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EXPERIENCE WITH FLIGHT SIMULATORS — TRAINING EFFECTIVENESS AND FUTURE DEVELOPMENTS

By

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This paper was prepared at the request of the DGLR Program Committee Chairman and presented at the German Society for Aeronautics Symposium held 20-21 May 1981 in Cologne, Germany. The theme of the symposium was "Simulators for Pilot Training."

As requested, the paper provides a discussion of experience in the use of simulators for pilot training in the United States of America. Because of the author's background, it was further limited to USAF utilization and related areas.

The use of ground based flight simulators in pilot training programs as alternatives to more expensive training

Item 20 (Continued)

media has been practiced at some level for over 50 years. This paper opens with a brief discussion of the very early experiences of Mr. Ed Link and his "PILOT MAKER." Progress is then summarized in three time frames: 1934-1949, 1950-1970 and 1971-1980.

The first period (1934-1949) spans WWII and notes the emphasis in the use of trainers in instrument and procedures training for propeller driven aircraft.

The second period (1950-1970) covers the transition from conventional to jet aircraft simulators and the evolution of electronic devices (as opposed to bellows or manual linkage actuations). Simulator training objectives retain their focus on instruments and procedures to which are added weapon system operations. Trainers are procured for nearly 30 jet aircraft weapon systems.

The third period (1971-1980) includes a discussion of factors which caused increased use of simulators, a summary of major equipment modifications to increase training capabilities and a discussion of training research activities.

The final section of the paper provides the author's opinion as to future simulation applications. Three areas are discussed; the first includes comments on how we may improve utilization of existing equipment, the second provides some ideas concerning future simulator training requirements, and the third provides a broad summary of planned and needed research.

A short summary section provides comments as to the evolving role of simulators in flight training programs. Because of developments in visual system technologies and computer capabilities, it is probable that future simulation systems will include multiple aircraft attacks on multiple enemy targets in which displays of combat areas and threats possess near real world qualities. The ultimate goal is combat rehearsal which can achieve increased combat effectiveness and reduce first exposure losses.

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EXPERIENCE WITH FLIGHT SIMULATORS - TRAINING EFFECTIVENESS - FUTURE DEVELOPMENTS

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The use of ground based flight simulators in pilot training programs as alternatives to more expensive training media such as aircraft has been practiced at some level for over 50 years. This paper provides a summary of simulator developments in the United States Air Force (USAF), significant changes which occurred during the period 1971-1980, and some ideas concerning the direction simulation may take in the future and research programs needed to support future applications (Figure 1).[1] The contents of this paper are based on the author's 35 years of experience with simulation and the USAF. The opinions stated are those of the author and do not necessarily reflect official USAF position.

HOW IT STARTED

The first reported use of a flight trainer (the terms "trainer" and "simulator" are interchangeable in this paper) in the United States of America (USA) was for the purpose of reducing the number of aircraft flight hours (and resultant costs) required to teach a student to fly solo in an aircraft. This is credited to Mr Ed Link and his invention of the "PILOT MAKER" in the year 1929 (Figure 2). Using this device, which permitted teaching basic visual flight maneuvering, Mr Link soloed his brother after 6 hours in the PILOT MAKER and 42 minutes in the aircraft. A few years later, while owner and manager of the Link Flying School, Mr Link offered to teach new pilots to solo an aircraft for 85 dollars. The instruction consisted of as much ground trainer time as required and 2 hours in an aircraft. Over 100 students completed this course. Since an estimated 12 to 15 hours of dual aircraft training was normally required to solo, a transfer of training achievement of over 80 percent can be computed (Kelly, 1970, pp. 32-34).[2]

Over the next few years emphasis was given to using such a trainer in learning blind flying (note the change to instrument flight) and, in 1933, the New York Herald Tribune presented an article on the Link Trainer. In this article the sponsors were reported to believe that 15 hours of new style "hangar flying" (using the ground trainer), and 5 hours in the school's blind flying training aircraft would produce pilots of equal proficiency to that obtained by 25 hours of all aircraft training (Kelly, p. 41).

1. Refers to 35mm slides used in briefing; figures provided in Appendix A.
2. Historical data referenced throughout the early part of this report were obtained from: Kelly, L.L., The Pilot Maker. New York: Grossett and Dunlap 1970.

PROGRESS: 1934-1949

The USA Simulation Industry is reported to have begun in 1934 (Kelly, p. 53). In this year the first six instrument and procedures trainers were delivered to the United States Army at a cost of $3,400 each (Figure 3). By 1941, Link trainers were located in 35 countries (including Japan). Use of trainers for pilot training in instrument flying and procedures (Figure 4) expanded rapidly during World War II and by 1945 there were at least 30 different types of devices in use.

How effective were they? A report to the subcommittee of the United States House of Representatives Committee on Appropriations gives this estimate (Kelly, p. 78):

> Navy report--19 types of Link special devices used by the Navy are estimated to have had a potential savings of $1,241,282,400 in one year; no estimate was made as to probable savings in lives.
>
> Army report--at least 524 lives, $129,613,000 and 30,692,263 manhours were saved in one year through Army Air Corps use of 11 types of Link synthetic training devices. This also freed 15,043 men for other military duties.

Post WWII emphasis was on electronic simulators. The result is best represented by the C-8 trainer and by early versions of so-called operational flight trainers such as the SNJ (Figure 5). While still used principally as procedures and instrument trainers, they could be used for some basic visual flight training (Figure 6). A series of studies demonstrated that the P-1 trainer which simulated Air Force T-6 aircraft, could be used to replace 30 of 130 scheduled aircraft hours normally used in basic pilot training.

PROGRESS: 1950-1970

In the early 1950s, the procurement of jet aircraft caused existing devices to be outmoded and a new breed of trainer appeared. This was the Link built C-11 Trainer for F-80 aircraft (Figure 7). It was a fixed base electronic device, 4.88 meters (16 feet) long and weighed 1701 kilos (3750 lbs). Almost 1000 of these devices were procured for all services. The average cost was $75,000 each (Kelly, pp. 79-80). For the Air Force this procurement meant that all pilot trainees and jet upgrades would receive instrument and procedures training in a simulator.

From 1950 on, electronic simulators were procured for most major aircraft weapon systems. These devices, not equipped with visual systems, provided a capability for training aircraft system operations, all normal and emergency procedures, instrument flight to include weather phenomena, and fire control system operations. They were particularly useful when used with all-weather interceptor aircraft which were equipped with relatively complex fire control systems, and which were expected to perform well under instrument and night conditions (Figure 8). Simulators were also used in multiple-crew aircraft for crew coordination, fire control offensive and defensive system training and as trainers for navigators. Devices without visual capabilities were much less effective when used with fighter aircraft in which most flying required the use of out-of-the-cockpit visual cues for mission accomplishment (Figure 9). Except for support of a research study, no visual systems were procured for Air Force simulators in this time frame. Because little definitive simulator effectiveness data were available, simulator specifications tended to reflect the latest hardware/software technology a manufacturer could show rather than documented characteristics that would provide devices to meet specific training needs. Instructional system development (ISD) procedures, while widely used by the airlines, were in their infancy in Air Force circles and (to my knowledge) had never been used to specify a total military pilot training system. In the mid 1960s a study was conducted which reviewed long term USAF pilot training needs, identified pilot training research requirements and provided specifications for a device to support the research. The result was procurement of the Advanced Simulator for Undergraduate Pilot Training (ASUPT) which became a reality in 1974. In the late 1960s a Flying Training Research Division was established and located at Williams AFB, Arizona. This Division subsequently became the manager of the ASUPT.[3]

By way of a summary it is significant to note that during this 20-year period, from 1950-1970, USAF simulators remained instrument and procedures trainers (Figure 10). While some research was done using visual systems, no simulators with visual system capabilities were procured for incorporation in any military pilot training program (Figure 11). Further, available simulators were generally not updated to remain current with aircraft modifications. As a result, user attitude toward simulator training was not highly motivated.

PROGRESS: 1971-1980

In the early 1970s, several events occurred which changed Air Force ideas concerning the use of flight simulators. A very significant factor was the steadily increasing cost of a flight hour. These increasing costs, resulting in part from increasing fuel costs and in part from the complexity of recently procured weapon systems, placed a serious strain on an already limited military budget. This factor, coupled with the widely reported economies achieved through the use of simulation in airline pilot training, caused Congress to pressure the services to apply simulation as a cost reduction alternative. In addition, flying space for high performance jet aircraft was becoming less available and ecologists were becoming more and more concerned with aircraft operations. Finally, simulation technology, particularly in the areas of visual systems and computer capabilities, was advancing rapidly. The combination of all these factors caused USAF training managers to take a fresh look at most pilot training programs with attention focused on increased usage of ground training devices. The results were (1) several modifications or additions to existing training equipment and programs directed toward improving capabilities and training effectiveness, and (2) increased emphasis on training research focused on improving training strategies and providing data for use in specifying training device requirements. The more significant items are discussed below.

3. Renamed Advanced Simulator for Pilot Training (ASPT).

Modifications to existing training equipment are as follows (Figure 12):

a) ISD procedures were applied in the design of the first A-7D pilot training syllabus. Significant savings over other single place aircraft pilot training programs were reported.

b) New simulators were procured for T-37 and T-38 instrument training in the Undergraduate Pilot Training program. Aircraft hours required for instrument training were reduced by over 80%; some of these hours were added to other areas of training (Figure 13).

c) Single window visual systems were attached to A-7D and F-4 simulators; this permits visual breakout on instrument low approaches and limited air-to-surface weapons delivery training.

d) To the extent possible all TAC A-10 pilot trainees are provided transition and conventional range air-to-surface weaponry training in a simulator prior to flying the aircraft on such missions; the ASPT is used (Figures 14&15).

e) To the extent possible all TAC F-16 pilot trainees are provided transition and conventional range air-to-surface weaponry training in a simulator before flying the aircraft on these missions; the ASPT is used (Figure 16).

f) All F-4 trainees are given air combat maneuvering training in the Simulator for Air-to-Air Combat (SAAC) prior to similar training in the aircraft (Figures 17, 18, 19, 20).

g) Part-task trainers were procured for teaching tanker refueling system operators and receiver pilot trainees the skills required for airborne refueling. Both trainers were demonstrated to be effective.

h) New simulators for A-10, F-15 and F-16 aircraft were procured and accepted (Figure 21). These simulators provide a capability for training instrument flights, procedures and weapon system operations. A single window visual system is being added to the A-10 simulator for evaluation.

i) Tactical Air Command (TAC) initiated an Air Combat Engagement Simulation (ACES) training program for F-4 pilots. A commercially owned simulator with a cockpit surrounded by a large dome was first used. The program is now conducted in the SAAC.

i) New simulators with modest field of view visual systems were procured to teach E-3A pilot transition (Figure 22), B-52 pilot transition and refueling, KC-135 pilot transition and F-111 low level flight and fire control system operations. Acceptance of a three channel four window visual system for F-111 training has not been completed.

Increased emphasis on training research resulted in the following (Figure 23):

k) A pilot training research division within the Air Force Human Resources Laboratory (AFHRL/FT) was staffed and provided simulators. The mission of the Division was twofold: (1) to develop a data base which identified training areas where training effectiveness could be increased through the use of ground trainers and (2) develop device specification recommendations for use by the simulator procurement community. This division acquired the ASUPT with two T-37 cockpits and the use of some research time on the Tactical Air Command (TAC) SAAC equipped with two F-4 cockpits; several other much simpler devices were also available for special efforts. Toward the end of the decade, the ASUPT was converted to an A-10 and an F-16 cockpit and renamed the Advanced Simulator for Pilot Training (ASPT). These devices provided capabilities for extensive research in a broad spectrum of pilot training tasks with particular emphasis in the areas of performance measurement, visual system requirements, force cuing requirements, simulator subsystem training effectiveness and evaluation and the study of air-to-air and air-to-surface combat rehearsal capabilities.

l) Several transfer of training studies were conducted to identify the effects of platform motion on learning in various types of training. Significant learning was obtained in the simulator and the skills did transfer to the aircraft; however, the addition of task correlated platform-motion cuing resulted in a negligible increase in transfer for either initial jet piloting skills or air-to-surface weaponry skill acquisition. As a result, future fighter aircraft simulators are being procured without motion systems; other force cuing techniques such as "G" seats and suits are still being considered.

m) A series of research studies were conducted in the ASPT using a Computer Image Generated (CIG) model of a conventional air-to-surface weaponry training range, (Figure 24). The results indicated that a high transfer of air-to-surface weapon delivery skills to the aircraft could be achieved using either a low fidelity device (a T-37 simulator to an F-5 aircraft) or a reasonably high fidelity device (A-10 simulator to an A-10 aircraft).

n) A series of studies were initiated using a tactical range as modeled on the ASPT. As a result of development studies, the visual scene was revised to provide improved low level flight cuing and the tactical range modified to include increased system capabilities and more realistic threats, (Figures 25, 26, 27, 28). Subsequent studies show that even combat experienced pilots learn and become more effective in both offensive and defensive maneuvering (at least in the simulator) with practice using this threat environment. They also exhibit motivation, and recognize and accept the modeled environment for its training potential.

o) The capability to simulate and teach manual reversion problems caused by engine out or system damage in the A-10 aircraft was demonstrated in the ASPT. Pilot learning was also demonstrated.

p) The feasibility of operating a simulator located at one base against a simulator located some 60 miles away was demonstrated; the mission was Air Combat Maneuvering (ACM).

q) Three visual systems (TV/Model board system, a raster scan day CIG and a point light source night only CIG system) were compared while training new KC-135 pilots. Significant training transfer was reported with the best success resulting from the use of either CIG system.

r) Cost models were developed to assist in the decision making process of whether or not to buy what device. More basic input data are required.

s) A comprehensive survey of how the USAF utilizes its simulators was completed. The results, including recommendations for improvement and identification of new research requirements over and above those included in existing research programs, were published in seven reports.

t) A study was initiated to determine why application of the ISD process to USAF pilot training programs was proceeding a such a slow pace. Several problem areas were identified, many of which concerned management. Follow-on study has been delayed.

WHERE TO FROM HERE: 1981-????

While significant progress in the use of simulation has been achieved over the past 10 years, there is still much which can be done. The challenge of achieving increased training effectiveness at reduced cost remains. To present the direction I believe future USAF simulator applications will take, I have divided the subject matter into three areas. They are; how we can do more with what we have, training objectives which future systems must be able to address, and research that will be needed to permit simulator training and hardware technology to meet the training goals.

A. DOING MORE WITH WHAT WE HAVE

A recent review of simulator utilization in the USAF provided a summary of judged strengths and weaknesses. The results of this study combined with problems identified through familiarity with other programs suggest there is a high potential for improving training effectiveness if we attempt to achieve the following (Figure 29):

a) Provide instructors with a better understanding of what skill learning is achievable in the simulator if the device is used effectively rather than as a surrogate for an aircraft.

b) Restructure specific aspects of the syllabi to optimize for effective training rather than effective device scheduling. Examples of the items to investigate are phasing with academics, grouping of common tasks, duration and frequency of practice, and training only tasks compatible with the device.

c) Insure that instructors are trained to teach and how to operate and use the device capabilities. The instructor console should be modified as necessary to support this objective.

d) Maintain flexibility and responsiveness in the Aircrew Training Device (ATD) program to meet changes in operational and training needs.

e) Structure a formal assessment program to be used regularly in documenting simulator training program success.

f) Update the simulator and its subsystems to reflect any aircraft modifications that have an impact on the performance of tasks being trained.

g) Include high device reliability as an essential part of design and maintenance programs.

h) Foster positive attitudes toward ground training.

In my opinion item "h)", the attitude issue, needs special attention. Many of our upper level management personnel were last associated closely with ground training devices when the trainers were used only for instrument and procedures training, were not kept current with aircraft modifications, and possessed only modest reliability. In addition, the trainers were scheduled to maximize device utilization with little regard for pilot training needs, experience or availability. With these memories some skepticism is understandable especially when simulator procurements with significant dollar costs are surfaced and suggested as substitutes for a percentage of already limited aircraft flying hours. It must be made clear to all that a simulator is a unique training medium with capabilities of its own. It is not a surrogate for an aircraft and need not be used like an aircraft. Its function is to provide a capability for pilots to practice and learn specific skills which transfer to the aircraft or cannot be practiced in the aircraft. If transfer of training to the aircraft cannot be demonstrated or estimated, the subsystem or device being used should either be modified until adequate transfer is achieved or discarded. New devices and subsystems which are being considered for procurement should be subjected to the same criteria. It seems to me that if this philosophy is adopted by the policy makers and the users and if we can insure strict endorsement and practice in support of items "a)" through "g)" above, we will go a long way toward optimizing our use of ground training devices.

B. FUTURE TRAINING CAPABILITY REQUIREMENTS (Figure 30)

By the year 2000, assuming manned aircraft are still affordable weapon system alternatives, our goal should be to provide a realistic combat mission rehearsal system through the use of ground trainers. This should include presentation of all external visual cuing necessary to mission success, either air-to-air or air-to-surface or both, and should include simulations of friendlies, targets, threats, defensive and offensive weapon systems, sensor equipment and all other task loading activities. The capability to present a realistic day, night or weather visual reproduction of any geographic area and any combination of threats will be essential. This capability should be used as a final operational certification program for combat ready pilots.

Prior to participating in the final operational certification program all pilots should have completed a training program which provides for learning individual and team combat skills to specified criteria. This program should utilize part-task trainers, full mission simulators and aircraft as necessary to learn individual specialized skills in such tasks as "many versus many" air-to-air, etc. The maintenance of proficiency in these skills should be documented through continued use of exercises and the Air Combat Maneuvering Installation (ACMI) and by the use of airborne measurement systems which should be an integral part of future aircraft system procurements.

In addition, the concept of portable rehearsal trainers for use in a particular theatre and programmed for specific problems as identified by intelligence reports should be examined and, if feasible, implemented.

The primary objective of the devices dicussed above is to train; however, with properly modeled terrain and threats there would also be a capability to test and validate new tactics and/or new weapon system technology before initiating procurement. While computer models will provide preliminary estimates of the potential of new weapon systems or tactical concepts, it is essential that the person who must operate the sytem be put in the loop to validate system usability as early as possible; and certainly before a final procurement decision is made or doctrine is established. The objective is to test the operators' ability to achieve mission success under full task loading. The equipment noted above should support this part of the decision process.

As of 1981 there are several training areas in which, assuming proper attention is given to the items discussed in section "A" above, ground trainers have been demonstrated to be effective. These training areas include all tasks in which visual cuing from outside the cockpit is not required. To a lesser extent, most flight training managers would agree they also include all routine transition tasks in which required visual cuing occurs directly ahead of the pilot and in which the cues can be provided by a single window visual system (i. e., approximately 28 degrees by 44 degrees). For these areas of training it is generally agreed that current simulator technology is adequate and will facilitate high transfer of training in the following tasks: normal and emergency procedures training; aircraft system operation including malfunction diagnostics; basic and advanced instrument flight training including navigation, communications, penetrations, low approaches, and breakouts; basic visual flight including airwork, target tracking, straight-in approaches, landings, and takeoffs; and the use of refueling director lights.

There are other training areas in which specialized research simulators have been demonstrated to be effective but for which training devices have not been procured. A conventional air-to-surface weaponry training range was modeled and displayed in the ASPT visual system. Using this visual display high level transfer of training for individual skills has been demonstrated for both beginning and experienced pilots transitioning to A-10 and F-16 aircraft. In addition, the SAAC is used to teach both new and experienced fighter pilots basic one-on-one (I-V-I) air combat maneuvering skills. While learning in the simulator can be documented from the first to the fifth day of training, it is extremely difficult to document how much transfer to the aircraft occurs; again, the problem is the lack of definitive airborne performance measures. Use of the ACMI would be helpful but as currently scheduled it is not readily available for I-V-I evaluation.

Existing simulation capabilities have been examined for use in other training areas including: low level flight, extended formation flight, refueling, medium and long range air-to-air combat, many-versus-many combat tactics, tactical air-to-surface weaponry with target detection and multiple moving target problems (Figures 31, 32), radar and sensor training and the capability to model and display larger threat areas for full-scale tactics and battlefield coordination. Simulator equipment capabilities have been judged to be inadequate for achieving acceptable transfer in these areas. To solve the problems will require significant progress in simulator visual system technology, and to a lesser degree, progress in instructor station design, sensor equipment simulation, improved computer information processing and airborne performance measurement strategies. Research is planned or has been initiated to assist in these areas.

C. PLANNED RESEARCH (Figure 33)

As I noted earlier, these are many areas in which relevant data are inadequate for use in specifying the characteristics which training equipment should have if it is to be effective in meeting stated training needs. As a result, in many cases the practice is to procure what a contractor proposes. Often, this equipment is more exotic and more expensive than is subsequently determined to be necessary. Were this done knowingly to increase user motivation, it could well be worthwhile; however, in most cases it is done unknowingly at a significant cost and with no increase in training effectiveness. Such financial waste must be reduced. Affordability of devices will be a critical element in future procurements. Full mission devices (very expensive devices) will of necessity be limited to use as check devices. A variety of less expensive part task trainers will receive increased attention. To assist in this effort, transfer of training studies are planned to provide cost-effectiveness data for complete systems; other types of research studies are planned to measure the value of subsystems.

At this time major emphasis is being given to visual system research and technology development. Data have been collected which indicate that a monochrome computer generated imagery visual system with low resolution (estimated at six arc minutes) can be used to teach certain air-to-surface tasks and achieve an acceptable level of transfer. What must be determined is the increase in transfer that may be possible on the same task using improved systems (e.g. one arc minute, two arc minutes, color, etc). Current CIG systems have been proven to be inadequate for the air-to-air task because beyond 730 meters (2,000 feet) the relative aspect of the other aircraft cannot be determined. Two system revisions to the visual display have potential for resolving this problem. The revisions are the use of a light valve projector and the use of a helmet-mounted display. These are only examples; obviously there are many other approaches. A research plan which will include investigation of many aspects of the visual area has been prepared and is being circulated among the major commands and the simulator procurement agency for approval. It involves new display technology, new scene generation technology, and changes to existing equipment such as improved resolution and contrast, increased edges, improved texturing capabilities, etc.

A major subsystem of any simulator procurement is the instructor operator station. Its features and their usability have significant impact on the amount of training effectiveness achieved and on instructor acceptance. With the extension of simulator usage from instruments and procedures to all areas of visual reference flight, this problem gains added dimension. Unfortunately, developments in these areas possess less appeal and receive less visibility than other subsystems such as visual displays; as a result they also tend to receive less priority. A plan has been developed which will tie currently available data together and specify studies that must be conducted to solve this problem area.

The development of techniques for measuring pilot performance which possess reliability and validity has been a problem for research personnel since pilot training research began. To identify changes which occur because of variations in only a part or parts of a total operational training program often requires the use of unique performance measurement strategies which have little or no potential for use by operations personnel; however, the results of studies using these measures may produce recommendations which have significant impact on student or training device scheduling. In addition, to provide diagnostic information during a training program or to distinguish differences in human performance at the end of a total program, it is often necessary to have more than pass/fail results; for example, it may be necessary to know the direction of the error rather than the fact an error occurred. Performance scoring capabilities which have been developed over the last 5 years in research simulators are quite adequate for most training areas and significant progress is being made in the other areas such as ACM. The same cannot be said for airborne measurement, particularly in single place aircraft. Since the major thrust of our research is improved combat effectiveness (which may be estimated but not validated short of actual conflict), it is essential to continue airborne performance measurement strategy development efforts which build on ACMI capabilities, provide the fine discriminations required by research, and will be usable by operational commands for continuation training. We have initiated a revised research program aimed at the identification and/or development of performance measurement strategies which will satisfy these requirements and which may provide a base for generalization to other training areas. A high level of operational command coordination is being solicited. It is important to understand that the results of transfer of training studies in which these performance measurement strategies are used are provided to major command users as recommendations. As a general practice, our research personnel do not make training policy; therefore, it is essential that performance measurement systems used in collecting the research data and deriving the research results have sufficient face validity to be accepted by operations personnel who may have to make significant changes in device and student schedules to implement the findings.

Finally, as any pilot who has attempted to operate in high threat hostile environments under daylight, night or weather restricted conditions knows, an essential part of applying a total task load during the operational certification check discussed earlier will be the full application of offensive and defensive sensor capabilities. At the present time, the quality of sensor simulation displays and correlations between position information in the simulated displays and the real world as provided in simulator visual systems are very low. To overcome these and other deficiencies in sensor simulation, a study team has been formulated and a plan developed which, if properly supported, should permit reaching our overall goals and objectives.

SUMMARY (Figure 34)

In this paper I have presented an overview of how simulation began in the USA, what the USAF did with it over 47 years from 1923 to 1981, and the direction I think it should take in the next two decades. To cover that much material in 40 minutes means I have already provided a summary; therefore, a summary of my summary is inappropriate! Instead I will close with a few general thoughts and open the floor for questions.

Traditionally, simulators in the USAF, have been used for initial skill acquisition and to a much lesser degree for remedial training. Their value for the maintenance of flying skills by operational personnel, particularly those related to visual flight which I estimate to be at least 80% of the total skills required, has not been addressed. Over the next few years as simulation technology progresses and we gain additional experience with visual skills training in simulators, I expect an increase in their use in remedial programs and I expect applications studies to move from initial skill acquisition to skill maintenance for operational pilots. When the results are implemented, they should have significant impact on existing rated force management policies and the distribution of available aircraft flight time. For example, results of a small study we completed suggest that better pilots benefit more from a fixed number of simulator hours than weaker pilots. Thus it could be implied that a remedial phase with its inherent scheduling problems should be incorporated. Obviously, results of additional studies concerning the visual training areas discussed earlier will have significantly larger impact on ongoing programs. Flexibility will be essential as will top level management support.

Earlier I alluded to the fact that cost models, which are becoming popular and perhaps essential in making procurement decisions, suffer from input data shortages. To improve the validity of cost-effectiveness forecasts requires transfer of training data obtained from models specific to training areas and tasks, thereby reducing errors due to improper generalizations. To date there are few of these studies. Over the next decade I anticipate a significant increase in the number of studies conducted and the amount of data available; and while I have heard numerous comments and have seen much evidence concerning recent increases in simulator procurement and operation costs, I have also heard similar comments as to aircraft and fuel costs. As a result, I would expect our current estimated aircraft to simulator cost ratio of 10:1 per training hour to remain reasonably accurate. When adequate transfer of training data become available, it will be essential to exercise the model and determine whether dollars should be spent optimizing the effectiveness of current weapon systems through improvement in characteristics and training programs or in the development of a new system which is inherently superior but much more costly. Research plans are underway which will provide baseline training data for input to the life cycle cost model; the objective is to help the model provide more accurate cost tradeoff data which may be used by managers in the decision process.

I realize that the program as discussed in this paper is ambitious and will require a significant amount of resources. All USAF resources possible will be applied to the problem; however, we will also maintain a close awareness of relevant research completed by other services and agencies in the USA, by commercial companies and by international agencies such as the AGARD.[4] To meet our goal will be difficult; however, the payoff potential is significant. For example, if we reach our goal of providing a ground device which will provide reasonably effective combat rehearsal and through this rehearsal reduce the loss of new pilots on the first engagement sortie of a conflict to that achieved historically on the fifth sortie, the result will be a significant force multiplier and the payoff manyfold. Are there any questions?

4. Advisory Group for Aerospace Research and Development.

APPENDIX A: COPIES OF FIGURES 1-34

FOLLOWING ARE COPIES OF FIGURES USED IN SUPPORT OF THE PRESENTATION. THE FIGURE NUMBER (IN PARENTHESIS) IS INCLUDED AT THE APPROPRIATE LOCATION IN THE TEXT.

- HOW IT STARTED IN THE USA
- PROGRESS: 1934 to 1949
- PROGRESS: 1950 to 1970
- PROGRESS: 1971 to 1980
  - CHANGES IN TRAINING SYSTEMS
  - TRAINING RESEARCH
- WHERE TO FROM HERE: 1981 to ???
  - DOING MORE WITH WHAT WE HAVE
  - TRAINING REQUIREMENTS
  - RESEARCH REQUIREMENTS

Figure 1. Outline of presentation.

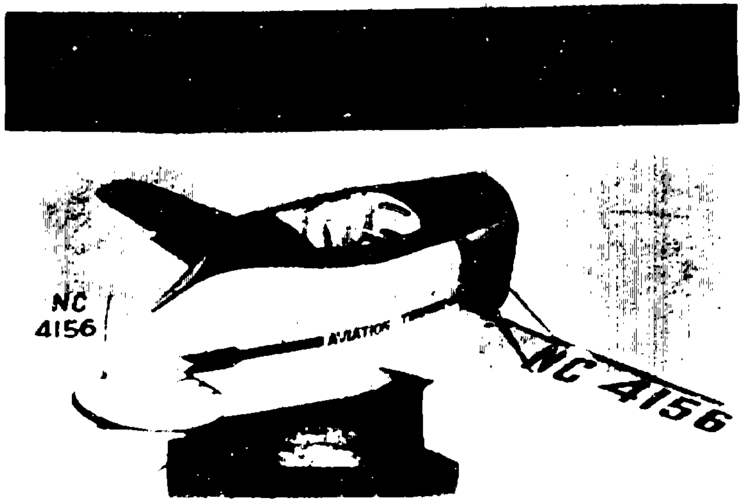

Figure 2. Mr. Link's first "pilot maker."

Figure 3. The "blue box" instrument trainer.

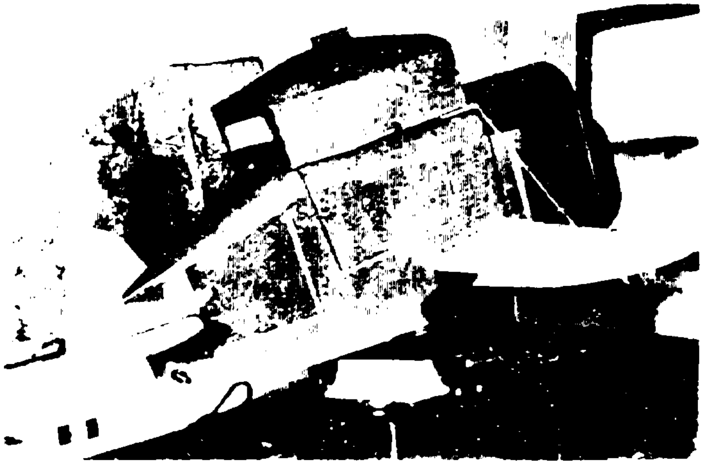

Figure 4. WWII instrument trainer.

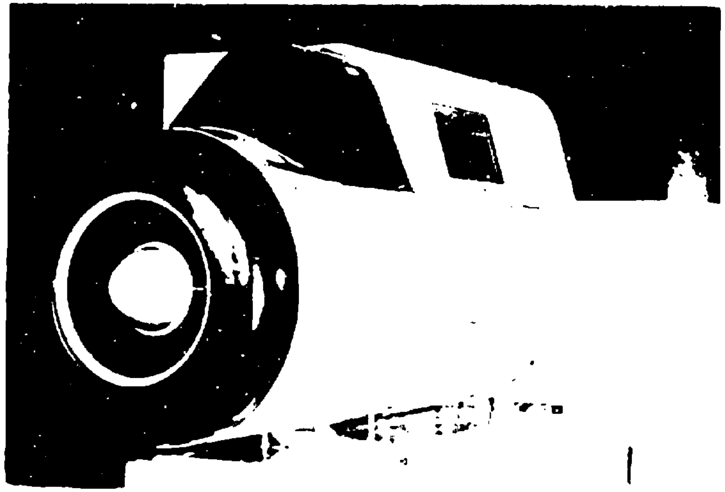

Figure 5. **Post WWII SNJ operational flight trainer.**

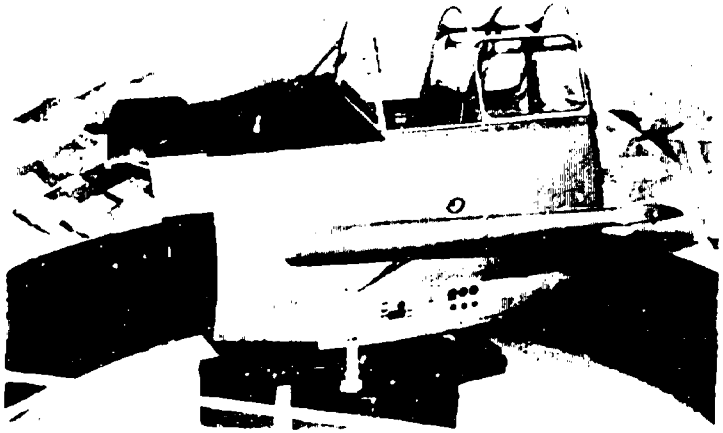

Figure 6. **P-1 contact and instrument flight trainer for T-6 aircraft.**

Figure 7. **C-11 instrument and procedures training for jet (F-80) aircraft.**

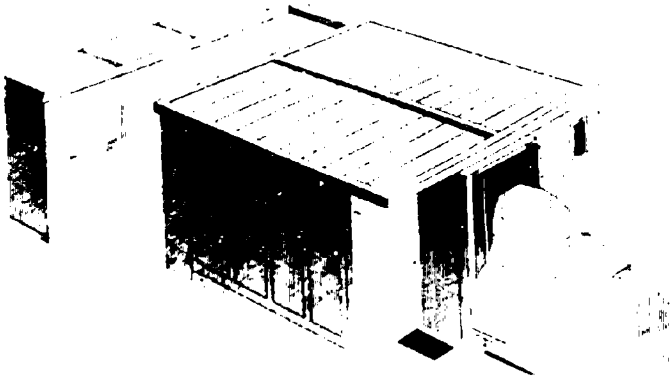

Figure 8. **Flight simulator for F-86D.**

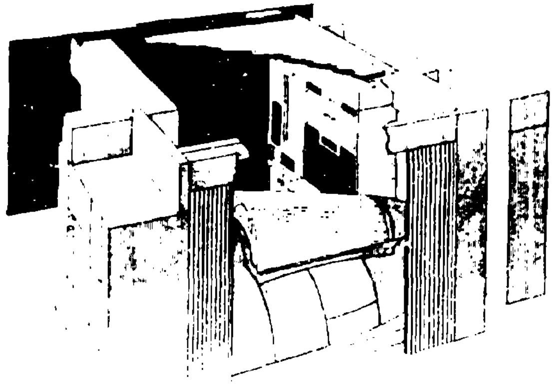

Figure 9. Flight simulator for F-100.

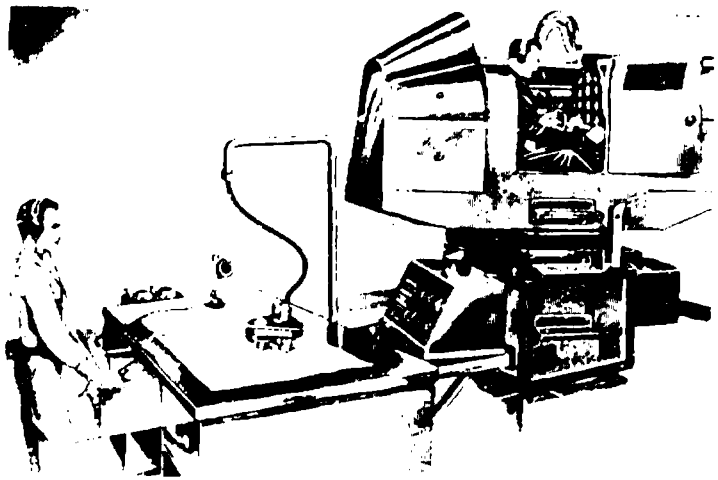

Figure 10. Early 1950 instrument and procedures trainer.

Figure 11. T-4 instrument and procedures trainer for USAF T-37 trainer.

MODIFICATION TO EXISTING TRAINING SYSTEMS

- ISD FOR A-70 PILOT TRAINING
- IFS FOR UPT PROGRAM
- LIMITED VISUALS FOR A-70 AND F-4 SIMULATORS
- A-10 PILOT A/S TRAINING IN ASPT
- F-16 PILOT A/S TRAINING IN ASPT
- F-4 PILOT ACM TRAINING IN SAAC
- REFUELING TRAINERS
- NEW SIMULATORS WITHOUT VISUALS A-10; F-15; F-16
- F-4 PILOT ACES TRAINING
- NEW SIMULATORS WITH VISUALS F-3A; B-52/KC-135; C-130; F-111

Figure 12. Summary of significant modifications to pilot training system: 1971 to 1980.

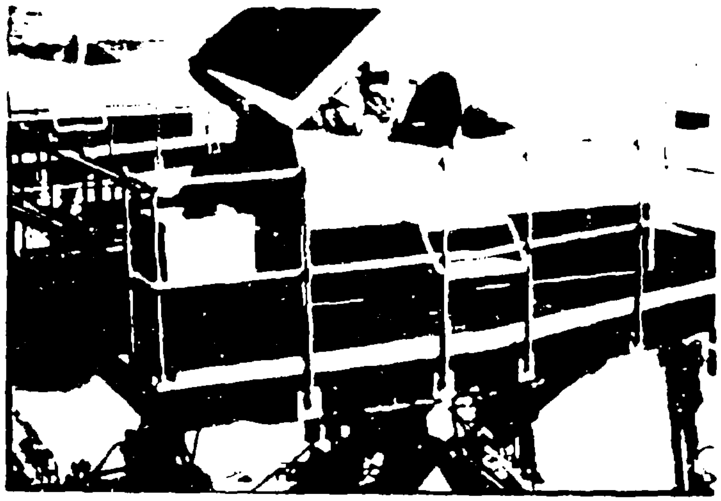

Figure 13. UPT instrument flight simulator.

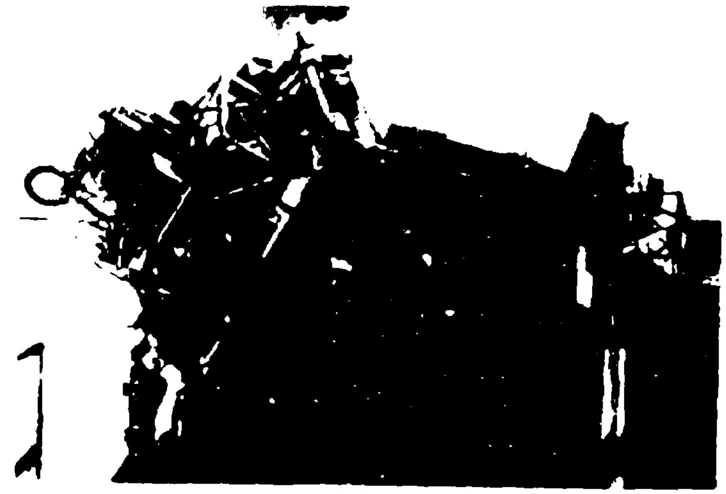

Figure 14. A-10 cockpit of the ASPT.

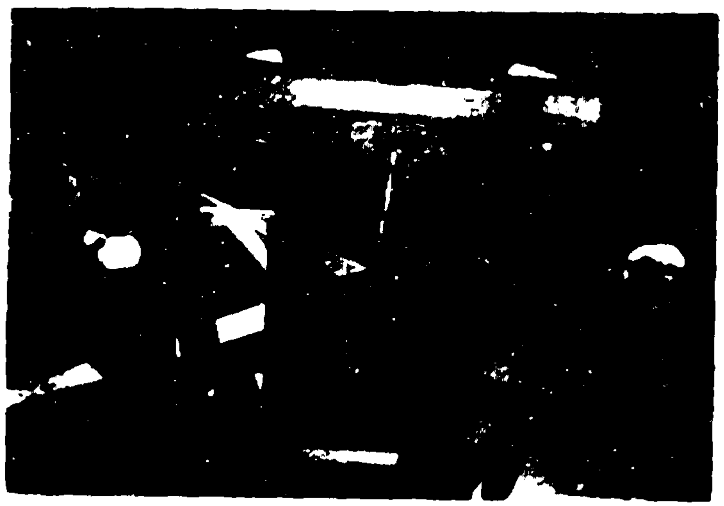

Figure 15. Conventional air-to-surface weapons delivery range as viewed from the ASPT A-10 cockpit.

Figure 16. F-16 cockpit of the ASPT.

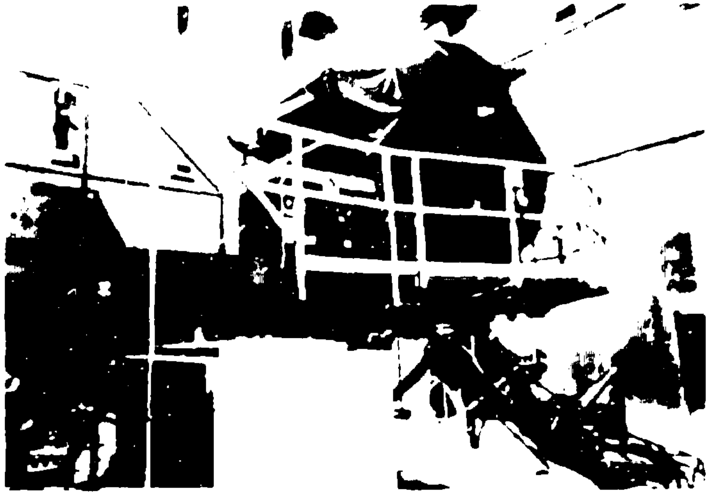

Figure 17. The SAAC F-4 simulator.

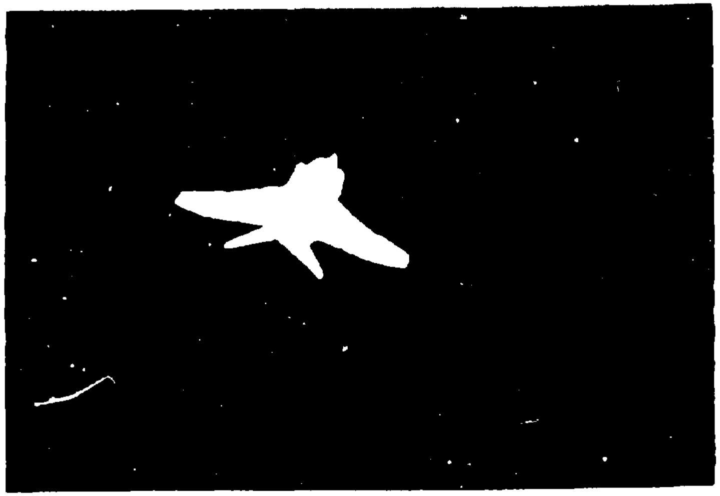

Figure 18. A view of an opponent as displayed in the SAAC.

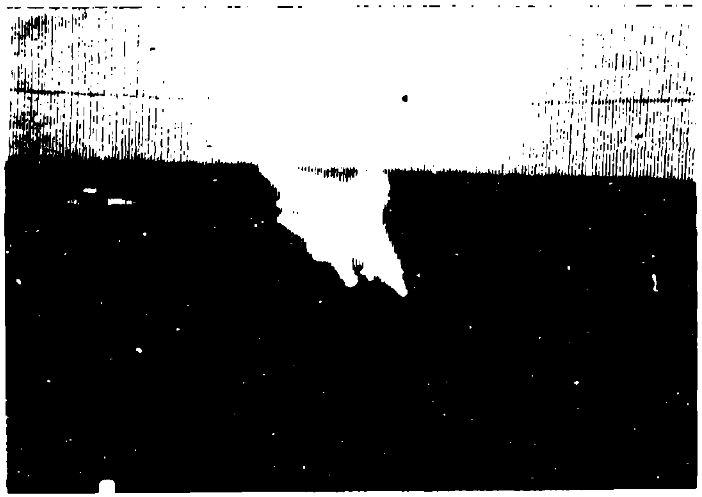

Figure 19. The opponent closer up in the SAAC.

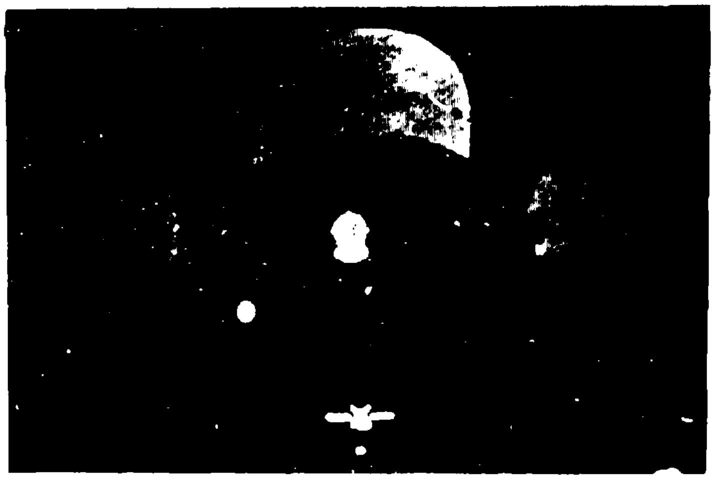

Figure 20. A kill as displayed in the SAAC.

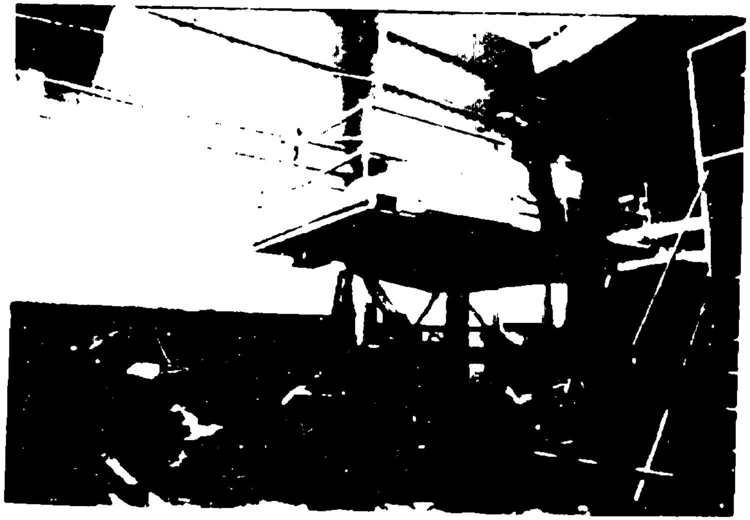

Figure 21. The simulator for F-15 aircraft.

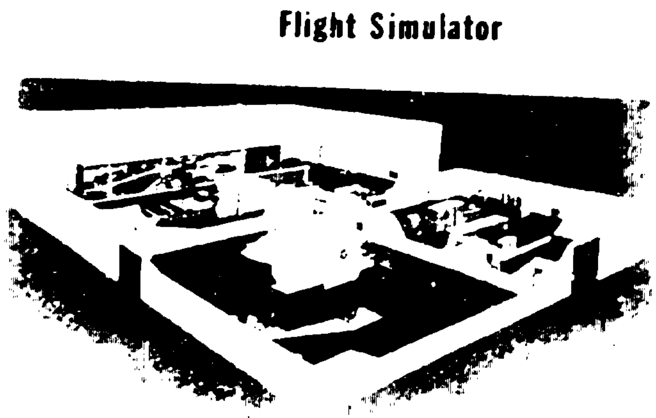

Figure 22. Artists concept of F-3A simulator.

TRAINING RESEARCH

- ASUPT-ASPT-SAAC
- CORRELATED PLATFORM MOTION CUING
- AIR TO SURFACE WEAPONRY
- A-10 MANUAL REVERSION TRAINING
- SIMULATOR LASHUP
- VISUAL SYSTEM COMPARISON
- COST MODEL DEVELOPMENT
- UTILIZATION SURVEY
- ISD APPLICATION STUDY

Figure 23. Summary of significant training research: 1971 – 1980.

Figure 24. CIG scene of conventional air-to-surface weapon delivery training range.

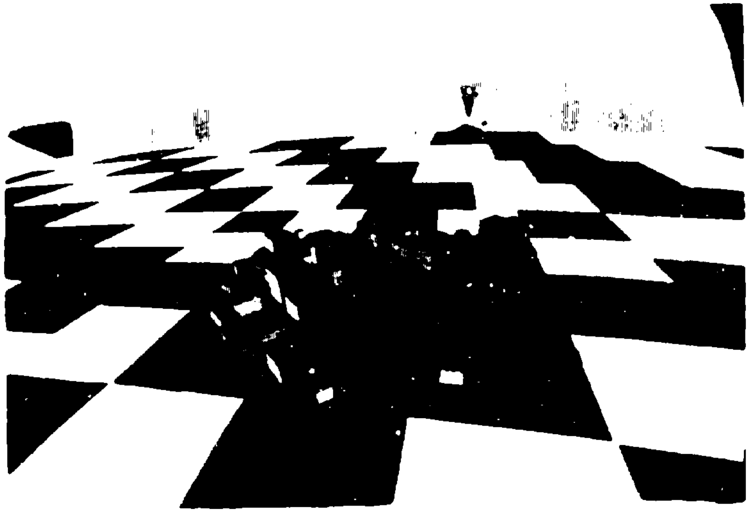

Figure 25. CIG scene of a town, the earth surface and mountains.

Figure 26. CIG scene of valley with inverted cones (i.e., trees) for height cuing.

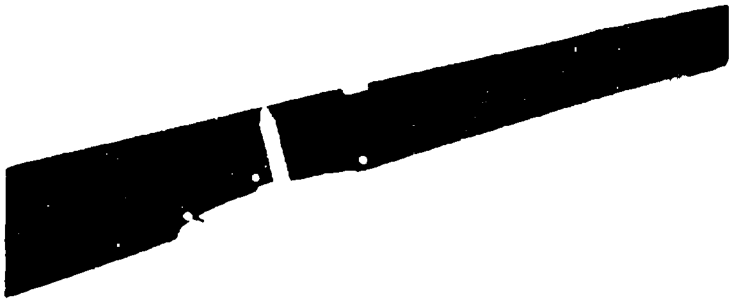

Figure 27. CIG scene of a SAM site launch pad.

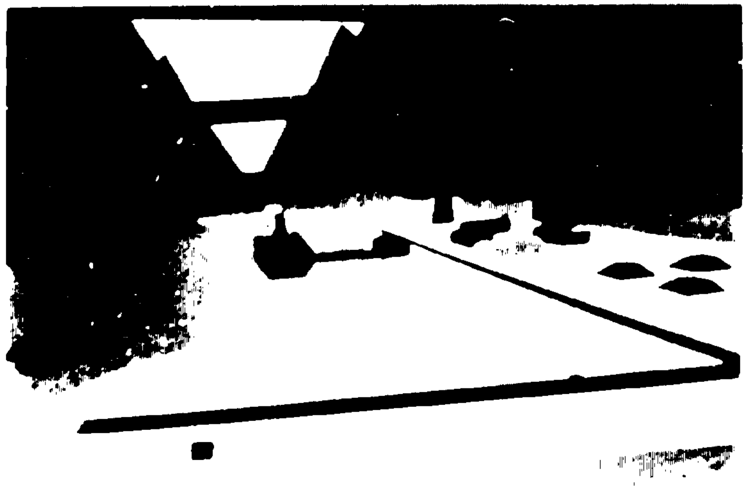

Figure 28. CIG scene of a river bounded by mountains with a defended island and a distant bridge.

DOING MORE WITH WHAT WE HAVE

- INSTRUCTOR TRAINING
- OPTIMIZE SYLLABI
- USE OF DEVICE CAPABILITIES
- MAINTAIN PROGRAM FLEXIBILITY
- FORMAL ASSESSMENT PROGRAM
- SIMULATOR MODIFICATION
- IMPROVED DEVICE RELIABILITY
- POSITIVE ATTITUDES

Figure 29. Suggested strategies for achieving increased training effectiveness with existing equipment.

FUTURE TRAINING REQUIREMENTS

- MISSION REHEARSAL SYSTEM
  - OPERATIONAL READY CERTIFICATION
  - TACTICS/CONCEPT TESTING
- PREOPERATIONAL CERTIFICATION PROGRAM
- SKILL AREAS
  - LOW LEVEL
  - FORMATION
  - REFUELING
  - A/A COMBAT, LONG RANGE
  - MANY-VERSUS-MANY
  - MULTIPLE TARGETS/FRIENDLIES
  - RADAR & SENSOR
  - BATTLEFIELD COORDINATION

Figure 30. Suggested training areas that simulators have potential for meeting by the year 2000.

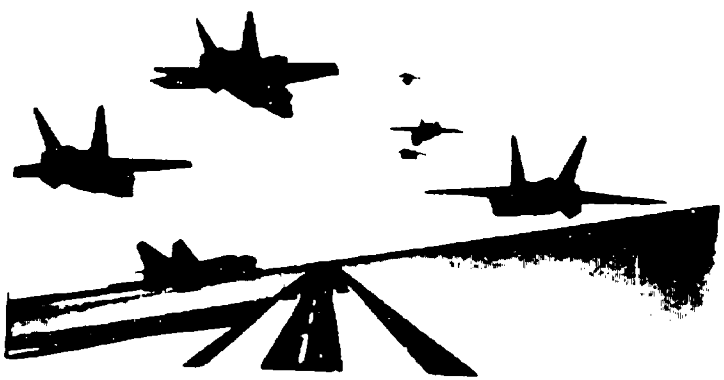

Figure 31. Multiple moving models as generated in the ASPT.

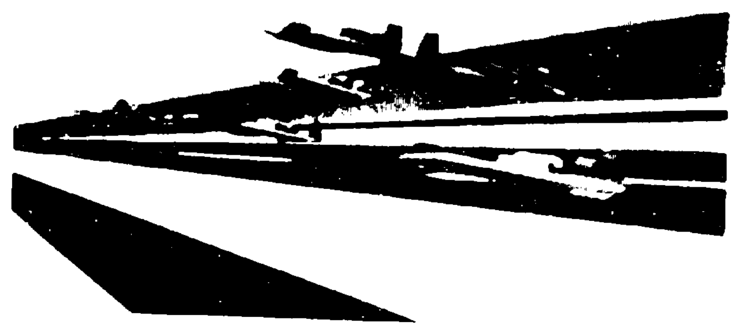

Figure 32. Multiple moving models as generated in the ASPT.

PLANNED RESEARCH

- SCENE GENERATION AND DISPLAY TECHNOLOGY
- INSTRUCTOR/OPERATOR STATION
- PERFORMANCE MEASUREMENT
- OPERATIONAL AREA TASK LOADING

Figure 33. Major research areas for next few years.

SUMMARY

—— GOAL ——

IMPROVED COMBAT EFFECTIVENESS

Figure 34. Major goal of training research.