APPLICATION OF ADVANCED SIMULATION TECHNOLOGY TO PILOT TRAINING

MESSRS. J. F. SMITH AND D. W. SIMPSON
Link Division, The Singer Company

INTRODUCTION

For many years flight crew training followed a very traditional pattern; pilots were required to practice maneuvers in an aircraft for the purpose of developing skill levels sufficient to pass a rating check. Each new training program was modeled after those preceding; changes were minimal.

Later, as a result of the ingenuity of personnel concerned with training problems, the use of ground training devices was introduced into pilot training programs. These trainers were first used for instrument flight training and later for procedures training. After several evolutions of ground-based trainers, each possessing increased training capability, managers of pilot training programs became increasingly aware that simulators provide a suitable training environment and achieve many training objectives in a more efficient manner and with greater safety than the aircraft they simulate. At the present time, flight simulators have progressed to a point where airline training center managers foresee using little or no aircraft time in upgrading pilots to new equipment qualification.

Even with increased emphasis on the use of ground training devices little attention was given to the role of the instructor. Simulator flight instructors were also burdened with such tasks as problem control and simulator operation, and thus were too overburdened to apply their instructional talents effectively. The result was less than maximum effectiveness in the use of modern ground training devices.

With the advanced digital computers and programming techniques now available, solutions to these instructor problems exist. Automated instructor aids such as problem initialization, malfunction insertion, and objective performance evaluation can relieve the instructor of much of his auxiliary workload, allowing him to assume his unique role as a manager of training.

AUTOMATED TRAINING FEATURES

Following is a discussion of some advanced training techniques that have been devised for use with modern pilot training in flight simulator complexes (the order in which the items are listed is irrelevant).

1. Rapid Initialization. Many years of pilot training have produced a general sequence for teaching flying. Generally, flight training begins with the instructor flying the aircraft to a safe altitude, and then allowing a student to examine the effect of control movements. Simple, basic maneuvers such as straight and level flight, medium turns, climbs, and descents are then practiced. These are followed by maneuvers of increasing complexity until the entire syllabus has been presented. This sequence of learning has proven successful and necessary only, when aircraft are used and, when safety of flight is paramount. However, since these first-learned basic maneuvers are required in all later flights, a considerable amount of expensive aircraft time is necessarily consumed in repeating these maneuvers for other than learning requirements. This is true for both instrument and contact flight activities in either beginning flight schools or professional pilot

training. While such inefficient use of expensive hours cannot be eliminated, when using aircraft, it can be eliminated when using simulators. Rapid initialization allows the instructor (or student) to quickly select a preprogrammed position and simulator configuration without flying to that position. The result is restricting practice to the desired training objectives, greater utilization of simulator, trainee and instructor time, and a significant reduction in costs. With the use of currently available computers, the number of preprogrammed starting points and configurations are almost unlimited.

2. Automated Demonstrations. Another technique commonly used in flight instruction is the demonstration of a maneuver by an instructor after which the student is permitted to practice the same maneuver. The demonstration of these maneuvers varies not only from instructor to instructor but also from trial to trial; this inconsistency provides a poor model for the student. By using a high-speed computer to drive the simulator, it is possible to present a consistently perfect (or purposely erroneous) model performance which may be used again and again by all students. Any number of maneuver demonstrations may be developed. This technique frees the instructor from the aircraft flying task and allows him to concentrate on insuring that the trainee understands the basic cues and subtleties necessary to perform the maneuver. These models also permit increased efficiency in the use of the simulator for solo student training flights, and may be used effectively to standardize instructors as well as ratings of performance.

3. Automated Sequencing of Maneuvers. An extended application of the automatic demonstration mode is the capability of preprogramming a sequence of maneuvers. Since each maneuver, or mission segment, is coded for individual selection it is a simple process for an operator to either program a series of maneuvers, or to call up new ones, if student performance indicates such to be desirable.

4. Automated Malfunction Insertion. An important aspect of all pilot training, particularly in aircraft with more complex systems, is the handling of malfunctions and emergencies. While some of this training can be taught in the aircraft, it is an expensive classroom. Since many of these procedures may induce safety of flight problems, or cannot be taught in the aircraft, the use of ground trainers is required for hands-on training. An additional consideration is that the handling of malfunctions and emergencies can best be taught if no artificial cues, such as observing the actions of an instructor or engineer, are provided. The use of computer-controlled malfunction insertion provides more realistic cueing (progressively worsening if appropriate), and realistic and effective training can then be achieved.

5. Monitoring Procedural Items. Early phases of pilot training involves the learning of new procedures as well as basic perceptual-motor skills. Once the basic piloting skills are learned, more advanced flight maneuvers are performed by simply using different combinations of these skills. On the other hand, new or added equipment usually involved learning procedure sequences which differ significantly from those learned earlier.

Since these procedures are well-defined, and can be described in terms of system logic, they are readily adaptable to monitoring by the computer software associated with modern simulator complexes. For the same reason, it is relatively simple to automate a training program for student use. This capability, when used in modern simulators, serves to relieve the instructor of a significant portion of this otherwise attention-demanding and time-consuming task. This capability will also permit effective trainee practice during solo simulator missions.

6. Automated Recording of Student Performance. In pilot training, as in other learning situations, it is necessary to determine trainee progress. Since the computer, which provides the brains for integrating all simulator components, uses basic aircraft performance data and computed derivatives to make the simulator perform, these same data may be output in objective terms to describe student performance. Such data on selected parameters can be made available in real-time to assist the instructor in his complex task and later as feedback to the student. These accurate objective records reduce the instructor's recording task significantly and thus allow him additional time to observe student activities, which do not lend themselves to objective recording.

7. Automated Performance Comparison. Pilot performance in several parameters such as ability to maintain desired altitude, airspeed, heading, rates of turn, rates of descent, and coordination are particularly adaptable to recording as described in (6). Once these data are provided, it is then a relatively simple matter to program the computer to compare these data with predetermined criteria, and to provide an immediate readout or printout of how student performance compares with predetermined criteria. Such records are extremely valuable in supplementing the instructor's overall evaluation.

8. Knowledge of Results. The annals of research literature, in the field of learning, are filled with studies which indicate that immediate feedback of information on the quality of trainee performance proves valuable in accelerating student learning. The capability of recording performance (6) allows the development of techniques for presenting the student with a comparison between his performance and some selected standard. The use of data, as discussed in (7), provides him with pass-fail data; however, at the start of training, it may prove more valuable to set the standards at a lower level and increase these standards with student progression, using these readouts as a method of "rewarding" student effort. Such manipulations can be easily executed, either manually or automatically, and the data presented in terms of digital readouts or some other means of information transmittal.

9. Adaptive Training. Considerable research has been conducted which indicates that learning of perceptual motor skills can be accelerated by varying task difficulty in a controlled, orderly way. This theory suggests that a motor skills task can be learned more quickly if made easier by some means until the skill is learned, and then increasing the difficulty level as performance improves until final criterion performance is achieved. One term for this is adaptive training. The computer capability of current and projected simulator complexes provides a means of using this training technique. However, there are differences of opinion among experts as to whether the changes in difficulty should be based strictly on student performance or whether a stepped increase in difficulty, based on time or trials, should be used. (Where good performance is rewarded by increasing the task difficulty, this is not necessarily a reward in the trainee's mind.) In either case, the simulator computer can provide this capability.

10. Self Confrontation (Playback). A final training feature, which is possible as a result of the computer capabilities discussed earlier, is recording a trainee's performance which can later be replayed. This feature allows the student and instructor to observe and analyze trainee performance in a relaxed atmosphere wherein the student is not distracted by performance requirements. A freeze and slow replay capability, such as currently used in sports television productions, as well as a fast forward selection mode, is also provided. This capability should be extremely valuable for increasing the effec-

tiveness of debriefings. However, the question, not yet answered, is whether or not such a feature is as valuable as additional real-time trials; since the playback, as now conceived, will require simulator time. Additional research is needed.

OTHER ADVANCED INSTRUCTION CAPABILITIES

The ten features discussed above reflect the use of digital computers to automate various training systems. There are two other simulator developments that promise to provide better instruction, and deserve mention. The first is the use of cathode ray tube (CRT) display systems to present data to instructors. In recent years, the combination of increased computer capability and reduced CRT costs has led to the use of CRT displays as instructional aids. Such systems are in use for presenting automated performance readouts to trainees; for presenting instrument readouts, check lists, and repeater visual displays at instructor stations; and for providing information to training observers and maintenance personnel. They have proven extremely versatile and effective and, since the information displayed may be computer-stored and recalled as needed, they also permit a savings in space that otherwise would be needed at the instructor's console. While performance records presented on CRT's are temporary, permanent records can be made by photography or electrostatic techniques.

CRT's should also be extremely useful in presenting animated or filmed maneuver descriptions. Recent developments suggest that a 3-dimensional picture can be presented, which may prove valuable for some applications, when displaying maneuver patterns.

A second instructional aid associated with computer utilization is the capability to provide automated audio briefings. With proper software application, it is possible to present a standard briefing to all trainees and recall all or a portion of these briefings for individualized instruction.

The preceding are some of the more significant capabilities that have recently become possible, but have not yet been fully exploited.

SPECIFIC APPLICATION

The features discussed include some which have recently come into general application with advanced simulator complexes, and some which are ideas that are feasible, but need to be validated in a pilot training system. For example, two years ago Link Division of the Singer Company, and the TransWorld Airline Training Center completed a joint experimental program for recording trainee performance. Software was developed for automatically recording all significant parameters (and other parameters considered interesting but not critical to performance) on three of the 12 maneuvers required for upgrading pilots to a new aircraft. Programmed comparisons and error scores were output. The results indicated that such programs were feasible, workable, and useful.

In a more recent project, Link delivered to the United States Armed Forces a "Synthetic Flight Training System" (SFTS) for use at the U.S. Army Aviation School.

The SFTS was designed for the Army's helicopter training program. It is a flight simulator that is a "generation" in advance of any current simulator in use for commercial or military training. Simulators other than the SFTS are basically instructor-controlled devices; i.e., the instructor sets-up the training problem and the flight environment being simulated and monitors the trainee, while he practices to develop the required skills.

In the SFTS, the computer rather than instructor can be made responsible for:

1. Selecting the flight problem - what the trainee will do in a particular training session,

2. briefing the trainee on the training problem to be executed,

3. demonstrating the ideal performance to the trainee,

4. scoring and evaluating trainee's performance against objective standards, and,

5. providing feedback to the trainee concerning his performance.

The SFTS incorporates the latest developments in automated training techniques and digital computer technology and performs the above listed functions efficiently and objectively. The automated training features also make possible adaptive training, whereby task difficulty is modified by manipulating selected variables, and making incremental additions and deletions of control inputs, and/or helicopter stability augmentation.

Like existing simulators, the SFTS also provides high fidelity simulation of motion cues, aural cues, cockpit instrumentation, and cockpit controls to provide a realistic environment for the training of pilot tasks. When fully implemented, it is anticipated that the SFTS will substantially reduce flying time in the Army's helicopter training program.

SUMMARY

Modern ground-based flight simulators have evolved, in part, from rapid development of increased computer capabilities. These same computer capabilities can, by innovative software development, be used to reduce the workload of the simulator instructor. Some of the major areas in which assistance can be provided are: (1) Rapid initialization for specific maneuvers; (2) automated demonstrations; (3) preprograming of a sequence of maneuvers; (4) automated malfunction insertion; (5) automated monitoring of procedural items; (6) recording of student performance; (7) automated performance comparisons; (8) providing knowledge of results; (9) adaptive training; and (10) providing a recording and playback capability for later study. In addition, other equipment capabilities have been developed for evaluation as to their application in a simulator pilot training complex. These include increased use of CRT display systems and automated briefings.

All of the features discussed are aimed at reducing the load of the instructor, thereby allowing him more time to function in the role of a manager of training and permitting him to concentrate on parameters which can only be handled by subjective evaluation. Such remaining activities are: (1) Diagnosis of problem areas resulting from a lack of student understanding; (2) identification of trends of incorrect performance across the total training spectrum; (3) identification of judgmental errors; and, (4) development of decision-making ability.

The combination of all the special training features, and the increased capability of the instructor to concentrate on required subjective evaluation areas, will result in maximizing the training value and efficiency of the simulator complex, thereby insuring a most cost-effective training program.