performance of the operator, the greater the acceptance of the simulator, which in turn can affect performance [Abrams, et al, 1977].

Instructors have a great deal to do with the attitudes of their trainees. This is not only reflected by the instructors own attitudes about simulation, but in the way the simulator session is run. In a recent Air Force study [Caro, 1977], students complained that the intensity of the session was too "busy," resulting in dreading the next simulator session. Instructors were so busy plugging in malfunctions that the students didn't have time to fly the aircraft. This frustration would result in negative attitudes towards simulator use. By providing both instructors and students with positive simulator experiences, they could realistically access the limitations and advantages of the device, allowing rational attitudes to be developed. This method would promote favorable attitudes and would enhance trainee performance [Abrams, et al, 1977].

Expectations also play a significant role in simulator training effectiveness. If an instructor does not feel training in a simulator is as effective as in the aircraft, the resulting simulator training will, indeed, be less effective. If the simulator is only viewed useful as an emergency procedures or instrument trainer, then it will probably only be used as such, even though it offers a greater range of training opportunity. It appears expectations tend to place a limit upon realized effectiveness, by limiting the manner and extent of simulator training [Caro, 1977].

An obvious factor in user expectations and attitudes is prior contact with simulators, and extent of flight experience. Studies note that older pilots make poorer instructors, because of hesitancy to adopt new training methods and the reliance on flight time for training in the past. Similarly, contact with old simulators usually

resulted in unfavorable experiences, further placing confidence on in-flight training. With the advent of new simulators, and well-designed training programs, as well as fuel and fiscal constraints, in-flight training is no longer a viable alternative. Perhaps use of simulator hours in place of flight hours for career goals such as mission commander, section leader, etc., will further reduce unnecessary aircraft time. Only through positive contact with simulators will attitudes and expectations be changed, and resistance to simulator use fade.

F. CONCLUSIONS

No single influence can be attributed to the effectiveness of a simulator training program. It is more likely that those factors discussed in preceeding sections of this chapter, and many more subtle ones, combine to produce effective simulator training. Other variables might include the natural resistance to using simulators instead of aircraft, or the maintainability of the simulator itself. The latter could alter effectiveness by omission or degradation of training, if the simulator were not fully operational. Even other factors which would not normally be considered an influence in isolation, may combine to effect simulator training. It has become clear that the simulator itself, although an important component in a training program, is no longer the overriding consideration as once thought. Well-designed training programs and the personnel that use them have been shown to be of great importance for effective simulator training. Perhaps those factors influencing simulator training effectiveness have been best described by Povenmire and Roscoe [1973]:

"The effectiveness of a ground-based flight trainer depends not only upon its degree and fidelity of simulation, but also upon its trouble-free operation, the ingenuity of the flight instructor using it, and the confidence that all of these instill in the student."

VI. A-6E WST - DEVICE 2F114

A. GENERAL DESCRIPTION

The A-6E WST was designed to support A-6E replacement pilot and B/N training, as well as to fulfill fleet squadron and ground crew maintenance turn-up personnel training. Design characteristics were based on Fleet Project Team inputs identified at a military characteristics development meeting in mid-1973 [Schilling, 1973]. The WST was designed to provide training in aircraft control, instrument procedures, airframe system and engine control, emergency procedures, and all modes of weapon system operation. Characteristics included in the WST are a direct result of training objectives identified by Fleet Project Teams. These objectives are presented in the detailed military characteristics report [Schilling, 1973], and are reproduced below:

> "The device shall simulate the environment of the A-6E cockpit within which the trainees will operate. The training shall include system familiarization; development of operational skills and operating techniques; weapon system capabilities and limitations; normal and emergency operation of aircraft and navigation/attack systems and sub-systems; crew coordination; recognition of system/sub-system malfunctions/failures, identifying possible causes, and learning techniques to circumvent the malfunctions/failures and still accomplish the mission; recognition of "external" threats (i.e. enemy radar, ECM, missile(s)) and techniques to counter the threats as displayed in the cockpit or heard in the crew headsets."

Thus, the A-6E WST allows crewmembers to perform virtually all functions associated with the aircraft mission.

The A-6 WST is divided into four areas: Trainee Station, Instructors Station, Simulation Area, and Mechanical Devices Room (See Figure 2).

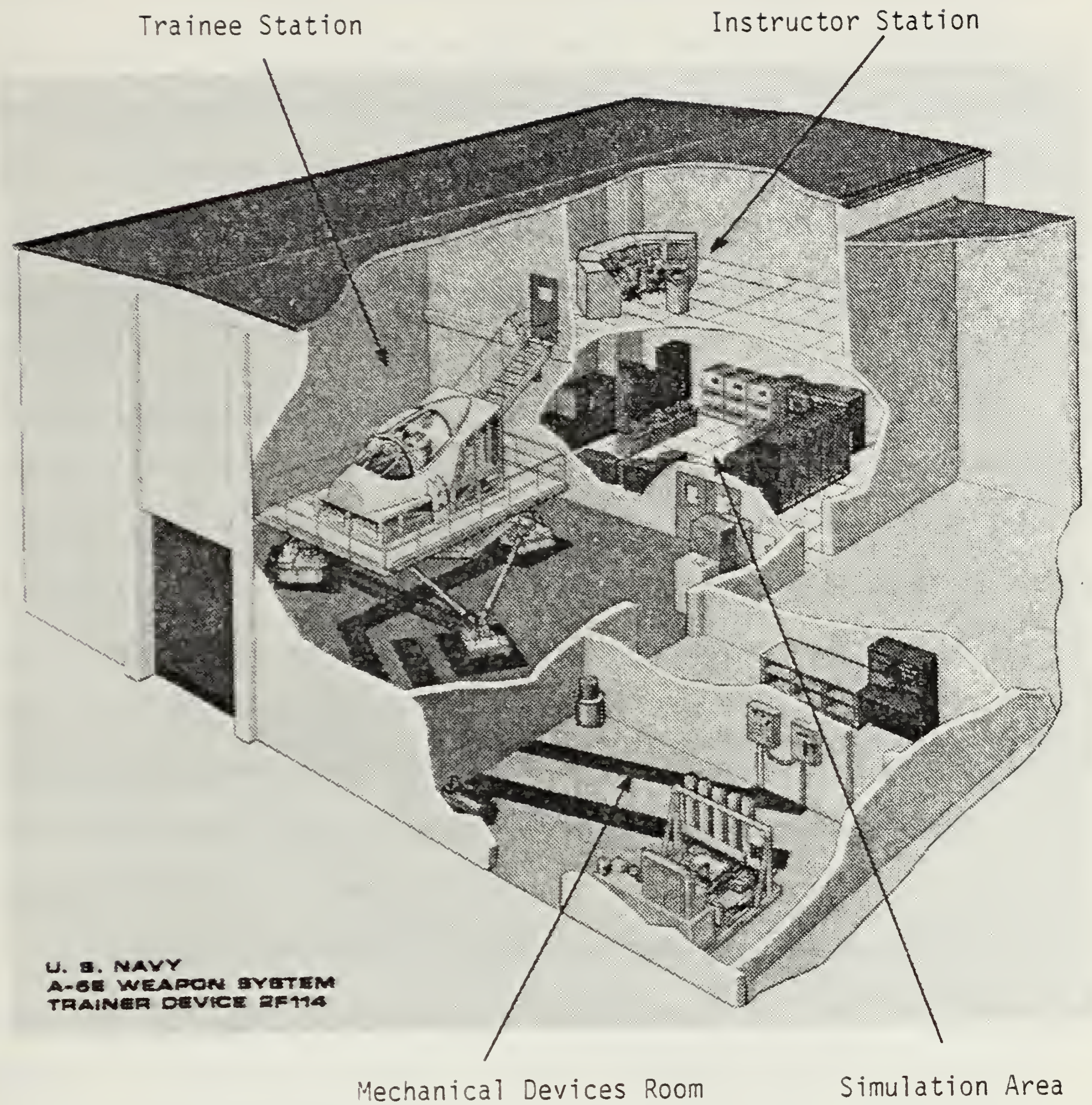

Figure 2. Device 2F114, A-6E WST

The Trainee Station, an exact replica of the A-6E CAINS cockpit, is mounted on a hydraulically controlled six degree-of-freedom motion system to give the WST realistic acceleration cues. Sound cues, environmental controls, and controls with realistic "feel" add to the fidelity of the device. The Trainee Station simulates normal and emergency flight configurations and all modes of weapon system operation. Procedures for all mission phases can be performed under normal, degraded, and emergency conditions.

The instructor Station, where training is initiated and controlled, is located exterior to the motion platform. This station is capable of implementing the mission, inserting malfunctions, monitoring the action and effectiveness of the trainee, and evaluating trainee performance. To achieve these tasks, the station includes two consoles with four interactive CRT displays for presenting alphanumeric and/or graphic data, together with repeater displays of the vertical display indicator (VDI), direct view radar indicator (DVRI), and electronic countermeasures displays (ECM) found in the aircraft.

The Simulation Area contains four, real time minicomputers; two for flight, one for tactics, and one for the Digital Radar Land Mass Simulation (DRLMS). Disc and tape drives, printers, teletypes, digital conversion equipment, and the DRLMS are also contained in this area. The DRLMS is designed to provide a realistic, real time simulation of the functional, operational and performance characteristics of the AN/APQ-156 radar, which is a major component in the A-6 navigation/weapon system.

The Mechanical Devices Room contains hydraulic and power equipment needed to position the trainee station motion system. This room also contains compressed air needed to provide the g suit and breathing air

requirements.

In addition to operating as a system trainer, the A-6E WST is capable of functioning as an Operational Flight Trainer (OFT), or a tactics trainer. When used as an OFT, pilots can be separately trained in aircraft control, instrument procedures, communications, airframe system and engine control, and normal and emergency procedures. As a tactics trainer, B/N's receive separate training in the use of the attack/navigation system, including radar scope interpretation and navigation, communications, and normal and emergency procedures.

B. SYSTEM FEATURES

The A-6E WST is a high fidelity device which realistically duplicates the actual aircraft environment. A comprehensive list of system features and characteristics is beyond the scope of the present effort, but can be found in NAVTRAEQUIPCEN WA 8620 [Schilling, 1973]. Those features which most affect B/N training and A-6E WST training effectiveness are discussed below:

(1) The WST is an exact replica of an A-6E CAINS cockpit, which is the current aircraft modification. Future aircraft modifications can be incorporated in the WST.

(2) The system contains a six degree-of-freedom motion system to give realistic acceleration cues. Besides this maneuver motion system, the WST provides disturbance motion cues including; runway roughness for takeoff motion, mach number and turbulance effects, anti-aircraft (AAA) and surface-to-air (SAM) burst effects on the aircraft, and landing effects for both ship and shore. The system also contains g suit inflation for g cues during simulated maneuvers.

(3) The WST duplicates the entire flight envelope of the aircraft, including all weapon loads and aircraft configurations.

(4) A variety of aural cues are incorporated in the device. Some of these include; normal flight noise, configuration changes, aircraft system failures, engine operation, including out of sync engines, missile firing tones, ECM gear response, normal "hum" in communications systems, and tire touchdown noise upon landing.

(5) Although no visual system will be available on initial delivery, a visual display option can be provided when funding and wide angle visual systems are available. Simulated environmental lighting is available, and can vary from light clouds to night conditions.

(6) The WST environmental control system will be as in the actual aircraft. Ejection seats, cabin pressurization, defog and rain removal systems will all be simulated. In addition, breathing air for use with oxygen masks is provided.

(7) The WST ECM system will simulate both active and passive threats, including warning tones. The use of ECM sets and chaff will have the appropriate effect on simulated threats (i.e. SAM, AAA).

(8) All operating display and tracking modes of the AN/APQ-148 search radar shall be simulated, including built in test (BIT/FIT) functions. Radar simulation of terrain and cultural (man-made) features is performed by the DRLMS, a very authentic, state-of-the-art radar simulator. DRLMS fidelity is very close to the actual A-6E radar fidelity. Additionally, weather conditions, such as clouds or fog can be presented on the B/N's DVRI. DRLMS allows instructor update of cultural features, use of moving targets with the airborne moving target indicator (AMTI), and an operational search radar terrain clearance (SRTC) mode. The radar presentation is dependent on the DRLMS data base, and each readiness squadron (RAG) will have an area reproducing their normal training areas.

(9) The AN/ASQ-133 digital computer will operate as in the aircraft, including all controls, indicators, and readouts. All navigation options, computer steering selections, attack modes, and self-test features shall be simulated. The velocity correct feature, both manual (MVC) and automatic (AVC), used in target tracking will also be simulated.

(10) Other components of the navigation/weapons system include: the video tape recorder (VTR), radar altimeter, AN/APN-153 doppler navigation radar, and AN/ASN-92 inertial navigation system. WST operation of these systems duplicates aircraft performance, including all controls and indications.

(11) All components of the weapon release system will be simulated. This system provides for manual and/or automatic system release of the full range of weapons compatible with the A-6E aircraft. The WST also contains a bomb scoring capability.

(12) The WST will contain all components needed for simulation of the communication, navigation, and identification system. This feature includes all modes of the automatic carrier landing system (ACLS).

In addition to the high fidelity features of the device, several design for training features have been incorporated into the instructors station of the WST. Display systems will be provided to monitor cockpit instruments, indicators and switches. Repeaters will be provided to monitor VDI and DVRI displays. Also, an effectiveness display will monitor specific procedures associated with the Naval Air Training and Operating Standardization Program (NATOPS), such as engine starting, or emergency procedures. The instructor can insert various initial conditions or malfunctions into the simulated mission to monitor crew performance under various flight conditions. The WST contains a freeze control, to stop the simulated mission at any point in the training session. Release from freeze is provided which allows continuance from the point of freeze, as well as a reset control that will return the simulation to the initial problem conditions. The WST will contain a demonstration mode, where the trainer can perform all the flying, including control movement and instrument indications. The trainee can then perform the same maneuver.

Programmed missions can be incorporated into the system. Each flight can then be recorded, providing a record of trainee performance and deviations from desired parameters. A continuous mission playback feature is also provided, allowing the trainees immediate feedback of the mission. The playback feature has the capability to "flag" specific mission events

for rapid reference. Associated with the dynamic replay capability is the ability to save any mission recording or to print a hard copy of the mission flown. These design for training features definitely enhance the capabilities of the WST and should provide an environment for positive transfer of training.

C. COMPARISON WITH CURRENT TRAINING DEVICES

At the present time, two simulation devices are used in B/N training; the TC-4C aircraft and device 2F67, A-6A WST. The TC-4C is a twin engine turboprop aircraft with an A-6 radome and an A-6E cockpit in the aircraft cabin. It is effectively an airborne simulator, and is used extensively in B/N training programs. The instructor is seated beside the trainee, and monitors his performance. Usually two students fly the proposed route, each occupying the B/N position for half the mission. The only feedback possible is from VTR tapes, when used, and instructor comments during the mission and debrief session. Reconstruction of the flight can be difficult, due to mission length of 3 1/2 to 4 hours.

Device 2F67, A-6A WST, is the ground simulator used in training. However, since it is two aircraft modifications behind the current A-6 aircraft, and the B/N system barely resembles the A-6E either physically or operationally, it is not used extensively. In fact, the A-6A WST is used primarily as an emergency procedures trainer.

Device 2F114, A-6E WST combines the advantages of both device 2F67 and the TC-4C, by providing a safe and economical means of training replacement B/N's. It provides design for training features that are not now available in either the A-6A WST or the TC-4C. Fidelity characteristics of the A-6E WST are designed to make the trainee feel like he is actually in the A-6E flight environment, and in this sense,

the WST provides a more realistic flight environment than either system currently in use. Additionally, the A-6E WST avoids the basic shortcomings of actual aircraft training discussed earlier.

VII. OBSERVATIONS AND DISCUSSION

A. READINESS SQUADRON TRAINING PROGRAMS

B/N replacement training is conducted by both the East coast RAG, Attack Squadron Forty-Two (VA-42), and the West coast RAG, Attack Squadron One Twenty Eight (VA-128). Each RAG has developed and maintains its own training program, however these programs are quite similar in nature. Each syllabus is divided into specific phases, which are further divided into lecture, simulator, and flight segments. Each phase is designed to develop certain skills, such as navigation, system operation, or attack procedures. Knowledge of skills in preceding phases is necessary to progress through the syllabus. In the author's opinion, this building-block technique reinforces skills that have been developed earlier, and aids in learning.

This study will focus its attention on a Category One (CAT I) B/N training program. A CAT I replacement B/N (RBN) is a designated Naval Flight Officer (NFO), who has no previous experience in the A-6 aircraft. This encompasses both NFO's who have just completed basic flight training, to those with flight experience in other aircraft. Since a CAT I RBN requires the maximum amount of training, effects of the A-6E WST on training effectiveness can be seen most easily.

1. Content

Appendix A, "Proposed B/N Training Syllabi," provides a general description of the content of proposed B/N flight training programs for both VA-42 and VA-128. Ground training for both RAG's is quite detailed and well formulated. Content for ground training is clearly defined, and

program components are structured to specifically address those tasks which are required to develop the skills necessary to become a fleet B/N. This organization incorporates many of the features discussed earlier, which are beneficial for effective training.

Simulator and flight training do not appear as effective as ground training, however. Both RAG's tend to treat the simulator as an addition to training rather than integrate the WST into the flight training portion of the syllabus. This is possibly due to past experience with the A-6A WST, which has lost much of its training value. As a result, planners relied heavily on the A-6 and TC-4C aircraft for B/N training. Alternative mixes of simulator and aircraft hours, and the associated measures of effectiveness will be discussed in a later section. Although the flight programs can be improved, they do contain desirable features which provide a foundation for an effective simulator program. Course content has been clearly defined, and training is paced for the individual student. Additionally, sequencing of instruction insures RBN's learn prerequisite skills prior to progressing to more advanced stages. With sound integration of the A-6E WST into the flight training syllabus, this foundation can insure an effective training program.

2. Personnel

Readiness squadron flight instructors are designated Naval pilots or NFOs whose primary billet is to train replacement pilots (RP) and RBNs. Each prospective instructor has completed at least one squadron tour in the A-6 aircraft. Instructors are required to complete an instructor training course, which is designed to develop instructional techniques and methods which are necessary to effectively train replacement crewmembers. The amount of training varies with the prospective instructors

previous background and experience level, but includes both ground and flight phase instruction. This course identifies training syllabus content and objectives, allowing the prospective instructors to develop their own training style. Since grading criteria are generally subjective in nature, each instructor has some latitude in the manner in which he presents syllabus objectives.

Flight instructors are not always the same individuals that instruct in the simulator. There is no indication in the VA-42 instructor-under-training syllabus that the prospective flight instructor is even introduced to the A-6E WST. VA-128 plans to designate certain individuals WST instructors, whose primary duty will be to teach in the simulator. These individuals will not serve as flight instructors. All simulator instructors will be required to complete a two week WST training program. Although the concept of special simulator training programs for instructors does agree with previously discussed factors increasing training effectiveness, the separation of flight and simulator instructors does not. An instructor who teaches in both areas not only has a better understanding of training program content, but also increases his potential to conduct effective training.

3. Attitudes/Expectations

Attitudes have been shown to be an important factor in simulator training efficiency, in that, trainees with favorable attitudes tend to use the device more extensively than those with negative attitudes [Caro, 1976]. The A-6E WST seems to have been designed, in part, with crew attitudes in mind. The high fidelity characteristics incorporated into the WST are designed to make the crew feel like they are actually in the A-6 aircraft. These fidelity and design for training features are

expected to produce effective B/N training. However, other attitude factors must be considered.

In the author's experience, student attitudes are generally favorable towards simulators, since trainees are introduced to simulator flight early in the training program. Devices used in basic NFO training have been well designed, and are used as integral parts in flight training. By efficient simulator use at this early stage in an aviators career, he can see the advantages of simulators, and develop favorable attitudes towards them.

Instructor attitudes, in the author's opinion, are quite different from those of the trainee. In the military flight community there is an overriding concern for flight time. A great deal of prestige is afforded those who acquire the most time airborne, and career goals, such as mission commander or section leader, are based, for the most part, on flight time. Additionally, it appears poor performance of early simulators has resulted in some prejudices towards simulator training. The author has found this especially true of the A-6A WST. As discussed earlier, instructor attitudes influence the trainee and can destroy favorable attitudes. This problem could be a stumbling block for the effectiveness of the A-6E WST. To overcome some of these attitudes, members of the A-6 community should be afforded the opportunity to observe and use the A-6E WST. Only through positive experience can preconceived attitudes be changed. In addition, flight time must be placed in proper perspective by those in authority. With increasing costs, and airspace limitations, each aircraft flight must achieve the maximum amount of training possible. Only when simulators are designed <u>in</u>to a training program, instead of <u>on</u>to the program, will attitudes toward simulators change.

4. Training Program Alternatives

Although current training proposals advocate the use of the A-6E WST as an addition to existing training programs, more effective use, in terms of training, can be accomplished. Appendix B, "Alternatives in B/N Training" discusses possible substitution practices which could result in more efficient training, and would definitely prove to be cost effective. By exploring previously discussed transfer of training measurements for both proposed programs, and alternatives, a better understanding of A-6E WST effects on B/N training may be developed.

Neither RAG proposal results in a reduction of current flight hours, although both do increase simulator use significantly. Computations of Percent Savings and FSR are based on figures summarized in proposed B/N training programs. Appendix A details the hour totals which are used in this section. Formulae used are described in the Transfer of Training section of this report. Using the measure of effectiveness, Percent Flight Syllabus Reduction (Percent Savings) we find:

(1) For VA-42

$$\text{Percent Savings} = \frac{101 - 101}{101} \times 100 = 0.0$$

(2) For VA-128

$$\text{Percent Savings} = \frac{103 - 103}{103} \times 100 = 0.0$$

This indicates that neither RAG proposal results in savings of actual flight time, and therefore, A-6E WST use, as proposed, will not be as effective as possible. In order for the simulator to be effective, it must be capable of taking over training that was previously only possible in the aircraft.

Efficiency of a device may be expressed by the FSR. As discussed earlier, the smaller the value of a positive FSR, the more efficient the

simulator. Computing the FSR for current RAG proposals results in the following:

(1) For VA-42

$$FSR = \frac{13.0 - 5.5}{101 - 101} = \infty$$

(2) For VA-128

$$FSR = \frac{22.5 - 11.0}{103 - 103} = \infty$$

Again, although both RAGs increase simulator use in the B/N training syllabus, the device is not being used efficiently, since no reduction in flight hours occurs.

Similar computations can be made for alternatives to the RAG proposals. Using the possible substitution of the A-6E WST for aircraft flights discussed in Appendix B, Percent Savings and FSR can again be computed. It will be assumed for computational purposes that the amount of flight time reduced will be added in simulator missions. Results are indicated below:

(1) For VA-42 Alternative (41.0 hours reduced)

$$\text{Percent Savings} = \frac{101 - 60}{101} \times 100 = 40.59\%$$

$$FSR = \frac{54.0 - 5.5}{101 - 60} = 1.18$$

(2) For VA-128 Alternative (38.0 hours reduced)

$$\text{Percent Savings} = \frac{103 - 65}{103} \times 100 = 36.89\%$$

$$FSR = \frac{60.5 - 11.0}{103 - 65} = 1.30$$

These results indicate the efficiency and effectiveness possible with the A-6E WST, when integrated <u>into</u> the training program. Although these calculations are performed on what could be considered the most severe amount of flight substitution, it does suggest that integration of device

2F114 into a well-designed training program can result in more efficient B/N training. Additionally, the results from the alternative syllabi do correspond to results obtained in a study evaluating current substitution practices in flight training [Diehl and Ryan, 1977].

There is little doubt that the A-6E WST has sufficient fidelity and training advantages to significantly enhance B/N training programs. Cost advantages, which are discussed in the following section, also highlight the desirability of extensive WST use. However, the amount of effectiveness that the new simulator produces will depend entirely upon the use by training personnel. Some substitution must be made, if the program is to operate efficiently. It should be remembered that the goal is for efficient and effective B/N training. The A-6E WST has the potential to accomplish this goal, but only if integrated, not added, to current training programs.

B. COST CONSIDERATIONS

Thus far, only factors influencing training effectiveness have been considered. For a simulator program to be totally effective however, device use must also be cost effective. Estimates of flight costs for the A-6E and TC4C aircraft were derived directly from averages in the Navy Program Factors Manual, OPNAV-90P-02, revised 1 August 1977. A-6E WST operating costs can only be estimated at the present time, since the system is not yet deployed to readiness squadrons. However, the most recent estimates have been used in this report [Scott, 1978]. Cost per flight hour for both fleet and readiness squadron A-6E aircraft is summarized in Table I below:

TABLE I: COST PER FLIGHT HOUR FOR A-6E AIRCRAFT

COMMAND	TOTAL OPERATING COST PER AIRCRAFT PER YEAR	ESTIMATED HOURS PER MONTH PER AIRCRAFT	COST PER FLIGHT HOUR
VA-42	$1,695,000	35.15	$4,018
VA-128	1,653,000	33.20	4,149
CINCLANTFLT	1,308,000	25.68	4,245
CINCPACFLT	1,319,000	25.68	4,280

Extensive use of the A-6 in training is not particularily cost effective when one considers the average cost per flight hour is over $4,100. This fact requires that all flights must be designed to achieve maximum training value. The aviation community can no longer afford the luxury of excessive flight time.

Cost per flight hour for the TC-4C aircraft was computed in a similar fashion. Since there is a relatively small number of these aircraft operational, costs are pooled, and therefore only one cost is calculated.

TABLE II: COST PER FLIGHT HOUR FOR TC-4C AIRCRAFT

TOTAL OPERATING COST PER AIRCRAFT PER YEAR	ESTIMATED HOURS PER MONTH PER AIRCRAFT	COST PER FLIGHT HOUR
$843,000	34.64	$2,028

Thus, the TC-4C is more cost effective for B/N training than the A-6. This cost advantage, coupled with many training advantages, has resulted in extensive use of the TC-4C in the B/N training programs for both RAGs.

The introduction of the A-6E WST in training programs can have a profound effect on B/N training. Estimated total operating cost per device per year is $348,000, almost two and one half times less than current TC-4C operating costs [Scott, 1978]. Using projected device operating schedules of sixteen hours a day, five days a week, cost per flight hour

for the A-6E WST is only $87. This cost is twenty-three times less than the TC-4C aircraft. Even if current cost estimates for the device are significantly in error, the WST should still provide a more economical training platform that current aircraft.

RAG proposals to augment current training programs with the A-6E WST are limiting the training value of the simulator, and merely increasing the cost of the overall training program. Substantial savings can be achieved by substituting the WST for actual flights, where feasible. Again considering the possible substitution discussed in Appendix B, projected savings have been calculated and are displayed in Table III.

TABLE III: PROJECTED B/N SYLLABUS SAVINGS

RAG SQUADRON	A-6 REDUCTION PER STUDENT		TC-4C REDUCTION PER STUDENT	
	HOURS	SAVINGS	HOURS	SAVINGS
VA-42	23.5 of 66.0	$92,379	17.5 of 17.5	$33,967
VA-128	14.0 of 79.0	$56,868	24.0 of 24.0	$46,584

If only the TC-4C were eliminated from the training program, and its associated hours transferred to the A-6E WST, VA-42 could realize a savings of $33,967 per RBN, while VA-128 could save $46,584 per RBN.

The A-6E WST has definite advantages in B/N training. Substantial savings can be obtained by integrating the simulator into current programs, while maintaining a high level of training efficiency and effectiveness.

VIII. RECOMMENDATIONS AND CONCLUSIONS

The introduction of device 2F114, A-6E WST, into readiness squadron training programs has the potential for providing a more effective and efficient means of training A-6 B/N's. Although this examination can only estimate simulator effectiveness, the manner in which the device is used will determine the amount of effectiveness actually achieved.

Proposed readiness squadron training programs identify A-6E WST use as augmentation to existing flight programs. Although increased simulator use indicates favorable attitudes towards simulators, maximum effectiveness is not necessarily achieved. In fact, measures of transfer of training indicate that no added efficiency or effectiveness will be achieved by the A-6E WST if used only as an addition to existing programs. The only effects on B/N training will be an increase in training costs, and the misuse of simulator training potential.

The A-6E WST will be more effective only if treated as an integral component in B/N training programs. This will require not only augmentation of simulator missions into the syllabus, but also reduction of flight time, where feasible. Substitution of TC-4C missions appears particularly promising. The A-6E WST provides design for training features that cannot be achieved in the TC-4C aircraft. Not only does the WST provide a better learning environment, but also more realistically presents the A-6 aircraft environment. Finally, cost considerations favor more extensive simulator use.

The concept behind all military flight training is simulation. All training flights, whether in ground simulators or aircraft, are designed to develop skills which will be required for combat. Each training

mission then, results in a choice of which simulation device can most effectively and efficiently train combat skills. This is where integration of devices, such as the A-6E WST, into training programs becomes an important factor. Modern simulators provide training platforms that have never before been possible, allowing crews to develop skills in a safe, efficient, and economical environment. Through prudent management of these devices, maximum training potential can be realized.

APPENDIX A: PROPOSED B/N TRAINING SYLLABI

Current proposed B/N training programs incorporating the A-6E WST are quite similar to programs already in existence. Both RAG training syllabi indicate that the 2F114 will augment already existing flight training programs. The addition of the A-6E WST will not affect current ground training or syllabus phase lectures, and will therefore not be discussed here. Since flight and simulator phases are affected, proposals from both RAG's are identified in this section.

The VA-42 syllabus enclosed summarizes the published B/N training program, CAT I, from that command. VA-128 at the present time has not formally published their training program with the addition of the A-6E WST. However, the enclosed syllabus has been constructed from the present VA-128 B/N training program and estimates from training instructors and Fleet Project Team members in that command.

VA-42

I. FLIGHT TRAINING

PHASE	SORTIES	AIRCRAFT HOURS+ A-6E	TC-4C
Familiarization	1	1.5	0.0
Navigation	11	12.0	21.0
Radar Target Identification (RTI)	8	12.5	10.5
System Weapons	10	19.5	3.5
Visual Weapons/Tactics	5	7.5	NA
FMLP	5	5.0	NA
Carrier Qualification (CQ)	4	8.0	NA
TOTALS	44	66.0	35.0

II. SIMULATOR TRAINING A-6E WST

DESCRIPTION	SORTIES	HOURS++
Turn Up and Shut Down Procedures	1	1.0
Normal Operating Procedures/Single Emergencies	1	1.5
Introduction to Multiple Emergencies	1	1.5
Ready for Flight Check	1	1.5
Search Radar Operation and Controls	4	3.0
Digital Computer Operation	3	3.0
ECM Mission	1	1.5
TOTALS	12	13.0

\+ 101.0 Total Aircraft Hours - Represents no change with the introduction of the A-6E WST.

++ Simulator Hours - Represents an increase from 5.5 to 13.0 hours with the introduction of the A-6E WST.

VA-128

I. FLIGHT TRAINING*

PHASE	SORTIES	AIRCRAFT HOURS+ A-6E	TC-4C
Familiarization	2	4.0	0.0
Navigation	12	10.5	16.0
System Weapons	13	24.0	8.0
Visual Weapons	8	12.0	0.0
Tactics	5	6.5	0.0
FCLP	14	14.0	0.0
Carrier Qualification	4	8.0	0.0
TOTALS	58	79.0	24.0

II. SIMULATOR TRAINING A-6E WST**

DESCRIPTION	SORTIES	HOURS++
NATOPS	2	3.0
Familiarization	4	6.0
Navigation	3	6.0
System Weapons	2	4.0
ECM Mission	1	1.5
Carrier Qualification	2	2.0
TOTALS	14	22.5

* Current A-6E RBN flight training program

** Estimates from training instructors and Fleet Project Team members

\+ 103.0 Total Aircraft Hours - Represents no change with the introduction of the A-6E WST.

++ Simulator Hours - Represents an increase from 11.0 to 22.5 hours with the addition of the A-6E WST.

APPENDIX B: ALTERNATIVES IN B/N TRAINING

The effectiveness and efficiency of the A-6E WST will depend on how the device is used in B/N training. As previously discussed, current RAG proposals indicate the device will only augment already existing programs. However, the capabilities of the device allow its use in a much expanded role. This role could include the substitution of current syllabus flights, or a combination of augmentation and substitution. Either of these roles would use the simulator as an integral part of the B/N training program.

The fidelity and training features of the A-6E WST leave little doubt that it could be used to substitute current syllabus flights. This is especially true of TC-4C flights, which are neither training or cost effective as compared to the A-6E WST. The following tables indicate those flights from both readiness squadrons that may be feasibly replaced by the 2F114 simulator. These particular flights lend themselves to simulation, since the flight objectives they attempt to accomplish can be performed more effectively and efficiently in a simulator. Although further reductions might be possible, it is felt by the author that doing so would negatively affect training. There should be a reluctance to reduce actual flights in some areas of B/N training, such as low level navigation with search radar terrain clearance (SRTC), and actual weapons deliveries, due to the critical nature of these missions.

The most viable use for the A-6E WST would be some combination of augmentation and substitution. Simulator design makes the A-6E WST an

especially good substitute in navigation and system weapons phases. This is particularily applicable to the TC-4C flights. The simulator could be used to augment B/N training by providing a platform to train equipment familiarization, or normal and emergency flight procedures. The device can also implement the NATOPS flight program. By logical augmentation and substitution, including the A-6E WST as an integral part in the B/N training program, more effective and efficient training can be achieved.

VA-42

SYLLABUS FLIGHT	AIRCRAFT/HOURS PER RBN	2F114 COMPATIBLE	FLIGHT OBJECTIVES
NF 1	A6/1.5		Local Area Familiarization
NN 1	A6/2.0		Visual Navigation
NN 2	TC4/1.75	X	Search Radar Introduction
NN 3	TC4/1.75	X	Computer Navigation
NN 4	TC4/1.75	X	Computer Nav/MVC
NN 5	TC4/1.75	X	Computer Nav/AVC
NN 6	TC4/1.75	X	Full System, AMTI, Malfunctions
NN 7	TC4/1.75	X	Radar Tracking, Landing Mode
NN 8	A6/2.5	X	System Navigation
NN 9	A6/2.5	X	System Navigation
NN 10	A6/2.5	X	System Navigation
NN 11	A6/2.5	X	System Navigation
NR 1	TC4/1.75	X	RTI
NR 2	TC4/1.75	X	RTI
NR 3	A6/2.5	X	Complex Breakup, RTI
NR 4	A6/2.5	X	RTI
NR 5	TC4/1.75	X	RTI
NR 6	A6/2.5	X	Medium Altitude RTI
NR 7	A6/2.5		System/Visual Low Level RTI
NR 8	A6/2.5		System/Visual Low Level RTI
NS 1	TC4/1.75	X	Target Familiarization
NS 2	A6/2.0	X	System Weapons Delivery
NS 3	A6/2.0	X	System Weapons Delivery
NS 4	A6/2.0		System Weapons Delivery
NS 5	A6/2.0	X	Mining Procedures
NS 6	A6/2.0		System Weapons Delivery
NS 7	A6/2.0		System Weapons Delivery
NS 8	A6/2.5		Conventional Weapons Strike
NS 9	A6/2.5		Low Level/Weapons Delivery
NS 10	A6/2.5		Special Weapons Strike
Visual Weapons/ Tactics	A6/7.5		
FMLP	A6/5.0		
CQ	A6/8.0		

AIRCRAFT	REDUCTION	PERCENT FLIGHTS REDUCED
A-6	23.5 of 66.0	35.6
TC-4C	17.5 of 17.5	100.0

VA-128

SYLLABUS FLIGHT	AIRCRAFT/HOURS PER RBN	2F114 COMPATIBLE	FLIGHT OBJECTIVES
NF 1	A6/2.0		Local Area Familiarization
NF 2	A6/2.0	X	Instrument/Airways Procedures
NN 1	TC4/2.0	X	Search Radar Operation
NN 2	TC4/2.0	X	Computer Steering, Navigation Modes
NN 3	TC4/2.0	X	System Navigation
NN 4	TC4/2.0	X	Radar Interpretation
NN 5	TC4/2.0	X	AMTI, Landing Mode, Radar
NN 6	TC4/2.0	X	Computer Steering, Landing Mode
NN 7	A6/3.0		Section Visual Navigation
NN 8	A6/2.5	X	System Navigation
NN 9	A6/2.5		Low Level Navigation
NN 10	TC4/2.0	X	Navigation with Malfunctions
NN 11	A6/2.5		Low Level Navigation
NN 12	TC4/2.0	X	Navigation Check Ride
NS 1	TC4/2.0	X	Attach Procedures/Switchology
NS 2	A6/2.5	X	System Weapons Delivery
NS 3	A6/2.0	X	Mining and AMTI
NS 4	A6/2.5		Low Level/AMTI
NS 5	TC4/2.0	X	Radar Bomb Scoring (RBS)
NS 6	A6/3.0		System Weapon Delivery/RBS
NS 7	A6/3.0		Low Level/Weapon Delivery
NS 8	TC4/2.0	X	RBS
NS 9	A6/3.0		Low Level/Weapon Delivery
NS 10	A6/3.0		Night Low Level/System Weapons Delivery
NS 11	A6/2.5	X	RBS
NS 12	A6/2.5	X	RTI
NS 13	TC4/2.0	X	RBS/Weapons Check Ride
Visual Weapons	A6/12.0		
Tactics	A6/6.5		
FCLP	A6/14.0		
CQ	A6/8.0		

AIRCRAFT	REDUCTION	PERCENT FLIGHTS REDUCED
A-6	14.0 of 79.0	17.7
TC-4C	24.0 of 24.0	100.0

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