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PART I

EXECUTIVE SUMMARY

NASA/FAA HELICOPTER SIMULATOR WORKSHOP

PART I: EXECUTIVE SUMMARY

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SUMMARY

A workshop was convened by the FAA and NASA for the purpose of providing a forum at which leading designers, manufacturers, and users of helicopter simulators could initiate and participate in a development process that would facilitate the formulation of qualification standards by the regulatory agency. Formal papers were presented, special topics were discussed in breakout sessions, and a draft FAA advisory circular defining specifications for helicopter simulators was presented and discussed. A working group of volunteers was formed to work with the National Simulator Program Office to develop a final version of the circular. The workshop attracted 90 individuals from a constituency of simulator manufacturers, training organizations, the military, civil regulators, research scientists, and five foreign countries. A great amount of information was generated and recorded verbatim. This information is presented herein within the limits of accuracy inherent in recording, transcribing, and editing spoken technical material.

INTRODUCTION

A NASA/FAA-sponsored helicopter simulator workshop was convened (23-26 April, 1991) at the Biltmore Hotel in Santa Clara, California. The purpose of the workshop was to support the Federal Aviation Administration in clarifying qualification requirements for rotary-wing flight-training simulators and to review the draft Advisory Circular, "Helicopter Simulator Qualification," AC 120-XX written to implement these requirements. Funding for this and other project activities were provided by the the FAA's Vertical Flight Special Programs Office, ARD-30, in support of the National Simulation Program Office, ASO-205. These activities are authorized and funded by Interagency Agreement DTFA01-88-Z-02015, Rotorcraft Simulator Technology, between the FAA and NASA, June 15, 1988.

Three important purposes were identified that could best be served at a workshop consisting of knowledgeable and interested representatives of the training simulator community. First, the workshop would provide a forum. In rotary-wing flight simulator training and technology there are many indeterminacies, and there is no systematic method for the formulating and resolving of questions

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relating to the ability of simulators to accomplish the training required by FAA regulations (Title 14 CFR). A primary goal of the workshop would be to elicit expert opinion and experience in an effort to define those questions and to cull from the attendees' presentations and comments some guidelines for an approach to their resolution. Subsequent documentation and dissemination of this information would make a substantive contribution to simulator qualification efforts and to the guidance of future research and development.

Second, the workshop would provide a context for public preview and comment on the draft Advisory Circular, 120-XX, October 22, 1990, "Helicopter Simulator Qualification." The attendees would be those professionals for whom the Advisory Circular is of immediate concern. They would be a pool of candidates for membership on a working group, requested by the manager of the National Simulator Evaluation Program, that would be responsible for developing the final form of the Advisory Circular.

Third, the workshop would serve to collect valuable information which would be documented and disseminated. The NASA/FAA simulator qualification project is not currently a research project with long-term goals but a circumscribed effort dependent on existing technical information, driven largely by the need to produce a valid and consensus Advisory Circular and training regulations. The workshop was conceived as a source of "data" which would (1) help in the finalization of the draft Advisory Circular, (2) increase the helicopter community's awareness of and concern with training simulator issues, and (3) perhaps identify further research and development objectives. The results of the workshop would be documented in two parts, this Executive Summary, and Part II, Workshop Proceedings and Session Compendium. Both parts would be distributed to all attendees.

WORKSHOP STRUCTURE

Seventeen speakers were invited from the helicopter training simulator industry and from the military to present formal papers over the first day and a half of the conference. Three panel discussions (breakout sessions) were scheduled on the afternoon of the second day and three more on the morning of the third day. The panel session topics were:

- A. Training Limits, Allowances, Future
- B. Scene Content and Simulator Training Effectiveness
- C. Low-cost Training Alternatives: Part-and Full-Task Trainers
- D. Dynamic Response and Engineering Fidelity in Simulation
- E. Current Training: Where Are We?
- F. Aero Modelling.

Panel sessions D and F were combined into a single session at the request of the panel members because of the similarity of their content and the overlapping expertise of the discussants.

The panel moderators and participants were instructed that the intention was to promote a free-flowing discussion in which all contributions were welcomed and desired. At the completion of the breakout sessions each session moderator summarized the discussions that had taken place.

On the afternoon of the third day the manager of the National Simulator Evaluation Program, Mr. Ed Booth, chaired a meeting of the conference-at-large at which he invited comment on the draft Advisory Circular, 120-XX. He also formed a volunteer working group from the assembled participants to meet with him at a future date to work on the finalization of the draft Advisory Circular.

The welcoming address was presented by C. Thomas Snyder, Director of Aerospace Systems, NASA Ames Research Center. Mr. Snyder presented a short history of simulator development at Ames.

The keynote speaker was James D. Erickson, Manager, Southwest Region Rotorcraft Directorate, Aircraft Certification Service, FAA. Mr. Erickson noted that rotorcraft simulation has not kept pace with fixed-wing simulation. He said that the military successes with simulation would be given attention and that the importance of developing useful, acceptable, and objective standards in the civil sector would be emphasized.

PRESENTATION ABSTRACTS

The duties of moderator of the formal-paper sessions were ably executed by Mr. James McDaniel, Manager, Vertical Flight Program Office, ARD-30, FAA Headquarters. Seventeen speakers made presentations at the workshop. Abstracts of the presentations follow. Cliff McKeithan's paper, which was not originally scheduled, is also abstracted.

1. **HELICOPTER SIMULATOR STANDARDS.** Edward Boothe, Manager, FAA National Simulator Evaluation Program.

The initial advisory circular was produced in 1984 (AC 120-XX). It was not finalized, however, because the FAR's for pilot certification did not recognize helicopter simulators and, therefore, permitted no credit for their use. That is being rectified, and, when the new rules are published, standards must be available for qualifying simulators. Because of the lack of a data base to support specification of these standards, the FAA must rely on the knowledge of experts in the simulator/training industry. A major aim of this workshop is to form a working group of these experts to produce a set of standards for helicopter training simulators.

2. **HELICOPTER SIMULATION: AN AIRCREW TRAINING AND QUALIFICATION PERSPECTIVE.** Richard A. Birnbach, Manager, Air Carrier Training Branch, FAA Flight Standards Service.

This paper reviews some of the unique considerations that distinguish the commercial rotary-wing domain from its fixed-wing counterpart and that should give the FAA cause to proceed cautiously in drawing upon its fixed-wing experience. A major point: device qualification should be accomplished in a context of an overall training and qualification system. This approach would take as its starting point a detailed analysis of rotary-wing missions and tasks from which proficiency objectives can be systematically developed.

3. ROTORCRAFT MASTER PLAN. Peter V. Hwoschinsky, FAA Vertical Flight Program Office.

The Rotorcraft Master Plan contains a comprehensive summary of active and planned FAA vertical flight research and development. Since the Master Plan is not sufficient for tracking project status and monitoring progress, the Vertical Flight Program Plan will provide that capability. It will be consistent with the Master Plan and, in conjunction with it, will serve to ensure a hospitable environment if the industry presents a practical vertical-flight initiative.

4. SIMULATORS FOR CORPORATE PILOT TRAINING AND EVALUATION. Curt Treichel, Manager, Training for Corporate Aircraft, United Technologies, Inc.

Corporate aviation relies heavily on simulation to meet training and evaluation requirements. It appreciates the savings in fuel, money, noise, and time, and the added safety it provides. Also, simulation provides opportunities to experience many emergencies that cannot be safely practiced in the aircraft. There is a need to focus on the advantages of simulator training over aircraft training and to provide appropriate changes in the regulations to allow the community to make it possible for users to take full advantage of simulation.

5. TRAINING EFFECTIVENESS ASSESSMENT: WHERE ARE WE? Greg McGowan, Manager, West Palm Beach Learning Center, FlightSafety International.

Over 9,000 pilot training courses have been conducted at FSI using the Bell 222 and Sikorsky S-76 simulators. Through the use of FAA exemptions, these simulators can be used for certain training and checking credit. The history of the development and use of commercial helicopter simulators and the opportunities for their increased utilization and use were explored.

6. CURRENT TRAINING: WHERE ARE WE? Gerald Golden, Director of Training, Petroleum Helicopters, Inc.

Petroleum Helicopters, Inc. maintains a staff 750 helicopter pilots. The initial, transition, upgrade, and recurrent training for these pilots requires a significant financial outlay. Since a major portion of that training is done to satisfy the requirements of FAR 61.57, "Recent Flight Experience, Pilot in Command" and 135.297, "Pilot in Command: Instrument Proficiency Check Requirements," much could be accomplished using an approved simulator. However, it is imperative that credit be given for training time spent in the simulators and that the device be realistic, practical, and affordable.

7. HELICOPTER SIMULATION QUALIFICATION. Brian Hampson, Director of Engineering Administration, CAE Electronics.

CAE has extensive experience in building helicopter simulators and has participated in group working sessions for fixed-wing advisory circulars. Against this background issues that should be addressed in establishing helicopter approval criteria were highlighted. Some of these issues are not immediately obvious and may, indeed, be more important than the criteria themselves.

8. HELICOPTER SIMULATION: MAKING IT WORK. Barry Payne, Aviation Network (NZ) Limited.

The opportunities for improved training and checking by using helicopter simulators are greater than they are for airplane pilot training. Simulators permit the safe creation of training environments that are conducive to the development of pilot decision-making, situational awareness, and cockpit management. This paper defines specific attributes required in a simulator to meet a typical helicopter operator's training and checking objectives.

9. HELICOPTER TRAINING SIMULATORS: KEY MARKET FACTORS. John McIntosh, Vice President, Hughes Simulation Systems.

Simulators will gain an increasingly important role in training helicopter pilots only if the simulators are of sufficient fidelity to provide positive transfer of skills to the aircraft. This must be done within an economic model of return on investment. Although rotor pilot demand is still only a small percentage of overall pilot requirements, it will grow in significance. This presentation described the salient factors influencing the use of helicopter training simulators.

10. TRAINING EFFECTIVENESS ASSESSMENT: METHODOLOGICAL PROBLEMS AND ISSUES. Kenneth Cross, President, Anacapa Sciences.

The U.S. military uses a large number of simulators to train and sustain the flying skills of helicopter pilots. Despite the enormous resources required to purchase, maintain, and use those simulators, little effort has been expended in assessing their training effectiveness. One reason for this is the lack of an evaluation methodology that yields comprehensive and valid data at a practical cost. Some of these methodological problems and issues that arise in assessing simulator training effectiveness, as well as problems with the classical transfer-of-learning paradigm were discussed.

11. DETERMINING THE TRANSFERABILITY OF FLIGHT SIMULATOR DATA. David Green, President, Starmark Corporation.

This paper presented a method for collecting and graphically correlating subjective ratings and objective flight test data. The method enables flight-simulation engineers to enhance the simulator characterization of rotorcraft flight in order to achieve maximum transferability of simulator experience.

12. PROGRESS THROUGH PRECEDENT: GOING WHERE NO HELICOPTER SIMULATOR HAS GONE BEFORE. Richard J. Adams, Vice President, Advanced Aviation Concepts.

Helicopter simulators have been approved by means of special exemption; there are no FAA standards for simulators used in training or airmen certification checking. The fixed-wing industry provides a precedent which can be used for expediting implementation of helicopter simulators. The analysis in this paper is founded on the experience with that precedent and is driven by a clear definition of helicopter user needs for (1) improved training at lower cost, (2) more comprehensive emergency training at lower risk, (3) increased fidelity of transition and instrument training compared with low-cost aircraft alternatives, and (4) certification credit for improved simulator training.

13. TRANSFER OF TRAINING AND SIMULATOR QUALIFICATION. Jack Dohme, Research Scientist, U.S. Army Research Institute.

Transfer of training studies at Fort Rucker using the backward-transfer paradigm have shown that existing flight simulators are not entirely adequate for meeting training requirements. Using an *ab initio* training research simulator, a simulation of the UH-1, training effectiveness ratios were developed. The data demonstrate it to be a cost-effective primary trainer. A simulator qualification method was suggested in which a combination of these transfer-of-training paradigms is used to determine overall simulator fidelity and training effectiveness.

14. VALIDATION AND UPGRADING OF PHYSICALLY BASED MATHEMATICAL MODELS. Ronald Du Val, President, Advanced Rotorcraft Technology.

The validation of the results of physically-based mathematical models against experimental results was discussed. Systematic techniques are used for: (1) isolating subsets of the simulator mathematical model and comparing the response of each subset to its experimental response for the same input conditions; (2) evaluating the response error to determine whether it is the result of incorrect parameter values, incorrect structure of the model subset, or unmodeled external effects of cross-coupling; and (3) modifying and upgrading the model and its parameter values to determine the most physically appropriate combination of changes.

15. FREQUENCY RESPONSE TECHNIQUES FOR DOCUMENTATION AND IMPROVEMENT OF ROTORCRAFT SIMULATORS. Mark Tischler, Rotorcraft Group Leader, Army Aeroflightdynamics Directorate, Ames Research Center.

Pilot-in-the-loop characterizations are most naturally formulated in terms of end-to-end frequency responses, so a frequency-response-based method is the natural approach to assessing simulator dynamic fidelity. A comprehensive frequency-response approach used heavily by Ames Research Center researchers was described, and results were presented from a number of simulator fidelity assessment studies. Those studies included UH-60 mathematical model validation and upgrade, ASTOVL linear model extraction, and documentation of the Vertical Motion Simulator (at Ames Research Center) motion and visual system characteristics.

16. BANDWIDTH AND *SIMDUCE* AS SIMULATION FIDELITY CRITERIA. David Key, Chief, Flight Control Branch, Army Aeroflightdynamics Directorate. Ames Research Center.

The potential application of two concepts from the new Handling Qualities Specification for Military Rotorcraft was discussed. The first concept is bandwidth, a measure of the dynamic response to control. The second is a qualitative technique developed for assessing the visual cue environment the pilot has in bad weather and at night. SIMulated Day Usable Cue Environment (SIMDUCE) applies this concept to assessing the day cuing fidelity in the simulator.

17. METHODOLOGY DEVELOPMENT FOR EVALUATION OF SELECTIVE FIDELITY ROTORCRAFT SIMULATION. Cliff McKeithan, Georgia Institute of Technology. (Authors: Major William D. Lewis, Dr. D.P. Schrage, Dr. J.V.R. Prasad, Major Daniel Wolfe).

This paper addressed the initial step toward the goal of establishing performance and handling qualities acceptance criteria for realtime rotorcraft simulators through a planned research effort to quantify the system capabilities of "selective fidelity" simulators. Within this framework the simulator is then classified based on the required task. The simulator is evaluated by separating the various subsystems (visual, motion, etc.) and applying corresponding fidelity constants based on the specific task. This methodology not only provides an assessment technique, but also provides a technique to determine the required levels of subsystem fidelity for a specific task.

COMMENTARY

The workshop presentations and discussions evoked a broad range of pertinent background and experiential information, problem definitions, and problem solution guidelines. Some of the more significant of these are summarized below.

1. There appears to be a ready worldwide market for simulators and training devices. Although the military has hundreds of simulators, little has been done in the civilian market as a result of lack of enabling legislation for helicopter simulators. There are only two helicopter simulators in the United States that have been provisionally approved by the FAA, the Bell PH 222 and the Sikorsky S-76B. These are approved by exception for considerable credit toward pilot certification, but the pilot must still pass a checkride in the helicopter. These simulators are sophisticated devices in terms of, for example, their dynamic models and motion systems. At the other end of the market lies a generic, fixed-base training device that can be used to teach and review all of the visual helicopter flight maneuvers and techniques, along with systems functionality and navigation. This type of device offers the manufacturer the most flexibility in providing all of the helicopter fidelity and functionality at the lowest cost without having to comply with FAA AC-120 XX.

2. A report (Abstract #9) of a survey of the simulator market indicated that only eight so-called high-end (\$12 million to 25 million) simulators are needed worldwide over the next decade. Many more (100 to 200) lower-end devices (\$1.0 million to 1.2 million) could be supported. Rotary-wing training managers emphasized this in their desire for approval of less expensive part-task training devices in earning credits toward meeting regulatory requirements. In addition to helicopter training simulators, the industry and government should move out on issues related to tilt-rotor/wing and the regulations, infrastructure, and technology issues that will be of consequence in the mid to late 1990's. Timing of FAA action is consistent with market forecasts and the needs of helicopter operators.

3. There was a general feeling that the full capability of current helicopter simulators was not being exploited owing, perhaps, to some hesitancy on the part of the authors of regulatory requirements. The regulations and exemptions as they stand today still discourage industry from using the simulator to its fullest potential. Many maneuvers and emergency procedures cannot be safely done in the aircraft but can be done safely, repetitively, quickly, and economically in a simulator. Thus, a desire was expressed to expand the uses of simulators to allow credit for the training of tasks from more emergency procedures through instrument ratings to crew coordination and resources

management. As one attendee stated: "the couple of things that cannot be done well in the simulator are nothing compared with the many things that cannot be done [at all] in the aircraft." Also, the more that credit is withheld for training and checking done in simulators the more it is a disincentive to use them.

4. A boost in support of helicopter simulator utilization will be provided by a new proposed rule, NPRM, Part 142, which will authorize and regulate **Certificated Training Centers**. The objectives of the new rule are to increase simulator use, eliminate simulator exemptions, standardize training, and standardize FAA oversight of trainers through a centralized, national training program approval process. The new rule will cross air-carrier and non-air-carrier lines, and no distinction is made between fixed-wing and helicopter simulators. In an effort to maintain a broad perspective the rule would not specify in any detail differences in use of helicopter and fixed-wing simulators. Rather, the FAA would issue a certificate to the training center based on a set of training specifications which could be changed much easier than changing the certification. Part 142 will train to existing standards of Parts 61, "Certification: Pilots and Flight Instructors," 121, "Certification and Operations: Domestic, Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft," and 135, "Air Taxi Operators and Commercial Operators," and may be expandable to Parts 63, "Certification: Flight Crewmembers Other Than Pilots," 133, "Rotorcraft External Load Operations," 137, "Agricultural Aircraft Operations" and possibly others. Parts 121 and 135 operators contracting with Part 142 training centers would not have to duplicate any part of the training program. Part 142 will either replace Part 141, "Pilot Schools," or complement it, in which case Part 142 schools would cooperate with Part 141 schools in finding mutually satisfactory arrangements for training students. This alternative will be presented in the NPRM and comments will be solicited.

5. There is a dichotomy of training philosophy and opinion with respect to the amount of credit that should be allotted to simulators as opposed to aircraft for skill demonstration. The regulatory agencies, though enthusiastic and motivated to grant approval for more simulator training and checking, must proceed cautiously, supported by empirical evidence, in the interest of safety, and training relevancy, and in view of potential liability in a litigious society. On the other hand, industry is also enthusiastic about increased use of simulators in lieu of the aircraft in the interest of safety, relevancy, and economy, and its representatives point out that these interests, based on their experience, will be better served by more use of simulators that offer much more versatility in terms of task and maneuver repertoire than can the aircraft. The aircraft, as a training device, is severely limited. Exemptions should still be sought in the interim before the publication of Part 142 (perhaps late 1992).

6. At a seminar in 1987, *Vertical Flight Training Needs and Solutions*, co-sponsored by the FAA and the Helicopter Association International, it was determined that human error-related accidents were the greatest problem the helicopter industry faced. Up to 80% of all helicopter accidents were in one way or another caused by human error, not by deficiencies in flying or control skills, and simulator training along with decision-making training was seen as an effective way to help reduce this kind of accident. The helicopter pilot frequently is under the pressure of a high workload situation and engages in a variety of industrial-commercial tasks, such as sling operations, flying crane, airtaxi, offshore oil platform work, high-altitude slope work, and cattle/wildlife herding that are inherently difficult and potentially dangerous. These are seldom "canned" or routine maneuvers and

therefore require good decision-making and judgmental skills. This kind of training, reminiscent of line-oriented flight training and cockpit resources management training in the fixed-wing world, requires neither high dynamic fidelity nor a type-specific simulator; a generic model (low-end cost) would be more than sufficient. The expanded use of and increased FAA credit for training in more generic simulators (training devices) was a pervasive issue at the workshop (see below).

7. The expanded use for credit of simulators in fixed-wing training, which has been successful under the Part 121, Appendix H, Advanced Simulation Plan, was frequently referred to. However, the application of fixed-wing simulator technology to rotary-wing training has some drawbacks. The different maneuvering capabilities of helicopters with omni-directional flight in proximity to the ground appears to require more capability in the visual scene than is currently available. The complaints are that the simulated visual cues do not adequately support veridical perception of altitude and altitude rates. This is mainly attributed to lack of good textural cues and to restricted fields of view, particularly in the downward direction, since the ground plane must be extrapolated by the trainee from the forward-oriented, perspective-drawn visual scene. Other attendees felt that existing simulators do give effective training down to the ground. These opinions probably should be tempered by consideration of the kind and skill level of the training being given. This caveat would appear to apply to all discussions of the contribution to training of all the simulator subsystems.

8. Physical simulator fidelity is desirable, but functional fidelity (training effectiveness) should be the goal. The lack of a systematic method within the civil rotary-wing community for determining simulator cost and training effectiveness makes it difficult to predict the levels of fidelity that are required for meeting (or exceeding) training performance and regulatory standards except through user experience; this is a long-term, unsystematic, and possibly biased process.

9. Current simulator design is hardware technology-driven. However, high fidelity of individual components of the simulator such as handling qualities, motion, and the visual scene does not of itself guarantee high training effectiveness. In the absence of discriminatory data, the effort to provide high fidelity is a current default position based on inferential logic. The proof of simulator efficacy is transfer-of-training from simulator to aircraft at reasonable savings and return on investment. Controlled studies of these outcomes in the civil community are neither available nor planned.

10. Training industry representatives expressed interest in joining NASA and the FAA in addressing the issue of transfer-of-training studies as a screening strategy for the selection of behaviors trainable in simulators for credit. This could be done by using current training facilities, training personnel, and trainee pools. None of these three potential participants (training industry, NASA, FAA) currently has a unique capability in the area of formal transfer-of-training and training assessment studies of large populations but probably could share in the planning, cost, management, and technology applications of such efforts.

11. Our current difficulty in relating engineering simulator fidelity to training excellence also presents difficulties in the specification of test values and tolerances for the proposed advisory circular for simulator qualification.

12. It is recognized that the body of descriptive data obtained during the development of a helicopter is rarely adequate for definition of an accurate simulation model. Later flight tests to

gather the necessary data tend to be very expensive. The FAA prefers that these data be generated by the manufacturers of the aircraft, but simulator manufacturers have on occasion relied on third-party tests. The absence of data necessarily increases reliance on pilots' subjective assessments.

13. NASA and the military have been making increased use of a flight-testing technique known as "frequency-sweep" that produces data, at modest cost in flight time, that is well-conditioned for use in helicopter modelling. The technique can be applied to the complete simulator, including motion and visual systems, for comprehensive verification of simulator fidelity.

14. Blade-element rotor modelling was recommended as the way to insure the fidelity of the simulator dynamic response and a strong point was made regarding the rapidly decreasing cost of computer capacity to accommodate such models. Again, because of uncertainties in the description of the aircraft, and the uncertain correlation between dynamic fidelity and training efficiency, this position was contested to some degree. Less complex models cannot be discarded out-of-hand until more evidence is available that the added complexity is training-justified.

15. There appears to be a consensus that a maximum visual scene and cockpit motion transport delay of 100 msec is a realistic specification for helicopter simulators. This more rigorous constraint than imposed on fixed-wing trainers reflects the higher control band-width typical of helicopters.

16. The value of expensive and complex motion systems is questioned when their contribution to training is considered. A bad motion system is worse than no motion system at all, and the contribution of a motion system to training may be highly task-dependent. The research literature seems to support this position, but, other than for the advantageous cueing of disturbance motion over simple maneuver motion, it has not been determined which sets of tasks can be better trained using motion cueing. Simulation of the vibration modes is recognized as a valuable contributor to simulator subjective fidelity.

17. The need for a wide field-of-view and abundant scene detail in simulation of hover tasks is recognized. It is also recognized that the visual simulation represents about half the cost of a modern simulator. This cost is especially high if the two crew members are provided with equivalent fields. Particularly, considering some of the new lower-cost visual systems being demonstrated, there exists a strong challenge to develop more cost-effective systems identified by a careful assessment of training needs and aircraft/simulator training time trade-off.

18. Collimation of visual scenes, a source of increasing simulator initial cost and upkeep, may be of questionable value in comparison with real image displays. They do provide a dramatic illusion of great distance and of a large "gaming" area; however, the localization of all picture elements at optical infinity leads to perceptual difficulties in estimating size and distance at short ranges, say, 10 ft (wheels on ground) to 50 ft (hover), the crucial range for helicopter maneuvering near the ground. This effect, coupled with limitations in the downward field of view and texture, make it difficult to localize the ground plane and to perceive altitude and altitude rates.

19. It is recognized that because of visual and motion cueing limitations, simulated tasks, particularly those in proximity to the terrain, are harder to fly than the real task, even if the aircraft model itself is of very high fidelity. The extent to which this presents an obstacle to effective use of the simulator was the subject of brisk discussion. Some voices supported the addition of compensation (for example, stability augmentation) to effect a more realistic work load in the critical tasks.

20. The hearing session on the draft of the Advisory Circular 120-XX for the qualification of helicopter simulators was cooperative rather than contentious, probably a result of the wide latitude given to industry participants in voicing their viewpoints throughout the previous 2 days of the workshop. Mr. Boothe had no problem in recruiting 30 volunteers to make up a panel to assist him in the further refinement and finalization of the circular. Several areas for further review were suggested and will be pursued by the volunteer working group. They seemed united on the need for the proposed advisory circular and the enabling FAA regulation; and the draft circular appeared to be a workable document for their efforts. The first meeting of the panel was scheduled for 23-25 July, 1991 in West Palm Beach, Florida.

EPILOGUE

The individuals of the NASA/FAA project team who were responsible for the inception, organization, and execution of the Helicopter Simulation Workshop are indebted to panel moderator David A. Lombardo for his unsolicited reflection of their intentions. In part, he said:

In the early days of aviation the designer was the trainer and the user. Most things were done by trial and error, including aircraft design, pilot certification and standards, and pilot training. . . . Fortunately, that trend is slowly changing with the old guard passing the torch to new, better technologically informed replacements. The new emphasis is on user involvement in the initial design of hardware, software, and liveware training and certification. This symposium is an example of that emerging trend.”

The NASA/FAA project team members would like to extend to all workshop participants a very sincere expression of gratitude for their involvement in the workshop. Your enthusiasm and willingness to take responsibility for the future of simulator training by bringing your expertise to bear on a difficult technological area is greatly appreciated. We will extend a modest return-of-favor by delivering to you in a timely manner the planned workshop documentation.

MESSAGE FROM THE CONFERENCE CHAIRMAN

BILL LARSEN

I wish to thank you for participating in the recent Helicopter Simulator Workshop and for making it such a success. Without your contribution the workshop would not have been possible.

It is clear, considering recent advances in training simulator technology and your statements during the workshop, that we will see enabling legislation that will provide increased credit for ground-based training. To some extent, this is already taking place, as reflected by the proposed rule making of Part 142 Title 14 CFR entitled "Certification Training Centers," the National Simulator Program Offices' Draft Advisory Circular No. 120-XX, "Helicopter Simulator Qualification," the recently published special FAR 58 "Advanced Qualification Program," and the FAA's National Plan for Aviation Human Factors.

For reasons, the simulator has become the aircrew training and checking tool of choice. This view was very apparent at the recent workshop. Along with the advances in simulator and training equipment technology has come an increasing awareness of the need for a systematic approach to device and training system design and specification. The emerging realization is that simulators and training devices are more than just an example of modern engineering technical excellence: they are quintessentially devices for the enhancement of human behavior.

The FAA certifies personnel, equipment, and procedures. The equipment certified includes aircraft, simulators (aircrew training/checking devices), and other equipment used in the NAS. Traditionally, the FAA has qualified flight simulators on the basis of engineering criteria that reflect the extent to which the characteristics of a given system are equivalent to those of the aircraft. Training transfer effectiveness—the extent to which an individual who meets a standard of proficiency in the simulator

can be expected to exhibit a known level of proficiency in the aircraft—has been assumed. This approach has proved satisfactory for high-fidelity simulations, but it is appropriate that additional factors be considered in establishing qualification criteria for training devices that rank lower on the physical fidelity continuum.

The FAA regulatory mission requires a sound basis for qualifying such equipment in training program and airman certification applications. Operators have been encouraged by the advanced qualification program to be innovative in designing training systems and equipment. Equipment used to establish or to maintain currency must be evaluated and approved against a set of criteria established by the FAA administrator for a particular qualification level. In this regard it is imperative that research be conducted to establish scientifically solid evaluation criteria that will be applicable to all such devices subject to FAA qualification.

The program's goal is to determine what level of simulator or training device is necessary to achieve a given training objective so that an aircrew member can qualify for credit toward regulated flight training. The amount of simulator training that is necessary to satisfy flight training requirements currently is determined by regulation. The regulation reflects the assumption that the more realistic the simulator the greater the value of the training. However, the level of the fidelity of represented parameters (e.g., visuals, handling qualities, motion) that is required to satisfy these regulations has not been empirically determined.

The transcribed and edited versions of the speaker's presentations follow. Summary statements of the separate panel discussions and a list of workshop attendees appear as appendices.



Bill Larsen served as a test pilot in the Air force and worked for 27 years in the aerospace and computer industries and with NASA. During that period, Mr. Larsen participated in R&D programs related to military and commercial transport aircraft and various missile systems, and served as engineering director for the design and development of a main frame computer. At NASA, he developed and conducted flight experiments for the Apollo spacecraft. Since joining the FAA in 1974, Mr. Larsen's work has encompassed cockpit alert and warning systems, an ATC simulation system, digital avionics systems, and fault-tolerant digital aircraft systems. In addition, he has conducted extensive investigations into the effects of electromagnetic threats to aircraft systems, including fly-by-wire and fly-by-light digital flight control systems. Mr. Larsen has served on several technical committees, and has participated in and organized several Digital Avionics Systems Conferences sponsored by the IEEE and AIAA. He has a B.S. degree in mechanical engineering and B.S. and M.S. degrees in electrical engineering from the University of Washington.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

WELCOME

C. THOMAS SNYDER

Good morning, ladies and gentlemen. It is a pleasure for me to welcome you to this Helicopter Simulator Workshop on behalf of NASA and the FAA. I am sure that many of you in the audience are aware that the relationship between NASA and the FAA here at Ames Research Center has been a very strong one over the years, especially in simulation. The purpose of the workshop today is to assess the state of simulation technology, especially that of helicopter simulation, and to define a path leading to the qualification of helicopter training simulators. We see NASA's role in this process as one of support to the FAA, and we are pleased to be a part of this process in that sense. We believe that it has important implications for the entire vertical flight community.

Now, I mentioned this very close relationship between NASA and the FAA. I have had a first-hand involvement in that activity, especially during my early years as a researcher at Ames. So I hope you will bear with me while I reminisce a little about the changes we have seen in simulation over 25 short years.

The genesis of the NASA-FAA relationship really goes back to the early 1960s here at Ames and to a very visionary and a very energetic FAA employee from the Western Region named Joe Tymczyszyn. I am sure many of you know Joe. It is with a really warm spot in my heart I remember Joe predicting how simulators could be applied to expedite and simplify the certification of new classes of aircraft, to understand their operating characteristics before they really became hardware, and to get a jump on the process. I remember, too, the energy he put into pursuing that goal, as a result of which the NASA-FAA research program was established.

One of our first activities was to set up a simulation of a DC-8 to validate the idea; a kind of mock certification was conducted with that simulation. The hardware was basically a fixed-base transport cockpit with a rather crude single-window external visual display (fig. 1).

The display was generated by a moving-belt model runway viewed by a servo-driven TV camera that created

a black and white picture projected onto a screen, and viewed through a collimating lens (fig. 2). I remember all the trouble we had keeping the servo system tuned up to do a job that was more than it was designed for. From that relatively successful experiment we moved on to examine supersonic transport flight characteristics and the certification criteria related to them.

In 1969, the large-motion-base six-degrees-of-freedom Flight Simulator for Advanced Aircraft, or FSAA as we came to call it, was commissioned (fig. 3). With that came digital computation (up to that time we used analog computation) and much improved visual displays of the model terrain-board type. The very large (± 50 ft) lateral travel of this simulator was excellent for studying lateral directional characteristics of large aircraft and for studying the effects of engine failure. So there was a lot of work done in those areas.

Following the demise of the U. S. Supersonic Transport program, attention was directed toward Concorde certification, and a very successful program was conducted with the joint authorities that contributed to the special conditions for the Concorde. It was also during that time frame that the FAA decided to establish a field office at Ames, and that office has continued to this day. The certification criteria simulation work was then directed to questions related to the introduction of wide bodies, the Boeing 747, and later to STOL certification criteria. The FSAA was also used during that period in the competitive evaluation of the proposals leading to the XV-15 tilt-rotor research aircraft. That was the first such use of a simulator, to my knowledge

In 1980 the six-degrees-of-freedom Vertical Motion Simulator (VMS) was introduced (fig. 4). It has ± 30 ft of vertical travel, ± 20 ft of lateral travel and six degrees of freedom. It is the real workhorse of our activity today.

It was also at about that time that we transitioned to computer-generated visual displays and multi-window external scenes. In addition to continuing research on powered-lift STOL and VSTOL aircraft using this

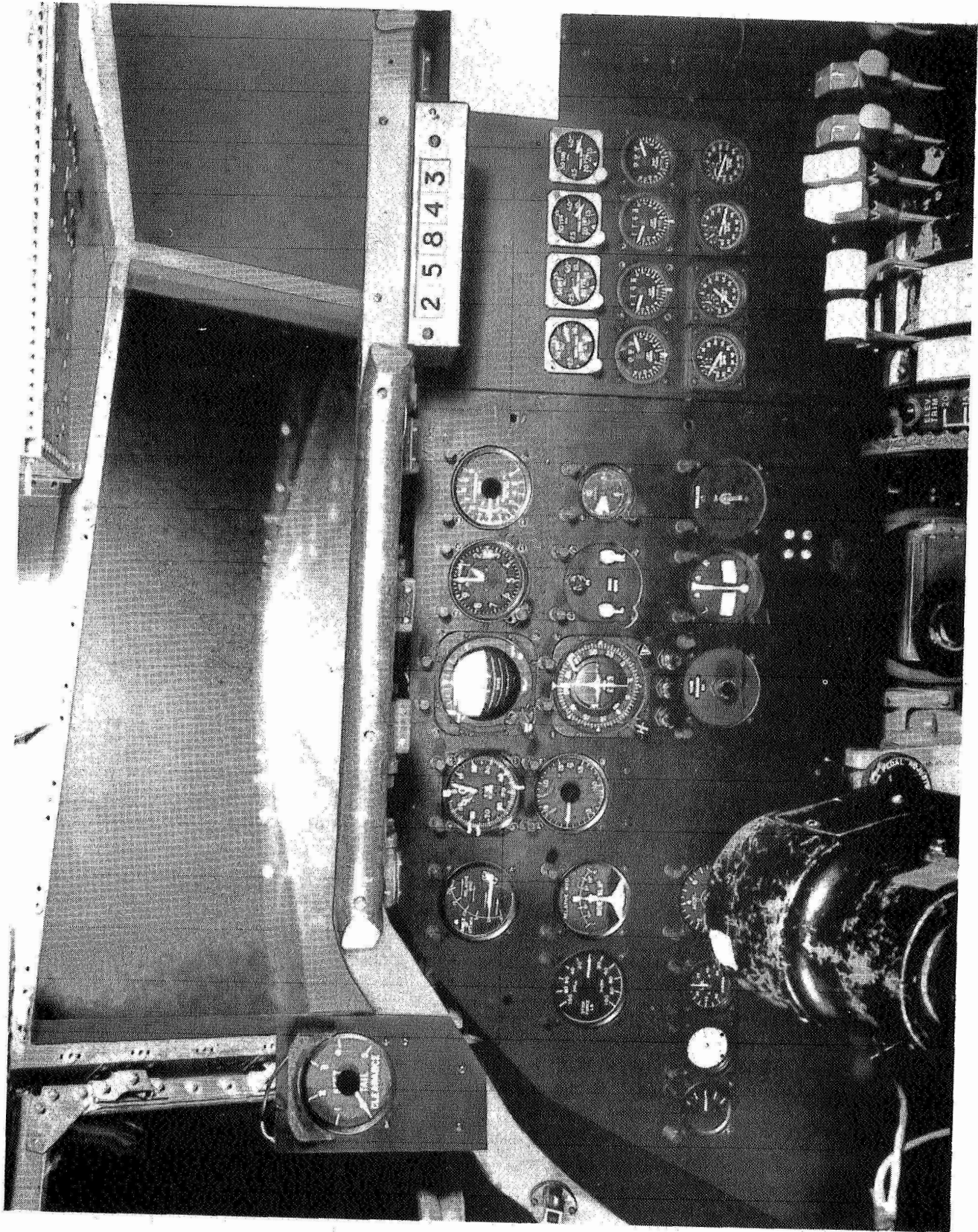


Figure 1. Fixed-base transport simulator.



Figure 2. Moving-belt visual image generator.

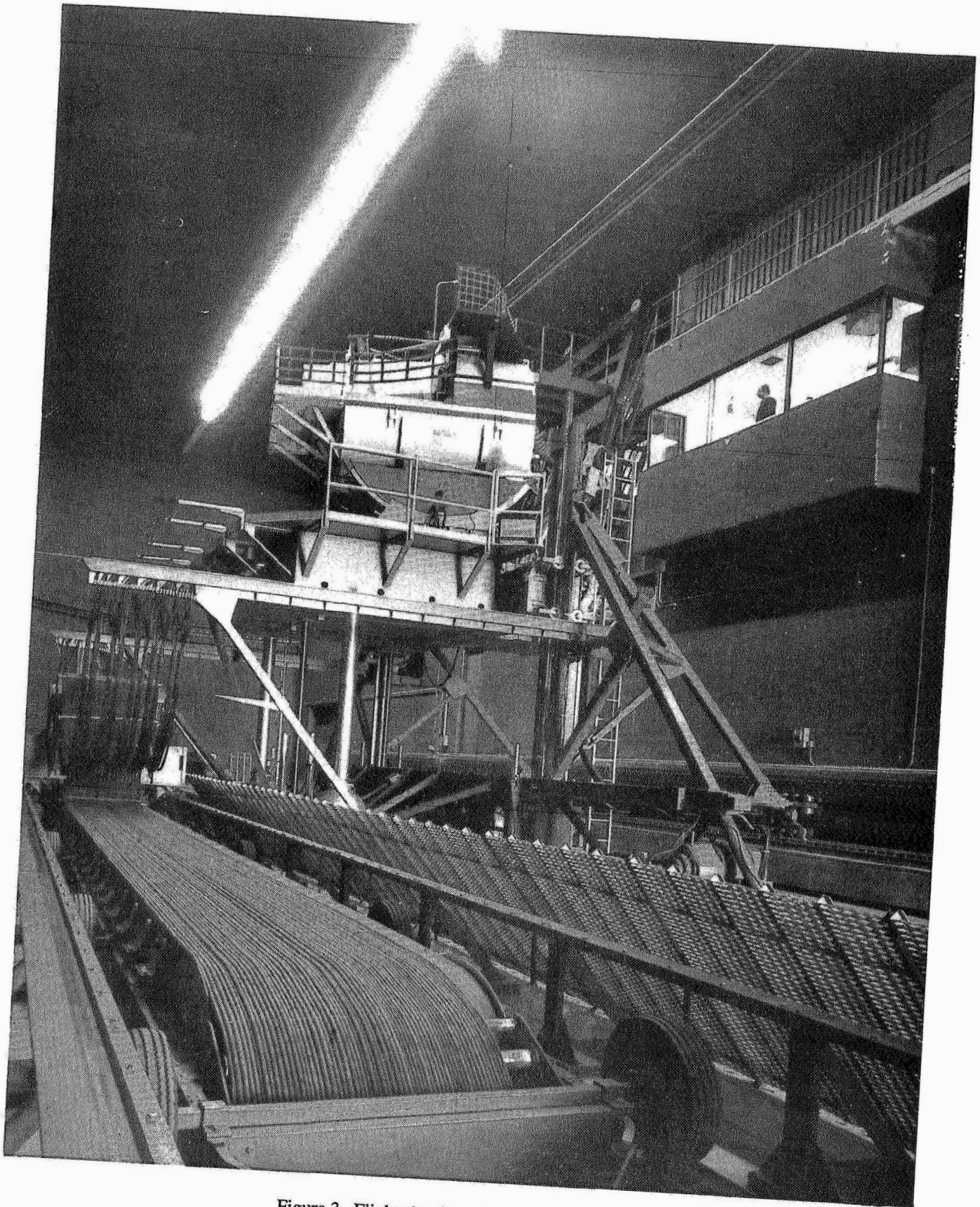


Figure 3. Flight simulator for advanced aircraft.

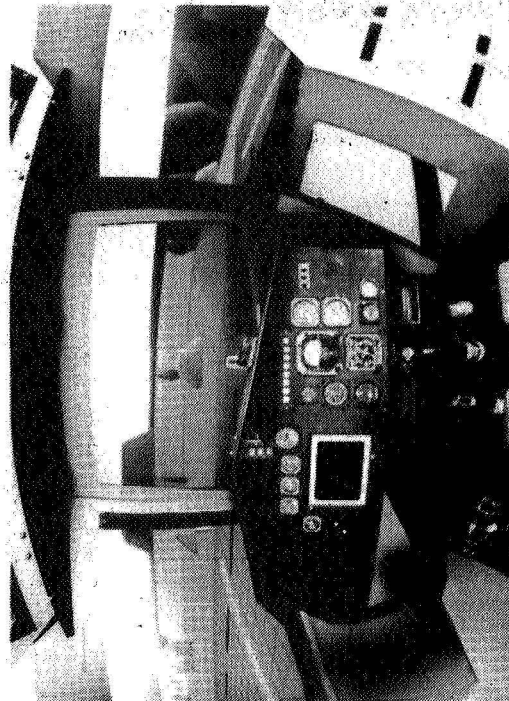
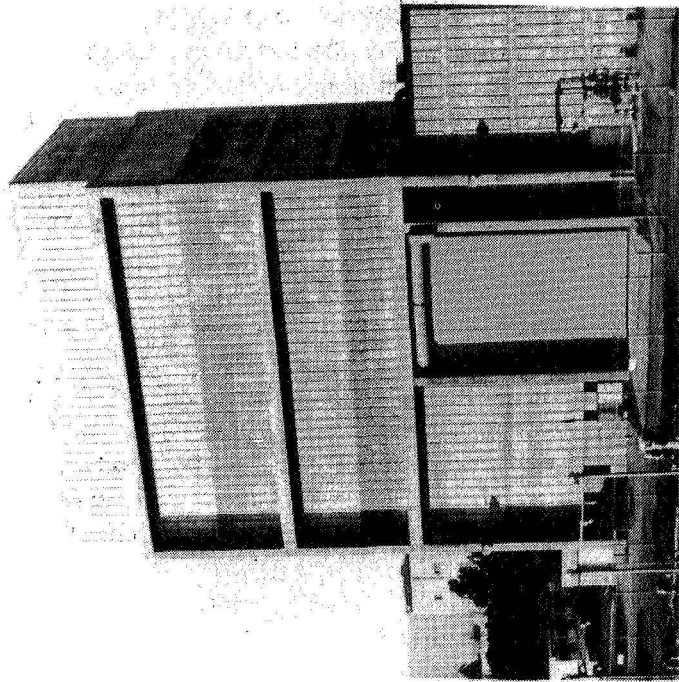
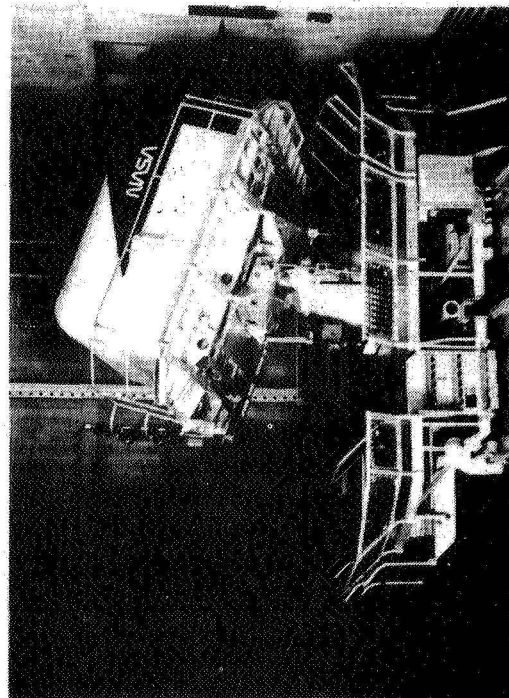
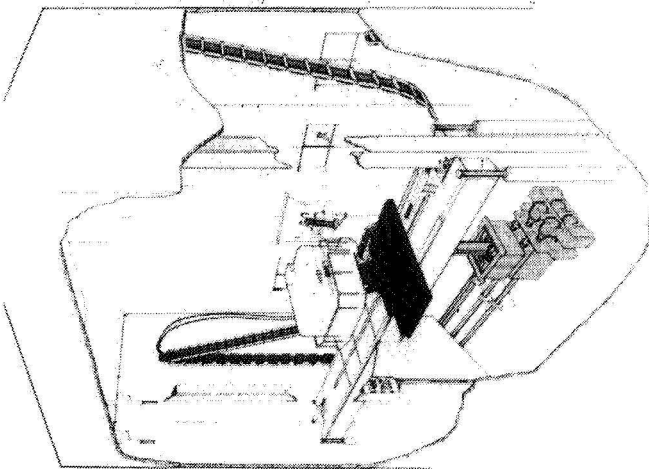


Figure 4. Vertical motion simulator.



simulator, the VMS became quite popular for rotorcraft research and Space Shuttle approach and landing investigations. Regarding the Shuttle, the landing gear and ground reactions were simulated to such a degree that, for

example, the effects of blown tires, of runway surface (landing on a lake bed versus concrete runway), of anti-skid system design changes, and of nose-wheel steering could be studied. This was also the first use of the VMS

as a training tool. The Shuttle folks have continued to use the VMS about twice a year, six weeks each entry, to cycle through all the pilot-astronauts in a combined systems-development and training activity.

Getting back to the subject of rotorcraft simulation, the VMS was also used, quite successfully, in the development of helicopter IFR certification criteria, in the development of Army Light Helicopter design specifications, and in Army helicopter accident investigations. It is currently being used to investigate Civil Tilt Rotor approach criteria and how these are affected by various levels of control and display sophistication and winds.

Also during the 1980s, a new simulation capability was established expanding further our FAA relationship. This was the introduction of the Man-Vehicle Systems Research Facility, a simulation facility with two transport cockpits (fig. 5). This facility provides very high fidelity representation of total missions and is used for studying the human factors issues in the aviation system. I would say that about two-thirds of all the work that is done in that facility is done jointly with the FAA.

In the 1988-89 period we developed, with the Army as partner and CAE as contractor, the Crew Systems R&D Facility (fig. 6) to address helicopter crew-station design issues—driven in the near term by the one-versus-two-crew LHX issue. This simulator is also a full-mission simulator, which allows the flying of complete missions as a member of a scout attack helicopter team with all the threats represented. That is a very significant capability. Another special feature is its visual display capability, with its virtually unlimited field of view provided by a helmet-mounted display. It is a very impressive system.

Over the years, simulator visual displays have been significantly improved and been made increasingly compelling. The effects of disharmony between visual cues and motion cues on the human body, factors in simulator sickness, become increasingly apparent. The simulators I talked about earlier are being used in a joint research program designed to shed more light on that particular subject.

A final topic I would like to discuss is research directed at the human factors issues associated with the use of pilot night-vision devices. Apparently, both the Army and the FAA are interested in this topic. Civil operators have asked for certification to enable them to use such devices in various aspects of their civil missions. As a result, research is being conducted in the simulators at Ames and in the Cobra helicopter (fig. 7) to address these issues.

In summary, we have seen major changes in simulation technology and in the way simulators are used. Those of you in the commercial simulator business have seen an enormous number of changes and have implemented a number of very significant technological advances over the years. During this period Ames and the FAA have enjoyed an excellent relationship, one in which rotorcraft simulation has played an increasing role.

As a result, we are certainly pleased to cohost this Workshop with the FAA. I want to wish all of you a very productive meeting and a pleasant stay in the Bay Area. I hope that later in the week you will avail yourselves of the opportunity to visit Ames Research Center where you can see some of the hardware I have spoken of this morning.

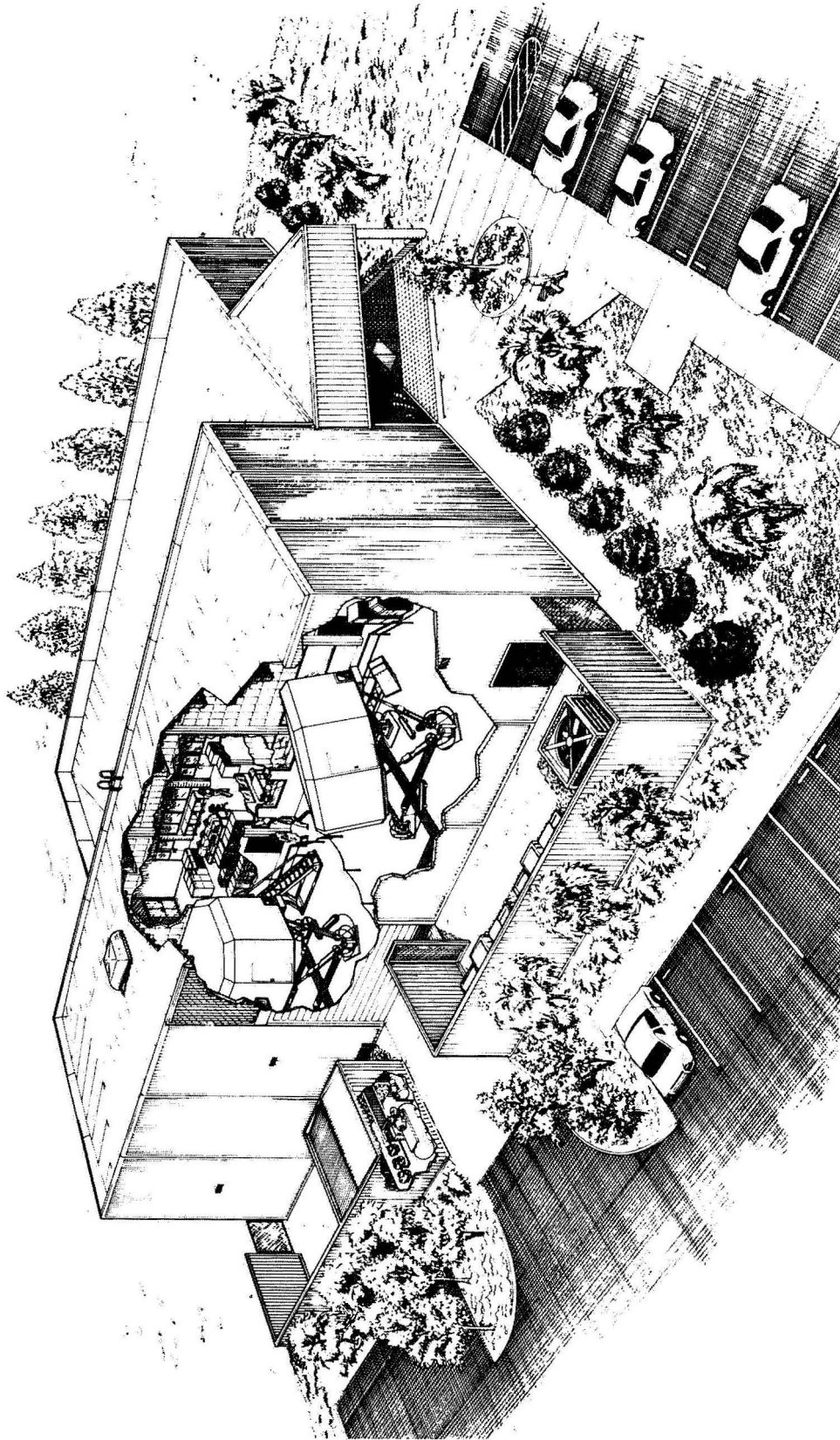


Figure 5. Man-Vehicle Systems Research Facility.

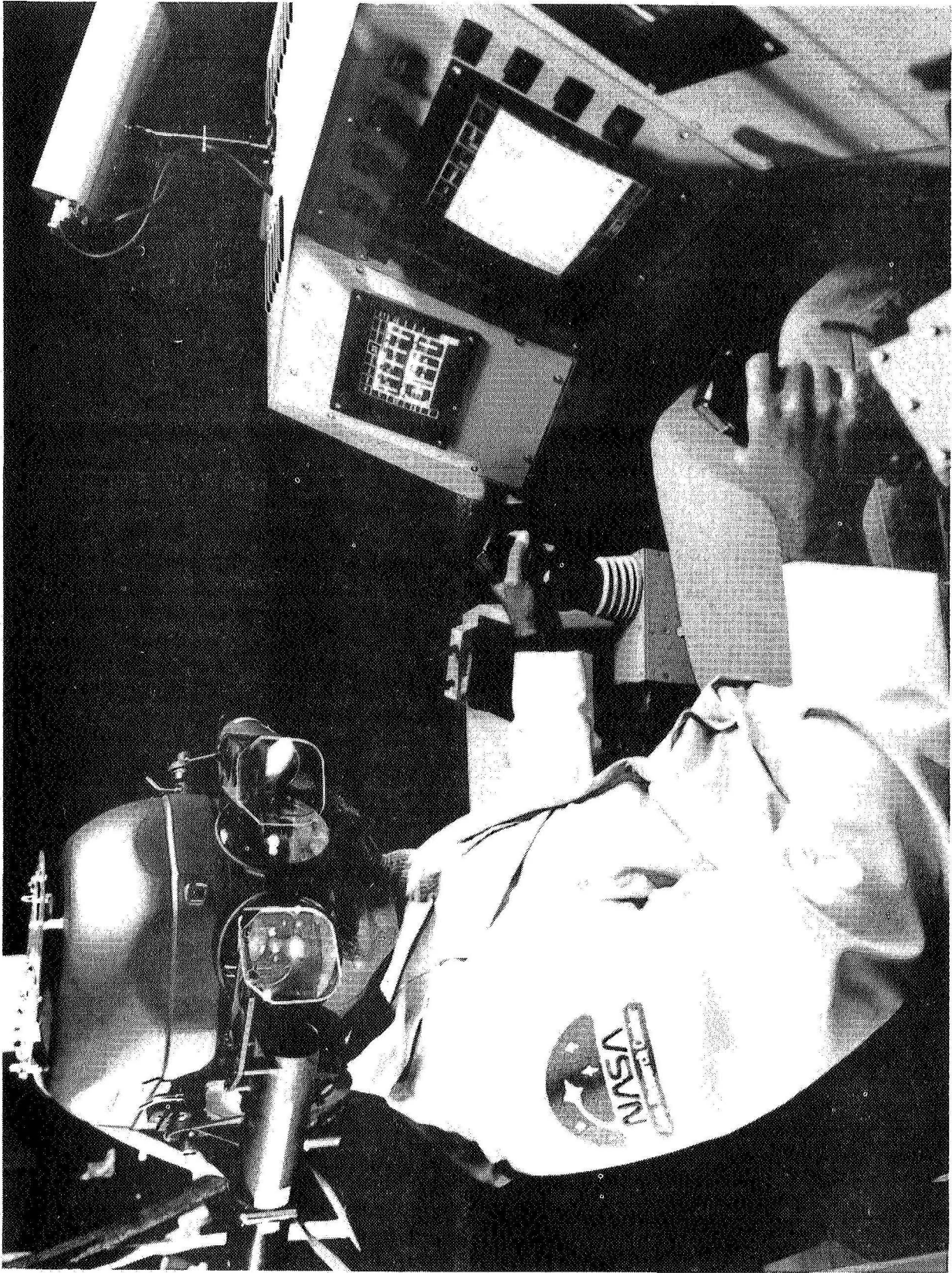


Figure 6. Crew Station Research and Development Facility.

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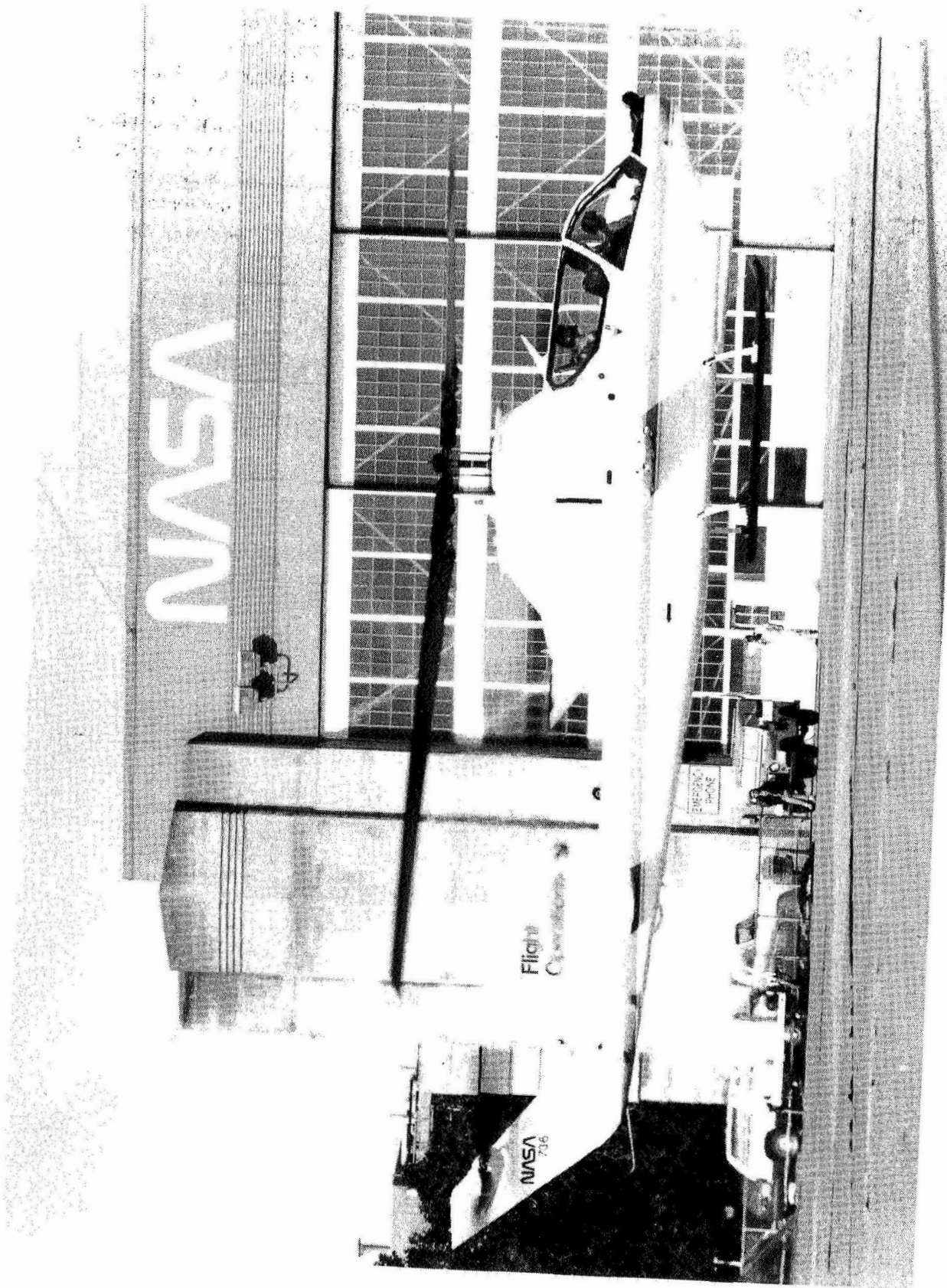
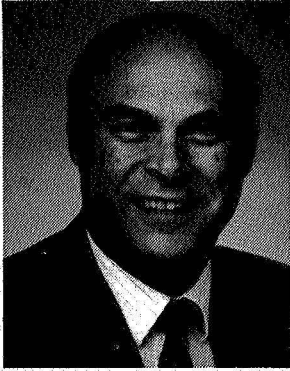


Figure 7. TH-1S Cobra.

WELCOME



C. Thomas Snyder has been Director of Aerospace Systems at NASA Ames Research Center, Moffett Field, California, since 1985. He is responsible for a broad program of research and technology development in the areas of advanced aircraft concepts and systems, human-machine system integration, and automated systems. Mr. Snyder also has operational responsibility for the National Full-Scale Aerodynamics Complex and major simulation facilities. He has a master of science degree in aeronautics and astronautics and the degree of Engineer in Aeronautics and Astronautics from Stanford University. Mr. Snyder is a former member of the Board of Directors of the American Helicopter Society, and was the 1986 recipient of NASA's Exceptional Service Medal.

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KEYNOTE ADDRESS

JAMES D. ERICKSON

I must admit I am new at this business of keynote addressing, but when I was asked to speak at this workshop I gladly accepted. I like to talk about things that I have strong personal feelings about, and simulation is certainly a subject that qualifies.

I always like coming out here to Ames. I like to see the latest and greatest in tomorrow's technology, and I like to see advanced hardware, hardware that really flies and really performs. I like being in and around the R&D community. It is always interesting, it is always inspiring, and it is always exciting to be with R&D people and to hear people like Tom Snyder tell us what state the technology is in. I know a lot of you work in R&D-related jobs as well.

One of the things that I learned is that if you take material from only one source, it's called plagiarism, but if you take it from several sources, it's research. I have learned, too, that without management support you cannot implement programs that make all the sense in the world and that with management support you can implement programs that make no sense at all. And that is not at all unique to the R&D community.

I want to concentrate on three things while I am here: (1) how far the business of rotor simulation has come, (2) what are some reasons why it is not where the transport airplane simulation is, at least in terms of use, and (3) what are we trying to accomplish here. I think sometimes when you are frustrated by the inability to make progress as fast as you think you should, it is particularly useful to reflect back on what has been accomplished.

I remember my first exposure to simulators. It was in 1961, a fixed-wing aircraft, fixed-based T-37 simulator. Thirty years ago! I thought it was the neatest thing I had ever seen. I had had a couple of rides in the aircraft and I thought this thing was magic, it was so real. And believe me, a fixed-base simulator can be real. I don't know how much motor sensing is provided by the eyes; I am sure some of you here can tell me that, but I think it is a very high percentage. And let me tell you about a personal

experience. It's a true story, a little story about Jack Cayot. Jack is a past manager of the FAA office here at Ames. He managed the office for many, many years. He was a person with a flight-test background like me and Ed Boothe. I happened to be out here flying on a simulator program several years ago and Jack was so excited, because NASA had the first daylight four-tube visual display that had been developed for rotorcraft. There were three tubes across the front, one in your direct field of view, one to give you a little more perception forward, the side one for lateral sensing. But the fourth tube was the real key, it was focused downward to provide contact with the surface, something that rotorcraft pilots can understand. Revolutionary stuff back then.

Unfortunately, it had not been put on a motion simulator yet, and it was sitting on the floor of a very large storage room downstairs in the simulator building. Jack kept apologizing because it was a fixed-based system. He kept saying, "I wish we would let you see it on a motion system." Well, when we got down to the simulator, I got in. I got the thing into the air, manipulated the controls for a while, and made a couple of patterns around the airfield that they had there. Even though the pictures were kind of cartoonish, I was amazed at how much I felt I was really in a helicopter.

One test of my burgeoning pilot skills at that point was to do sideward flight. I positioned myself in front of a row of hangars and started doing sideward flight, faster and faster toward the left. I was right in front of a row of hangars and there was a lot of detail on those hangars; you could see knobs and doors and windows, that sort of thing.

The four-tube visual display took a lot of computer capacity in terms of the computers of that era. It so happened that the control drivers for the control system for the simulator also came from the same computer network. Things were flashing by the window at a pretty good clip, and if I had known a little bit more about computers I

would have surmised this was eating up a whole lot of computer capacity, but I didn't.

When it came time to begin slowing down there was no response. I started moving the controls toward the hover position, back to the right. But things just kept progressing faster and faster to the left. Soon the controls were against the full right stop and still we went faster. I was okay, because every once in a while I looked around the room, looked at the concrete floor and at all the junk piled around the room. Jack was standing directly behind me. He was holding onto the seat, looking over the seat to coach me through this new bit of technology. When I looked back to show everyone that the stick was full right and that we were still moving faster and faster to the left, I saw a panic-stricken Jack Cayot holding onto the back of the seat with terror on his face, genuine terror, and standing in a body position preparing for a crash. It looked kind of silly. Here I was looking back at a man with years of flying and testing experience standing on a concrete floor in a room piled full of junk preparing to crash. I will never forget it. It was powerful evidence to me of the very great power of visual systems.

Getting back to the T-37 simulator I flew 30 years ago, I thought it flew remarkably well. The technology existed back then, minus the visual systems to simulate instrument control motions and noise so that you thought you were flying the real aircraft. There were vacuum tubes and big rooms were needed to hold them, but the basic technology was the same.

The other day a pilot said to me, "You know, these helicopters are starting to fly like simulators." These helicopters are starting to fly like simulators. That says to me that we have come a long way. I don't know if that man was saying that artificial control systems are making aircraft sort of feel artificial, or that the simulators are just getting better and getting more like the aircraft. I failed to ask him. But simulators are now able to fly very much like the aircraft. Why, we are even effectively using simulators to design an aircraft's control system before the aircraft ever flies. Who could have thought 30 years ago that we could be doing that?

But I would argue that today's simulators are valuable tools even if they did not fly like the aircraft. It is important that you know the value of what you have. Like the story of two ladies walking along a Fort Worth sidewalk. This is a true story. I am from Fort Worth. They are walking along when a frog jumps out in front of them. They tried to get around the creature but he said, "Don't pass me by. Kiss me and I will turn into a Texas oil man."

One of the ladies picked him up, put him in her purse and closed the purse. The other young lady said, "Aren't you going to kiss him?" "Heck no," the other one said, "a talking frog is worth a lot more than a Texas oil man."

So you have to recognize the value of what you have. Several pilots have said that FlightSafety's 222 simulator does not fly like the aircraft, and I guess I have contributed a few comments like that myself. That does not mean the simulator is not a very valuable training tool, or that it is not a valuable simulator. The simulators today have a wonderful capability to not only simulate but to surpass or to extend what is possible in the aircraft. Let me explain.

There are diabolical training scenarios known to rotorcraft pilots who have flown simulators that cannot be duplicated anywhere else. Things like critical instrument failures, high-side governor failures on twins, twin-rotor failures, progressive engine and transmission failure, those kinds of things. Failures like these cannot be set up with any degree of credibility and safety in the aircraft. But a simulator can actually give the pilot the opportunity to experience something very close to real-world symptoms and real-world conditions, and to train the real-world motor skills necessary to deal with such problems should they occur in the aircraft. With today's simulators you can equip the pilot to recognize and deal with symptoms that he or she would otherwise see in the aircraft for the first time only under actual emergency conditions. What a marvelous tool. You can give crews the experience base to deal with these situations before they ever happen in the real world. How many of you are rotorcraft pilots? Oh, my goodness. You could have a pilot's convention here.

In my experience there is nothing quite like a high-side governor failure in a twin-engine rotorcraft. For those of you who are not pilots, let me explain. In a twin-engine rotorcraft, the two engines share the job of powering the rotor. If a high-side governor fails, one of the engines loses its governing capability and begins to put in excess power. When the good engine senses that the other engine is overspeeding the rotor, it begins to decrease its torque and power. Now, if the pilot isn't paying close attention, the initial symptoms can cause him to think there has been an engine failure. As a result, he will treat the good engine instead of treating the engine that has had the failure. Experiencing such a failure in a simulator, and talking it over with the crew and with the instructor, can prepare a pilot for the real thing, even for something as subtle as a high-side governor failure. Simulators are great tools. I think we all agree with that. But I probably need to add

that some rotorcraft simulators do fly just like the real aircraft. I had a testimonial to that from Jack Hart this morning about one of those simulators and how good the fidelity really is. But back to one of the issues I promised to talk about: Why hasn't rotorcraft simulation progressed to the same level of development and use as transport airplane simulation?

I think there are a couple of simple answers to that question. Up until 15 years ago, an IFR flight in a civil helicopter was almost unheard of. Sure, the military was doing it, because you don't prepare to fight a war only on clear days. Even in the military, however, IFR was the exception, not the rule. So the commitment to simulation of rotary-wing flight came much later than it did in the commercial airlines where IFR for every aircraft and for every crew was a necessary condition for doing everyday business.

The fixed-wing pilots were taught IFR flying at an early stage, particularly in the military. Those who transitioned to rotorcraft brought IFR skills with them. But today there are many civil helicopter pilots who do not have instrument ratings. Many of the civil missions are utility VFR applications for which an IFR simulator has only limited value. Thus, the late start in rotorcraft simulation: the lack of a mission that demanded IFR capabilities on every flight, particularly on the civil side.

I think we have to remember that the fixed-wing experience is out there as a benchmark for us and, needless to say, we have to be alert so that lessons learned in transport airplane instrumentation in use of simulators are not repeated. The technology is on hand. Pilots report that the XV-15, the S-76, and V-22 all have excellent fidelity. It's not a matter of mastering the technology to make the devices fly like real aircraft. I said earlier that we were pretty much on our way with the T-37 simulators many years ago. That technology was brought forward very effectively by the military programs and by all the military pilots who were trained with those marvelous machines many, many years ago. The job has been handled well in terms of technical development, but the technology has not been able to master and reduce the cost of simulation.

I believe there are great opportunities to lower the cost of simulation. I don't have the answers, but I do know that if Jack Cayot could be convinced he was about to crash while standing on a concrete floor in a store room, there are possibilities for decreasing the cost of motion systems. I do know that as long as simulators cost more than the aircraft they are simulating, there will be an economic disincentive to simulation. I know, too, that we are making wonderful advances in every area of electrical and digital technology so that there are opportunities on the horizon for reducing the cost of everything that the pilot sees in simulation. I know that there is a lot we can do, and that what we can do in this area is inherently good for the advancement of the state of the art of rotorcraft simulation. And it will lead us to a point where everyone can afford to send every pilot through simulator training on a regular basis. There is a challenge and an opportunity here. There is a challenge that I would make to each and every one of you: when talking technology over the next three days, include the word "cost" somewhere in your thoughts. I am not sure we always do that. And it is my opinion that that is where many of the opportunities lie. We have come a very long way in mastering the technology and in articulating the standards for design. The opportunity is in mastering the cost of those technologies and managing the costs imposed by the standards that we require.

I would like to say just a couple of words in support of Ed Boothe's public meeting, which I understand is going to be on Thursday. We in the FAA really seriously need your thoughts and your best words and your wisdom on that activity. It is important that we in government not make decisions in the dark. When we do, they are inherently bad decisions. Please come to that meeting prepared, and please express your thoughts in the meeting. The FAA is counting on you.

I hope each of you has an exciting and productive conference. In glancing over the agenda this morning I saw a whole variety of interesting subjects dealing with people, technology, theory, equipment, and standards. I am anxious to hear the presentations and I look forward to meeting many of you while I'm here.

KEYNOTE



James D. Erickson is manager of the FAA's Southwest Region Rotorcraft Directorate. He has served as assistant manager of the Southwest Region Rotorcraft Directorate, as manager of the Southwest Region Helicopter Certification Branch, and as flight test pilot for the Southeast Region Engineering and Manufacturing Branch. Mr. Erickson is a graduate of the Air Force Academy and of the Air Force Test Pilot School, and holds the Airline Transport Pilot Certificate. He is a member of the American Helicopter Society.