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ABSTRACT

Aircraft simulators have in the past been designed and used primarily as substitutes for aircraft. CGI provides the flexibility to enhance training in ways not normally possible in an aircraft. This research conceived and demonstrated training approaches to take advantage of this flexibility. Rather than duplicate the real world cockpit environment, this study considers other objectives attainable. This requires a change from thinking of a simulator as an airplane substitute to thinking of it as a training device that can complement 'real world' training from text through actual aircraft. Another change requiring consideration is the expected change in military use of simulators from teaching initial, simple flight skills and procedures, to teaching and maintaining complex combat skills involving interactions among several aircraft and ground systems.

Scene elements were incorporated into a computer generated visual presentation which did not represent "real world" objects, but which were there solely for instructional purposes.

Hopefully these techniques will be used to improve the effectiveness of actual aircraft hours spent in training rather than replace them.

INTRODUCTION

In the past, aircraft simulators have been designed and used primarily as substitutes for actual aircraft. Computer generated imagery provides the flexibility to enhance training in ways that cannot be done in an aircraft, at least under peacetime regulations. The thrust of this research is to conceive and demonstrate new 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) simulation of tasks untrainable in aircraft during peacetime but required during combat, and (2) application of

teaching/learning methods unavailable in aircraft. Examples of the first category are surface-to-air missile (SAM) avoidance and air-to-air missile avoidance. This category was not emphasized, since many of these techniques are incorporated in present state-of-the-art visual systems or will be in the near future. The second category is exemplified by techniques such as making visible something that the pilot must visualize but cannot see in the real world (e.g., a radar antenna pattern of an opposing aircraft during air-to-air combat or a diagram of the relative energy state of the aircraft and their flight envelopes, or allowing the student to view an engagement from various viewpoints (his own, ground threats', air threats', overview, etc. (See Figures 1-3).

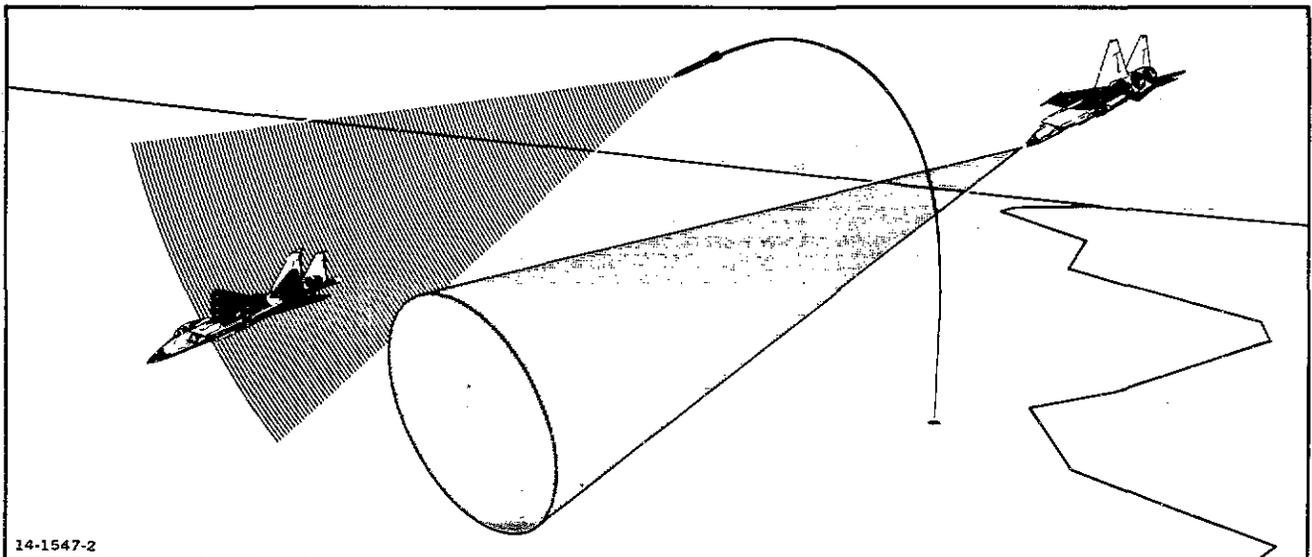
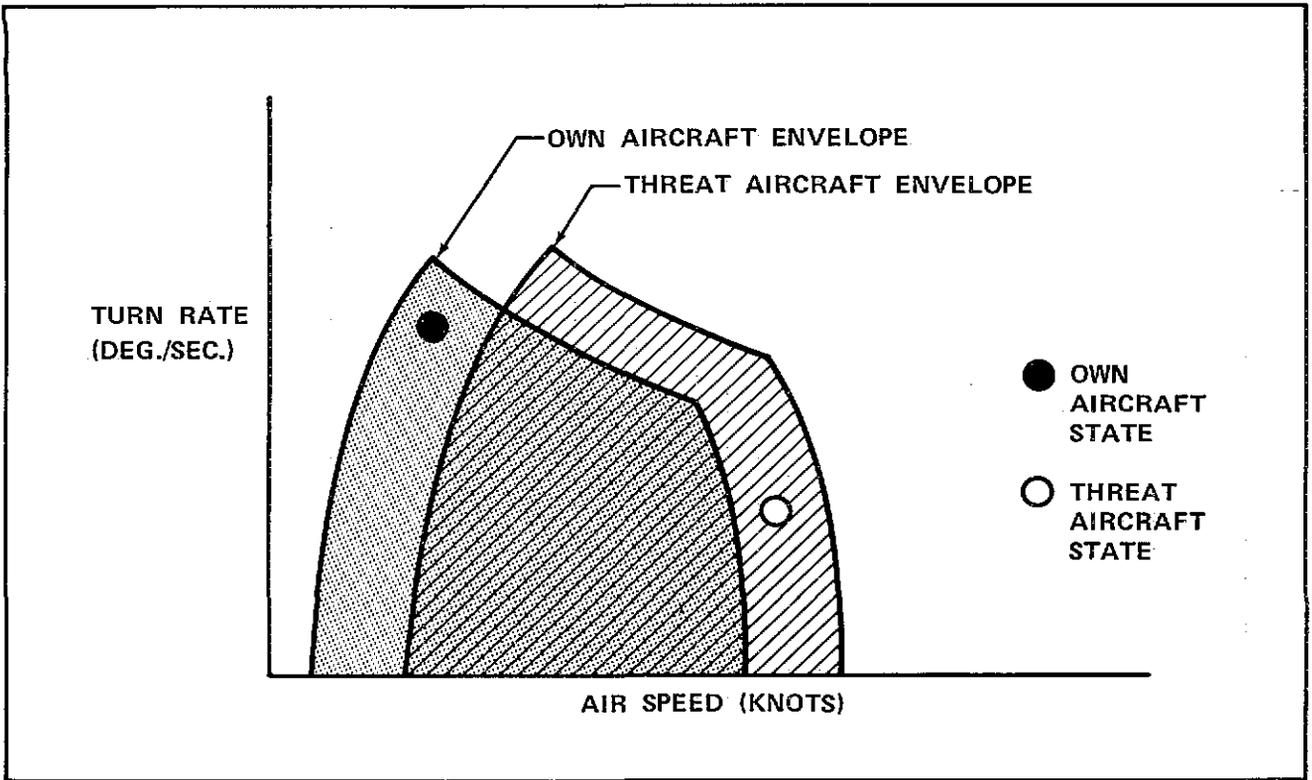


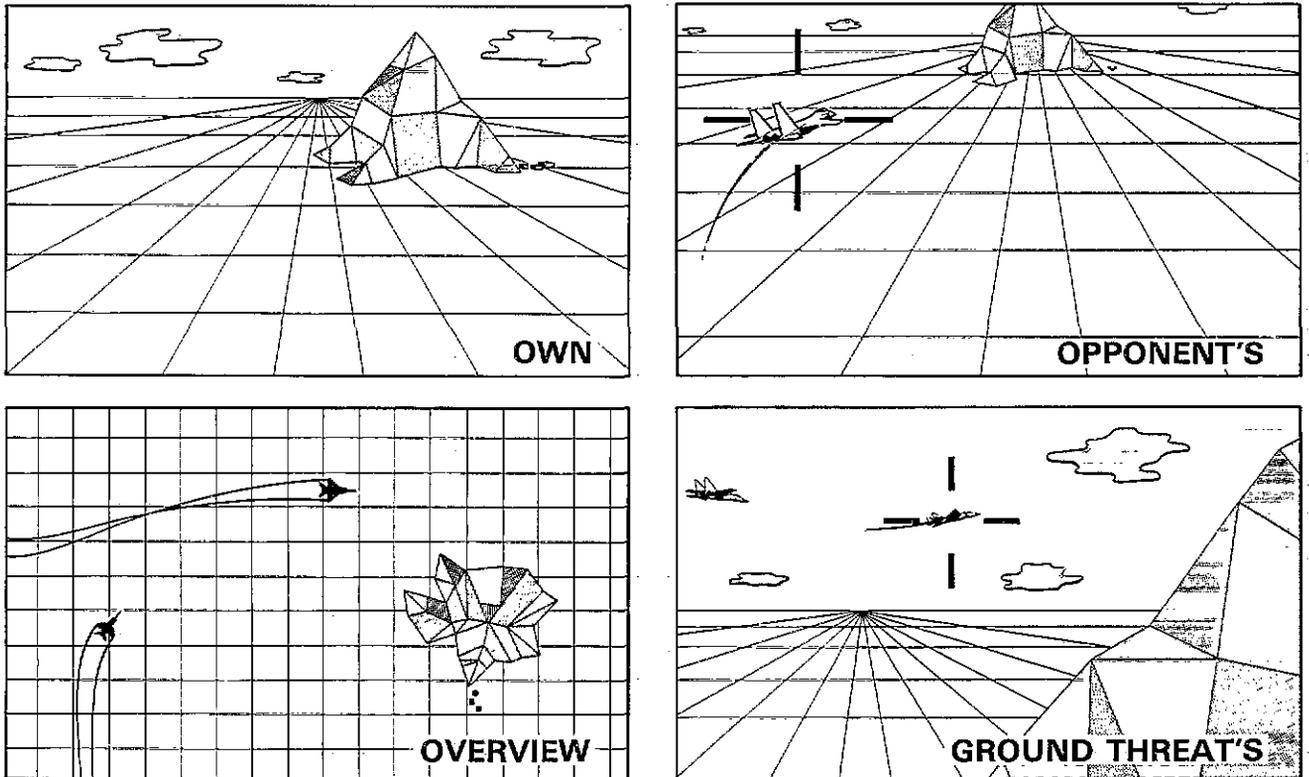
FIGURE 1. VISIBLE THREAT CONE

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FIGURE 2. RELATIVE FLIGHT ENVELOPE PERFORMANCE DIAGRAM



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FIGURE 3. SITUATION AWARENESS TRAINING - MULTIPLE VIEWPOINTS

OBJECTIVE

The objective was to conceive and demonstrate examples, such as described above, of concepts in aircrew training that would take advantage of the flexibility of computer generated imagery to provide enabling and instructional features unavailable in the "real world". The emphasis was in complex combat skill training as opposed to simple tasks such as takeoff and landing.

APPARATUS

Some of the concepts resulting from this effort have been demonstrated on a VITAL IV computer generated image (CGI) system, located at McDonnell Douglas Electronics Company. This system consists of a general purpose minicomputer, special purpose high speed computational hardware, and a calligraphic color display with collimating optics as shown in Figure 4. The display is normally mounted outside the window of an aircraft simulator cockpit.

to display a representation of the "real world" to the pilot. The simulator position and attitude information in the response to the pilot's controls is fed into the visual system which updates the scene correspondingly thirty times per second. Typical scenes are shown in Figure 5. The scenes are made according to customer desires and have in the past been made specifically to simulate the real world flight environment including special effects such as variable weather conditions, surface-to-air missiles, air-to-air missiles, anti-aircraft artillery, tracer bullets, and so forth.

All of these scenes are made up using two basic elements, flat convex polygonal shapes and strings of light points. There are no restrictions however on how one can use these basic scene elements. In particular, they need not be used to make scenes to look like the "real world." It is the objective of this project to explore these other uses to which the basic scene elements (common to many computer generated image systems) may be put.

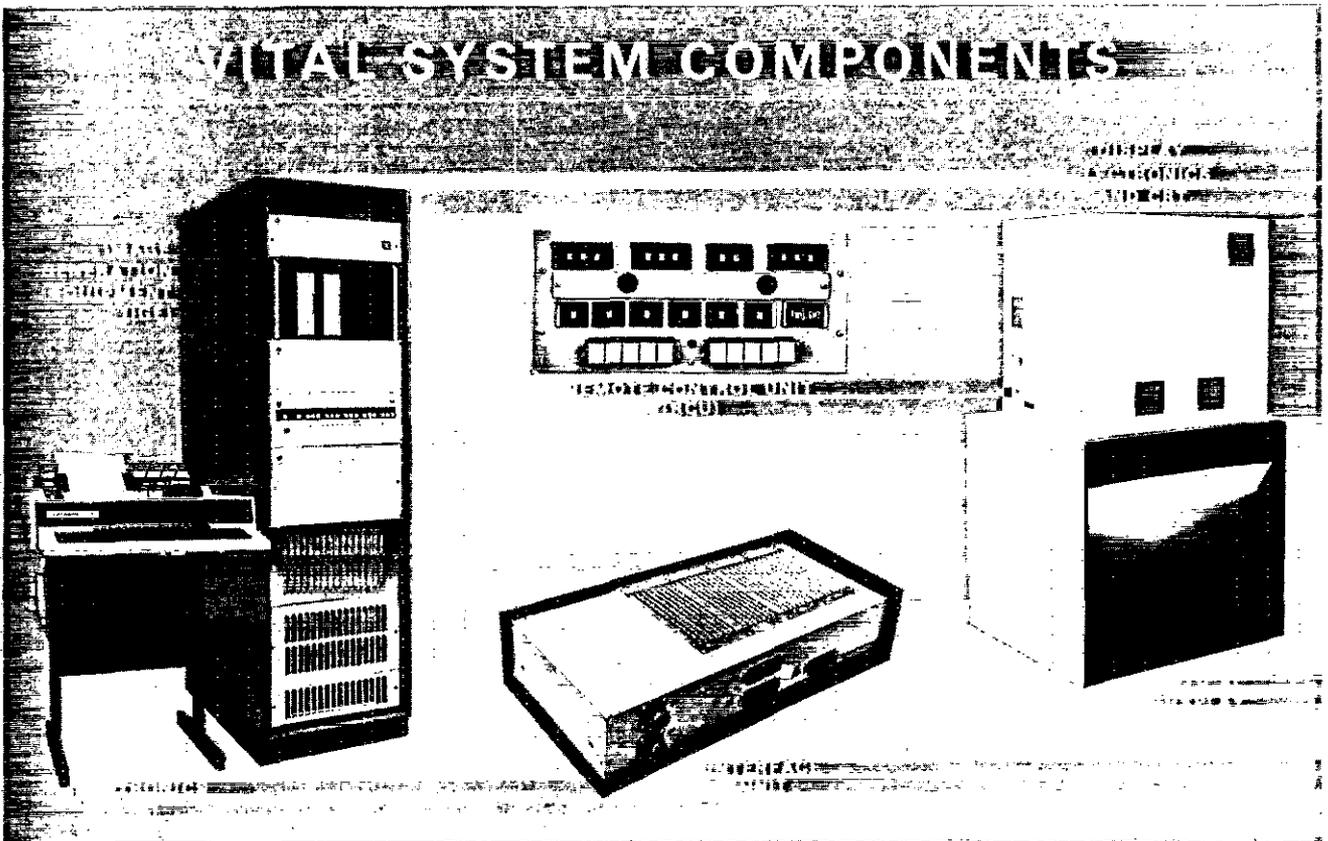


FIGURE 4. VITAL III SYSTEM COMPONENTS

IDEA GENERATION PROCESS AND RESULTS

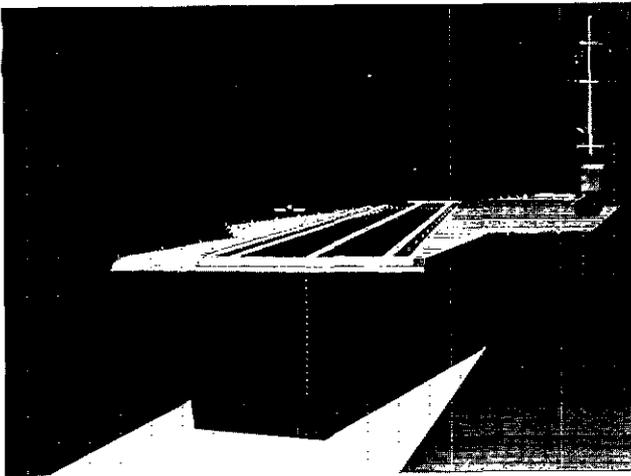
To provide a framework for the idea generation process a list of key issues to be trained was drawn up (Table 1).

Simultaneous with the generation of specific training techniques a list of generic techniques was created to avoid getting into a rut of essen-

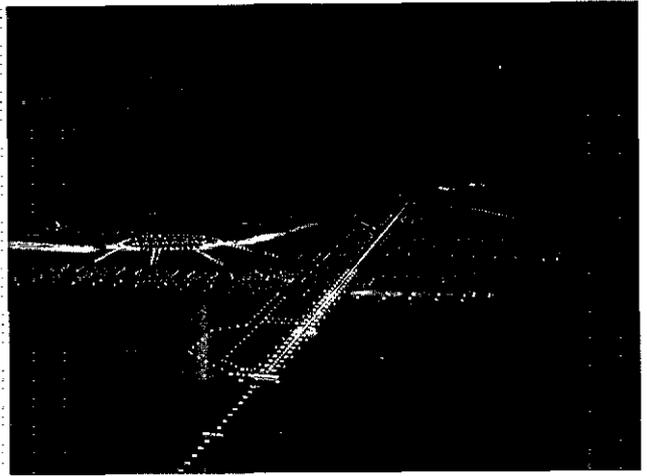
tially similar approaches. In the next year's work the idea generation process will continue but will have the added benefit of feedback from preliminary trials.

GENERIC TECHNIQUES

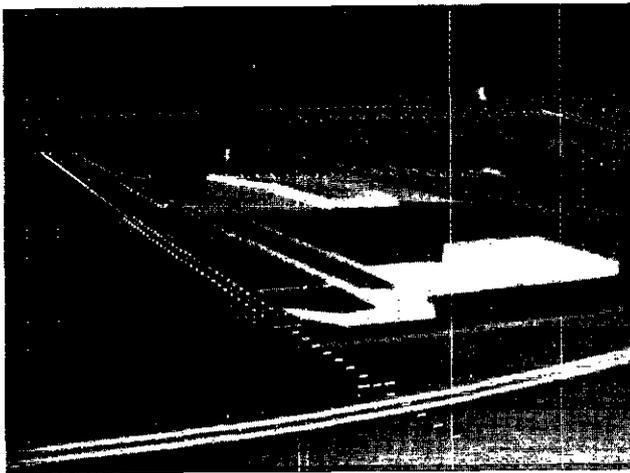
A list of generic training techniques is given in Table 2. Each will be discussed in the paragraphs that follow. These are not all claimed to be new, nor is the list comprehensive.



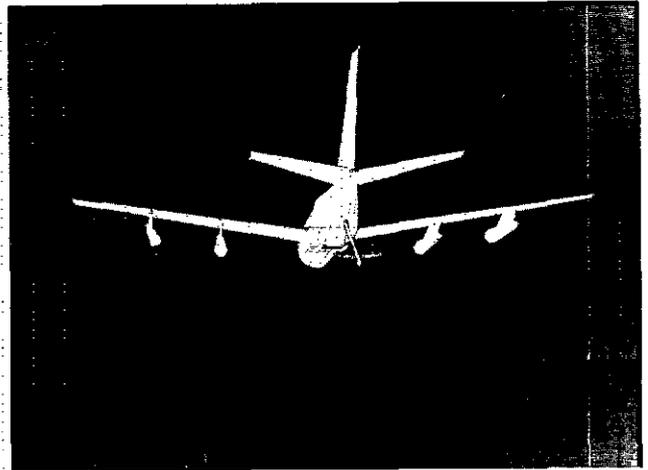
AIRCRAFT CARRIER WITH
SEA SURFACE AND WAKE



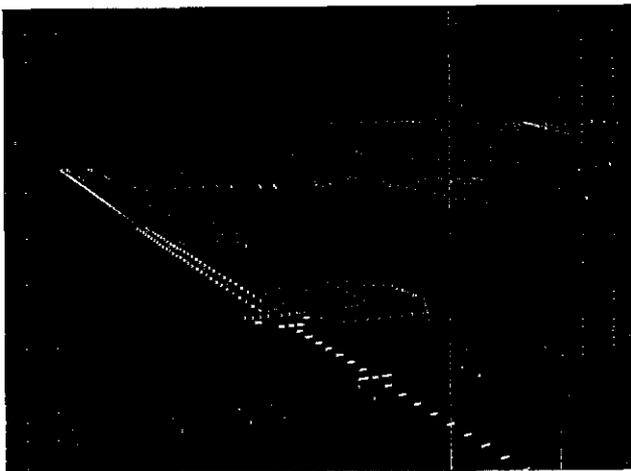
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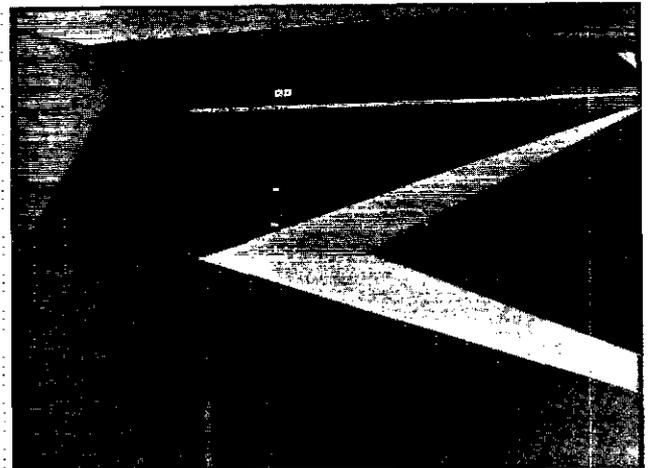
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INTERNATIONAL (TWILIGHT)



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MINNEAPOLIS - ST. PAUL
INTERNATIONAL (NIGHT)



GROUND TARGETS

FIGURE 5. TYPICAL STANDARD VITAL IV IMAGERY

TABLE 1. KEY ISSUES TO BE TRAINED

- A. Factors Affecting Probability of Kill (P_K)
1. Energy Management
 - a. own
 - b. threat energy state
 2. Offensive Weapons Systems
 - a. switchology
 - b. knowledge of best system selection
 3. Assessment of Threat (Current)
 - a. status assessment
 - b. knowledge of what to do about it.
- B. Factors affecting Probability of Survival (P_S)
1. Energy Management
 - a. own
 - b. threat (know energy state of threat)
 2. Defensive Systems Management
 - a. display threats
 - b. respond to threats
 3. Assessment of Threats
 - a. status/number
 - b. knowledge of what to do about it.
- C. Maximizing $P_K \times P_S$

TABLE 2. GENERIC TEACHING AID SUMMARY

1. Make visible something the pilot normally cannot see but tries to model or visualize in his mind.
2. Perspective changes. Allow pilot to select various viewpoints in his out of the cockpit scene (e.g., overview, threat's view, etc.).
3. Demonstration and/or exaggeration.
4. Awareness stimulators.
5. Pointers for instructor and/or student.
6. Sense exercise.
7. Dynamic student control of scene and cues.
8. Analogies.
9. Cue indicators.
10. Cue supplementation or augmentation.
11. Adaptive aids.
12. Scoring and immediate error feedback.
13. Feed forward predictors.
14. Time compression or expansion.
15. Time quantization or task segmentation.
16. Discrete indicators (situation recognition/response).
17. Abstraction

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 that 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 could be expected to be useful for training.

2. Perspective Changes - Advanced pilots generally do not view their actions only from their own viewpoint, but abstract the situation to an overview or "God'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 viewpoint 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. This type of technique might aid in the development of situation awareness.

3. 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". 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.

4. 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.

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. There are at least three ways such a pointer could be used once positioned by either the instructor or student. When released it could remain stationary in ground coordinates (three dimensional), or in display screen coordinates (two-dimensional), or it could remain a fixed number of degrees below the horizon. This last method of operation would be applicable to designating a particular dive angle or glide slope.

6. 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.

7. 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 were uncertain, he could test it by seeing how it responds to his control inputs.

8. 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.¹

9. 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 a pointer, exaggeration, elimination of other extraneous cues, and so forth.

10. Cue Supplements or Cue Augmentation - 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 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 cues until control is learned and then teaching the perceptual task of detecting glideslope deviations from subtle cues.²

11. Adaptive Aids - This is a 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 Gaven Lintern³ of the University of Illinois is an example.

12. 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. For bombing practice, miss distances and aircraft parameters at time of release could be shown after each bombing pass.

13. 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.

14. Time Compression/Expansion - Sometimes events occur too quickly for the novice to appre-

ciate them individually and to think through the ramifications. Conversely, the more experienced student may need to "over-learn" one task, 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.

15. Quantization of Time - A task can be broken into discrete steps such as in the task taxonomy of Robert Meyer⁴. These may be learned singly in whatever order is best suited to learning. Examples would be the backward chaining technique of Hughes⁵, a slide presentation, or flash cards.

16. 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.

17. Abstraction - In air-to-air combat it is useful to view what is happening and develop tactics from the point of view of where each aircraft is in a relative performance diagram, such as a plot of air speed versus acceleration (g - forces). This is an example of abstracting events. Another example might be to teach certain perceptual tasks in a scene not at all resembling the "real world" and then transfer the skill to the real world or realistic simulation situation.

SPECIFIC EXAMPLES

Specific examples of training techniques possible using computer generated imagery follow. They do not have a one-to-one relationship with the generic technique list. Most of the specific examples incorporate several of the generic techniques at once. Also, each generic technique is represented in several specific examples to varying degrees.

1. For the task of training air combat maneuvering defensive tactics, it may be useful to enhance the defender's awareness of the attacker's "lethal cone". The "lethal cone" might be the attacking aircraft's antenna pattern within which he could lock on and launch an air-to-air missile. This pattern could be represented by a cone of appropriate range and angle visibly emanating from the attacking aircraft. This could be modeled red on the inside and green on the outside so that the defender would immediately know when he is in this danger zone. The main objectives here would be to teach the pilot how this normally invisible cone looks in three dimensions from the various positions attained during an engagement, and to allow him to develop techniques for avoiding it. One would have to take care with such a technique not to overuse such an added cue to the point of dependency. (See Figure 1.)

2. In air-to-air gunnery using tracer bullets, it is difficult to judge where the bullet passed closest to the target, and hence the miss distance. A simple way to aid this judgement would be to indicate to the pilot where this point is. This could be accomplished in a number of ways. Perhaps the simplest is to change the brightness of the tracers once they have passed the target range. (See Figure 6.)

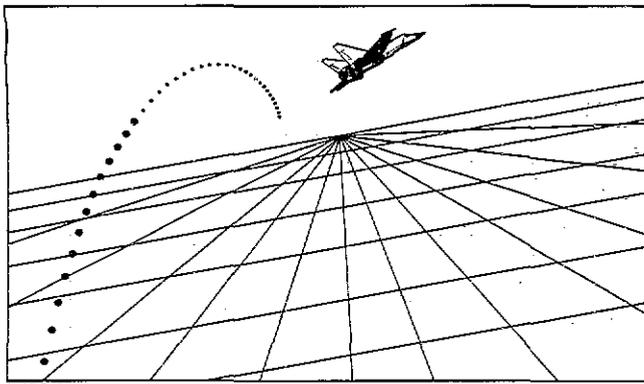


FIGURE 6. TRACER RANGE JUDGEMENT SUPPLEMENT

3. There is a large number of situations in which it is useful for the pilot to know his or another aircraft's flight path either during or immediately after a maneuver. This can apply both to air-to-air and air-to-ground combat. In some cases this type of information is already being used in training. On the Air Combat Maneuvering Range (ACMR) several pilots can fly instrumented real aircraft in an engagement and later review on ground displays what happened as seen by an instructor operator from the ground during the engagement. This is very useful, but unfortunately it requires delayed feedback of several hours. Some simulators present this information to the instructor/operator, but it is again unavailable to the pilot without delay. There is no reason at all why this information cannot be presented to the pilot in the same out-of-the-window display he uses in the simulator for training. This can reduce feedback delay to zero or negligible times which ever yields the best training for a given situation. A simple way to think of implementing this is to have the aircraft drop a trail of zero muzzle velocity tracer bullets as it flies along. This visible trail could be used in a wide variety of ways. It could be viewed during an air-to-air engagement or immediately afterward. (See Figure 7.)

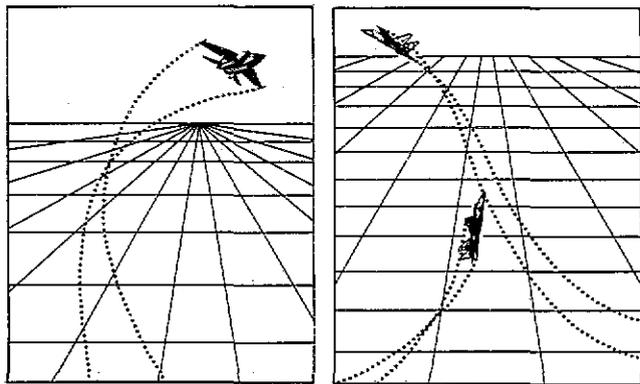


FIGURE 7. VISIBLE PATH, CONTRAILS, OR RIBBONS

This technique can usefully be joined with the one described in the next example (number 4).

4. It is of paramount importance for a combat pilot to develop what is referred to as "situation awareness." This involves a constant appraisal by the pilot of the factors in Table 1. He must be

continuously aware of what is going on around him, where he is, and what to do about it. This is not easy to do while performing difficult tasks. Advanced pilots frequently comment that they do not always think of their situation from their own point of view. Rather they may view the situation from an overview or from some abstract viewpoint (discussed further in example number 17). As an aid to teaching this situation awareness, one could allow the pilot to literally see what is happening from several different viewpoints at his selection either during or immediately after a simulated engagement. Useful viewpoints would include, in addition to his own: an overview or "God's eye view", an opposing aircraft's view, and a ground threat's view. There are even situations where a viewpoint attached to but outside of his own aircraft would prove of utility. (See Figure 3.)

5. A simple method for an instructor to enter and store a flight path into the visual database to be either viewed and/or followed by the student would be to have him fly the route or maneuver while leaving the visible path as described in example number 3. The instructor could, for instance, lay a trail showing an ideal air-to-ground delivery or air-to-air maneuver. The student could then attempt to retrace this path while also dropping "bread crumbs" to mark his path. The two paths could then immediately be visually compared while the instructor provides comments. Alternatively, the instructor's path could be kept invisible until the student's maneuver also was completed and then the paths could be compared. (See Figure 8.)

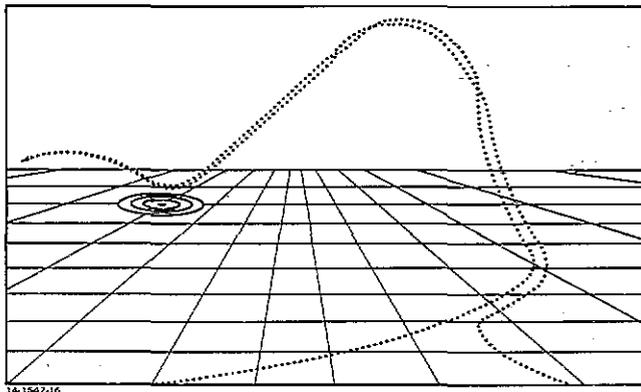
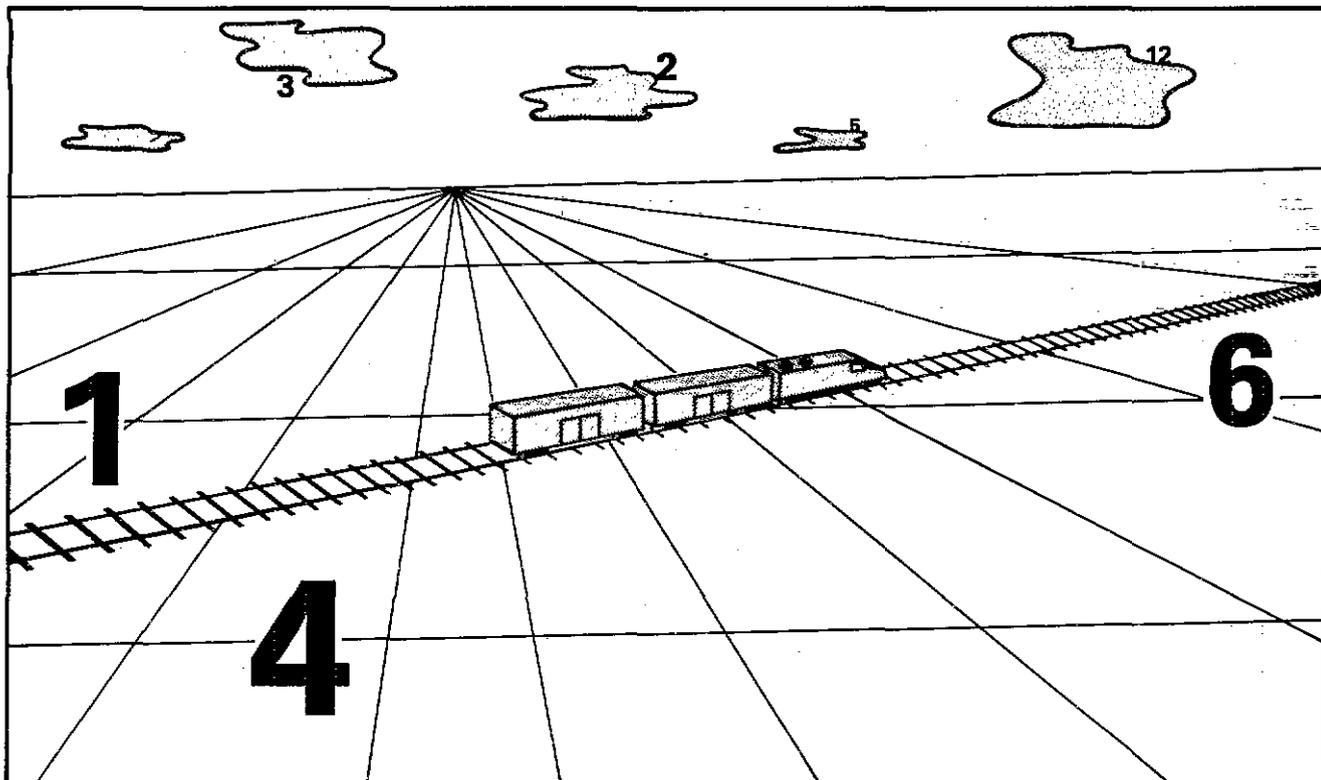


FIGURE 8. VISIBLE INSTRUCTOR DEMONSTRATION PATH

6. Situation awareness and target aircraft motion judgement training could be addressed by entering a large number of moving airborne objects in the scene. For this purpose they need not be models of aircraft but could be any identifiable object. While performing some task, for example ordnance delivery, the pilot would have to monitor continually the position, velocity, and direction of each of the moving objects. These objects are illustrated below as flying numbers. The pilot could be tasked with calling out which number is closest or approaching the fastest and so forth. If the computer monitored the pilot's head and/or eye position, it could even perversely bring objects into view from wherever the student was not looking. This would force him to learn effective scan patterns. (See Figure 9.)



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FIGURE 9. SITUATION AWARENESS TRAINING

7. A cursor has long been used as a valuable tool in computer-aided design applications. It would be equally valuable as part of the computer-generated scene in aircraft simulation visual systems. In that application a number of useful modes of operation can be envisioned that would allow instructor and student to more easily communicate about the visual scene. One mode would be as presently used in other applications, that is a two-dimensional cursor in display window coordinates. Another would be a cursor that moved in three-dimensional ground coordinates. A particularly unusual mode of use in flying training would be a cursor that moved in coordinates relative to the horizon. For example, the cursor in this last mode could be set to 30 degrees below the horizon and would thus help the student learn to establish a 30 degree dive bombing angle to a particular target. A similar cursor set at 3 degrees below the horizon would continuously point to the landing spot that would be impacted if the plane held a 3 degree glideslope. Simply setting the cursor to various known degree settings below the horizon would aid the student in learning some important visual judgements.

8. Visual exercise may improve judgement of air target or other motion cues. The student could spend time looking at displays showing moving objects (using monocular and/or binocular cues). Such displays are particularly amenable to computer generation. They need not necessarily look like real world objects. In fact the optimization of what display to show and the feedback of results schedule would be an intriguing study in itself. It might turn out that abstract displays of some sort optimally exercise these visual senses. Per-

haps sense exercise is separable from teaching judgements using that sense. The first might address lowering of perceptual thresholds, while the other would address quantitative suprathreshold judgements. (See Figure 14.)

9. In learning to judge distant target aspect angle and motion it may be very useful to let the student practice flying simulated remotely piloted vehicles (RPV's). This task requires knowledge of aspect and motion to succeed and could aid in learning aspect since the aspect can be determined from reactions of the RPV to the pilot's controls. This task might also help develop the ability to visualize a situation from another viewpoint as discussed in example 4. (See Figure 10.)

10. When a pilot is performing a task that is very demanding his attention tends to concentrate on that task. His attention to peripheral cues is reduced. There are two ways to attack this problem. One mentioned in example 6 is to attempt to teach him to overcome this tendency to overconcentrate his attention. The other, which may complement the first, is to help him learn to at least get the most from the information available in the narrow area of concentration. Thus one could practice flying with minimal cues such as available in the immediate target area. (See Figures 11 and 12.)

11. While flying, a pilot generates and maintains an internal model of where he is with respect to other objects such as the ground, other vehicles, or a particular target. He continually updates this model from all available sources of information using all of his senses. The ability to accurately update this model from limited or con-

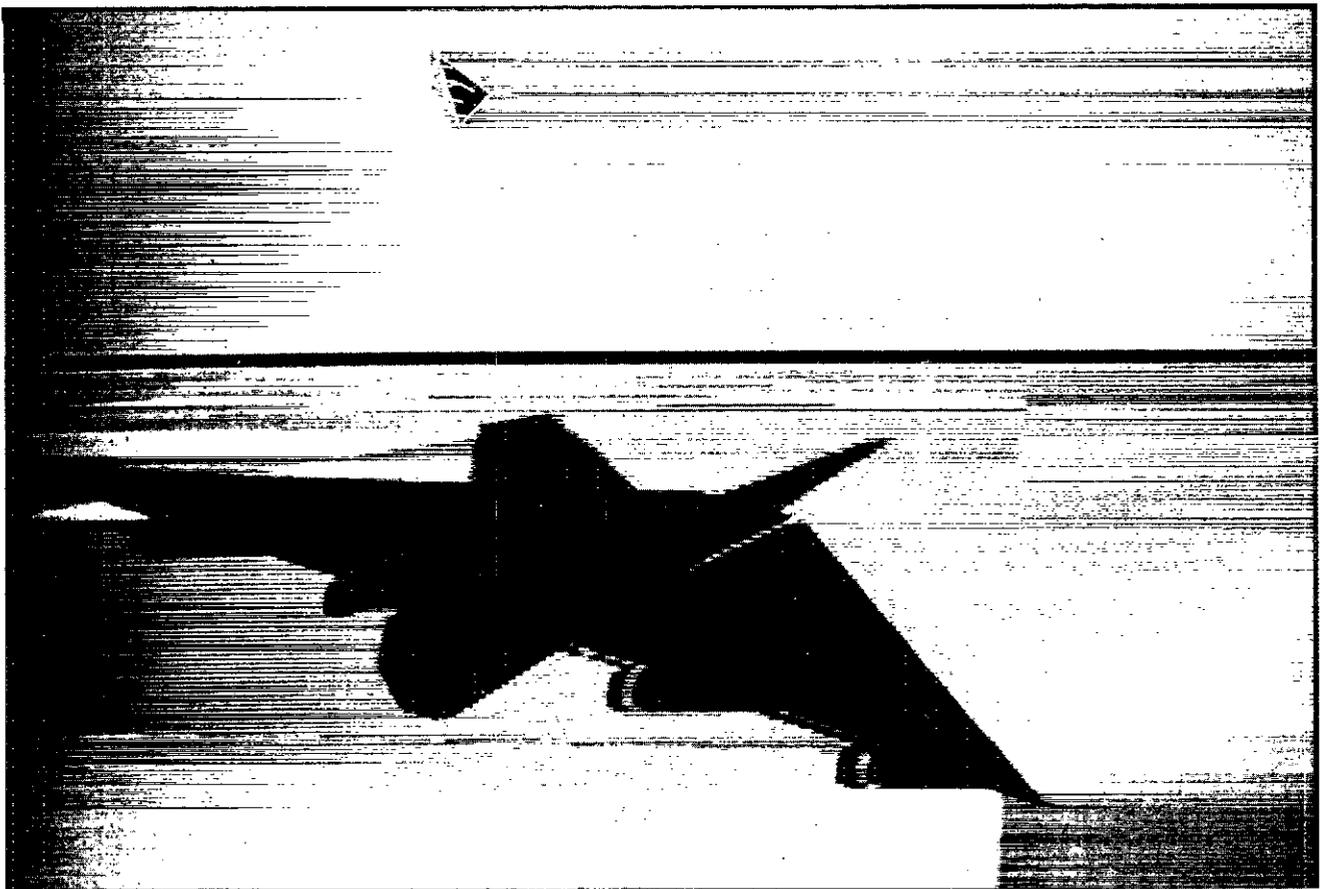


FIGURE 10. PRACTICING ASPECT AND MOTION JUDGEMENT BY FLYING SIMULATED REMOTELY PILOTED VEHICLES

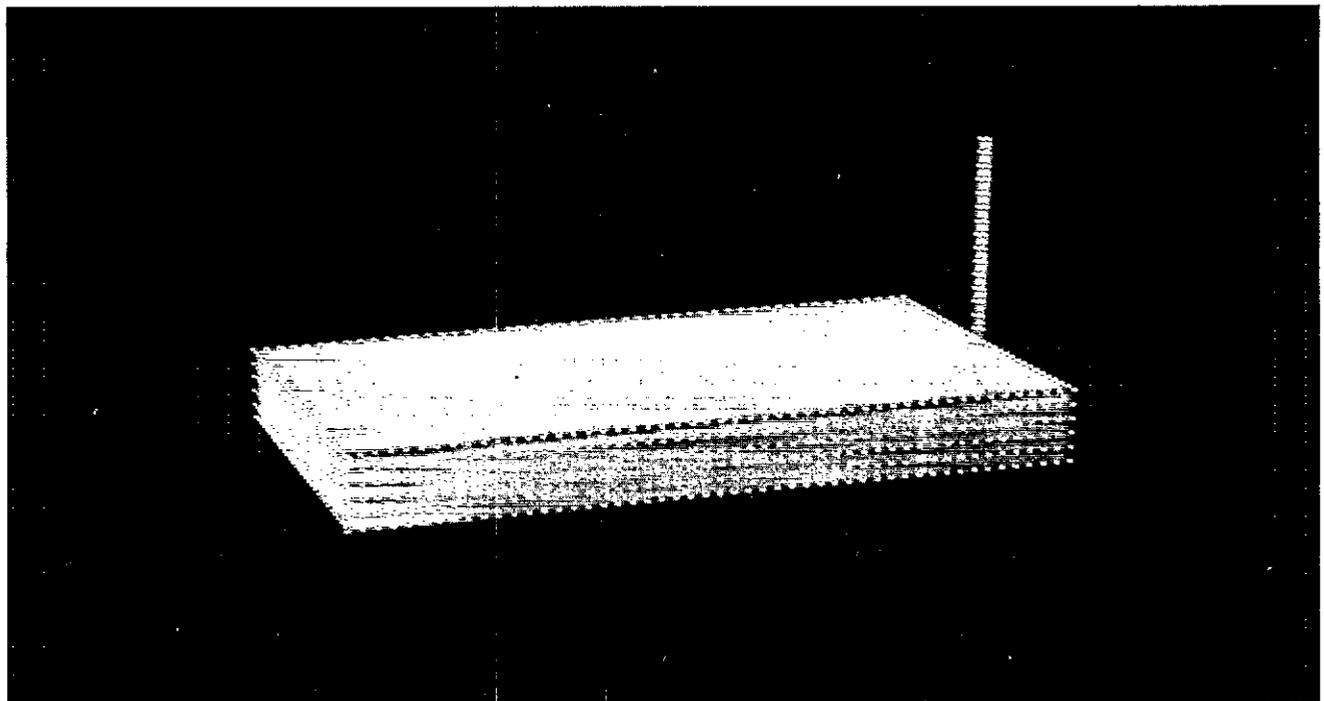


FIGURE 11. MINIMAL CUES - LEARNING TO POSITION ONESELF WITH RESPECT TO A SIMPLE BALL OR CUBE WITH NO OTHER CUES AND/OR WITH A HORIZON

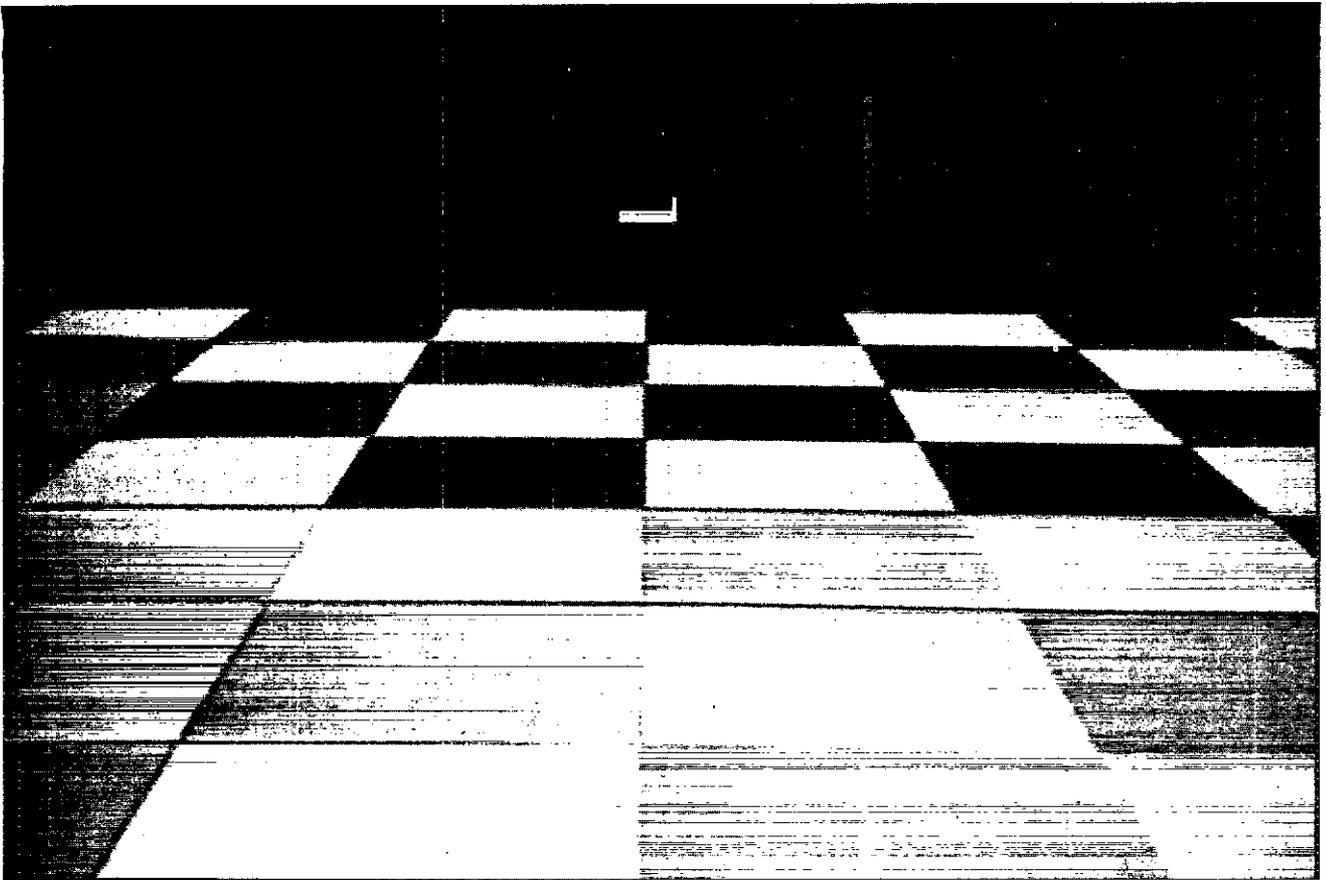
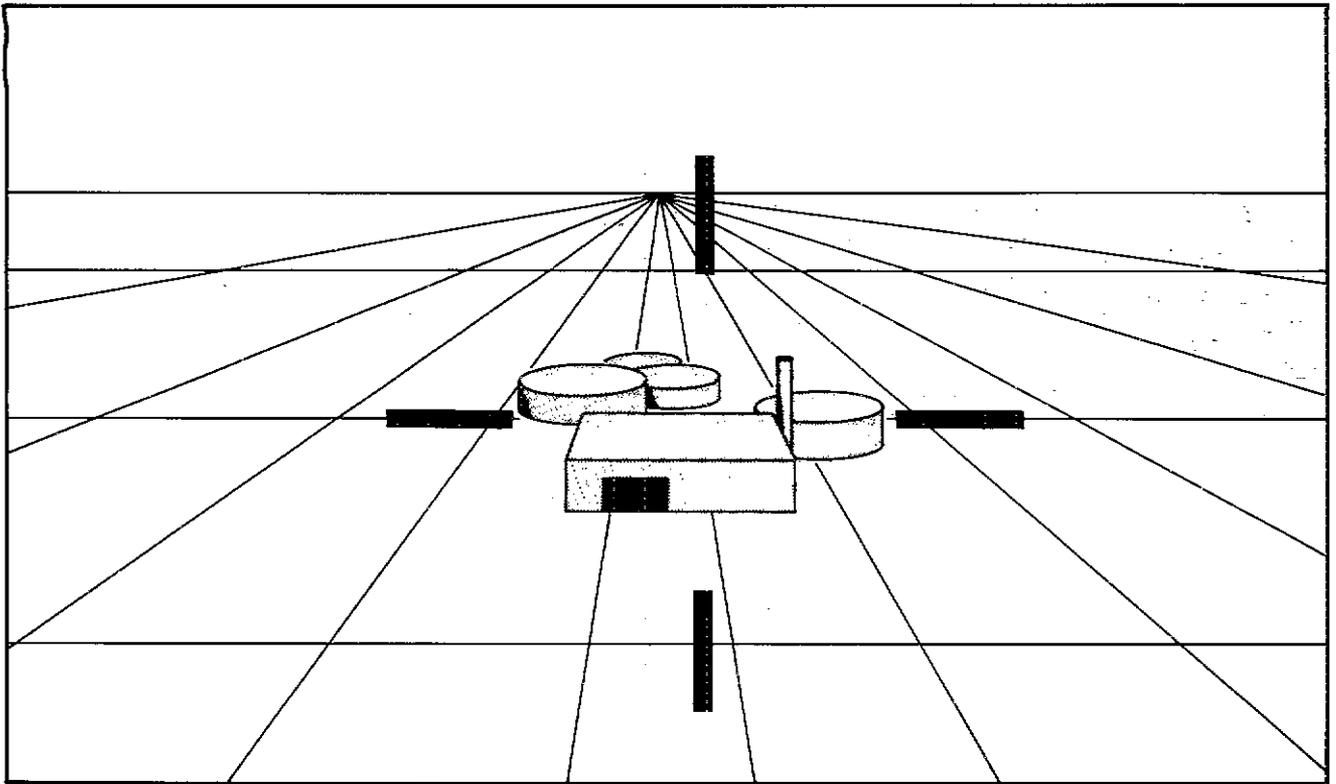


FIGURE 12. TARGET AREA ONLY CUES SCENE

flicting information is useful. An example would be the situation in which a pilot is attempting to attack a ground target by dive bombing. During the initial attack phase the target might appear off to one side. He could fly along till the target approaches 90° off to one side then roll the aircraft to turn towards the target. Prior to the roll maneuver he would generally look sometimes at the target to update his internal model of its location with respect to him, and at other times in front of his aircraft to check his flight direction. Flying an aircraft in one direction while looking for a prolonged period in another direction could cause disorientation. Hence the pilot is tempted to move his eyes and, hopefully less so, his head back and forth between these two data sources to maintain the accuracy of his internal situational model. It might be worthwhile to give the pilot practice flying the aircraft in one direction while his field of view is limited to another direction such as at the target. He might then learn to update his internal model accurately from different information than he usually uses, requiring reduced head movement for this task and allowing more concentration on the target. A caveat is that he still would have to look in other directions to maintain awareness of other vehicles in the area.

12. The ideal position, size, and shape of a target ("sight picture") for a particular type of air-to-ground attack could be shown for comparison to how it looks during the student's approach. (See Figure 13.)

13. The angle of attack (the angle at which the airplane wing meets the air⁵.) of an airplane in flight is of paramount importance to flying. Yet, it is not readily apparent in a real airplane unless indicated by an instrument. A pilot must learn to appreciate angle of attack, but in the real world other cues such as those to pitch angle are much more prominent and at first divert his attention from this important concept. In the computer generated simulation one can remove the extraneous cues and initially supplement the cues to angle of attack. The student could fly in a scene with no ground or horizon references at all to avoid confusion and the air could be made visible by filling it with points so that angle of attack could easily be judged. Thus the student would first learn to fly with respect to the air, not the ground. One could also, in this environment, position the pilot outside the plane (either fixed with the plane or fixed with the air) to make visualization and understanding of relative wind easier. Then, with this firm foundation, the ground reference cues such as pitch angle could be brought in with less confusion. He would for instance become more readily aware that the stick is not the up lever. The scene for this training situation might have the points representing the air randomly distributed in a volume to preclude any pitch cues. A similar scene, but with the points regularly distributed, could be used to teach perspective judgements and motion judgements frequently used in flying such as location of the "aim point", the point toward which the aircraft is headed. Another use



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FIGURE 13. IDEAL SIGHT-PICTURE DISPLAY FOR COMPARISON DURING AIR-TO-GROUND ATTACK TRAINING

for such scenes would be to exercise visual perception of motion. (See Figure 14.)

14. To aid in learning the proper sight picture and how to make corrections during dive bombing one could show a cone emanating from the target at the proper dive angle so that the pilot knows when he is at the proper dive angle or how far off he is.

15. Although it would be difficult to compute, it could be useful to provide the student pilot with a cue to his fluctuating probability of survival (P_s), probability of killing a target (P_k) or a combination of the two such as $P_s \times P_k$. This could be done by showing an object in a corner of the display which would change as $P_k \times P_s$, P_s^2 or P_k change. This would be particularly useful in teaching tradeoffs between offensive and defensive tactics in crowded dogfights.

Another way to implement this might be to have the display grow more red as the probability of survival is reduced. (See Figure 15.)

16. Showing the student pilot a predicted path for himself and his opponent including an indication of relative speed at intercept to help him learn to judge when he would overshoot, when to bleed off energy, and when to discontinue bleeding off energy could help give the student a feel for optimum solutions in various basic air combat maneuvering (ACM) situations and help him learn energy management.

17. In air combat it would be very useful for the student to learn to detect, take advantage of, and affect a threat aircraft's "g" state, energy state, and where the two aircraft are in their relative performance envelopes. This type of information could be presented in the training simulator even though it might clog his already overloaded sensory channels to put it in the actual aircraft in combat. An ideal example of this approach is given in Moroney, et al. (See Figure 2.)

DEMONSTRATIONS

Several of the specific techniques have been implemented on the MDEC VITAL IV system. These are:

1. - Visible lethal cone
3. - Visible aircraft paths in sky (wing tip ribbons).
4. - Multiple viewpoints.
7. - Cursor
10. - A minimal target cues scene in which most of the scene elements (horizon, target, ground grid) can be independently turned on or off.
13. - A scene having no ground or horizon references composed of a solid cube of light points.

A small number of people have flown these scenes and found them exciting and challenging. It will take some practice utilizing these scenes to learn what effects they have and how to make the most of them.

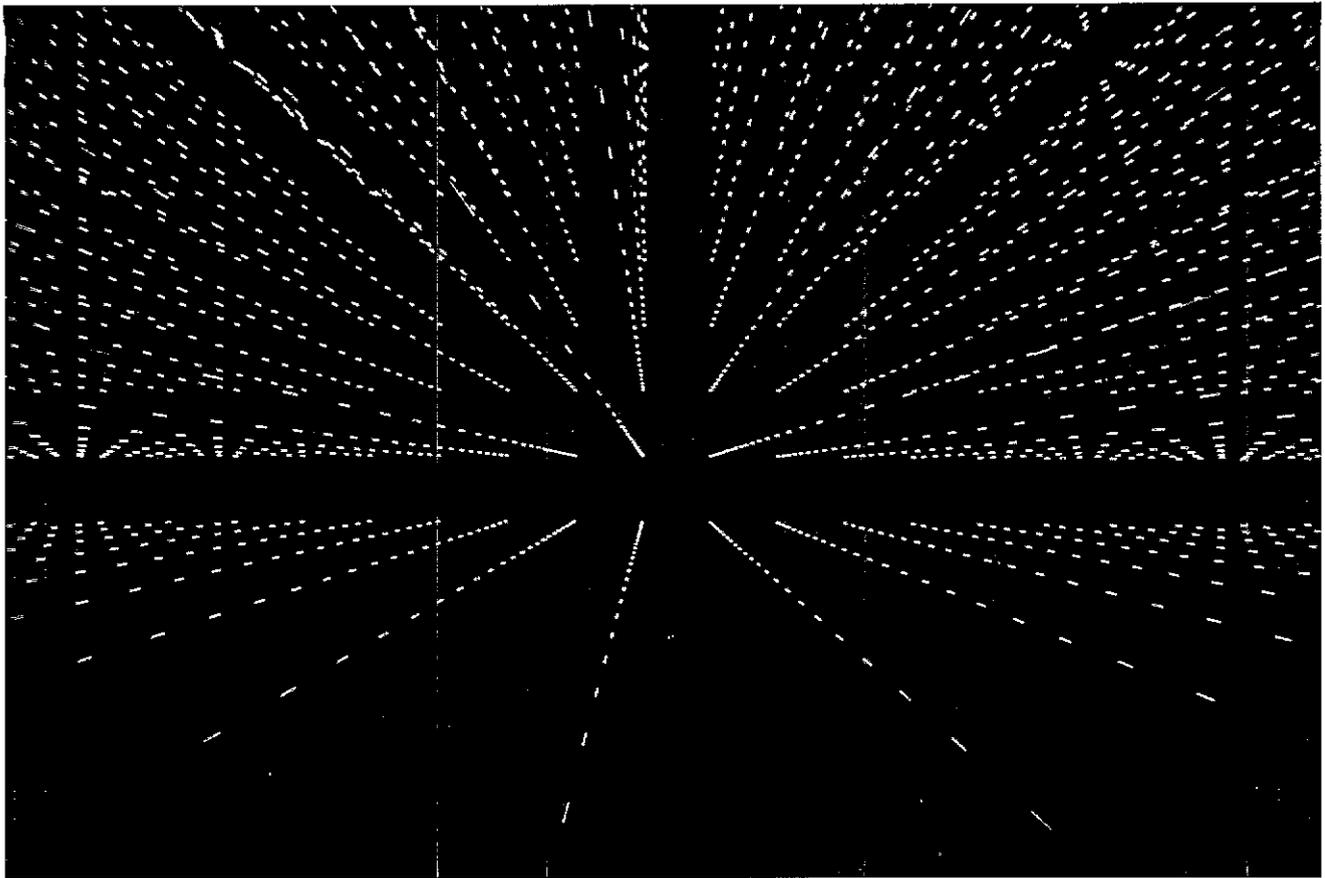
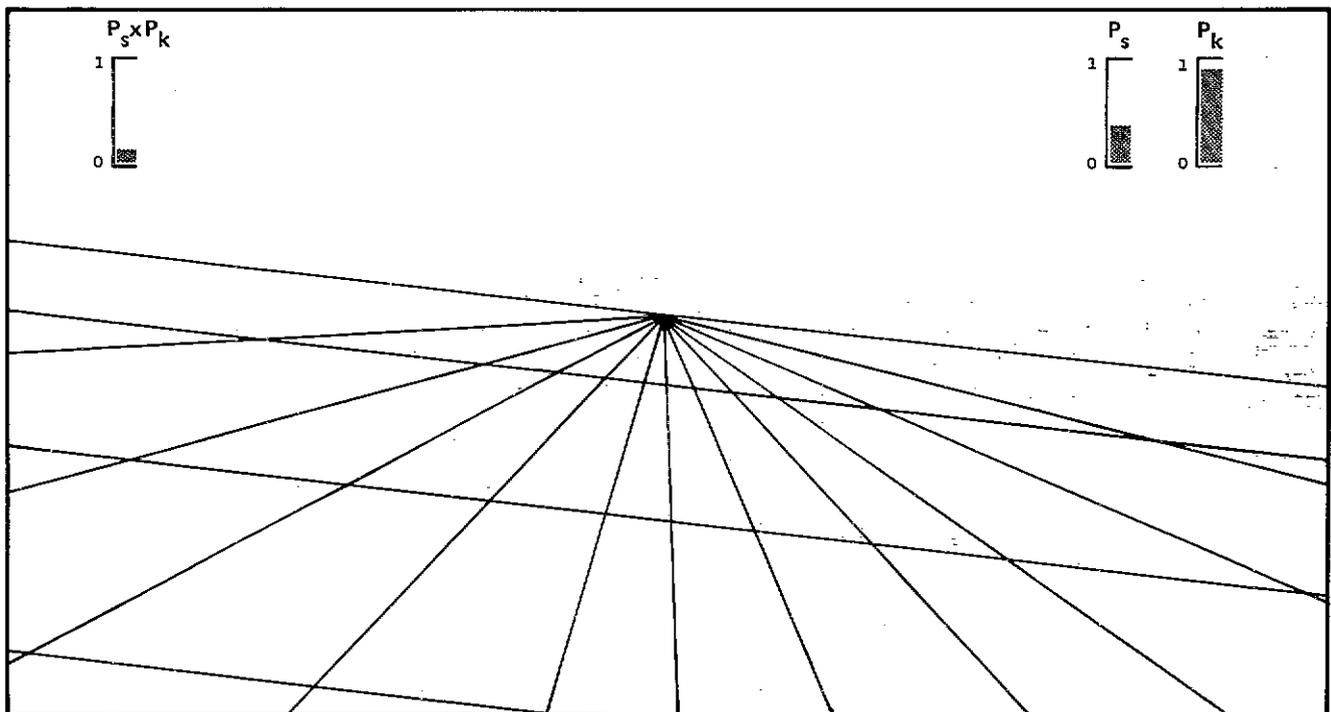


FIGURE 14. VISIBLE AIR FOR ANGLE OF ATTACK, PERSPECTIVE JUDGEMENT TRAINING, OR SENSE EXERCISE



14-1547-4

FIGURE 15. PROBABILITY OF SURVIVAL AND KILL INDICATORS

CONCLUSIONS & DIRECTIONS FOR FUTURE WORK

This report represents a mere tip of the iceberg compared to the vast array of training techniques that are made possible by computer generated visual simulation. The objective of this study was to generate and demonstrate concepts in aircrew training methods that take advantage of the flexibility of computer generated imagery. While in the past the main objective of simulation was to duplicate the real world cockpit environment, we are now in a position to consider other objectives that will be attainable with training devices. This requires a change in orientation from thinking of 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 change requiring new thinking is the expected change in military use of simulators from teaching only initial, simple flight skills and procedures to teaching and maintaining of complex combat skills involving interactions among several aircraft and ground systems.

The study attempted to take a step in this direction by creating examples of ways a computer generated visual system could be used within this context. Scene elements were incorporated into the visual presentation which did not represent "real world" objects, but which were there solely for instructional purposes.

Lists of generic and specific training techniques were generated, some of which are presented here. Selected examples were implemented on a VITAL system at McDonnell Douglas Electronics Company. A list of key issues to be trained was drawn up to provide a framework for concept generation. Upon examination of the above mentioned lists, it was noticed that most of the listed techniques are intended to address the teaching of "recognitional" type tasks as defined by Klein. 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.

The next stage of this work will involve exploratory testing of some of the techniques discussed in this report. A portion of this work will be performed at MDEC using relatively inexperienced pilots drawn from the flight student population at Parks College of St. Louis University. The class of 289 students should provide an ample subject pool. The remainder of the exploratory testing will be performed on a VITAL equipped flight simulator being used by the Air National Guard which will provide a high experience level subject population. Feedback from these activities will refine the present concepts and perhaps stimulate new ones. The results will serve several pur-

poses. Feedback will be provided from operational users into the idea generation process to more directly and effectively serve their needs. The study will aid in the selection of effective techniques for further more formal testing by others which, in turn, would provide the type of hard data required to support incorporation of these techniques into operational training programs.

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