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In the CBI phase, the PLATO program presents information and questions (center display screen) and controls the touch-sensitive Spiritus slide-tape units.

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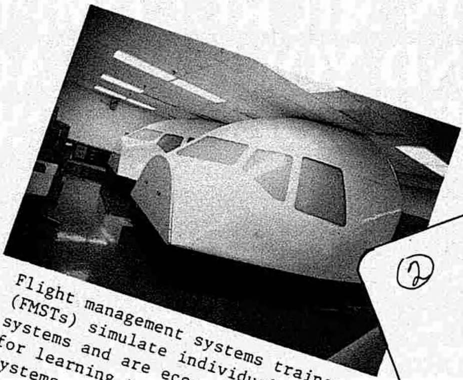

Flight management systems trainers (FMSTs) simulate individual flight systems and are economical devices for learning to operate actual systems prior to flight simulator training.

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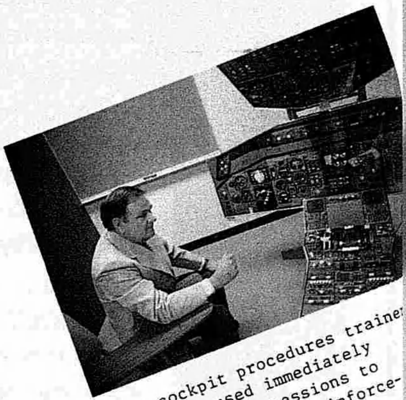

The cockpit procedures traine (CPT) is used immediately following CBI sessions to provide hands-on reinforcement of lesson material.

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Modern simulators depict actual flight conditions – hydraulic jacks provide motion cues, computers generate visual images and sounds.

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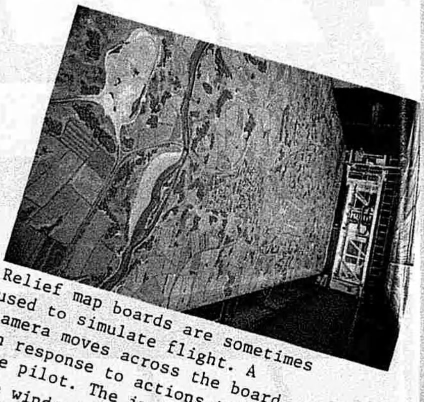

Relief map boards are sometimes used to simulate flight. A camera moves across the board in response to actions taken by the pilot. The images appear in the windows of the simulato cockpit.

Fly the Safe Skies—And Thank Training

High above the clouds, at every moment of the day, airline pilots make decisions that determine the safety of thousands of people. Pilots must make the right decisions—and they almost always do. Largely responsible for this nearly flawless performance are the flight training specialists who develop, implement and evaluate the uniquely proactive, integrated training described in this article.

By MARY CONDON, Staff Writer

In 1966, a revolution in airline pilot training began. Larger, faster planes, an influx of new pilots, high fuel costs, increased air traffic and changing technology led to more accidents and made in-flight training (training in planes) prohibitively expensive. Throughout the industry, managers recognized the need to overhaul existing training techniques. Training needed to be improved, and it needed to cost less.

Conventional classrooms, early simulators and in-flight instruction have given way in the past 20 years to a new approach to pilot training. Centralization of training, instructional systems design concepts and improved simulators started the transformation toward the most advanced training in any industry.

A major step taken by several carriers during the mid-1960s was centralizing all training at one location. This helped make training methods more consistent, and clarified and standardized training maneuver requirements established by Federal Aviation Administration (FAA) regulations.

Profound advances also were made in the instructional design of training. Using newly identified applications of instructional systems design concepts, training specialists developed multiphase programs for training to proficiency. At each phase of the training program the student developed to the level of proficiency and could move to more complex tasks confident of his or her skill in those learned previously.

Redesigned ground training programs used specific behavioral objectives to emphasize essential knowledge for performance of crew duties on the line. Nonessential information—that could contribute to anxiety, the overloading of some learning tasks and failure to learn essential information—was eliminated or moved to a later phase of the training program.[1]

Training objectives also took a new form. Audio-visual modules were developed to replace the standard training format, a class of 15 to 20 students taught by an instructor who used an electrical response unit to monitor students' progress. These audio-visual modules could be used by students in individual study carrels. Part-task trainers or mock-ups of cockpit instruments were used for reinforcement of material learned in the carrel presentations.

The upgrading of flight simulators expanded their utility and shortened the training time in planes, thus greatly reducing training costs. Engineering research and test flights were designed to obtain performance data, which had not been available before. Through collaboration with simulator manufacturers, high-fidelity simulation of ground effects and visual cues for takeoffs and landings became possible.[2]

Training maneuvers and emergency procedures could be accomplished more realistically and more safely in the simulator than in the aircraft. And when studies showed that training in the improved flight simulators could ensure complete transfer of training to the aircraft, the FAA permitted simulator training as a substitute for certain in-flight training.

Refinement

The new systems approach to pilot training was a success. Training times were reduced substantially, non-revenue airplane training was almost eliminated, and the product was a better trained pilot. But new systems often bring new problems.

Jack Mansfield, manager of training techniques, and Jerry Plemons, manager of training program development at

American Airlines, identified the difficulties they experienced with the systems of the late 1970s:[3]

- The individual carrel presentations were single track and linear. To obtain information, the student had to go through the entire program, limited by the pace of the audiotape. Adjustment for individual differences was difficult.
- Multiple choice and true-false questions throughout the slide-tape carrel presentations gave feedback to the student on comprehension of the material, but gave no remedial information on why an answer was wrong.
- Carrel presentations were overwhelmingly passive learning activities. Some programs were as long as three hours, with listening and observing the only activities. The probability of fatigue or boredom was high.
- Carrel presentations immediately followed by part-task trainers or cockpit-procedures training were most effective because the devices offered hands-on practice while the information was still fresh. Some very complex systems were not operable on the mock-up trainers, but that complexity also made these tasks the most difficult for the student to understand and master. As a result, additional simulator time was required for students to learn to operate these complex systems.
- Basic training materials and exercises weren't available at domicile bases for crew persons who needed to use them between recurrent training periods.

Computer-based training devices provide a flexible, cost-effective method for system training. There are many types, but allowing students to progress at their own pace and being interactive are essential characteristics. The student is not confined to a classroom or the learning pace of other students. Rather, the computer paces learning according to correct or incorrect responses to the material presented.

American's training specialists reviewed instructional research and visited other training centers in an effort to refine their training programs. They found that computer-based instruction (CBI) offered the best chance of eliminating the deficiencies of the existing programs. Of the major CBI systems, American chose the PLATO computer-aided learning system, developed by the University of Illinois.

PLATO–An early interactive system

The PLATO system offered features that were (and are) considered essential for flight training programs: high-resolution graphics, animation, a touch-sensitive screen for student interaction, and rapid response that would not degrade with increased student load. Mansfield says that PLATO's touch-sensitive screen is a key factor in the effectiveness of the training modules. "We have very complex schematics on our PLATO system. The needles move on the instrument being simulated, the lights light and the numbers roll just as the instruments do on the plane. Even the function keys, like *next, back* and *data*, are on the touch screen because most pilots would rather touch than type."[4]

Several short flight and maintenance training modules were developed before a major CBI training program for the complex DC-10 flight guidance system was produced in 1979. That program presents information in a slide-tape format in short lessons, 6 to 10 minutes each. The interface between the slide-tape unit and the PLATO unit was manual; the student was instructed by the PLATO program when he or she was to refer to a slide-tape segment, and a slide in the series instructed the student to go back to the PLATO program to continue the lesson.

After each lesson, the student was tested at the terminal on each objective covered in the lesson. Wherever possible, students were asked to answer questions by using the touch screen, and true-false and multiple choice questions checked for knowledge of objectives. If the student made an error, he or she received remedial information and was tested again. If the student then made a second error, he or she was given the correct response and asked to check with the instructor on any further doubts about the objective.[5]

Doug Crandall, a flight training development specialist at United Airlines, explains a valuable PLATO branching capability that teaches pilots to fly efficiently as well as safely. "There are several ways to shut down the auxiliary power unit (APU). Each way is more fuel efficient under certain conditions. When the pilot chooses one of the procedures in a PLATO simulation, the system will respond with appropriate feedback, either saying, 'Congratulations! You just did your share to save $50,000 worth of fuel annually,' or 'You just wasted 30 seconds of APU operating time.' "

Following the lesson material on the DC-10 program, the student performed a complete profile activity, operating the flight guidance system in a CAI mode, using only the touch screen.

Telecommunications problems with the program's delivery system were the most frequent complaints from students and instructors. In April 1981, all existing courseware was converted for delivery at "stand-alone" micro PLATO units in each of the multimedia study carrels. The units eliminated interruptions from telephone lines or main computer failures, and made graphic and text display time almost instantaneous.

An instructor was available to all students at any time during the self-paced study phase. Continuity of training by the same instructor through all training phases ensured standardization and compliance with approved procedures. In addition, each student's error record, which was maintained by the PLATO program and reviewed by the instructor daily, enabled instructors to identify student weaknesses and to design subsequent exercises to reinforce correct responses.

High-tech training for high-tech applications

In 1982, a new aircraft with an automated cockpit made its debut. The Boeing 767 uses computer screens and push-button controls instead of the dozens of dials, levers and gauges that we're used to seeing in pictures of airplane cockpits. This aircraft, designed to be flown by two people instead of the usual three, represents a major advance in aviation technology.

Once again, flight training specialists were ready with some new ideas for courseware. The CBI phase of training for this plane also became automated. Both American and United Airlines established, for the first time, a computer interface between the PLATO programmed instruction units and audio-visual devices.

The CBI study phase for learning 767 systems uses a random-access 35 mm Spiritus™ slide-tape unit that is controlled by the micro PLATO unit in each study carrel. In addition to the simulation exercises and the evaluation and program management functions, the Spiritus™ unit interacts with the audio instruction and the PLATO program to permit branching to any part of the slide-tape presentation.

As before, the CBI instruction is teamed with other applied learning activities. With current training techniques, the student spends an average of four hours per day in a study carrel using the PLATO/Spiritus™ programs. This course material is presented in modules of no more than 20 minutes, separated by evaluation and testing exercises.

After the CBI training, the student spends about half an hour at the cockpit procedures trainer (CPT) in a briefing session with the instructor. The CPT is a backlighted color transparency model of the cockpit instruments for the appropriate type of aircraft and is used to reinforce learning and clarify objectives about which there may have been confusion.

Following the half-hour CPT briefing, the student spends approximately two hours in a flight management systems trainer (FMST). This device is an enclosed cockpit environment that allows for the simulation of flight management systems. For example, real switches, computers and display screens are used by the trainee to program the flight path the same way it would be done on an actual 767. The realistic logical display of visual cues, motion and other simulations of actual flight conditions, however, are not possible in the FMST.

The specialized flight simulators used in training at the major airlines cost millions of dollars to purchase and operate. "What we do with the PLATO system and mock-up," says American Airline's Plemons, "is prepare the crew members so that when they get to a simulator, they are ready to use the full capability of that training device."[6]

Once the student is familiar with individual flight systems, these operations need to be integrated into the flight deck, and proper crew coordination needs to be established. This integration is best accomplished in the flight simulator. Depending on a pilot's familiarity with a particular aircraft (he or she may be in initial, transition or upgrade training), it may be necessary to allow several hours of "batting practice" during which the pilot has an opportunity to fly the simulator and gain experience with the interaction of the aircraft systems. After that, the demonstration of proper learning is accomplished during line-oriented flight training (LOFT) scenarios.

By 1978, visual flight simulators using computer-generated image systems were so advanced that the FAA extended credit for landing maneuvers performed in simulators that had adequate aerodynamic programming. After extensive test programs, the FAA published a rule, the advanced simulator plan, that permitted complete replacement of conventional training in planes with electronic simulators for a range of air crew training.

Of the five levels of simulator approval (non-visual, visual, Phase I, Phase II and Phase III), Phases I, II and III are advanced technology simulators that may be used for total training and checking of pilot skills. The FAA examines each airline's syllabus and each simulator before any approval is granted. The three phases of flight simulator training covered under the FAA's advanced simulator plan are:

- Phase I: approved for night takeoffs and landings to reestablish or maintain currency;
- Phase II: approved for the training of pilots or co-pilots for the same positions on different aircraft (e.g., co-pilot on a 737 to co-pilot on a 727, which is a larger, more expensive plane);
- Phase III: approved for the upgrading of flight crew into different positions on different aircraft (e.g., co-pilot on a 737 to pilot on a 727).

"In theory," says United Airlines pilot John Perkins, "Phase III would permit us to take a man off the street (with a commercial pilot's license and an instrument rating) and turn him into a qualified captain on a heavy jet transport aircraft."

The accurate depiction of daylight visual systems with a 70-degree field of view; the sights, sounds and movements of turbulence ranging from moderate to a full-blown tornado; operational scenarios depicting loss of visual reference below the decision height on final approach; crosswind landings on icy or flooded runways; and traffic conflicts leading to near misses or mid-air collisions are all required for Phase III approval.

These special effects are the essence of Phase III. United's Perkins explains, "In training, you wouldn't normally expose a pilot to these hazards. With this level of simulation, instead of lecturing pilots on 'what to do if. . . ,' we can now demonstrate what to do with a very high degree of realism." Perkins adds that "the more expensive the airplane is to operate, the greater the value of simulator training." Although converting simulators to meet FAA specifications is expensive, the cost is about one-tenth that of in-flight training.[7]

In addition to the hardware and software requirements for advanced simulation qualification under FAA regulations, line-oriented flight training (LOFT) scenarios must also be performed as part of Phase III training, and most major U.S. airlines currently train with this concept.

First, time is allowed for simulator practice in situations like engine-out on takeoff, approach and landing, missed approach and other operational problems. Then, LOFT scenarios are conducted in real time with a complete flight crew. The scenarios are designed to be exactly like a real flight: A route with intermediate stops is planned; weather conditions vary;

Types of training

Pilots accepted for airline training programs have already been through extensive health, aptitude and psychological tests. And most are experienced pilots with more than 2,200 hours of flying time. Of the three persons in the cockpits of most planes, the captain has the most responsibility, followed by the first officer, or co-pilot, then the flight engineer.

People in these three positions may move to progressively more sophisticated and expensive equipment: from 727s to DC-10s, to 747s, and on to the most advanced commercial aircraft today, the automated Boeing 767. Crew members must undergo training periodically and, to move from one level of responsibility to a higher level, must undergo specific kinds of training, according to FAA regulations.

- *Transition* training is required to qualify for the same seat on a more advanced aircraft;
- *Upgrade* training is required to qualify for a higher position on the same or a more advanced aircraft;
- *Requalification* training qualifies a crew member to perform in more than one capacity on more than one type of plane;
- *Recurrent* training is required of all cockpit crew members to keep skills sharp and current. Pilots are required to undergo recurrent training every six months, first officers and flight engineers, annually.

and other en route conditions requiring the pilot to demonstrate total understanding of concepts, procedures and systems are built into the LOFT scenario. Also, the scenarios must include at least the emergency maneuvers that may be expected in line operations, and they must incorporate a representative flight segment that the carrier would assign to the pilot.

While industry experts agree that the new level of simulation provides unequaled realism, the question remains whether pilots are better trained in the all-electronic environment. In economic terms, the answer is definitely yes. If a pilot changes aircraft five times during his or her career, transitional in-flight training on a 747, for example, would cost more than $6,000 per hour, with two to three hours required for each qualification.[8]

Simulator training, on the other hand, is free from air traffic control restrictions, fuel costs, weather conditions and aircraft availability. In addition to saving dollars by not using aircraft for training, the airline profits from the productivity of the pilot by sharply reducing the time needed to qualify. A pilot can practice landing a new type of aircraft many more times per hour in a simulator than in a real plane.

In terms of flight safety, it is more difficult to say that advanced simulator training is actually better. But the failure rate of pilots in transition training has declined since the introduction of the phase approach to simulator training.

What about the accidents that *do* happen? The human system

In an industry where training and safety are essential for survival, there is always room for improvement. Since the revolution in pilot training began, the airline industry consistently has used technological advancements to make training delivery more efficient from both economic and quality standpoints.

While the technical training of airplane pilots can truly be called state of the art, accident reports and incident investigations for the decade between 1970 and 1980 show a leveling off of safety improvements. Data for that 10-year period show that more than 60 percent of fatal air carrier accidents have had, as at least one causal factor, some aspect of poor human resource management. If all fatal accidents in corporate and general aviation are added to the tally, more than 80 percent were caused in part by a human resource factor.

In all such accidents, the common cause has been identified as a lack of, or improper use of, cockpit human resource management—there was no problem with the plane or the technical skills of the crew members that would have prevented a safe conclusion to the flight. As a result of this mounting evidence, the National Transportation Safety Board (NTSB), the FAA and the Airline Pilots Association (ALPA) have made recommendations for training to address the problem of mismanaged human resources.[9]

The human factors most often addressed by the commercial air carrier industry include equipment design, location of equipment in the cockpit, and items of comfort and use (seats, manuals, etc.). When attention has been given to the human element, it has been directed to the crew members as individuals: the effects of altitude, vibration and noise; night versus day flying; and the jet-lag effects of long trips. The problem of handling an incapacitated crew member and the additional workload brought on by the loss of a crew member have also been addressed through training.[10]

While technological advances have allowed the pilot to absorb increases in speed, altitude and traffic density, they have also required pilots to assume new management and monitoring roles.

While technological advances have allowed the pilot to absorb increases in speed, altitude and traffic density, these same advances have required pilots to assume new management and monitoring roles in operating aircraft. More attention needs to be given to helping the crew function as an effective unit in this advanced environment.

Organizations that have pursued human resource issues have developed one-time training approaches and have scheduled only captains for training. Captains throughout the industry have not been taught systematically to use group dynamics for setting crew performance objectives, to develop crew interaction skills or to communicate effectively. Other crew members have not been trained to understand the responsibility they have to contribute their skills and resources to successful management by the captain.

Many carriers have avoided the problem because they believe either that it is too sensitive an issue or that the problem cannot be resolved. Indicating that an accident was caused by poor resource management may be too much like saying "It was pilot error."

Industry leaders in focusing attention on the human side of flight safety, United Airline's training strategists determined that a training program in this area must not be viewed as a threat to the pilot's security or as something just to cover legal responsibilities. The program's best chance for success, they believe, lies in being recognized as enhancing the professionalism of an already professional group. Such a program would have to be of high quality and would have to be accepted by the population. It also would have to be repeated often enough so that the skills became an inherent part of day-to-day operations.[11]

According to United's Captain J.S. Crump, "The problem confronting all of us might be expressed as, 'Why does a person who is carefully selected, highly trained, properly checked and licensed, physically fit, mentally well balanced and usually well paid, sometimes perform less than optimally, despite the awareness that the penalty of human error could be catastrophic?' "

Training for the human system

United's cockpit resource management (CRM) program represents the airline industry's first comprehensive effort to improve flight safety through leadership development. The Management Grid concept, developed by Robert Blake and Jane Mouton, was selected as the cornerstone for the training, with Scientific Methods, Inc., serving as the primary consultant for program development. The frame of reference provided by the Grid was seen as appropriate because it uses simple numerical indications for specific management styles.

The concept of synergy, wherein the total performance of the crew operating as an effective unit is greater than the sum of their individual performances, is at the heart of the CRM program. To achieve synergy among crew members and captain, the CRM program focuses on five leadership elements essential to productive teams:[12]

- Inquiry—the constant, proactive interrogation of the technical and human environment to uncover discrepancies or danger signals;
- Advocacy—the direct expression of convictions as to a sound course of action;
- Critique—the process that allows captain and crew to learn from experience before, during and after a flight;
- Conflict resolution—acknowledging conflict and resolving it in a constructive way that promotes mutual trust, respect and agreement.
- Decision making—the most visible and critical element of leadership, with an emphasis on *how* decisions are made, not on *who* makes them.

Once these elements of leadership effectiveness were identified, program development began. With nearly 5,000 crew members across the country, a self-study format was an expeditious way to explain why the program was needed, to familiarize the crew with "Grid language" and to provide a foundation for subsequent training. A self-study course of seven booklets, one booklet approximately every two weeks, was distributed to cockpit crew members.

The second phase was a formal seminar to provide first-hand application of the principles learned in the self-study course using role-playing exercises to confront situations that occur on flights. The scenarios assumed the presence of sharp professional skills, but solving the scenario problems required effective interpersonal management skills as well. Participants provided feedback to each other.

The third phase was incorporated into LOFT simulator training. The LOFT experience was videotaped, then reviewed in a debriefing session to determine how the scenario had been flown. The instructor would say, "I want you to discuss among yourselves why it went so well," or, "where it might have been improved." After the discussion, the crew erased the videotape to ensure that it wouldn't be used in the future.

Although it is too soon to establish empirical evidence (the program has been used for only two years) data show a 50 percent reduction in failures on flight checks taken after CRM training exercises. United intends to integrate the CRM program into all transition, upgrade and new-hire training and en route checking so that CRM will be a part of every crew person's career from the first day to retirement.[13]

Obviously, most businesses don't need to depend on training the way the airlines do. From maintenance personnel and dispatchers to cabin and cockpit crews, airlines must pursue flawless performance through an industry-wide emphasis on training. But airline trainers can serve as a model for your training department. Their dedication to finding the most efficient, effective way of ensuring performance would serve any industry well.

And their ability to deliver consistent, high-quality training to trainees whose actions determine the fates of others should give all trainers pride in their profession and confidence in their own abilities.

There is more than one way to accomplish a training task, and identifying and implementing the most suitable techniques should call forth the full range of any trainer's expertise.

A note on competition . . .

Despite fierce competition among airlines, safety and training are not competitive matters. Knowledge and techniques that enhance training effectiveness are shared throughout the industry. As a result, the technical and human systems training described in this article is representative of a broad cross section of airlines' practices.

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