THE POTENTIAL USE OF ENGINEERING SIMULATORS TO PROMOTE TRAINING ECONOMY

MR. JOHN C. DUSTERBERRY

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California 94035

INTRODUCTION

Training simulators are used as part of a total training course. This training course includes conventional classroom work, programmed instruction, part task trainers, and training in the production aircraft or other vehicle. The total training course must be cost effective, and, in addition to the direct cost of the training, there must be included a consideration of other factors more difficult to quantify: safety, fuel availability, noise, atmospheric pollution, etc. The total training program must be effective and economical, and a choice must be made among the various training devices to achieve overall effectiveness and economy. On the other hand, engineering simulators are used differently, so a different set of criteria apply to their requirements, specifications and design. Analysis and wind tunnel testing precede engineering simulations. Since extention of the analysis to the man-machine interface has proved to be largely unsatisfactory, experiments on the manned flight simulator follow. The alternative to simulator experiments is flight time in an experimental aircraft or proof-of-concept vehicle--a very expensive vehicle to build and operate. Indeed, even if a proof-of-concept aircraft is to be built, engineering simulator tests will be required to make it safe and economical. To insure that engineering simulators will have a reasonable useful lifetime, they must be designed to allow simulation of aircraft with systems and controls not yet built or even contemplated, and indeed, to simulate hardware that may never be built. Thus, training and engineering simulators are built to satisfy different requirements. They cannot be compared to each other, but each must be judged on its economy and effectiveness in meeting the requirements it was designed to meet.

THE TRAINING SIMULATOR AND ITS ENVIRONMENT

Training simulators and the environment in which they are used impose stringent requirements on their design and specification. Each simulator represents a single aircraft, and the computer programming and the mathematical model can be regarded as essentially fixed. Great progress has been made in recent years by the use of general purpose digital computers, but the flexibility of these computers has been largely required by and used to retrofit simulators to later models of the same aircraft. Maintenance personnel are highly trained, but since they have not participated in specification or design decisions they may be handicapped by a lack of knowledge of ways to achieve possible equipment improvements. The amount of operating time is a most important measure of the simulator success since a simulator not available for a scheduled training session sends waves of distress which propagate throughout the entire training program. The modern military weapons system trainer requires a simulation not just of the airplane or other vehicle, but of a wide range of ordnance and electronics equipment, often operated by multi-manned crews. Simulators such as these represent the most complex training devices ever built.

THE ENGINEERING SIMULATOR AND ITS ENVIRONMENT

The uses of engineering simulators impose a different set of requirements and lead designers of these simulators along different paths. Since the alternative to using an engineering simulator is often the construction of a series of experimental aircraft, more money can be justified in the fabrication of a given simulator. Such simulators are generally one of a kind. Indeed, many proposed engineering simulators are specified for a combination of aircraft type and mission that cannot be handled by any existing engineering simulator.

Many engineering simulator visual and motion systems exceed in size and performance those that have been built for training (1), (2), (3). However, this additional performance can be justified by the attaining of more faithful cues to the pilot leading to an aircraft that is neither excessively expensive, nor unnecessarily limited in performance.

The necessity for aerodynamic parameter variation on a run-to-run basis imposes, for the same mission or mathematical model complexity, more stringent requirements on the engineering simulator computer. So does the necessity of accumulating data on aircraft performance as well as pilot performance. Since the engineering simulator is generally designed to be used for a variety of vehicles and missions, programming time and the cost of programming become most important over the lifetime of the simulator. As a result, the computer-cost/programming-cost trade-off is tilted toward spending more money for a more powerful computer.

Engineering simulators are used in a range of experiments from the early investigation of concepts to the flight test support of an experimental aircraft (4). In the early investigation of concepts, the simulator becomes what Cooper calls "the pilot's tool" (5). The simulated aircraft is usually a very rudimentary model, and an essential requirement for such tests is the use of an engineering test pilot, formally trained in aerodynamics and experienced in flying a variety of aircraft. His ability to aid in experiment design, to disregard the inadequacies of those parts of the simulation which do not bear on the crux of the experiment, to analyze aircraft systems that are essential to the decision, and to communicate this largely subjective analysis to the experimenter is essential and rewarding to the aircraft and simulator engineers and scientists.

Another important advantage in the engineering simulator environment is the ready availability of the simulation system and sub-system specifiers and designers. These personnel have a high motivation to meet not only the original requirements of their design, but to see that the simulator hardware and software continue to operate successfully. This motivation for their equipment to show continued successful performance, combined with an intimate knowledge of the equipment from the drawing board stage, provides a back-up trouble shooting crew of professionals that is indispensible to any engineering simulator laboratory. It provides the talent necessary to make expeditious and economical alterations to meet new and unforeseen requirements by making alterations or additions to existing simulation equipment.

For many years, engineering simulation laboratories have utilized the developments of the manufacturers of simulation equipment, many of which were stimulated by the requirements of their military customers. Many of the laboratories which use motion simulators have at least one training simulator motion system. The feasibility of visual simulation systems for the straight-in approach and landing of conventional aircraft has been demonstrated by developments intended to meet a military requirement. Many engineering laboratories use one of these commercially available systems. The laboratories which have built their own visual systems have done so stimulated by the feasibility demonstrated by the systems built for military and commercial users. The use of general purpose digital computers as the simulator computer was first studied and demonstrated in a military training study project.* Much of the instrumentation, cockpit hardware, control loading devices and other simulator sub-systems used in engineering simulation laboratories traces its origin to the training simulator.

The capabilities of engineering simulation laboratories are limited not by the imagination of those who set the requirements for them, but by real-world considerations of costs, of the state-of-the-art, and of the compatibility of requirements. The time required to design and build a major piece of simulation equipment can be a substantial percentage of the time required to design and build a new aircraft or weapons system. Therefore, the completed simulation system will be used on unforeseen projects in unforeseen ways, especially in the early studies of new concepts. For example, visual simulation systems designed for the straight-in approach and landing of conventional aircraft have been used in engineering simulations of surface effect vehicles (6), and for the simulation of aircraft forward-looking infrared equipment (7).

AN ADDITIONAL POTENTIAL FOR ENGINEERING SIMULATORS

The training simulator is an essentially fixed assembly of hardware that represents one aircraft and its mission. The engineering simulator is not really a simulator at all. It is part of a laboratory consisting of a collection of simulation apparatus composed of one or more motion systems, visual systems, instruments, pilot control devices, including control loaders, computers and interfacing and interconnecting equipment. Although these laboratories are designed so that one can conveniently change from the simulation of one airplane to that of another in a short time, the preparation period of a new simulation can stretch into weeks or months. After the airplane is chosen and the experiment designed, the airplane must be analyzed and a computer program written. Simulation hardware and computer software may be inadequate for a new project, and required changes to this hardware and software must be designed, executed, and checked out. The cockpit hardware of the new configuration will have to be designed and built. The time period spent in the assembly and check-out of a training simulator is short compared to the useful life of the simulator. The scales are tipped the other way when the assembly of engineering simulation apparatus is put together for an experiment. The period spent programming the computer, putting together the apparatus, and checking it out is

---

* A contract was awarded by Naval Training Device Center in 1950 to the Moore School of Electrical Engineering, Univ. of Pennsylvania for such a study.

greater than the time period of piloted runs. The ratio of the make-ready time to piloted operation time can easily exceed ten to one, so the doubling of the period of piloted simulation does not double the resources expended on a simulation; it may require only about a ten percent increase in resources to double the amount of piloted time on a given engineering simulation.

The results of this expenditure of resources required by the aircraft program is usually seen only by the user who is interested in the development of the aircraft itself. Training personnel, both those involved in the design of training courses and those involved in the specification and design of training simulators, seldom see or become involved in these simulations. In many cases, these simulations represent an opportunity for the earliest look at the vehicle or weapons system, and very often represent the most difficult pilot control and training task to be encountered in the vehicle. Despite the limitations of some of these, it is incumbent on those of us in the engineering simulator community to bring them to the attention of the training simulator community on a case-by-case basis and to encourage their utilization. Programs which test training effectiveness and simulation hardware feasibility can often be conducted at little additional cost, utilizing the already paid-for analysis, programming, hardware modifications, and check-out that were required for the aircraft development program.

The use of engineering simulators for training research is not new. They have been successfully used in this manner before. My proposal, rather, is for the engineering simulator community to be alert to point out to the training community when opportunities arise for particularly economic use of these simulators; when the checked-out simulation of a future aircraft will be available for use.

Two types of participation suggest themselves. The first type is cooperative or informal participation with the aircraft development personnel. Such participation would result in largely subjective opinions. However, this method offers the prospect of participants obtaining the insight necessary to design experiments which will later give objective, quantitative results. The same insight may also prove useful when requirement and specification decisions must be made in the absence of quantitative data. The second type of participation is the formal experiment or experimental program. After the completion of the aircraft development experiments, training personnel could use the simulator to conduct formal experiments to determine the amount and kind of training that should be conducted on the training simulator and its economic balance with other training aids. This could include parametric variations in simulator characteristics, as opposed to the variations in the aircraft characteristics required by the aircraft development experiments.

Such participation will require the active cooperation of aircraft development personnel. Since many of their simulations are conducted to obtain data to make design trade-off decisions, the simulated aircraft will not always have the desirable combination of characteristics that the final configuration will have. Training system personnel must have an understanding of the tentative state of the aircraft design, and they must communicate this understanding to aircraft development personnel. This understanding will be necessary for the two groups to attain economically their common goal--an effective weapons system manned by trained crews.

CONCLUSIONS

I believe there are two ways in which training economy will be promoted by the use of engineering simulators in training system design. First, I believe there is an underutilized resource, the simulator set-up time, that can be readily utilized. Secondly, I believe that experiments will show that some of the seemingly crude cue-producing equipment will unexpectedly prove to be adequate and economic for the training simulator.

I believe the use of engineering simulators in the manner I have described represents an opportunity for the engineering simulator community to repay to the training simulator community the debt we have incurred by the use of their developments. I believe the responsibility for pointing out to training people the availability of engineering simulations of future aircraft belongs to the engineering simulator community. I ask the training simulator community, if they are interested, to help us discharge this responsibility by reminding us when we forget, by expressing interest so we will know the proper avenues of approach, and by expressing their interest to the military aircraft or weapons system project people.

REFERENCES

1. Zucarro, Joseph J., "The Flight Simulator for Advanced Aircraft - A New Research Tool." Presented at AIAA Visual and Motion Simulation Technology Conference, Cape Canaveral, Florida, March 16-18, 1970, AIAA Paper No. 70-359.

2. Ashworth, B. R., and W. M. Kahlbaum, Jr., "Description and Performance of the Langley Differential Maneuvering Simulator," NASA-TN-D-7304, June 1973.

3. Hass, R. L., H. E. Hotz, and G. R. Mills, "The Large Amplitude Multi-Mode Aerospace Research Simulator," Presented at AIAA Visual and Motion Simulation Conference, Ames Research Center, Moffett Field, California, September 10-12, 1973, AIAA Paper No. 73-922.

4. Quigley, Hervey C., and Curt A. Holzhauser, "Requirement for Simulation in V/STOL Research Aircraft Programs," Presented at AGARD Fluid Dynamics Panel Symposium on V/STOL Aerodynamics, Delft, Netherlands, April 24-26, 1974, Paper No. 25.

5. Cooper, George E., and Fred J. Drinkwater, III, "The Pilot Assessment Aspects of Simulation," Presented at AGARD Flight Mechanics Panel Specialists' Symposium, Ames Research Center, Moffett Field, California, March 10-13, 1971, AGARD Conference Proceedings No. 79, AGARD-CP-79-70, pp. 9-1 thru 9-16.

6. "Final Technical Report, Arctic SEV Program," Boeing Aerospace Co. Doc. No. D-180-15356-1, April 1973 (Work done for Naval Ship Development Center).

7. "Synthesis, Analysis and Evaluation of Avionics Concepts, Task I, Close Air Support," Vought Aeronautics Co. Doc. No. TR2-50110/3R-3042 (Work done for Air Force Avionics Laboratory under Contract F33615-72-C-1454).

ABOUT THE AUTHOR

MR. JOHN C. DUSTERBERRY has been with NASA Ames Research Center since 1943. Starting as an electrical engineer, Mr. Dusterberry specialized in aerospace research and development experimental facilities and is currently Assistant Chief of Simulation Sciences Division specializing in facilities for aerospace research and development simulation. His technical papers include "Multi-Purpose Laboratory for Flight Simulation", ASME 63-ASGT-87; "Manned Flight Simulation Facilities", AGARD-O-Graph 99; and "The Simulator to Match the Transports to Come", Astronautics & Aeronautics, September 1969. Mr. Dusterberry is a member of AIAA, IEEE, SID, and AAAS.