Flight simulation in air-combat training

By Colonel Richard C. Needham, USAF, Bernell J. Edwards, Jr., and Colonel Dirk C. Prather, USAF

Sophisticated training equipment makes it possible for aircrews to experience the stress of battle without the risk.

The mission of the Air Force is to fly and fight. Providing essential support to the accomplishment of this mission is the Operations Training Division of the Air Force Human Resources Laboratory. Established in 1969, the division applies the best available scientific knowledge and technology to make Air Force operations training as effective as possible.

Within the Operations Training Division are two elements that develop and test technology applicable to operations training. The engineering research and development element provides the hardware systems for training; the behavioral-science research and development element develops and tests methods for integrating the human component with the hardware systems.

During the early and middle 1970s, operations training research focused on part-task trainers that demonstrated the potential for using simulators for undergraduate pilot training. A series of laboratory studies revealed that a great deal of time could be saved in both the instrument and contact phases of training without adversely affecting the pilot’s performance capabilities.

The instrument flight simulator now used for undergraduate pilot training is an outgrowth of these studies. Affirming the instrument flight simulator’s value in reducing training time, a study involving 1,750 undergraduate pilots revealed an annual savings of no less than 90 thousand flying hours and 25 million gallons of fuel.

In 1975, a more sophisticated simulator, the Advanced Simulator for Pilot Training (ASPT), was produced. It was originally designed to be a state-of-the-art simulator that could be used to develop and test technology as a procurement guide. To date, however, it has been used as a test bed for identifying the specific capabilities a training device must have if it is to offer effective training in particular tasks.

The Advanced Simulator for Pilot Training has two six-degree-of-freedom motion platforms. Aircraft flight dynamics and control loading characteristics are computer-programmable for both the motion and visual systems. The visual display is a computer generated through a seven-channel cathode ray tube system that provides a 300-degree horizontal and 140-degree vertical field of view. The instructor interacts with the student pilot via an operator console that allows the instructor to manipulate a variety of training conditions and task elements.

An early concern in testing ASPT involved the relative contribution of platform motion to training effectiveness. Simulator platform motion is an expensive item and its costs must be justified in terms of benefits gained. Over the past several years, a number of studies of platform motion have indicated that platform motion does not improve training, suggesting that simulation dollars are perhaps better spent on visual systems and on research in other features. Evaluations of ASPT have generated sufficient data to predict simulator requirements for given transfer effectiveness ratios in certain task areas. These include:

- Normal procedures.
- Emergency procedures.
- Instrument flight.
- Aerial refueling.
- Takeoff.
- Landing approach.
- Close formation.

Presently, more research is needed to define simulation requirements in the areas of:

- Air-to-air tasks.
- Air-to-surface weapons delivery.
- Low-level navigation and advanced weapons delivery.
- Tactical formation.
- Force cue requirements for pilot-induced gravity-force cuing and externally induced disturbance.

Thus far, the Advanced Simulator for Pilot Training has demonstrated that relatively low-fidelity simulation training can transfer effectively to air-to-ground weapons delivery skills.

A study of F-5B pilot training was the first effort directly supporting tactical pilot training and marked the beginning of a trend toward collaboration with Tactical Air Command in training and research efforts.

In the F-5B study, recent pilot training graduates were the subjects. Half of the subjects, the experimental group, received an air-to-ground mission training in the ASPT; the other half, the control group, did not receive simulator training. Both groups flew an actual air-to-ground mission in the F-5B with an instructor pilot in the back seat for safety purposes. The simulator-trained experimental group performed better than their counterparts in the control group in all tasks (see Figure 1, p. 20).

The ongoing effort in A-10 simulation development is really an extension of the earlier F-5B study. In the A-10 training, several experiments in initial air-to-ground training produced some interesting results. Again, a transfer-of-training paradigm was used. An experimental group received three air-to-ground training missions in the A-10 simulator. In
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## Abstract

During the early and middle 1970s, operations training research focused on part-task trainers that demonstrated the potential for using simulators for undergraduate pilot training. In 1975, a more sophisticated simulator, the Advanced Simulator for Pilot Training (ASPT) was produced. This article discussed the training capabilities a training device must have if it is to offer effective training in particular tasks.

### Subject Terms

Operations training research; Simulators; Flight simulators; Undergraduate pilot training; Advanced Simulator for Pilot Training (ASPT); Training capabilities; Air combat training
strafe task, the experimental group outscored the control group in all five missions (see Figure 2). In the dive-bomb task, the experimental group's error was better on all seven missions (see Figure 3, p. 22). This is the first study to demonstrate the durability of simulator training. Earlier studies suggested that the effects of simulator training disappeared after two or three missions. Here, effects were still evident after seven flights. Performance results were analyzed on the basis of whether the pilot hit or missed the target, survived, or was destroyed. All participants showed progressively improved performance in offensive and defensive skills (see Figure 4, p. 23). After terrain-crash and overstress losses were removed from the two runs, the learning curves were similar to those of actual combat, indicating that this kind of training should improve pilot survivability, particularly during the first few combat missions.

Judging from these results, there seems to be no apparent reason why combat scenarios cannot be modeled for simulation training. If losses in the first few missions of a war can be decreased through the expanded use of simulation, then this type of training is, in effect, a force multiplier.

Another part of A-10-related research and development addresses the use of the Advanced Simulator for Pilot Training for the A-10 Manual Reversion Flight Control System (MRFCS) and a 3D off-nominal events, a 3D off-nominal environment, and a 3D off-nominal training mode is trainable through simulation, and it appears likely that a simulator-trained pilot can fly a battle-damaged aircraft deftly enough to safely land or eject. Some specifics in the data show that a wide field of view in the simulator results in better pilot performance for this task and that the more complex the failure mode, the poorer the pilot performance. Moreover, the presence or absence of platform motion does not appear to affect performance in any failure condition. Indeed, there can be little doubt that this manual-reversion example reflects the value of simulators in teaching those maneuvers that cannot be taught safely in the aircraft.

Another important ongoing effort is Project SMART, Skills Maintenance and Reacquisition Training. This effort is central to the Air Force's commitment to maintaining adequate aircrew readiness with minimal use of energy resources. The thrust of SMART is the objective measurement of flying skills. To date, development of skill measures has been directed toward B-52 aircrew proficiency, primarily crew coordination, task analysis, and radar bombing skills.

Simulators have been used mainly for transition and instrument training. Units with simulators have used them as substitute aircraft for a portion of their training programs. With the advent of sophisticated full-field-of-view simulators, devices capable of depicting interactive training scenarios between geographically separated units.

The Air Force's long-range goal is the development of a high-technology base for air-combat training through simulated combat environments. The target date is FY87. As this technology evolves, it is expected that the products—hardware and methodology—will transfer to user commands.

Of course, the final test of training effectiveness is crew performance in combat: the better the training, the better the aircrew performance and survivability. The high cost of the first ten days of war is well reflected in projected aircrew and aircraft attrition figures. Three shortcomings in training opportunities are generally cited as contributors to this early attrition. These are:

- Lack of threat-aircraft replication in the aircrew training environment.
- Omission of actual air-to-ground attacks by real aircraft.

Certainly, in light of the expectation of high attrition in the first week of combat, a training device that introduced aircrews to the combat situation and that permitted them to practice critical skills under the stress of engagement would be tremendously valuable. It appears to be a matter of only several years before such a training device is developed. In the next eight years, air-combat training technology will focus on the reduction of first-
The employment of visual-skill components. Consequently, it is very
important to identify and define visual cue requirements for air-combat training. In fact, because of its
great impact on training cost and effectiveness, it may well be the single most important research area.
Although the low-level flight task has been identified as the most demanding combat training prob-
lem, visual simulation in this area is quite limited because of the high level of visual detail required.
The training requirements for the visual tasks asso-
ciated with the low-level environment must be
identified and developed before full mission simu-
lation can be achieved.
As work in this area proceeds, behavioral re-
searchers and engineers will be testing the training
utility of various visual-system improvements, such
as scene detail, dynamic modeling of the environ-
ment, and color. This technology development and
testing will be pursued in a number of areas as
hardware state-of-the-art progresses.
The full development of a simulated hostile en-
vironment is the goal. It will help the Air Force
groom better, combat-ready pilots. It will spur
development of low-altitude flight skills through visual
nap-of-the-earth simulation. Moreover, it will pro-
vide a test bed for measuring combat performance
and may even lead to the merging of simulated air
and ground operations. As development advances, a new, nontraditional
concept of fidelity seems to be emerging. In combat
simulation, those quantifiable variables known to
affect the outcome of engagements are of the great-
est importance. Several areas of development are
now being considered for the expanded-combat
simulation model.
Of high priority is visual-terrain simulation. A-10
close-air-support training will require the best repre-
sentation available. The data base should offer a
suitable likeness of European and Mideastern ter-
rain. The Defense Mapping Agency has digitized
basic data bases for these areas and the Army is consid-
ering using these areas for its Armor Full-Crew Re-
search Simulator.
The visual simulation of maneuver elements on the
ground is also very important. It should depict
both friendly and hostile forces in the forward edge
of the battle area and should impose the A-10
close-airsupport scenario over a preprogrammed
ground battle. The battle scene should be on the
order of two enemy tank regiments against one
reinforced friendly tank battalion. This scale corre-
sponds to a reasonable level of simulation for
close-air-support engagements.
Moving models would be included in the pilot's
visual scene. A single moving model could
represent unit movement as the aircraft was in the
distance. As it got closer to the battle, movement of
individual companies could be visualized represented
with several models. Then, when the A-10 was
within attack range, moving models would represent
individual vehicles.
Experience is needed to define precise limits for
this order of simulation. Visual feedback for
training will be important. The system should have a
look-back or reverse display so that the pilot can see
how his aircraft appears from ground positions.
For battle scenarios, it is foreseen that the in-
structor will be able to select the presence of spe-
cific weapons, their position and firing characteris-
tics, engagement strategies, the effect of smoke, and
other elements affecting battle interaction pro-
grammed as hit probabilities. For instance, the
A-10, when hit by antiaircraft artillery fire, might
go into a manual-reversion mode. The suppressive
effects of air-to-ground fire would also be provided,
altering the firing probabilities of ground units.
Active and preprogrammed control of tactical air-
craft other than those piloted would be available, as
would all communication modes between them. An
instructor or operator would be able to position
weapons on the ground using a light pen and
cathode-ray-tube display. This will yield feedback
the operator needs to set up a fire plan and position
weapons for a combat scenario. The graphics system
will permit the operator to zoom in on specific
areas. Additionally, the system will have on-line,
three-dimensional playback that will provide a visu-
al trace of the flight path, aircraft-state parameters,
and threat envelopes. Graphics playback would
feature slow-motion and freeze modes.
Future engineering efforts in the training equip-
ment area will focus on immediate and long-range
improvements to the Advanced Simulator for Pilot
Training and on the advancement of visual
simulation technology. Projected improvements to
the Advanced Simulator for Pilot Training will in-
clude modularization of aircraft types for rapid
cockpit changeovers, including programmable con-
trol loading and flight dynamics and provisions for
manual-reversion simulation. The visual system for
the Advanced Simulator for Pilot Training will be
modified to include moving ground models, in-
creased edge capacity and circle generation for more
realistic scene content, helmet-mounted sensors, and
displays for improved pilot perception.
These improvements are interim steps toward a
comprehensive engagement-simulation technology
that will support full mission combat training. In-
deed, forthcoming engineering and behavioral re-
search and development will to make it possible for
aircrews to train under conditions that truly ap-
proach actual combat conditions.

Figure 3. The effect of simulator training on low-angle strafe
performance in the A-10 aircraft

Figure 4. Survivability and attack
learning curves of A-10 pilots
operating in a simulated combat
environment

COLONEL RICHARD C. NEEDHAM, USAF.
is chief of the Operational Training Division of the
Air Force Human Resources Laboratory, Williams
AFB, Arizona. A former instructor pilot, he holds a
bachelor of science degree from the University
of Nebraska.

COLONEL DIRK C. FRATHER, USAF, is a
technical advisor for the flight-simulation research
program at the Air Force Human Resources Lab-
oratory, Williams AFB. He is a former instructor
pilot and holds advanced degrees in psychology and
educational psychology.

DR. BERNELL J. EDWARDS, JR., is an ed-
uation specialist at the Air Force Human Resources
Laboratory, Williams AFB. He is responsible for
the development of a media-research laboratory to
support a variety of flight-training activities. His
docorate is in educational technology from Arizona
State University.