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

Hardware components of the Advanced Simulator for Pilot Training (ASPT) were studied during this period and an interim technical report was issued. An examination of the ASPT platform motion system was accomplished and reported to a special Scientific Advisory Board convened to study the procurement of motion bases for upcoming training simulators. This work was additionally benefitial to the AFHRL/FT conversion of one ASPT-37 cockpit to an A-10 configuration. A paper entitled "Advance Simulation for New Aircraft" was presented at the 11th NTEC/Industry Conference on 15 November 1978.

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DEPARTMENT OF THE AIR FORCE
AFHRL FLYING TRAINING DIVISION (AFSC)
WILLIAMS AIR FORCE BASE, ARIZONA 85224

REPLY TO ATTN OF: FTE

6 February 1979

SUBJECT: Final Report AFOSR Grant ~~#77-0684~~ AFOSR-77-3245

TO: AFOSR/XO (Col Robert Sigethy)

Enclosed is a copy of the paper "Advanced Simulation for New Aircraft," by Michael L. Cyrus and Laurence E. Fogarty. The paper was presented by Dr Fogarty at the 11th NTEC/Industry Conference on 15 November 1978. This paper, together with my interim report constitutes the final report for Grant No. ~~77-0684~~. AFOSR-77-3245

L. E. Fogarty
L. E. FOGARTY

AFOSR-TR- 89-0887

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ADVANCED SIMULATION FOR NEW AIRCRAFT

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Air Force Human Resources Laboratory
Williams Air Force Base, Arizona

ABSTRACT

The traditional procurement process for new military aircraft simulators results in a long, costly, and dangerous delay in availability of training equipment, after introduction of the aircraft. The Advanced Simulator for Pilot Training (ASPT) of the Human Resources Laboratory, Flying Training Division has been modified to provide early simulation of the A-10 and F-16 aircraft. The resulting advance in A-10 program development has been dramatic. Although not yet fully operational, the ASPT F-16 simulation will provide at least comparable benefits for F-16 training program development. The ASPT modification program demonstrates a reasonable method of greatly improving availability and effectiveness of simulator training programs.

THE PROBLEM

Military aircraft simulators, more aptly described as weapon system trainers, are an integral part of the modern operational flight training system. These devices provide the capability to acquire (and practice) outside the aircraft, skills, both cognitive and motor, critical to the successful completion of tasks ranging from aircraft transition training to advanced weapons delivery and air-to-air combat; however, current simulator procurement schedules seriously limit simulator design and effective utilization within the overall training program. At present, the time delay from the initial integration of the aircraft into the operational inventory until the corresponding simulator system is available for training is normally about five years. This lag adversely affects not only the energy, equipment, and manpower costs within the operational training schedule, but also the design of the weapon system trainer itself. Virtually every important simulator (and syllabus) design decision must be based on experience, judgement, or guesswork - everything except concrete evidence founded upon first-hand knowledge. Although simulation is widely used during preliminary engineering design and aircraft development, these simulations are not suitable for training system development. These inputs are provided during the first few years of operational development of a given aircraft, when often by trial and error, marked at times by loss of life, training problems are gradually eliminated. We believe that this dangerous transition period can be eliminated by using a training system development simulator. A reasonable simulation of the new aircraft coincident with operational deployment could be used to address training issues, as well as simulator design issues prior to their requirement for use.

SOLUTION

The solution to this problem involves, as we see it, the following organizational and engineering elements:

a. A simulation facility (or combination of facilities) with sufficient potential to construct, in a short period of time, reasonable models of a wide variety of aircraft and aircraft task environments.

b. A close cooperation between the aircraft development group, the Command Instructional System Development team, the simulator manufacturer having responsibility for the final weapon

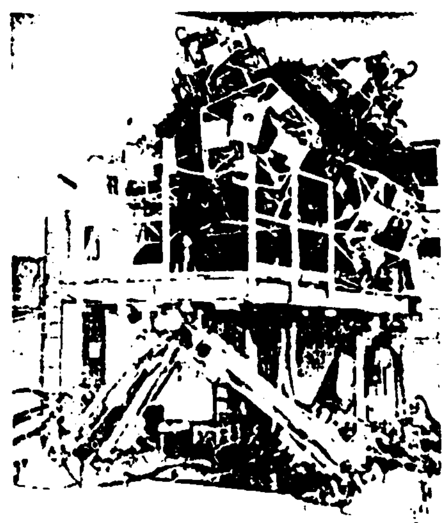


FIGURE 1.
ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT), SHOWING 60 INCH, SIX DEGREE OF FREEDOM, SYNERGISTIC PLATFORM MOTION SYSTEM AND WRAPAROUND COMPUTER IMAGE GENERATED VISUAL DISPLAY.

systems trainer, and the designated facility where the preliminary training and research will occur.

The simulation facility should support, as a minimum, the following basic systems:

(1) Flight dynamics.

(2) Basic aircraft instruments and controls.

(3) Wide field of view, high resolution visual.

The systems (1)-(3) are absolutely required in all critical aircraft tasks. Additionally, to be effective, a research facility should have most or all of the following:

(4) Six degrees of freedom motion.

(5) G seat.

(6) G suit.

(7) Other Aircraft/Environment systems such as sound, navigation, communication, hydraulics, etc.

(8) An advanced instructor-operator station with automated student performance measures.

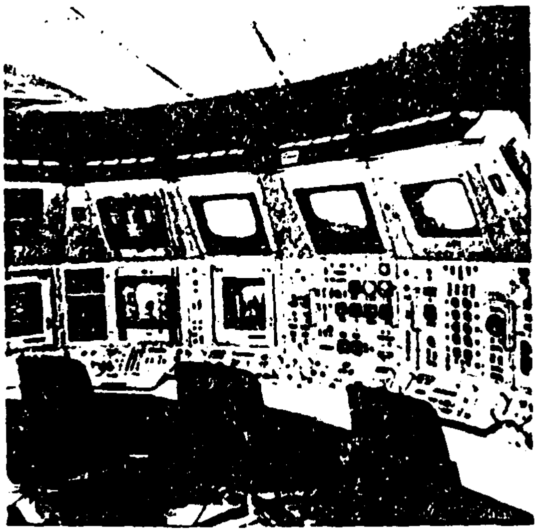


FIGURE 2.

ASPT ADVANCED INSTRUCTOR OPERATION. THROUGH THIS STATION, THE RESEARCHER CONTROLS THE ASPT SIMULATION EXPERIMENTATION. USING ALPHANUMERIC, VECTOR GENERAL GRAPHICS DISPLAYS, AND A WIDE VARIETY OF INSTRUMENTS, RECORDERS AND CONTROLS, ENTIRE MISSION PROFILES CAN BE CAREFULLY CONTROLLED.

The HRL ASPT has all of these features and is admirably suited for training program research and development,(Figures 1-6.)

Most important of all, the facility should have an extensive performance measurement capability backed by sufficient computer capacity to support such special research requirements specific to a given operational aircraft.

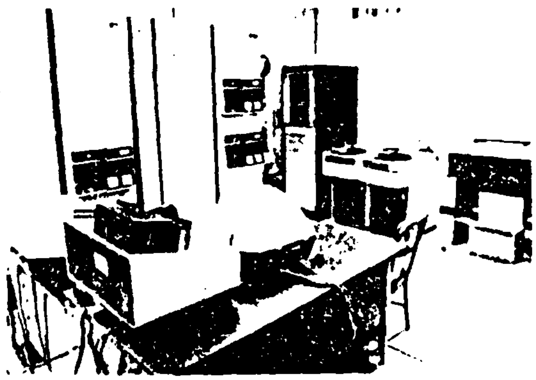


FIGURE 3.

DISTRIBUTED PROCESSOR SIMULATION SYSTEM. THIS COMPUTATIONAL NETWORK PROVIDES THE CAPABILITY FOR AN AIRCRAFT/ENVIRONMENTAL SIMULATION AT A MINIMUM OF 30 HZ FOR ALL AEROSPACE VEHICLES EXCEPTING CERTAIN HELICOPTER SIMULATIONS, WHILE PROVIDING SUFFICIENT BACKGROUND TIME TO SUPPORT PARALLEL RESEARCH AND ENGINEERING DEVELOPMENT CAPABILITY.

Care must be taken to limit the scope of the simulation development. Because the timing of the research is critical to the vitality of the entire projects, we recommend a multiphase effort based on the critical task approach. Within this philosophy, the Phase I simulation would be a "no frills" model capable of performing, say, transition tasks. Only those instruments, controls, and accessory equipment essential to the accomplishment of the Phase I objectives need be simulated.

PAYOFFS

The payoffs associated with this approach, as we see them, are direct force readiness, as measured by the capability of a group of pilots to perform their assigned mission, will be greatly increased. Transition training will be safer and more efficient. Emergency situation training, perhaps impossible to practice safely in the aircraft, can be provided in the simulator. The greatest areas of training payoff will naturally be associated with the principally cognitive tasks (such as those in air-to-air or air-to-surface attack). In addition to the enhanced safety and improved training, large amounts of fuel, manpower, and equipment dollars will be conserved, a real bonus for the operational commander. At the same time, research payoffs will be equally great. Major design considerations for the weapon systems trainer can be fully determined and this information provided to the simulator contractor. High-cost hardware issues, such as visual system design, instructor operator station design, and even motion cueing systems alternatives, can be effectively determined. At the same time, issues related to both simulator and aircraft utilization for operational training, including syllabus development, course content, task sequencing, development and validation of performance assessment measures will be possible.

RESULTS

To date, the Flying Training Division, Air Force Human Resources Laboratory, has successfully applied the approach outlined in this paper to the A-10 aircraft, using the ASPT as the development simulator, and is preparing a similar effort for the F-16 aircraft. The A-10 Phase I simulation on the ASPT, while austere, has been successful. In general terms, the objectives of the ASPT A-10 Phase I conversion were:

(1) To provide interim transition training for A-10 pilots in the period before delivery of the A-10 WST.

(2) To provide introductory surface attack training during the same period.

(3) To assess advanced training features of the ASPT instructor-operator console for possible adaptation to future fighter/attack simulators.

(4) To develop automated objective performance measures of fighter/attack pilot performance.

(5) To develop the A-10 simulator training program and provide hands on experience for A-10 simulator instructor pilots.

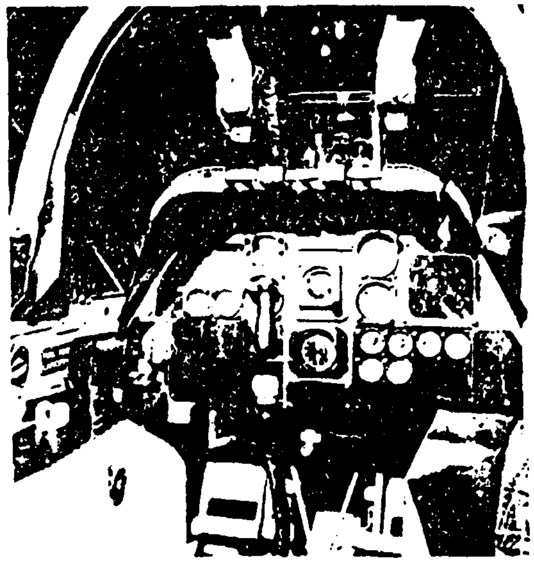


FIGURE 4.

ASPT/A-10 PHASE I COCKPIT SIMULATION. THIS PICTURE DEMONSTRATES THE LEVEL OF SIMULATION REQUIRED TO ACHIEVE TRANSFER OF TRAINING GOALS FOR PHASE I. PICTURED ELEMENTS INCLUDE PRINCIPAL AIRCRAFT CONTROLS, INSTRUMENTS, AND HEADS UP DISPLAY.

All of these objectives were met satisfactorily; in most cases, results were considerably better than were expected from the rather austere Phase I simulation.

TRANSITION TRAINING

By May 1978, 17 B course students had received transition training in the ASPT A-10. All of these pilots successfully transitioned into the airplane. Although numbers are too small for statistical significance at this time, it appears that the ASPT trained pilots are the equivalent of about two aircraft sorties ahead of where they would be without ASPT training. This undoubtedly is at least partially due to the extensive cooperative effort by instructor pilots from Davis-Monthan AFB and AFHRL engineers to assure that the A-10 performance and handling qualities were as faithfully simulated as available data would permit.

The transition training results for the first class were:

(1) Of 47 rides, only one failed.

(2) In the first 67 rides, there were no unsatisfactory patterns or landings.

(3) In the first 67 rides:
50% rated 01 (Fully Qualified).
50% rated 02 (Qualified with Additional Training).

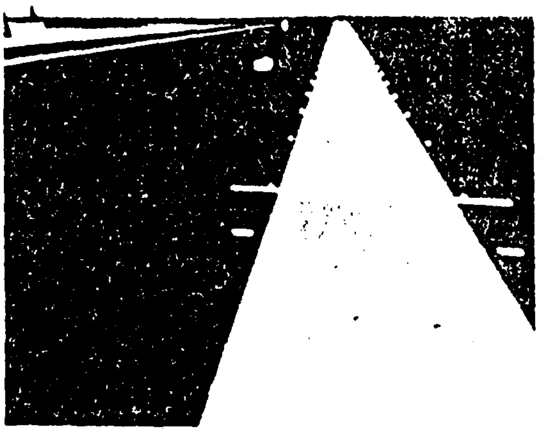


FIGURE 5.

ASPT PHASE I RUNWAY SIMULATION. THIS AUSTERE DATA BASE SHOWS THE LEVEL OF DETAIL REQUIRED FOR SUCCESSFUL TRANSITION TRAINING FOR THE A-10 PROGRAM.

INTRODUCTORY SURFACE ATTACK TRAINING

Results of the introductory surface attack training are spectacular. The ASPT A-10 proved to be exceptionally effective for bomb and gunnery range instruction - in fact, the simulator is more effective, sortie for sortie, than the airplane.

The surface attack training results for the first class are:

Event	Needed to Qualify (CEP)	First Class Average (CEP)
30 Deg Dive Bomb	140'	80'
20 Deg	175'	65'

A number of factors probably contribute to the high effectiveness of the ASPT A-10. Prerecorded demonstration runs show the student exactly how to

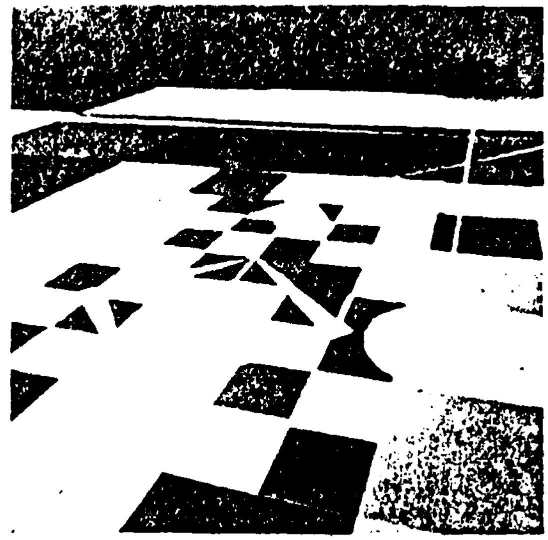


FIGURE 6.

CONVENTIONAL BOMBING RANGE. THIS PICTURE SHOWS THE APPROXIMATE LEVEL OF DETAIL REQUIRED TO TRAIN CONVENTIONAL BOMBING TASKS.

achieve best results. Using freeze and reset features, many more practice runs are possible in the simulator than in the airplane. The student is immediately informed of the results of each run, as well as the exact conditions that existed at release time.

ADVANCED TRAINING FEATURES

As mentioned above, the ability to record and play back demonstration flights appears to have great training value, particularly for single seat aircraft such as the A-10. The related capability to record a student flight and play it back later for a critique also seems to have great promise.

The ability to freeze the action at any point and to reset rapidly to chosen initial conditions allows concentrated practice and assessment of procedural errors.

Use of automated performance measures (discussed below) assures objective evaluation of performance.

A number of such training features were evaluated during the ASPT A-10 Phase I, and recommendations for future fighter/attack simulators are being developed. This research will continue during Phase II. Evaluation of the training value of such features as "faster than real-time" operation and special training displays such as continuous display of impact point is under consideration.

AUTOMATED PERFORMANCE MEASURES

There are many reasons for developing automated measures of student performance:

(1) The student is assured of accurate, impersonal, objective assessment of his performance.

(2) Many more aspects of performance can be evaluated automatically than is possible for a single instructor pilot.

(3) Instructor pilot workload is eased, permitting him to devote his attention to instructional duties.

In general, performance measures must be specially developed for each aircraft and each task. Following is a list of A-10 tasks for which automated performance measures have been developed and used:

A-10 PERFORMANCE MEASUREMENT TASKS

TRANSITION

Takeoff, climb and level off
Slow Flight
Lazy 8, Aileron Roll (clean & 40% speedbrake)
Loop, Cuban 8, Split S
Simulated flameout pattern
Straight-in pattern
Normal overhead (360°) pattern
Closed normal pattern
Closed no flap pattern
Closed simulated single engine pattern
Re-entry to normal overhead pattern

AIR-TO-GROUND

30 Degree Dive Bomb
20 Degree Low-Angle Low-Drag Bomb
15 Degree Low-Angle
Low-Angle Strafe
High-Angle Strafe
Low-Angle Low-Drag Pop-Up
Low-Angle Pop-Up
Low-Angle Strafe Pop-Up
Hung Bomb Pattern

SIMULATOR TRAINING PROGRAM

At this time, the A-10 simulator training syllabus has been used with 17 students. Ten instructor pilots have participated in the training program. Without the ASPT A-10, this status would not have been achieved for at least two more years. Experience with an A-10 simulator including a full visual system would not be possible for at least five years. Thus the A-10 training program has been advanced by 2-5 years, with a very substantial improvement of the effectiveness of the A-10 aircraft.

CONCLUSIONS

We have presented, and to a large degree, tested and verified a managerial tool for solving the problem of time delay between the deployment of an operational aircraft and its corresponding weapon system trainer. This approach is seen to have large payoffs in terms of direct research and design benefits, as well as a positive impact force readiness, pilot safety, and fuel expenditure. We have restrained throughout this discussion from detailing any particular potential engineering mechanization of this plan, as such a mechanization depends primarily on the aircraft (or system) simulated and the engineering characteristics and capability of the host facility. We feel that the procedure presented is a natural extension of the use of simulation to solve training problems and, as such, should become a permanent part of all future aircraft development and deployment schedules.

77-3245

Interim Report of Activity on AFOSR Grant ~~#77-0604~~, L. E. Fogarty

RECOMMENDATIONS FOR IMPROVEMENTS TO ASPT

Introduction.

The work statement of my grant requires that I "become familiar with the design and performance characteristics of ASUPT hardware and with the math models and software computational techniques used in simulating T-37 aircraft." When the grant work statement was written, emphasis was placed on undergraduate pilot training, T-37 simulation and particularly the performance of the ASUPT platform motion system. Since that time, there has been a considerable shift of emphasis: The word "undergraduate" has been removed from the title acronym which now is ASPT. A complex of eight T-37 and T-38 simulators has been activated here at Williams AFB so that T-37 simulation research is not limited to ASPT as it once was, and force cueing by means of platform motion is being examined independently by a number of investigators. As a consequence, Col Boren suggested that I should not emphasize T-37 simulation and ASPT platform motion in my study, but instead should emphasize the probable future uses of ASPT and should be particularly concerned with future Air Force training problems such as those that will be associated with T-37 replacement aircraft, and with the new fighter/attack aircraft. In essence, he suggested that I should "become familiar with the design and performance characteristics of ASPT hardware and with the math models and software computational techniques that should be used in simulating newer Air Force aircraft."

As a useful means of doing this, I have been working with HRL to develop a simulation of the A-10A aircraft, using one unit of ASPT as a basis. The A-10 simulation development effort has been very successful. (See the attached letters from Maj Gen Ellis and Maj Gen Hendricks.) As a consequence of my participation in the ASPT A-10 project, I have gained some familiarity with the performance characteristics of ASPT hardware and software. I have a number of recommendations for improvements to ASPT. All of these, as I believe they should be, are in response to specific training research needs that have been generated by the ASPT A-10 project.

ASPT HARDWARE

As mentioned in the introduction to this report, my grant statement of work particularly emphasized a study of the characteristics of ASPT platform motion, so I will discuss motion at greater length than I will other aspects of the ASPT system.

The grant work statement (which is an offer to have ASPT motion system studied by an independent "expert") was generated by the continual controversy over the merits--or lack thereof--of platform motion for simulator flight training. A number of training studies which were conducted at HRL/FT using ASPT motion had failed to show any beneficial effect of motion on the training. The results were questioned on the basis of imperfections in the ASPT motion system. The tautological statement "If benefits are not shown, the motion system is not good enough" can hardly be refuted, so the prime objective of the grant probably can't be achieved positively and directly. The motion system controversy will continue and the question will arise again and again, particularly among the uninformed.

Fortunately, the results of many years of training with and without motion, and of many studies specifically directed at simulator motion, including those from HRL, are beginning to make sense. In a separate report, I will furnish a more complete discussion of platform motion than is possible here. This discussion necessarily will be brief--just enough to clarify the reasons for my recommendations as to ASPT platform motion.

Review of Motion Findings Interpretation.

The accumulated evidence of many years of simulator flying training and research supports the opinion that for most flying training purposes, there is no measurable benefit of platform motion. On the other hand, there are studies which show that in some cases there are beneficial effects of platform motion.

In order to be more specific and to try to indicate the types of training tasks that might benefit from platform motion, we adopt the motion classification scheme proposed by Gundry (G1, G2) and used by Caro (C1). Gundry distinguishes between motion that results from pilot control actions, which he calls maneuver motion and motion due to external influences (such as turbulence or failure of an aircraft component) which he calls disturbance motion. It appears that if the flying training task is to learn to maneuver a stable, easily controllable airplane--such as a T-37--then maneuver motion cues are of little consequence. Thus, the HRL/FT ASPT results, and the success of the many thousands of hours of fixed base simulator training, are understandable. It appears that maneuver motion cues probably are measurably beneficial if the control task is difficult and requires that the operator introduce significant lead into his control actions. Such tasks are the "critical control task," the unstable system control task used by Young, et al (Y1), or helicopter hovering--again, control of an unstable system. All of the studies which show appreciable benefit of maneuver motion cues involve control of such a system.

Disturbance motion cues can have profound effects on pilot control actions and on training transfer. In fact, it seems that it might be beneficial to subclassify disturbance motion according to these effects.

One effect of disturbance motion is to alert the operator to the fact that an external force has influenced the control task. Such effects as sudden asymmetrical yaw due to loss of an engine, roll due to asymmetrical external stores configuration, pitch due to runaway trim, etc., alert the operator to contend with the external influence. One would naturally call such motions alerting disturbances.

A second type of disturbance is that due to turbulence. In this case, the disturbance is not correlated with an event that must be countered but still there may be a very significant effect on operator task loading and on the difficulty of the control task. One would naturally call such motions loading disturbances. An unanswered question is the degree to which loading disturbance might change the effects of maneuver motion cues on control of an unstable system.

With the previous discussion in mind, we can now describe some essential performance characteristics of a platform motion system for general flying training research.

1. The system must have very good small motion frequency response to provide correct maneuver motion cues in those cases where they are needed. In general, the cues are needed for control of an unstable system, the degree of instability and system natural frequency being related. Due to human operator control capability, the small motion frequency response should be good out to several hertz.

2. What the large motion characteristics should be is not so clear--as far as ASPT is concerned, we can beg the question, since ASPT motion system amplitude already is fixed. If small motion response is good enough, probably the large motion response will be adequate.

The measured small motion performance of the ASPT motion system is shown in Figures 1 and 2.

Recommended Improvements to ASPT Motion System

The small motion performance of the platform motion system is determined by the iteration rate of the computer system, by the motion algorithm (the "washout" scheme) and by the frequency response of the motion hardware. I believe that the ASPT system should be improved in all three respects:

1. Iteration rate

It has for some time been recognized that the present iteration rate of 7.5/sec is quite inadequate. On the basis of recommendation by the Scientific Advisory Board, the rate is being increased to 30 i.p.s. (The change will be completed in Mid-1978.). This will provide good computation frequency response up to about 3 hz. Because it would be relatively easy to increase the iteration rate to 60 i.p.s. while the computer change project is active, I recommend that it should be done, to provide a wide margin in which computation rate will not cause system response problems, and to provide the possibility of software compensation for hardware characteristics.

2. Motion Algorithm

The present translational "washout" algorithm works as follows:

For very small commanded motions of the aircraft, the platform motion is intended to follow commanded aircraft motion. The motion computation includes two predictions: a prediction of the approach to hydraulic cylinder velocity limit and a prediction of the approach to hydraulic cylinder extension limit.

When the predicted velocity limit is reached, the commanded motion cue is terminated and the "washout" algorithm is commenced. A sinusoidal acceleration profile is imposed to reduce the cylinder velocity to zero and when the velocity reaches zero, a second sinusoidal acceleration profile is superimposed to return the cylinder extension to mid-point. The resulting measured acceleration profile is shown in Figures 3 and 4. It is seen that the resulting motion can be quite jerky.

It is recommended that the washout algorithm be changed to a simple type 0 linear transfer operator of either first or second order, to obtain smoother response.

3. Motion Hardware

There are available special low friction hydraulic cylinders that could be substituted for the ASPT cylinders but with an appreciable improvement of smooth performance. It is recommended that this change be investigated further.

ASPT A-10A Research Plan Justification of Motion System Improvements

We have received a request from the Simulator SPO for HRL to furnish information about the training capability of the A-10A OFT which will be delivered in 1979.

The A-10 airplane is equipped with two hydraulic systems to power the airplane flight controls. If one hydraulic system is lost, the other provides somewhat reduced control capability and if both are lost, the airplane still can be flown but with drastically reduced control capability. In full manual reversion, the airplane is quite difficult to fly under certain conditions.

Obviously, it is very important to provide pilot training in flight with hydraulic power lost and HRL has been requested by TAC OTD to furnish this capability. The question raised by the SPO is whether the A-10 OFT will be capable of providing such training. The OFT will have a limited (single window, night only) visual system and no platform motion. The very difficult manual reversion control task faced by the pilot well may be exactly the sort of task that benefits from platform motion cues (both maneuver and disturbance cues could be important) and a panoramic visual display. The ASPT A-10A can begin to provide answers to such important questions after the "Category I" engineering developments listed in the ASPT A-10A research plan have been accomplished. These include the above improvements to the motion system.

Visual System

The most striking feature of ASPT is the panoramic visual system which immediately impresses one as furnishing a startling improvement over other types of visual systems. After observing it in use for nearly a year, I still retain that impression but also am now aware of a number of system limitations and deficiencies that should be eliminated or improved as soon as possible.

Some major limitations or deficiencies of the ASPT visual system are:

1. Reliability. The visual system, particularly the special purpose computer of the CIG system, accounts for the majority of ASPT down time. Because of the importance of training research results to the Air Force, an attempt should be made to improve reliability beyond the present 90% up time.

2. There are insufficient height cues for flight near the ground due to lack of adequate texturing capability.

3. Resolution of the scene presented is not sufficient for some purposes.

4. The scene represented is monochrome, so research in effects of chromaticity is impossible.

For A-10 training research, all of these limitations are important.

The A-10A combat mission will be conducted at very low altitude. There is no firm data concerning the altitude cue requirements needed to conduct simulator training at very low altitudes. Similarly, there is no firm data concerning the resolution required for long-range detection of enemy aircraft attitude changes or for identification of ground targets. Probably color is required for training in camouflaged target identification but again, there is no reliable experimental data.

Project 2360, Fighter/Attack Simulator Visual System, is intended to develop the visual system for the A-10 and F-16 simulators. The specifications of 2360 generally were arrived at by considering the resolution, texturing and color requirements thought to be needed for air-to-air and air-to-surface combat. (At this time, no manufacturer can meet these requirements, at any price.) Obviously, there is an urgent need for experimental data about the effects of resolution, texture and chromaticity on training effectiveness for both the A-10 and F-16 simulator programs.

The ASPT A-10A research plan includes studies of the effects of a number of visual system variables: field of view, texture, resolution and color. The results of these studies will be immediately applicable to procurement of the visual systems for A-10 and F-16 WST's. It is, of course, necessary to make major improvements in the ASPT visual system in order to provide these research variables. This is a sizeable project that will need at least a year from official approval to accomplish.

Advanced Instructor-Operator Station

ASPT has two stations, a "conventional" station and an "advanced" station. The conventional station has severely limited capability--in particular, it is not possible to use automated performance measures or to control system parameters, initialization conditions, etc., from the conventional station. As a consequence, nearly all training research programs depend on use of the advanced IO station and therefore, only one ASPT unit can be controlled at one time. With the installation of an improved computer system for ASPT in mid-1978, it will be possible to operate the two ASPT simulators independently. A second advanced station is clearly desirable. The ASPT A-10A research plan includes replacement of the conventional IO station with one specifically configured for fighter/attack training research.

General Recommendation

One of the serious problems the armed services face when introducing new aircraft, such as the A-10 or the F-16, is that of transition training for the new airplane. For many reasons (among them flight safety, energy restrictions, and atmospheric pollution), great reliance must be placed on flight simulators for pilot training. Unfortunately, modern flight simulators are so complex that a simulator for a new airplane ordinarily is not available until about three or four years after the airplane enters service. During this long period, the advantages of flight simulation for pilot training and program development generally have not been available.

With the ASPT A-10 project, HRL/FT clearly demonstrated a way for major improvement in making flight simulators available early in the airplane program. In less than a year, HRL altered ASPT from one set of flight characteristics and cockpit configuration to another; from T-37 to A-10.

The conversion was made very quickly and economically and pilot training commenced 9 1/2 months after official go-ahead for the project was received. Nearly all of the hardware changes occurred in the physical arrangement of the cockpit, nearly all of the program changes occurred in aerodynamics and engine characteristics simulation and in the visual system data base (to represent a different visual environment).

In spite of the relatively limited changes, what was once a T-37 simulator is now an A-10 simulator and is being used very successfully for transition and introductory surface attack training and training research. The handling and performance characteristics of the A-10 are accurately represented, essential instruments and controls are simulated, the head-up display operates correctly and the CIG visual system has been reprogrammed to represent Davis-Monthan Air Force Base and the Gila Bend gunnery range.

Although the ASPT A-10A project is fulfilling a very important training function for the Air Force, the greatest value of the project is that it demonstrated how the Air Force can bridge the gap between aircraft and simulator availability. The staff and simulator systems of HRL/FT comprise the major portion of Air Force flying training research capability and should not be used for routine training. I believe very strongly that HRL capability should be updated and continuously expanded as training research needs dictate. I also believe that the need for both training research results and for introductory training is so great that the Air Force should reserve the FT facilities for research and also establish special facilities for early transition training.

In view of the lessons learned from the ASPT A-10 conversion, it would seem that the services might consider procuring a number of basic simulator systems that could be modified for use during early training and training program development. The basic system would consist of:

HARDWARE

Cockpit platform with limited motion system

CIG visual system

Instructor/operator console

Computer system and peripherals

A-D and D-A systems

SOFTWARE

Supervisory programs

Motion system program

A-D and D-A programs

CIG basic program with at least one standard data base

Instructor/operator programs with some performance measures

Skeleton aircraft equations of motion

Navigation and communication programs

The intent of the basic system is to furnish that large percent of the simulator that need not be peculiar to a given airplane.

A number of such basic systems could be installed at appropriate locations--for example, there could be one at the Air Force Flight Test Center (AFFTC) at Edwards AFB and one at the Naval Air Test Center (NATC) at Patuxent River Naval Air Station. Others should be installed, for example, at HRL/FT, Williams AFB, and at air bases that would be receiving new types of aircraft.

The simulator at AFFTC would be modified to represent the new airplane as flight test results become available. The simulator at HRL could use the AFFTC programs, and thereby allow related research and training program development.

With reasonable care to maintain system compatibility, the FTC and HRL programs could be transferred directly to the base that is to receive the new aircraft. Obviously, these same programs could be used by the OFT manufacturer.

With careful planning and coordination, it should be quite practical to have a good and useful aircraft simulation and a developed training program installed at the receiving base when the aircraft are first received.

REFERENCES

Since this is not a formal report, I have made no effort to prepare an extensive list of references. Important sources of information were unpublished summary reports by E. E. Eddowes and M. Cyrus of HRL. The references mentioned are:

C1 Caro, Paul W. Platform Motion and Simulator Training Effectiveness Proceedings. 10th NTEC/Industry Conference, Nov 15-17, 1977.

G1 Gundry, A.J. Thresholds to Roll Motion in a Flight Simulator. Paper presented at American Institute of Aeronautics and Astronautics Visual and Motion Simulation Conference. Dayton, Ohio, April 20-26, 1976.

G2 Gundry, A.J. Man and Motion Cues. Third Flight Simulation Symposium Proceedings. Royal Aeronautical Society, London, April 1976.

Y1 Young, L.

ASPT MOTION
HEAVE AXIS DYNAMIC PERFORMANCE

Phase Shift in Degrees with Actuator Displacement of 3.0 inches pk/pk

Cockpit	Leg No.	at 0.5 Hz Meas.	at 0.5 Hz Max Permitted	at 1.0 Hz Meas.	at 1.0 Hz Max Permitted	at 2.0 Hz Meas.	at 2.0 Hz Max Permitted
A	1	18	20.	30	45.	63.4	90.
A	2	18	20.	30	45.	63.4	90.
A	3	18	20.	30	45.	63.4	90.
A	4	18	20.	30	45.	63.4	90.
A	5	18	20.	30	45.	63.4	90.
A	6	18	20.	30	45.	63.4	90.
B	1	16.6	20.	30.6	45.	72	90.
B	2	16.5	20.	32.4	45.	72	90.
B	3	16.5	20.	30.6	45.	72	90.
B	4	16.2	20.	30.6	45.	72	90.
B	5	16.5	20.	32.4	45.	72	90.
B	6	16.5	20.	32.4	45.	72	90.

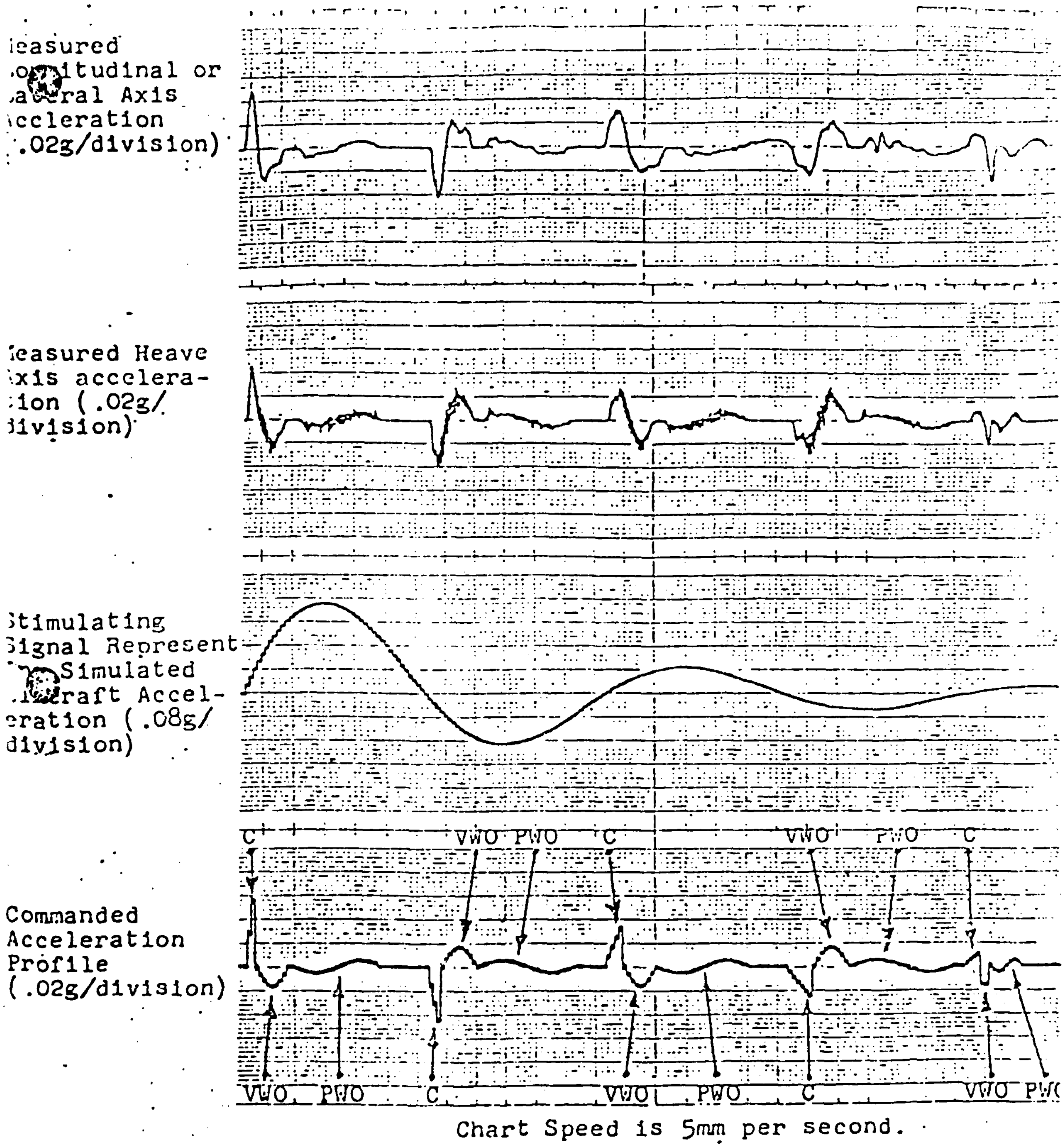
Figure 1

ASPT MOTION
YAW AXIS DYNAMIC PERFORMANCE

Phase Shift in Degrees with Actuator Displacement of 3.0 inches pk/pk

Cockpit	Leg No.	at 0.5 Hz Meas.	at 0.5 Hz Max Permitted	at 1.0 Hz Meas.	at 1.0 Hz Max Permitted	at 2.0 Hz Meas.	at 2.0 Hz Max Permitted
A	1	18	20.	32.4	45.	64.8	90.
A	2	18	20.	32.4	45.	64.8	90.
A	3	18	20.	32.4	45.	64.8	90.
A	4	18	20.	32.4	45.	64.8	90.
A	5	18	20.	32.4	45.	64.8	90.
A	6	18	20.	32.4	45.	64.8	90.
B	1	16.2	20.	30.6	45.	79.2	90.
B	2	13	20.	32.4	45.	65	90.
B	3	16.2	20.	30.6	45.	79	90.
B	4	16.2	20.	30.6	45.	79	90.
B	5	18	20.	32.4	45.	76	90.
B	6	18	20.	32.4	45.	79	90.

Figure 2



Legend:

C: Cue displayed
VWO: Velocity Washout
PWO: Position Washout

Figure 3 - Typical Translational Cues and Washout Profil

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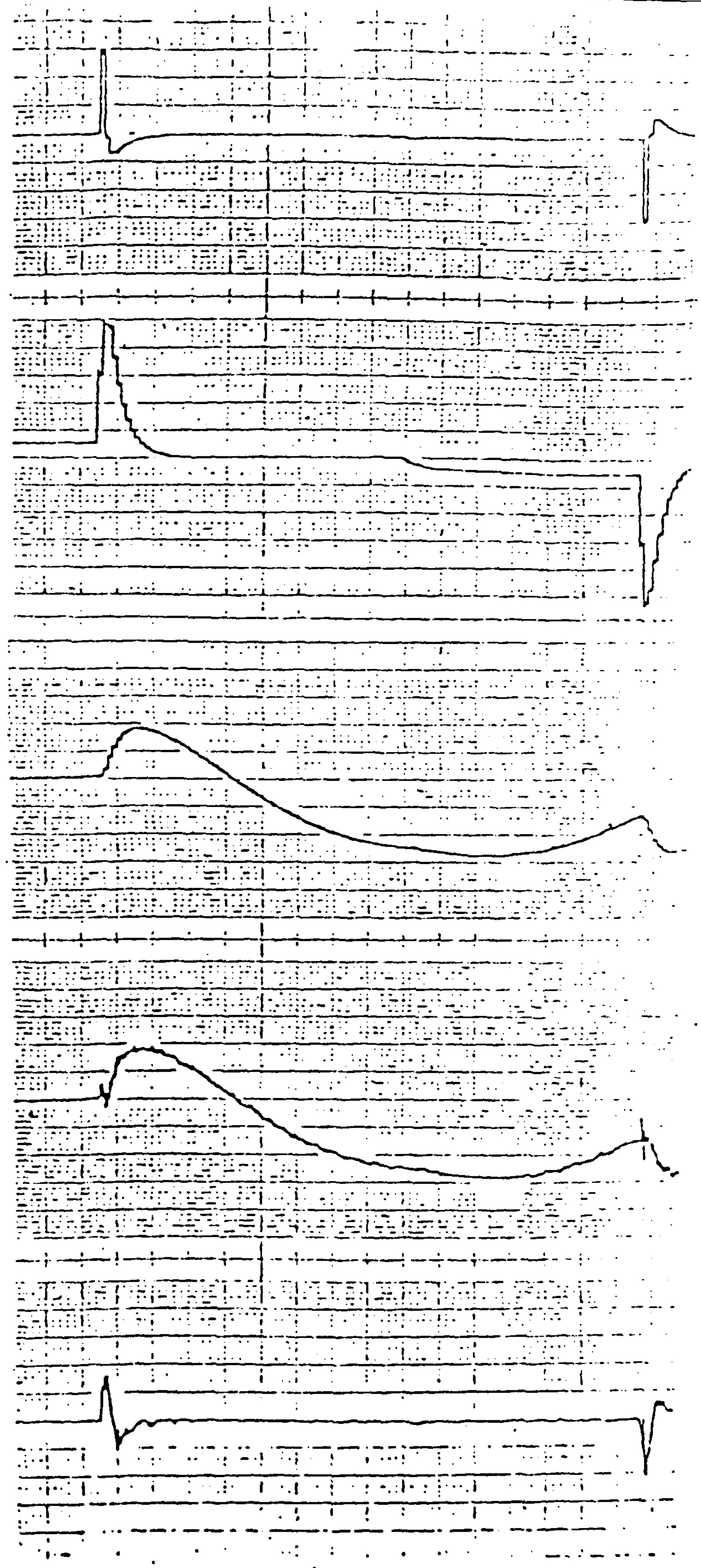

Chart Speed is 5mm per second.

Figure 4 - Typical Rotational Cue Profiles

DEPARTMENT OF THE AIR FORCE
AFHRL FLYING TRAINING DIVISION (AFSC)
WILLIAMS AIR FORCE BASE, ARIZONA 85224

18 January 1978

Dr. Laurence E. Fogarty
AFHRL
Williams AFB, Arizona

Dear Dr. Fogarty

It is a pleasure to forward the attached letters of appreciation from Generals Hendricks and Ellis concerning your outstanding efforts in the A-10 Program.

Your knowledge and professional expertise were key factors in the continued success this program is enjoying.

I encourage your continued support for quality research and offer my sincerest appreciation for a job well done.

J D. BOREN, Colonel, USAF
Chief, Flying Training Division

AIR FORCE—A GREAT WAY OF LIFE

DEPARTMENT OF THE AIR FORCE
AIR FORCE HUMAN RESOURCES LABORATORY (AFSC)
BROOKS AIR FORCE BASE, TEXAS 78235

REPLY TO ATTN OF: CC

20 December 1977

SUBJECT: Recognition of the A-10 Training/Research Program (AFSC/DL Ltr, 9 Dec 77)

TO: AFHRL/FT

1. It was very generous and thoughtful for Maj Gen Ellis to take the time to personally thank Gen Hendricks for the outstanding support that you and your division have provided to Tactical Air Command in support of their A-10 training program. From what you have told me and from what I hear from knowledgeable participants, the program is providing irrefutable evidence of the remarkable contribution a simulator with even reasonable fidelity can make to a flight training program. Undoubtedly the key capability has been ASPT's CIG visual system and its readily assessable data base which has permitted the demonstration of a wide variety of terrain features. All of your efforts with this system since 2235 have confirmed ASPT as the most flexible device available to the Air Force.

2. However, ASPT is only a hardware-software system that contributes nothing without the expertise, the long hours of hard work, and the devotion of the people who operate it. I recognize and appreciate the time pressures your scientists, engineers, and contractor personnel had to work under in order to meet TAC training requirements. My staff and I will make every effort to provide you with whatever support is necessary to successfully carry out our commitments to TAC in this program. The research data gathered during this program should make a very significant contribution to not only hardware and training program designs for the A-10, but should provide considerable training data for all tactical air-to-surface systems.

3. I know that you have put a lot of personal direction into this effort and I congratulate you on the acceptance of the A-10 program as received from TAC. I am sure you agree that without the exceptional capabilities of Dr Larry Fogarty it would have been very difficult to achieve the same level of success. Much credit certainly must go to Mr Warren Richeson and his entire branch for the many, many hours of hard, dedicated work that must have been necessary to support this project, and also to Dr Tom Gray for his outstanding contributions to the program design. May I suggest that you consider special recognition for Dr Fogarty, Mr Richeson, and Dr Gray for their noteworthy accomplishments. Again, along with Generals Hendricks and Ellis, congratulations to all of you and may the success of your program continue unabated.

DAN D. FULGHAM, Colonel, USAF
Commander

1 Atch
AFSC/DL Ltr, 9 Dec 77 w/1 Atch

Cy to: AFSC/DLS
AFHRL/XR

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SYSTEMS COMMAND
ANDREWS AIR FORCE BASE, DC 20334

REPLY TO ATTN OF: DL

9 DEC 1977

SUBJECT: Recognition of the A-10 Training/Research Program

TO: AFHRL/CC

1. References: a. AFSC/DLS Ltr, 25 Oct 77, Subj: AFHRL-TAC Memorandum of Agreement
b. AFSC/DLS Ltr, 25 Nov 77, Subj: Training Effectiveness R&D Using A-10 Configured ASPT

2. The attached TAC/DO letter reconfirms what we have noted in our referenced letters. AFHRL/FT personnel have put forward a superior effort in preparing ASPT for its role in an A-10 training/research program. This success is even more notable as we place more R&D emphasis on transition and advanced flying skills vice undergraduate pilot training.

3. Please convey my appreciation to Colonel J. D. Boren, Dr. Laurence Fogerty, and Mr. Warren Richeson for their effort. Let me also take this opportunity to reinforce the AFSC/DLS letter dated 25 November 1977. We need to know status and results of the training/research efforts on a timely basis. We also need a detailed plan on the R&D program being conducted using the A-10 configured ASPT.

GERALD K. HENDRICKS
Major General, USAF
Director of Science and Technology

1 Atch
TAC/DO Ltr, 30 Nov 77

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS TACTICAL AIR COMMAND
LANGLEY AIR FORCE BASE, VIRGINIA 23665

30 NOV 1977

Major General Gerald K. Hendricks
Director of Science and Technology
Andrews AFB, DC 20334

Dear Gerry

I have recently received a preliminary report from my Operations Training Development Team concerning our A-10 Advanced Simulator for Pilot Training research effort at Williams AFB. The program is producing remarkable results. Gunnery scores of our first test group leave no doubt about the benefits of research in the area of air to surface visual simulation.

The contributions of Col Boren and his staff to the program have been notable. Their interest, attentiveness and responsiveness have been outstanding. It is particularly significant that within just one year from conception they developed this hybrid device which began operations when needed with capabilities surpassing the original expectations.

It is obvious that many long, hard hours were devoted to this effort in order to arrive at such a quality product on a tight schedule. Please convey my congratulations and appreciation to Col Boren, Dr. Fogerty and other individuals who worked the project. It is a job well done.

Sincerely

Billy

LLY J. ELLIS, Major General, USAF
Deputy Chief of Staff, Operations

AMERICAN REVOLUTION BICENTENNIAL 1776-1976