A REVIEW OF AIRCRAFT SIMULATOR FIDELITY REQUIREMENTS IN HUMAN FACTORS RESEARCH

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INTRODUCTION.

This paper is a result of an investigation and review of aircraft simulator fidelity requirements in human factors research. This investigation into simulator fidelity was necessary to obtain information about what levels of fidelity are required for a simulator to provide functional equivalence in regards to the aircraft being simulated. The information obtained will be used to evaluate the Reconfigurable Cockpit Simulator (RCS) being developed at the FAA Technical Center. The investigation reviewed reports dealing with both environmental (out-the-window visual system) and physical (inside the cockpit displays and control systems) fidelity within a flight simulator cockpit.

A comprehensive literature search was performed in an effort to investigate simulator fidelity requirements. Hundreds of technical reports were reviewed to search for information dealing with the fidelity requirements of flight simulators. Searches were performed on report titles with the following keywords: Cockpits, Simulator Cockpits, Simulator Fidelity, Fidelity, etc. Author searches included Gavan Lintern, Stanley Roscoe, and M. Baarspul. The searches revealed over 500 reports that had to be reviewed to search for relevant information about simulator cockpit fidelity. Reports that contained pertinent information that could be used to evaluate the (RCS) were singled out from the list of hundreds. A list identifying these reports is presented on the following pages. The complete reports will not be included at this time, if desired at a later date they will be available for review.

FLIGHT SIMULATOR FIDELITY REPORTS.

1) Title: Flight simulation technique with emphasis on the generation of high fidelity 6 DOF motion cues
   Author: Baarspul, M. (Delft, Technische Hogeschool, Netherlands)
   Publication Date: 1986   References: 31 Refs.

ABSTRACT: The current status of flight simulation technology has reached the level, where the aircraft dynamics can be simulated with the fidelity, required for 'Total Simulation' in civil air crew training. This paper discusses the main systems of a piloted flight simulator. They are as follows: 1) the real-time digital computer system, driving the simulator, 2) the simulator cockpit, providing various levels of equipment fidelity to the pilot, 3) visual systems, where improved display devices should take advantage of improvements in CGI-systems, 4) Motion systems, generating aircraft like specific forces and angular accelerations. The flight simulator cockpit is separated into
equipment cues (providing duplication of flight displays and controls) and environment cues (providing duplication of the out-the-window environment). Furthermore, requirements for objective and perceptual fidelity within the cockpit are discussed.

2) Title: A review of flight simulation techniques
Author: Baarspul, M. (Delft, Technische Universiteit, Netherlands)
Source: Progress of Aerospace Sciences (ISSN 0376-0421), vol. 27, no. 1, 1990, p. 1-120.
Publication Date: 1990
References: 109 Refs.

ABSTRACT: The evolution of flight simulator techniques and operations is described. A description is given of the main components of piloted flight simulator, including the similarity between aircraft and simulator in cockpit layout, and flying controls based on the equipment and environmental cue fidelity required for training and research simulators. Furthermore, FAA requirements for Phase I, II, III approval levels for flight simulators are described. In conclusion, the status of flight simulator technology is reviewed and future prospects in this area are discussed.


ABSTRACT: This report examines the design of flight simulators. The major objective of virtually any sophisticated "full-scope" simulator training device is to provide the highest degree of transfer possible to its operational system counterpart. Concerns for operational readiness have stimulated interest in the concept of transfer of training. Therefore, the objective of this report is to provide an overview of the role of transfer of training concepts in the design and development of simulator training devices. Several transfer studies involving flight simulators were reviewed, and results showed that positive transfer of training can be achieved under varying degrees of fidelity in the simulator. With the increasing emphasis on making simulators a cost-effective alternative to hands-on operational training, the studies of transfer which can isolate the effects of major simulator cost drivers such as visual and motion cues will become more important.

4) Title: Simulator fidelity specification based on training needs
Author: Levinson, E. D.; Donovan, M.
Corporate Source: General Physics Corp., Atlanta, GA, USA
ABSTRACT: This report summarizes the work to date on a simulator qualification methodology project. The development of a simulator qualification process, based on a training perspective, is described so that it can be used in other qualification projects. The measures used to quantify the simulator's performance are provided and the results of demonstration analysis are described.

5) Title: An informational perspective on skill transfer in human-machine systems
Author: Lintern, Gavan (Illinois, University, Savoy)
Source: Human Factors (ISSN 0018-7208), vol. 33, June 1991, p. 251-266
Publication Date: Jun. 1991 References: 53 Refs.

ABSTRACT: Differentiation of perceptual invariants is proposed as a theoretical approach to explain skill transfer for control at the human-machine interface. In this report it is proposed that sensitivity to perceptual invariants is enhanced during learning and that this sensitivity forms the basis for transfer of skill from one task to another. The hypothesis implies that detection and discrimination of critical feature, patterns, and dimensions of difference are important for learning and for transfer. To the extent that those conceptions are specific, they cannot account for effects in which performance is better following training on tasks that are less rather than more similar to the criterion task. Lintern reported that the transfer observed following training on a task that differs in some specific respects from the criterion task is often better than transfer observed following equivalent training on the criterion task itself.

6) Title: Explicit and implicit horizons for simulated landing approaches
Author: Lintern, Gavan; Liu, Yeou- teh (Illinois, University, Savoy)

ABSTRACT: In a flight simulator experienced pilots flew landing approaches to a representation of an airport scene in which various sources of information had been distorted or removed.
The data reported here suggest that in a simulator for teaching aircraft landings the emphasis in scene design should be on abstract relationships rather than on high-fidelity representation of specific objects or details. Another observation made in this discussion is that simulation instruction might be more efficient if the critical functional invariants could be made more salient. The basic research in perceptual learning has shown that enhancement or contrast of critical features enhances sensitivity to those features. Much of the challenge associated with the acquisition of flight control skills related to problems in perceptual learning, which is viewed here as enhancement of sensitivity to functional invariants and calibration of those invariants to the capabilities of the controlled system, so emphasis of these two aspects in the design and use of simulators is likely to enhance training efficiency.

7) Title: Simulator design and instructional features for air-to-ground attack: A transfer study
Author: Lintern, Gavan (Illinois, University, Savoy); Sheppard, Daniel J.; Parker, Donna L.; Yates, Karen E.; Nolan, Margaret D. (Essex Corp., Orlando, FL)
Publication Date: Feb. 1989 References: 30 Refs.

ABSTRACT: A transfer experiment was conducted to define simulator design requirements and instructional procedures for an air-to-ground attack trainer. Two levels of scene detail, three levels of field of view, and three levels of simulator training trials were manipulated. The data obtained attests to the fact that physical similarity is not a requirement for high positive transfer and thereby lend further support to the need for notions such as functional equivalence or psychological fidelity. The point that less-than-perfect fidelity on the stimulus dimension of a task permits high transfer seems to have escaped the notice of those involved with the design of flight training simulators and, if recognized, may blunt the ardent push for high-fidelity visual systems. In addition, research concludes that there is a wide range of possible approaches to the design and use of training simulators and that an appeal to physical fidelity as a principle for design and use will be overly expensive and less than maximally effective.

8) Title: Simulator qualification - Just as phony as it can be
Author: Roscoe, Stanley N. (ILLIANA Aviation Sciences, Ltd., Arcata, CA and Las Cruces, NM)
Publication Date: 1991 References: 17 Refs.
ABSTRACT: The qualification of airplane simulators for pilot training is based on the assumption that transfer of such training is directly related to the similarity of the device to an actual airplane. The consequence of this widely held position has been the specification of training device requirements solely on the basis of engineering criteria. However, the proper criterion is the flight hours saved in airborne training for each incremental investment in ground training. Furthermore, research has shown that innovations in training strategies, in some cases involving intentional departures from reality, can have stronger effects than high simulator fidelity on the resulting quality of pilot performance. Ideally, each aspect of the training curriculum could be taught to some criterion performance level on the ground. Competence in each block of training would be demonstrated after a brief transition in the airplane. Certification for each license and rating would be based on demonstrated competence, thereby making possible large reductions in the minimum required flying hours. Credit for ground-based training would no longer be a formal issue.

9) Title: A new meaning to "flying the desk" (high fidelity cockpit simulator)
Author: Sexton, G.A. (Lockheed-Georgia Co., Marietta, GA)
Corporate Source: Lockheed-Georgia Co., Marietta.
Publication Date: 1986

ABSTRACT: A unique advanced transport flight station (Pilot's Desk Flight Station) design is described. This design has been incorporated into various flight simulation facilities across the country. The various systems and displays of the design are described, including: the configuration; switches; tailored logic/artificial intelligence; primary flight controllers; front panel displays; primary flight/navigation display; engine power/status, approach charts, and weather display; the Advisory, Caution, and Warning System/Cockpit Display of Traffic Information display; checklist/functional systems display; head-up display; voice command and response system; Flight Management Computer system; and integrated communications/navigation system. The baseline design described represents a point from which to begin further research and development in the simulation of crew systems. The architecture of the system is designed to provide the utmost flexibility in exploring the multitude of research issues which face us today, as well as tomorrow.