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Some Current Problems in Simulator Design, Testing and Use

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This report is concerned with the general problem of the effectiveness of simulator training and reflects information developed during the conduct of aircraft simulator training research projects sponsored by the Air Force, Army, Navy, and Coast Guard. Problems are identified related to simulator design, testing and use that impact simulator training effectiveness. These problems are (1) isolation of the simulator user from the design and development process, (2) inattention to behavioral and training models during that process, (3) ignoring training considerations during simulator testing,

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(4) inadequate feedback to simulator designers concerning simulator training effectiveness, (5) inattention to techniques of simulator training that differ from techniques of aircraft training, (6) inadequate training for simulator instructors, (7) use of rate of simulator utilization as an index of its training effectiveness, and (8) inadequacies of simulator training cost effectiveness data.

PREFATORY NOTE

This paper is based upon a presentation made by the author at the 38th Military Operations Research Symposium in December, 1976. The paper is concerned with the general problem of the effectiveness of simulator training and reflects information developed during the conduct of aircraft simulator training research projects sponsored by the Army, Navy, Air Force and Coast Guard. The principal focus of the paper is the identification of problems related to simulator design, testing and use that impact simulator training effectiveness.

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SOME CURRENT PROBLEMS IN SIMULATOR DESIGN, TESTING AND USE

INTRODUCTION

It has become the policy of the Federal government to treat aircraft simulators as a major training resource. Led by examples set by commercial airlines and spurred on by the energy crisis, our military flight training agencies are relying upon modern simulators for a significant portion of the training of air crews. It is becoming increasingly difficult for even the most conservative and traditional training program manager to justify extensive use of aircraft for training when simulators are available. It is therefore imperative that our military simulators be optimally designed and used. Otherwise, our state of preparedness could suffer disastrously.

Fortunately, advancements in a number of technologies have led to the development of simulators that are very convincing representations of aircraft. It is now possible to perform in simulators many of the complex tasks required during operational missions, and tests have shown that simulators can be used effectively to develop many of the skills underlying those tasks.[1] Overall, the simulator training available with today's engineering technology can be quite effective, and in many instances its extensive use as a substitute for training in aircraft is probably well justified. The quality of most simulator training activities today is unquestionably superior to that of a decade ago.

In spite of the fact that simulators are better than ever, there are problems within the overall simulator training system that mitigate against effective simulator training. These problems are technical, conceptual, and managerial in nature, and they encompass all aspects of simulator design, testing and use. Technical problems related to simulator engineering have tended to receive the most attention, but conceptual and managerial problems require attention because they also can reduce the effectiveness of simulator training.

The purpose of this paper is to call attention to some of the conceptual and managerial problems that the writer has noted during reviews of simulator projects of the Army, Navy, Air Force and Coast Guard. Although there are important differences in the way each service conceptualizes and manages its simulator programs, there are many commonalities to those programs, and some

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[1] Caro, P.W. "Aircraft Simulators and Pilot Training," Human Factors, 1973, 15, 502-509.

of the problems described below are common to all four services. It should be noted, however, that the following discussion is not directed at a particular simulator project, simulator procurement agency, or simulator user. Instead, the discussion is an attempt to synthesize types of problems that can be found, in varying degrees, in each of the services' programs.

In order to provide a structure to the discussion, problems will be identified in relation to three phases of the life cycle of a simulator. These are the Design Phase, the Testing Phase, and the Use Phase. Two problems associated with the Design Phase will be described first.

SIMULATOR DESIGN

Isolation of the Simulator User.

Because of the many specialized and technical functions associated with simulator design and procurement, there has been a tendency for agencies responsible for these functions to be staffed with specialists who can perform them in an efficient manner. Such agencies have full responsibility for designing simulators to meet the reported or observed needs of the eventual user of the simulators. Concurrently, the eventual user is relieved of any responsibility for simulator design and procurement so that he may be about his business of training.

This separation of responsibilities between designer and user during the simulator design phase has unfortunate consequences: (1) it places all design decisions in the hands of specialists who may lack an understanding of training processes, (2) and it tends to isolate the user from the design process so that information that could be helpful to the design specialist is never called to his attention. The resulting simulators sometimes are different from what the user expected them to be when he submitted the original requirement statement.

In the absence of a strong user influence during the simulator design process, decisions can be made that compromise the future device's training potential. The user's needs are not necessarily the prime concern of the designer. The effectiveness of the agency responsible for simulator design is measured principally in terms of its adherence to budget and time constraints, not whether the simulator is useful for training. This point deserves emphasis. Simulator procurement agencies have no explicit responsibility for simulator training effectiveness. Training with simulators is the user's responsibility.

If future simulators are to be effective training tools, the user must be actively involved in the important decisions made during the simulator's design phase, not just represented by someone whose concerns may be different.

Inattention to Behavioral and Training Models.

Another problem associated with the design phase has to do with the fact that simulators are designed to simulate rather than to train. They are designed to reflect physical models rather than behavioral or training models. This fact was reflected in a comment made at a recent conference on training and simulation.[1] A participant in that conference was overheard to complain "I came here to learn about simulators, not about training."

Modern flight simulators are complex physical systems that simulate other complex physical systems, e.g., aircraft. Because of this emphasis upon physical systems, it is not surprising that they usually reflect physical rather than behavioral models. They look, feel, and sound very much like the physical creations after which they were modeled, but the relationships between the physical features of the simulators and the training for which they primarily were intended is not always apparent.

The principal physical models used by flight simulator designers are the aircraft and the flight environment. The aircraft being simulated is a design model that determines the physical size and appearance of the portions of the simulator with which the trainees interact (i.e., the trainee station) and the manner in which the controls and displays located there function. Usually this model is well defined through aircraft design and flight test data, and the dominant role of this model in simulator design is apparent.

The atmospheric, electronic and visual environments in which the design model aircraft operates are other models that play major roles in simulator design. Since these environment models are easily quantified, they are readily usable, and their precise representation in simulator design also receives a great deal of attention.

A behavioral model of the training process should be equally important in simulator design, but behavioral considerations usually receive relatively little attention from simulator designers. A training process model would describe for the designer how the simulator will be used to accomplish the

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[1]The 9th Naval Training Equipment Center/Industry Conference, Orlando, FL, March 9-11, 1976.

objectives prescribed for it, but unfortunately, a well defined model for the learning process has never been developed for simulator training. Consequently, simulator designers have been forced to ignore the training process on the assumption that faithful adherence to the aircraft and environmental models will provide an adequate setting for an instructor to conduct training in a simulator much as he would in an aircraft.

During the past decade, the adequacy of the in-flight or aircraft training process model for simulator training has been challenged, and suggestions have been made that a more appropriate training process model would take advantage of the simulator as a learning environment not subject to some of the limitations or negative learning features of the aircraft. While such a concept has merit, a suitable training process model based on the concept has not yet been defined and articulated for use by simulator design engineers.

Because of the inadequacy of the existing simulator design models related to the training process, the simulator designer designs new simulators that are very much like the last ones he designed, or at least he looks to an existing simulator's instructor station and instructional features as a model for comparable portions of his new design. Thus, many of today's simulators are being designed very much like those of decades ago, largely because no other relevant design models are available.

SIMULATOR TESTING

Simulator Tests Ignore Training Suitability.

Now let us turn to the Testing Phase of the Simulator life cycle. Here again, there are two problems that warrant attention. The first problem involves the device's initial testing, a process that occurs at the completion of the simulator development process. Emphasis in these tests is two-fold; first, upon the simulator's conformity to design hardware specifications, and second, upon simulator reliability and maintainability. These two areas of consideration are important, of course, but where in this testing process is it determined that the device is appropriate to the training requirement? If a military service buys an aircraft, a missile, a ship or a tank, it conducts extensive tests to determine the equipment's suitability to perform a military mission. How often does one hear of a mission suitability test for a simulator that emphasizes mission accomplishment (i.e., training) over hardware factors?

It should be apparent that the testing that must take place to determine the acceptability of a simulator must attend primarily to the extent to which the device is suitably designed and constructed with respect to training functions and processes. It should be emphasized that training functions are the primary considerations in device testing. Whether the device conforms to hardware and performance specifications, or is reliable and maintainable, are secondary considerations. If it is not useful for training, the other considerations are of no concern.

Obviously, these secondary considerations must receive attention, and no one would advocate procuring simulators that are unreliable. The concern is not whether engineering tests should be conducted during acceptance testing; rather, the concern is that most present day simulators have been accepted without regard to their suitability for training, obviously on the assumption that the user will solve any problems that may arise during training. Unfortunately, some of the simulators that have been accepted in the past were so poorly suited to training needs that they literally could not be used. The user's solution in many cases has been either to initiate requirements for major modification to the devices, or to ignore them altogether.

Poor Feedback to Simulator Designer.

A second problem associated with the simulator Testing Phase relates to information that is obtained concerning the training mission suitability of simulators, either as a part of an extended acceptance or operational testing process, or as a result of use of the device following its acceptance. While the designer often is involved in the conduct of acceptance testing activities related to matters of engineering concern, he is not often involved in activities related to determining the device's suitability for training, if indeed there are any such activities during the Testing Phase. He should be, of course, if he is to benefit from any information gained. Feedback to the designer about the adequacy of his design for training is essential.

This problem relates to another of the problems mentioned earlier -- division of responsibility between the simulator designer and user. Not only is there a need to keep the user in the design process, there is a need to keep the designer aware of the user's activities with the device after it has been put to use. Seldom do simulator designers have an opportunity to observe simulator training except on a very casual basis while touring training facilities. They have little opportunity to learn of deficiencies in existing simulators that limit their training value, and they have even less opportunity to interact with simulator instructors to suggest alternate ways of using existing simulators or to discuss alternate simulator design concepts that might improve future training. Simulator designers' limited budgets sometimes permit them to visit government laboratories and manufacturers' facilities, and occasionally to attend professional and technical meetings. But they seldom have money left over to support extended interaction with simulator users or observation of or participation in simulator training activities. Future simulator designs would benefit if the designers were given more feedback about the training suitability of existing simulators and were encouraged to consider innovative simulator design approaches to training problems with which they have become familiar.

SIMULATOR USE

Inattention to Techniques of Simulator Training.

The final group of problems to be discussed are those that occur during the Use Phase, the period during which the simulator is used to train personnel operationally. While there undoubtedly are many problems associated with the use of simulators, four are of particular concern. The first has to do with the fact that no one really knows much about how to train in simulators. Very little attention has been devoted to the development of a technology of simulator training.

How do we train in simulators? In the case of aircraft simulators, we train in simulators pretty much like we train in aircraft. In many respects, that probably works out reasonably well, but one cannot but wonder if there might not be a better way. It was noted earlier that good models of the simulator instructional process have not been developed. The aircraft is a very poor learning environment, and the flight instructor must function primarily as a safety pilot. In-flight instruction is constrained by aircraft fuel capacity, the availability of navigation aids and gunnery ranges, and a host of safety restrictions that make tactics training quite unrealistic in some instances. Although simulator training can be freed of each of these restrictions, little effort is being devoted to the development of training profiles and techniques optimized for training in simulators -- with many of the safety and time restrictions necessary in the aircraft inappropriately carried into the simulator as well.

It would be inappropriate to criticize simulator instructors for their less than optimum uses of simulators. They are doing exactly what they have been told to do -- conducting flight training in simulators. If they are to do otherwise, techniques of instruction more appropriate for simulators must be developed for their use.

Inadequate Training for Simulator Instructors.

The second problem associated with the use of simulators is related to the first. Even with our present limited understanding of how to use simulators, the training provided simulator instructors is inadequate. Simulator instructor training varies from program to program, but seldom can one find a simulator instructor training program that could be considered exemplary. The training provided simulator instructors varies from a "checkout" on the instructor's console during which the location and function of switches and other controls are demonstrated and questions are answered by an already qualified instructor, to a more lengthy "practice teaching" program in which a newly selected instructor may spend a week or more observing simulator training and actually conducting training under the supervision and with the assistance of a qualified instructor. In addition, since simulator instructor trainees are usually flight qualified and often instruct in aircraft as well as in the simulator, instructor training typically includes an extended effort to raise their proficiency and to standardize their performance in the aircraft itself, and in some instances, such training includes instruction in the techniques of flight training, lesson planning, and preparation of instructional material. The principal deficiency of these courses, however, is that they do little to provide the instructor the specialized knowledge and techniques that will allow him to employ the simulator effectively and efficiently as a training vehicle that has unique capabilities different from those of the aircraft.

In a recent survey of simulator training, frequent instances were found in which instructors did not know how or when to use advanced simulator training features such as adaptive training, performance playback, and automatic performance monitoring.[1] It is indeed rare to find a simulator instructor who has been taught to use instructional techniques such as discovery learning, to shape and reinforce desired behaviors, or to employ individualized proficiency

[1] Isley, R.N., and Miller, E.J. The Role of Automated Training in Future Army Flight Simulators. Final Report FR-ED-76-27. Human Resources Research Organization, Alexandria, VA, October 1976.

advancement as a training process management tool.

Documents available to simulator instructors related to the use of simulators as instructional tools provide very little how-to-train guidance. Typically, these manuals, handbooks and course outlines indicate the tasks to be performed by the trainee during a simulator mission, but they contain little or no information as to how training is to be accomplished, how student performance will be graded, and what performance criteria apply to the trainees, given their particular skill and experience levels.

Emphasis Upon Rate of Simulator Utilization.

A third problem associated with the use of simulators is strictly a managerial problem, although its effects are to reduce simulator training effectiveness. The problem is simply that simulator training typically is evaluated in terms of rate of device utilization, rather than in terms of training benefits or trainee performance increments.

Emphasis in many pilot training organizations at the present time is upon achieving high rates of simulator utilization, and quotas, such as 80 hours per week per cockpit, are being assigned to training units on an apparently arbitrary basis. While the reasons for such an approach may be laudable, the consequences are often undesirable. One such consequence is an inflated estimate of the need for simulator training. More importantly, however, the requirement that a simulator be used for a specified number of hours per week increases the likelihood that at least some simulator training will be ineffective. Since such a requirement is essentially unrelated to training needs or to number of personnel to be trained, keeping the simulator busy sometimes involves repeating training missions or exercises that already have been mastered. At one location recently visited by the writer where a fixed rate of simulator utilization was a requirement, time recorded as simulator training time was not always being spent in the device, and pilots of junior ranks were required to use up the excess simulator time although they were already proficient at tasks that could be practiced in the device. The negative effects of such a requirement upon attitudes toward simulator training are predictable.

Inadequate Simulator Cost Effectiveness Data.

The fourth problem also concerns management practices. It is simply that no one knows the extent to which particular simulator training programs may be cost effective. There are two reasons for this. First, cost accounting procedures commonly employed by the military services make it difficult to identify all relevant costs and to attribute them differentially to simulator versus aircraft training. While some of the costs of operating and maintaining simulators can be compared with similar costs associated with aircraft, the full cost of each kind of training is seldom known. Most training managers would be surprised at just how inexpensive simulator training is, compared to aircraft training, if the cost data available to them included the full costs of factors such as constructing and maintaining airfields, gunnery ranges, and navigational facilities used for no purpose other than training. Further, it is doubtful that most planners and managers know how little is saved when a large number of hours of aircraft training is shifted to simulators while all these expensive training facilities must continue to be maintained and used for the few hours which continue to be flown in aircraft. It seems safe to say that the military training cost models presently employed do not provide all of the information needed to make the best decisions about using simulators.

The second reason we do not know about the cost-effectiveness of simulator training relates to the effectiveness question. The effectiveness of almost all military simulator training programs is being assumed, and, in many cases, these assumptions may be in error by significant amounts. There has been virtually a total absence of controlled tests designed to validate military simulator training programs. In the absence of such tests, simulator training usually has been substituted for aircraft training on an overkill basis. That is, training managers have substituted simulator training for aircraft training on a ratio that typically exceeds parity, thus quite likely inflating simulator training needs and costs. The consequences of excessive simulator training may be better training overall, of course, but without validating tests, we really do not know whether the ratios are adequate or excessive.

CONCLUDING COMMENT

The eight problems described in this report suggest that military simulator training systems may not be as healthy as one would wish. At least some of these problems are possibly related to the fact that simulator training is seldom viewed as a system that encompasses, but is by no means restricted to, simulator design, testing and use. Simulator training is itself part of a much larger training system that includes training in operational vehicles and classrooms and training with supporting resources such as airfields, target ranges, and maneuver areas. As long as we treat these and other system elements as independent, with responsibilities fractionated, simulator training will continue to be beset with problems of importance equal to or greater than those identified here.