ATTACKING TRAINER COST FOR UNDERGRADUATE JET PILOT TRAINING PROGRAM

Walter S. Chambers
NAVTRAEQUIPCEN
Orlando, Fl 32813

James J. Riley
NAVTRAEQUIPCEN
Orlando, Fl 32813

ABSTRACT

The Navy T-45 Trainer System (T45-TS) will expand the role of Visual Flight Rule (VFR) training in simulators to increase cost effectiveness of the overall Student Naval Aviator (SNA) program. While today's simulator visual technology can support training beyond field take off and landing to include introductions to carrier landing, weapon delivery, formation flight and low level navigation, it must be achieved with lower life cycle cost trainers than those supporting fleet aircraft. Lower cost technologies must be examined but reductions in the trainer's capabilities from proven training effective approaches must be validated through training evaluation. If achieving trainer cost goals leads to loss of training effectiveness, the low cost trainer may be the most costly to the training program. The Navy is applying inhouse as well as contractor resources in a research and evaluation program to meet this goal of defining an affordable training effective T-45 simulator visual system. Specific training tasks such as weapon delivery, carrier landing and formation flight normally requiring higher cost simulator implementations are being investigated in a series of training transfer experiments. The high cost equipment factors of display field of view size and type of scene content (i.e., dusk versus day) for SNA training are the principal research issues. The findings from current training experiments and planned evaluations to provide inputs to complete the guidelines are presented.

Carrier landing training of some 90 SNA's under simulator conditions of day or night, wide or narrow angle displays, and part or whole task training are compared with non-simulator trained pilots by evaluating their subsequent field carrier landing and carrier landing performance in the T2C aircraft. Thirty degree dive bomb training of SNA's will be evaluated under simulator conditions of day or dusk and alternate field of view arrangements and evaluated by their subsequent TA4J aircraft performance of this task.

INTRODUCTION

The Navy Student Naval Aviator, SNA, Training program includes a large variety of piloting skills to be acquired and demonstrated. It is known and respected as a challenging curriculum. In addition to taxi and takeoff, formation flight, basic airwork, instrument flight procedures and landing there are introductions to low level visual navigation, air to air gunnery, basic air combat maneuvering, air to ground weapon delivery and carrier landing qualification. This large variety of tasks also presents a challenge to the training devices which support the program, especially the flight simulator trainers. The use of simulators in the T-45TS program is extensive and enables a reduction of nearly 40 percent in the number of aircraft required (Polski, 1984). The challenge comes in the form of the simulator needing to be low cost and yet be effective in training the large variety of tasks. A simple guideline to maximize cost effectiveness is to eliminate the simulator features which are not training effective within the context of the SNA Training Programs, include the features which are, but implement them with the least life cycle cost technology available. Of the major simulator subsystems (i.e., cockpit, motion device and visual system) the visual system has the most uncertainty with regard to payoff and cost for SNA training.

High fidelity within cockpit simulation including instruments, switches, safety devices and controls along with aerodynamic models adequately computed and updated for good dynamic fidelity have shown high SNA transfer of training to the aircraft (Ryan, 1972).

Motion cues which aid training have not been identified. Current motion platforms and G-seats have not shown training effectiveness when tested for transfer to fighter/attack aircraft from simulators (AGARD, 1980). Until there is evidence of training effectiveness, motion cueing devices will remain low priority items compared with other simulator features.

Visual cues which aid training have been identified. Several versions of visual systems have shown transfer to the aircraft of training received in simulators with visuals (Waag,1981). They have included virtual image and real image displays, day and night scenes and various levels of field of view, scene content and resolution depending on the task being trained. The large variety of successful and unsuccessful visual systems along with their high cost has made them the subject of much research and development. While government and industry have both participated in and contributed to technology developments, research to define visual system requirements needed for military aviation training has been and probably will continue to be the role of the services. Unlike the motivation for industry to improve their simulators to obtain FAA approval in order for them to be used for certification of commercial pilots, there is no regulation incentive for industry to prove training effectiveness of simulators or their subsystems.

The biggest cost drivers of visual systems for simulators are field of view, resolution, scene content, extent of the gaming areas and the number of dynamic models in the environment (Beck, 1981). These are the factors that affect the volume of equipment and software required and therefore the major cost. They are also the most critical for influencing training because they determine whether the information is present or absent, and it must be present to provide the necessary task information for the pilot. Other visual factors such as brightness and contrast determine how well or how comfortably the information is viewed (assumes they are above perceptual threshold values) and fortunately the eye has a large accommodation range for different levels of these values. It is also necessary that the cueing information which is present is in its proper place (i.e., low spatial distortion) and presented in a timely manner (i.e., low temporal distortion). These two factors like the previous two have reasonable tolerances which can be acceptable. Spatial distortion of 3-4% are accommodated in areas other than the gunsight although they must accumulate gradually over the FOV as sharp discontinuities are unacceptable. Temporal distortions or time lags of up to 200 milliseconds are usually accommodated,(Westra, 1981, 1983), but some fast response vehicles or demanding tasks require not more than 100 to 150 milliseconds total system time lag. Usually half of this time lag is consumed by input signal sampling of the stick and throttle and the computation time, while the other half is consumed by signal distribution and response generation (e.g., meter and servo movements, motion device displacements, computer image generation and image display).

The major visual system cost drivers for SNA training are FOV, scene content and resolution. Large gaming areas and multiple dynamic models required for tactical combat training are not needed to support the SNA syllabus. Since there are no visual systems on the Navy's 27 Device 2F101 T2C or 32 Device 2F90 TA4J simulator trainers there is very little direct experience with simulator visual system VFR training effectiveness in the SNA Training Program. The exception is the 3 Device 2B35 visual systems, now obsolete, which were attached to TA4J simulators, one at each of three training sites. A transfer of training evaluation was conducted on the trainer at NAS Meridian, Mississippi in 1979. Training in selected visual tasks (i.e., familiarization flights and air to ground weapon delivery) was found to transfer to the aircraft. This evaluation provided training effectivenesss data on only one equipment configuration and one training simulator strategy (Hagin, 1979). However, the effectiveness of equipment variations (e.g., a more narrow or wider FOV) was not determined.

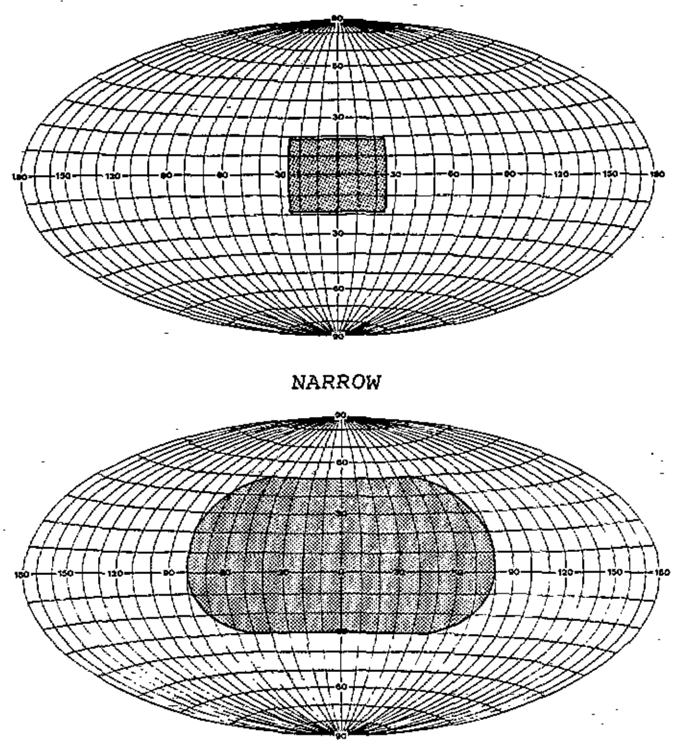
Without good training effectiveness data the process of making design decisions to minimize cost is both difficult and risky. The T-45 is an austere program utilizing existing technologies and prudent procurement guidelines. A small investment in applied research can result in a tailored visual system that provides the maximum transfer of training at minimal expenditure of funds. Therefore, NAVAIRSYSCOM (PMA273, AIR 413, AIR 330), CNATRA and NTEC have joined in a research program to obtain training effectiveness data to establish guidelines for a cost effective visual system for the T45 simulators. This cooperative team effort combines effective and meaningful research applied directly to the acquisition process, enabling management to exercise trade off's to meet budget and schedule constraints. The priority training tasks to be investigated which would define the boundaries for the major cost drivers of FOV, scene content and resolution were identified as carrier landing, 30 degree dive bomb, formation flight and low level visual navigation. The first two of these tasks are currently under investigation with planning underway for the latter two.

CARRIER LANDING EXPERIMENT

SNA's currently do not receive carrier landing training in a simulator prior to their first Carrier Qualification (CARQUAL) in the T2C aircraft. At the time of CARQUAL they will have accumulated 70 hours in the T2C aircraft, 20 hours in a T2C instrument simulator, Device 2F101, along with classroom and other training during a 22 week period. Just prior to CARQUAL they receive 10 days of Field Carrier Landing Practice (FCLP). It is during this period they learn the approach pattern, spacing between aircraft, transitioning the aircraft to landing configuration and speed, and the important final approach procedures of holding Angle of Attack (AOA), line up with the runway, and glideslope control using the Fresnel Lens Optical Landing System(FLOLS).

During the period from September 1983 to July 1984 approximately half (90) of the undergraduate pilots from VT-26 at Chase Field, Beeville, Texas, will receive carrier landing training in the VTRS T2C simulator at the Naval Training Equipment Center, Orlando, Florida. The remainder of the group will be the control group for comparison performance testing in the T2C aircraft during FCLP and CARQUAL. The simulator training takes place during the weekend after students receive the initial carrier qualification lecture and prior to FCLP. Performance data for all students (approximately 180) will be collected for analysis from the following areas: a special battery of performance tests; grades from primary training, cumulative intermediate grades up to FCLP, FCLP and CARQUAL; and glideslope deviation during FCLP final approach. The aircraft glideslope deviation data is being obtained with the Hybrid Terminal Assist Landing (HYTAL) Laser tracking system. The van mounted system operated by the Naval Weapons Center, China Lake, tracks a retroreflector mounted in the landing light housing near the T2C nose wheel. During the final 4000 feet of approach it provides range, azimuth and elevation data 30 times per second with an accuracy of one foot and 0.1 degrees respectively. When completed, tracking data will have been taken on approximately 14,000 aircraft landings. The data is encoded and placed on tape by the HYTAL for decoding and analysis in computers at NTEC.

The students who receive carrier landing training in the T2C simulator at VTRS will train under one of 36 possible configurations defined by: Field of View (FOV), conditions shown in Figure 1, (wide, 160 degrees H x 80 degrees V or narrow, 48 degrees H x 36 degrees V), Scene Detail (day or night), Approach Type (straight-in, circling or segmented) and Amount of Training, (20, 40 or 60 approaches). The least expensive configuration would therefore be 20 segmented approaches with a narrow angle night visual system. The most expensive would be 60 circling approaches with a wide angle day visual system. The data from this one transfer of training experiment will provide information for trade off analysis of four high cost simulator equipment conditions and six simulator utilizatiion conditions interacting with the amount of aircraft training to achieve performance criterion. Having this broad a data base is necessary for further trade off analysis with training effectiveness data from other tasks such as dive bombing and formation flying when looking at overall simulator and aircraft effectiveness in the training curriculum.



NARROW

WIDE

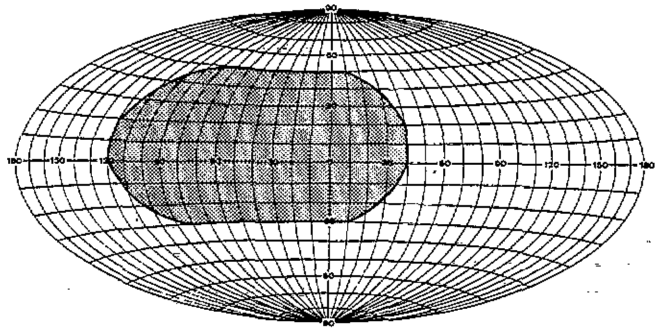
Figure 1. Alternative Field of View Display Plots for Carrier Landing

30 DEGREE DIVE BOMB EXPERIMENT

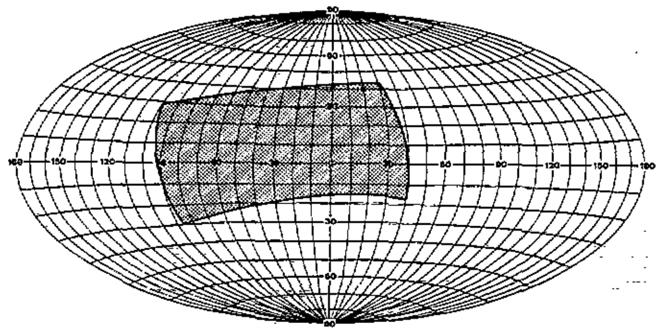
SNA's currently do not receive dive bomb training in a simulator prior to their bombing training in the TA4J aircraft. They have completed basic jet training in the T2C and are in the 11th week of the advanced jet training program having completed 28 TA4J flight hours and 45 hours in a TA4J instrument simulator, Device 2F90. The 30 degree dive bomb task is the principal introductory manual bombing task. The maneuver starts from a 30 degree cone pattern at an 8000 feet altitude and 250 knots airspeed. A roll in bank of 120 degrees is performed to make a pass along a designated run-in line to the target. A stable 30 degree dive is established after roll out with bomb release at 3000 feet altitude and 450 knots airspeed. Compensation techniques are taught for deviations from optimum release conditions and for wind effects.

During June through August 1984 36 TA4J student pilots from VT-24 and VT-25 at NAS Chase Field, Beeville, Texas, and VT-21 and VT-22 at NAS Kingsville, Texas will receive 30 degree dive bomb training in the VTRS A4 simulator at NTEC, Orlando, Florida. Thirty-six additional student pilots will be the control group for comparison performance testing in the TA4J aircraft. The simulator training takes place during the weekend prior to aircraft bombing training. Performance data for all students (approximately 72) will be collected for analysis from the following areas: a special battery of performance tests; grades from basic jet training, cumulative intermediate grades up to dive bombing, and dive bombing; bomb impact locations; and instructor ratings on dive performance during dual runs.

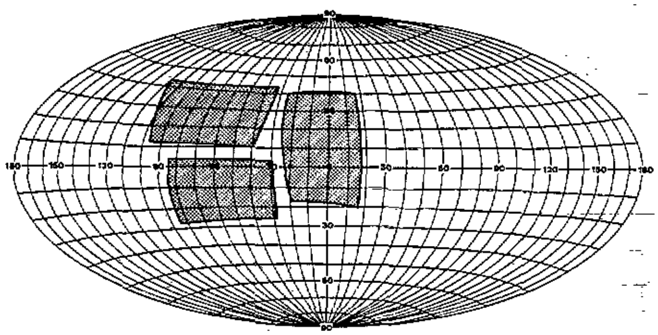
The students who receive dive bomb training in the A4 simulator at VTRS will train under one of 18 possible configurations defined by: FOV (A, B or C), Scene Detail (day or dusk), and Amount of Training (24, 48 or 72 runs). The three FOV conditions shown in Figure 2 are: A. 120 degree H left and 40 degrees H right X 80 degrees V; 100 degrees H left and 40 degrees H right X 60 degrees, V; C, 90 degrees H left and 10 degrees H right X 80 degrees V. These FOV conditions explore the training effects of the FOV boundary locations. They also represent the cost differences associated with 6, 4 and 3 window displays respectively with each window being approximately 60 degrees X 40 degrees. The scene detail factor examines the differential training effects of lower cost dusk calligraphic image generators compared with moderate cost day scenes based on polygon raster image generators. The more recently developed high detail image generators with dedicated texture processors were not included due to lack of availability and their current higher cost. The amount of training factor will provide data on incremental transfer effectiveness useful in trade offs of simulator and aircraft utilization within the syllabus. All three amounts of training levels will utilize a backward chaining segmented training strategy (Bailey, 1980) with the first 25% of the runs starting just after roll-out the next 50% at the abeam position and the final 25% flying the whole pattern.



FOV-A



FOV-B



FOV-C

Figure 2. Alternative Field of View Display Plots for 30 Degree Dive Bomb

A second phase of the 30 degree dive bomb experiment will be conducted as a check on the training effectivenesss of the lowest cost hardware configuration emulated in the VTRS experiment conditions. This condition is the C FOV with dusk scene detail. A group of 18 TA4J student pilots will receive 30 degree dive bomb training in Device 2F108, an A4M simulator at MCAS, Yuma, Arizona. Only one equipment configuration will be tested, but amount of training will be tested at the same three levels of 24, 48 and 72 runs. An additional 18 TA4J student pilots will be the control group. Performance of these pilots in the aircraft will be measured in the same manner as the first phase pilots trained at the VTRS simulator.

FUTURE EXPERIMENTS

Formation flight and low level visual navigation training in the simulator are to be investigated. Both of these tasks offer high payoff for SNA training if they can be effectively trained in a simulator. These tasks also stretch the limits of visual systems especially the lower cost visuals.

Some simulator training effectiveness data are available for formation flight. A training evaluation of a T38 part task trainer using an area of interest (AOI) dome display (Reid and Cyrus, 1974) gave a Transfer Effectiveness Ratio (TER) of 0.4. However, in a follow-on test reconfigured as a T37 it did not show significant training transfer (Reid and Cyrus, 1977). Another evaluation with a small group of 5 pilots on the ASPT T37 simulator showed a high TER of 1.0 for the two simulator sorties flown by each pilot (Woodruff, 1976). Both of these simulators had much larger FOVs than are being considered for the T45 simulator. Other simulators have been built with a formation flight capability but are apparently used for limited demonstrations rather than a structured part of the training syllabus. A great deal remains to be learned by investigating the effectiveness of various simulator features on training formation flying skills. Of particular need is the impact of a limited FOV on the types of SNA formation and tactical formation positions which can be trained (e.g., parade, cruise, column, combat spread, and tactical wing).

Simulator effectiveness data have not been reported for low level visual navigation training,although some studies have examined the needs (Edwards, 1981 and Miller, 1984). The importance of a wide horizontal FOV of approximately 180 degrees and high scene content levels of ground truth data have been demonstrated (McGraph, 1973) and are being tested in USAF C-130 simulator studies. Since SNA training is at an introductory level and does not require large gaming areas, the scene content levels appear to be available. However, FOV requirements should be verified for the T-45.

Near term plans for further research to provide guidelines for the T-45 simulator visual requirements include several tasks. A FOV performance test will be conducted in the simulator for formation flight. Results from this and the 30 degree Dive Bomb experiments will define final FOV candidates to be tested in the T-45 aircraft. A method of masking the aircraft canopy FOV used in previous evaluations (Yeend, 1978 and Carico, 1981) will permit determination of their acceptability in the three principal FOV defining tasks (i.e., weapons delivery, formation and low level visual navigation). While this type of testing does not provide training effectiveness data, it does provide valuable FOV guidelines on syllabus tasks that can be performed in the simulator and those which are marginal or inadequate.

DISCUSSION

It is repeatedly stated that simulator designers have very few design guidelines to work with which are based on training effectiveness results. Most data relate to the ability to perform the task in the simulator and come from simulator contract acceptance testing and simulator validation testing. An example of validation test methods conducted on completed trainers is described in Naval Air Test Center Technical Memoranda, IH 76-4SA and TM77-1TM (Galloway, 1976 and Woomer, 1977). Most training effectiveness data comes from Transfer of Training evaluations conducted on operational trainers using various methods (Hagin, 1982). However, this provides effectiveness data on only one equipment configuration and usually only one training procedure. This is why the accumulation of simulator training effectiveness data has been so slow. The training effectiveness evaluation does not determine if training is affected when certain simulator equipment or training procedures are altered. Designers need to know the differences in training effectiveness between simulator equipment options and utilization options. To obtain this differential training effectiveness data, more complex training effectiveness evaluations or experiments are needed. Since the trainer doesn't exist at the time a design experiment needs to be conducted, it is necessary to emulate the possible trainer configurations by building a prototype or modifying an existing simulator. Due to the cost and time of building a prototype sufficiently early in the acquisition cycle, very little of this type experimentation was conducted prior to the availability of the USAF ASPT and Navy VTRS research simulators.

The Navy T-45 acquisition program is one of the few to conduct differential training effectiveness experiments. This will place the acquisition team in a strong position to make cost effective decisions. For example, simulator training of carrier landing and dive bombing may be highly effective with relative low cost simulator options. Even moderate training effectiveness of formation flight and low level visual navigation may require much higher cost simulator options. A sound choice would be to acquire the lower cost simulator options, perform more carrier landing and dive bomb training hours in the simulator, and transfer the gained aircraft time to the tasks better trained in the aircraft.

Since data on the two experiments described are being taken concurrently with the preparation of this paper, no results on differential training effectiveness of options is available. Trends in early data collection do show a significant reduction (50%) in aircraft glideslope deviation on the third day of the ten day FCLP for pilots trained in the simulator (average of all simulator configurations). It further shows for these same simulator trained pilots a higher frequency of number three wire traps (preferred wire) when landing on the carrier after completion of the 10 days of FCLP in the aircraft.

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ABOUT THE AUTHORS

MR. WALTER S. CHAMBERS is manager of the Naval Training Equipment Center's Visual Technology Research Simulator (VTRS). He has been conducting research in visual technology for flight simulator trainers since 1968. He is a member of the Institute for Electrical and Electronic Engineers (IEEE) and the American Institute of Aeronautics and Astronautics (AIAA).

MR. JAMES J. RILEY is T45TS Project Director at the Naval Training Equipment Center. During his 17 years at the Naval Training Equipment Center he was also project engineer in the Logistics Department. Prior to government service he was project manager for simulator development with Curtiss Wright for 12 years.