Personal Computer–Based Flight Simulation To Teach Aircrew Teamwork, Crew Resource Management, And Decision Making

John C. Duncan
Lynn C. Feterle
Charles V. Starkey
Kent State University—School of Technology

Abstract

The recent advent of the Personal Computer–Based Aviation Training Device (PC–ATD) allows flight education programs to provide a realistic multi–crew simulated cockpit environment that can be used to teach the fundamentals of crew resource management (CRM) and decision making. The Elite 142 PC–ATD is a personal computer–based flight simulation device that simulates several different single– and multi–engine two crew aircraft. The flight simulation and the multi–crew arrangement allows an instructor to engage students in a variety of scenarios where they can directly apply the principles and theories of crew resource management to realistic situations. Various exercises can be presented by an instructor to illustrate and reinforce CRM techniques in an airline and aircraft–specific operational environment. Also, the use of instrument display and cockpit video recorders allows the instructor to review the flight for further instruction and evaluation.

Introduction

Over the past decade many segments of the aviation industry have moved toward widespread incorporation of CRM as part of flight crew training and aircraft operation. During this same period, there has been an increasing demand for qualified pilots by the commuter or regional airline industry, with a corresponding need for colleges and universities to provide a curriculum that prepares their graduates for a rapid transition

to multi–crew transport category aircraft airline operations. As a result, one of the major needs that has emerged is for colleges to incorporate multi–crew CRM into the flight education curriculum as an essential component of flight education. Although the fundamentals of CRM can be presented to students through classroom lecture, lecturing and similar modes of delivery have severe shortcomings that readily appear when CRM is put to the test in actual application. Because of these instructional limitations, nearly all major and regional airlines use large scale, high–fidelity flight simulators or flight training devices to provide a realistic multi–crew operational environment that is optimal for the initial and recurrent CRM training they provide to their aircrews. However, the cost of these devices, ranging from several hundreds of thousands of dollars to millions of dollars, makes them cost–prohibitive for most universities. Faced with this high–cost dilemma, those colleges wishing to incorporate multi–crew CRM fundamentals into their programs have, until very recently, found very few alternative means of providing safe, effective, and economical means of doing so. However, the recent advent of the PC–ATD can allow flight education programs to provide a realistic multi–crew simulated cockpit environment that can be used to teach the fundamentals of crew resource management and decision making.

Fundamentals Of Multi–Crew CRM

One of the most commonly accepted descriptions of Crew Resource Management is that it is "the effective use of all resources available to the flight crew, including equipment, technical/procedural skills, and the contributions of flight crew and others" (Taggart, p. 309). The adoption of CRM follows years of analysis of aircraft mishaps that has revealed that in most cases the mishap was not due to circumstances beyond the control of the flight crew. Investigation has shown that many incidents could have been readily avoided or mitigated if the crew had responded differently. According to the Federal Aviation Administration (FAA), over the past 20 years 66–80% of all air carrier accidents involved human error or resource management error as a contributing factor (Federal Aviation Administration, p. 2). In fact, a study by Boeing Commercial Airplane Company found that nearly 75% of all fatal

commercial jet accidents occurred in aircraft that were still capable of landing safely (Taggart, p. 310). The FAA has noted that "many problems encountered by flight crews have very little to do with the technical aspects of operating in a multi–person cockpit. Instead, problems are associated with poor group decision making, ineffective communication, inadequate leadership, and poor task or resource management" (Federal Aviation Administration, pp. 2–3).

As a result of accident analysis by the FAA, the National Transportation Safety Board (NTSB), Boeing, and others, CRM has evolved to become a means of improving crew coordination and enhancing decision making. It has become a necessary and fundamental basis for many types of flight operations. One of the main purposes of CRM is to evaluate, develop, and improve teamwork, decision making skills, situational awareness, critical thinking, and interpersonal skills. In order to utilize CRM in the flight environment, it is necessary that the crew be properly educated in CRM fundamentals and learn how to function as members of a coordinated team. Training is needed to enable crews to engage in proper crew coordination and resource management during both normal flight conditions and abnormal flight conditions, and it is necessary that they effectively practice those fundamentals in the operational environment.

Typical CRM topics include the following (Federal Aviation Administration, pp. 10–12, Appendix 3, pp. 1–2; Mellor, p. 372; Wilson, pp. 388–389; Kern, pp. 138–139):

- Communications Processes and Decision Behavior
  - Internal and external influences on interpersonal communications
  - Conflict resolution techniques
  - Decision making skills
  - Communication barriers
  - Listening skills
  - Feedback
  - Information transfer and communication errors
  - Precision and efficiency
- Team Building/Group Dynamics
  - Effective leadership and followership

Coordination of activities
Proper balance between respecting authority and practicing assertiveness
Non–flying pilot functions/First Officer: Effective and positive methods of monitoring and challenging pilot functions/errors
Flying Pilot/Captain functions: Effective and positive methods of giving and receiving challenges of error
Concern for safe and efficient operations
Leadership
Responsibility
Conflict resolution
Interpersonal relationships
Personality types/differences
Leadership styles
Command authority
Crew member roles
Group dynamics
Behavioral styles
Hazardous attitudes
Team building

- Workload Management and Situational Awareness
  - Preparation, planning, and vigilance
  - Awareness of the operational environment
  - Anticipating contingencies
  - Time management
  - Workload distribution
  - Avoiding distractions
  - Task prioritization
  - Aircraft systems management
  - Management of automation
  - Available resources
  - Overload/underload issues
  - Checklist discipline
  - Standard operating procedures
  - Judgement and risk assessment
  - Problem solving
  - Information processing

Increased situational awareness
Tools for maintaining situational awareness
Tools for recovering from lost situational awareness
Risk management
Breakdowns in judgement and discipline
Evaluation of hazards

- Physiology and Human Performance
  Stress and fatigue reduction
  Stress factors
  Recognizing stress
  Fatigue effects
  Coping techniques
  Effects on performance
  Effective interpersonal communications during stressful conditions
  Cognitive processing
  Mental attitudes
- Mission Planning
  Pre–mission analysis and planning
  Crew briefing
  Ongoing review
  Post–mission review and critique

CRM Education Using Flight Simulation

Ideally, CRM education involves the study of basic CRM principles, investigation of case studies, the use of classroom exercises, direct student participation in simulator practice and exercises, and effective postflight debrief and analysis of the simulator session. In particular, the use of flight simulation provides an ideal method for students to obtain the knowledge, skills, and experience necessary to effectively operate as a crew member.

Flight simulators have demonstrated that they can be tremendously effective educational tools. There are substantial educational and instructional benefits offered by simulators, and they provide an excellent platform for practice, instruction, and evaluation. Flight instruction in simulators has proven to be very effective, mainly because of the high

transfer of knowledge that occurs due to the simulator's ability to closely reproduce actual flight operation. In fact, the training environment presented by the flight simulator allows it to provide better training than what is possible in an actual aircraft, primarily because simulator training can provide much more concentrated, intense, and varied training than actual flight training. Simulators provide a very controlled environment that eliminates many distractions—allowing more concentration on training—and also enable the instructor to interact with the crew to maximize learning to meet the ability and needs of the crew. In particular, simulators provide several instructional benefits that aircraft can not, including the following:

- A highly controlled physical environment—a quiet, comfortable classroom that allows one–on–one flight instruction and minimizes distractions.
- Instructor control of pilot and crew workload. The instructor can simulate air traffic control communications, deviations, and associated distractions to the level desired; introduce malfunctions; and control turbulence and weather.
- The instructor has control of aircraft systems: the instructor can degrade or fail critical systems at crucial times.
- The simulator can fly scenarios that would be impossible or risky in an aircraft.
- Simulators have the ability to freeze action and to play back, reset, and repeat scenarios, allowing immediate feedback and correction when needed. Freezing the simulator allows the instructor and student to analyze and discuss procedures or errors immediately and in–depth when they occur, to reset the conditions, and to repeat the scenario.
- Many simulators provide flight recording capabilities: playback and replay, snapshot and hard copy printouts, videotaping and recording of the flight, and scoring that are available for online or follow–up or debriefing critique. In addition, map displays and screens are often provided that show 3–dimensional position with respect to routes and navigational aides such as airways, fixes, instrument approaches, radials, waypoints, airports, and other features for in–flight and post–flight analysis.

- Simulators provide instantaneous positioning of the simulated aircraft at different geographical locations and altitudes. This ability saves time and allows crews to operate at different locations with the terrain, airports, facilities, and electronic navigation aids associated at those locations. Lessons can be repeated in a short period of time and reset and replay can be used to review and/or repeat specific scenarios over and over.
- The instructor or observer can easily monitor crew conversations and actions without distracting the crew.
- The simulator can simulate various avionics, aircraft systems, and other equipment that is not available, economically feasible, or safe and appropriate to use on training aircraft (i.e., radar, Flight Management Systems, Electronic Flight Instrument Systems, Ground Proximity Warning Systems, Traffic Alert and Collision Avoidance Systems, Global Positioning System satellite navigation, autopilots, flight directors, etc.).
- Custom avionics and cockpit layouts are possible with easy and quick reconfiguration, particularly with respect to cathode ray tube (CRT) based Multi–Function Displays (MFD).
- Aircraft configuration, flight characteristics, and performance are programmable.
- A variety of electronic navigation aids can be simulated.

One attribute of simulators stands far above the rest in importance: the simulator's unique abilities in emergency procedure and accident prevention training. Simulators are ideal for emergency procedure training, enabling instructors to introduce aircraft malfunction conditions that are difficult, unsafe, or impossible to duplicate in aircraft. The simulator lets an instructor induce the loss, degradation, or malfunctioning of critical systems at critical times, thereby providing emergency procedures practice for the crew and allowing the instructor to evaluate crew response and control crew workload.

One of the most significant flight simulation objectives is to train crews so that they quickly recognize threatening events and react automatically to remedy the situation or prevent problems when things go wrong or when threatening types of events occur. The training is mainly intended to reduce the amount of time involved in reacting to a

situation based upon the principle that repeated practice will allow a pilot's initial reaction to be instantaneous—without the necessity of substantial analysis—until the crew has the time to investigate the situation. This particular attribute of flight safety training was noted by McLanaghan (1983, p. 59):

> At the heart of flight simulation is the ability to introduce all types of accidents, mistakes, and incidents that a flight crew might encounter and then train the crew to react properly. The goal, once everything has been stripped away from simulation, is to minimize the time that elapses between the moment a flier recognizes a situation and the moment he has dealt with it effectively.

Typically, an instructor can introduce, either automatically or manually, a variety of failures, malfunctions, and/or unusual conditions, including the following:

- Fires and overheat conditions in engines, cargo bays, auxiliary power units, wheel well, brakes, etc.
- Flight control failures
- Introduction of unusual flight attitudes
- Brake and tire faults: flat tires, brake failure, overheats
- Instrument and avionics errors and failures
- Various in–flight emergencies: split flaps, fires, overheating, cabin decompression, hydraulic system malfunctions, electrical system malfunctions, etc.
- Landing gear malfunctions and failures
- Engine malfunctions: overheats, fire, compressor stall, surges, failure
- Circuit breaker actuation
- Hazardous weather conditions

Flight simulation allows an instructor to provide an almost ideal flight and operational environment for CRM education. The simulator can be used to bring into play a student's knowledge, flying skills, spatial and temporal orientation, resource and systems management skills, and situational awareness. When combined with classroom presentation and

exercises, the simulator provides a superb opportunity for reinforcement of CRM fundamentals and theory through student practice, demonstration, feedback, and self–assessment. The use of simulation also allows colleges to incorporate the Line Oriented Flight Training (LOFT) approach used in much of the aviation industry. A LOFT–focused approach involves the nearly complete application of flying skills and operational requirements in an aircraft–specific environment. It typically includes complete flight planning, proper flight documentation, preflight activities, dispatch processes and activities, and postflight debriefing.

Challenges To The Educator

In CRM training the effectiveness of the instruction is much more heavily dependent upon the expertise and actions of the instructor than in traditional lecture delivery methods. CRM requires a very different instructional approach than that usually required for non–CRM instruction. CRM requires that the instructor take on a very unusual role: to act mainly as an observer and facilitator. In a true LOFT/CRM scenario the instructor's main role is to act as a facilitator without the direct continuous intervention or instruction normally utilized in flight training. The role of the instructor is to remain as unobtrusive as possible, to observe and intervene only when necessary to make a critical point or to moderate the situation, to note crew actions and behavior, and to provide detailed feedback through postflight debriefing and review of the session. This approach is taken in recognition that one of the most effective teaching techniques—and one that most quickly and directly affects changes in behavior—is through self–discovery. The instructor can facilitate this process by allowing the crew members to operate as much on their own as possible and to allow them to reach their own conclusions and discuss their own actions/behavior during or after the flight. In this way, self–critique becomes a powerful aid to learning. CRM also introduces a variety of heretofore unusual measures or outcomes that must be evaluated by the instructor:

- Can the crew detect examples of problematic areas, behavior, or actions?
- Can the crew more effectively communicate?
- Can the crew more effectively share or manage workload?

- What can the crew do to increase situational awareness?
- Is there a proper balance among the roles and responsibilities of each crew member?

For effective CRM training, it is crucial that the instructor be an expert not only on the subject matter but also in the psychology and instructional techniques needed to provide effective instruction in this mode.

Use Of The PC–ATD In Multi–Crew CRM Flight Education

The faculty of the Aeronautics Division at Kent State University has recognized that there is an urgent need to move beyond providing just the basic technical and flight knowledge necessary to navigate and operate an aircraft. Therefore, a curriculum that utilizes the practices found in a LOFT/CRM environment has been incorporated into the flight education program at KSU.

The Aeronautics program at KSU has begun using PC–ATD simulators as a means of providing instruction in specific areas, including CRM and turboprop aircraft operations. PC–ATDs are flight simulation devices that replicate aircraft–specific performance and cockpit control panels. They provide a simulated aircraft environment that is so realistic that the FAA has approved them for some types of flight instruction in lieu of instruction in actual aircraft. The PC–ATD used by the Aeronautics Division is the Elite 142 manufactured by Elite Simulation Solutions. The Elite 142 is a personal computer–based flight simulation device that simulates several different single– and multi–engine, two–crew–member aircraft, including a King Air B200 turboprop. The aircraft and flight simulation capabilities and the multi–crew arrangement of the PC–ATD allow an instructor to engage students in a variety of scenarios in which they can directly apply the principles and theories of crew resource management to realistic situations. Various exercises can be presented by the instructor to illustrate and reinforce CRM techniques in an airline– and aircraft–specific operational environment.

One of the most significant positive attributes offered by simulators is that many simulators provide flight recording capabilities in the form

of playback or replay, snapshot or hard–copy printouts, or easy videotaping or recording of the flight, all of which are available for in–flight or postflight discussion and analysis. In particular, videotaping is a tremendously effective tool that allows easy review, analysis, and discussion of a flight so that students can better recognize and respond to effective and ineffective behaviors.

The PC–ATD at Kent has been uniquely modified for the use of video recorders for the computer–generated displays used by the instructor and the crew. The simulator is configured so that the instructor's display and cockpit instrument panel can be recorded on video tape during the simulator session. In addition, two video cameras can be used to record the behavior and actions of the crew. These video tape recordings can then be used for detailed postflight review and evaluation by the instructor and students to assess student performance.

Conclusions

The recent advent of the PC–ATD provides flight education programs with an economical means of providing a realistic, simulated multi–crew aircraft and flight environment that can be used to teach the fundamentals of line oriented flight training and crew resource management.

One of the essential components of effective CRM is that crew members be able to analyze their own strengths and weaknesses with respect to interaction, teamwork, and decision making. As noted by the FAA, proper CRM "provides an opportunity for individuals and crews to examine their own behavior and to make decisions on how to improve cockpit teamwork" (Federal Aviation Administration, p. 6). The PC–ATD is superb in this regard because its use in CRM training gives students an opportunity to observe others and to analyze their own attributes as part of a team. Above all else, the PC–ATD presents a superb platform for flight education: the simulator thoroughly engages students in involvement–centered learning in which feedback, critique, and decision–making are emphasized. This approach is one of the most effective means of learning because learning is not imposed—it is self–convincing (Taggart, p. 320).

References

Federal Aviation Administration (1995). *Crew Resource Management Training* (Advisory Circular, AC 120–51B, 9/8/95). Washington, DC: Department of Transportation.

Kern, T. (1995). *Redefining Airmanship*. NY: McGraw–Hill.

McLanaghan, R. (1983, November). "Simulation: Overcoming The First Day Of Combat." *National Defense*, pp. 58–81.

Mellor, A. (1993). "Design, Development And Implementation Of A CRM Program." In R. Telfer (Ed.), *Aviation Instruction And Training* (pp. 368–384). Brookfield, VT: Ashgate Publishing Company.

Smith, G.M., and Hanebuth, C.E. (1996). "Differences In CRM Evaluation Between LOFT Facilitators And Line Check Captains." In *Applied Aviation Psychology: Achievement, Change And Challenge; Proceedings Of The Third Australian Aviation Psychology Symposium* (pp. 148–158). Brookfield, VT: Ashgate Publishing Company.

Taggart, W.R. (1994). "Crew Resource Management: Achieving Enhanced Flight Operations." In N. Johnson, N. McDonald, and R. Fuller (Eds.), *Aviation Psychology In Practice* (pp. 309–339). Brookfield, VT: Ashgate Publishing Company.

Wilson, T. (1993). "Crew Management In Supplementary Airlines." In R. Telfer (Ed.), *Aviation Instruction And Training* (pp. 368–384). Brookfield, VT: Ashgate Publishing Company.

Biographies

John C. Duncan has more than 27 years of technical and engineering experience in the aerospace industry with more than 11 years in the U.S. Air Force and Air National Guard as a Flight Simulation Specialist, followed by several years of experience as a lead Simulation and Avionics Systems Design Engineer with Northrop Aircraft and Boeing Aircraft. He has an extensive flight simulation background with maintenance, design, and research experience in F–106, F–4, T–38, F–15, F–18, F–20, Advanced Tactical Fighter, B–1, B–2, and UH–60 flight simulators. Duncan is a licensed pilot, and is currently an assistant professor of aeronautics at Kent State University where he has taught courses in

aircraft systems, avionics, propulsion systems, aircraft design, and electronics since 1988. Duncan may be reached at jduncan@tech.kent.edu.

Lynn Feterle is an assistant professor of aeronautics at Kent State University. He is a retired U.S. Air Force Colonel with significant experience as an air force transport pilot. He is also an aviation consultant and expert panelist for the FAA. Feterle holds a Master of Science degree from the University of Southern California, a Master of Arts degree from Webster University, and a Bachelor of Arts degree from Kent State University. Feterle may be reached at lfeterle@tech.kent.edu.

Charles V. Starkey is an assistant professor of aeronautics at Kent State University. He is a formal naval aviator with experience in maritime patrol and transport operations, and he also served as a military instructor pilot, aviation safety officer, pilot training program manager, and aircrew coordinator training facilitator. Starkey holds certificates as an airline transport pilot and flight instructor and also has airplane, multiengine, and instrument ratings. He holds a Masters in Technology from Kent State University and a B.S. in Mechanical Engineering from Boston University. Starkey may be reached at cstarkey@tech.kent.edu.