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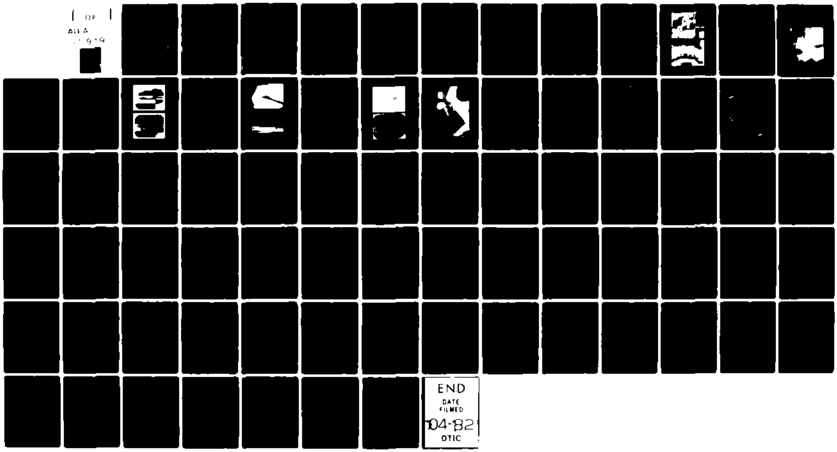

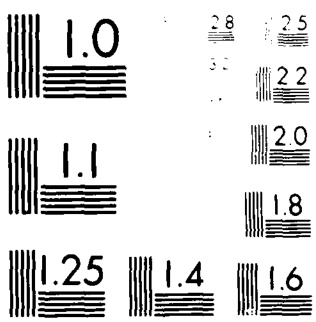

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ADVANCED TRAINING TECHNIQUES
USING COMPUTER GENERATED IMAGERY

D. Hauck
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McDonnell Douglas Electronics Company
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15 September 1981

Annual Technical Report for Period-

16 May 1980 - 15 July 1981

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Prepared for
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Aircraft simulator systems have been primarily designed as substitutes for actual aircraft. The computer generated imagery of these systems provides the flexibility to enhance training in ways that cannot be done in the real world. The thrust of this research is to conceive and demonstrate training approaches to take advantage of this flexibility as a step towards reducing pilot combat attrition and increasing readiness. Two broad categories of techniques are available to us: (1) synthesizing tasks that are untrainable

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in aircraft during peacetime but are required during combat; and (2) application of teaching/learning methods unavailable in aircraft. Exploratory testing has begun on numerous techniques. A VITAL IV computer generated image (CGI) system has been used for testing and demonstration.

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INTRODUCTION

This annual report describes continuation of the study effort on contract number F49620-79-C00067 entitled "Advanced Training Techniques Using Computer Generated Imagery." This reporting period is from 16 May 1980 through 15 July 1981. The objective is to generate and demonstrate new concepts in aircrew training methods that take advantage of the flexibility of computer generated imagery to enhance critical combat skills. The previous study generated concepts for new utilization methods and scene content for aircrew training device visuals. This was followed by implementation of several examples on an MDEC Virtual Image Take-off And Landing (VITAL) Model IV computer generated imagery simulation system. Incorporated into the visual presentation were scene elements which existed solely for instructional purposes rather than as representations of "real world" objects. Examples are given in the progress section of this report.

Statement Of Work

The following research tasks define the statement of work for this contract through the current reporting period:

a. Review relevant literature concerning visual simulation techniques.

b. Review combat flying task cue requirements for selected flying maneuvers.

c. Generate training approaches for modeling and using scenes which might result in positive training of these flying tasks.

d. Develop these scenes using computer image generation systems.

e. Select final training techniques to be implemented and tested.

f. Make experimental plan for testing these techniques which includes specific experimental objectives, subject type and number, experimental protocol, and type of data analyses.

g. Continue coordination with AFOSR, Air National Guard and Parks College to arrange and implement experimental testing of pilots.

h. Implement modifications to MDEC VITAL system as worked out between AFOSR and contractor. Modifications to MDEC system at MDEC will be retained by MDEC.

i. Implement proposed modifications to A-7D simulator at Davis Monthan AFB in such a way to avoid interference with normal training procedures as agreed by NGB/XOO.

j. Arrange details of data collection with National Guard simulator technicians and instructors.

k. Conduct sample interviews with students, instructors, and simulator technicians and analyze this data.

l. Continue concept generation.

Project Goals

The goals of this study were to generate and demonstrate concepts in aircrew training methods that take advantage of the flexibility of Computer Generated Imagery (CGI). While in the past the main objective of simulation was to duplicate the real world cockpit environment, we are now in a postion to consider other objectives that are attainable with training devices. This requires a change in orientation from considering a simulator as an airplane substitute to thinking of it as a training device that can complement "real world" training as part of a total training system which cohesively runs the gamut from text through actual aircraft. Another basic change requiring consideration is the shift in military use of simulators from teaching only initial, simple flight skills and procedures to adding the teaching and maintenance of complex combat skills involving interactions among several aircraft and ground systems.

Specifically the goals were:

- Raise the average standard of skill achieved from a given training segment.

- Develop proficiency more rapidly.

- Maintain skill levels more efficiently.

- Extend the upward limits of skill achieved by the best pilots.

- Make fuller use of conceivable visual stimuli.

- Develop and evaluate non-real world display enhancements.

Past Progress

During the first contract period, a list of key issues to be trained was drawn up to provide a framework for concept generation. (See Appendix A.) A list of 18 generic and 44 specific examples of training techniques was also generated. (See Report No. MDC M3020 and Appendix B.) Selected examples of these were implemented for demonstration purposes on a VITAL computer generated visual system at MDEC. Upon examination of the lists it was noticed that most of the listed techniques are intended to address the teaching of "recognitional" type tasks as defined by Klein in AFOSR Report TR-SCR-79-8, October 1979, entitled, "User Guides: Some Theoretical Guidelines for Their Use." They tend to make use of the learning theory principle of immediate feedback of results and are amenable to inclusion within holistic and/or adaptive training schemes as well as more standard techniques.

1980-81 PROGRAM DESCRIPTION

This effort began exploratory testing of some of these new training concepts for two main purposes. The results were fed back into the concept generation process, and the exploratory testing helped select which of the large number of concepts should first be submitted to more formal testing. That later formal testing (not part of this effort) would provide the type of data required to assure that the techniques indeed add to training effectiveness.

The exploratory testing was divided between two locations and used two different subject samples. Relatively inexperienced flight students and movies were available as subjects for testing at MDEC on a VITAL system with a simple aircraft simulator. In addition, an experienced sample of the Air National Guard pilots and instructors was available for testing on a sophisticated VITAL equipped A-7D simulator. That system was modified under the contract to incorporate some of the advanced training techniques for testing.

Coordination With Air National Guard & Parks College

Coordination was required, particularly early in the program, between MDEC, AFOSR, and the Air National Guard. In addition, coordination was required between MDEC and Parks College (which has a low experience subject pool). With regard to Parks College, Mr. Gerald Spittler, Director of Flight Training, agreed to assist by helping us make his flight students aware of our need for subjects and to help in scheduling student subjects. Parks College presently has approximately 289 flight students on the roster at various levels. They have about 20 flight instructors and operate 23 light aircraft.

With regard to the Air National Guard, personnel from the Operations and training Division were contacted on 4 December 1979. They informally agreed to support our on-site testing and, if necessary, to cooperate in the collection of minor data (e.g., sound recording) that may require the use of an A-7 aircraft. It was mutually understood that National Guard assistance was on a non-interference with training basis and that the National guard is not responsible for funding this effort. In addition, it was agreed that the National Guard may retain any modifications made to their A-7D simulator (Figure 1) and visual system at Davis Monthan AFB. Conversely, any modifications not desired by the National Guard Bureau will be removed by MDEC.

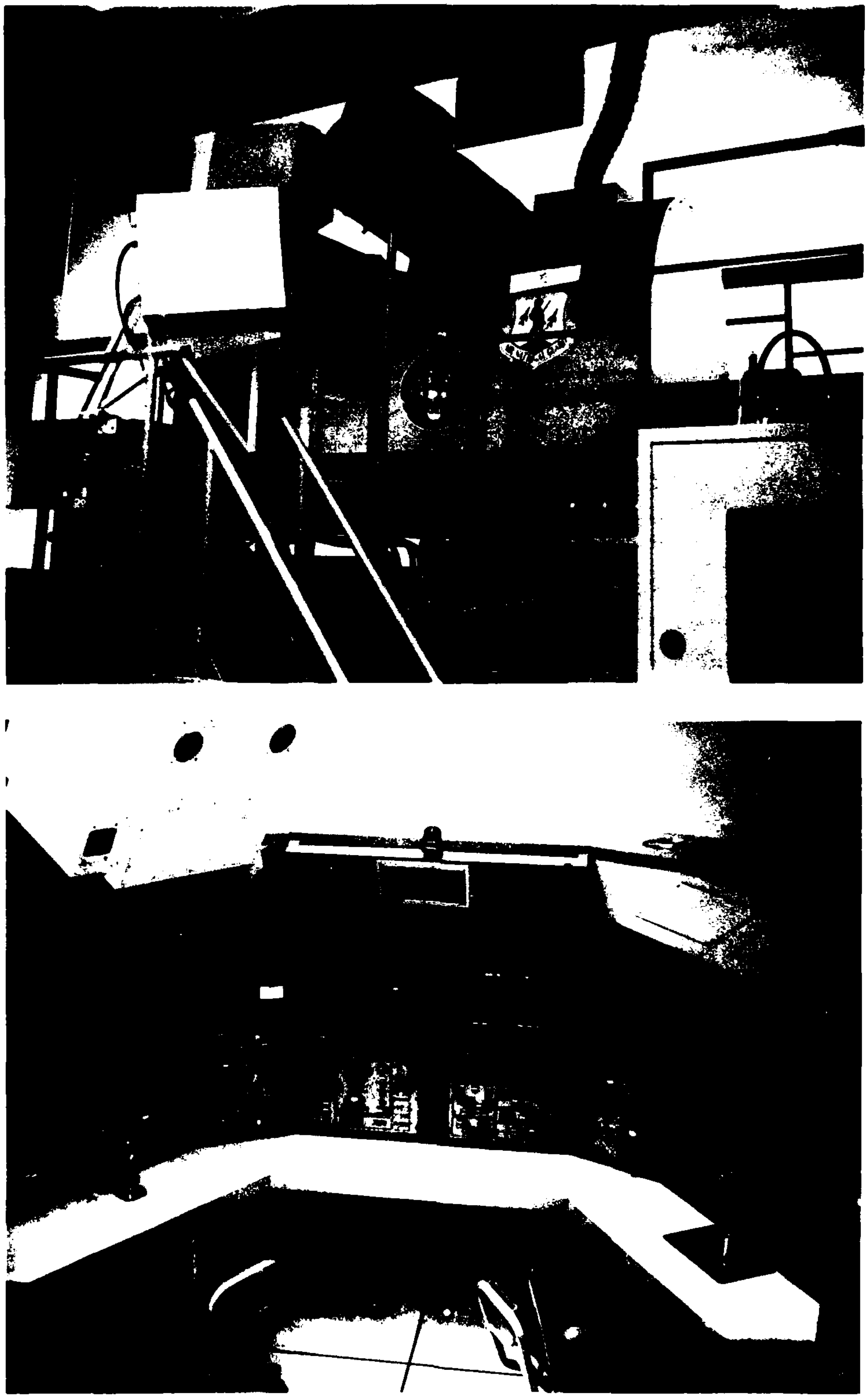


Figure 1. The ANG A-7D Simulator

Continued coordination with the Air National Guard, particularly at Davis Monthan AFB was required to establish methods and schedules for data acquisition and to obtain feedback from experienced users.

Modifications To MDEC VITAL System

Some of the concepts had been implemented on the VITAL system at MDEC during the previous reporting period for demonstration purposes. Additional modifications were required to set up for data taking and experimentation, and to implement other additional concepts. During the course of the contract it was mutually agreed between AFOSR and MDEC that it would be advantageous to change the initial plan, which called for upgrading the software driven by a simplistic joystick box. Instead, an inexpensive analogue flight simulator was procured and interfaced to the VITAL IV system. (See Figure 2.)

Modifications To The Air National Guard System

The A-7D simulator system at Davis Monthan AFB, Arizona, is equipped with a VITAL IV visual system and has access to a large subject pool consisting mainly of experienced pilots but with some less experienced pilots. These conditions combined with the sophisticated training attitudes of the Air National Guard personnel made it an ideal location for exploratory testing of our training approaches. The operational feedback from students and instructors was beneficial. Modifications of the simulator and visual system were performed in such a way as to avoid interference with normal training schedules or methods. It was envisioned that after a student's normal session in the simulator he would spend a short additional period, 15 minutes for instance, using new visual environments. Afterwards, he and the instructor would each spend a few minutes filling out an evaluation form. Instructor and operator participation and comment is crucial since several of the techniques are aimed at providing them with better facilities to perform their jobs. In addition, they are expected to operate the system using the new facilities, collect the data from each session on forms to be provided by MDEC, and provide their own comments, reactions, and suggestions. MDEC personnel installed the changes and explained to the operators and instructors the intended use, operation, and how to collect the data required at each

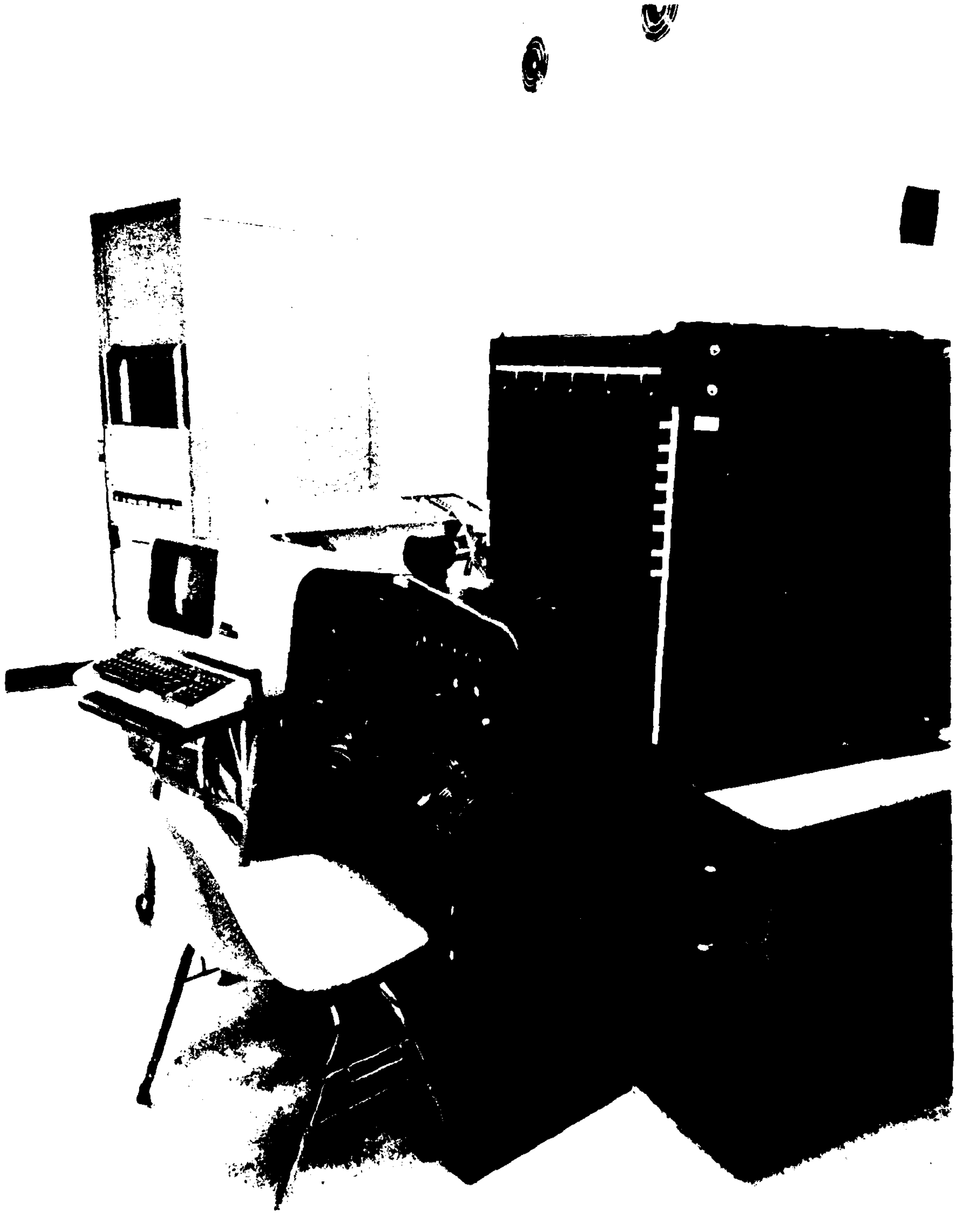


Figure 2. The Analogue Flight Simulator With VITAL IV

session. The data collection did not require much additional time from the operators or instructors beyond their normal training duties.

Data Acquisition and Analysis

As mentioned in the previous section, data was collected by the Air National Guard simulator technicians and instructors during a short period at the end of each normal training session. A sample evaluation form is given in Appendix C. In order to mesh this activity with the normal syllabus and to help us in picking training concepts relevant to the syllabus, we requested a copy of the Air National Guard A-7D training syllabus.

Sample interviews with students, instructors, and simulator technicians involved were conducted to ascertain their reactions to the program and solicit their suggestions. The data was analyzed by MDEC.

Feedback To Idea Generation

Although the emphasis of the program has now shifted from idea generation to demonstration and exploratory experimentation, the concept generation portion of the program continued. Feedback from demonstration, experimentation, and outside sources naturally lead to refinement of the present concepts and the addition of new ones. For example, the Air National Guard Bureau has already given suggestions regarding their Low Level Awareness Training (LLAT) program. A suggestion from the Davis Monthan Team was for an aid to learning range judgment required for planning an attack on a ground target of opportunity.

1980-81 PROGRESS

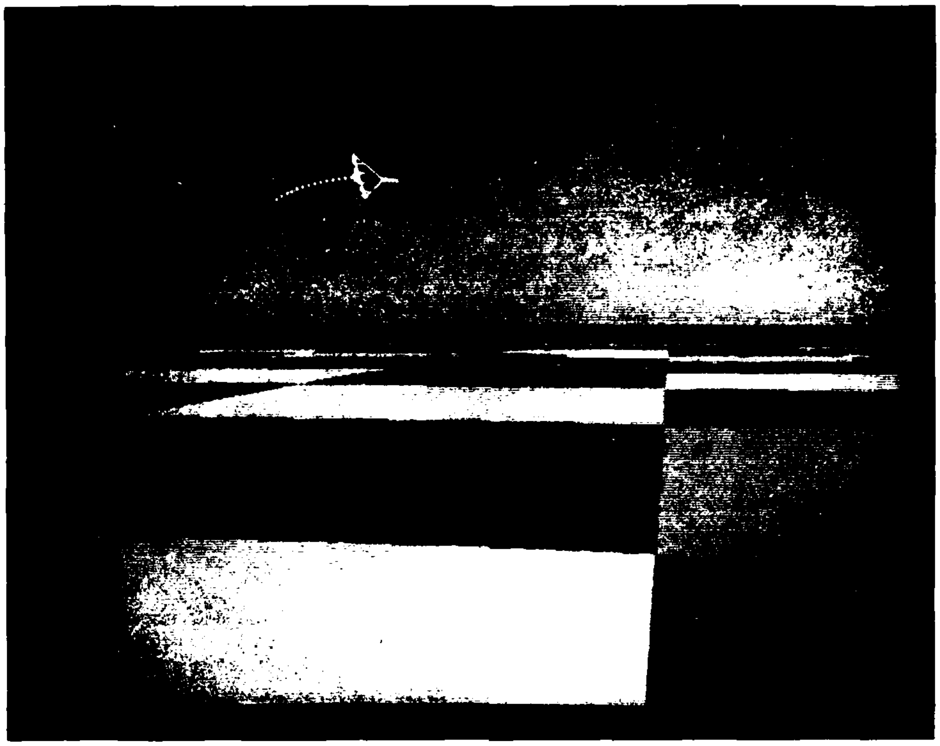
The development of the basic aircraft control interface, using an inexpensive analogue flight simulator, provided a means to evaluate CGI visual training. A study was made using presently accepted imagery practice along with systematic treatment of advanced elements, both real and non-real. Inhouse subjects along with pilots from the Air National Guard at Tucson, Arizona, were used during this study.

Flight and Ground Path Markers

Flight path markers were generated to mark the position and attitude of the simulated aircraft, target, or both. A marker at each wing tip was generated and stored at an easy-to-recognize interval. The relative flight movement during skill development could then be observed to provide the pilot with a comprehensive insight of the task during instructor and self evaluation of a maneuver. It should be noted that this differs significantly from past practice in that now these effects were provided in the student's out-of-the-window display for immediate student feedback and not in the instructor station only. The ground path markers are a modified flight path marker with zero altitude that was used when the target markers were not active. The ground track adds a three-dimensional element. The flight path markers for target aircraft provided additional demand for this enhancement. The markers need to have controllable intensity if used to evaluate air-to-air maneuvers. They should not always be visible from the target during the attack. The marker of the target during attack would be of value to emphasize direction of flight and the present attitude of the target. (See Figure 3.) However, what his attitude was before is of little value. The use of a single light string trail of less than ½ mile and an emphasized target would be best. (Emphasized target subject discussed separately.)

The attitude of attacking aircraft is less important than the flight path over an extended time. The use of a single light string trail would be a better utilization of resources and allow the observation of longer segments of the task. (See Figure 4.)

The implementation of the flight path markers pointed out additional demand for this enhancement. The number of markers displayed needs to be controllable. The instructor may not wish to have the markers visible during the performance of an attack; however, when the results are evaluated the flight paths could add a new dimension to the interpretations. The markers of the target during attack could be used to emphasize direction of flight; however, the attitude and flight path over ½ miles was found to be of little value; however, extended markings are useful for debriefing. (See Figure 4.) The aircraft path markers are best used when combined with the stop action



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(1215-1768)R Figure 3. Shortened Flight Path Markers

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Figure 4. Extended Flight Path Marker Single String

capability of flight simulators and multiple viewpoints. (Multiple viewpoints is in separate topic.)

Cursors

Two types of cursor were prepared. This feature gave the instructor a direct link to the student's visual impressions. The instructor's joystick was used for controlling the desired position in addition to a choice of preselected positions. A horizon depression cursor was controllable in azimuth and elevation angles. The shape of this cursor was a graduated square. After being positioned it would stay a fixed number of degrees below the horizon to represent a desired dive or glide angle. (See Figure 5.) A display cursor was a measuring cross that could be positioned horizontally and vertically in display coordinates with the instructor's joystick. (See Figure 6.) The use of the cursors depends much on the creative imagination of the instructor when combining this aid with his lesson plan. The A7-D simulator joystick is located on the opposite side of the instructor's console from the visual display monitor. For better results, the control should be in a convenient position while he is observing the instructor monitor. The poor position resulted from the fact that the instructor station joystick was originally designed for use with the electronic warfare console only. The visual system and our modifications to its software were only added much later. The addition of a cursor that was scene stabilized was suggested by all instructors that used the system. They expressed the need to have the ability to point out a specific location in the scene and such a cursor would stay on the object once set in position making this easier.

Immediate Scoring

The importance of the ability for the pilot to self-evaluate cannot be overemphasized. The instant that the maneuver is completed, the conditions are fresh in the pilot's mind, and immediate scoring enables him to make best use of this knowledge when evaluating events associated with a maneuver. The visual system program was modified at ANG request to provide this immediate scoring information across the top of the student's out-the-window scene.

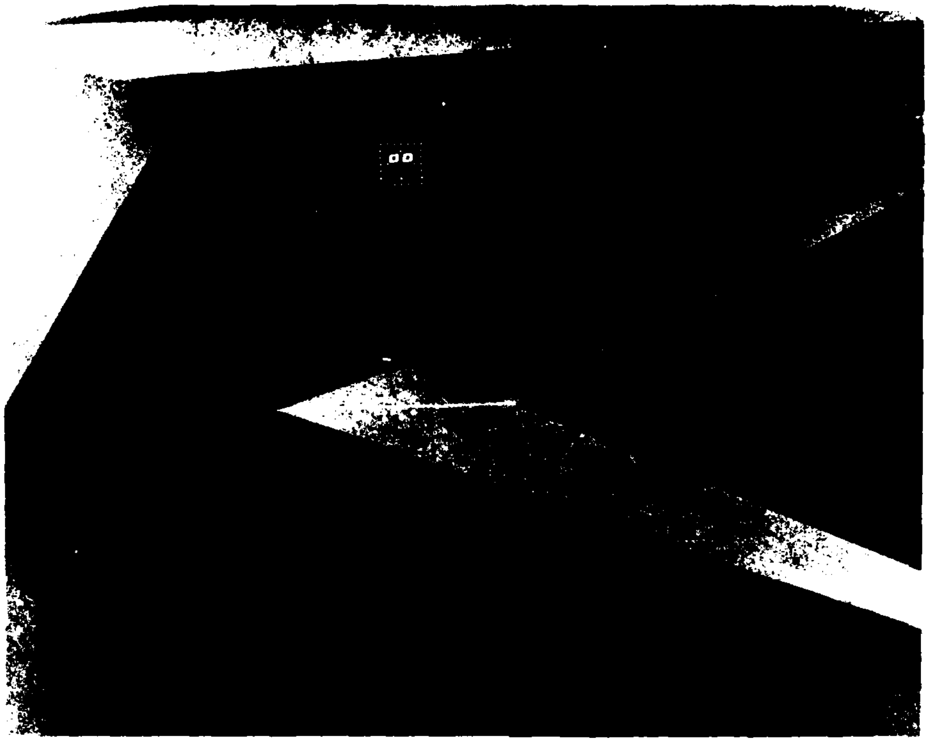

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Figure 5. Horizon Depression Cursor

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Figure 6. Display Cursor

Weapon Delivery Scene Requirements

Air-to-Air - The model of an air target can have many demanding visual requirements. The element resources available to CGI systems to represent the target are lightpoints and shapes. The tasks of air-to-air refueling formation flying, and aircraft identification require a model of high detail when observed at relatively close range. Shapes are, under most circumstances, used to generate the visual image. The modeler should be made cognizant of the visual requirements when selecting the modeling process. (See Figure 7A.)

The visual requirements for a target that is to be used for air-to-air gunnery differ. The pilot is mentally developing how to maneuver his aircraft into a favorable position; to do this, he must learn to judge the target airspeed, attitude, range, and heading. The model for this is best presented as a generalized ground plane and a highly defined outline of an airplane of specific wingspan. (See Figure 7B.) The shapes can be arranged in such a manner as to present a dimensional target, however resolution and minimum size reduces their effectiveness with range. The calligraphically drawn lightpoints are very resolvable, but not realistic when representing solid objects at close range.

Air-to-Ground - The scene data base requirements for air-to-ground weapon delivery should be well understood by the modeler.

The scene modeler should first consider the task's requirements when selecting elements to be used. A single scene can be used for more than one task, however, one should be careful not to omit significant elements that would be advantageous to learning a particular maneuver. The outstanding features of a scene must contain the proper balance of detail for the visual requirements, for example, a mountain that is to be a checkpoint. The modeler could represent the mountain with from one to fifty scene elements; the final selection should be based on the visual demand of the training task the scene will be associated with. (See Figure 8.)

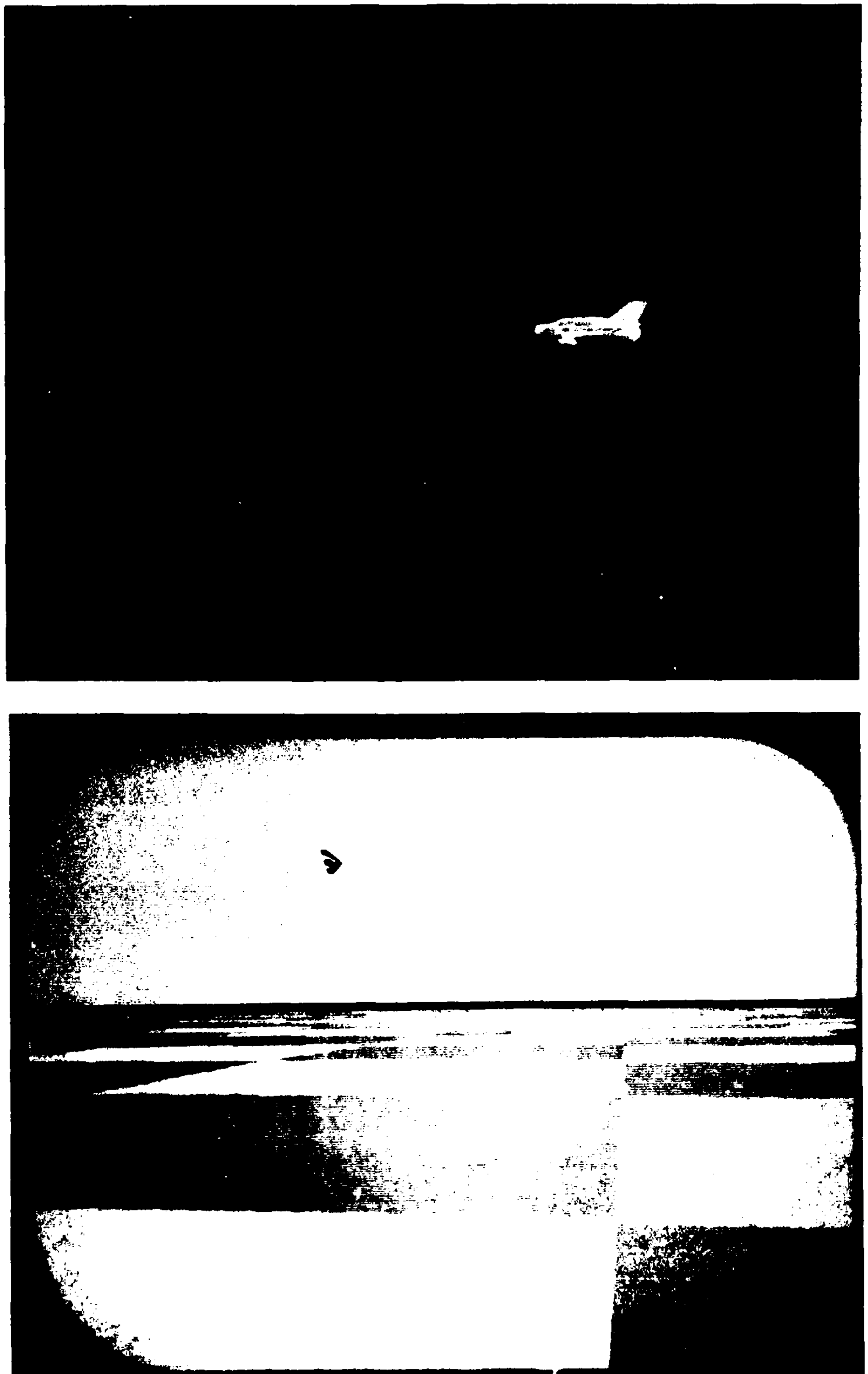

Figure 7. Target Modeling Techniques

Figure 8. Scene Modeling in Progress

The scene modeler should consider more than the selection of real world elements for a training task. Non-real world elements can be just as important, if not more so. The elements can take many forms. However, some examples are course markers, range markings, key window, attitude direction, etc., (See Figure 9.) The capability to turn on/off scene elements exists now in most computer generated imagery systems. This adds to the flexibility that the instructor can be given for effective adaptability.

Cannon Tracer Range Emphasis

The cannon tracers were emphasized by increasing their intensity when their range matched that to the target. It was hoped this would aid the pilot in learning to make accurate range estimates and miss corrections. (See Figure 10.)

The primary mission of the Air National Guard at D.M. is air to ground weapon delivery. The air-to-air effects should be evaluated at a location that is directly involved with air-to-air gunnery as part of their primary duty.

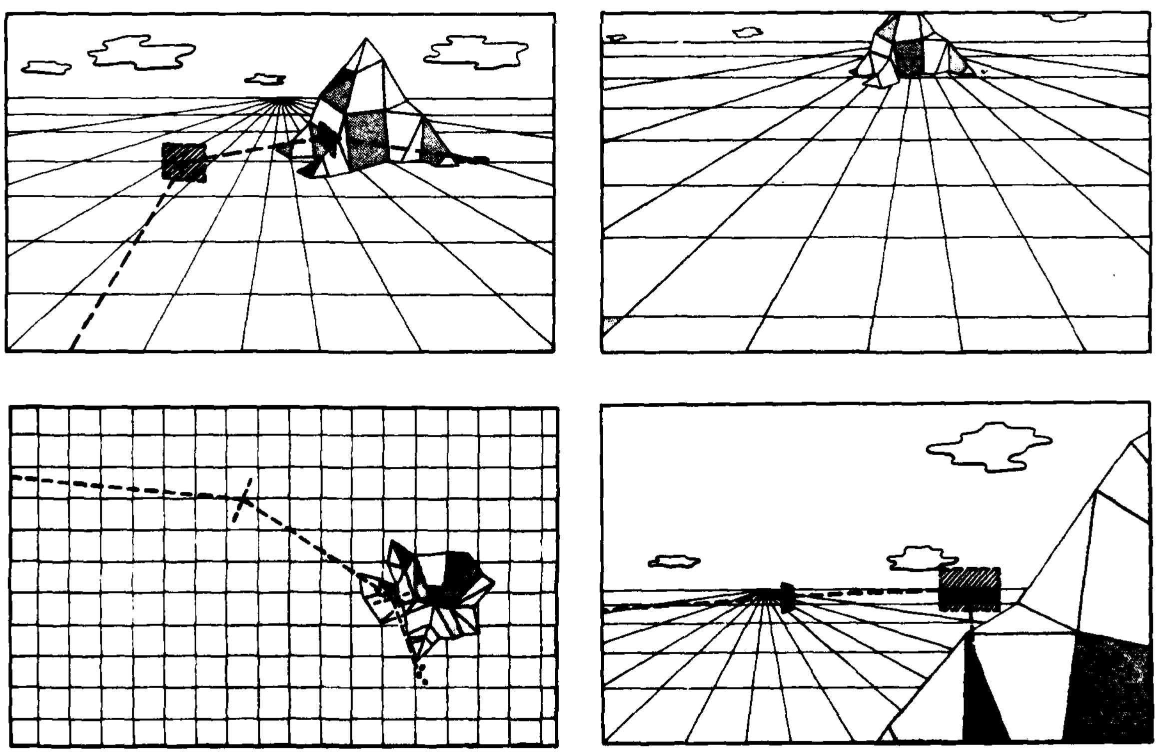

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Figure 9. Example of Non-Real World Scene Elements

Multiple View Points

The importance for the pilot to form a mental survey of the situation at different phases must be stressed. (See Figure 11.) The ability to generate multiple view points for visual situation presentation during training not only gives the instructor an additional aid, it also stimulates the pilot for self-evaluation. The selected view points visually presented the situation from offensive and defensive aspects for a complete understanding of the required tactics. The multiple view points are desirable for developing both air-to-air and air-to-ground procedures. When used in combination with other features like problem freeze and special effect programs (flight-path markers, cursor, emphasized target, etc.), multiple view points can be expected to accelerate training at all levels. The actual view points could be chosen to fit the conditions to be observed. One example showed the pilot what he looked like to a surface-to-air missile operator so that effective evasive survival techniques could be practiced. The National Guard pilots expressed little interest in this. They were totally offense oriented in their thinking.

Velocity Vector

The velocity vector is a visual mark to indicate to the pilot the extended flight path of the aircraft. The CGI display can be used to supply this feature for any aircraft. The A-7D has this feature in the aircraft as part of the HUD; however, other common types of aircraft do not have this aid. The vector provides the pilot with a visual reference that can be relied on while developing an error-free aim point perceptual judgment. The skill to judge aimpoint is applied to all ground reference maneuvers, whether it be take-off and landings or delivering air-to-ground weapons.

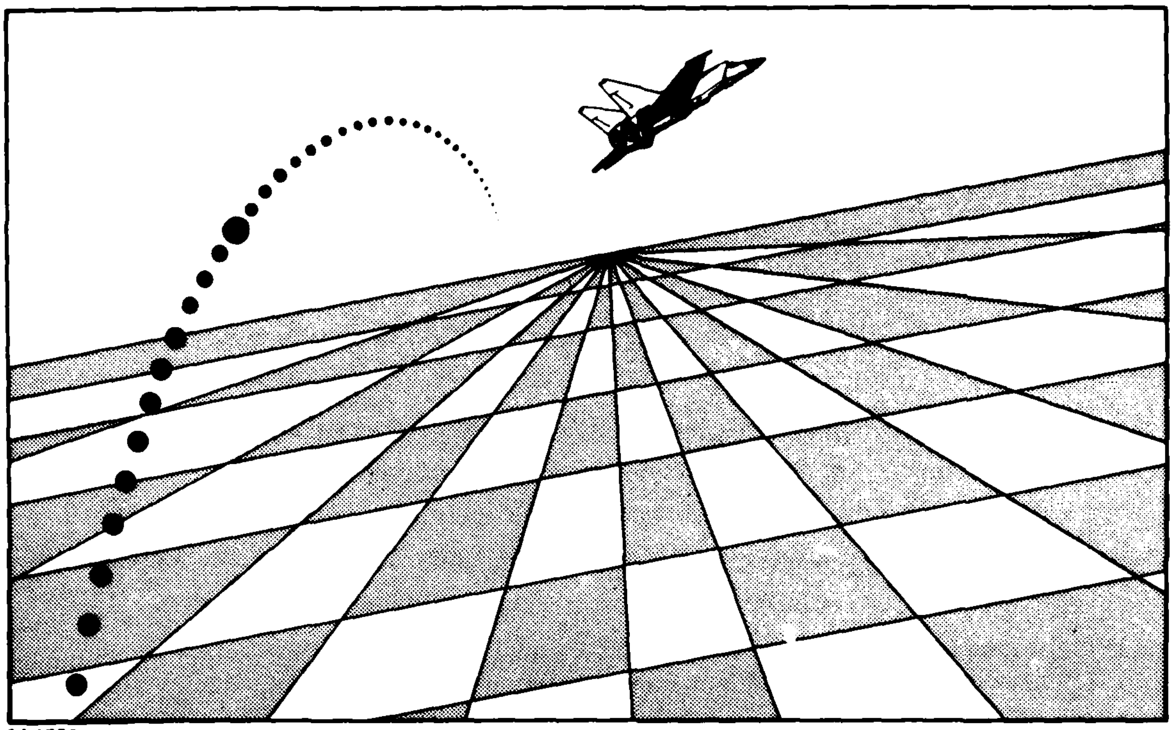

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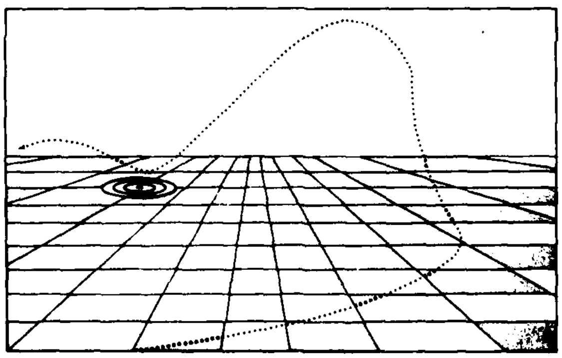
Figure 10. Tracer Range Emphasis



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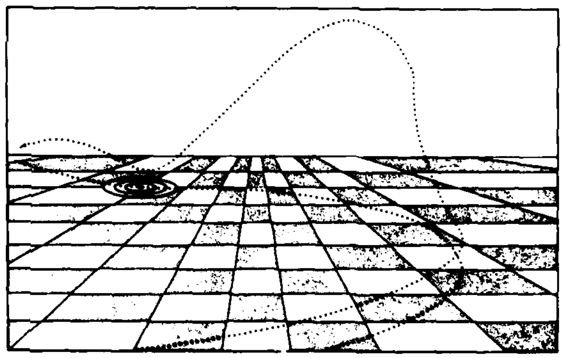

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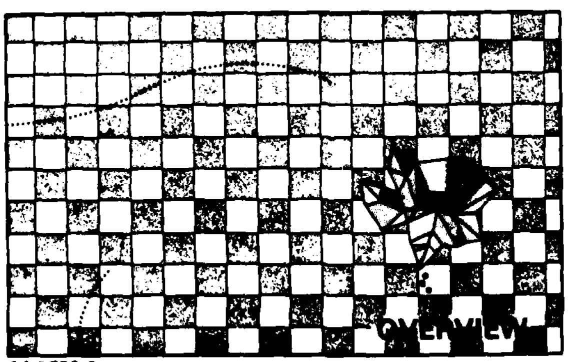

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Figure 11. Multiple Viewpoints

Target Attack Cone

The ability to visually project a three dimensional geometric volume of importance with respect to a target was demonstrated using scene elements to form a danger zone as part of the air target database. The Air National Guard at Davis Monthan does not regularly engage in air-to-air combat in their present flight commitments; however, many of the pilots had past experience. The scene that was utilized outlined the area that the pilot must avoid to prevent the target from having the combination of circumstances favorable to become the aggressor. (See Figure 12.) The boundary of the area to which the pilot must gain position to be an effective attacker for his weapon system was requested by all who were shown this feature. Despite the fact that there was little interest in the particular area modeled, there was much interest in the potential capacity of this instructor aid. (See Figure 13.)

Scene Element Utilization

The use of the simplified analogue simulator with a VITAL IV visual provided the mechanism to dynamically evaluate scene element utilization. The single task detection of changes in roll, pitch, or yaw indicated that novice pilots and non-pilots could perceive the same movement of scene elements on a CGI display. This was demonstrated by introducting angular changes at various rates from level flight and measuring the angular change accumulated before the subject took corrective action. (See Figure 14.)

The ability to meanfully recognize characteristic movement patterns of scene elements was demonstrated. The subjects were asked to make altitude judgments from visual observations while descending over generalized terrain. The scene used was a random set of lightpoints on the ground and a predominate horizon. The first attempt showed random estimates; however, when exposed to the same task after observing correct examples for immediate comparison, the results were consistent.

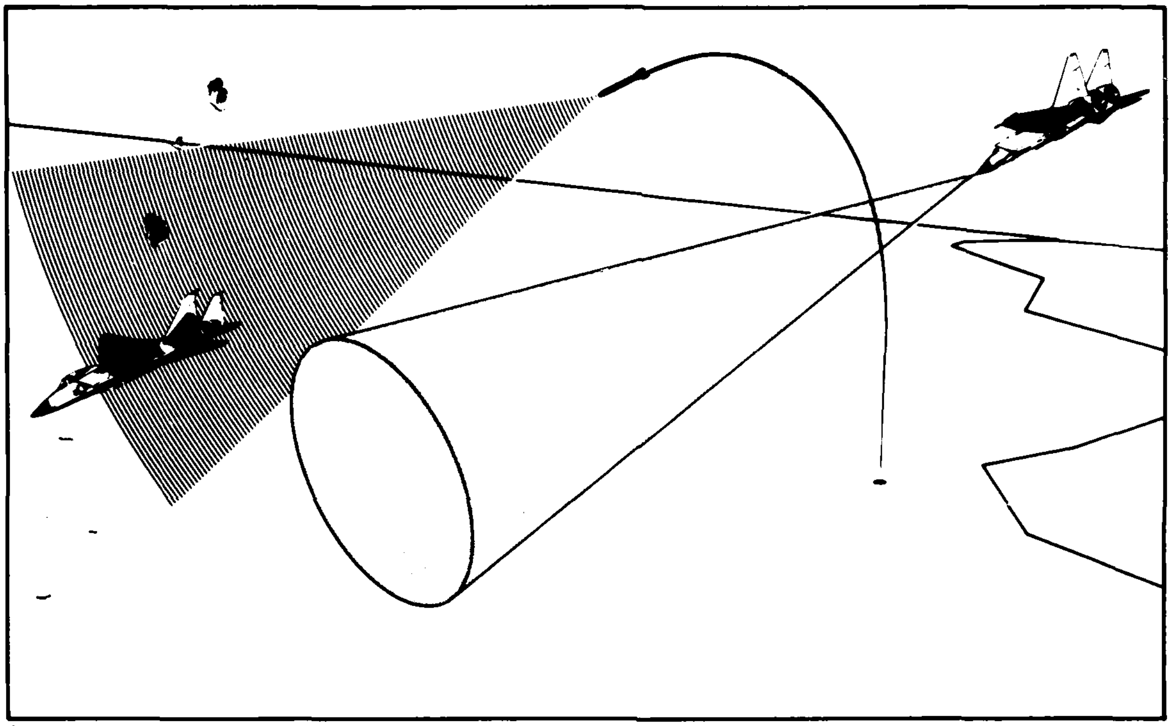

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Figure 12. Visible Lethal Cone

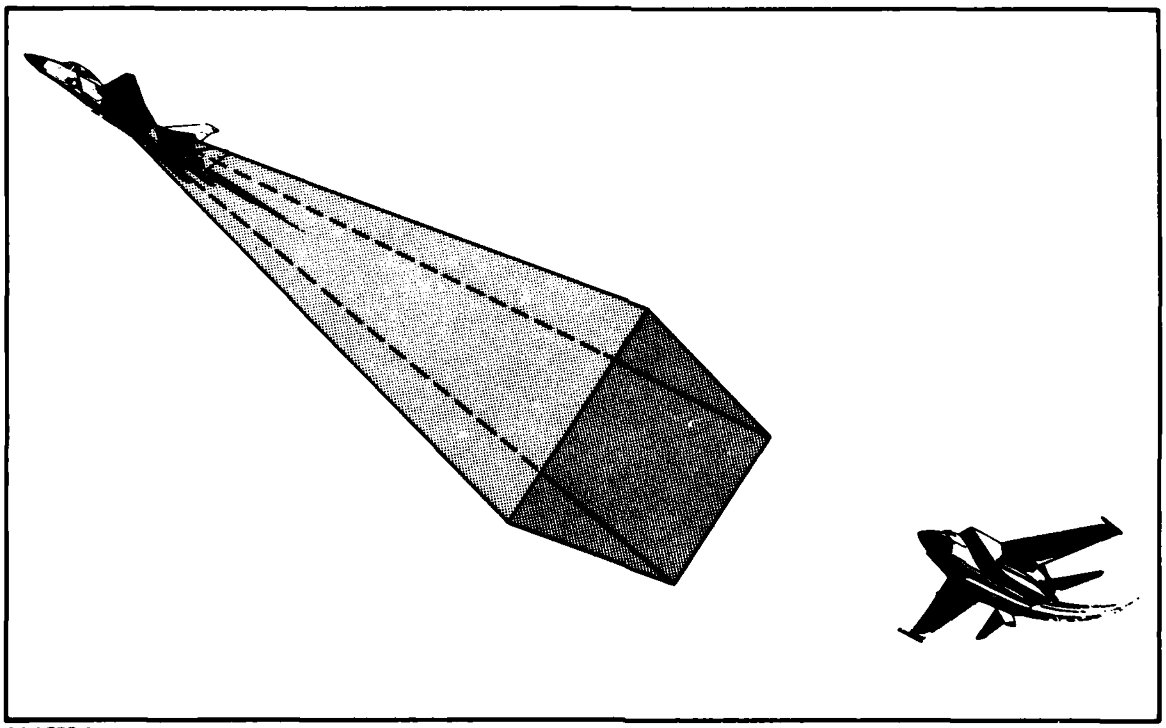

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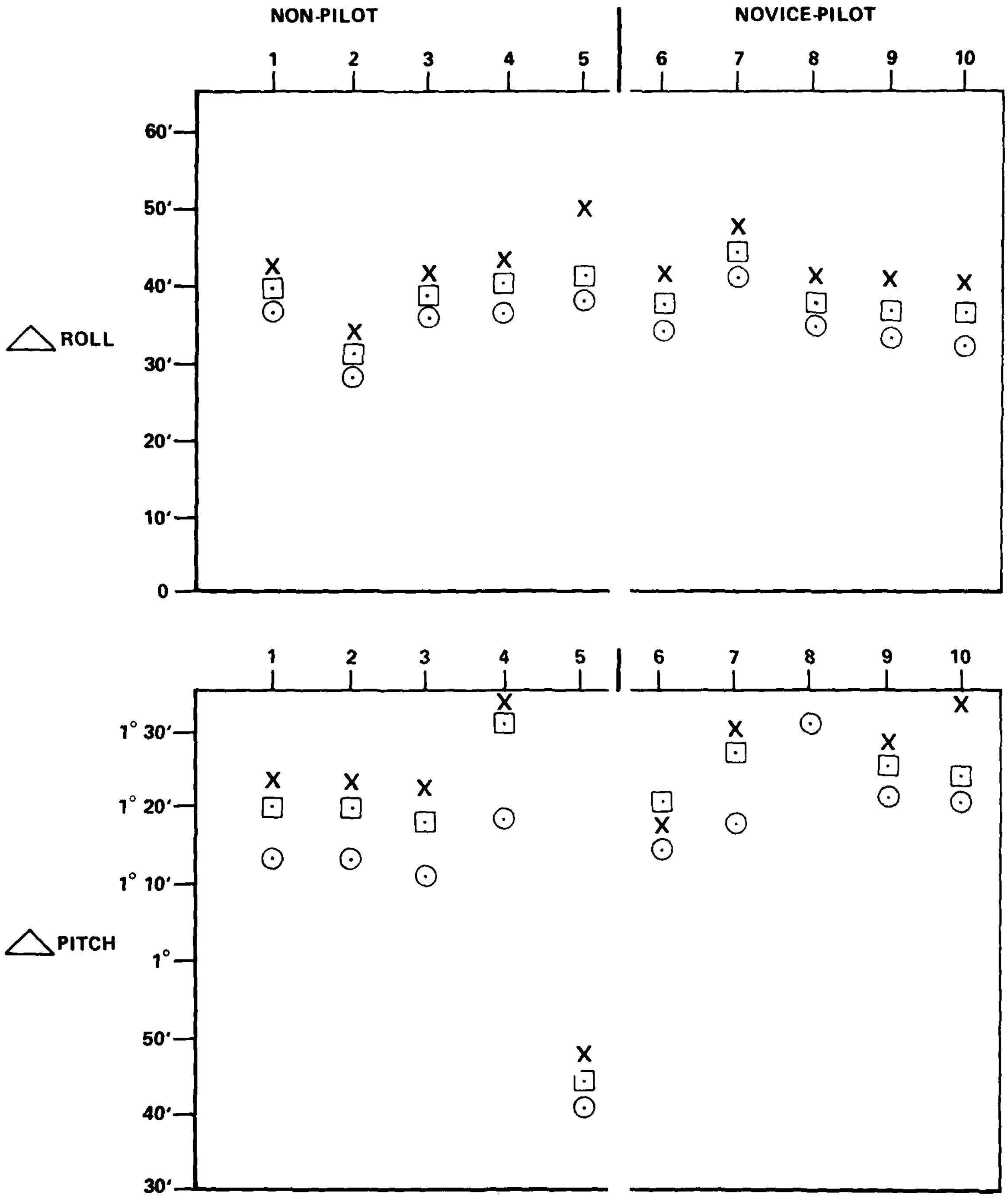
Figure 13. Visible Attack Cone



Condition: Subjects were asked to correct any angular change while observing a dynamic scene in straight and level flight. A single axis rate of change of 2'/sec. was introduced, the angle at which the first correction occured was recorded.

⊙ = Horizon and unlimited visibility
⊡ = No horizon and unlimited visibility
X = Visibility 1-1/2 mile

Figure 14. Angular Change Recognition

The ability to accurately judge small angles using scene elements was immediately improved when examples were shown for comparison. (See Figure 15.)

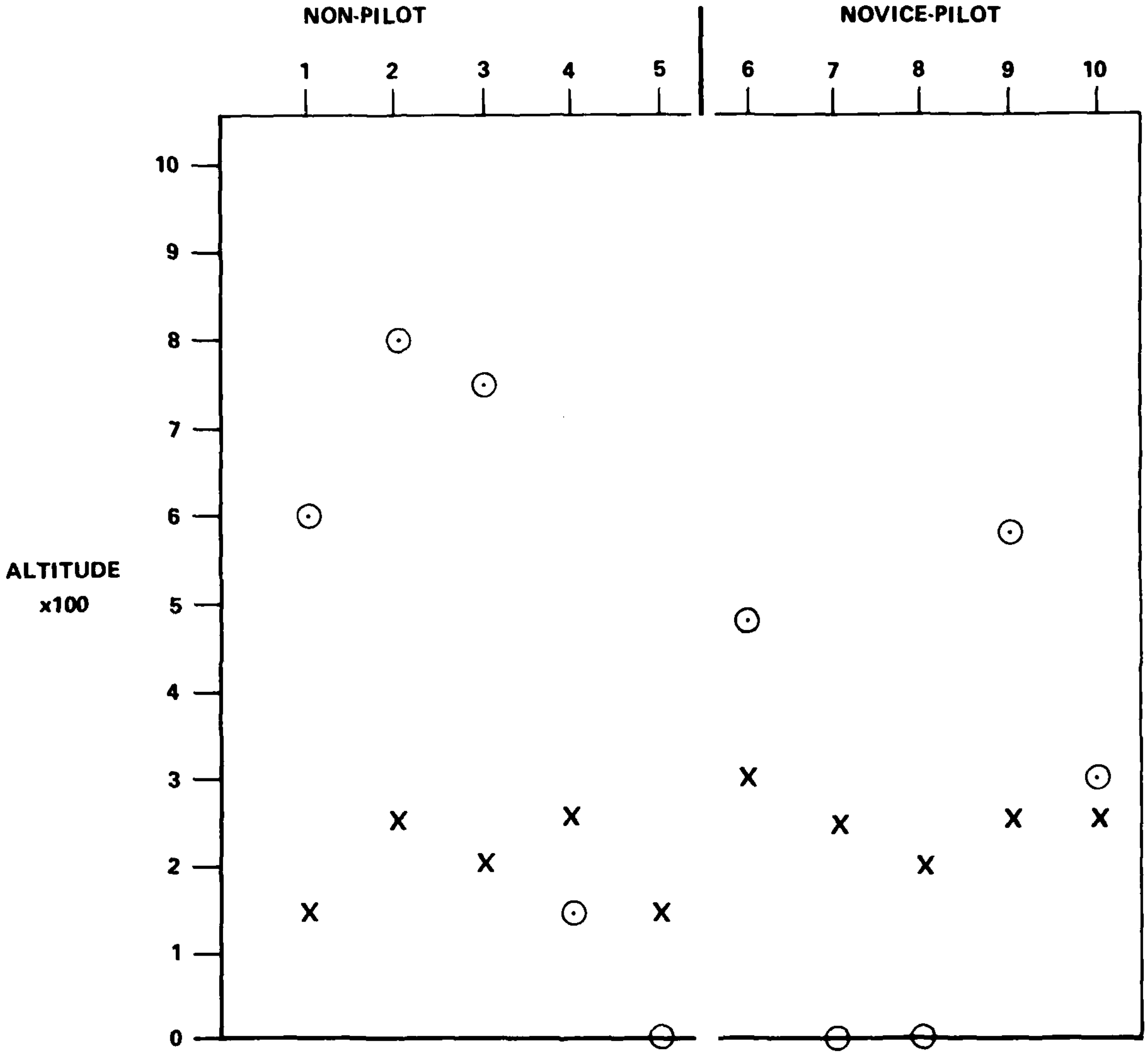
The immediate visual observation of the ideal model for a complex maneuver can be presented utilizing controllable scene elements. The model provides the trainee with a visual example for comparison during skill development. (See Figure 9.)

The requirement to demonstrate low altitude flight control skill has continually been expressed as a key element when developing many advanced combat maneuvers. The demand to generate real world scenes to accomplish effective training in this area is outside the present capability attainable with CGI. A simple pattern of section divisions of an area 20 N.M x 20 M.M. could completely consume the elements available for a scene. Low altitude (defined as from the surface to 300 ft. A.G.L.) training requires more visual stimulation than that available from a pattern of this size.

A dynamically relocated overlay grid provided much greater visual stimulus. A grid made up of thirty stripes visible only below 300 ft. A.G.L. and less than 3500 ft. range was used to provide ten times the visual cues utilizing less than ten percent of the scene capability that would have been required using normal techniques. Other elements such as altitude reference markings (trees) were also included in the relocating overlay. This relocating overlay can be used along with existing training scenes.

The principal of the relocating overlay was successfully demonstrated in the lab as part of MDEC's in-house research. It will be field evaluated next year under this contract.

Movement of scene elements can be clearly perceived on a CGI visual system. The single task detection of changes in roll, pitch and yaw showed that pilots and non-pilots see the same thing. The reaction to the visual inputs, however, does vary with the experience and training of the individual. Training for reaction based on specially designated scene elements can then be used to improve real world performance. The single



Condition: Subjects were asked to judge when their altitude was 200ft. while observing a dynamic visual scene of a generic ground plane.

⊙ = First attempt.

X = After observing condition for comparison.

Figure 15. Altitude Comparison

instructor controllable introduction of a non-translating lightpoint at specified relative azimuth and intensity would present to the pilot the first visually recognizable elements of a collision. This feature would allow this recognition awareness to be included with other training syllabus elements. This is an example of scene elements that can be introduced to improve pilot reaction to visual stimulus rather than describing a specific object.

Interactions With Other Organizations

A number of interactions with people from other organizations occurred during the reporting period. The major one was a paper presenting results from the first reporting period. This was given at and included in the proceedings of the Interservice/Industry Training Equipment Conference, Nov., 1980, in Salt Lake City, Utah. The paper was well received and resulted in discussions of the proposed training techniques with personnel from the Naval Training Equipment Center, Air Force Human Resources Lab, Army Research Institute, National Research Council, and Tri Service Simulation Technology Adivsory Group (SIMTAG). A presentation at the Annual Review of the Air Force Office of Scientific Research fostered many fruitful interactions with other researchers in the field. Among these were Dr. Regan, several vision researchers at MIT, and those addressing similar issues at Ohio State University. The future subcontract activity involving Cambridge Intelligent Systems for design of a tactical decision making display and training approach also resulted from this conference. Such tactical decision training displays were discussed with individuals representing a number of organizations including the Naval Training Equipment Center, the Naval Air Test Center, McDonnell Aircraft Company, and the Israeli Air Force. The Air National Guard and Parks College have cooperated in this research by offering test subjects and suggestions.

FUTURE ACTIVITY

In addition to continuing the concept generation activity, the following year's statement of work calls for:

a. Design and testing of novel dynamic CGI scenes to train tactical judgment. One of these scenes should include an energy diagram (or other representation which dynamically changes in response to flight conditions).

b. Development and testing of novel training techniques specifically designed to improve performance in low level flight. These techniques should incorporate the new concepts in aircrew training methods generated during the first two years of the contract.

c. Completion of exploratory testing of training techniques developed during the first two years of contract.

d. Development of a dynamic demonstration (film or videotape) which illustrates the most promising training techniques developed during the course of this research effort.

The examples given in the progress section may be thought of as a form of calisthenics for fighter pilots. Instead of exercising their muscles we are exercising their visual perception and tactical judgment. Perceptual calisthenic implementation and testing will be continued and implementation and testing tactical judgment training techniques will begin. Experimental subjects will be drawn from flight students at Parks College and from Air National Guard pilots and instructors at Davis Monthan AFB, Arizona. Two Israeli instructor pilots presently living in Boston, Massachusetts, will assist under subcontract in the design of the tactical judgment training display and its utilization. This display will be implemented by MDEC on a VITAL system.

Key combat flight issues identified in the previous study effort were energy management and low altitude flight. A recent Air Force study (AFHRL-TR-79-44) identified visual lookout and maintaining position as key to the overall success of low level tactical formation missions. The studies involving Parks College students at MDEC on the simple simulator will concentrate on visual cues and training techniques to improve performance in low level flight. The effort to improve energy management training will center on the use of an energy diagram (or other representation) which dynamically changes in response to flight conditions. This is part of an overall strategy of using the training device to aid tactical judgment training. In addition, testing of other training techniques will continue in cooperation with the Air National Guard.

The National Guard will continue to supply test subjects and instructor pilots for evaluation. MDEC will supply the evaluation forms and perform the data analysis. As exploratory testing results become available, an effort will be made to begin coordination with the Air Force Human Resources Laboratory and other testing agencies to begin formal testing of the most promising techniques.

Coordination With Cambridge Intelligent Systems

The subcontract to Cambridge Intelligent Systems (Israeli instructor pilots) will have as goals: The design of a dynamic visual presentation of energy maneuverability data, and development of a training procedure for optimal use of a simulator having this visual presentation. MDEC will implement the presentation on a VITAL system. Appropriate people at MCAIR will be consulted to avoid duplication of past work in this area.

Feedback To Idea Generation

Although the emphasis of the program has now shifted to implementation, exploratory test, and demonstration, the concept generation will continue. Feedback from demonstration, experimentation, and outside sources will naturally lead to refinement of the present concepts and addition of new ones. For example, the Air National Guard has already given suggestions regarding their Low Level Awareness Training (LLAT) program. Another of their suggestions this year was a cursor that a pilot could place on a ground target of opportunity in the scene. The computer would then show the range to the cursor after the pilot has made his guess. This could be used as an aid to learning to judge range.

SUMMARY

This report presents the results of exploratory testing of an array of training techniques using non-real world element enhancement of CGI visual systems. The feedback from this activity has varified the effectiveness of the concepts. The continuation of testing and refinement of these techniques for explicit skill development will establish a base for utilizing CGI during advanced combat maneuver training. The next period in this process of development will be used to illustrate the principles for selected complex combat skills and compile exploratory testing.

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APPENDIX A

KEY ISSUES TO BE TRAINED

I. Factors Affecting Probability of Kill (P_K)

- A. Energy Management
  1. own
  2. threat energy state
- B. Offensive Weapons Systems
  1. switchology
  2. knowledge of best system selection
- C. Assessment of Threat (Current)
  1. status assessment
  2. knowledge of what to do about it.

II. Factors Affecting Probability of Survival (P_S)

- A. Energy Management
  1. own
  2. threat (know energy state of threat)
- B. Defensive Systems Management
  1. display threats
  2. respond to threats
- C. Assessment of Threats
  1. status/number
  2. knowledge of what to do about it.

III. Maximizing $P_K \times P_S$

IV. Low Level Fight

APPENDIX B

GENERIC LIST OF TRAINING TECHNIQUES

1. Make "visible" something the pilot normally cannot see, but tries to model in his mind. For example, let's say a pilot knows that another aircraft will have to get him within a 10-degree cone and within a six-mile range to lock on some particular kind of missile. This "cone of danger" emanating from the nose of the other aircraft needs to be visualized by the pilot, so that he may avoid it. This visualization in three dimensions under a wide variety of circumstances could be taught by simply showing the cone emanating from the other aircraft in a computer generated image visual system. As the pilot flies against this target, he can learn to internalize the image of the lethal cone for use in the "real world", where the cone is invisible. Obviously, there are many other examples of situations where this technique of making a cue available in the simulator that is hidden in the real world would be expected to be useful for training.

2. Scoring/Error Feedback. This is not a new technique, but it certainly could be used in new ways. Computer generated image out of the cockpit displays provide the opportunity for quicker feedback, which is known to produce quicker learning. An example of this technique would be to superimpose scoring data on the pilot's outside scene during a training flight in the simulator. For instance, the pilot's probability of survival could be displayed in a corner of the scene as a bar graph ranging from zero to one and if the probability gets too low, the computer could display a brief explanation of what he has done wrong immediately while he is still in the cockpit, instead of waiting until later. Or for bombing practice, miss distances and aircraft parameters at time of release could be shown after each bombing pass.

3. Feed Forward/Predictors. An example here would be during air-to-air combat. When a pilot is on the offensive, he could be shown where his present course and closure rate would cause him to intercept the target's flight plane.

4. Discrete Indicators. A simple discrete indicator can be used to teach the student to recognize and respond to a particular situation. In teaching low level flight, if it is desired to stay below 250 feet, a simple tone or indicator could be given when that limit is reached or exceeded.

5. Pointers for Instructor and/or Student. It has long been known that a simple pointer is useful in communication about visual displays, yet no aircraft simulator has such a pointer available for use in the out-of-the-window scene.

6. Adaptive Aids. This is an extremely broad category which must be carefully used to avoid student dependence on the aid, but can be extremely effective in quickly making the student capable of performing correctly. The visible adaptive glide slope of Gavan Lintern[1] of the University of Illinois is an example.

7. Awareness Stimulators. There is a dangerous tendency for a pilot while performing a difficult task, such as air-to-ground or air-to-air attack, to focus on that task to the exclusion of perception of other events around him. To maintain the pilot's awareness, other objects or events could be presented in the scene, such as other aircraft, and the pilot's ability to monitor them during his task could be included in his score for the task.

8. Demonstration/Exaggeration. If a subtle cue must be detected by the pilot, it can be helpful to exaggerate the cue first, so that the pilot has a good awareness of what he is looking for. For example, a pilot has an altitude below which he is so involved in avoiding ground impact that he can not perform other tasks. That altitude is his "comfort level".

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1. Lintern, Gavan, Transfer of Landing Skills after Training with supplementary Cues, Procedings of the Human Factor Society, October 1979, p. 301-304.

If it is desired to demonstrate to the pilot that his comfort level depends on his speed, a simulated course may be flown at Mach 3 and then at 30 knots before allowing him to learn his comfort level for more normal speeds.

9. Cue Supplements or Cue Augmentation. Again, subtle cues may initially be supplemented with more obvious ones, to lead quickly to correct performance and then weaned away as the student's proficiency increases. This would be particularly adapted to the case where the pilot is learning two different tasks simultaneously, while one is dependent upon the other. For example, in landing, the two tasks are: controlling the airplane, and perceiving the flight path. One cannot control the airplane without perceiving the flight path. One cannot control the airplane without perceiving the flight path and one cannot test one's flight path perception before getting the airplane under control. This contradiction can be avoided by supplementing the normally subtle flight path perceptual cue until control is learned and then teaching the perceptual task of detecting glideslope deviations from subtle cues.

10. Cue Indicators. There are many subtle cues in flying. These may be indicated to the student in a variety of ways such as, use of "pointer, exaggeration, elimination of other extraneous cues, and so forth."

11. Time Compression/Expansion. Sometimes events occur too quickly for the novice to appreciate them individually and to think through the ramifications. Conversely, the more experienced student may need to "overlearn" one task, as to be able to perform other tasks simultaneously. One could slow the system down for the former and speed it up for the latter. This technique might also be used to simulate the situation when one's internal clock is running faster than normal.

12. Quantization of Time. A task can be broken into discrete steps such as in the task taxonomy of Robert Meyer.[2] These may be learned singly in

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2. Meyer, R. Laveson, J., Pape, G.; Development and Application of a Task Taxonomy for Tactical Flying, AFHRL-TR-78-42, Air Force Systems Command, Brooks AFB, Texas, Sept. 1978.

whatever order is best suited to learning. Examples would be the backward chaining technique of Hughes[3], or a slide presentation.

13. Sense Exercise. A computer generated visual system can readily be used to give a student practice in certain types of fine perceptual tasks with feedback such as immediate knowledge of results. There are many useful examples of this technique; one could practice closure rate judgements, target aspect from motion judgements, landing flow pattern discrimination, low contrast target detection, scan patterns, and so on.

14. Dynamic Observer Control of Scene and Cues. For example, if it is desired to teach a student to judge target aspect, he could be given control of the target as if it were a remotely piloted vehicle. If the aspect was uncertain, he could test it by seeing how it responds to his control inputs.

15. Analogies. It is often useful to show similarities between a task to be learned and a more familiar task. It may even be useful to teach a simple task for later use in analogy to a more complex task.

16. Perspective Changes. Advanced pilots generally do not view their actions from their own viewpoint, but abstract the situation to an overview or "G-d's eye view". Some simulator instructor stations show this viewpoint to the instructor or to the student after an engagement. More immediate feedback to facilitate this perspective abstraction could be given by allowing the student to change the vewpoint being displayed while still in the cockpit. Other viewpoints could also be helpful, such as how he looks to a ground threat or to his opponent.

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3. Hughes, R. G., Advanced Training Features: Bridging the Gap Between In-Flight and Simulator Based Models for Training, AFHRL-TR-78-96, Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, AZ, March 1979.

APPENDIX C

SAMPLE EVALUATION FORM

FILL OUT IMMEDIATELY AFTER EACH FLIGHT USING SPECIAL EFFECTS:

INTRODUCTION:

This questionnaire will help us determine your reaction to some special effects being tried on the A-7 Simulator under sponsorship of the Air Force Office of Scientific Research (AFOSR) in cooperation with the Air National Guard. This is exploratory research. *The effects you have seen are not intended as the last word.* We only hope that seeing these effects will broaden and stimulate your thinking about how simulator visual systems could be designed and used. Therefore we urge you to give us not only your reactions to and opinions of the effects you have seen, but also your suggestions of other visual effects you believe might help training for combat flight tasks.

Please answer the following questions by marking the appropriate word or place on a response line and adding any comments you wish.

EVALUATOR CHARACTERISTICS:

Name ______________________ Rank ______________________

Are you an instructor/student/other (Specify)? ________________

What is your experience in each aircraft type flown?

Aircraft	Hours	Combat Hours

What is the percentage of your experience in or preparing for the following missions?

General Flying ___________

Air-to-Air ___________

Air-to-Ground ___________

Transport ___________

Intercept ___________

Other (Specify) ___________

GENERAL COMMENTS & SUGGESTIONS:

Place a circle on the answer scale in the appropriate spot:

1. Did you have an opportunity to use this effect?

Effect	Answer			
	No	A Little	Some	A Lot
Sensor Cone	___	___	___	___
Contrail Path Ground Track	___	___	___	___
Air Track	___	___	___	___
Both Together	___	___	___	___
Tracer Range Emphasis	___	___	___	___
Horizon Depression Cursor	___	___	___	___
Instructor/Student Cursor	___	___	___	___
Immediate Scoring Feedback	___	___	___	___
Ranging Cursor	___	___	___	___
Viggen Targets	___	___	___	___
Multiple Viewpoints	___	___	___	___
Velocity Vector	___	___	___	___
Grid/Target Building With Adjustable Cues	___	___	___	___

2. Did you find this effect helpful?

Effect	Answer			
	No	A Little	Some	A Lot
Sensor Cone	____	________	____	____
Contrail Path Ground Track	____	________	____	____
Air Track	____	________	____	____
Both Together	____	________	____	____
Tracer Range Emphasis	____	________	____	____
Horizon Depression Cursor	____	________	____	____
Instructor/Student Cursor	____	________	____	____
Immediate Scoring Feedback	____	________	____	____
Ranging Cursor	____	________	____	____
Viggen Targets	____	________	____	____
Multiple Viewpoints	____	________	____	____
Velocity Vector	____	________	____	____
Grid/Target Building With Adjustable Cues	____	________	____	____

3. Could this effect be made more useful?

How?

Effect	Answer			
	No	A Little	Some	A Lot
Sensor Cone	___	___	___	___
Contrail Path Ground Track	___	___	___	___
Air Track	___	___	___	___
Both Together	___	___	___	___
Tracer Range Emphasis	___	___	___	___
Horizon Depression Cursor	___	___	___	___
Instructor/Student Cursor	___	___	___	___
Immediate Scoring Feedback	___	___	___	___
Ranging Cursor	___	___	___	___
Viggen Targets	___	___	___	___
Multiple Viewpoints	___	___	___	___
Velocity Vector	___	___	___	___
Grid/Target Building With Adjustable Cues	___	___	___	___

4. What applications would be appropriate for this effect? Explain.

Effect	Answer
Sensor Cone	______
Contrail Path Ground Track	______
Air Track	______
Both Together	______
Tracer Range Emphasis	______
Horizon Depression Cursor	______
Instructor/Student Cursor	______
Immediate Scoring Feedback	______
Ranging Cursor	______
Viggen Targets	______
Multiple Viewpoints	______
Velocity Vector	______
Grid/Target Building With Adjustable Cues	______

5. Would (or did) this effect affect your learning speed?

Effect	Much Slower	Slower	Faster	Much Faster
Sensor Cone	___	___	___	___
Contrail Path Ground Track	___	___	___	___
Air Track	___	___	___	___
Both Together	___	___	___	___
Tracer Range Emphasis	___	___	___	___
Horizon Depression Cursor	___	___	___	___
Instructor/Student Cursor	___	___	___	___
Immediate Scoring Feedback	___	___	___	___
Ranging Cursor	___	___	___	___
Viggen Targets	___	___	___	___
Multiple Viewpoints	___	___	___	___
Velocity Vector	___	___	___	___
Grid/Target Building With Adjustable Cues	___	___	___	___

6. Would or did use of this effect affect your performance?

	Worse	No	Better	Much Better
Sensor Cone	___	___	___	___
Contrail Path Ground Track	___	___	___	___
Air Track	___	___	___	___
Both Together	___	___	___	___
Tracer Range Emphasis	___	___	___	___
Horizon Depression Cursor	___	___	___	___
Instructor/Student Cursor	___	___	___	___
Immediate Scoring Feedback	___	___	___	___
Ranging Cursor	___	___	___	___
Viggen Targets	___	___	___	___
Multiple Viewpoints	___	___	___	___
Velocity Vector	___	___	___	___
Grid/Target Building With Adjustable Cues	___	___	___	___

7. Did this effect help you communicate with your instructor/student?

Effect	Interfered	Nuetral	Helped Some	Helped A Lot
Sensor Cone	___	___	___	___
Contrail Path Ground Track	___	___	___	___
Air Track	___	___	___	___
Both Together	___	___	___	___
Tracer Range Emphasis	___	___	___	___
Horizon Depression Cursor	___	___	___	___
Instructor/Student Cursor	___	___	___	___
Immediate Scoring Feedback	___	___	___	___
Ranging Cursor	___	___	___	___
Viggen Targets	___	___	___	___
Multiple Viewpoints	___	___	___	___
Velocity Vector	___	___	___	___
Grid/Target Building With Adjustable Cues	___	___	___	___

8. How did you use this effect?

Effect	Answer
Sensor Cone	______
Contrail Path Ground Track	______
Air Track	______
Both Together	______
Tracer Range Emphasis	______
Horizon Depression Cursor	______
Instructor/Student Cursor	______
Immediate Scoring Feedback	______
Ranging Cursor	______
Viggen Targets	______
Multiple Viewpoints	______
Velocity Vector	______
Grid/Target Building With Adjustable Cues	______

9. For what tasks did you use this effect?

Effect	Answer
Sensor Cone	____________
Contrail Path Ground Track	____________
Air Track	____________
Both Together	____________
Tracer Range Emphasis	____________
Horizon Depression Cursor	____________
Instructor/Student Cursor	____________
Immediate Scoring Feedback	____________
Ranging Cursor	____________
Viggen Targets	____________
Multiple Viewpoints	____________
Velocity Vector	____________
Grid/Target Building With Adjustable Cues	____________

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