EVIDENCE FOR THE NEED OF REALISTIC RADIO COMMUNICATIONS FOR AIRLINE PILOT SIMULATOR TRAINING AND EVALUATION

Judith Bürki-Cohen
Volpe Center National Transportation Systems Center
Research and Special Programs Administration
U.S. Department of Transportation
Cambridge, Massachusetts

Abstract

This paper presents arguments in favor of realistic representation of radio communications during training and evaluation of airline pilots in the simulator. A survey of airlines showed that radio communications are mainly role-played by Instructor/Evaluators (I/Es), which increases I/E workload but reduces pilot workload. Opinions gathered from I/Es and the literature indicate that this may lead to inadequate preparation of pilots to handle the complex radio-communications environment encountered in the air. A look at incidents during Initial Operating Experience (IOE) in revenue service via a review of the Aviation Safety Reporting System (ASRS) give additional support to this hypothesis. The paper concludes with a discussion of industry and airline efforts to find alternative means to provide realistic radio communications.

Nomenclature

AC	Advisory Circular
ACARS	Aircraft Communications Addressing and Reporting System
ALA	Approach and Landing Accident
AQP	Advanced Qualification Program
ASR	Automated Speech Recognition
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
CD	Compact Disc
COTS	Commercial Off-The-Shelf
CRM	Crew Resource Management
CTM	Cockpit (or Concurrent) Task Management
DARPA	Defense Advanced Research Projects Agency
DFS	Deutsche Flugsicherung
FAA	United States Federal Aviation Administration
GA	General Aviation
GATES™	Ground and Air Traffic Environment Simulation
I/E	Instructor/Evaluator
IOE	Initial Operating Experience
IRAS	Interactive Real Time Audio System
JOINT	Joint Operational Incidents Training
LCA	Line Check Airman
LOE	Line Operational Evaluation
LOFT	Line Oriented Flight Training
PC	Personal Computer
PCATD	Personal Computer Aviation Training Device
PDC	Pre-Departure Clearance
TRACON	Terminal Radar Control
UAL	United Airlines
UPS	United Parcel Service
VHF	Very High Frequency (30 – 300 MHz)

Introduction

Since the introduction of the United States Federal Aviation Administration's (FAA) Advanced Simulation Plan in 1980 [FAA, 1980], certain types of training and certification of airline pilots can be completed entirely in a qualified simulator. This is followed by supervised IOE in the airplane carrying paying passengers, for consolidation of knowledge and skills acquired in the simulator. The FAA requires no further official training and no additional check in the airplane [FAA, 1996]. The skills acquired in the simulator must therefore fully transfer to the airplane, and pilots' in-air skills must be accurately reflected in the simulator. To achieve this, pilots must perceive the same cues in the simulator as in the airplane.

Simulator qualification still mainly focuses on accurate representation of flight performance and handling qualities, which are important for aviating. Today's airline operations, however, with highly automated flight decks operating in congested airspace, require more and more system management and coordination from pilots. This need is being met by a trend towards line-oriented flight training and evaluation, as implemented in the FAA's Advanced Qualification Program (AQP) [FAA, accessed 2003a; Longridge, 1997; FAA, 1990a]. Line-oriented flight training (LOFT) and line-operational evaluation (LOE) [FAA, 1990b] use elaborate real-life scenarios emphasizing Crew Resource Management (CRM), which refers to the effective use of both human and technology resources, on and off the flight deck [FAA, 2001].

For simulators used in airline-pilot training and evaluation, this shift in training needs entails that a faithful representation of the cognitive aspects of the flying task imposed by the air-traffic environment may be just as important as the faithful representation of the airplane. This paper summarizes the results of an investigation of the need for simulation of communications with entities outside the flight deck, i.e., air-traffic control (ATC) and company representatives. First, current radio-communication practices are presented, followed by I/E opinions and a literature review. The information on radio-communication practices and I/E opinions is based on questionnaires administered in 1999/2000, and was followed up by interviews with a sample of the original participants in 2003. Then, the effectiveness of current practices was evaluated by examining ASRS reports on IOE. This is followed by a review of industry and airline efforts.

Current Practices

Twenty-nine I/Es of a representative cross-section of airlines participating in AQP were queried, all but one conducting LOFT and 20 conducting LOE. Percentages are based on the number of I/Es conducting a particular event.

Type of radio communications simulated

ATC. All I/Es reported simulating communications during LOFT and LOE from Tower Ground/Local and Terminal Radar Control (TRACON), and from en-route control during LOE. During LOFT, 93 percent simulate en-route communications. Automatic Terminal Information Service (ATIS) and Pre-Departure Clearance (PDC) delivery are simulated by 95 and 89 percent during LOE and 89 and 93 percent during LOFT.

Company. Dispatch is most consistently simulated, by 93 percent of I/Es during LOFT and 95 percent during LOE. Communications with maintenance personnel are simulated by 67 percent during training and 84 percent during evaluation. Sixty-three and 70 percent of I/Es, respectively, simulate Ramp/Gate and cabin personnel communications during both events.

Other aircraft. We also asked I/Es whether they simulated communications between ATC and other aircraft on the same frequency (the so-called "party line"). Only 38 percent of all I/Es reported simulating some communications to other aircraft, at least on the surface. Even fewer provide communications both ways, i.e., to and from other traffic (28 percent). Less than 7 percent provide communications to or from airborne aircraft.

With regard to visual simulation of other aircraft, 59 percent indicated that their simulators provided some out-the-window view of traffic, mostly on the airport surface (48 percent). Some indicated that they also simulated emergency vehicles on the surface. Thirty-four percent each reported simulating visual traffic in the terminal and/or en-route environment. Ten I/Es also reported representation of traffic via Traffic Alert and Collision Avoidance System (TCAS).

Methods of simulating radio communications

Most radio communications are role-played by the individual I/Es. About a fifth of the I/Es indicated the availability of Aircraft Communications Addressing and Reporting System (ACARS) for communications from the company dispatcher and PDC. Fifty-six percent reported the use of audio recordings or printouts for conveying ATIS information.

Three of seven respondents from one airline indicated that occasionally, two I/Es may participate in a simulator session, at least when instructing a three-person crew. One of these specified that in this case, the I/E for the Captain and First Officer would role-play the ATC communications, whereas the I/E for the flight engineer would provide the company communications.

Finally, two I/Es indicated the availability of a recorded or synthetic controller voice for communications to other vehicles in the terminal environment. Follow-up discussions with one of these revealed that he was referring to the availability of Ground and Air Traffic Environment Simulation (GATES™) on some simulators. This is a relatively new technology providing background chatter offered by the Canadian simulator manufacturer CAE which is further described in the Industry Efforts section.

2003 Update. I/Es still mainly role-play radio communications. Background chatter via GATES™ appears to be available more readily than during the survey, but is not widely used for two reasons. Some I/Es forgo its use because they are concerned with consistency of training and evaluation across simulators equipped with or without it. Others find it "very easy to use," yet still are "too busy with all we have to deal with," and resent that they "can't stop it." They say that it "steps on" ongoing conversations on the flight deck and is generally "in the way." They attribute this to flexibility and programmability issues, but in truth it may accurately represent interference from background chatter as it will be encountered during actual operations. An obstacle to its use may also be the perceived increase in material to be covered per simulator session since the last survey.

An I/E reported that some of his colleagues recorded their own tapes for specific emergency radio traffic. One air carrier has taken this idea further, developing a simple method to provide I/Es with real-life recordings of ATC instructions and party-line chatter that they can call up when needed in the scenario from a compact disc (CD). This effort is further described in the Airline Efforts section.

Despite the increase in operational use of data-link systems, its availability during simulator training and evaluation varies across airlines with the availability of newer vintage simulators. The use of ACARS still is taught in the classroom at some air carriers, without even the availability of computer-based training. On the other end of the continuum are especially those airlines with international operations. These spend considerable effort programming their simulators and high-level training devices to duplicate the entire communications suite available to the line pilot for world-wide operations to ensure a smooth transition from the simulator to the line and vice versa for evaluation. This includes ACARS, PDC, ATIS, Controller-Pilot Data Link Communications, Automatic Dependent Surveillance, Oceanic Clearance Delivery, etc..

Effect of radio communications on I/E workload in the simulator

Given that the burden of providing realistic radio communications lies mainly with the individual I/Es, I/Es were also asked to indicate their perception of the percentage of time and effort spent running the simulation, simulating radio communications, instructing and observing. According to the 1999/2000 survey, I/Es spend about half of their time and effort observing. Even during LOFT training, the time and effort spent instructing is surprisingly small, 8 percent vs. 4 percent during LOE (for Special Purpose Operational Training [FAA, 1990b] however, the time and effort spent instructing shoots up to 25 percent). The rest of I/Es' time and effort is more or less equally divided between managing the simulator systems and providing radio communications. One I/E indicated that his time and effort spent filling out forms and taking notes is similar to his involvement in radio communications and simulator management. Although this activity had not been explicitly mentioned in the question, it is probably safe to assume that all I/Es spend some time and effort with paper work, which may further detract from their ability to provide a realistic radio-communication environment.

2003 Update: Follow-up interviews indicate that this picture of high I/E workload with competing responsibilities persists. "When you are an instructor you have to split your brain between presenting information and evaluating," one I/E observed, and added that attempting to provide realistic radio communications compromises the ability to observe. They all reported to be too busy to provide party-line chatter.

Radio communications were reported to range still between 10 and 35 percent of I/Es' workload, on the higher end of the range in the terminal environment and for new I/Es, on the lower end en-route and for experienced I/Es. Newer simulators allow for the use of a preprogrammed lesson plan that can be easily set-up using a windows interface with touch screens, reducing the workload to as little as 10 percent compared to the 25 percent for older interfaces. Paperwork is still considered too labor-intensive despite some simplification, about 10 to 15 percent. "You need a court stenographer," one I/E mentioned. Several I/Es wished that a second I/E would take care of running the simulator and completing paperwork. Being able to record the grades directly on the simulator via the lesson plan would further ease I/E workload.

I/E Opinions

The same I/Es who were asked about airlines' current radio-communication simulation practices were queried on their perceptions of the effect of role-playing radio communications on their own workload and on the workload of the pilots during simulator training and evaluation. They also offered their opinions on the importance of simulating radio communications realistically for training and evaluation effectiveness.

Effect of radio-communication role play on I/E and pilot workload

I/Es rated their workload consistently higher in the simulator than during training and evaluations in the actual aircraft. This applied to all ATC environments and to all communications with company. Moreover, role-playing radio communications "divides [I/E's] attention," one I/E added. This is especially difficult for new I/Es, another mentioned. A third added that the "I/E can become task-saturated when crew works two VHF [very high frequency] radios and/or communications with cabin simultaneously." The highest discrepancy in I/E workload was indicated for simulation of communications with other aircraft.

Pilot workload in the simulator, however, was rated consistently lower than in the actual aircraft for all ATC environments and company communications, and also for listening to the party line. "I/E [communication simulation] is less than actual, therefore it reduces pilot workload," one I/E explained. Another I/E alluded to the fact that even the manual workload of pilots is reduced by I/E role play of radio communications, because "[p]ilots are not normally given a chart frequency, nor do they need to redial a new frequency to communicate."

Importance of radio communications for training and evaluation effectiveness

I/Es were asked about the importance of radio communications for training and evaluation effectiveness in two contexts, first in the context of their company's communication practices, then in the context of specific training/evaluation goals.

Overall Importance. Some I/Es may have downgraded the importance of radio communications in the context of their own company's practices, because they feel that their company's communication simulation is "not very effective during simulation, because the instructor must cover all bases himself," as one I/E explicitly stated. Nevertheless, as many as 73 percent of respondents rated the overall importance of ATC communication simulation in the context of their company's practices as high or very high (for communications with TRACON). (The corresponding percentages for the other ATC communications were, in descending order, 68 for tower ground, 65 for tower local, and 61 percent for Air Route Traffic Control Centers.) No more than 8 percent of the respondents rated any of the ATC communications as of low importance. None of the ATC communications were rated as of very low importance.

Fewer I/Es rated the importance of company communications in the context of their company's practices high or very high. Communications with cabin personnel achieved the highest rating with 57 percent considering it highly or very highly important. (The corresponding percentages for dispatch and ramp/gate were 43 and 27, respectively.) Up to 15 percent of I/Es rated any of the indicated company communications as of low or very low importance.

Despite the limitations of their own company's practices, as many as 84 percent of the I/Es considered ATC communications to other aircraft medium to highly important. Sixteen percent gave it low importance in the context of their own practices. However, several I/Es commented on the importance of radio communications to other aircraft for the realism of the simulation. "I believe the 'simulator mind-set syndrome' must be fought with realism. How can we expect crews to 'treat the sim[ulator] like the aircraft' when the audio environment belies the condition so often?" one I/E asked. "Party line enables CRM elements such as workload and distraction to be assessed more effectively," added another. One last I/E mentioned that the simulation of ATC communications to other aircraft is his "biggest concern, so pilots are listening."

Importance for Specific Training/Evaluation goals. The overall importance of radio communications was confirmed in the context of specific training (or evaluation) goals. I/Es indicated how often they relied on radio communications and how important they found radio communications for effective training (and evaluation).

I/Es indicated relying most often on radio communications for training CRM and non-routine ATC, such as pilot-ATC coordination, where 93 percent of the respondents indicated that they use it at least sometimes. The importance of radio communications for effectively training CRM and non-routine ATC was rated as high or very high by 89 and 86 percent of the I/Es, respectively. "If CA[ptain] does not delegate duties, my technique is to load the crew with B.S. [sic] radio transmissions," one I/E added.

Radio communications are also very important for training and evaluating distraction management skills. Eighty-two percent of I/Es rely on radio communications for this purpose at least sometimes, with 78 percent rating their importance as high or very high. They are used to train and evaluate situation awareness skills, where 88 percent of I/Es reported using them at least sometimes, with 68 percent rating their importance as high or very high. For training and evaluation of new ATC procedures, such as simultaneous approaches to closely spaced parallel runways, 92 percent of I/Es responding to this question indicated relying on radio communications at least sometimes, and 62 percent rated the importance of radio communications as high or very high.

2003 Update. These feelings were echoed in the follow-up interviews, despite indications that given the current curriculum overload, realistic radio communications would be one more distraction that neither I/Es nor pilots would be able to handle.

I/Es expressed that realistic radio communications are important for safe transition from the "schoolhouse" to the "dynamics" of the operational environment with "changing clearances." They believe that it is less important for initial training or maneuver training than in LOFT and especially LOE, where it is perceived as "critical." Interestingly, one I/E made the point that simulation of communications from ATC beyond those necessary for the scenario may be useful as a distracter, but what really needs to be accomplished is to familiarize pilots with the terminology used in dealing with ground crews. Party line was considered as important to train pilots to remain task oriented and to sift out calls to ownship among the chatter.

Summary of Practices and Opinions

In summary, I/Es spend about a fifth of their time and effort during pilot training and evaluation providing radio communications, which they almost exclusively simulate by role play. This effort is mainly spent in the terminal environment and with ATC communications to own aircraft that are necessary for a particular scenario. "Company communications," one I/E added, "are not normally used [in simulation]; too time-consuming." With regard to communications to other aircraft, another mentioned, "some instructors simulate

[them], but none of our formal training documentation requires it."

I/E workload is thus increased by the need to role-play radio communications, but because there is too little time to do so, pilot workload is decreased. According to the I/Es queried, this decreases training and evaluation effectiveness, both because instructors don't have time to observe, and because pilots are not exposed to a realistic environment. "Without communication simulation, when the pilot trainee finally arrives in the 'real world,' he must add another component, which was not learned during training. This new (additional) component can really complicate line flying."

2003 Update. I/Es expressed similar opinions. They are very concerned that because of the changes in economic climate, imitating real-life operations is now "considered a luxury," with emphasis shifting towards training basic techniques and procedures, on "yank and bank", getting the airplane off and back onto the ground according to standard operating procedures.

They feel that training sessions are too packed to deal with distractions from radio communications, even if they were provided by an automated system such as GATES™. So, most communications are still role-played, with one interesting exception of providing communications via a CD player (see Airline Efforts).

The biggest technological change appears to be the full data-link suite that is available on some modern simulators. Also, the I/E interface seems to have improved greatly on the latest simulator models, reducing I/E workload. A suite of modern simulators that additionally includes some automated grading technologies reducing paperwork seems to be on everybody's wish list, together with an extra instructor and/or an extra training session to "have time to work on the finer points."

Findings in the Literature

This section presents the results of a review of the AQP/CRM and the task management training literature. It was found that many of the subject matter expert opinions found in the previous section are confirmed in the literature [for more detail, see Bürki-Cohen et al., 2000].

AQP and CRM

The founding principle of AQP is that training and evaluation of pilots should be based on the activities encountered on the job. AQP requires a thorough analysis of all tasks a pilot needs to perform during actual operations, which then guides curriculum and scenario development. The AQP task-listing example found on the AQP Management Website [FAA, accessed 2003b] clearly shows that coordination with company and ATC over the radio frequencies is an integral part of line operations and that frequency monitoring is important for maintaining traffic and weather situation awareness.

The Advisory Circular (AC) on CRM training not only lists onboard flight-deck and cabin personnel, but also ground-based maintenance personnel, aircraft dispatchers, and air-traffic controllers as part of the CRM process. CRM training is regulatory not only for pilots, but also for flight attendants and aircraft dispatchers. The latter must be trained in Dispatch Resource Management. In a section on Joint CRM Training, the AC highlights the benefits of using real air-traffic controllers, dispatchers, and maintenance personnel during full mission simulation training [FAA, 2001].

Many ASRS surveys, research investigations, and aviation magazine articles discuss the role of communications in incidents and accidents. The Flight Safety Foundation Approach and Landing Accident (ALA) Reduction Task Force report found that "incorrect or inadequate ATC instruction/advice/service" was a causal factor in 33 percent of the 76 ALAs and serious incidents analyzed [Khatwa and Helmreich, 1999]. It ranked eleventh among the most common causal factors, long before "interaction with automation" in seventeenth place. "[D]emanding ATC clearances" are also explicitly mentioned in context with even higher placed causal factors such as the eighth placed "press-on-itis." In many cases of "press-on-itis," "a breakdown in CRM between the flight crew and ATC" was observed.

Other ATC-communications-related causal factors in the ALA reduction task force report that are not included in the 33 percent mentioned above are misunderstood or missed communications such as missed read backs, call-sign confusions, and simultaneous transmissions (12 percent). Instances of controllers and crews using non-standard phraseology are also mentioned. This can become especially problematic when non-native English speakers/listeners and an emergency situation are involved, as shown by the 1990 Avianca Airlines crash on Long Island and the 1995 American Airlines crash near Cali, Columbia [National Transportation Safety Board, 1991; Simmon, 1998].

In summary, the ALA Reduction Task Force recommends that operators "[i]nclude training scenarios that allow crews to experience overload, task saturation, loss of situational awareness, out-of-control and too-far-behind-the-aircraft situations, and communications in stressful circumstances." Joint training should be held between pilots and air-traffic controllers including scenarios that "promote mutual understanding of issues on both the flight deck and in the ATC environment, and foster improved communications during emergency situations."

Cockpit task management (CTM) training

The need for cockpit or, as it is increasingly called, concurrent task management training has been documented not only using incident and accident reports, but also experimentally. Chou, Madhavan, and Funk [1996] elicited the CTM errors found in an accident and incident review in a controlled simulator experiment and confirmed that task prioritization is greatly degraded by the number of concurrent tasks. Another study found that ATC interruptions significantly increased procedure performance errors as well as flight-path management workload of commercial airline pilots [Latorella, 1996].

The question then is whether CTM training in the simulator is effective. Gopher, Weil, and Bareket [1994] showed that task management training even in a very low physical-fidelity computer game did transfer to flight. Gopher et al. report that the computer game was perceived as such a successful auxiliary training tool that the Israeli Air Force incorporated it into their curriculum.

Part-task vs. whole-task training

Given that CTM can be effectively trained in a synthetic environment, the next question is what are the best methods for delivering such training. As has been mentioned before, some I/Es have indicated that with a tight curriculum, realistic radio communications may represents "too much of an overload during training." They appear to favor a part-task training regime where trainees acquire skills unencumbered by secondary tasks such as communicating.

The question of part-task vs. whole-task training has been researched extensively, with often contradictory results. The Defense Advanced Research Projects Agency's (DARPA) Learning Strategies project, e.g., found two strategies to be most successful. One was Frederiksen and White's part-task training method based on principled decomposition of the task into its component skills [1989]. Then, a set of specific activities for training these skills individually was constructed. The other successful strategy was Gopher, Weil, and Siegel's whole-task training method with shifting emphasis, where subjects always practiced the whole task, with instructions to shift their focus of attention between various aspects of the task [1986].

Fabiani, Buckley, Gratton, Coles, Donchin, and Logie [1989] compared these two training techniques on the computer game used by Gopher et al. [1994]. Both groups were trained with their assigned technique for seven sessions, then they practiced the game for three sessions. During the final five sessions, they played the game with interference from a series of concurrent tasks. The part-task group outperformed the whole-task emphasis-shift group when the game was played alone. When they had to perform a concurrent task, however, the advantage of the part-task group in the game was reduced or, for more demanding concurrent tasks such as generating and voicing random letters, even reversed in favor of the whole-task emphasis-shift group. There was no difference between groups in the way the performance in the concurrent tasks was affected by having to play the game simultaneously. There was, however, a difference in how the performance in the game was affected. The whole-task emphasis-shift group was more resistant to interference from the concurrent task than the part-task group, with an over 60 percent smaller average decrement in game performance. The authors state that their recommendation of training method would therefore depend upon whether operators had to perform in a single- or multi-task environment. Clearly, the flying task involving concurrent aviating, navigating, communicating and managing systems would fall into the latter category, with extremely demanding concurrent tasks compared to the ones tested.

Gopher et al. [1994] carried Fabiani et al.'s work further by comparing two groups, a mixed-training group and a whole-task emphasis-shift only group. Both groups were trained for the same amount of time, but the mixed-training group started each session with training the part-task components (for about 18 percent of total training time), followed by emphasis-shift whole-task training. They found that although the mixed-training group again scored significantly better in the game than the group trained with the whole-task with emphasis-shift technique only, the groups did not differ in subsequent real-life flight performance. The authors conclude that the practice of part-task components, although it did lead to superior performance of the mixed-training group in the game, was too specific to generalize to an advantage in the air. It must have been the whole-task training with emphasis shift administered to both groups that led to "the development of more general skills and response strategies" that transferred to flight.

In summary, these studies indicate that the emphasis-shift whole-task training technique a) is superior to part-task training at least in terms of resistance to interference from concurrent tasks, if not generally for training demanding concurrent tasks, and b) foster skills and strategies that transfer from the simulator to the airplane. Extrapolating to the question at hand, if pilots are exposed to an impoverished environment without realistic radio communications in the simulator compared to the real world, they may end up unprepared for the concurrent task demands in the air, which "add a new component" that "can really complicate line flying," as one of the I/Es in the study presented earlier admonished.

Effect of Current Practices on IOE

A review of the ASRS was conducted to see whether the concerns expressed both by I/Es and in the literature would be confirmed by reports of line check airmen (LCA) and pilots on incidents during their IOE.

Method

A search of the 205,070 reports in the ASRS database, which was established in 1988, up to October 1999 [ASRS, queried 2001] using the terms Initial Operating Experience, IOE, and Operating Experience yielded 423 reports after exclusion of duplicates. After exclusion of reports referring to incidents that had occurred prior to 1993 or not during IOE, or reports covering non-flying issues, 93 reports remained for analysis. Types of errors and primary and contributing factors were determined from the ASRS reporters' narrative. Most of the errors involved several factors. This paper will focus on errors related to radio communications only [see Bürki-Cohen and Kendra, 2001, for more detail].

Types of errors and contributing radio-communication factors

Radio communications contributed to as many as 87 percent (81) of the reports, and were the primary factor in 72 percent (67). This clearly demonstrates the importance of radio-communication training. Table 1 shows the number and types of errors where radio-communication problems played a primary role. As can be seen, these were not trivial errors, including 25 altitude deviations, six runway incursions, and several landings without clearance, on the wrong runway and even at the wrong airport.

Types of Errors with Radio Communications as a Primary Factor	Number of Reports
Altitude Deviations or Crossing Restriction Violations	25

Types of Errors with Radio Communications as a Primary Factor	Number of Reports
Course Deviations	7
Runway Incursions	6
Landings without Clearance	6
Approaches/Landings on Wrong Runway	5
Separation Losses	5
Approaches/Landings on Wrong Airport	3
Lost Communications	2
Takeoffs without Clearance	2
Other Incidents	6

Table 1. Number and types of errors with radio communications as primary factor.

The factors contributing to errors are shown in Table 2. Demanding, inadequate, or even erroneous ATC instructions were implicated most often as a primary or (23) or contributing (15) factor. Reporters often cited amended clearances requiring reprogramming of the automation or erroneous expectations raised by the controllers. After an instruction to "expect no delays," e.g., the crew "perceived that there would be no delay at the end" and taxied on an active runway.

Primary Factors Contributing to Reports	Number of Reports
Demanding/Erroneous ATC	23
Inadequate CRM	21
ATC Interruptions	8
Blocked/Congested Frequency	5
Operating Radio	4
Phraseology/Accent	3
Flight Attendant/Passengers	3

Table 2. Factors contributing to reports.

Inadequate CRM or CTM involving radio communications played a role in 40 reports (21 primary, 19 contributing). "The cause […] was my inexperience with the quick pace of an airline environment and its associated distractions," explained a pilot after deviating from the assigned altitude. Another explained a near-midair collision during an approach to the wrong runway by the crew being "so busy that we were not paying attention to what the controller was saying." An LCA after landing without clearance blamed the fact that IOE is comparable to "flying 'single pilot with a distraction'."

ATC interruptions including traffic calls were mentioned in 14 reports, and in eight of these they appeared to be the primary reason. After a crew missed an instruction to clear the runway, the pilot complained "tower controllers […] give instructions […] while the aircraft is still in a critical phase."

Frequency congestion, stuck microphones blocking an entire frequency, or pilots stepping on an ongoing conversation played a role in 14 reports as well, but were the primary reason in only five reports. After a course deviation due to a misunderstanding, the pilot reported, "several aircraft were stepping on each other's radio calls."

Problems with tuning the radio played a role in four reports and was the suspected primary reason for each of the errors, such as in a runway incursion after loss of communications where the "F[irst] O[fficer] possibly moved [the] radio select switch from tower to [the] other side in [an] attempt to contact ground control prior to selecting [the] frequency."

Phraseology and/or accent contributed to seven reports. They appeared to be the primary reason in three of these, such as in an approach to the wrong airport in Mexico where "the transmissions and comm[unication]s from the tower were exceedingly hard to understand and [we] had to ask several times for clarification."

Interruptions from the cabin, be it from flight attendants or passengers, played a role in seven reports, being the primary reason in three. One pilot reported a near-midair collision and mentioned that "as [the] clearance was coming off the printer, [the] F[light] A[ttendant] entered [the] cockpit for meal orders."

No comparison has been made to determine whether radio-communication related problems occur more frequently in IOE than during non-IOE flights. Also, the overall incidence of such occurrences cannot be determined from ASRS reports, which are naturally biased towards cases where something did happen. Nevertheless, improved realism of radio-communication simulation during simulator training may have better prepared pilots for many of these IOE occurrences.

Effect of pilot experience on radio-communication problems

One of the I/Es queried in the study presented earlier in this paper expressed his opinion that experienced airline pilots have “proven their abilities” to handle radio communications, implying that airline pilots may require radio-communication training and evaluation only early in their career. He also appears to imply that when pilots graduate to another position or airplane type, they will need training only in skills such as handling the airplane and managing its systems, because radio-communication skills transfer between airplanes.

The ASRS reports do not consistently provide a direct means to test this hypothesis, such as flight time of the pilot flying, but may indirectly indicate the experience level of crews by providing the weight class of the airplane involved. The assumption is that in general, less experienced pilots fly lighter airplanes than more experienced pilots.

If radio-communication problems, because the ability to “walk and talk” is carried over from one airplane to the other, decrease with experience more rapidly than other problems, then the weight-class distribution in the IOE reports with communications problems should be shifted towards lighter airplanes compared to the distribution of weight in the overall database. At a ratio of .97, however, there is a very high correlation between airplane weight-class distribution in the sample of IOE ASRS incidents with radio communications as the primary factor and the weight-class distribution in the ASRS overall.

Therefore, prior experience with communications in different airplanes does not seem to protect airline pilots from experiencing problems with radio communications during IOE. This may be due to the fact that even if the ability to “walk and talk” does transfer between airplanes, a heavier and presumably more automated airplane may involve increased overall CTM demands that require pilots to sharpen their “walk-and-talk” skills further.

Simulator-Industry Efforts

Both the simulator and the gaming industry have recognized a potential market in adding realism to their simulations via automated radio communications. Several examples are described below.

GATES™

The Canadian simulator manufacturer CAE has developed a system in response to customer demand for coordinated visual out-the-window and radio traffic. GATES™ automatically generates a continuous flow of simulated visual traffic and associated relevant communications to and from aircraft on the airport and in the terminal environment without following a scripted scenario. The traffic elements are aware of and will react to each other and the simulated ownship. The I/E still provides all ATC communication to ownship, however. For reasons explained in the Methods of simulating radio communications section earlier, it has found only limited applications in some qualifications scenarios.

Personal Computer (PC) Based Systems

The PC commercial off-the-shelf (COTS) target general aviation customers and thus don’t include any company or data-link simulation. The discussion below focuses on two PC aviation training devices (PCATDs) approved for limited credit in the presence of a certified flight instructor [FAA, 1997], and the latest version of Microsoft Flight Simulator.

PCATDs. Two PCATDs offer low-cost add-ons with ATC simulations, FLITEPRO™ by Jeppesen and Elite by Elite Simulation Solutions. These consist of scripted party-line chatter for a specific airspace, with interspersed communications to own aircraft that train the desk-top pilots to pick out their call sign. Some of Elite’s ATC communications are recorded from actual controllers.

In FLITEPRO™, once an instruction has been acknowledged (see below), ignoring instructions to ownship will have no consequences beyond getting off course and losing scenario continuity. Elite however will remind pilots to get back on course. Dependent on the add-on package, they will hear “[call sign], did you copy that last clearance?,” or a written reminder to fly their “last assigned altitude or heading” will appear in the message-display area of the screen. The programmed tolerances vary across environments.

Interaction with ATC is very limited. FLITEPRO™ offers two ways to contact ATC, one is to press R on the keyboard for a repeat of the last instruction and the other to press C to acknowledge receipt. Elite offers similar options to ask for a “say again” and to acknowledge a request such as “report field in sight.” For both systems, the buttons on the yoke or joy stick can be programmed as an alternative to the keyboard.

Microsoft Flight Simulator. Despite the fact that Microsoft Flight Simulator is intended as an entertainment system, its built-in non-scripted ATC simulation may be the most advanced PC COTS ATC software available. It is advertised as “one of [its] most exciting features” and offers flight-plan appropriate party-line chatter and instructions to ownship, as well as traffic advisories that then can be verified visually out-the-window [Microsoft 2003]. Novice pilots can reduce the density of the traffic in the same airspace.

Pilot-initiated interaction with ATC is driven by a set of numbered menu options that are appropriate to the situation. This includes requests to change destination, approach, and landing runway while flying under Instrument Flight Rules (IFR). The desired option is chosen by typing its number on the key board.

Most ATC instructions have to be acknowledged by typing the appropriate response option number. If pilots deviate from the instructions, ATC will issue a new heading and/or ask to expedite altitude capture.

Microsoft pilots can chose from male and female voices mainly drawn from the Microsoft team impersonating ATC and party-line chatter. They even can choose a voice for themselves, which will speak whatever option they pick from the menu (see above). This occasionally leads to the same voice impersonating pilot and ATC. Pilots also can chose from many airplane types including large jets, however, ATC appears to default to a vectoring strategy appropriate for the largest airplanes in the data base. PCATDs appear to restrict themselves to general aviation (GA) airplanes.

In summary, COTS ATC software adds excitement and some realism to PC-based flight simulations. It will at least provide GA pilots with some familiarization with ATC procedures and phraseology. It also requires them to handle some interruptions, especially if they must dial in the appropriate communication frequencies. Finally, they can also hone their skill to differentiate their own call sign from other call signs in the party-line chatter.

Airline Efforts

Interactive Real Time Audio System (IRAS)

In the 1990s, United Airlines’ (UAL) undertook a pioneering effort to provide realistic radio communications automatically in the form of IRAS. UAL recorded actual communications from UAL routes and dubbed ATC with the respective I/E voice, so that I/Es could intervene without the pilot trainees realizing it. Communications were triggered based on ownship position. Trigger algorithms, however, were sometimes unable to adapt to normal variations in crew responses, especially in dense terminal areas, where embarrassed I/Es often had to intervene. Also, it was often difficult to integrate IRAS with different visual, audio, and navigation models and I/E interfaces across simulators. All this in combination with expensive scenario development including field recording, transcribing, dubbing, database maintenance, as well as costly route, sector map, and simulator-interface code development contributed to the program gradually losing support.

The lessons learned from IRAS are that for a system to be successful, it must be flexible, transparent, easy to use, easy to implement and maintain without undue technical difficulties, and easy to integrate with different scenarios, simulators, and simulator systems (e.g., visual, audio, etc.). There may be a cost/benefit trade-off for the different aspects of realism required for different training and evaluation events. For instance, it may not be necessary to conceal I/E intervention from the pilots, a capability achieved by IRAS, but at a high price.

United Parcel Service (UPS)

UPS is the air carrier mentioned earlier that provides I/Es with a CD containing real-life recordings of ATC instructions and party-line chatter. The system appears like a pared-down, low-technology version of UAL's IRAS. Unlike IRAS, where radio communications were triggered automatically based on the simulated airplane's position, UPS I/Es call up radio communications when needed from a CD player connected to the simulator. This leaves I/Es in full control of the ATC profile, avoiding some of the frustrations generated by IRAS.

As at UAL, UPS recorded ATC instructions and party-line chatter on scenario-specific routes, capturing typical operational issues such as similar company call signs on the same frequency, stuck microphones, etc. Using COTS PC signal processing software, these recordings were then sliced into audio files stored chronologically on subsequent CD tracks. Party-line chatter is grouped by controller and frequency, but ATC instructions are each saved in its own file. A typical sequence may contain, on Track 01, tower radio chatter including a request to let UPS know that one of its airplanes has a "stuck mike." The next track contains the instruction for ownship to taxi into position and hold. Track 03 contains some garbled party line while holding, due to another stuck microphone. This is followed by a request from tower that ownship switch to "my [other] frequency." On Track 05, tower explains that this was because of the stuck mike and gives the takeoff clearance. After some more chatter on Track 06, own aircraft is vectored towards en-route airspace (Track 07), where it experiences wind shear and is handed off to the Center (Track 08).

I/Es are provided with a LOFT manual listing the contents of all tracks and the verbatim ATC instructions, with indication of who issued them on what frequency. The text is also displayed on the CD player. According to a UPS representative, the system provides about 80 percent of all needed ATC communications and all party-line chatter. Usually, only vectoring for the final approach is left entirely to the I/E. This greatly reduces the workload of I/Es, who now can concentrate on observing the crews. At the same time, it renders pilot workload more realistic.

The system requires only minimal I/E training. UPS is currently working on reducing the effort required to edit the audio tapes and write and coordinate scenario and ATC scripts, which represent UPS' largest investment.

Lufthansa's Joint Operational Incidents Training (JOINT)

A last effort to expose pilots to realistic radio communications in the simulator to be described here is the German airline Lufthansa's JOINT training program with the German ATC organization, Deutsche Flugsicherung (DFS) [Hensel, 2000; Jung, 1999; Lexen, 1999; Strassburger and Nowack, 1997; see also Strassburger, "Integration of ATC- and Flight Simulation," this conference]. JOINT was conceived as part of Lufthansa's shift from maneuver training towards CRM oriented LOFT, where CRM involves not only the flight crew, but also coordination between pilots and ATC. Starting in 1996 with the connection of one ATC sector simulator with simulated traffic to one airplane simulator, the program was later expanded to include several ATC sectors with traffic that can be connected to several full-flight simulators representing the entire Lufthansa fleet. The full flight simulators are staffed as usual with a crew and a flight instructor. Each ATC sector simulator is staffed with a real controller (trainee) and a "pseudo pilot." The latter "flies" the simulated airplanes seen on the controller's radar scope, and provides the voices of their crews. The flight crews and the pseudo pilots communicate with the sector controllers via VHF frequencies. The program was enthusiastically received by controllers and pilots, who say that JOINT realistically prepares them for the coordination and concentration demands of real-life emergencies with all their uncertainties and distractions. Moreover, both find the insight into the realities of each other's jobs invaluable.

Conclusions

Providing realistic radio communications during airline-pilot simulator training and evaluation would clearly improve the safety of the flying public. The review of ASRS reports shows that without it, airline pilots may not be adequately prepared to handle the full complexity of an airline environment during IOE, forcing LCAs to administer remedial training [Bürki-Cohen and Kendra, 2001]. The importance of being exposed to the entire task during training especially in a multi-tasking environment is also born out in the literature.

The prevailing method to simulate radio communications is role play by the I/Es. Despite the fact that I/Es agree with the importance of providing realistic radio communications, they are too busy to provide a level that is comparable to real life. Even the low level of radio communications they are able to provide, however, is perceived as "compromis[ing] observations" of the crews.

It appears, then, that the solution would be to provide realistic radio communications via an automated system. This has also been recognized by the International Air Transport Association Flight Simulator Working Group, which has defined the capabilities and functionalities of such a system [see Gran and Braathens, "Training Potential of ATC Simulation in FFS-Pilot Training," this conference]. Several airlines and simulator manufacturers have undertaken promising initiatives in this direction. One obstacle to fully automate communications including those to ownship, is the state of the art of automated speech recognition (ASR). Although some ASR solutions for limited vocabularies such as embedded command-and-control systems have found applications in telephonic customer service, ASR solutions for less predictable continuous speech are still a few years down the road.

Ironically, however, a larger impediment to the use of an automated system appears to be the fact that in the current airline environment, the training and evaluation curricula are so packed that not only I/Es, but also the crews "are too busy with all [they] have to deal with" to be able to handle any further distractions. I/Es frequently express the wish to have "a four-hour block of time after all the training objectives are met with an extra instructor to ease the transition to the IOE." One commendable initiative in this direction is Lufthansa's and Deutsche Flugsicherung's (German ATC) JOINT operational incidents training.

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