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HUMAN RESOURCES

PROCEEDINGS OF THE SIMULATOR EFFECTIVENESS RESEARCH PLANNING MEETING

Edited by

Edward E. Eddowes

FLYING TRAINING DIVISION
Williams Air Force Base, Arizona 85224

December 1977
Final Report for Period 21 – 22 April 1976

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LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

This final report was submitted by Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224, under project 1123, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235.

This technical report has been reviewed and is approved for publication.

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Flying Training Division

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Commander

Unclassified

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

The proceedings of a Simulator Effectiveness Research Planning Meeting held at the Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona on 21–22 April 1976 are reported. The objective of the meeting was to identify simulator training requirements and to determine the availability of research facilities and personnel to use in studies of the training effectiveness of simulator motion and visual systems. The meeting consisted of two sessions. During the first session attendees were divided into four groups which studied: (a) capabilities and characteristics of simulators; (b) simulator requirements for flying training; (c) measurement of simulator training effectiveness; and (d) management and utilization of simulators. During the second session the findings of the study groups were summarized and discussed in a general meeting of all attendees.

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PROCEEDINGS OF THE SIMULATOR EFFECTIVENESS RESEARCH PLANNING MEETING

I. INTRODUCTION

The Flying Training Division of the Air Force Human Resources Laboratory (AFHRL/FT) was tasked to develop and conduct a research program designed to generate a description of the training effectiveness of flight simulator motion and visual systems. A working meeting was held at Williams Air Force Base, Arizona, on the 21st and 22nd of April, 1976 with the objective of identifying simulator training requirements and determining the availability of research facilities and personnel for use in studies of the training effectiveness of simulator motion and visual systems. This report documents the proceedings of the meeting. A list of attendees is presented in Appendix A.

Colonel J. D. Boren, Chief, AFHRL/FT, opened the meeting and welcomed the participants to the research planning sessions. Dr. E. E. Eddowes, AFHRL/FT, completed the opening session with a review of the organization of the two-day meeting. He underscored the meeting's objective and emphasized the opportunity the meeting provided to assist in the development of the research program needed to achieve the objective.

Following the opening session of the meeting, the participants divided into four groups to discuss various aspects of simulator training effectiveness research planning. The results of these discussions are reported in the following section of this report. The agenda is presented in Appendix B.

II. REPORT OF GROUP DISCUSSIONS

Study Group 1 Discussion
TOPIC: Capabilities and Characteristics of Simulators

The group expressed diverse points of view about many facets of the research discussion questions. Subsequent discussion focused on an attempt to better define an approach and agree on an objective for the discussion that was manageable.

The objectives selected were: (a) Identify available devices which should be considered for use in a future experimental program, and (b) identify simulator motion and visual system characteristics or independent variables that must be considered in any future experimental program.

Simulator Categories: The first step toward the initial objective was to categorize simulators according to the mission characteristics of the aircraft simulated. Two categories were selected: Cargo/bomber and fighter/trainer. Since the original issue to be addressed was motion, later changed to motion and vision since the two are virtually inseparable, the group looked first at simulators with appropriate motion systems. A need was recognized to ascertain the general characteristics of the motion system and other information such as availability, research support capability, and the type of visual system.

Eleven simulators or sets of simulators were identified for use on cargo/bomber motion/vision research as follows: (a) Facilities of two airlines and an aircraft manufacturer's training simulators, (b) Four engineering simulators, (c) Simulator manufacturing developmental system, and (d) Three operational training simulators. Eight simulators were identified for use on fighter/trainer motion/vision research as follows: (a) Four engineering simulators, (b) One training research simulator; and (c) Three operational simulators. (It should be noted that all but one of the simulators identified are equipped with a visual system.)

Selection criteria were established which led to consideration of the higher capability systems (5- or 6-degree-of-freedom motion rather than 2- or 3-degree-of-freedom motion systems). Thus, for near-term experimental efforts, the most capable simulators available should be used.

Motion Cueing Systems: The next step was to consider other motion simulation devices (G-seats, G-suits, buffet, display timing and sound). An attempt was made to identify other systems with these cue-generation capabilities.

The following devices other than training or engineering simulators were considered (lab-type systems): (a) Aerospace Medical Research Laboratory (AMRL) System (rotational arc tracking system) which includes motion/visual delays and various rotation drive algorithms, and (b) Grumman Lab System which includes the capabilities for studying acceleration thresholds and washout profiles or signatures. There were also discussions of study efforts such as are being accomplished at Massachusetts Institute of Technology (MIT) directed toward modeling human motion sensory mechanisms including the vestibular, proprioceptive, tactile and visually induced motion cues.

Summary of Group 1 Discussion: There is some information already (a) available on motion/visual system effectiveness. A first step should be to identify what is already known before another experimental effort is undertaken. (b) The impression that the experimental approach is not the final answer to the research questions was expressed. (c) There are a body of knowledge and a number of simulator motion experts available to provide information to be applied in developing short-term answers on the effectiveness of simulator motion systems. (d) Analysis of the cues displayed used by pilots in simulators may provide the key to being able to extrapolate forward to define future simulator requirements. Validation could then be provided through experimental evaluation with the experiments using existing devices. (e) Of the devices identified for fighter/trainer motion research, concern was expressed for ones which have known or suspected deficiencies, such as excessive time delays in the motion drive system. The feeling was that these kinds of deficiencies should be corrected as soon as possible. Although the Advanced Simulator for Pilot Training (ASPT) is considered adequate for research involving T-37 flight performance envelopes, for work on the motion requirement for simulators of higher performance aircraft such as the F-16 it should be improved particularly in the area of motion algorithms and computation iteration rates. (f) One recommendation was that research should be focused in the visual area to develop ways that visual systems can substitute for motion; for example, wider field of view (FOV) to foster visually induced motion. Consideration of the cost aspects of visual systems led to expectations that computer image generated (CIG) systems should get cheaper within the next 10 years, whereas motion platform system costs are likely to increase. (g) The final major point of discussion focused on where we are in the development of simulator motion systems. A question was raised about the validity of the results of some of the recent studies using ASPT which show no significant differences in transfer of training to the aircraft for students trained with or without platform motion.

Study Group 2 Discussion
TOPIC: Simulator Requirements for Flying Training

Command representatives were present from Air Defense Command (ADCOM), Air Training Command (ATC), Strategic Air Command (SAC), and Tactical Air Command (TAC). An orientation briefing was given which presented the objectives of the working group. In order to provide an adequate definition of simulator subsystem requirements, each command representative was requested to address the following questions: (a) Type of aircraft (fighter, trainer, bomber, transport, etc.); (b) Key missions (air-to-air, air-to-surface, instruments, navigation, etc.); (c) Projected simulator uses (initial training, proficiency maintenance, simulator flight-checks, etc.); (d) Experience level (novice pilots, UPT graduates, high-time, etc.); (e) Projected needs in the areas of visual and motion simulation; (f) Data required to influence decisions on the procurement of simulator subsystems–especially motion (e.g., transfer of training from simulator to aircraft, performance in the simulator, pilot acceptance, motion discrimination, etc.); and (g) Priorities (definition of critical task areas; selection of data points to maximize information, etc.). The planning effort to determine the incremental training effectiveness of platform motion was used as an example. Following the introductory session, the simulator requirements for ADCOM, ATC, SAC, and TAC were identified and discussed.

Summary of Group 2 Discussion: The following points of agreement and areas of concern seemed to emerge during the discussion: (a) Data are required in order to assess the effectiveness of platform motion, It was agreed that transfer of training data are required, (b) It was agreed that the maneuvers selected for motion research should exercise the motion system to as great an extent as possible (Because of their relatively higher motion cue requirements, aerobatic, or combat-type maneuvers, were suggested as more suitable for research on the training effectiveness of simulator motion than basic aircraft control training maneuvers.), (c) Concern was expressed over the need for motion cues for training emergency reactions in which there exists no safe way of assessing transfer to the aircraft, (d) Controversy was apparent in the extent to which simulator cues are necessary for experienced as opposed to novice pilots, (e) It was agreed that a need exists to assess the saliency of motion cues for various flight maneuvers–both subjective and objective methods were suggested, and (f) The question of generalizing study results from one motion system to another, as well as from one aircraft to another, was raised and is seen as a serious problem. Throughout the session, it was readily apparent that the role of motion cueing (in flight simulation training) is largely unknown and should be addressed in future research programs.

Study Group 3 Discussion
TOPIC: Measurement of Simulator Training Effectiveness

Group 3 addressed research methodologies which can be employed in the study of simulator training effectiveness. With the emphasis on the contribution of motion platforms to training effectiveness, three types of experimental designs were identified: motion discrimination comparisons, in-simulator performance studies, and training effectiveness research.

Simple Motion Discrimination Comparisons. Two types of "evaluations" of motion systems have come from the comparison of motion cues generated by the simulator. In the first, the pilot flies the simulator with the motion platform on and with it off, and then is asked if he perceived any difference in the sensation of motion. Normally, the pilot is not told beforehand that he is going to be asked about motion, since it seems that if he knows the question, he can deliberately twitch the control stick and detect the simulator's configuration from the resulting jarring (or lack of it). Informal demonstrations of this type of comparison on simulators with wide angle visual systems are often dramatic, with the pilot convinced that the simulator was moving when in fact it was not.

The second type of comparison involves the experienced pilot comparing the motion cueing of the simulator with the aircraft motion he has known as a pilot. The result of the comparison is a judgement about the fidelity of the motion cues. Currently, such comparisons are numerous as more and more representatives of operational commands and high level staff agencies visit simulator facilities to learn more about available simulation hardware and make decisions about upcoming procurements.

In both of these cases, the results of the comparison is some statement about the sensation of motion or fidelity of motion cues generated by the motion system. While it is important to know what types of cues the simulator generates, just how these cues relate to training effectiveness is less than clear. Fidelity is not always directly proportional to training effectiveness. Many skills can be trained and maintained at a desired level of proficiency with a low fidelity training device.

The hazard in the simple motion comparisons is their intuitive, instant compatibility with the observer's desire to form his opinions about motion cueing systems. Evaluations are formed quickly and convincingly. Unfortunately, such evaluations often have little to do with the training device's ability to train.

In-Simulator Performance Studies. In this type of design, the performance of the pilot flying the simulator is used as the indicator of the effectiveness of a training phase using a given simulator configuration. Performance in the aircraft is not observed, thus transfer of training data are not generated. The assumption is that performance in the simulator approximates the performance which would be observed if the pilot were going to fly the aircraft and therefore is acceptable for use in making transfer of training comparisons. This type of design is suited to flying tasks which cannot be flown in the aircraft during training (certain critical emergencies, for example), and there are data which indicate that a pilot's simulator performance is significantly and highly related to his subsequent performance in the aircraft. However, where transfer of training data can be collected, this design is less powerful than a direct test of training effectiveness.

Training Effectiveness Designs (Transfer of Training). As the simulator is a training device and its ultimate effectiveness (and the effectiveness of various components) is evaluated in the ability of the pilot to fly his airplane after simulator training, the most powerful experimental design for studying motion is the transfer of training design. While it has been pointed out that traditionally this is a more costly design, in some training programs, where efficient performance measurement techniques are used, the cost is justified by the quality and the applicability of the data obtained.

Given these three types of research approaches to training effectiveness, short- and long-term objectives for research were identified:

1. *Short-Term Objective.* The short-term objective is to create an information base for making procurement decisions in the near future. Since procurement decisions must be made regardless of the information available, the goal of the initial motion research is to supply useful information as rapidly as possible. This approach impacts the types and levels of independent and dependent variables selected for each study as well as the sample size. For example, the motion variable which has been used by AFHRL/FT on initial studies has compared training under no platform motion versus training under six-degree-of-freedom synergistic platform motion. If no difference in transfer is found under these extremes of the

motion variable, then the experimenter has the option of refining the motion results; for example, comparing no motion with three degree and with six degree of freedom platform motion, or manipulating completely different variables. In such studies, the concept of "stacking the deck for motion" prevails; i.e., the selection of variables and tasks in such a way that motion has the greatest probability of improving training, so that if no differential effect of motion is observed, then the researcher will have a high level of confidence that over all tasks and variables, there is no difference. This type of research strategy, based on the selection of critical variables and tasks, yields the maximum amount of information per unit of effort and expense.

2. *Long-Term Objectives.* Long-term research will continue to investigate new motion systems, recognizing that, in all probability, the "motion question" has neither a simple nor a single answer. Due to expected state-of-the-art advances and hardware and software improvements, engineering descriptions of experimental apparatus (software packages as well as hardware configurations) must be documented to permit comparisons of study results longitudinally.

Two additional areas which were addressed by Group 3:

Generalization. Regarding the problem of generalizing results across pieces of hardware, e.g., generalizing the results of a study conducted on ASPT to a newer about-to-be-procured simulator, Group 3 participants tended to see generalization as a nonproblem. Simply put, in the absence of better data, management decisions should be based on data that are available. The argument that results cannot be generalized because of differences in hardware or software is circular since each new device will differ in some characteristic from its predecessor.

Data. In all studies, it is essential that not only the amount of any differences between experimental groups be determined, but also *how long* such differences last during subsequent training or flying. For example, in a study assessing the contribution of a motion platform to undergraduate pilot training or transition training of an experienced pilot, a small advantage for pilots trained with motion might be seen on the first aircraft ride after training, evidence in support of motion procurement. However, if two rides later, no difference can be detected between pilots trained without motion and those trained with motion, the case for motion procurement is considerably weakened. The type of data generated by the upcoming series of short-term studies must be designed to give the decision-maker the maximum number of alternatives in his selection of investment strategies.

Study Group 4 Discussion
TOPIC: Management of Procurement and Utilization of Simulators

The discussion of the group which studied the management of procurement and utilization of simulators for flying training focused on simulator concepts of utilization, configuration, costs and certification. While these discussion topics did not emerge distinctly, completely, or in this sequence, they are presented as though they did to help organize and simplify this report.

Concepts of Simulator Utilization. The most obvious concept of the use of flight simulators in flying training is as a substitute for training in the aircraft. This concept leads directly to the notion of the simulator's being equivalent to the aircraft. However, simulator users inevitably discover that the simulator is not equivalent and cannot be substituted for the aircraft. The result is the frequently encountered nonacceptance of flight simulators by pilots and the continuing efforts of simulator engineers to design more realistic simulators.

This conceptual state of affairs, if it has been portrayed adequately, can be seen as an impetus for the development of increasingly more capable, more complex and more costly flight simulators.

The group generated the following observations with respect to the current state of concepts of simulator utilization:

1. Instructors and student pilots will come to accept simulators that work.

2. Instructors can "train around" typical simulator limitations by taking advantage of the strengths.

3. What training managers do with their simulators is more important than any specific properties of the equipment.

Simulator Configuration. A major problem in specifying the requirements for the configuration of any simulator is determining what the device is supposed to do, that is, how and where it fits within a flying training program. Very often operators generate requirements based on the kinds of equipment currently available. Frequently, the requirements describe a full-mission, high-fidelity trainer with all the latest simulation features, such as six-degree-of-freedom platform motion, G-seat, G-suit, large field of view visual display and a number of instructional aids. Such requirements are typically supported by the "conservative" notion that it is better to specify a more capable than a less capable simulator, because the added capability would cost more and take longer to obtain if it were added later during the procurement process.

In discussing this kind of problem related to determining simulator configuration requirements, the following observations were made:

1. Improved analyses of flying training requirements are needed to substantiate the design of simulators so the configurations selected are based on the demonstrated training effectiveness of simulator capabilities rather than the conservative approach noted above, or the relatively vague appeal that maximum capability generates maximum realism which yields maximum pilot and instructor acceptance.

2. Research designs which permit the determination of the incremental transfer effectiveness of a particular simulator configuration (as it might be employed at any point during the training program where it will maximally facilitate learning) should be used to determine the training effectiveness of simulator features before they are specified for procurement. An additional advantage of this technique is a portrayal of the quantitative research results that enables simulator designers to directly compare the training effectiveness of alternative simulator configurations.

3. The question of whether or not higher fidelity simulators are more effective for beginning students during their initial training, for experienced pilots during transition or continuing training, or for both beginning and experienced pilots at all stages of training should be tested and the results of the tests applied in the definition of simulator design requirements.

Simulator Costs. There are really only two issues of any substance that concerns the management of procurement and utilization of flight simulators for flying training: their training effectiveness and their costs. In the preceding sections, discussions by the group studying management problems have been stated in which both simulator training effectiveness and costs were viewed as parts of other major considerations. More attention appeared to be focused on areas other than costs. This misrepresents the content of the discussions reported, and more importantly, misses the point of this latest renaissance of serious attention to flight simulation. Flight simulators are an important concern in the Air Force (and elsewhere) primarily because of costs. The trick is to avoid having to spend money, fuel and aircraft service life to accomplish any flying training objective that cannot be achieved cost-effectively, using another training medium. The flight simulator is the largest cost generator, aside from the aircraft, among the training media currently being employed for flying training purposes and thus it becomes the "hot item" it is today among training researchers, simulator designers, military training managers and congressional committees. The discussion related to simulator cost touched on a number of issues of critical importance to the achievement of optimally cost-effective flying training programs for the military services.

The following observations emerged from the discussion of simulator costs:

1. Use of simulators in flying training programs typically focuses on either initial or continuation training. Cost savings are potentially greater if simulators can be used for continuation training, because the mission aircraft simulated routinely cost more to operate than typical training aircraft, and if simulators can satisfy the requirements for continuation training, there is every reason to expect that they would be suitable also for the transition training which prepares the pilot trainee for his operational assignment. On the other hand, it is often easier to demonstrate cost savings in initial training, because at this point the pilot's skill level is relatively low and the opportunity exists to generate gratifying cost savings through the use of relatively inexpensive training media given the fact that training aircraft are usually less complex than operational aircraft. Thus, both initial and continuing training should be attacked vigorously to identify how simulators can best be employed to minimize costs and maximize training.

2. In managing today's aircraft procurement programs, spending money for flying training appears to be a cost analysis, cost estimation proposition. The purchase of flight simulators is considered in the context of whole program costs; thus money spent on simulators will not be available for the purchase of additional aircraft. Since most managers of aircraft procurement programs are pilots and pilots are known to prefer flying aircraft to flying simulators, asking them to approve a simulator for aircraft trade requires substantial supporting documentation. Such documentation needs to be as solid as possible and, thus, requires considerable improvement.

3. The procedural routines for estimating simulator costs are relatively well developed and are not kept secret from training researchers. There is little evidence, however, that frontline training researchers consider simulator cost estimating techniques in the development of their experimental procedures or in the interpretation of their study results. Thus, the simulator program cost analysts end up using reasonable, ball park-type estimates and the training researchers seldom contribute very much to their refinement. It appears that the training effectiveness of flight simulators should be evaluated using research strategies and procedures designed to generate data that can be used at once by cost analysts, and that training researchers will need to emphasize cost analytical procedures in configuring their studies with approximately the same vigor they have learned to apply in the specification of experimental controls and statistical analyses.

4. Generally, the management of procurement of flight simulators is expressed in the documentation of the amortization of simulator life cycle costs in terms of the flying training costs avoidance which results from use of the simulator. This leads to the popular notion of the substitution of simulator training for aircraft training, noted earlier, which in turn leads to a misleading oversimplification of what teaches, who learns, and why. Rather than resorting to accounting routines that perpetuate misconceptions, it is preferable to include in life cycle cost estimates all the facts that can be marshalled to serve as the basis for a decision on the available alternatives so that the decision made will not turn sour in the future. For example, Operation and Maintenance (O&M) costs should be included even though they are ordinarily substantial and thus increase overall costs. Given the complexity of many of today's simulators, failure to take into account requirements for O&M support can result very quickly in unsatisfactory availability and invalid simulator training if O&M funds are not regularly provided, and the effectiveness of the simulation is degraded as a consequence.

Simulator Certification. The certification of simulators was discussed in terms of the current Navy and airlines programs. The Navy program involves periodic evaluation of the engineering or physical characteristics of a simulator. The airlines simulator certification efforts involve frequent engineering evaluations and extend to the maintenance of currency and standardization of the supporting instruction given in all aspects of the training program, including the instruction and instructor techniques used in the simulator. Current schemes for certification of a simulator's training effectiveness thus have avoided so far the difficulties associated with attempting to certify that the simulator will teach. Whether or not any instruction teaches is dependent in nearly every case on what and how well a trainee learns. If a simulator can provide relevant practice opportunities, then it has training potential. After all, if a student can practice a flying task, he can learn how to perform it; and if he can learn a flying skill, he can transfer it to the aircraft (unless flying skills operate according to different laws than other behavioral skills). The certification problem is not really concerned with a simulator's training effectiveness; that is an evaluation issue. Certification relates to the characteristics of a simulator that enable the simulator to generate accurately, and on a regular basis, the training task for which it has been designed.

Discussion of simulator certification yielded these observations:

1. Typically, aircraft flight data are not part of simulator procurements. The group members with experience in these matters reported consistent problems with evaluating simulator handling qualities, the simulator's aircraft-like "control feel," because of the unavailability of flight data for use in determining this aspect of the certifiability of the simulator. The need for flight data appears to be a self-evident and essential element in the certification of a simulator within a flying training program. Simulator procurement plans should include a requirement for this needed flight data.

2. Frequent evaluation of simulator engineering properties seems desirable. This will serve to document the simulator's operational characteristics and provide checks on such changes and updating of the simulator as are determined to be required during regular training operations.

3. While it is not feasible to certify that a simulator will train, it is necessary to include in certification procedures, coverage of the use of the simulator, the employment of its instructional features, and instructor techniques and training criteria. In this manner, flying training program managers can insure that the simulator is doing a reliable and valid job on the training objectives it supports.

4. Given that the certification of flight simulators is inevitable, and the certification programs can be made to work, the resulting flying training use of certified simulators should lead to some

form of credit for simulator training time in the pilot's log of flight experience. That is, pilots should be able to count simulator time along with aircraft flight time as a measure of their qualifications.

Recap of Discussion

This discussion concerning the management of procurement and utilization of simulators for flying training has been organized into four sections dealing in turn with: concepts of utilization, configuration, costs, and certification. Regarding concepts of utilization, it was found that instructor and trainee acceptance was related directly to whether or not the simulator worked, that instructors typically "trained around" simulator deficiencies to take advantage of their strengths, and that the simulators' uses were more important than their specific hardware properties. Improved specification of the training requirements, use of more powerful research procedures such as the incremental transfer effectiveness design in evaluating equipment alternatives, and a study of the fidelity, or realism, requirements for effective employment of simulators in the training of pilots with different levels of experience were discussed with respect to simulator configuration. On the issue of costs, the discussion indicated: (a) that both initial and continuation training were valid targets for cost avoidance through use of simulators, (b) that the program costs of simulators are often expressed in terms of aircraft not purchased, which results in close scrutiny being given documentation supporting the use of simulators, (c) that training researchers should consider the cost analyst's need for training effectiveness data in all phases of research so the results will in fact be useful in refining program cost estimates, and (d) that all factors known to bear on the life cycle costs need be considered in determining simulator cost amortization for use in deciding among hardware alternatives. Certification of simulators was discussed in terms of a continuing need for flight data for application in evaluating and documenting the physical or engineering properties of simulators, in terms of frequent checking and update of simulator configuration so records of the simulator characteristics will support its use in flying training, in terms of including all aspects of the training program in the certification procedures, not just the simulator hardware, and finally in terms of a need for counting simulator training hours with aircraft training hours for flight log purposes as an indication of pilot experience.

APPENDIX A: LIST OF ATTENDEES

Grade/Name	Organization
Capt Allan O. Pelcak	ATC/XPQC
Larry Pohlmann	AFHRL/FTS
Capt D. P. Thomas	CNO
Norman W. King	AFHRL/FTT
Edward E. Eddowes	AFHRL/FTT
Larry Fogel	Decision Sciences, Inc.
D. G. O'Connor	Singer-Link
G. Kron	Singer-Link
R. F. New	Singer-Link
Cdr Max Quitiquit	CNET Liaison, AFHRL/FT
Harry Beardsley	GE
Col J. D. Boren	AFHRL/FT
Thomas A. Payne	Decision Sciences
Robert C. Houston	American Airlines
James F. Smith	AFHRL/FTS
Lt Col John F. Ahlborn	HQ AFSC/DLS
John C. Dusterberry	NASA/Ames Research Center
Andrew Junker	AMRL/EMT
Charles Hopkins	Aviation Research Lab, University of Illinois
J. Hensley	Northrop Corp
A. D. Windsor	CNATRA, Corpus Christi, TX
M. Freitag	CNETS
Gary Morton	CNETS
Jesse Orlansky	IDA
Robert K. Jellison	Decision Sciences, Inc.
Col Calvin H. Markwood	ASD/SD-24
Milton Wood	AFHRL/FTXR
Howard L. Parris	AFHRL/XP
Stanley Brumaghim	Boeing-Wichita
John B. Dempster	Boeing-Wichita
James J. Regan	Navy Pers R&D Center
Joseph A. Puig	Naval Trng Equip Ctr
W. G. Matheny	Life Sciences, Inc.
Bill Albery	AFHRL/ASM
F. Thomas Eggemeier	AFHRL/ASR
R. N. Burrell	McDonnell Douglas
Col S. E. Shrum	ATC/XPT
Lt Col E. A. Crimp	USAFTAWC/OLAH
Capt George Buckland	AFHRL/FTS
Dave Kase	Rockwell/B-1 Div
George Kitchel	Vought Corp
Cdr J. A. Cade	CNET
Roland L. Bowles	NASA/Langley
Capt John M. Garrity	AFHRL/DOPF
Lt Col H. A. Hornbarger	ATC/XPQC
John D. Smith	Logicon, Inc.
King Povermire	Coast Guard, ATC
Maj Jeff Koonce	DFBL/USAF Academy
Capt Jack Thorpe	AFHRL/FTT
Wayne L. Waag	AFHRL/FTT
Capt Gene Englund	Hq SAC
Capt Oak DeBerg	ASD/ENECC

Grade/Name	Organization
Capt Barry McFarland	ASD/ENECC
Capt Terry Balven	ASD/SD24
Col Rondel E. Minter	AF/IGD (SEF)
Anchard F. Zeller	AFISE/SEL
Capt David L. Miller	AFISC/SES
John B. Shinn	GE, Daytona Beach
Capt Steven Rust	TAWC/TES
Thomas W. Sellers	Austin Electronics
Alfred R. Fregly	AFOSR/NL
Stanley N. Roscoe	Hughes Aircraft, University of Illinois
Donald W. Davidson	Goodyear Aerospace, Akron, Ohio
Conrad L. Kraft	Boeing Aerospace, Seattle, Washington
Bill Harris	NTEC, Orlando, Florida
W. J. Allsopp	Boeing Aerospace, Seattle, Washington
W. A. Lipman	Grumman Aerospace Corp
E. W. Cairns	Hydrosystems, Inc.
R. H. Mathews	McDonnell Douglas, Inc.
Gary McCulloch	United Airlines
Grant Beutler	United Airlines
W. E. "Bud" Nylen	United Airlines
R. E. (Bob) Coward	Hq ADCOM/DOXI
R. N. (Bob) Hale	Vought Corporation
W. D. (Bill) Hayden	Vought Corporation
H. T. Bruel	Grumman Aerospace
T. L. Keller	Grumman Aerospace
R. G. Palmer	NAVTRAEQUIPCEN
J. N. Puglisi	NAVTRAEQUIPCEN
Cdr Hugh Halpin	NAVTRAEQUIPCEN
Cdr Jim Murray	Navy Liaison Office, Wright-Patterson AFB
R. F. Browning	TAEG, Orlando, Florida
G. A. Wynn	American Airlines, Ft. Worth
Warren E. Richeson	AFHRL/FTE
Capt Dwight Kelly	USAFTAWC/OLAH
James E. Brown	TAWC/TES, Eglin AFB, Florida
Maj Robert E. MacArgel	TAWC/TES, Eglin AFB, Florida
Capt Jerry Stecklein	AF/XOOFB
Edward A. Stark	Singer SPD-Binghamton, New York
Dom Gibino	ASD/ENET
Don R. Gum	AFHRL/ASM, Wright-Patterson AFB
Barry Leshowitz	Arizona State University Tempe, Arizona
Col Carl G. Baily	82 FTW/DO, Williams AFB, Arizona
Lt Col J. H. Snelling	CNATRA, NAS, Corpus Christi, Texas
Frank Schufletowski	CNATRA, NAS, Corpus Christi, Texas
Pete Gadwa	Arizona State University
Bob Lawson	ONR, Pasadena, California

APPENDIX B: AGENDA OF SIMULATOR TRAINING RESEARCH PLANNING MEETING

SIMULATOR TRAINING RESEARCH PLANNING MEETING

21 April	0800	Registration, Coffee at Building 558, Lobby
	0830	Session 1. Welcome – Col J. D. Boren, AFHRL/FT Objectives – Col C. H. Markwood, ASD/SM24 Orientation – Dr. E. E. Eddowes, AFHRL/FT Bldg 571, Room 11
	0930	Session 2. Study Group Meetings Group 1. Simulator Capabilities and Characteristics, Bldg 571, Room 11 Group 2. Simulator Requirements for Flying Training, Bldg 571, Room 5 Group 3. Measurement of Simulator Training Effectiveness, Bldg S-561 Group 4. Management of Procurement and Utilization of Simulators for Flying Training, Bldg 558, Conference Room
	1130	Lunch, Williams AFB Officers' Club
	1300	Study Group Meetings
	1630	Adjourn
	1700	No-Host Cocktail Hour, Williams AFB Officers' Club
	1900	Tours of AFHRL Facility
22 April	0800	Coffee at Building 558, Lobby
	0830	Report of Study Group Findings, Bldg 571, Room 11 Group 1 – 0830 Group 2 – 0915 Group 3 – 1000 Group 4 – 1045
	1130	Lunch, Williams AFB Officers' Club
	1300	Discussion of Study Group Reports
	1430	Summary of Results
	1500	Adjourn

Study Group 1, Building 571, Room 11

SIMULATOR CAPABILITIES AND CHARACTERISTICS

Moderator: Mr. Gum, AFHRL/AS

Mr. Albery, AFHRL/AS
Mr. Allsopt, Boeing Aircraft
Mr. Barger, Singer SPD
Mr. Beardsley, GE Daytona Beach
Capt Burke, TAC/DOXS
Mr. Burrell, McDonnell Douglas
Mr. Cairns, Hydra Systems
Mr. Case, B-1 Division
Mr. Davidson, Goodyear Aerospace
Mr. Dusterberry, NASA/AMES
Capt Englund, SAC/XPHV
Mr. Hale, Vought Corp
Mr. Harris, NTEC
Mr. Hayden, Vought Corp
Mr. Heinle, Logicon
Lt Col Hornberger, ATC
Mr. Keller, Grumman Aerospace
Mr. Kiron, Singer SPD
Mr. Kitchel, Vought Corp
Mr. Mathews, McDonnell Douglas
Col Minter, USAF Safety Center
Mr. New, Singer SPD
Mr. Nylen, United Airlines
Mr. O'Connor, Singer SPD
Mr. Palmer, NTEC
Ms. Puglisi, NTEC
Mr. Sellers, Austin Electronics
Dr. Shiner, GE Daytona Beach
Mr. Smith, Logicon

Study Group 2, Building 571, Room 5

SIMULATOR REQUIREMENTS FOR AIR FORCE FLYING TRAINING

Moderators: Dr. Waag and Dr. Pohlmann, AFHRL/FT

Col Baker, USAF Safety Center
Capt DeBerg, ASD/ENEC
Lt Col DeMuth, SAC/XPHV
Mr. Jellison, Decision Sciences
Maj MacArgel, TAWC
Col Markwood, ASD/SD24
Mr. McCullock, United Airlines
Mr. Morton, CNETS
Col Shrum, ATC/XPT
Lt Col Snelling, CNATRA
Capt Stecklein, AF/XOOFB

Study Group 3, Building S-5561

MEASUREMENT OF SIMULATOR TRAINING EFFECTIVENESS

Moderators: Capt Thorpe, Capt Fuller, AFHRL/FT, and Capt Rust, TAWC

Mr. Beutler, United Airlines
Dr. Bowles, NASA/Langley
Mr. Browning, NTEC
Dr. Eggemeier, AFHRL/AS
Dr. Freitag, CNETS
Dr. Hopkins, Aviation Research Laboratory, University of Illinois
Dr. Houston, American Airlines
Maj Koonce, AFA/DFBL
Dr Matheny, Life Sciences
Capt McFarland, ASD/ENEC
Capt Miller, USAF Safety Center
Dr. Payne, Decision Sciences
Mr. Puig, NTEC
Dr. Shufletowski, CNATRA
Dr. Stark, Singer SPD

Study Group 4, Building 558, Conference Room

MANAGEMENT OF PROCUREMENT AND UTILIZATION OF SIMULATORS FOR FLYING TRAINING

Moderators: Dr Eddowes and Dr King, AFHRL/FT

CDR Cade, CNET
Dr. Fregley, AFOSR
Dr. Fogel, Decision Sciences
Dr. Orlansky, Institute for Defense Analysis
Dr. Parris, AFHRL/XP
Dr. Regan, NPRDC
Dr. Roscoe, Hughes Aircraft
Capt Thomas, CNO/OP596
CDR Windsor, CNATRA
Dr. Zeller, USAF Safety Center

RESEARCH VARIABLES

The research program envisioned to investigate the training effectiveness of flight simulator motion and visual systems will be focused on the following independent and dependent variables:

A. Independent Variables:

1. Simulator Characteristics

   a. Motion Generation Systems:

      1. Platform motion
      2. G-seat
      3. G-suit

   b. Visual Display Systems

      1. Model board
      2. Caligraphic
      3. Computer generated imagery

2. Pilot Flying Experience Level

   a. Novice
   b. Low (UPT graduate)
   c. Medium
   d. High (Airlines Captain)

3. Type Aircraft Simulated

   a. Performance Characteristics

      1. Low
      2. Medium
      3. High

   b. Size, Weight and Complexity

      1. Low
      2. Medium
      3. High

4. Training Maneuvers

   a. Maneuvers expected to require motion simulation to produce positive transfer to the aircraft.

   b. Maneuvers not expected to require motion simulation to produce positive transfer to the aircraft.

B. Dependent Variables:

1. Training effectiveness, as shown by transfer of training to the aircraft.

2. Pilot performance in the simulator.

3. Pilot acceptance ratings of the simulator motion and visual conditions tested.

4. Pilot discrimination of the presence or absence of simulator motion.

Study Group 1. SIMULATOR CAPABILITIES AND CHARACTERISTICS

Research Discussion Questions

1. How many different types of motion systems should be tested in terms of: degrees of freedom of platform motion, motion drive philosophy, platform motion mechanization, G-suit and G-seat, or others? The issue here is what array of motion generation alternatives is so provocative, inexpensive, reliable, acceptable, etc, as to require full research evaluation?

2. How many different visual simulation system features must be tested? For example, field-of-view, black-and-white vs. color CIG, relative enrichment of scene presented, modifiability of scene content, initial costs vs. refinement and update costs, etc.

3. Is there any feasible means available to evaluate the likely impact of state-of-the-art advances in motion simulation systems using currently available devices? That is, are convincing extrapolations likely to result from this research program, or must we revalidate all the evaluations next month or next year if a "new improvement" becomes available?

4. What biasing factors are there known to engineering specialists which should be signaled to decision-makers to aid them in interpreting research outcomes? That is, is there a convincing way to portray the current consensus on the inherent strengths and limitations of available simulator motion and visual systems?

5. What criteria may be used to determine if research or training simulators, such as may be available for use in this research program, and can furnish a set of pilot performance data which decision-makers can use in determining what simulation motion/visual systems to buy?

6. Are there devices that may be added to simulators for the purpose of collecting quantitative pilot performance measurements, or must this feature be provided through modification of the simulator? What costs are involved in either of these possibilities? What other alternatives are available?

7. Others. . . .

Study Group 2. SIMULATOR REQUIREMENTS FOR FLYING TRAINING

Research Discussion Questions

1. How will simulators be used in the flying training programs of the various major commands (MAJCOMs)?

2. Are there key missions/maneuvers that are to be trained using simulators equipped with motion and visual systems which must be a part of any evaluation of these simulator capabilities?

3. What flying experience levels are characteristically found among various MAJCOM pilots who use simulators in their flying training?

4. Are there known biases among the pilots who are potential users of simulators in favor of or against simulators equipped with motion and/or visual systems? What are the characteristics of such pilot biases as may exist?

5. Will the same simulators be used for cockpit procedures, emergency procedures, instrument procedures and full mission training? If not, what other training devices may be expected to be used in MAJCOM flying training programs?

6. What types of data on simulator effects on pilot performance are likely to be convincing to MAJCOM training managers: training transfer effectiveness, performance in the simulator, pilot acceptance, pilot discrimination of the presence or absence of motion, others?

7. Others. . . .

Study Group 3. MEASUREMENT OF SIMULATOR TRAINING EFFECTIVENESS

Research Discussion Questions

1. What are the relative merits and shortcomings of the various experimental designs which can be used to study the training effectiveness of motion?
   -- Training (transfer) effectiveness
   -- In-simulator performance comparisons
   – Pilot discrimination of the presence or absence of simulator motion
   – Pilot acceptance or attitude

2. What techniques have been used in the past for testing the effects of simulator characteristics on pilot transfer to the aircraft?

3. What are the practical strengths and weaknesses of dependent variables used in these designs?
   -- Pilot ratings in the aircraft
   -- Instrumented aircraft measures
   – Objective performance measures in the simulator
   – Pilot opinion questionnaire

4. What current performance measurement systems and approaches, including pilot rating schemes, structured rating scales and rater training sessions are available for measuring simulator training effectiveness?

5. What types of performance differences are we looking for and what should their magnitude and duration be?
   -- How large should a "significant" difference be to be meaningful?
   – Are we mostly concerned with short-term effects, i.e., those which can be observed over the first few flights, or are longitudinal effects important, and if they are, how do we control all the possible confounding factors in a pilot training program so that they can be studied with some degree of orthogonality (or believability)?

6. How will the problem of generalization be resolved? What rationale can be offered to relate the results of small *n* studies using one specific simulator and aircraft type combination to the data generated in another simulator-aircraft combination or to another simulator-aircraft combination where no studies have been conducted?
   -- Are different rationales needed to relate such differences in pilot experience levels, maneuver types, simulator characteristics, (motion, G-seat, visual system) and aircraft type as are studied?

7. How do we avoid proving the null hypotheses?
   -- Are there procedures that can be used to prevent experimental outcomes which show no differences?
   – Are decisions based on the cost of other features or devices which generate no measurable performance effects supportable?

8. What is a reasonable heirarchy of studies to provide the most potent information earliest?

9. Is there a best way to study new configurations proposed by contractors (for example, in the search for "good" motion)?

10. Others. . . .

Study Group 4. MANAGEMENT OF PROCUREMENT AND UTILIZATION OF SIMULATORS FOR FLYING TRAINING

Research Discussion Questions

1. What attitudes or positions are found frequently among Air Force/Navy training managers on the absolute or relative value of simulator motion and visual systems?

2. Is there any tendency among training managers to consider training effectiveness factors beyond pilot acceptance and cost? If so, what are the most salient of the other factors?

3. What is the likely response of flying training managers to a proposal that any study of simulator training effectiveness should include the optimization of the integration of ground training, simulator and flight training? Can you detect any strong feelings that integrated ground and flying training is a major goal of future flying training programs?

4. There has been much attention focused on reducing flying time. Has there been much attention focused on how to best use what flying time may be available? For example, can enough flying hours be gained by giving instrument training and flight checks in the simulator to permit redistribution of flying hours to missions/maneuvers less easy or less expensive to simulate on the ground?

5. In managing flying training, is there any possibility that a competitive cost reduction approach may be the best route to success? For example, establish two or more competitive teams with the objective of generating an optimum mix of ground and flight training and then evaluating the effectiveness of the resulting programs in terms of yearly dollar costs required to maintain force readiness, or in terms of weapons delivery data or flight hours saved to attain some agreed-to performance criterion (such as an FAA check). Might incentives be used such as allocating all cost savings to provide additional aircraft training time?

6. What is the likelihood of acceptance by training managers of radical changes in flying training program structure? For example, giving flight hour credit for simulator time or cash incentives to pilots who qualify in the least expensive manner for their mission-ready status?

7. Is there any conviction among training managers regarding the utility or desirability of accomplishing part of the flying training requirements in a simplified or low-cost aircraft in addition to the mission aircraft?

8. Others. . . .

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