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16. ABSTRACT

Research Integrations as subcontractor to National Institute of Aerospace completed a series of reviews and analyses to provide the FAA with guidelines and recommendations for flight crew training in the future NextGen environment. This future environment is expected to require increased flight deck automation to enable National Airspace System (NAS) procedure improvements and future performance capabilities.

The work was funded by the FAA Human Factors Research & Engineering Group (AJP-61) [currently renamed the NextGen Human Factors Division (ANG-C1)] through contract DTFAWA-10-A-80000 to the National Institute of Aerospace (NIA) and subcontracts F09-8101-RII and F10-8101-RII from NIA to Research Integrations Inc. Contract monitors were Dr. Tom McCloy and Dr. Eleana Edens. NIA oversaw the project through guidance and support provided by Mr. Fred Brooks in managing the logistical elements of the contract for this project.

In addition to a summary with guidelines and recommendations for flight crew training in NextGen, the report contains supporting materials including the results of a literature review, an annotated bibliography, the results of interviews with flight crew training experts in the aviation industry, results of focus group workshop discussions on pilot training needs and gaps in current practice, a summary of ongoing and planned research, and a list of acronyms.

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# Flight Crew Training for NextGen Automation

## Final Report

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**September 2011**

# Final Report

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# Acknowledgements

# Introduction

This report is the product of an FAA-sponsored project designed to build a foundation of knowledge upon which to address flight-crew training for NextGen operations, focusing particularly on the use of automation.

NextGen operations propose to overhaul our national airspace system by increasing air traffic density and improving flight precision while effectively making air travel safer, more convenient, and more dependable. Advances in flight deck technology, satellite-based navigation systems, and secure digital communications along with enhancements to flight-operations procedures will work in collaboration to effect these improvements.

NextGen will also fundamentally change the roles of flight crews that operate in this environment. Increases in the use of automated systems for communication and aircraft performance will be central to effective pilot decision-making, flight operations, and safety. With these changes, it is expected that flight crews will need to enhance their current skills through training, in particular for the use of automation, and develop new methods and strategies for managing their aircraft in the highly complex NextGen environment.

For detailed and current information on NextGen progress and plans, including information on existing and new aircraft capabilities and mid-term operations, we recommend visiting the FAA website on the Next Generation Air Transportation System (NextGen): http://www.faa.gov/nextgen/.

# Purpose

Our purpose in this project was to gather information to provide an understanding of the state of the art knowledge related to pilot training for automated aircraft and to analyze this information and prepare recommendations that would provide a foundation for future consideration by the FAA and industry as we move toward NextGen operations. To accomplish this, we took the following steps.

- Conducted a literature review and developed an annotated bibliography.
- Gathered available details about relevant research that is not yet completed, but is currently ongoing or planned.
- Gathered information about current training practices and their effectiveness by interviewing those involved in pilot training.
- Developed an understanding of how training may need to change when operational changes related to NextGen are introduced.
- Developed an understanding of any new or emerging training needs through a comparison of the future training needs and the current training practices.
- Used all of the information gathered to develop recommendations for actions by the FAA including guidelines to be used for future training development.

The intended focus of our work was to address pilot training for multi-national mainline and regional carriers. Although some of the resources that we examined included references to ab-initio, general aviation (GA), and military flight training, these operational areas were beyond the scope of this work. We included those types of references only when it seemed they would provide useful information for the intended scope of our work.

Also, related to NextGen, our charter was to consider the needs of mid-term NextGen operations as defined by the FAA. We considered those operational definitions as we planned our work and developed our methods; however, except for using specific references to the concepts of RNAV/RNP, 4-D trajectory, and self-separation operations as the

structure to focus our future training discussions, we did not examine the technical elements of proposed NextGen technologies or procedures. Lastly, this work does not place particular emphasis on any single training development methodology, instructional practice, or training media, but instead takes a broad view using those identified through our project.

# Organization of Report

This report describes all aspects of our Flight Crew Training for NextGen Automation project. It is organized into this first chapter that provides an overview of the project and presents the guidelines and recommendations that resulted from all the work in the study. The subsequent chapters each describe the details for one of the other elements. The chapters are organized as follows.

- Literature Review
- Annotated Bibliography
- Summary of Ongoing and Planned Research Applicable to Airline Pilot Training
- Current Training Practices Interviews
- Pilot Training Vision Workshops

Finally, we have included an appendix with a list of acronyms. A brief description of each of our project steps and the general methodology used to accomplish the associated activities is included below as a project overview. Detailed methods and results for each step are provided in the associated chapter for that project element.

## Literature Review

The Literature Review chapter summarizes our review of the research literature and other documents relevant to pilot training, including information on training content, methods and media (training devices and simulators), instructor training and evaluation, crew resource management, threat and error management, and training program evaluation. Our initial search reviewed literature that spanned roughly thirty to forty years of research and related reports. From this, we narrowed our list of applicable documents to those with continued relevancy in current pilot-training methods, practices, and operations. Literature that addressed outdated technologies or practices was not included. The information that we gathered in our literature review also gave us a basis from which to proceed in developing the goals and objectives for our training interviews and workshops.

## Annotated Bibliography

The Annotated Bibliography provides a list of annotations for all of the relevant literature we reviewed. We included a number of references focused on GA research as it relates to transport training but did not complete a comprehensive analysis for this area of aviation literature as it was out of scope for this project.  Each of the annotations includes general information about the document (authors, date, title, publication, etc.), a brief description focusing on those aspects related to pilot training, and the author's description of the work (abstract or executive summary), if available.

## Current Training Practices Interviews

The Current Training Practices chapter describes the methods and results of our work in conducting interviews with people who have a direct interest or involvement in pilot training within major and regional air carriers, pilot training organizations, and industry organizations. The results include what our participants described about their current practices and what they noted as challenges and best practices. Individuals from twenty-

four domestic and foreign organizations participated in our interviews and their responses are included in our results. The focus of our work on this element of the project was to identify current practices for pilot training as they are being carried out in daily operations. We developed a structured survey instrument to guide the interviews that addressed topics related to pilot training based on our literature review and consultation with various airline-training representatives. The interviews were conducted by phone and on condition of anonymity. The results of the interviews, coupled with what we learned in our literature review, served to establish a baseline of current pilot-training methods and practices and became the basis for developing the goals and objectives for the two workshops described in the next section.

## Pilot Training Vision Workshops

The Workshops chapter describes methods and results for the two workshops that we conducted in March and April of 2011. The intent of these workshops was to envision pilot training as it would need to be after the implementation of certain aspects of NextGen operations. These were invitation-only workshops. The participants were selected because of their extensive experience related to pilot training and their abilities to think broadly, communicate well, and their willingness to apply their experience to discussions about the future.

Because many NextGen technologies and procedures are still in development, and we had limited time available to meet with participants (approximately eight hours in each workshop), we enlisted assistance from the FAA to identify operational changes that will occur in the current conception of mid-term NextGen implementation. Presentations about the expected operations and associated technologies served as the basis for discussion at the workshops. Our FAA contacts also presented this information at the start of our first workshop and allowed us to record the presentation for use in the second workshop. The NextGen operational implementations on which we focused our discussions were RNAV/RNP, 4-D trajectory, and self-separation. There was also a time for general discussion about other topics related to pilot training in the future. As with the training interviews, participants contributed in our workshops on condition of anonymity.

## Summary of Ongoing and Planned Research Applicable to Airline Pilot Training

The Ongoing and Planned Research chapter summarizes the methods and results of our survey of researchers who are conducting research on pilot training issues relevant to our scope or have plans to do so in the near future. We selected researchers to survey primarily from the various authors of research documents that we read for our literature review, and requested information by email. In several cases, we were able to visit with the researchers at their facilities to learn first hand about their work.

## List of Acronyms

No technical field would be complete without an acronym and abbreviation language of its own. Aviation is no exception. This appendix defines the acronyms and abbreviations that are used in our report.

# Guidelines and Recommendations

This section provides guidelines and recommendations that were developed based on the findings from the various elements of our project addressing flight crew training for NextGen operations. These guidelines and recommendations are a culmination of points that became

evident through the review and analysis of our research products, including our review of literature, interviews with training organizations, training vision workshops, and survey of ongoing and future research.

The differences between the guidelines and recommendations are based on who may be able to ultimately take the actions described. The guidelines focus on actions that will impact the development of all aspects of pilot training programs. These can be used by the FAA as input for future review and modification of their materials for training development guidance and oversight of pilot training programs. The guidelines will also be useful to those who develop training programs within the airlines and training organizations. The list of guidelines is not intended to be a comprehensive guide to training development, but rather a list of guidance-related highlights that resulted from our research findings and will be particularly important when developing pilot training for NextGen operations. Many of these guidelines address issues that the industry has been aware of for some time; however, we felt it was important to continue to emphasize items that still need prominent attention based on our research findings and, in some cases, that may need renewed attention or increased emphasis as operations evolve.

The items we list as recommendations are focused on actions that can be taken outside of those directly related to training development. These concepts addressed in the recommendations still affect training development and delivery but will be addressed by others in the industry including simulator and flight-training device manufacturers, airline management, ATC, aircraft manufacturers, and the FAA. The description of the recommendation should make clear the intended target of the information.

## Guidelines

### Guideline #1 Planning for new technology

When introducing a new technology, the period of time between when training is administered and when the technology is implemented in operations should be minimized.

> **Rationale**
>
> There are many moving parts to the process of designing, developing, and implementing new technologies or procedures, as well as many different stakeholders. It can take months, even years, to implement new technologies. Changes or delays with any of the variables associated with new technology implementations can have a deleterious effect on pilots' knowledge and skill retention and on pilots' confidence in their ability to satisfactorily use the new technology.
>
> The closer in time the training is to the technology implementations, the better chance the pilots will have of retaining the knowledge and skills required for effective and safe operation of the new equipment and procedures. Pilots will also have more confidence in their capabilities to implement the operational changes. This will become even more important as new and complex NextGen operations and equipment are introduced.
>
> Depending on the criticality of the operational change, it may be appropriate to devote dedicated time to the new training that would allow the change to be accomplished more quickly than if it were introduced during the regular training cycle. All situations are unique, and each airline should make the best choices for their own training and operational situations and requirements.

## Guideline #2 Curriculum sequencing

When organizing pilot-training programs, consider curriculum designs that are sequenced in an easy-to-follow and logical manner (e.g. simple to complex) and that intentionally build on prior learning and established skills.

### Rationale

Learning and retention of knowledge and skills is affected by how the training program is organized and delivered. Using a building-block approach enables pilots to successively develop greater depths of knowledge and skills to be effective in line operations. Organizing training in a logical and easy-to-follow manner will help pilots more efficiently acquire and retain knowledge and skills, because they will more effectively be able to develop appropriate expectations and mental models for the training program and the material. As new NextGen technologies are introduced, it will be important to consider how to effectively build on existing pilot knowledge and experience in the training of new operational system and procedural changes.

## Guideline #3 Repetition and practice

Pilots should be provided adequate opportunity for sufficient repetition and practice to develop new skills and maintain existing skills.

### Rationale

High-level skills and knowledge structures can only be developed with sufficient repetition afforded through appropriate drill and practice of what has been taught in training. Failure to provide opportunity for adequate repetition in the development of novel skills and the maintenance of existing skills may result in safety vulnerabilities caused by inadequate performance of the skills in operations.

It would be advantageous for pilots to be provided access to training devices for practice opportunities, as their schedules permit. However, the use of these tools will need to have some structure, because complete free play without structure has been shown to have the potential to lead to negative training. Lower-fidelity training devices may be useful for providing more drill and practice in the training of automation skills.

Another approach that may be considered to provide repetition for skill development is to "practice" a task through repeated observations of effective task performance (e.g. video, role playing). Our survey of ongoing research identified some current efforts to evaluate the effectiveness of video observation as a practice method.

## Guideline #4 Devices that meet training objectives

As the availability and variety of simulation and training devices increase, the focus should remain on choosing the best tools to meet training objectives.

### Rationale

Training device technology is rapidly changing, and new devices are being developed at an increasingly rapid pace. It is easy to get caught up in the latest technology, which marketing materials promise will provide many enhancements to training programs. It is even more important in the face of such a barrage of information to keep the objectives of training at the center of the decision about which training tools and devices to use.

NextGen proposes goals in which aircraft will fly closer together, on more precise paths and tighter schedules, than they do today. Much of this will be enabled by the increased use of automation on the flight deck. To meet these goals, pilots will need to achieve through training, both a deeper understanding of aircraft automated systems and the opportunity to practice working with each of the systems. The choices of device and simulator usage will be important to providing the best transference of knowledge and skills economically. Some devices may be more effective than others at teaching certain tasks, and therefore matching the right training tool to the right training objective will be a key consideration. Careful and systematic planning on how these tools are used in relationship to one another, and how training objectives can be integrated across devices, will enhance the quality and efficiency of pilot training.

## Guideline #5 Timely pilot feedback

Pilots should be provided adequate and timely feedback about performance during training. This will allow pilots the opportunity to learn what they are doing well, what errors they have made, and how to improve future performance.

### Rationale

Effective and timely feedback is a critical element in developing knowledge and skills. This type of feedback promotes pilot retention of information and prevents the development of incorrect skills or knowledge. Failure to provide timely and useful feedback during training will lead to missed learning opportunities and therefore subsequent threats to safety. When errors occur, the instructor must balance the need to provide timely feedback and the need to provide opportunity for the student pilots to identify and recover from errors on their own. Timely feedback may not always mean immediate feedback.

Consideration should be given to providing timely and constructive feedback even in circumstances when a live instructor is not participating in the training. Distance learning and computer-based learning applications should be designed to provide immediate feedback, including useful explanations about the pilot's performance.

The use of video in debriefing sessions may be an effective method to provide timely feedback, so that the instructor does not have to interrupt the flow of the live simulation performance.

## Guideline #6 Scenarios based on safety data

Realistic scenarios and examples should be used throughout training to make it operationally relevant and credible to the pilots.

### Rationale

Participants in the training interviews and training-vision workshops suggested that using realistic scenarios and examples in training was one method to better prepare pilots for the tasks that they will encounter in line operations. Research has also shown that embedding realistic information in training content helps to more efficiently develop effective mental models for the tasks being trained.

A strategy that interview and workshop participants noted was particularly useful in developing realistic scenarios was to use safety data as a reference. Safety data is often a reflection of the issues and challenges pilots encounter in line operations. In

addition, safety data has the potential to help identify trends or deficiencies that might be corrected through training.

## Guideline #7 Automated systems

When developing training for use of automated systems, include curriculum content that helps pilots to develop a comprehensive understanding of the systems as necessary for effective and safe line operations. The pilots' understanding of the automated systems should go beyond strictly procedural knowledge to facilitate effective detection, diagnosis, and resolution of errors and system malfunctions or failures.

### Rationale

The literature and our research have shown that there is a trend toward teaching pilots only how to use automated systems as covered in the procedures and scenarios included in the training program. Research has shown that pilots need more information about how the systems actually work to be able to develop accurate expectations of system behavior and to intervene when necessary.

Operations in the NextGen environment will require increases in the use of automated systems to maintain precision in nearly all aspects and phases of flight. The automation required by NextGen to maintain flight precision has an increased potential to cause pilots and their aircraft to be placed in situations that are not covered by procedures in training. A comprehensive understanding of the functions of each automated system, including how the automated systems integrate and work together, will be essential for pilots to operate their aircraft in a safe and effective manner.

## Guideline #8 Basic piloting skills

The training program objectives should include consistent and ongoing emphasis on the development and maintenance of basic piloting skills, including associated manual-handling skills and cognitive skills.

### Rationale

As the number and sophistication of automated systems on the flight deck have increased, many pilot-training programs have spent more time on teaching those automated systems resulting in less time spent on basic flying skills. Research results and aviation safety reports have implicated this reduction in attention to basic flying skills as contributing to accidents and serious incidents. We heard from our interview and workshop participants that this is a current concern that may become more of an issue with the introduction of increased use of automated systems and associated procedures with NextGen operations.

It is tempting to reduce the time devoted to these basic manual handling and cognitive skills as other requirements increase, but it is important to resist this reduction. In addition, it becomes increasingly important to monitor levels of proficiency on these skills. Pilots may not use the skills as much on the line because of NextGen requirements for more precise flight paths that can best be accomplished using the automated systems. Training-evaluation data focusing on the proficiency of these skills must be continually monitored and fed back in to the training program to make improvements.

## Guideline #9 NextGen knowledge and skills

The list of skills and knowledge areas below will become more crucial as we move toward NextGen operations and should be appropriately emphasized in pilot training programs.

- Loss of control and upset recovery
- Integration of systems
- Spatial orientation in 4-D and self-separation environments
- Vertical situation awareness
- System monitoring
- Managing and recovery from system failures
- Recovery from flight path disruptions
- Data interpretation and integration
- Automation use and automated system management
- Information awareness
- Information management
- Mode Awareness

- Situation Awareness
- Flight path management
- Flight path awareness
- Airplane performance management
- Threat and Error Management
- Basic flying skills & knowledge
- Manual flying
- Energy management
- Communication
- ATC coordination
- Crew coordination
- Cross-checking

### Rationale

Most of these areas of knowledge and skills are being addressed at one time or another by many airlines and training organizations. However, there will be increases in the use of automation and the complexity of operations as we move toward NextGen. Pilots will need to manage larger amounts of information for automation systems that are increasingly interdependent between systems on the flight deck and between the aircraft and ground stations. Participants in our workshops suggested that while many of the skills noted in the list are addressed in current training programs, particular emphasis will need to be continually and consistently applied to developing them to a greater level of proficiency for operations in the anticipated NextGen environment.

It will be useful to clearly define for the specific operator the differences between how these skills are used in their current operations and how they will be necessary when they implement particular NextGen technologies and operations. This understanding will be helpful in determining how best to address these areas in their particular pilot training programs.

## Guideline #10 CRM skills

Training developers should continue to emphasize the CRM skills contained in AC 120-51E *Crew Resource Management Training* (Federal Aviation Administration [FAA], 2004) to ensure that these skills are trained and that skill proficiency is maintained. In addition, we recommend that the following list of CRM skills be considered for consistent and ongoing emphasis in the training program. These include the items that were documented in our research findings along with those mentioned as "evolving" in the CRM AC (FAA, 2004).

- Information management

- Information interpretation
- Information gathering from automated systems
- Dealing with information overload
- Crew monitoring and cross-checking
- System management
- System monitoring
- Mode awareness
- Failure identification
- Failure management
- Failure recovery
- Error management
- Threat management
- Situation identification
- Flight plan deviation recovery
- ATC coordination
- Knowledge of ATC operational environment, roles and responsibilities
- Problem solving
- Fatigue management

**Rationale**

Airlines and training organizations have been using AC 120-51E *Crew Resource Management Training* (FAA, 2004) since its release to help them develop and focus the content included in their CRM courses. The suggested CRM curriculum topics described in the AC are presented in Table 1.

**Table 1. Curriculum Topics from AC 120-51E (FAA, 2004)**

| CRM Curriculum Topics |
| --- |
| Communications Processes and Decision Behavior |
| Briefings |
| Inquiry/Advocacy/Assertion |
| Crew Self-Critique (Decisions and Actions) |
| Conflict Resolution |
| Communications and Decision making |
| Team Building and Maintenance |
| Leadership/Followership/Concern for Task |
| Interpersonal Relationships/Group Climate |
| Workload Management and Situation Awareness |
| Preparation/Planning/Vigilance |
| Workload Distribution/Distraction Avoidance |
| Individual Factors/Stress Reduction |

In addressing CRM, many training organizations have taken a cyclic approach to choosing topics to include in their programs, often choosing a focus theme topic each year or training cycle. Research has shown that it is the CRM skills that tend to be underlying the deficiencies identified in accident investigations (e.g., crew coordination, crew cross-checking). Our project results suggest that the CRM skills should be considered on-going with consistent delivery and evaluation given similarly to other skills. Consideration should be given to defining the minimum set of CRM skills that each airline wants to ensure are adequately acquired and maintained to provide their minimum level of safety. This training objective is not supported by addressing CRM skills in a cyclic manner.

With the introduction of NextGen, many CRM skills will become even more crucial. As the volume of information presented by systems in the flight deck increases, skills related to information management (identifying, integrating, and using information) and the management of automated systems especially will become more crucial. Pilots will need to have the skills to be able to identify and utilize flight-deck system information manually as well as the skills to perform these same tasks using the appropriate automated system.

Research findings and training experts suggest that CRM training be integrated throughout the training program, utilizing realistic scenarios. As NextGen operational changes are implemented, it will become even more important to focus on interactions with those outside the flight deck (controllers, dispatchers, flight attendants, maintenance personnel) as well as among the flight deck crew. Decisions regarding specific CRM skills to train should be driven by safety data (both industry as well as organization-specific) and continually modified as determined by this data. Refer to Guideline #6 for information related to the use of realistic scenarios during training.

## Guideline #11 Interruptions and distractions

Pilot training should include time to learn and practice strategies to manage interruptions and distractions to ensure the completion of interrupted tasks. Particular emphasis should be given to high workload periods such as prestart and taxi.

### Rationale

Interruptions and distractions are a regular occurrence in the flight-deck environment and are also a common cause of incidents and accidents. Several accidents have been caused by normal procedural steps being missed because of interruptions, including multiple occurrences of failure to extend wing flaps and slats prior to takeoff.

Training pilots to effectively manage interruptions so that they can successfully return to and accomplish interrupted tasks is one way to contribute to improvements in aviation safety both on the ground and in the air.

Some basic research from *Prospective Memory, Concurrent Task Management, and Pilot Error* (Dismukes, in press) provides two possible strategies for dealing with interruptions and deferred tasks. One strategy is for the pilot to take a brief pause when interrupted to form a mental intention to return to the interrupted task and consider cues that might serve as reminders to return to the task. The second strategy is for the pilot to take a brief pause immediately following the interruption to consider which task should be completed next. Research results suggested that

both of these strategies can be trained and can reduce the effects of interruptions and distractions (Dismukes, in press).

Other strategies have been observed to be effective in similar situations and also appropriate for training, such as the following:

- Making lists of deferred items to be completed
- Considering environmental cues or creating salient cues as reminders that will be noticed at the appropriate time
- Periodically pausing to try to remember any deferred items

(Dismukes, in press).

## Guideline #12 ATC disruptions during RNAV/RNP approaches

Pilots should be trained to appropriately manage ATC disruptions of planned flight-navigation procedures, with particular emphasis on RNAV/RNP approaches.

### Rationale

Disruptions during an RNAV/RNP approach are particularly challenging to effectively manage, as is returning to the approach path in a timely manner. These types of disruptions may result in safety concerns, especially in areas of mountainous terrain and major metropolitan areas. Workshop participants indicated that in areas of heavy air traffic, many incident reports have been submitted as a result of interruptions during RNAV/RNP approaches.

In our research several suggestions were made for handling the training for disruptions during these types of approaches. It was suggested that specific training for these contingencies would be an effective way to involve pilots and prepare them to fly in these situations. In addition, threat and error management skills may need to be better defined and better trained to appropriately address disruptions to RNAV/RNP approaches. Lastly, it was suggested that training deeper knowledge of RNAV/RNP systems, beyond procedural knowledge, may provide promote better success in handling interrupted RNAV/RNP approaches.

To better prepare pilots for disruptions during RNP/RNAV approaches, it may be appropriate to incorporate realistic ATC communications during simulator training time, specifically providing simulation of interruptions to this type of approach.

## Guideline #13 Unexpected and unplanned events

Consideration should be given to providing pilots with a systematic approach to effectively identify and manage unexpected and unplanned events.

### Rationale

Airlines have done a good job at proceduralizing most pilot tasks and incorporated them into standard operating procedures (SOPs) for use on the line. However, it is impossible to proceduralize or train every possible task or situation that a pilot might encounter, including those that may be unforeseen.

Some airlines have recently shared the methods they have developed to help their pilots actively and systematically manage unexpected and unplanned events. Some of the considerations in these models include the phase of flight in which the event

occurred, assessment strategies to determine the severity of the issue, decision support tools to manage workload and flight crew actions, and communications.

One method being used by Delta Air Lines is shown in Figure 1. This TEM model provides an ordered process that is straightforward and simple to use allowing flight crews to "proactively manage both expected and unexpected threats".

Pilots flying their aircraft in NextGen environments will have less room for error, and subsequently less opportunity to affect corrections to unexpected and unplanned events in a timely manner. Therefore it is incumbent on all air carriers to develop methods and practices for handling unexpected and unplanned events and train their pilots in the use of these tools. It would also be advantageous to find ways to share such models across the industry.
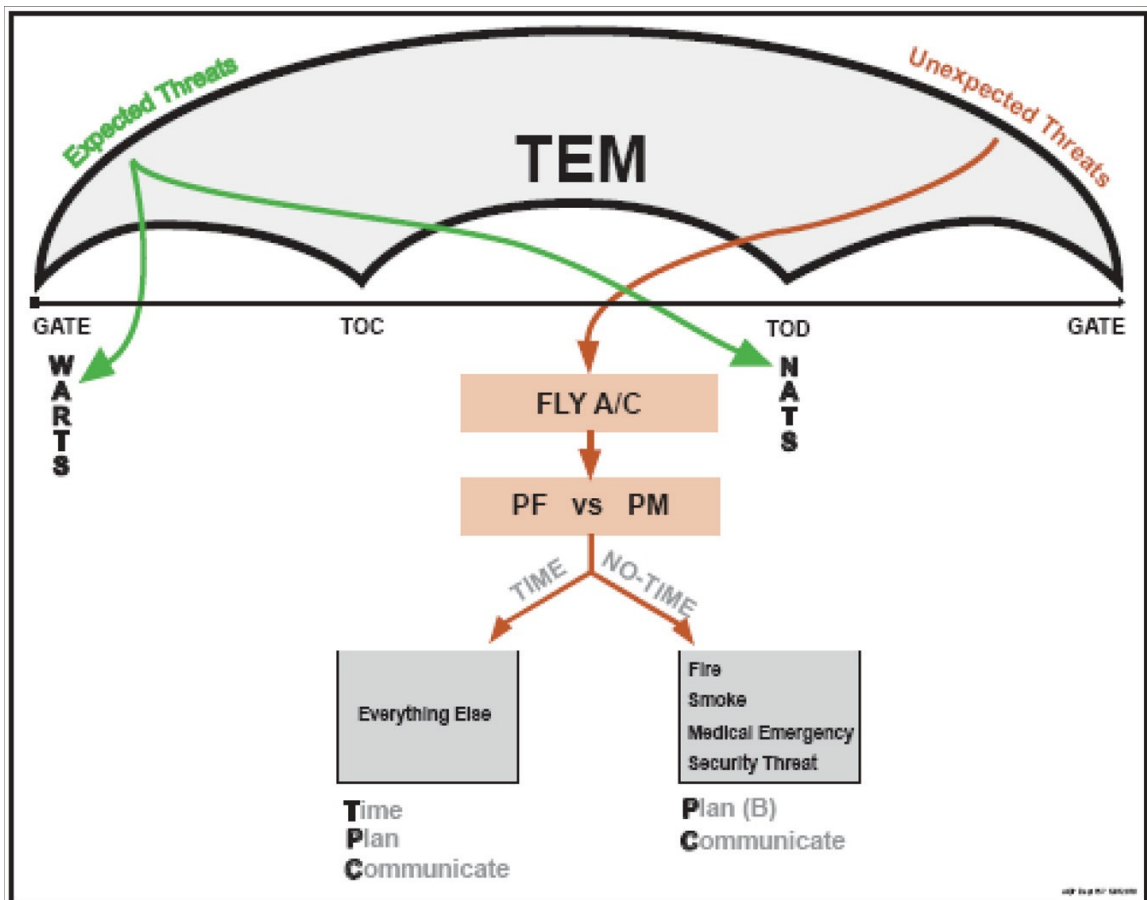


**Figure 1. Delta Airlines TEM Model**
**(Source: Captain Steve Dempsey courtesy of Delta Air Lines)**

This figure describes a systematic approach for addressing Threat and Error Management. As unexpected threats occur, the first priorities are to continue to fly the aircraft and for the captain to clearly communicate who will fill the roles of pilot flying (PF) and pilot monitoring (PM) (typically, the captain would assign the first officer to be PF, allowing the captain to focus on threat assessment and decision making). The next step in the process is to determine whether the threat falls in the "Time" or "No-Time" category. The "No-Time" category is clearly defined with only 4

possible threats (fire, smoke, medical emergency, and security threat). These threats require the most immediate action possible to safely land the airplane. Upon identification of a "No-Time" threat, the captain immediately communicates a scripted, memorized Plan B protocol to begin the process of attempting to safely land the airplane as soon as possible. For threats that fall under the "Time" category, the captain is trained to first take some action to allow more time for threat assessment and decision making, such as making an altitude change, speed change, s-turns, or holding pattern. After taking necessary action to "buy some time", the captain can then focus on gathering the necessary information to appropriately decide how to manage the threat and effectively communicate the plan. This model is being very well received by the pilots and is being considered for implementation of something similar by other airlines.

## Guideline #14 Instructor/Evaluator skills

Training developers should continue to emphasize the Instructor and Evaluator (I/E) skills contained in AC 120-54A *Advanced Qualification Program* (Federal Aviation Administration [FAA], 2006) to ensure that these skills are trained and that skill proficiency is maintained. In addition to the skills presented in the AC (FAA, 2006) shown in Table 2 and Table 3, we recommend that the following list of I/E skills be considered for consistent and ongoing emphasis in the training program based on the literature and our other research results:

- Knowledge of line operations
- Knowledge of systems use, underlying logic, and interactions with other systems
- Skills and techniques for observing pilot behaviors
- Skills and techniques for observing system behaviors
- Tools and techniques for training the use of automated systems
- Tools and techniques for evaluating the use of automated systems
- Scenario management under high-workload conditions

### Rationale

To be effective in training others, instructors and evaluators (I/Es) should have line experience with the technology that they will teach and be trained in current instructional methods and practices. Along with providing necessary experience, knowledge about line operations lends authority and credibility to the instructors and evaluators. Having training in instructional methods and practices gives the I/Es the tools they need to be effective in their roles as trainers.

To train NextGen, flight instructors and evaluators will also need to add to their aeronautical systems and instructional technologies knowledge base and draw deeper from their line experience with NextGen procedures and technologies. With NextGen's increased emphasis on the use of automated systems, it will be especially important for I/Es to have thorough knowledge of the function and use of NextGen automated systems and contexts in which they are used.

The tables below include information excerpted from the Qualification Training section of Advisory Circular 120-54A, *Advanced Qualification Program* (Federal Aviation Administration [FAA], 2006) and show the important skills and knowledge needed to be effective as flight crew instructors and/or evaluators. Although this information is detailed in the AQP AC (FAA, 2006), the instructor/evaluator skills and

knowledge listed in this table are equally applicable to I/Es in non-AQP training organizations.

**Table 2. Instructor Training Topics from AC 120-54A (FAA, 2006)**

| Instructor Indoctrination Curriculum | Instructor Qualification Curriculum | Differences Between Traditional and AQP for Existing Instructors |
|---|---|---|
| <ul><li>The learning process</li><li>Elements of effective teaching</li><li>Student evaluation, quizzing, and testing</li><li>Overview of AQP program development, implementation, and operation policy</li><li>Lesson preparation and application</li><li>Classroom instructing techniques</li><li>Techniques for instructing in the cockpit environment</li><li>Standardization and rater/referent reliability</li><li>Resource management (CRM/DRM) and human factors training</li><li>How to conduct training modules for students with varying backgrounds and varying levels of experience and ability</li><li>Instructor responsibilities</li></ul> | <ul><li>Effective use of, and qualification in, specific flight training devices, flight simulators, and aircraft</li><li>Limitations on use of training equipment</li><li>Evaluation of performance against objective standards</li><li>Effective preflight and post-flight instruction</li><li>Effective analysis and correction of common errors</li><li>Teaching/facilitation of CRM/DRM skills</li><li>Performance and analysis of standard flight events and procedures</li><li>Safety considerations in the training environment</li><li>Data-gathering procedures</li><li>Standardization and rater/referent reliability</li></ul> | <ul><li>Overview of AQP program development, implementation, and operation policy</li><li>CRM/DRM and human factors training</li><li>Standardization and rater/referent reliability</li><li>Data-gathering procedures</li><li>Effective use of, and qualification in, specific flight training devices, flight simulators, and aircraft used in the AQP</li><li>Limitations on use of training equipment used in the AQP</li><li>Evaluation of performance against objective standards</li></ul> |

**Table 3. Evaluator Training Topics from AC 120-54A (FAA, 2006)**

| Evaluator Indoctrination Curriculum | Evaluator Qualification Curriculum |
|---|---|
| • Evaluation policies and techniques<br>• The role of the evaluator<br>• Administrative procedures<br>• General safety considerations<br>• Evaluating human factors and CRM/DRM skills<br>• Standardization and rater reliability | • For each crewmember position requiring a particular evaluation the method of conducting:<br>  – Line check<br>  – In-flight proficiency evaluations if required<br>  – Proficiency evaluations in flight simulators and/or flight training devices<br>  – Special purpose evaluations (e.g., long-range navigation)<br>• The standards for the evaluations in the previous paragraph<br>• The methods and standards associated with airman certification evaluation<br>• How to conduct evaluations while simultaneously serving as pilot-in-command (PIC), second-in-command (SIC), or safety pilot<br>• Safety considerations for the various types of evaluations<br>• Safety considerations particular to the make, model, and series aircraft (or variant)<br>• How to evaluate instructors/evaluators<br>• Company/FAA policies with regard to the conduct of evaluations<br>• Administrative requirements particular to evaluations<br>• Evaluating CRM/DRM skills<br>• Briefing and debriefing techniques<br>• Data-gathering procedures |

### Guideline #15 Training measurements

Appropriate measurements should be used at regular planned intervals to determine whether the training program goals and objectives are being met and where improvements can be made.

**Rationale**

A systematic measurement process for evaluating the training program will help ensure that the program is meeting the goals and objectives and allow for ongoing improvements to be implemented.

These methods require some type of data collection and may be based on data-collection methods that are already in place at the time of program development. The validation methods should include processes for communicating the results of the validation back to those within the training program.

Consider safety data as part of a larger strategy, combined with other training evaluation information, to provide a comprehensive measure of training effectiveness.

## Recommendations

### Recommendation #1 Early involvement of training developers

Airlines should involve training developers in the process of acquiring new equipment or developing new procedures as early in the process as is practical to allow for effective synchronization of training delivery and implementation of equipment or procedures.

**Rationale**

Airline training organizations need as much lead time as possible to comprehend new technologies or procedures and then to develop and synchronize effective training solutions with the implementation of the new equipment or operations. Workshop participants noted that in current processes the training developers often do not have access to the details of new technologies or procedures until the airline is well on its way to implementing them.

Including training developers and other training decision makers in the early stages of deciding to acquire new equipment or make changes to procedures ensures that the developers will be reasonably well informed and be in a better position to develop and implement timely and effective training solutions.

### Recommendation #2 Updates to simulators and training devices

Industry should continue working to provide timely and cost efficient ways to update simulation and training devices as airlines introduce aircraft-equipment modifications.

**Rationale**

Because of continuous advancements in flight-deck technology, regular hardware and software updates are needed for training devices and simulators.

In current practice, the cost and development time for many of these updates, especially those for full flight simulation, make it difficult for training programs to keep devices and simulators current, often resulting in mismatched or outdated training tools. When updates are available, applying them to training devices may require significant time and expense. Often, the challenging time constraints

resulting from delays in training device updates and pressure to implement pending operational changes may require trainers to create work-arounds that are potentially time consuming and less effective for the students in achieving learning objectives.

Implementing NextGen initiatives will bring additional challenges as operational and technological changes may be many and frequent. Airlines and training organizations will need to keep up with these changes by updating their training and their training equipment in an effective and timely manner.

## Recommendation #3 Pilot roles and responsibilities/aircraft capabilities and limitations

ATC training programs should include information related to the roles, responsibilities, limitations, and capabilities of the pilot (along with the capabilities and limitations of particular aircraft) as they attend to ATC directions in high-workload environments (e.g., approach, take-off). In particular, thorough information on the implications that deviations from an aircrafts' prescribed flight path has on safety and efficiency should be provided.

### Rationale

With the introduction of NextGen equipment and procedures, the roles of controllers and pilots will become even more interdependent. It will be important for both controllers and pilots to have a shared understanding of the roles, responsibilities, and capabilities of one another. If controllers are not provided with this information, it is more likely that the pilot will be interrupted by requests during crucial tasks or periods of high workload. In addition, communications between controllers and pilots may break down. Providing controllers with specific information about the pilot roles and responsibilities will facilitate them working as a team, improve communications and expectations, and provide a beneficial awareness of varying aircraft and their associated capabilities and limitations.

Before September 2011, familiarization rides in which controllers performed jump-seat observations were reported to be very beneficial. Opportunities to conduct these types of rides are currently being reinstated, and incorporating them explicitly into the controller training programs will be useful. Other methods can also be useful for this purpose. Some that were mentioned during our research were the use of simulators, video-taped observations, computer-based distance learning, and informational electronic or physical hand-outs. Some other suggestions are made by EUROCONTROL, including the idea that joint meetings attended by both pilots and controllers be held for the discussion of operational issues, and joint flight training or simulator sessions be held with both controllers and pilots present. (European Organisation for Safety of Air Navigation [EUROCONTROL], (2004). Of course, tradeoffs are associated with the choice of any methods, and their appropriateness may be different for different work groups or organizations.

## Recommendation #4 Single forum for sharing information

The FAA should use its authority to establish an easily accessible means for sharing lessons learned (including those based on safety data) by all organizations involved in pilot-training development and implementation.

**Rationale**

Several industry initiatives are used by airlines to share and collaborate on information that makes their operations safer and more efficient (e.g. industry conferences like AQP and WATS, industry meetings of ATA, RAA, ALPA, industry working groups). However, there is not a single forum whose focus is to share lessons learned across, and for the benefit of all, carriers.

Implementing NextGen will bring additional challenges to the aviation community, and the sharing of information will become even more valuable. Also, costs and other factors will prohibit some carriers from implementing NextGen technologies in step with the rest of the industry. Having access to lessons learned will be invaluable to those carriers that join the technology later rather than sooner and may allow them the opportunity to do so with an increased level of confidence for safe operations.

Finding ways to share information across organizations certainly presents challenges related to legal liability and labor organization concerns, but finding acceptable methods for accomplishing this can only serve to improve aviation safety across the industry.

## Recommendation #5 Participation in industry venues

Airline management should commit resources to allow participation in industry-wide opportunities to share pilot training best practices and lessons learned (including those based on safety data).

**Rationale**

Airlines share a common objective of enhancing safety in their operations. The airline-training community is open to communicating with one another; however, the real-world practice of sharing information and best practices across the industry could be improved upon, allowing wider use of innovative training methods that will result in safety enhancements. Opportunities for information sharing are currently provided through a number of venues and organizations, such as the FAA AQP conference; WATS conference; meetings of ALPA, RAA, and ATA committees; as well as industry working group meetings and Aviation Rulemaking Committees (ARCs). However, none of these opportunities serve the industry as a whole. They each have their own members or constituencies. It is important as we move toward NextGen operations, which will provide some safety challenges not yet seen, that all training organizations are able to access and share information that will enhance training effectiveness and safety. These information-sharing forums could also provide opportunities for improvements in training consistency across airlines or regulators where appropriate.

Management's commitment to providing dedicated resources to these efforts will foster a more collaborative environment across airlines that will result in faster, more widespread progress in training innovation and safety enhancement. Also, there is potential cost savings for airlines as they are able to benefit from lessons learned through the work of others.

There are many ways to effect improvements in industry collaboration. Developing more effective online-collaborative environments may provide great benefit in this area, allowing opportunities for sharing without requiring expensive travel costs.

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# Literature Review

## Contents

## Tables

# Introduction

This chapter describes a review of research literature and other documents related to the design, development, implementation, and evaluation of flight-crew training, including instructor and evaluator training and the approaches to the use of training tools and devices. The next chapter presents the annotated bibliography that includes descriptions of all of the literature described in this review document.

The following sections are generally organized by the steps of the training development process. The top-level sections address culture and training, the training-development process, training content, training methods, training media (tools, devices, simulators, etc.), instructor and evaluator training, and training-program evaluation. To wrap up, there are sections that summarize literature on pilot opinions about training and the challenges faced throughout the training process. Conclusions are included at the end followed by a list of references.

# Culture and Training

External factors beyond the training program can affect learning outcomes. For example, Salas, Wilson, Priest, and Guthrie (2006) point out that characteristics of the organization as well as characteristics of the trainee can affect training effectiveness.

The culture within an organization includes the values, beliefs, perceptions, goals, collective experience, routines, and traditions that influence the way its members think, feel, and respond to situations within the organization (Salas et al., 2006). The organization's culture can affect the quality and effectiveness of the training delivered by the organization (Salas et al., 2006; Salas et al., 2008; Salas, Wilson, Burke, & Bowers, 2002).

The leadership in the organization and the level of support from training management can also affect the effectiveness of training. Along with this, the organization's policies (both written and unwritten) and procedures can affect training success (Salas et al., 2006).

Training is more successful when students value the training and are motivated to learn. These attitudes can be influenced by the organization's culture. For example, the value that a student places on training can be positively influenced by management effectively sending the message that training is important and by an organizational promotion of a culture of continuous learning. In addition, the way that training is framed (e.g., remedial vs. advanced) can influence how motivated the student is to learn the material (Salas et al., 2008; Salas et al., 2006).

Salas et al. (2008) recommend that an organizational analysis be conducted to determine if the culture supports training or if there are organizational elements that may stand in the way of a successful training program. In particular, constraints or conflicts within the organization may significantly affect the effectiveness of training. Once any challenges are identified and considered, they can be addressed (Salas et al., 2008; Salas et al., 2006).

While attempting to implement the overarching organizational culture, training departments are also faced with the challenge of teaching pilots from diverse backgrounds and with different preferred learning styles (Turney, Henley, Niemczyk, & McCurry, 2001). If training is not designed to take diversity into account, pilots who do not fit the typical model of learner may not be effectively addressed (Turney et al., 2001). It seems that the pilot populations are getting even more diverse as pilots are moving between jobs more often than before and fewer pilots are coming from military backgrounds than in the past.

The environment in which training is conducted is important and is affected by the broader organizational culture. Training outcomes have been found to be more successful when the

students feel comfortable and do not feel threatened while they are participating in the training event (Salas et al., 2008).

# Training Development Considerations

This section describes the elements that need to be considered at the beginning of the process for training program development or modification. These include choosing the process that will guide the effort, the general approaches to teaching, considerations for structuring or sequencing the program, and identifying specific objectives for knowledge, skills, and attitudes to be addressed.

## Choosing a training-development process

Several authors discussed the importance of the approach used to design a successful training program. For example, McCauley (2006) points out that training devices alone cannot effectively and efficiently teach pilots to fly the aircraft, but rather it is the design of the training system that utilizes the training devices and its content that makes the training program successful. Therefore, it is important at the beginning to choose an appropriate training development process to be used to guide the training development effort.

**The Advisory Circular (AC) for the Advanced Qualification Program (AQP) from the (Federal Aviation Administration [FAA], 2006), AC 120-54a, recommends pilot training organizations use an Instructional Systems Design (ISD) process to develop the foundation and full scope of their training program approach and requirements**. Table 1 presents the list of steps of the training-development process from AC 120-54a.

### Table 1. Training Development Steps from AC 120-54A

1. Develop a job task listing.

2. Analyze that listing to determine essential skill and knowledge requirements (either directly or by reference).

3. Determine which skill and knowledge requirements must be trained/tested.

4. Develop proficiency objectives that capture all training requirements.

5. Develop qualification standards that define acceptable operational performance levels.

6. Develop tests that measure proficiency in skill and knowledge areas.

7. Provide instructional programs that teach and test training requirements.

8. Establish and maintain an audit trail of explicit links between task requirements, training requirements, training and evaluation activities, and evaluation results.

9. Measure student performance against proficiency objectives and qualification standards for all curriculums.

10. Revise the training program based on student performance levels on an ongoing basis. This de-identified data (stored in the Performance/Proficiency Database) will be collected and reported to the FAA on a regular basis.

Previous work by our team (Lyall, Vint, Niemczyk, Wilson, & Funk, 1998) expanded the AQP approach into a complete development process for automated aircraft. This list is presented in Table 2. The expanded list was developed to provide a general description of the steps that are typically included in aircraft training development and are based on the general points of decision making that happen during training program development. A cross-reference of this list with the AQP steps is presented in the Lyall et al. (1996) report.

### Table 2. Training Development Steps from Lyall et al., 1998

1. Identify the need for training program development or modification
2. Determine the type of training program to be developed
3. Describe the characteristics of training participants
4. Determine whether to provide precourse general automation information
5. Develop training objectives
6. Develop methods to accomplish objectives
7. Determine the devices to use with training methods
8. Determine the integration of training components
9. Develop participant performance evaluation methods
10. Develop program validation methods
11. Develop instructor training
12. Develop evaluator training

# General approaches to training

The literature references various training approaches derived from accepted principles of learning to be used for effective training. Some examples of these training approaches and principles are presented below. For a full treatment of principles of learning, literature in such domains as education and instructional design should be referenced.

## General educational theory, design and practice

D'Alessandro (2007) recommends that the effectiveness of training curricula and training devices be improved by leveraging advances in educational theory, design, and best practices.

The training program should be designed so that all the training objectives can be met, are sequenced logically, and are easy to follow (Salas et al., 2006).

Salas et al. (2006) state that training should be designed to include proven instructional features to facilitate the learning process. The instructional features should include the following:

- Creating a training environment in which knowledge, skills, and attitudes (KSAs) can be learned and applied
- Developing performance measurements that appropriately measure the desired skills

- Designing a system in which timely and constructive feedback to the students is provided

## Incremental construction of knowledge and skills

A number of authors recommend incrementally constructing knowledge and skills during training. To do this, the training begins by presenting basic knowledge and skills. This basic training is followed by a reinforcement of previously learned knowledge and skills, which are then augmented. This process continues until the training objectives are met. In this way, complex knowledge and skills are built up incrementally from a strong foundation (Holder & Hutchins, 2001; Sherry, Feary, Polson, & Fennell, 2003; Wood & Huddlestone, 2006).

One example of using an incremental construction approach to train conceptual understanding is the work of Holder and Hutchins (2001). They developed a set of pedagogical principles that were used to develop training for a computer-based training (CBT) course. The principles outline a conceptual structure suggesting the incremental development of instruction to ensure a strong understanding of the relationships among concepts. Key concepts are introduced initially, and the remaining concepts are organized around these central concepts. Related concepts are then introduced. With key concepts placed early in instruction, they are then reinforced when new concepts are introduced. Normal system operations should be taught before any abnormal or unusual system behavior (Holder & Hutchins, 2001).

Another example of using this approach is described as training delivered in progressive phases. For example, Wood and Huddleston (2006) describe training phases for a type rating on technically advanced aircraft (TAA). Each phase of training builds on the learned skills from the previous stage, ensuring that the learned skills are reinforced.

The use of this progressive part-task training structure allows the next stage of learning to take place by freeing up more of the working memory of pilots. Concepts introduced and learned are then reinforced through practice sessions (Wood & Huddlestone, 2006).

The suggested stages are as follows:

- **Stage 1: Development of manual flying skills**
  In stage 1, the authors propose that more effective procedural knowledge could be developed by associating the initial stages of training with skill sets that the pilot has learned previously. The pilot should be provided instruction on the flight-control system and on basic parameters for maneuvering the aircraft. To ensure a progression from rule-based to skill-based behavior, the pilot is provided time to practice these skills in a full-flight simulator.
- **Stage 2: Development of automation flying skills**
  In stage 2, the principle of association is used to introduce the automated systems. The pilot is provided straightforward procedural knowledge related to the autopilot and autothrust systems and uses decision making to determine the flight path and targets as in Stage 1, but this time using the automation.
- **Stage 3: Systems management skills**
  In stage 3, the pilot develops system-management skills by building on the knowledge and skills acquired in the two previous stages. The declarative knowledge of the FMS is taught, and then the pilot flies the same tasks as were flown in previous stages, but this time using the FMS to calculate the appropriate targets for speed, altitude, and heading.
- **Stage 4: Familiarization with operational procedures**
  In stage 4, the focus is on augmenting the psychomotor skills developed in the initial stages with the cognitive skills required to control the automated systems.

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Preceding this stage, instruction is given regarding the appropriate human factors for using the automation. During stage 4, the pilot is given the opportunity to practice determining the requirements for a given situation using the automation (Wood & Huddlestone, 2006).

## The RAFIV model

Sherry et al. (2003) propose steps based on the RAFIV model to decompose automation tasks (RAFIV stands for reformulating the task, accessing the user interface, formatting data, inserting data, verifying and monitoring the automation). They state that the steps will help ensure that pilots are provided with the foundation for organizing and remembering task procedures. Training programs should provide the following, which can be based on the RAFIV model:

1. Explicit models for automation-task skills
2. Schemas to organize the skills and make them understandable
3. Schemas that enable the transfer of training from one skill to the next closely related skill
4. Training for the necessary memorized action sequences, such as mnemonics, drills, and practice (Sherry et al., 2003).

The formulation of a task by a pilot in response to an external triggering event and the sequence of pilot actions for commanding the automation can be modeled using the RAFIV model series of five stages (Sherry et al., 2003).

In this model, tasks with the same basic action-sequence structure are trained with very small incremental increases, from an overview of the task components for the first task to training the task components for the second task to an introduction of the schema (Sherry et al., 2003). The other tasks are then trained based on the schema.

## Performance improvement methods

Instructors should encourage students toward self-discovery by helping students recognize and diagnose their errors and providing assistance only when necessary. Instructors should be cognizant of individual student's abilities to complete tasks within curriculum or regulatory guidelines and have the flexibility to adjust required performance levels or complexities within these guidelines where doing so will improve student performance (Gipson, Bowman, & BraynSmith, 2006).

# Training program structure

The overall approach used to structure or sequence the program should be considered in order to create an effective training program.

One of the program structure questions discussed by Lyall et al. (1998) is that of deciding whether to include an element of the program that addresses general automation principles. The authors state that such a decision should be based on the characteristics, background, and needs of the pilots to be trained in the program. Pilot diversity was mentioned in the last section and that is one aspect considered here, but more important is the expected experience of the pilots with the types of automated systems and operations that they will encounter on the new airplane.

# Identifying training objectives

When developing training, it is important to identify specific objectives for knowledge, skills, and attitudes to be addressed. Salas et al. (2006) states that the objectives must be specific, measureable, and relevant to the task.

AC 120-54a recommends using the ISD process for identifying the skill and knowledge requirements (presented as step 3 in Table 1). Similarly, Lyall et al. (1998) recommend that training objectives be developed in order to lay the foundation for the depth and breadth of the training program (presented as step 5 in Table 2).

## Task analysis

The most frequently used formal method used to identify training objectives is a task analysis of the pilots' jobs on the aircraft for which the training is being developed (Lyall et al., 1998).

One method is to conduct a task analysis based on LOSA data. Findings demonstrate that when the LOSA methodology is used as a task analysis tool, it enables the training organization to ensure that training reflects actual operational needs. Threat and error management (TEM) data can be used to enhance the operational fidelity of the training to integrate the development of technical and non-technical skills. In addition, the data can be used to create effective instructional materials that support simulator instruction (Thomas, 2003a).

## Other Needs Analyses

Lyall et al., 1998 describe several other analysis methods that can be used to identify the objectives of training. These analysis methods are as follows:

- **Task factors analysis**

  A task factors analysis helps the training developers determine how best to validate and evaluate the performance of the tasks and their associated objectives by identifying the effects of various factors on each of the tasks, subtasks, and in some cases elements, in the task listing.

- **Learning analysis**

  A learning analysis helps the training developers determine the knowledge and skill levels required by pilots to perform each of the tasks, subtasks and elements. The results of a learning analysis can be used to inform decisions about the best media and methods to use when training to meet the objectives. A learning analysis is also called a KSA analysis, competency analysis, hierarchical analysis, and competency analysis.

- **Informal analysis methods**

  Various informal methods can be used to contribute to identifying training objectives. Some informal methods include analyzing past course critiques; summarizing feedback from the pilots, check pilots, or instructors; and summarizing management input about training needs.

# Training Content

The literature discusses concepts and skills to be addressed as part of a pilot's initial, recurrent, and transition training. Although this section presents a variety of topics discussed in the literature, it does not include a complete list of topics for pilot training. This

section focuses on concepts and skills that make up the content of training programs and the next section addresses the methods that can be used to present that content.

## Management and use of automation

One of the key topics of training as the industry moves toward the implementation of Next Generation Air Traffic System (NextGen) concepts is the training of the management and use of automated systems. Many authors have discussed skills related to the management and use of automation in general as included in the following:

- How and when to appropriately use automation
- How the flight crew and automation should work together
- How and when to transition between different levels of automation (including recognizing the appropriate cues that lead to choosing the appropriate level)
- Where to look for visual cues and how to recognize them
- How and when to revert to manual flight
- How to manage automated systems as one of the resources available to the flight crew
- How to use automated systems in highly dynamic operational environments, including the ATC environment
- How to maintain automation awareness
- How to maintain mode awareness
- What the human-factors implications are of working with automation (including potential for input errors, automation bias, and pilot-system-pilot communication)
- Which learned memorized-action sequences are required for automation tasks
- Which tasks are delegated to automation
- How the automation accomplishes tasks
- What the current aircraft configuration is and what it does
- How automated systems work with other systems (e.g., how the autopilot can be used during an engine failure)
- How to anticipate what the aircraft will do
- How to maintain vigilance
- Which procedural cognitive skills are necessary for controlling the flight path and managing the energy of the aircraft
- How to avoid over reliance on automated systems

(Casner, 2003a; Casner, 2003b; Federal Aviation Administration [FAA], 1996; Sherman, 1997; Sherry et al., 2003; Wood & Huddlestone, 2006)

In addition, Casner (1995) suggests that automation training include the following:

- Interactive demonstrations of automation used to perform particular tasks
- Informal descriptions of confusing experiences with automation
- Advice on successfully using automation.

The next subsections address other content suggested for training automated systems: general automation information, automation principles and concepts, levels of automation, mode management, and flight management system (FMS).

## General automation information

Ten to fifteen years ago, an introduction to automation training course was believed to be important for pilots who were transitioning to the glass cockpit and did not have previous automation training or experience (Taylor & Emanuel, 2000; Wiener, Chute, & Moses,1999) Lyall et al. (1998) suggest that it is important to determine whether such a course is necessary for a particular pilot group when developing new training. Suggestions for course topics include semi-generic technical information, issues, demands related to using and managing automation, and the company's philosophy for automation use. The prediction was that by now all airline pilots would have had exposure to automation, whether they were experienced pilots who had exposure on the line or new pilots who would be exposed in their ab-initio training (Wiener et al., 1999). With DC-9's and 727's still in service, an introduction to automation course may still be necessary in some cases.

## Automation principles and concepts

There are two basic philosophies for training automation:

- Pilots should be taught how to accomplish certain tasks with the automation but should not be weighed down with information about how the automation works.
- In addition to the procedural knowledge, pilots should be taught how the automation works to allow for the development of skills that may be transferable to other equipment.

(Casner, 2003a; Casner, 2003b; FAA, 1996; Feary et al., 1998; Holder & Hutchins, 2001).

Most of the literature reviewed support the second philosophy of including both procedural knowledge and knowledge of the underlying principles of automation. Several resources document a need for pilots to have a better understanding of the capabilities and limitations of the automated system:

- Wood and Huddlestone (2006) state that not enough focus has been placed on the environmental/operational context of the task environment. The context adds complexity that requires more complete knowledge to deal with real-world operations adequately. Training pilots solely on procedural steps does not allow pilots to respond optimally in non-normal situations.
- Sarter et al. (2003) state that if pilots have more accurate and complete contextual knowledge of automation, they could cognitively process observed cues more deeply, and they could more effectively allocate their attention.
- Holder and Hutchins (2001) state that pilots' use of the managed-descent mode would be greatly improved if they were taught how the autoflight system controls the aircraft while in managed-descent mode. Pilots often have difficulties understanding the aircraft's behavior in managed descent because it is contrary to their understanding of how aircraft fly.
- Sherman (1997) suggests that training departments provide pilots with the technical knowledge to understand how the automation functions, provide the wisdom to determine how best to utilize the automation, and provide training experiences that accurately represent the operational environment.

It has also been suggested that the training include the following:

- Information about the manufacturer's automation design philosophy (i.e., why certain functions were automated)
- Principles and attributes of the automation's design that have operational safety consequences (e.g., the vertical profile computation basis)

(Casner, 2003a; FAA, 1996)

## Levels of automation

A 1999 Air Transport Association (ATA) addressed the need for understanding the levels of automation that were of concern for the airlines. The group provided a description of varying levels of automation use. These levels of automation include the following:

- Hand flying
- Hand flying with flight-director guidance
- Autopilot and autothrust systems on, and commands entered by setting desired values on the mode-control and flight-guidance panels.
- Full use of automation using the FMS or GPS navigation with the autoflight system coupled.

(ATA Group Guides Training, 1999)

Pilot training has often focused on using the highest level of automation available, leading to many situations in which pilots used more automation than necessary (ATA Group Guides Training, 1999). Several resources suggest that pilots should be trained to, and permitted to, select the most appropriate level of automation for the current operational situation (ATA Group Guides Training, 1999; Damos, 1988; Young, Fanjoy, Suckow, 2006). This decision is based on the operating philosophy stated by the airline and the amount of time allocated to the training of the automated systems overall

Fanjoy and Young (2005) found that inadequate automation training combined with policies that require maximum use of automated flight modes may lead to problems, such as pilot complacency, overconfidence in automation, inefficient use of automation, incorrect mental models of how the automation functions, and the deterioration of manual flying skills.

A study by Nikolic and Sarter (2007) revealed that, contrary to their training, when trying to recover from a disturbance in pilot-automation coordination, pilots tended to remain in high-level modes of automation rather than revert to the lower levels of automation that respond more quickly to their inputs.

## Mode management

The FAA (1996) report recommends that training topics include the autoflight modes and any known aircraft energy-awareness hazards that may be encountered by the pilots. Hutchins (2007) provides the following definition of autoflight mode management:

> Autoflight mode management is the process of understanding the character and consequences of autoflight modes, planning and selecting engagement, disengaging and transitioning between modes, and anticipating automatic mode transitions made by the autoflight system itself (p. 1).

Hutchins (2007) also indicated that many airlines focus on training simple autoflight modes and do not provide training on the more complex lateral navigation (LNAV) and vertical navigation (VNAV) modes. Several studies emphasize the need for more comprehensive training on all automated flight modes (Fanjoy & Young, 2005; Hutchins, 2007; Wiener et

al., 1999) and proficiency with mode-selection tactics for deciding when to change from automated flight to manual control and vice versa based on the situation (Fanjoy & Young, 2005); Wiener et al., 1999). Wiener et al. (1999) also stated that pilots should be trained to know when autoflight should not be used (turn-it-off training).

A 1996 FAA human factors team report (FAA, 1996) made the following recommendations related to use of autoflight modes:

- Operators' manuals and initial and recurrent qualification training programs should include examples of when the autopilot should be engaged/disengaged or used in a mode with greater or lesser authority.
- Training and operations manuals should describe conditions under which the autopilot or autothrottle will or will not engage, will disengage, or will revert to another mode.
- Appropriate combinations of automatic and manual flight-path control should be outlined (for example, autothrottle engaged with autopilot off).

The FAA (1996) also recommends that the appropriate uses of mixed-mode flying as well as its advantages and limitations be taught to pilots. Specific procedures developed for mixed-mode flying should also be trained.

Another important aspect of mode management is ensuring that the appropriate mode engages after the pilot makes a selection. A 1999 ATA subcommittee recommends that pilots be trained to confirm that the proper mode is engaged by checking the flight-mode annunciator. The objective is to help avoid mode confusion and unexpected automation behavior that could lead to course deviations (ATA Group Guides Training, 1999).

To illustrate different modes and the situations for which the modes were developed, Feary and Sherry (1998) developed a CBT package, the Vertical Guidance Tutor, in conjunction with an MD-11 flight standards check pilot. The level of abstraction to be covered was determined by the operational procedure model of the vertical guidance system. The research team organized the information into normal operations, abnormal operations (i.e., emergencies), and special operations (which are not trained). The information covered in each module included the lower-level automated modes and the fully automated (FMS) modes. In the training conducted on the Vertical Guidance Tutor, differences in understanding and performance were not statistically significant; however, there was a trend toward the training yielding better performance. The Vertical Guidance Tutor was rated positively by pilots on a questionnaire. Pilots also felt that the training could be used in both initial and recurrent training (Feary et al., 1998).

## Flight management system

Some systems, such as the FMS, have been identified as a challenge to train effectively because the large number of concepts and skills to be learned is like "drinking from a fire hose" (Sherry et al., 2003).

Sherman (1997) promotes more free-play opportunities in pilot training to combat inaccurate and inadequate understanding of FMS behavior. Sherman (1997) contends that for free-play sessions to be effective, training departments must provide effective instruction in FMS logic and operation. Other research has shown that that free-play sessions must also have some stated goals or structure that is shared with the pilots to reduce the possibility of their learning inefficient methods or developing inaccurate mental models of the system (Lyall, Boehm-Davis, & Jentsch, 2008).

The literature recommends that the following FMS topics be included in training:

- Capabilities of the FMS and how the functions and features are used during line operations (FAA, 1996; Sherry et al., 2003; Wood & Huddlestone, 2006)
- FMS procedures; e.g., the use of FMS vertical-flight-path-modes, including VNAV submodes (Casner, 1995; FAA, 1996; Nikolic & Sarter, 2007)
- Explicit instructions regarding the necessary set of pilot actions that need to be performed in response to each FMS message (Sherry, Fennel, Feary, & Polson, 2006)
- More detailed information about how the vertical-guidance function operates; e.g., understanding PROF VNAV, optimal VNAV, FMS Speed Logic (Feary et al., 1998)

A study by Nikolic and Sarter (2007) found that 8 of 12 pilot subjects have inaccurate pilot knowledge of the VNAV submodes of the FMS, which contributes to problems in diagnosing and recovering from automation disturbances. Nikolic and Sarter (2007) suggest that their findings highlight the need for improved automation design and training so that pilots may be able to more quickly detect, accurately diagnose, and recover from errors and disturbances related to automation use. Work conducted by Sherman (1997) as well as an ATA human factors subcommittee (1999) highlight the vulnerability of pilots who over-rely on FMS navigation tools and recommend training pilots to avoid this behavior. In addition, the ATA group (1999) called for training pilots to display and cross-check ground-based NAVAID information to avoid over-reliance on automated navigation systems.

Feary et al. (1998) report that pilots want more training on the FMS and would like trainers to apply a basic approach by identifying the "must know" parts first, the "should know" parts second, and the "nice to know" parts last.

## Manual flying

This and the next few sections address some handling skills that the literature particularly has noted should be addressed in training. Wiener et al. (1999) state that airline management should develop a policy on maintaining manual-flying skills and that a portion of simulator training should be allocated to maintaining these skills. Wiener et al. (1999) also indicate that the manual-flying policy should include details on where hand flying can be used, including descriptions of appropriate weather conditions and types of approaches.

Young et al. (2006) conducted a study investigating the impact of the glass cockpit on manual-flying skills. Findings from this study indicate that flying fewer manual raw-data approaches contributes to a reduced level of control smoothness during manual flight.

Lyall et al. (2008) include a finding based on a long program of research that airlines should ensure that basic flying skills are effectively addressed in their training programs.

## Rejected takeoffs

Addressing decision making and properly performing procedures will likely make the most significant improvements on RTOs. The *Pilot Guide to Takeoff Safety* (Federal Aviation Administration [FAA], 1994) proposes to provide materials that will increase the knowledge and awareness of the factors that affect the successful outcome of a go/no-go decision during takeoff. The information is intended to be provided to pilots during academic training and then retained by the pilots for future review (FAA, 1994).

# Upset recovery

A 2003 study conducted for NASA evaluated the flying performance of newly hired pilots in scenarios derived from upset accidents. The study found that current training is not adequate to enable the pilots to reliably recover from all upset scenarios. To address this inadequacy, the authors proposed the following:

- Upset-recovery training should place greater emphasis on surprise in the initial encounter with conditions that lead to upsets.
- Instead of being taught general methods of recovering from various attitudes, pilots should be taught more specific methods of recovery from a variety of upset scenarios.
- Pilots could be trained in a relatively small number of classes of upset scenarios that might be relevant in most cases. For example, an upset consisting of reduced angle of attack and vertical g-load can improve pilot control response and aircraft performance in the recoveries from a number of scenarios.
- Distinguishing between situations that superficially appear similar but require fundamentally different responses should be emphasized during training.

(Gawron, Berman, Dismukes, & Peer, 2003)

The study concluded that although pilots cannot be trained for all imaginable scenarios, current aircraft upset-recovery training should be expanded to include more types of upset scenarios (Gawron et al., 2003).

Gawron et al. (2003) found that simulation could be used in upset-recovery training, exposing pilots to the following:

- Conditions that precede upsets
- The onset of upsets
- Opportunities to practice controls responses for upset recovery
- Unexpected upsets

Gawron et al. (2003) recommend that upset training be integrated with other forms of training so that the upset scenario will not be anticipated.

# Managed descent

Managed descent is one of the autoflight modes that has been specifically addressed in the research. To provide pilots with a conceptual framework for understanding how managed-decent mode works, a CBT module was developed by Holder and Hutchins (2001). This CBT helps pilots to understand how concepts are related and how they are dependent on each other. Holder and Hutchins (2001) redesigned the airline's CBT module for managed-descent mode based on an inventory of the concepts. In redesigning the CBT, Holder and Hutchins (2001) integrated the concepts with information on autoflight functions and the conceptual models to give pilots a foundation for understanding airplane behavior in different descent situations. To reduce mode surprises and confusion, Holder and Hutchins (2001) designed the CBT to enable a thorough understanding of how the automation controls the airplane. Pilots found the CBT module very helpful.

# Crew resource management

Crew resource management (CRM) involves reducing pilot error and enhancing safety by targeting skills related to effectively using all the resources available to flight crews (Thomas, 2004a).

The pilot skills typically taught under CRM are as follows:

- Communication
- Situation awareness
- Leadership
- Crew coordination
- Decision making
- Task management
- Time management
- Stress-and-fatigue management
- Appropriate attitudes toward performing CRM

(Bürki-Cohen, Kendra, Kanki, & Lee (2000)

The literature also discusses the need to extend CRM beyond the flight deck to include other personnel such as cabin crew, air-traffic controllers, aircraft dispatchers, and ground-based maintenance personnel (Bürki-Cohen, Kendra, et al., 2000).

The literature emphasizes that CRM training should be integrated throughout the training program and that realistic scenarios should be used (Bürki-Cohen, Kendra, et al., 2000; Baker & Dismukes, 2002; Beaubien & Baker, 2002; Seamster, Boehm-Davis, Holt, & Schultz, 1998; Thomas, 2004b; Wiener et al., 1999).

CRM training is especially dependent on organizational support to be successful (Salas et al., 2002). Salas et al. (2002) believe that CRM training requires subject-matter experts and learning experts to work together to design the training.

One challenge in designing the training is standardizing a pilot group that comes from a variety of corporate cultures and CRM backgrounds (Wiener et al., 1999).

Kearns (2008) also addressed single-pilot resource management (SRM). In SRM, the skills and concepts of CRM have been adapted to a single-pilot environment. The skills taught in SRM include automation management, decision making, situation awareness, and workload management specifically focused on the single-pilot environment.

The FAA provides extensive requirements and guidance information on CRM training, including information related to enhancing the realism of LOFT sessions (Bürki-Cohen, Kendra, et al., 2000; Bürki-Cohen & Kendra, 2001).

# Threat and error management

CRM has evolved over the years and has been reconceptualized as developing countermeasures to threats and errors occurring during flight. Threat and error management (TEM) comprises those skills involved in detecting and appropriately responding to internal or external factors that can negatively affect the success or safety of flight operations (Helmreich, Klinect, & Wilhelm, 1999). Thomas (2004b) describes the core skills of TEM as communication, situation awareness, task management, and decision making. Since these skills can be difficult to observe, most airlines identify behavioral

markers to address them in training and evaluations. Thomas (2004b) identifies behavioral markers for each of the TEM skills as follows:

- Communication
  - Communication
  - Environment
  - Leadership and followership
  - Inquiry
  - Assertiveness
  - Cooperation
  - Statement of plans and changes
- Situation awareness
  - Vigilance
  - Monitoring
  - Cross-checking
- Task management
  - Briefing and planning
  - Workload management
  - Workload prioritization
  - Automation management
  - Management of fatigue and stress
- Decision making
  - Contingency planning
  - Problem identification
  - Evaluation of plans

## Error management

To effectively perform error management, the literature discusses skills that must be developed in the avoidance, detection, and appropriate responses to error (Thomas, 2003a; Thomas, 2004a). Thomas (2004a) provides a curriculum structured to develop the skills required to perform effective error management on the flight deck. Thomas (2004a) developed the curriculum by synthesizing of the results from two studies. From the studies, Thomas (2004a) identified the core knowledge and skills necessary for developing competency in error management:

- Core knowledge
  - The nature of human error
    - Error genotypes
    - Error phenotypes
  - Error generation
    - Error occurrence and frequency
    - Error-producing conditions
    - Areas of vulnerability
  - Error-management strategies

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- ◦ Models of error management
- ◦ The role of technical and nontechnical skills
- • Error management
  - – Cognitive-skill dimensions
    - ◦ Information management
    - ◦ Planning and mental simulation
    - ◦ Monitoring and evaluation
  - – Team and interpersonal skill dimensions
    - ◦ Communication
    - ◦ Task management

# Briefings

Wiener et al. (1999) recommend that techniques, contents, and information on the importance of briefings be included in the training curriculum. Also, they believe that briefing of the flight attendants should be included and practiced during training. They suggest that instructors and evaluators demonstrate briefing skills throughout all phases of training and that the importance of briefings be continually emphasized, particularly during transition training.

# Monitoring skills

Although humans are not naturally good at monitoring, performance improves if monitoring skills are trained. For example, around 2002, US Airways changed its training curricula to ensure that standard operation procedures (SOPs) are monitored and cross-checked from the first day of training in the simulator. In the training, monitoring was emphasized by introducing subtle failures that could be caught by proper monitoring and then by ensuring that the instructor debrief any monitoring errors committed by the crew. This was accepted as an effective method throughout their training and also included by some other airlines. (Sumwalt, Thomas, & Dismukes, 2002).

# Decision-making skills

The literature also discusses the need to train decision-making skills (Bürki-Cohen, Kendra, et al., 2000; Dornan, Beckman, Gossett, Craig, & Mosey, 2007; FAA, 1994; FAA, 1996; Thomas, 2004a; Thomas, 2004b; Wood & Huddlestone, 2006). Some specific examples in which the need for decision-making skills is discussed in the literature are related to the following:

- • Unanticipated events (FAA, 1996)
- • Rejected takeoffs (RTOs) (FAA, 1994)
- • Highly dynamic, event-driven operational environments (Wood & Huddlestone, 2006)
- • Task and error management (Thomas, 2004a; Thomas, 2004b)

Decision-making skills help prevent rushed and ill-considered attempts to resolve errors. Pilots should be training in the decision-making process. GRADE is an example addressed by Thomas (2004a) in his research:

- Gather
- Review
- Analyze
- Decide
- Evaluate

## Stress-management skills

The literature discusses the need for stress-management skills to be taught to pilots (Gibson et al., 2006; Thomas, 2004a; Thomas, 2004b). Gibson et al. (2006) state that it is important for pilots to be taught to identify stress and the ways to effectively manage it.

Stress-exposure training (SET) is an instructional strategy that trains people to deal with technological uncertainties (Salas et al., 2006). SET has three phases:

- Providing information about different types of stressors and their effects
- Developing skills to manage and adapt to the stressors
- Applying the skills gained during the previous phases

Salas et al. (2006) state that there have been mixed experiences with the effectiveness of SET.

## Other skills and concepts

The following are other skills or concepts that were mentioned in the literature as being important to include in pilot training:

- Checklists (Wiener et al., 1999)
- Procedures and procedural skills (Wiener et al., 1999)
- Communication skills (Wiener et al., 1999)
- Radio communication skills (Bürki-Cohen & Kendra, 2001)
- Safety-related knowledge (FAA, 1996)

In addition, Wiener, Chute, & Moses (1999) make a general point that flight training must be consistent between ground-based instruction and line operations, and curricula should be followed explicitly and intentionally.

It is important to include examples of specific difficulties that have been encountered during operations or in training (FAA, 1996; Hutchins, 2009). In addition to providing operational relevance to scenarios or other training content, the specific problem-solving methods or work-arounds used to deal with the situation can be beneficial knowledge for pilots. For example, Hutchins (2009) discussed an example of how instructors and line pilots teach a work-around to use when the heading bug is on a heading that is behind the airplane and is, therefore, hidden.

The FAA (1996) also suggests that to improve the training process, airlines should have more line-oriented practice with scenarios that have regular updates from incident-reporting systems or other sources and that the scenarios should emphasize unique error-vulnerable situations.

# Training Methods

This section presents information about the methods that can be used to provide the content to the pilots including classroom training, scenario-based training, computer-based training and e-learning, and blended training methods. The next section (Training Media) describes research about the use of tools, devices, and simulators.

## Classroom training

Traditional classroom instruction has evolved as a delivery method for pilot training including teaching CRM in commercial aviation. Classroom training is typically used to present core knowledge and skills. It has also been shown that many topics that have been questioned in the past as being teachable in the classroom can be taught well in that setting. One of those topics is error management (Thomas, 2004a). Classroom training can provide a foundation for developing appropriate attitudes towards effective avoidance, detection, and response to error. Classroom-based error-management training should include the use of video, cockpit-voice-recorder transcripts, and incident-and-accident reports, along with examples from other industries. Error-management training in the classroom must use practical examples to illustrate theory, allowing crews to better understand human error. Examples of real errors should be used to illustrate the technical and nontechnical aspects of both outstanding and poor crew performance. Classroom training should also allow for the personal analysis of errors by having crews identify and discuss errors that have occurred during their own operations (Thomas, 2004a).

The results of one study have shown that fundamental cockpit-automation concepts can be taught to professional pilots in the classroom without the use of training devices (Casner, 2003b). Principles of flight, which include proper control of the flight path and management of energy, should be trained in the classroom before training automation (Damos, 1988). Classroom instruction must train pilots to understand which tasks are delegated to automation, how the automation achieves those tasks, and what the aircraft is configured to do at all times (Casner, 2003b).

One study suggested that the classroom can even be used to teach elements of upset training. The training can help pilots identify cues that precede classes of upsets and distinguish the type of recovery that is necessary (Gawron et al., 2003).

## Scenario-based training

According to Salas et al. (2006), scenario-based training is an instructional strategy that has several benefits. The main benefits are as follows:

- Scenario-based training is both practice-based and flexible
- Scenario-based training can be combined with other instructional strategies

Practice scenarios are critical to the success of any training program. While high-fidelity simulations are believed to be important for practice scenarios, Salas et al. (2006) contend that low-fidelity simulations have similar benefits.

Scenario-based training can help trainees develop higher-order thinking skills and facilitate critical thinking and decision-making skills (Salas et al., 2006).

Based on the results of a study and literature review, Wood and Huddlestone (2006) recommend that pilots be trained to choose and should practice choosing the appropriate functions to be performed by the automation. They recommend this be done with realistic scenarios that reflect the dynamic nature of descent into a busy terminal area.

The FAA implemented the FAA-Industry Training Standards (FITs) program in response to a need to improve safety training in TAAs. This is a general aviation program, but the results are interesting for other pilot training programs as well. The FITs training approach is based on pilots using a cognitive decision structure that is more complex than they would normally use in traditional training. In the FITS concept of scenario training, student pilots must face consequences for their decisions, such as the need to divert to a new location, in order to simulate real-world situations. Middle Tennessee State University is involved in FITs and has implemented the use of what they call consequence-based scenarios (Dornan et al., 2007).

## Scenario-based training for CRM/TEM

CRM core knowledge can be done initially in the classroom; however, experiential forms of training (i.e., scenario-based) must be used for the development and maintenance of skills. An instrument-rating-renewal simulator session could be designed with an error-management focus (Thomas, 2004a).

Thomas (2004b) conducted a study aimed at understanding the nontechnical skills that contribute to TEM. He concluded that one means for improving TEM could be the use of more extensive scenario-based training for CRM skills. Nontechnical skills play a key role in enhancing operational performance. Other factors such as crew experience, operational pressures, and team structure are also important in understanding how to manage threats and errors.

LOSA-type evaluation data could be used to develop integrated training programs, since they capture real examples of effective TEM countermeasures. A series of scenarios could allow crews to work beyond technical knowledge and skills to solve problems. This approach could allow more immediate and effective instructor feedback. A scenario-based training program can enhance crew performance by breaking down the perceived divide between technical and nontechnical aspects of performance. More extensive scenario-based training could play an important role in enabling crews to integrate technical and nontechnical skills to improve TEM (Thomas, 2004b).

## Line-oriented flight training and evaluations

Line-oriented flight training (LOFT) is a specifically-defined type of scenario-based training. In LOFT, flight crews practice flying an operational scenario for a simulated flight segment in which they must satisfactorily address problems such as system malfunctions and other in-flight events. Following the simulated flight in a LOFT session, the instructor/evaluator facilitates a debriefing in which the flight crew analyzes its performance and looks for opportunities to improve (Thomas, 2004b).

Taylor & Emanuel (2000) describe an airline program that at the time of their study annually revised its basic scenario and backups with a focus on safety. The scenario designs typically included a series of eight event sets with trigger events, distracters, and criteria for completing the scenario successfully. The criteria included no major deviations from standard procedures and a safe landing. The flight crew failed the scenario if the same event set was failed twice or three of the eight sets were failed. The crew passed the check if they initially failed two event sets but were able to accomplish them successfully in a subsequent attempt. Crews that failed the scenario received retraining and had to retest a scenario satisfactorily.

## Debriefings

Instructors do not intervene during a LOFT session (or during many other types of scenario-based training sessions); therefore, the performance enhancement due to training occurs in the debriefing sessions. The debriefings help flight crews evaluate their performance on the

simulated flight and identify opportunities for improvements. Helping high-performing crews recognize and understand the behaviors that contributed to their success is as important as guiding crews with LOFT deficiencies toward a realization of improvement strategies (Dismukes, McDonnell, & Jobe 2000).

Facilitation tends to work well in debriefing sessions because of the high degree of professionalism and motivation among pilots to actively participate in the debriefing process in order to continue to improve their performance. LOFT debriefings require crew members and instructor/facilitators to respond differently from what they are accustomed to in traditional training. For the crew to understand how to participate in the debriefing, the instructor/facilitator must provide clear instructions on the role of the facilitator and the role of the crew members (Dismukes, McDonnell, Jobe, & Smith, 2001).

One study found that LOFT debriefings may more effectively help flight crews remember relevant aspects of the LOFT if the debriefings are held immediately following the simulator session rather than later, such as after maneuvers training in the same simulator with similar conditions (Dismukes, McDonnell, & Jobe, 2000)

Dismukes, et al. (2000) also found that although an optimal length for LOFT debriefings is not established, most LOFT discussions can be accomplished effectively in about an hour.

The results of an airline pilot training survey performed by Baker, Beaubien, and Mulqueen (2002) demonstrated that some pilots find LOFT training more challenging than other features of flight training. Baker et al. (2002) noted that more than half of the respondents, regardless of the type of training program (e.g., Part 121, AQP) believe that LOFT debriefings provide valuable performance feedback.

## Distance training/learning

Distance training allows students to receive training from a remote location.

The literature distinguishes between *distance training* and *distance learning*: Distance learning is the expected result of distance training. Distance training can be considered synonymous with distance education and may use various forms of e-learning (Kosarzycki, Salas, DeRouin, & Fiore, 2003).

As organizations continue to expand geographically, distance training has become a more popular method of delivering instruction. While more research needs to be done on the benefits of distance training, specifically on required levels of interaction between trainers and trainees, the use of videoconferencing, electronic performance support systems, internet/intranet courses, and the like continues to grow (Salas et al., 2006).

Several advantages are currently associated with distance training. It can reduce travel costs associated with traditional forms of education, and it can reduce the cost of training materials if courses are delivered online. Distance training allows for more flexible scheduling as well as the ability to update content quickly and effectively. Material can be individualized and can permit trainees to interact with one another (Kosarzycki et al., 2003). Distance learning can also address the needs of a diverse population, particularly in areas such as aviation that compete for talent in a multicultural environment (Turney et al., 2001).

## Computer-based training and e-learning

Traditionally computer-based training was accomplished by the use of computer programs that pilots used on a bank of computers available in the training center of the airline. These courses were addressed in the pilot survey conducted by Wiener et al. (1999). They found

that many pilots transitioning to a glass cockpit who participated in the study felt that the CBT provided good or excellent training (Wiener et al., 1999). Some of the pilots said that the CBT contained errors, that they were frustrated when they had to re-review a topic, and that they wanted an FMS trainer available (Wiener et al., 1999). Wiener et al. (1999) suggest that management ensure errors are minimized in all training software and that an instructor be available to answer questions and resolve conflicting information during CBT (Wiener et al., 1999).

E-learning (electronic learning) is a more common broad term used today and can be defined as training that is delivered on a computer and used for individual learning or to support the goals of an organization (Clark and Mayer, 2008). The term e-learning has been used to include applications and processes such as the following:

- Internet
- Intranet
- Web-based learning
- Virtual classrooms
- Computer-based learning
- Digital collaboration
- Audio or video
- PowerPoint® slides
- Message boards
- Chat rooms

(DeRouin, Fritzsche, Salas, 2005; Kosarzycki et al., 2003; Salas et al., 2006)

Approximately 90% of all e-learning is currently being done using either the internet or an intranet according to Clark and Mayer (2008).

According to the literature, e-learning has the potential to be an effective training tool, but research on its use is lagging. Various studies make it difficult to determine the effectiveness of e-learning vs. traditional classroom training. E-learning studies conducted in organizational settings found more positive results than studies conducted in educational settings. The best ways to design the e-learning environment, maximize its delivery, and determine how and when it is effective still needs to be explored (DeRouin et al., 2005).

Currently e-learning has no dominant theory controlling its design, delivery, and implementation (DeRouin et al., 2005). DeRouin et al. (2005) talk about the need for an integrated theory of learning and more emphasis on using cognitive information-processing models to guide the development of e-learning systems. They state that work in this area has shed some light on e-learning's benefits, but that a significant amount is still to be learned.

Though an integrated theory of e-learning is not yet available, DeRouin et al. (2005) suggest some individual learning models and principles, including the behavioral/objectivist model, the collaborative/cooperative learning model, and Clark and Mayer's (2003) principles, described below.

## Design principles for e-learning

Generally, e-learning goals fit into one of two categories: inform or perform. Informing involves lessons designed to communicate information. Performing can be twofold: procedural-skill building or strategic-skill building in which there is no one right answer

(Clark & Mayer, 2008). Clark and Mayer (2008) contend that eight principles should be used when designing e-learning curriculum:

- **Multimedia principle**
  The multimedia principle asserts that both words and graphics should be used in e-learning courses. Organizational, relational, transformational, and interpretative graphics should be used rather than graphics that are decorative or representational.

- **Contiguity principle**
  The contiguity principle states that text and graphics should be integrated. The principle further asserts that printed words should be placed near corresponding graphics and that spoken words should be synchronized with corresponding graphics.

- **Modality principle**
  The modality principle says that words should be presented as speech. If graphics are the focus of the words, then the words should be put into spoken form. The modality principle has greater support from the research than the other principles, but it does have some limitations: It may not be practical, it may add to expenses, and it is more difficult to update rapidly. Along with this, printed words are sometimes necessary to aid in learner memory.

- **Redundancy principle**
  The redundancy principle states that on-screen text should not be added to narrated graphics in order to avoid overloading the learner with visuals.

- **Coherence principle**
  The coherence principle seeks to eliminate material that does not support the goals of the training. Audio, graphics, and words should be not be used only to entertain or motivate the learner.

- **Personalization principle**
  The personalization principle advocates using conversational rather than formal style. This includes using first-person and second-person language, speaking with a friendly human voice, and using polite wording. The principle also applies to the design of pedagogical agents, which are onscreen characters used to guide learning. Clark and Mayer (2008) support the use of a well-designed agent as a means for improving learning. The personalization principle also advocates making the author visible as a means of promoting learning.

- **Segmenting principle**
  The segmenting principle states that complex material should be broken down into small parts to help learners process material that could otherwise be overwhelming.

- **Pretraining principle**
  Like the segmenting principle, the pretraining principle addresses complex learning. The principle suggests that training should ensure that learners know the names and characteristics of key concepts before moving forward with instruction.

(Clark & Mayer, 2008)

Clark and Mayer (2008) support the use of practice in e-learning and have developed guidelines for constructing effective practice:

- Reflect the job that learners will be doing
- Provide feedback that includes explanations

- Determine the amount of practice based on job-performance requirements
- Distribute practice throughout the learning environment
- Use the multimedia principle when designing practice questions
- Move from examples to practice gradually

Once a learner gains some expertise, worked examples can impede learning. The learner should gradually move from having fully worked examples to completing problem assignments. This fading process allows the learner to gradually complete more steps in a problem independently. Along with employing a series of faded worked examples, learners should be required to explain worked-out steps by answering meaningful questions (Clark and Mayer, 2008).

According to Clark and Mayer (2008) e-learning is different from traditional forms of learning because it allows for the following:

- Practice with feedback automatically tailored to the learner
- Collaboration to be integrated with self-study
- Instruction adjusted dynamically based on learning
- Simulation

With e-learning, students have a more active role in the learning process (Turney et al., 2001). In general, attitudes toward e-learning are varied but appear to be positive (DeRouin, 2005). Since e-learning can be updated relatively quickly, learners do not have to sift through outdated information, and material can be accessed at the convenience of the learner (Wiener et al., 1999). E-learning also supports tactile learners, offers geographic flexibility, and provides cost savings (Kearns, 2008).

Along with the advantages of e-learning, there are some potential disadvantages:

- Lack of training transfer because of losing job focus
- Over or under use of technology in ways that defeat learning
  (Clark & Mayer, 2008).

In general, e-learning faces the same challenges as any other learning program: designing lessons that are compatible with the way humans learn (Clark & Mayer, 2008).

Some businesses are using e-learning to train skills, such as communication, teamwork, management, leadership, customer service, and quality management, which are similar to skills taught under CRM (DeRouin et al., 2005). No research has determined the effectiveness of e-learning for these skills or whether they can be developed without using face-to-face interactions, although some study and survey results indicate that e-learning can be used to alter employee behavior (DeRouin et al., 2005). E-learning is typically more cost effective than traditional forms of training and has been shown to be equally effective as traditional forms of training in terms of learning (Clark & Mayer, 2008).

## Intelligent tutoring systems

Salas et al. (2006) recommend the use of intelligent tutoring systems, which can be time consuming to design and program but are useful for allowing computer-based training programs to function without a facilitator. Intelligent tutoring systems are a type of decision-support system, which when used as a training aid teaches critical thinking and decision-making skills through the use of simulated scenarios (Salas et al. 2006).

Cognitive tutors are a specific type of intelligent tutoring system that have been shown to reduce training time in PC-based part-task simulators. PC-based part-task simulators work well with a building-block approach of training low-level actions and subgoals that then

contribute to higher-level goals. Although free-play tutors that do not provide error feedback are often used, they are not as effective as PC-based part-task simulators that are guided by progressive levels of feedback from an integrated cognitive tutor (Blackmon & Polson, 2002).

The McLennon Training Study found that the goals related to the current actions or subgoals in training exercises should be conspicuously displayed on the PC-based part-task simulator screen to reinforce the goal-based learning. Along with this, progressive feedback should be used. By reinforcing goals and subgoals in realistic training exercises, pilots will be better equipped to recognize patterns of conditions in real-world situations (Blackmon & Polson, 2002).

Autopilot Tutor is another web-based cognitive tutor currently being used to train pilots. The student is given a real-world problem, and as the student becomes more competent in the task, the tutor only provides reinforcement or correction (Sherry, Feary, Polson, & Palmer, 2001).

The main purpose of Autopilot Tutor is to map flight-mode annunciation (FMA) and other PFD cues to autopilot goals and to map pilot goals to pilotmode-control panel (MCP) actions. After providing the pilot with ATC instructions, the tutor both reinforces correct pilot behavior and flags incorrect behavior in real time (Sherry et al., 2001).

Autopilot Tutor uses logic that is consistent with the actual logic of the autopilot. This ensures accurate training, which is especially important for situations at the edge of the envelope. Along with being an instructional tool, the tutor can also be used to maintain the competency of pilots in the operation of the autopilot by strengthening their mental models (Sherry et al., 2001).

## Drill and practice

A number of resources pointed out that high-level skills and knowledge structures can only be developed through using appropriate drill and practice of what has been taught in training as a training method. Both the timing and frequency of the practice of a desired skill can change the effectiveness of the practice (AOPA Air Safety Foundation, 2007; FAA, 1996; Sherry et al., 2003; Wood & Huddlestone, 2006).

Wood and Huddlestone (2006) recommend that practice sessions be performed in simulators to establish rule-based activities for normal and non-normal procedures.

## Facilitation vs. traditional instruction

Facilitation is currently being used with traditional training in aviation. According to Dismukes et al. (2001), the training objectives should determine which method, traditional or facilitation, is best.

Traditional instruction should be used to transfer large amounts of information from an instructor who knows substantially more about the topic than the students know. Facilitation should be used in situations in which existing knowledge is being applied (Dismukes et al., 2001).

For example, teaching the use of an FMS to pilots who have never used the system should be done using traditional methods, while LOFT debriefings may be better suited for facilitation. In traditional instruction, the instructor does most of the talking and keeps discussion focused on a topic. In facilitation, the instructor encourages more discussion and input from the students (Dismukes et al., 2001).

While traditional instruction requires testing, facilitation relies on the group evaluating itself and understanding the options for problem-solving (Chung, Bürki-Cohen, & Go, 2004).

An obstacle to facilitation identified by Dismukes et al. (2001) may be the fact that LOFT instructors play two roles in most U.S. training programs: The instructor typically provides traditional instruction and evaluation as well as facilitation. Because crewmembers know the instructor will be evaluating them later in the visit, they may not be open to expressing concerns with their performance.

# Recommended training methods

## AOPA Air Safety Foundation recommendations

According to the AOPA Air Safety Foundation (2007), training for TAA should not rely on traditional methods. A variety of seminars, online training programs, CDs, DVDs, videos, computer-based simulators, and online simulations are now available for all popular avionics systems used in TAA (AOPA Air Safety Foundation, 2007). At some large GA flight training facilities, FDRs and digital cameras are being used to provide a comprehensive review of the training sessions (AOPA Air Safety Foundation, 2007).

The AOPA Air Safety Foundation (2007) states that the best way to initially train pilots or train them to transition to TAA is to familiarize them with the aircraft on the ground. The AOPA Air Safety Foundation (2007) has outlined a four-step training program for TAA:

1.  Provide basic avionics and system training with a CD/DVD, a part-task trainer, or online. The pilot should complete a good portion of the training before arriving at the training center.
2.  Use a part-task trainer to simulate the GPS navigator or PFD/MFD.
3.  Use a cockpit simulator or flight-training device with or without a visual system or motion, but duplicating all other aspects of the aircraft. The pilot should experience basic physical airplane handling and local flights before simulator training is complete.
4.  Advance to flying the airplane.

The pilot should have a sound understanding of the glass or MFD/GPS equipment before completing full-fledged, cross-country VFR and IFR departures. Too much training is currently being done in the actual airplane, which may compromise safety (AOPA Safety Foundation, 2007).

## FAA human-factors team recommendations

The FAA (1996) believes that continuous learning is necessary for pilots to manage and use automation effectively in a wide range of situations. It recommends that the aviation industry and the FAA investigate innovative training tools and methods as well as incentives that encourage training beyond the minimum in order to improve flight crews' safety knowledge. The FAA (1996) suggests the following improvements to pilot training:

-   Use more coaching and less pass/fail testing
-   Improve the flight crew debriefings after simulator sessions, IOE, proficiency checks, and the like
-   Increase the focus on practicing how to manage automated systems in different circumstances
-   Encourage initial/recurrent assessments or checks to be oriented towards learning

- Reward and support continual learning by
  - Treating mistakes as an opportunity to learn
  - Allowing ample time for questions and comprehensive understanding
  - Using appropriate incentives to challenge flight crew members to further develop their skills

Along with this, the FAA (1996) suggests the following for the training process:

- Use automation surprises that occur on the line as training opportunities to support exploration and to learn more about the automation and how to manage it
- Follow up on simulator automation surprises in LOFT scenarios or LOEs
- Provide more opportunities to learn and practice, especially learning and practicing how to handle surprising situations
- Identify and correct oversimplifications in mental models of system functions
- Promote understanding rather than rote learning

### From Weiner et al. (1999)

In preparing pilots to transition to glass cockpit training, Wiener et al. (1999) suggest distributing a pretraining package consisting of a manual for the new plane, a syllabus, readings, and a schedule of events to reduce apprehension and misinformation. Wiener et al. (1999) also recommend that pilots take a jump seat ride in the model they will be flying, or if that is not possible, pilots should take a jump seat ride in any glass aircraft or observe a simulator session. Wiener et al. (1999) suggest following up with a one-day training session during each pilot's first year on the line. However, Wiener et al. (1999) recognize that implementing such a program could be very expensive; therefore, costs and benefits would need to be considered.

## Blended delivery methods

Blended learning involves a combination of training methods.

E-learning is typically blended with traditional classroom training and self-study. One of the benefits of this blended learning may be reducing costs without eliminating face-to-face instruction (DeRouin et al., 2005). Based on a compilation of study results, DeRouin et al. (2005) concluded that some organizations reap transfer-of-training benefits from blended learning when compared with e-learning alone. DeRouin et al. (2005) advise the reader to view their results with caution since the study has not been peer-reviewed.

Gawron et al. (2003) discuss a study conducted for NASA that investigated blended upset-recovery training. The upset-recovery training currently provided by major airlines typically consists of four to eight hours of classroom training and a simulator session. In this blended training, pilots were taught general rather than specific ways to recover from a variety of upset scenarios (Gawron et al., 2003). When faced with situations for which they had been specifically trained, many pilots were confused and could not recover from the upset (Gawron et al., 2003).

## Methods that affect the transfer of training

An indication that training is effective is dependent on the trainees' ability to use the skills in their jobs. It is important that the work environment supports and encourages transfer of training, because without transfer, training is not successful (Salas et al., 2006). Error

reduction and improved performance can be achieved if employees believe that their organization supports a continuous learning environment (Salas et al., 2006).

According to Salas et al. (2008) airlines may facilitate learning transfer beyond the classroom and simulator through several initiatives, including the following:

- Demonstrating support from all levels of management
- Providing opportunities to practice or demonstrate competencies
- Providing positive reinforcement of the desired behaviors
- Giving incentives
- Maintaining positive environment for learning both in the classroom and on the line

# Training Media

The AQP Advisory Circular (120-54A) defines training media as: "Physical means for providing the instructional content and experience to the student. Includes entire set of instructional presentation materials (e.g., workbook, videotape, overheads, computer-based training (CBT), mock-ups, FTDs, simulators, etc.)" (p.122). Clark and Mayer (2008) state that when training uses effective instructional systems, learning will be better, no matter what delivery medium is used. When the instructional system is essentially the same, learning will be the same, no matter how the training is delivered.

## Simulators

Certain types of airline-pilot training can be completed and certified exclusively in a simulator that is qualified for the training. The skills required of the pilot in flight operations must be accurately reflected in the simulator, and pilots must experience the same cues in the simulator that they would experience in the aircraft (Bürki-Cohen, 2003).

### Background

Before 1980, simulators were primarily used for procedural training; pilots acquired manual-flying skills in an actual aircraft. To address the hardware requirements for simulation, in 1975 the FAA developed the Advanced Simulation Program (ASP), which provided guidance for flight-crew training in simulators. The program allowed for zero-flight-time training and evaluation in approved simulators. Zero-flight-time training can be defined as training and evaluation that is carried out entirely in a simulator. When done properly, the training skills acquired will transfer to the actual aircraft (Bürki-Cohen & Go, 2005).

### Simulator advantages

Simulators provide the capability to train pilots without using an actual aircraft, with many potential benefits to both the pilot and the airline (McCauley, 2006). Simulator training is generally viewed as more effective than training performed only in aircraft (Bürki-Cohen et al., 2007; Carretta & Dunlap, 1998; McCauley, 2006).

Simulators allow for standardized training sessions, providing flight dynamics and environmental conditions that are the same every time (Moroney & Lilienthal, 2008). Immediate availability to simulated equipment as well as locations with defined environmental conditions are provided. Latitude and longitude as well as time-of-day and weather conditions can all be specified (McCauley, 2006; Moroney & Lilienthal, 2008).

Although the focus is often on the realism and fidelity of simulators, it is actually the departure from realism that is the simulators' most valuable feature. Moroney and Lilienthal

(2008) note that simulators provide the valuable ability to manipulate reality. McCauley (2006) supports this theory, noting several beneficial examples of the features and capabilities of simulator training that are departures from realism, such as the ability to fly without actually burning fuel and the ability to replay an event.

### Instructor control of training session

The use of simulators allows the instructor to control the training session (Moroney & Lilienthal, 2008). Moroney and Lilienthal (2008) note that simulators have many instructional features that facilitate the intervention of the instructor, while at the same time enhancing student learning.

A study of devices used by flight-training organizations performed by Wiggins, Hampton, Morin, Larssen, and Troncoso (2002) found that flight schools are using various training devices and computer programs instead of flight time in an airplane. The authors point out that one of the reasons for this is the instructor's increased control over the training environment (Wiggins et al., 2002).

### Environmental benefits

Simulators eliminate pollution, noise, fuel consumption, and the potential for hazardous leaks, all of which may occur when using an aircraft for training (Moroney & Lilienthal, 2008). The use of simulators also reduces the load on the national airspace system (Moroney & Lilienthal, 2008).

### Safer training

Much attention in the literature is given to simulators as a safe means of training (McCauley, 2006; Salas, Bowers, & Rhodenizer, 1998). Pilots are able to fly scenarios that replicate critical or emergency events and to make mistakes without endangering lives, damaging the aircraft, or violating regulations (Bürki-Cohen et al., 1998a; Bürki-Cohen et al., 2007; McCauley, 2006; Moroney & Lilienthal, 2008). The AOPA Air Safety Foundation (2007) notes that simulators provide an opportunity for the pilot to practice these events while learning appropriate responses and experiencing the sensations of flight.

Simulators also allow the instructor to focus on teaching without the concerns or responsibilities that an airborne instructor would have (Moroney & Lilienthal, 2008).

### Time savings

Compared with training in an aircraft, simulators can provide time savings for students and training organizations (McCauley, 2006; Moroney & Lilienthal, 2008). Simulators provide more training opportunities and allow more students to go through a training program than an actual aircraft provides in the same amount of time (McCauley, 2006; Moroney & Lilienthal, 2008). Moroney and Lilienthal (2008) point out that the number of approaches flown in a training session can be increased because the time required to re-enter the landing pattern is eliminated.

### Opportunity to repeat tasks

Tasks can be performed repeatedly in a simulator, providing the ability to make corrections. Simulators also allow pilots to learn a task until it becomes automated or over learned (Bürki-Cohen et al., 2007; McCauley, 2006; Moroney & Lilienthal, 2008).

Simulators are an effective means of training normal aircraft operations and developing necessary flying skills (Dahlström, 2008; Wood & Huddlestone, 2006). Simulators provide opportunities to practice these operations, allowing pilots to gain experience using automation and manual controls in an environment that simulates actual aircraft-operating conditions (Wood & Huddlestone, 2006). Wood and Huddleston (2006) note that a benefit of

practicing the basic skills that are part of initial training in a simulator is that it allows the pilot to transition from rule-based behavior to skill-based behavior.

**Performance measurement**

Simulators allow opportunities for data collection and the measurement of performance. The measurement of trainee performance is usually easier to accomplish in a simulator than in the aircraft (Moroney & Lilienthal, 2008). Simulators also provide data-collection opportunities that would otherwise not be available. This data can be collected for performance comparison, performance and learning diagnosis, and performance evaluation (McCauley, 2006).

## Simulator disadvantages

While many advantages are noted in the literature regarding the use of simulators for training pilots or aircrew, several disadvantages are also significant.

The value of a simulator ends if it does not accurately reflect the system it is simulating. An example discussed in the literature is the limitation of the motion platforms in their capability of achieving the sustained accelerations found in flight. At times, simulators present motion cues that depart significantly from the motion experienced in an actual aircraft (Bürki-Cohen et al., 2007; McCauley, 2006).

Moroney and Lilienthal (2008) note that simulation does not necessarily reflect real-world performance and that performance in a simulator may exceed performance in-flight. The authors offer three reasons:

- Stress levels in a simulator are manipulated.
- Trainee expectations of simulator events may lead them to review of procedures before training events.
- Fatigue and boredom are not experienced in a simulator; instead, the trainee is hypervigilent.

## Simulator fidelity

As a result of technological advances, the fidelity and functionality of simulators have improved (Salas et al., 2006).

**Simulator fidelity and training effectiveness**

Realism in simulation is addressed in the literature. Wallace and Hannibal (2008) recommend that the ability to move in the simulated environment as well as visual depictions be accurate and authentic. In addition, interactions with the system should be culturally and cognitively believable, and the system needs to respond realistically to inputs made by the trainee. Lack of realism in any of these areas may result in a negative transfer of training (Taylor et al., 2003). Simulator capabilities such as motion, noise, and vibration all contribute to the realism of the simulator (McCauley, 2006).

Dahlström (2008) notes that the use of high-fidelity simulation will not necessarily ensure improvement in the quality of training or guarantee better transfer of training. While some types of training and evaluation, such as LOFT and LOE, require high fidelity simulators, much of the literature points to the inaccurate and unsubstantiated assumption that the highest level of simulator fidelity will lead to better training (Bürki-Cohen, Kendra, et al. 2000; Dahlström, 2008; McCauley, 2006; Schneider, 1985). Lower levels of simulation have been found to be effective, especially for training general competencies (Dahlström, 2008; Salas et al., 2006). The level of fidelity required to train and evaluate to a safety standard

should be identified rather than assuming the most sophisticated level of fidelity is necessary (Bürki-Cohen et al., 1998a).

If the psychological fidelity of the system is sufficient, then low physical and functional fidelity simulations can be as effective as those with high fidelity (Salas et al., 2002). Rather than focusing solely on the realistic physical simulation of the airplane, consideration should also be given to the realistic representation of the cognitive aspects of flying such as those involved in radio communications (Bürki-Cohen & Kendra, 2001).

Estock, Alexander, Gildea, Nash, and Blueggel (2006) describe an approach, referred to as RELATE (relating effective learning to attributes of the training environment), that was created to establish a quantitative definition of the relationships between simulator fidelity and knowledge/skills. A comparison of the effect of the level of simulator fidelity on the effectiveness of training can be explored using predictive models.

Allen, Hays, and Buffardi (1986) performed a study that investigated the relationship between simulator fidelity and training effectiveness. Results of the study demonstrate the following:

- Physical fidelity and functional fidelity are interdependent; both should be considered during simulator design.
- Manipulations of fidelity have the greatest effect on temporal measures. Low functional fidelity is associated with longer problem-solving and response times.
- The social and masculine interests of the trainee interact with physical fidelity. Using low physical fidelity simulators may be possible when training pilots with high masculine interests.
- Both task and trainee characteristics should be considered when interpreting the effects of fidelity.

**Simulator motion**

Bürki-Cohen et al. (1998a) and Bürki-Cohen, Soja, and Longridge et al. (1998b) reviewed research related to motion and described an experimental study to be conducted to revisit the effects that simulator motion has on the training and evaluation of pilots. The study was meant to determine if simulator motion has a necessary effect that cannot be accomplished with a wide-field-of-view, visual-system-only simulator configuration (Bürki-Cohen et al., 1998a; Bürki-Cohen et al. 1998b).

According to Burki-Cohen et al. (1998a), much of the previous literature examined the benefits of motion on the performance of the simulator itself. They stated that the important question is actually whether simulator motion increases the proficiency of the pilot in the airplane.

The reviewed literature demonstrated that simulator motion improves the following:

- Acceptability of the simulator
- Performance and control for disturbance tasks
- Behavior during a tracking task when the aircraft is unstable

In addition, simulator motion was found to be especially useful when visual information is limited. All of these improvements transferred to a higher-fidelity simulator but were not proven to transfer to the actual airplane (Bürki-Cohen et al., 1998a).

The following problems were shared by the studies reviewed by Bürki-Cohen et al. (1998a) and may diminish the value of the study findings:

- The use of outdated motion and visual systems in many of the studies

- The use of tracking tasks instead of disturbance maneuvers (It is the disturbance maneuvers that will most likely benefit from the early alerting cues provided by motion.)
- The use of nonrepresentative subject samples
- The analysis of performance but not behavior in some studies (Pilots may have adapted to deficiencies in the equipment and changed their control strategy.)
- Possible bias caused by the pilots or instructor knowing that a simulator configuration did or did not include motion.

Research performed by Bürki-Cohen et al. (2007) found that the current use of motion in simulator training devices does not accurately represent the motion cues experienced in an aircraft. The authors note that simulators without motion have been used for a long time to successfully train pilots (Bürki-Cohen et al., 2007).

The Bürki-Cohen et al. (1998b) literature review examined whether fixed-base simulators could be used to provide a more cost-effective alternative to full-flight simulators for recurrent training. Their review did not find a definitive justification for modifying the qualification requirements for simulator motion. Recommendations are made for new research that considers past research as well as recent advances in simulator technology. Additionally, recommendations for the design and implementation of further research are provided.

Two types of tasks may be affected by the cues that motion provides: tracking tasks and disturbance tasks. Motion may affect each of these types of tasks differently, thus the authors note that it is important to consider the role of motion in each of these types of tasks (Bürki-Cohen et al., 1998a).

Much of the literature addresses the assumption that many make regarding the use of motion in simulators: that motion is necessary in all phases of training. This assumption is usually based on instinct or opinion rather than on actual scientific data. Some supporters of motion refer to the current and past use of Level B, C, and D simulators in pilot training as proof that motion is required (Bürki-Cohen et al., 2007). The FAA, in particular, has assumed that a Level D motion platform is necessary, but its decisions have not been based on empirical data. These assumptions may lead to negative transfer of training from the simulator to the aircraft (McCauley, 2006).

The testing of simulators is inadequate; typically the only tests performed are based on the simulator manufacturer's specifications and the initial performance of the simulator (Bürki-Cohen et al., 2007).

Despite inadequate testing and recommendations for motion that are not based on scientific data, it is probable that pilots will continue to be trained and evaluated in Level B simulators that require no more than three-degrees-of-freedom (DOF) motion systems (Bürki-Cohen et al., 2007).

McCauley (2006) points out that instead of considering whether a motion base is needed in a simulator, it would be better to consider how the motion requirements of a simulator vary depending on the following:

- Purpose of the simulator
- Level of pilot experience
- Type of aircraft
- Training objective
- Training maneuvers

- Training tasks
- Training criteria
- Budget available for acquiring and operating the simulator

Go et al. (2003) state that the effect of simulator motion depends on the task being trained. In addition, the quality of the motion provided is important.

McCauley (2006) performed an extensive research review of simulators, specifically whether army helicopter training simulators require motion bases. Findings include the following:

- No evidence was found to support the idea that simulator sickness can be prevented by the use of a motion base.
- Almost no evidence was found to support the training effectiveness of motion platforms.
- Almost no evidence was found to support the idea that flight-simulator-motion bases contribute to the transfer of training.
- Motion does contribute to in-simulator performance, especially for experienced pilots.
- Since most pilots prefer motion (or dislike no motion), adding a limited amount of motion may be preferable to no motion, even if the motion does not contribute to the training effectiveness.

**Fixed-base simulators with dynamic seats**

Bürki-Cohen et al. (2007) describe research and discuss the training value of a fixed-base flight simulator with a dynamic seat along with the difficulties and costs of using a complete dynamics model to ensure a high degree of physical fidelity and realism (Bürki-Cohen et al., 2007).

A Full-Flight Trainer (FFT) was developed by a leading turboprop manufacturer who provides type rating training worldwide. The training device is a high fidelity, fixed-base device that employs a wide field-of-view visual system (Bürki-Cohen et al., 2007).

The FFT-1 is intended to function and meet the requirements of a Level D simulator. The FFT-X generates the perception of motion using visual cues as well as a dynamic seat with physical heave motion. In addition, loud speakers are used to represent vibrations (Bürki-Cohen et al., 2007).

Simulator comfort depends on the absence of nausea or disorientation induced by the simulator. Discomfort may result when there are conflicts between visual and vestibular motion simulation. Users of the FFT-X did not experience any discomfort. Instructors rated the training device as equal to the full-flight simulator, and almost all the trainees rated the comfort of the device as equal to or higher than their comfort in the airplane (Bürki-Cohen et al., 2007).

During the final debriefing, the following was concluded:

- The decision maker from the National Aviation Authorities (NAA), a member of the European Joint Aviation Authorities (JAA), stated there were no training problems.
- Technical adjustments are needed particularly for flight phases near the ground.
- Experimental type-rating phase can be continued without restrictions.

**Radio communications simulation**

Radio communications, including air traffic control (ATC) communications to ownship or other aircraft as well as company voice communications, are not a current requirement of simulators used for the training and evaluation of pilots.

Current full-flight simulators are known by the airline training industry to be deficient in providing realistic radio communications. The responsibility for providing these communications falls on the instructor/evaluators and add to their demanding training and evaluation responsibilities. The radio communications provided by the instructor/evaluators are not standardized and are lacking in realism. As a result, the development of the cognitive and workload-management skills that are necessary for learning is likely to be negatively affected. (Bürki-Cohen & Kendra, 2001; Longridge, Bürki-Cohen, Go, & Kendra 2001).

A literature review focusing on the parts of AQP and CRM that are applicable to the simulation of radio communications demonstrated that a realistic radio communications environment is an important element of both training and evaluation scenarios (Bürki-Cohen, Kendra, et al., 2000).

Bürki-Cohen (2003) suggests the inclusion of an automated system in flight simulators for providing realistic radio communications on the flight deck during training.

A review of the Aviation Safety Reporting System (ASRS) revealed that that almost 90% of the incidents during initial operating experience (IOE) involve radio communications as a factor (Bürki-Cohen & Kendra, 2001). According to the authors, this demonstrates that safety would be improved if realistic radio communications were provided during simulator training and evaluation (Bürki-Cohen, 2003).

In their review of available technologies, Bürki-Cohen, Kendra, et al. (2000) concluded overall that the technology to automatically simulate ATC/company and party-line communications is still not fully developed, but that intelligent systems and automated speech generation/recognition both show promise.

A survey of 29 instructor/evaluators examined radio communications practices during simulator training and evaluation. The results demonstrated that in pilot simulator training, the instructor/evaluators are often responsible for the simulation of ATC and company radio communications. During pilot training and evaluation, instructor/evaluators spend approximately 20% of their time providing radio communications. These communications are primarily provided by means of role play, with the majority of the effort focused on the terminal environment as well as with ATC communications to own aircraft (Bürki-Cohen, Kendra, et al., 2000; Bürki-Cohen, 2003; Bürki-Cohen & Kendra, 2001; Longridge et al., 2001).

Instructor/evaluators were asked about their perceptions of the effect of radio-communications role playing on their own workload as well as on the workload of pilots during simulator training and evaluation. In addition, opinions were collected regarding the importance of radio communications for the effectiveness of training and evaluation (Bürki-Cohen, Kendra, et al., 2000; Bürki-Cohen, 2003; Bürki-Cohen & Kendra, 2001; Longridge et al., 2001).

For training and evaluation, instructor/evaluators consistently rated their own workload higher in the simulator than in the actual aircraft. They consistently rated the workload of the pilot in the simulator as lower than in the actual aircraft (Bürki-Cohen & Kendra, 2001).

A follow-up interview performed in 2003 with the same survey participants indicated that the instructor/evaluators still experienced high workload and competing responsibilities (Bürki-Cohen, 2003).

Bürki-Cohen, Kendra, et al. (2000) recommend that radio communications simulation meet certain requirements. The communications should be appropriate, reflect timing demands of ATC, include meaningful party-line communications, and expose pilots to potential problems with communication (e.g., technical difficulties, nonnative speakers of English).

Further research is necessary to find cost effective and efficient methods of providing radio communications in an operationally realistic manner (Longridge et al., 2001). In addition, government, the military, industry, and academia will need to work together to improve the supporting technologies and provide proof of the added safety and cost benefits (Bürki-Cohen & Kendra, 2001).

### Simulation environment preparation

Salas et al. (2008) provide information related to setting up an optimal simulation environment for training to positively affect training effectiveness. The authors note that the setting should be appropriate and comfortable for trainees, and the provision of suitable lighting, spacing, and seating should be considered. Resources necessary for training, such as training materials and equipment, should be prepared and provided to trainees.

## Flight-training devices

Wiener et al. (1999) define an FTD as a device with full systems and flight simulation that does not have a visual scene or a motion base. FTDs include autopilot and flight-director modes and glass displays and offer the pilots an excellent platform from which to obtain cockpit familiarization, including checklists, normal and abnormal cockpit procedures, flight maneuvers, and autoflight modes.

A study conducted by Wiener et al. (1999) recommends that the use of flight-management computer/control-display unit part-task simulators be examined, particularly in terms of their value as a free-play tool. Through interviews and questionnaires, Wiener et al (1999) noted a high number of FMC errors on the line during the first year. Specifically, they found a failure to arm lateral navigation LNAV after heading selection, confusion over the various autopilot-autothrottle modes; confusion over VNAV path and speed, often resulting in failure to make a crossing restriction; and failure to update winds. As a result of those findings, Wiener et al. (1999) suggest that a part-task simulator that allows for exploratory learning be tested as a possible solution.

## PC simulators

PC simulators, sometimes called PCATDs, are learning resources that provide opportunities for hands-on practice (Casner, 2003a). PC simulators provide interesting approaches to simulating the traffic environment (Bürki-Cohen, Kendra, et al., 2000) and they are becoming more prevalent in the public domain and are being used by licensed pilots and flying instructors (D'Alessandro, 2007).

Over the past two decades, the technological advances of PC simulators have allowed them to be used as a part of formal training programs. PC simulators have developed into sophisticated software packages that provide a low-cost, accessible, and flexible platform for learning, from self-directed learning done at home by nonlicensed pilots through fully integrated task training in commercial pilot training programs. PC simulators have become a viable tool for presenting realistic, high-quality, full-size graphic representations of aircraft instrument displays (D'Alessandro, 2007).

Despite the advancements, PC simulators are not universally accepted among those in aviation. A wide range of opinions exist on their advantages and disadvantages.

D'Alessandro (2007) states that there is a gap between the fidelity of high-end simulators and PC simulators, and research indicates that increasing the fidelity of PC simulators is not a viable solution. Because of simplistic control-input devices such as the yokes or joysticks used with PC simulators, the airplane handling and use of the flight controls is of low fidelity. Some argue that PC simulators are more appropriately used for training only the introductory skills and tasks and are not well suited for training complex tasks or using flight controls to master flying even basic maneuvers (D'Alessandro, 2007).

Given their advantages and disadvantages, PC simulators appear to have a significant yet limited role. Rather than having students use PC simulators as if they were real aircraft, training organizations should focus on creative ways to integrate them into their programs (D'Alessandro, 2007).

PC simulators can be used to train pre-flight preparation and to provide ongoing practice for skills and procedures. They are also useful for recurrent training, advanced instrument-flight-procedure training, and ongoing pilot practice (D'Alessandro, 2007).

To effectively balance the use of PC simulators, aviation educators, instructors, and software designers need to work with educational practitioners to produce more creative, innovative, and informed learning designs that leverage technical and educational advances. It is these designs that can realize the further potential that PC simulators offer the field of aviation training (D'Alessandro, 2007).

Determining the peak level for using PC simulators is important, as is establishing an effective balance between simulated training and in-flight training for each major area of training. Flight instructors must coordinate this balance and integrate various flight training tools (D'Alessandro, 2007).

### Comparison of FTDs, PC simulators, and other training media

**Effectiveness of PC simulators vs. FTDs**

Current PC technology can provide aerodynamic characteristics that are as accurate as current FTDs and that closely mimic those experienced in flight. They also have realistic flight controls and aerodynamics models that are at least as accurate as current FTDs. In addition, the navigation databases are unlimited in geographic coverage. Desktop computer devices offer a low-cost alternative for instruction of instrument tasks (Taylor et al., 2003).

A study conducted by Taylor et al. (2003) found that PC simulators are effective in maintaining recency of experience for instrument-rated pilots for six months. Pilots who had practice in either a PC simulator or an FTD had higher pass rates than a control group that had no practice. Along with this, the performance of the PC simulator was indistinguishable statistically from the FTD group (Taylor et al., 2003).

When considering individual maneuvers scored as passes by the check pilot, Taylor et al. (2003) found the training effectiveness of the PC simulators to be higher than the FTD or an aircraft. The effectiveness of the PC simulators for training altitude control, airspeed control, navigation procedures, and the like was observed by comparing performance on subsets of maneuver elements between the experimental groups. A significant improvement for the FTD group on procedural elements on the hold relative to the aircraft group and the control group was found. The PC simulator group showed a significant improvement on control elements for the instrument landing system (ILS) approach (Taylor et al., 2003).

## Media affects on transfer of training

In aviation training, trainees must be able to do more than merely acquire information. They must also be able to apply that information during operations with a high level of

mastery (Dismukes et al., 2001). When evaluating the effectiveness of a training device, multiple factors require consideration, including training personnel, students, the learning environment, and the curriculum. Changes to any of these factors using the same device could alter the training outcome (Blaiwes, Puig, & Regan, 1973).

Blaiwes, et al., (1973) note that improvements in the physical fidelity of a training device result in moderate increases in transfer of training. An optimal balance between transfer of training and physical fidelity is necessary for optimal cost-benefits.

## Transfer of training and simulators

Many factors influence research into the effectiveness of simulators, not the least of which is their overwhelming acceptance by the airline industry and pilot trainees, and government requirements to use them despite the lack of scientific evidence concerning their efficacy in flight training (Thurman & Dunlap, 1999).

Salas et al. (2002) suggest that research does not support the idea that if trainees liked their training, it was effective. Instead, it is important for organizations to look beyond trainee reactions.

Measuring transfer of training through the use of a simulator is challenging because of the impracticality of replicating the exact work environment for which the training is intended. Other challenges are the cost of the device, safety, and technical barriers (Blaiwes et al., 1973). However, safety and cost considerations typically make transfer-of-training studies to measure trainee performance easier when done in a simulator than in an aircraft (McCauley, 2006).

Within the context of AQP requirements, there is a need to determine the appropriate level of simulator fidelity to effect transfer of training from the simulator to the aircraft and from the aircraft to the simulator for evaluation (Bürki-Cohen, Kendra, et al., 2000).

According to McCauley (2006), there is no practical confirmation that flight simulators with motion contribute to transfer of training. In experiments conducted by Go et al. (2000) to determine the effects of simulator motion on pilot training and evaluation, the use of motion in the simulators did not result in any statistically significant differences for transfer of training between the motion and no-motion groups in the RTO experiments.

The results of the Bürki-Cohen, Boothe, et al. (2000) study on the effects of simulator-platform motion suggest that there is no significant difference in the transfer of training from platforms with or without motion to a platform with motion as a substitute for the airplane; i.e., quasi-transfer. Quasi-transfer consists of comparing simulator configurations to determine which elicits the best transfer to a simulator configuration that more faithfully represents the actual airplane; i.e., a higher-fidelity device (Bürki-Cohen et al., 1998a). Bürki-Cohen, Boothe, et al. (2000) caution that the results of the 2000 study may have been affected by the fidelity of the simulators used for training and that further study is recommended.

In *Do Army Helicopter Training Simulators Need Motion Bases?*, McCauley (2006) notes that while it is possible to measure the effects of positive transfer of training, the effects may be quickly dissipated by time and the experiences that intervene between the training and the transfer measurement. Therefore, it is important that the value of simulator features be considered in the context of transfer of training as well as considering cost-benefits (McCauley, 2006).

Studies have shown that the type of motion used for pilot training and evaluation does not improve transfer of training between the simulator and the airplane when the motion in the simulator should serve an alerting function (Bürki-Cohen et al., 2007).

A specific example addressed by Burki-Cohen et al. (2007) is that negative transfer may occur in upset-recovery training presented in conventional flight-training simulators because their visual, instrument, and motion cues cannot accurately represent what occurs in the aircraft. Furthermore, the pilots may develop habits based on their experience in the simulators that distracts them from their instruments, which are their only reliable source of aircraft orientation in an actual upset (Bürki-Cohen et al., 2007).

## Transfer of training and PC simulators

Most empirical studies and reviews have found positive transfer of training from PC simulators to flight training and flight. In a review of literature from 1997-2007 on the transfer of PC simulation training to aviation training, D'Assendro (2007) finds that PC simulators have a ceiling up to which transfer of training is effective, and that using them beyond that ceiling may decrease their effectiveness.

The literature has evidence that, despite some limitations, the use of PC simulators can have a positive effect on the transfer of training from novice levels to experienced levels (D'Alessandro, 2007).

PC simulators can provide transfer of training to the aircraft especially for part-task and procedures training along with training on underlying cognitive principles and tasks that need to occur early in training (D'Alessandro, 2007).

No obvious evidence suggests that PC simulators are effective transfer-of-training tools in the use of flight controls, and some evidence suggests that PC simulators negatively affect transfer of training for flight controls. PC simulators are not effective tools for teaching the fundamentals of flight handling and basic maneuvers and can even create poor habits that have to be relearned (D'Alessandro, 2007).

As more ground-based systems such as PC simulators are shown to be effective for certain evaluations (e.g., instrument currency requirements), further research should be conducted to determine both their efficacy for the intended certification and methods that provide more objective performance-measurement data, such as automated airborne performance measurement, in evaluations (Taylor et al., 2003).

# Instructor/Evaluator Training

While it is likely that most aviation training researchers would agree that the quality of the training of a program's instructors and evaluators can have a large impact on the effectiveness of the training delivered, only a small portion of the aviation training research provides specific guidance for instructor and/or evaluator training. This section describes the aviation training research literature that addresses training for instructors and/or evaluators beyond simply receiving the pilot training they are to train and then observing the lessons being taught. The topics covered include debrief facilitation training, simulator environment training, and evaluator training.

## Instructor debriefing facilitation training

The role of flight instructors as facilitators who guide a nontraditional, learner-centered approach to training, began to take shape in the airline industry in the 1970's. Within a decade, some airlines were training their instructors in facilitation skills or providing them with information that promoted the practice of facilitation (Dismukes et al., 2001).

Many training organizations believe that the debriefing conducted with pilots after a training session is a valuable part of the training process. Therefore, ensuring that this debriefing is conducted effectively is important; however, Dismukes et al. (2001) have found that most

U.S. airlines do not provide their instructors with much training on debriefings. This can be problematic because facilitation is a very different task from training or evaluation, and often an instructor must perform all of these tasks. If the instructor is not effectively trained, the pilot may not receive an effective debriefing, and the instructor may not see the value in facilitation. As a result, crews may perceive facilitation as an ineffective method of training, and insufficient crew learning may take place (Dismukes et al., 2001).

# Simulator environment training

When training within the simulator environment, Salas et al., (2008) state that instructors should be adequately trained to set up the simulation environment and demonstrate proficient knowledge of the training material, including the following:

- Ability to provide information in an understandable manner
- Encouragement of trainee participation
- Effective response to questions
- Useful feedback related to performance

# Evaluator training

As an essential part of reliable performance measurement, evaluators must be able to discriminate among the differing abilities of those they are evaluating (Beaubien, Holt, & Hamman, 1999), and they must be prepared with the knowledge and tools necessary for observation (Salas et al., 2006). Differences in experience or training can affect evaluation results among evaluators. Therefore, providing a good foundation for evaluation training and practice is important to minimize the variability of evaluator ratings (Baker & Dismukes, 2002).

Holt, Boehm-Davis, and Beaubien (2001) suggest that recurrent evaluation-process training is necessary to ensure that evaluators maintain proficiency in the critical aspects of their resource management assessments. Wiener et al. (1999) state that in-flight assessments require the observer to be as knowledgeable as or more knowledgeable than the crew under observation.

The presence of an observer on the flight deck may alter crew behavior such that the observations do not accurately capture actual line operations behaviors (Wiener et al., 1999).

Holt et al. (2001) describe other challenges, such as the number of evaluations the evaluator conducts. Evaluators with less experience may lack effectiveness because they may not possess the knowledge to judge the full range of performance. In addition, effects from the evaluation of one person or group may carry over to the next and may influence the ratings.

Several resources address consistency among evaluators. The personal-construct theory suggests that one instructor may focus on different areas than another. In addition, instructors may differ in their strategies for evaluating crew behaviors, such that different instructors may give different evaluation grades for identical performance (Baker & Dismukes, 2002). Baker and Dismukes (2002) suggest that practices such as a requirement to provide explanations only for extreme positive or negative grades may result in an unconscious bias to avoid giving extreme ratings. Such practices deprive the organization of comprehensive data with which to evaluate training and assess performance trends.

Further complicating reliability among instructor/evaluators in simulator settings is the amount of time that they must spend actually managing the simulator. Bürki-Cohen,

Kendra, et al. (2000), in a study on radio communications in simulator training, noted that instructor/evaluators spend approximately 22% of their time in LOFT managing the simulator. Baker and Dismukes (2002) also note that instructor/evaluators often run the simulator in addition to administering the training, and they may be distracted to the point that they are not able to adequately observe flight crews and make reliable judgments about their performance.

One way to test the reliability of performance measures is to use a test-retest method, in which raters assess the same set of performances at two different times and compare the results. This method is limited to one potential error source and may be biased (Holt et al., 2001). Since test-retest and reliability estimates can be misleading because of rater errors, inter-rater reliability (IRR) training is recommended. The IRR process determines reliability by comparing each evaluator's ratings to the group's using four indexes: congruency, systematic differences, consistency, and sensitivity (Holt et al., 2001).

Research should determine how much rater training transfers between event sets used for practice during training and event sets that are similar. Research should also determine if and how much the rater training conducted in the classroom transfers to the simulator, where instructor/evaluators have the additional workload of running the simulator. Whether rater training leads to instructors who are accurate across a wide variety of aircrews and performance needs to be determined.

# Training Evaluation

The research literature in this review suggests that effective training-evaluation programs are not only beneficial but also essential to sustained improvements in individual, team, and organizational performance. While the research concludes that training works, it is not clear what the best methods for evaluating training are (Salas et al., 2006). Nevertheless, training organizations should have a formal, continuous evaluation and improvement program for all of their training, including initial, recurrent, simulator, LOFT/LOE, type certifications, and check rides (Wiener et al., 1999).

Training should make a noticeable difference that does not occur by chance, has a practical value, and is measurable in terms of cost-benefit (Holt et al., 2001). The only way for an organization to determine if its training worked and adds value is to evaluate it (Salas et al., 2006). Furthermore, for an organization to benefit from an evaluation, it must look beyond trainee reactions. Measuring reactions alone does not indicate that learning has actually taken place or that the knowledge and skills learned will be used in the work environment (Salas et al., 2006; Wiener et al., 1999).

While there is agreement that evaluating training is a good idea, it may not be easy. Evaluating training is often costly, political, and labor intensive. Tradeoffs must be made between the best possible evaluation process and the constraints of cost, personnel, and time. Other challenges are that the results of an evaluation may yield bad news to the training organization, and the evaluation procedure may be difficult to conduct if it needs to occur on the job (Holt et al., 2001; Salas et al., 2006).

AQP has led to a significant amount of research on the process by which pilots are evaluated on their technical skills and on CRM (Mulqueen, Baker, & Dismukes, 2002). However, Thomas (2003b) suggests that current methods of training evaluation may not be adequate to measure overall organizational performance. While no single evaluation model is perfect, by using a combination of models that uses a systems approach, an effective model can be designed to guide, deliver, and evaluate training (Salas et al., 2006).

# Considerations for evaluation design

Students who do well in training should not be assumed to have accomplished learning. Evaluations should be appropriate and constructive for the task or knowledge trained and should highlight opportunities for improvement (Salas et al., 2002).

There are a number of considerations when designing the evaluation methods to be used to determine the effectiveness of training.

## Transfer of training evaluation

Transfer of training evaluation compares task execution to training variables. It is one method that can provide an unequivocal measure of training effectiveness (Blaiwes et al., 1973). The curve-fitting method can be used to measure transfer of training. However, the results of the method may not always be clear to the average training layperson (Damos, 1988).

Some maneuvers are just too dangerous to train safely in the aircraft; therefore, learning evaluation must, for practical and safety purposes, be measured in a simulator. Therefore, it may be impossible to conclusively determine training transfer in these situations (McCauley, 2006).

## Experimental evaluation design

Traditional experimental design is the most precise evaluation of training effectiveness, but it is not very practical. A variation is to have a waiting-list control group that allows everyone to receive the training but randomly assigns the order of training (Holt et al., 2001).

## Subsets of knowledge and skill

Holt, Boehm-Davis and Beaubien (2001) state that a comprehensive evaluation process would include performance assessments that address both task and context. Practical limitations, however, may dictate that the assessment focuses on a subset of the overall knowledge and skill set and include measures that assess the individual, the team, and the organization where appropriate.

## Instructor/student evaluation comparisons

Feary and Sherry (1998) note that evaluation methods in which the student and instructor complete evaluation instruments separately, then compare and discuss their findings, have proven to be very effective for the student. However, this method of evaluation can be time consuming and should be planned accordingly.

## Multilevel approach

Salas, et al. (2008) noted that simulator training programs should be evaluated using a multilevel approach to determine their effectiveness. Included should be considerations such as the following:

- Whether the learned knowledge and skills are applied on the job
- How the training has affected the organization as a whole
- Whether the trainee liked the training and found it useful

(Salas et al., 2008)

## Ruling out extraneous effects

When evaluating training, extraneous effects should be measured, and their implications on the criteria used for evaluation should be considered. Evaluation plans need to be long term with multiple measures to show delayed effects of training (Holt et al., 2001).

Training effects should be evaluated within the time interval that is appropriate for the performance being measured. If such an interval is not established, training assessments should be repeated within reasonable periods to test for immediate or delayed training effects (Holt et al., 2001). The effects of training typically appear first with individuals, then teams, and lastly organizations; therefore, the time to measure these effects should be adjusted accordingly.

The use of a time-series evaluation has the advantage of ruling out extraneous factors that might normally increase over time. However, the subjects can be aware of the testing, and this awareness can itself create extraneous factors. In addition, potential confounds must be eliminated as alternative explanations of the observations (Holt et al., 2001).

# Considerations for evaluating CRM training

To evaluate resource management effectively, resource management needs to be defined so that appropriate and statistically acceptable measures can be developed. A range of changes that take place in the pilot needs to be considered, such as changes in knowledge, attitude, and behavior (Holt et al., 2001). Using objective, measurable outcomes as criteria for evaluations allows for the impartial assessment of crew effectiveness, and experience suggests that crews more readily understand and accept such measures of their performance (Hamman, Beaubien, & Holt, 1999).

Holt et al. (2001) state that evaluating resource management should be a methodical and repeating process designed to result in continuous improvement. The results of any phase of the evaluation process may be used to adjust the training in an earlier phase of the curriculum, after which the training is re-evaluated. Evaluating resource management often requires tradeoffs dictated by time, staff, or other constraints. However, programs to evaluate resource management should include three basic components:

- A level at which to apply the measures
- Clearly defined criteria to accurately apply the measures
- A research design that will satisfactorily evaluate the selected level

(Holt et al., 2001)

And, the steps to evaluate a resource management training program should include the following:

1. Select the level at which to evaluate the program
2. Develop an evaluation plan
3. Develop measures of resource management performance
4. Analyze and interpret the evaluation results
5. Use information to make modifications for performance improvement

(Holt et al., 2001)

## Evaluating individual components

One method of assessing resource-management training is to evaluate individual components of information that result from training and contribute to crew performance.

Measures should detect differences that are extreme and those that are more subtle; for example, performance measures that detect the difference between barely safe and unsafe (Holt et al., 2001).

## Pre-post evaluation

The use of pre-post evaluation is an option to evaluate resource-management training if everyone must receive the training at the same time. While this is an easy method of evaluation, it is also subject to factors that can unnaturally cause the observed changes (Holt et al., 2001).

## Multiple evaluation methods

When possible and practical and to gain a more accurate indication of resource management performance, organizations should use different methods of measurement. The effects of resource-management training find strong support when multiple lines of evaluation evidence converge (Holt et al., 2001).

# Use of line data to evaluate training

Training evaluation data can come from a variety of sources within and outside training programs. Some sources of data that may be used to evaluate training include Line Operational Safety Audit (LOSA) data, Flight Operational Quality Assurance (FOQA) data, and Line Oriented Evaluation (LOE).

## LOSA data

Line Operational Safety Audit (LOSA) evaluation data provides a means to observe the practice of flight tasks, presumably learned in training, in real-world operational environments. The data may highlight opportunities for improvements to a variety of factors, including training, CRM, and SOPs. It is not necessarily an accurate indicator of transfer of training because of the many variables on the line that can affect performance. (Thomas, 2003a).

Thomas (2003a) notes that the collection and analysis of both training and LOSA data can support an ongoing process of improvements to both training and operations in which each supports the other. LOSA data provides a means to indirectly evaluate pilot training by examining how flight crews manage the flight deck, including their reactions to occurrences that affect flight safety. Thomas (2003a) suggests that there is a disparity between performance evaluated during training and performance observed on the line.

When training evaluations are used in conjunction with operational evaluations such as LOSA, a detailed picture about the health and effectiveness of both training and operations can be achieved. Moreover, the results of these evaluations, when applied in the instructional design process, can facilitate more effective approaches to safety in the operational environment (Thomas, 2003a).

## FOQA data

Several resources indicate that evaluation need not be limited to the pilot-training program alone. For example, Wiener et al. (1999) state that Flight Operational Quality Assurance (FOQA) data can be a source of feedback for training-program effectiveness if it is not used as an instrument against pilots.

## LOE

Thomas (2003a) asserts that to accomplish accurate measures of training effectiveness, organizations should integrate Line Oriented Evaluations (LOEs) with other training evaluation methods. Baker, Gustafson, and Beaubien (2003) note that LOEs simulate typical line operations more accurately than traditional maneuvers validations. Data from a survey of airline pilot's reactions to their check rides indicate that maneuver validations (MVs) and LOEs appear to be equally effective in assessing pilot performance (Baker et al., 2003).

## Pilot opinions about their training

The results of a nationwide survey of airline-pilot experiences and reactions to their check rides, while not necessarily attesting to the transfer of training, suggest that the more the pilots are satisfied with their training experience and find it helpful to their work, the greater the likelihood that the training will have been effective (Baker et al., 2003).

Baker et al. (2002) performed a survey of commercial airline pilots concerning their opinions and experiences related to training. The survey showed that pilots generally were positive about their training.

On the other hand, Young et al. (2006) conducted a study investigating the impact that glass cockpits have on pilots' manual flying skills in which they found that 21% of the participants stated that they did not like the overall training format and reliance on computer-based instruction.

# Overcoming Challenges

When developing and implementing training programs, there are various types of challenges that must be overcome to ensure that the pilot training program is effective. These include time challenges, cost challenges, technical challenges, and logistical challenges.

## Time challenges

Time-related challenges include how often pilots receive training and the duration of the training events.

### Training intervals

Under 14 CFR Part 121, captains are required to receive training at least once every six months and first officers at least once every year. Under AQP, captains and first officers are both required have training at least once every year. In a large training survey conducted by Baker, et al. (2002), these researchers found that most captains and first officers liked the length between their training events. However, a small but sizeable portion of the pilots receiving single-visit training (SVT) would prefer that training events were held more frequently.

### Training time

In a survey from a cross-section of U.S. airlines training under AQP, instructor/evaluators expressed a desire for additional time to accomplish all the training objectives. Instructor/evaluators would like additional time in the simulator to allow them to cover some of the finer points of flying the aircraft to ease the transition to IOE. One of the results of the follow-up interviews was that the instructor/evaluators noted that the provision of some automated grading technologies in a modern simulator would be a desirable feature, reducing the amount of paperwork required and therefore saving time (Bürki-Cohen, 2003).

Instructor/evaluators also felt that crews are currently too busy during training to deal with additional distractions introduced by an automated system to generate realistic radio communications in the simulator (Bürki-Cohen, 2003).

In addition, some systems such as the FMS have been identified as a challenge to train effectively within the allocated time because the large number of concepts and skills to be learned is like "drinking from a fire hose" (Sherry et al., 2003).

# Cost challenges

The cost of the resources required to deliver pilot training can be a major financial burden and a challenge that training departments must consider (Young et al., 2006; Wiener et al., 1999). The cost of pilot training includes the acquisition and maintenance of training devices, the development of training materials, the costs of running a training department, and the loss of revenue caused by pilots spending time in training rather than flying on the line. Costs can affect what training devices the training program chooses to use, the fidelity and features of the simulated environment in which the pilot is trained, the training modules and topics that are covered, and the amount of time that is allocated to training.

## Cost model for pilot proficiency

Justifying the costs of training can be challenging. Sherry, Feary, Fennell, and Polson (2009) described a cost model that can be used to determine the money an airline saves when pilot proficiency is improved. In their model, they assume that the level of pilot proficiency affects the number of instances in which a pilot fails to complete a task, and each task that is not completed (and has not resulted in an accident) will lead to additional flight time or distance flown, thus costing the airline more money. This model provides a tool to help demonstrate the monetary value of pilot proficiency (Sherry et al., 2009).

## Cost-effectiveness of training devices

Some training devices may be more cost-effective than others. In general, the literature advocates the idea of using only the fidelity necessary to achieve the desired training objectives to minimize cost.

To determine if a training device is cost effective, the literature discusses the importance of considering whether the benefit of the training device outweighs its costs (McCauley, 2006; Bürki-Cohen, Kendra, et al., 2000). A reasonable way to judge the benefit of a training device is by its training effectiveness. Training effectiveness is determined by how well the device helps students achieve their training objectives, provides positive transfer of training, and reduces other resources required to train effectively. There is good argument for including the training device in the program if the value gained through its training effectiveness is greater than the device's acquisition and maintenance costs (McCauley, 2006).

Whether to include certain functions or features likewise is a question of whether they are cost-effective. For example, in helicopter flight there are force cues present. It may be appropriate to include force cues in the simulator if providing the cues allows the student to demonstrate sufficiently improved skills in the helicopter and the level of improvement justifies the cost (McCauley, 2006).

For training objectives that require many potentially interacting systems, the use of a simulator can provide cost savings over using the actual aircraft for training (McCauley, 2006). However, for small aircraft, a simulator may not be available, or the cost of the aircraft may be less than or equal to the cost of a simulator (Bürki-Cohen, Sparko, & Go 2007).

For training objectives focusing a single system or concept, the use of part-task trainers are less expensive and may be an appropriate choice over the costly full-flight simulator (Bürki-Cohen, Kendra, et al., 2000).

For another cost savings method, Kearns (2008) suggests a technique called guided mental practice (GMP). In GMP, pilots watch a video of a scenario flown in a flight simulator as they imagine themselves as the pilot and are guided through the practice exercise. This is different from a purely internal imaginary process that is typical in a traditional mental-practice exercise. GMP can be offered through a computer-based or web-based trainer and does not require any additional peripheral devices. Therefore, this method can be delivered at a significantly reduced cost (Kearns, 2008).

## Cost of simulators

Simulators are expensive whether they are purchased for use in-house or simulator time is rented at another facility (Bürki-Cohen et al., 2007). While the cost of a high-fidelity simulator is a difficult challenge for a large airline, it can be beyond the reach of a small regional air carrier (McCauley, 2006).

The literature discusses an expanding need for qualified flight-simulation training devices (FSTDs) that are both affordable and effective. Bürki-Cohen, Sparko, Go, and Jo (2009) point out that the changes caused by NextGen and the European Commission's Single European Sky ATM Research (SESAR) program will create an even greater need for accurate simulation of environmental hazards and loss-of-control situations. Therefore, it is important that the FSTDs support these training needs and do so in an affordable manner so that their benefits can be taken advantage of by both large and small carriers (Bürki-Cohen et al., 2009).

### Cost effectiveness of simulators

The use of simulators to train pilots or aircrew members can be cost effective (Bürki-Cohen, Soja, & Longridge, 1998a; Moroney & Lilienthal, 2008). This advantage results from the ability to train without using actual aircraft and since the aircraft is not used, fuel usage is reduced (McCauley, 2006). Additionally, mechanical wear and tear on the aircraft as well as aircraft-maintenance costs are reduced, and aircraft that might have been used for training are available for flights that produce revenue (Moroney & Lilienthal, 2008).

A study of training devices used by flight-training organizations performed by Wiggins et al. (2002) found that flight schools are using various training devices and computer programs instead of flight time in an airplane. One of the reasons for this use is likely due to cost savings for both the student and the flight school (Wiggins et al., 2002).

### Cost of motion

The cost effectiveness of simulators used in training is a frequently noted advantage found in the literature. However, many sources note an increase in costs primarily related to full-motion simulators, especially at smaller or regional airlines.

There is a shortage of qualified full-flight simulators, which adds to the high rental and purchase costs (Bürki-Cohen et al., 1998a; Bürki-Cohen, et al., 2007). The loss of revenue when using the airplane for training is significantly less for small airplanes than for large airplanes (Bürki-Cohen et al., 2007). These factors often lead to decisions, especially by regional airlines, to perform at least part of the training program in an actual aircraft (Bürki-Cohen, et al., 1998a).

The cost of simulator motion is very high and includes the cost of procurement, maintenance, operating costs, personnel (i.e., highly trained technicians that are necessary to properly maintain the system), and the construction and maintenance of a facility to

house the large, heavy, motion-equipped simulator (Bürki-Cohen et al., 2007). In addition, it is very costly to create an aircraft-motion-dynamics model that captures all the rich and complex high-fidelity motion dynamics that produce effective motion cues (Bürki-Cohen et al., 2007). Because of these high costs, some training departments may not be able to afford to include motion in their simulations (Bürki-Cohen et al., 2007). Small regional carriers forced to use these devices suffer a financial burden (McCauley, 2006).

Bürki-Cohen, et al. (2007) estimate that when simulator time must be rented, airlines may experience an increase in rental costs for motion of between 25% and 50%. For recurrent training, an additional $385 million per year may be spent by U.S. airlines for motion (Bürki-Cohen et al., 2007). Additional costs are incurred, especially for motion-based and dome simulators, because they require air-conditioned facilities and specialized maintenance personnel (Moroney & Lilienthal, 2008).

**Cost of high fidelity**

In a survey of instructor/evaluators from a cross-section of U.S. airlines training under AQP, Bürki-Cohen (2003) found that instructor/evaluators are concerned that incorporating elements of operations that make them truer to real life but are not required in the regulations is now considered a luxury (e.g., realistic radio communications). Without either evidence that more realistic radio communications produce a gain in safety or it becomes an FAA requirement, training departments are unlikely to allocate funding for it (Bürki-Cohen, Kendra, et al., 2000).

Another example of a feature that may be difficult to justify is large-scale simulations with sophisticated representations of the external environment in which the aircraft is flying. The underlying expert or intelligent system is very expensive to develop, and the training benefit that this level of realism offers may simply be too expensive to justify. However, an alternative component-based development approach may allow for the cost-effective creation of such a system. To do this, small modular elements within a very limited range of criteria are developed, and then these small modules are each added into an existing system (Bürki-Cohen, Kendra, et al., 2000).

## Cost of PC simulators

PC simulators offer significant cost savings over training in an aircraft, full-flight simulator, or fixed-based simulator. The cost savings are realized not only through lower acquisition costs but also in significantly lower maintenance and operational costs (D'Alessandro, 2007; Taylor et al., 2003; Wiggins et al., 2002). However, D'Alessandro (2007) points out that PC simulators have a peak transfer-of-training efficiency. There is a point at which the use of the PC-based simulator no longer provides an efficient training benefit, and the pilot must move on to a different training device.

## Cost of training automation

Young et al. (2006) notes that because of financial burdens, training programs may minimize the hours they allocate to automation training.

Casner (2003b) suggests that automation skills be trained to some extent in the classroom.

## Cost of training safety-critical tasks (near transfer)

Sherry et al. (2009) describe a method using the near-transfer phenomenon for training and evaluating required safety-critical tasks. In this method, a single task is systematically chosen from each family of tasks to be the one that is trained and tested to proficiency. Because it is reasonable to assume that the single task accurately represents the pilot's proficiency in performing any task from that family, the need to train the other tasks in the

family is eliminated. The fewer tasks that need to be trained, the fewer training expenses are incurred (Sherry et al., 2009).

## Cost of new hires

Training is not only expensive for airline-training departments, but also it is expensive for private individuals who desire to become a pilot. Because the funds available for pilot training in the private sector or at the college level may be difficult to come by for some individuals, the result is a significant variation in the range of skills that new pilots possess when they are hired at an airline (Dahlström, Dekker, & Nählinder, 2006). One challenge training organizations must face is an additional training burden because the focus of the early stages of pilot training is not aligned with the initial requirements of the airlines (Harris, 2009).

NASA undertook a research effort comprised of a number of projects with the goal of promoting the learning of cockpit automation in professional education programs. Casner (2003a) and Casner (2003b) describe a study that was part of this effort which explored teaching cockpit-automation concepts and skill using advanced automated systems in small piston-engine training aircraft. The results of the study suggest that using the similarities between the automated systems of these small aircraft and large jets is a simple, cost-effective method to successfully introduce airline-bound student pilots to cockpit automation (Casner, 2003a; Casner, 2003b).

## Cost of overcoming design issues

If the user interface of a flight-deck system is not designed well, additional training often must be delivered to overcome usability issues. If design issues are removed, this additional training burden is eliminated and can result in a less costly training program. For example, usability issues have been identified with the FMS scratchpad error message. If the issues with the error message were addressed, it is likely that less training would be needed (Sherry et al. 2006).

## Cost of AQP

Wiener et al. (1999) discuss the use of AQP, the voluntary alternative to traditional regulatory requirements. In a study done at Continental Airlines, Wiener et al. (1999) found that the savings expected from AQP are hard to find. While Wiener et al. (1999) does not offer a stand on cost-benefits and drawbacks, some of AQPs adherents feel that AQP is inherently expensive, but it allows the training department to do a better job.

# Technical challenges

When developing and implementing training programs, technical limitations must be overcome to ensure that the pilot training is effective.

## Challenges in developing accurate models

Challenges in developing accurate models include the following:

- Difficulty of representing many independent asynchronous actions within systems
- Complex relationships among systems
- Appropriate scaling representations of sequences of behaviors or actions
- Need to start or stop an action based on changing conditions
- Accurately modeling the external physical world
- Accurately modeling cognitive phenomena

- Running a model in real time

(Taylor et al., 2003)

## Challenges of motion simulators

To simulate motion, specialized platforms are used to generate physical motion cues. The capabilities of the platform hardware have a greater affect on motion fidelity than the dynamics model used in software. The hardware is limited by such things as its ability to dynamically cover the frequency of bandwidth and by the maximum displacement that the hardware can produce. The most fundamental limitation is that motion-system platforms cannot generate the sustained acceleration cues that are experienced during real flight because they are limited by the actuators' available linear displacement. The linear-displacement capability constrains the duration and amplitude available for producing the acceleration cues (Bürki-Cohen et al., 2007).

To overcome these hardware constraints, simulators must rely on cues other than physical motion, such as high-fidelity visual systems, to provide the motion cues to the pilots in the simulator (Bürki-Cohen et al., 2007).

## Logistical challenges

The logistics of training pilots can pose significant challenges. Instead of bringing pilots to the training, distance-learning tools can bring training to the pilots, allowing them to engage in training when and where it is convenient (Kearns, 2008).

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# Pilot Training Research Annotated Bibliography

This annotated bibliography includes research literature and other documents addressing state-of-the-art knowledge about pilot training as we look toward future development of training programs for NextGen operations. The focus of the literature search was on research related to pilot-training development, content, and tools and devices with priority given to more recent literature that describes the current understanding of each of the topics. Some research about general aviation research was read and included in this list as it relates to transport airplane training; however, general aviation training is not covered comprehensively here. Similarly, some reports about the development and evaluation of simulator algorithms and models were reviewed and is included, but that area was not covered exhaustively as it was deemed out of scope of this project.

This chapter describes the relevant literature that we identified and includes information allowing readers to make a preliminary determination about the usefulness of each document for meeting their needs. To this end, the annotations include a description of the training-related focus of the document that we developed, along with the author's description of the document (abstract or summary). When possible we tried to include the association between documents in our short, training-focused description, such as when they are describing the same study or analyses of the same data, in hopes that this would be a useful addition for readers trying to understand the work as a whole. Annotations are presented in alphabetical order by last name of the first author.

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Abbott, T (1997). *A comparison of two control display unit concepts on flight management system training*. NASA Technical Memorandum 4744.

### Training-Related Highlights

This experimental study examined the effects of the control display unit (CDU) on initial FMS pilot training. Two CDU interfaces were developed, one similar to a current design and the other a graphical user interface. The results were marginally better for the graphical CDU, but greater benefits could perhaps be obtained with designs that directly support pilot operational tasks.

### Author's Description
*From the Introduction*

"One of the biggest challenges for a pilot in the transition to a "glass" cockpit is understanding the flight management system (FMS). Part of this challenge is brought about by the complex nature of this system, and a component of this complexity may be the pilot-FMS interface (refs. 1–4). For these reasons, a large portion of transition training is devoted to the FMS. The intent of the current study was to examine the impact of the primary pilot-FMS interface, the control display unit (CDU), on initial FMS pilot training. The hypothesis of this study was that the interface could significantly impact training. For this experiment, two CDU interfaces were developed. One of the CDU's was similar to a current-generation design, and the other was a multiwindows concept based on graphical-user-interface (GUI) techniques. For this initial design, both CDU's were of the same physical size and were as functionally equivalent as possible, with the graphical interface functionally

superimposed over the conventional system. Further constraints were applied so that the evaluation could focus primarily on the effects of the multiple windows and direct-manipulation aspects of GUI designs. The FMS pilot training was based on a traditional airline training syllabus, but with the training time severely abbreviated. At the end of the training, an evaluation was conducted in a final, full-mission simulation context. This paper briefly describes the results of this study" (p. 1).

Allen, J.A., Hays, R.T., & Buffardi, L.C. (1986). Maintenance training simulator fidelity and individual differences in transfer of training. In R.W. Swezey and D. H. Andrews (Eds.), *Readings in Training and Simulation: A 30-Year Perspective* (pp. 272-284). Santa Monica, CA: Human Factors and Ergonomics Society.

### Training-Related Highlights

This study investigated the relationship between simulator fidelity and the effectiveness of training electromechanical troubleshooting. Results indicated that physical and functional fidelity were interdependent and that temporal measures were most sensitive to fidelity manipulations.

### Authors' Description
*From the Abstract*

"This study was undertaken to investigate the relationship between simulator fidelity and training effectiveness. Two aspects of simulator fidelity were manipulated, namely, the degree to which a training simulator "looked like" actual equipment (physical fidelity), and the extent to which it "acted like" real equipment (functional fidelity). A transfer of training design was used to assess learning. Performance on an electromechanical troubleshooting task was correlated with a number of individual difference variables. Results indicated that physical and functional fidelity were interdependent and that temporal measures were most sensitive to fidelity manipulations. Low functional fidelity was associated with longer problem solution and inter-response times. Persons with high analytic abilities took longer to solve problems, but required fewer troubleshooting tests and made fewer incorrect solutions" (p. 272).

AOPA Air Safety Foundation (2007). Technologically advanced aircraft safety and training. *Air Safety Foundation Special Reports.* Retrieved February 19, 2010 from http://www.aopa.org/asf/publications/topics/TAA2007.pdf.

### Training-Related Highlights

This report describes accident trends in technically advanced GA aircraft and suggests changes to training and to the aircraft.

### Author's Description
*From the Executive Summary*

"Technically Advanced Aircraft (TAA) are entering the general aviation (GA) fleet in large numbers. The categories are newly designed aircraft, newly manufactured classic design aircraft equipped with new avionics, and retrofitted existing aircraft of varying ages.

Early reviews of accidents show nothing unique to TAA relative to other categories of aircraft.

Training requirements center on differences in new-design TAA handling characteristics and the addition of capable but complex avionics packages. Light GA pilots are now undergoing the transition that the airlines and corporate pilots did in prior decades. The use of autopilots as an integral part of single-pilot IFR TAA operations should be embraced.

Deliveries of new equipment have overtaken the training infrastructure in some cases. CFIs and pilots are adapting with the manufacturers and training organizations, ramping up in experience and in capability. More and better simulation will ease the transition. Training nontraditional avionics in the traditional inflight way is not optimal. Use of CD/DVD and online simulation is a big step forward, as is the development of relatively inexpensive simulators for new TAA" (p. 1).


ATA Group Guides Training. (1999). *Aviation Week & Space Technology* Section: Air Transport, *151*(4), 66.

### Training-Related Highlights

This resource is a magazine article that describes the work of an ATA sub-committee on Human Factors. The subcommittee suggests that airlines should create policies related to the use of flight-deck automation and then provide training programs that teach the policies in a useful manner. The subcommittee also suggests that pilots should be able to decide on the appropriate level of automation to use, depending on the situation. This is a change in the initial guidelines related to automation use where the training focused on instructing pilots to use the highest level of automation at all times.

### Author's Description
No abstract, executive summary, or other short descriptions were included in the document.


Baker, D., Beaubien, J. M., & Mulqueen, C. (2002). *Airline pilot training survey: Final report.* Washington, DC: American Institutes for Research.

### Training-Related Highlights

This paper describes a large pilot survey that included 30,000 pilots from 24 of the 30 main U.S. passenger carriers at the time. The survey addressed pilot perceptions of, and experiences in, pilot training. This resource is the final technical report for the entire airline pilot survey. Documents that focus on particular areas of the survey results have been described in other resources in this bibliography.

### Authors' Description
*From the Executive Summary*

"This report summarizes the methodology and results from a nationwide survey of commercial airline pilots regarding their perceptions of and experiences in their training. As a result of the implementation of the Advanced Qualification Program (AQP) at a number of major and regional air carriers, commercial airline pilots are now trained under 14 CRF Part 121, AQP, or single-visit training (SVT), which is an interim phase of AQP development. Therefore, a unique opportunity existed to

identify the strengths and weaknesses of different approaches to pilot training – traditional Part 121 training and the AQP – the results of which could be used to improve these training programs.

To ensure the success of this effort, the American Institutes of Research (AIR) worked closely with the Air Line Pilots Association (ALPA), Independent Association of Continental Pilots (IACP), the Allied Pilots Association (APA), and the Air Transport Association (ATA) to develop the survey's content. The survey was truly a collaborative effort among the federal government, unions, and the air carrier industry. Each group was represented on a technical advisory board that provided oversight throughout the project.

The *Airline Pilot Training Survey* was one of the largest surveys ever conducted in aviation. The survey was developed and administered to a stratified random sample of 30,732 pilots from 24 of the largest U.S. passenger carriers. The survey sought to answer several questions:

- To what extent do pilots find their training useful (i.e., utility reactions)?
- To what extent are pilots satisfied with their training (i.e., affective reactions)?
- To what extent do affective and utility reactions vary by:
    - Training program (i.e., AQP, SVT, and Part 121 training);
    - Training type (e.g., initial qualification, continuing qualification, etc.); and
    - Training experience?
- What are pilots' opinions about different training issues?

Utility reactions, affective reactions, and opinions were collected on a number of different training content areas including: training and checking intervals; general reactions to training, instructors, evaluation and training information; training content and instructional techniques; crew resource management (CRM); Line-Oriented Flight Training (LOFT); Special Purpose Operational Training (SPOT); and Check Ride" (pp. v-vi).

Baker, D. P., & Dismukes, R. K. (2002). A framework for understanding crew performance assessment issues. *International Journal of Aviation Psychology,* 12(3), 205-222*.

### Training-Related Highlights

This paper introduces a special issue of the journal devoted to the training of instructors for assessing crew performance. The authors lay a foundation for the special issue by describing a framework that applies to crew-performance training and evaluation.

### Authors' Description
*From the Abstract*

"The focus of this special issue is on training pilot instructors to assess crew performance. In this opening article we attempt to set the stage for the other articles in this issue by introducing a framework for understanding crew-performance assessment. We use this framework to outline issues that should be addressed when training pilot instructors and we point to specific articles in the special issue that begin to answer these questions. We also look to literature from domains outside aviation psychology for guidance. Research on performance appraisal in the field of

industrial psychology provides techniques and knowledge relevant to training instructors to evaluate crews reliably and validly. We conclude with a series of research questions that should be addressed" (p. 205).

Baker, D. P. & Dismukes, R. K. (2003). *A gold standards approach to training instructors to evaluate crew performance*. (NASA Technical Memorandum 212809). Moffett Field, CA: NASA Ames Research Center.

### Training-Related Highlights

This paper defines three limitations of pilot instructor training and methodologies to address them. The proposed method, Gold Standards Training, focuses on teaching new instructors to rate crew performance the same way highly experienced instructors rate them.

### Authors' Description
*From the Introduction*

"The Advanced Qualification Program requires that airlines evaluate crew performance in Line Oriented Simulation. For this evaluation to be meaningful, instructors must observe relevant crew behaviors and evaluate those behaviors consistently and accurately against standards established by the airline. The airline industry has largely settled on an approach in which instructors evaluate crew performance on a series of event sets, using standardized grade sheets on which behaviors specific to event set are listed. Typically, new instructors are given a class in which they learn to use the grade sheets and practice evaluating crew performance observed on videotapes. These classes emphasize reliability, providing detailed instruction and practice in scoring so that all instructors within a given class will give similar scores to similar performance.

Only a few studies have examined the reliability achieved in typical classes for new instructors, however, the limited data available suggest that it can be fairly good: instructors within a given class give fairly consistent ratings (Baker, Mulqueen, & Dismukes, in press; Goldsmith & Johnson, in press; Holt, Hansberger, & Boehm-Davis, in press). However, the existing approach has important limitations; (1) ratings within one class of new instructors may differ from those of other classes; (2) ratings may not be driven primarily by the specific behaviors on which the company wanted the crews to be scored; and (3) ratings may not be calibrated to company standards for level of performance skill required. In this paper we provide a method we have developed to extend the existing method of training instructors to address these three limitations. We call this method the "gold standards" approach because it uses ratings from the company's most experienced instructors as the basis for training rater accuracy. Further, this approach ties the training to the specific behaviors on which the experienced instructors based their ratings. Gold standards training focuses on teaching new instructors to rate crew performance the same way highly experienced instructors do.

The gold standards approach is based on preparing annotated videotapes of crews performing at several levels of effectiveness in specific event sets. The airline-training department assembles a team of highly experienced instructors who view the videotapes and identify strong points and weak points of crew performance relevant to the skills on which the crew is to be evaluated. Through discussion the instructors reach consensus on what grade to give for each event set and which behaviors are relevant to that grade. These grades and behaviors are listed in the

annotation of the videotapes. During class new instructors can compare their ratings to the consensus ratings of experienced instructors and can discover on which specific behaviors the ratings should be based. Research has shown that formal evaluation of performance is most effective when evaluators are trained to conduct evaluation as a two-part process: (1) identification and observation of relevant behaviors and (2) scoring the relevant behaviors. The gold standards approach delineates these two aspects and provides training in both. In this paper we provide a practical description of how to use the gold standards approach" (pp. 1-2).

Baker, D.P., Gustafson, S., & Beaubien, J.M. (2003). Airline pilots' experiences in and reactions to their check rides: Results from a nationwide, representative survey. Published in *Proceedings of the 2003 Society of Automotive Engineers' World Aviation Congress and Display*. Washington, DC: Society of Automotive Engineers.

### Training-Related Highlights

This paper presents a portion of the results from the pilot survey described earlier in Baker, D., Beaubien, J. M., & Mulqueen, C. (2002) and focuses on a comparison of the pilot' perceptions about the effectiveness of the maneuver validation (MV) evaluations and line operational evaluations (LOE). No significant differences in the effectiveness between the two were found.

### Authors' Description
*From the Abstract*

"While a substantial body of research has explored the effectiveness of airline pilot training programs, few studies have examined the check rides that occur at the end of training. To address this critical gap, we conducted a nationwide, representative survey of commercial airline pilots. In this paper, we explore their reactions to maneuver validations (MVs) and Line Operational Evaluations (LOEs). On average, the respondents rated both types of checking procedures favorably. Moreover, despite having a representative sample, reliable scales, and a high degree of statistical power, we found no practically or statistically significant differences between the perceived effectiveness of MVs and LOEs. The data suggest that airline pilots perceive both types of check rides as being equally effective. Implications and directions for future research are discussed" (p. 1).

Beaubien, J. M., & Baker, D.P. (2002). Airline pilots' perceptions of and experiences in crew resource management (CRM) training. *Proceedings of the 2002 Society of Automotive Engineers' World Aviation Congress and Display*. Washington, DC: Society of Automotive Engineers.

### Training-Related Highlights

This paper presents a portion of the results from the pilot survey described earlier in Baker, D., Beaubien, J. M., & Mulqueen, C. (2002) and focuses on the survey questions specifically addressing perceived effectiveness of CRM training.

### Authors' Description
*From the Abstract*

"We surveyed over 30,000 airlines pilots to assess their perceptions of and experiences in their professional training. In this paper, we describe their responses

to a series of questions that focus on Crew Resource Management (CRM) training. The results suggest that most pilots are satisfied with their CRM training and find it useful. However, the respondents indicated that training programs which integrate CRM principles throughout the entire curriculum are substantially more useful than stand-alone CRM training courses" (p. 1).

Beaubien, J. M. & Baker, D. P. (2003). Post-training feedback: The relative effectiveness of team-versus instructor-led debriefs. *Proceedings of the 47th Annual Meeting of the Human Factors and Ergonomics Society, 13-17 October 2003, Denver, CO,* 2033-2036.

### Training-Related Highlights

This study presents a portion of the results from the pilot survey described earlier in Baker, D., Beaubien, J. M., & Mulqueen, C. (2002) and focuses on results about the effectiveness of four post-training debriefing approaches: team debriefings with and without videotape, and instructor debriefings with and without videotape. The results indicated that the approaches may be equally effective.

### Authors' Description
*From the Abstract*

"In many high-risk domains, simulators are used for training and evaluating team performance under realistic conditions. Once the simulation is complete, the teams review their performance to identify the lessons that they have learned. These post-training debrief sessions may be either instructor- or team-led. Unfortunately, the relative effectiveness of instructor- versus team-led debriefs remains unclear. To address this question, we surveyed a nationwide, representative sample of over 30,000 pilots from 24 U.S. airlines. Despite having a high degree of statistical power and a reliable scale, we found no statistically or practically significant differences among the four most common approaches to post-training feedback: team debrief with videotape, team debrief without videotape, instructor debrief with videotape, and instructor debrief without videotape. The results suggest that all four approaches may be equally effective" (p. 1).

Beaubien, J. M., Holt, R. W., & Hamman, W. R. (1999). Evaluating LOE quality from performance database information. *Proceedings of the Tenth International Symposium on Aviation Psychology. Columbus, OH*: The Ohio State University Press.

### Training-Related Highlights

This paper describes multiple methods that can help airlines assess the usefulness of their AQP crew-performance data.

### Authors' Description
*From the Abstract*

"Carriers operating under the FAA's Advanced Qualification Program (AQP) are required to maintain databases of crew performance information for use in curriculum refinement and validation. Unlike traditional database management systems, however, crew performance databases must be developed and maintained in such a manner as to allow an assessment of the data's psychometric properties. Using grounded theory and conventional statistical techniques, the authors present a

variety of procedures to assist carrier personnel in assessing the usefulness of their crew performance data" (p. 1).

Blackmon, M.H., & Polson, P.G. (2002). Combining two technologies to improve aviation training design. In *HCI-Aero 2002 Proceedings*, *American Association for Artificial Intelligence (AAAI)*, (pp. 24-29).

### Training-Related Highlights

The paper describes seven key guidelines for cognitive tutors and how they can facilitate the learning of automated systems, reduce overall training time, and improve transfer to situations that may not have been explicitly trained.

### Authors' Description
*From the Abstract*

"Combining two recent technologies can markedly improve the performance outcomes and cost-effectiveness of aviation training. The first is a well-tested design methodology for developing cognitive tutors (Anderson et al. 1995, Anderson and Schunn 2000) based on modern theories of skill acquisition. The second is the advent of high-fidelity PC-based part-task simulators on which pilots can ''learn by doing' and ''progress to real-world performance," two essential guidelines for designing cognitive tutors. An experimental flightcrew automation training program (McLennan et al. submitted) produced results consistent with non-aviation training results using Anderson's cognitive tutors, implying that pilots trained on cognitive tutors can attain the same or higher level of competence in approximately one-third the training time for traditionally trained pilots" (p. 24).

Blaiwes, A.S., Puig, J.A., & Regan, J.J. (1973). Transfer of training and the measurement of training effectiveness. *Human Factors, 15*(6), 523–533.

### Training-Related Highlights

This paper reviews the evolution and challenges of transfer-of-training research, reviews methods for determining training effectiveness, identifies transfer-of-training research themes, and presents desirable characteristics for future research. The paper gives reasons for the difficulty of measuring the transfer of training through the use of a simulator.

### Authors' Description
*From the Abstract*

"Transfer of training research has been conducted on actual training systems to determine: (1) the effectiveness of present training; (2) whether the training can be improved; and, (3) how the training might be improved. The present paper includes some major methodological and analytical considerations in performing this research-the experimental and descriptive models to use in investigating and expressing transfer, cost effectiveness evaluations, and aspects of the training system to be included in the study. A number of conclusions are derived from the transfer research and some popular research themes are identified. Desirable features for an applied research program for military training purposes are presented. Problems arising from the use of the transfer of training model are traced to operational constraints placed on experimental manipulation and control, and to

the inadequacy of performance measurement systems. Solutions to these problems are discussed. One solution provides alternate methods to the transfer of training model for evaluating the effectiveness of a training system. Another approach recommends the employment of laboratory simulations of training or operational situations for transfer research" (p. 2).

Bürki-Cohen, J. (Ed.). (1996). Electronic transcript of the *Joint FAA/Industry Symposium on Level B Airplane Simulator Motion Requirements, 19-20 June 1996, Washington Dulles Airport Hilton.*

### Training-Related Highlights

This paper includes the transcript of a symposium held to "discuss motion in Level B flight simulators and updates to FAA qualification requirements." The intent was to determine whether Level B simulators could be manufactured for a lower cost and still meet the recurrent training requirements. Requirements resulting from the effort included a minimum of four degrees of freedom for the Level B simulator (pitch, roll, heave, and sway). Research that should be accomplished was also discussed.

### Author's Description
No abstract, executive summary, or other short descriptions were included in the document.

Bürki-Cohen, J. (2003). Evidence for the need of realistic radio communications for airline pilot simulator training and evaluation. In *Proceedings of the International Conference Simulation of the Environment, Royal Aeronautical Society, 5-6 November, London, UK.*

### Training-Related Highlights

This paper provides a summary of research related to the need for the simulation of radio communications during pilot simulator training and evaluation. This work includes a review of current practices through a survey of pilot instructors and evaluators, a literature review, an ASRS incident study, and a review of current efforts to improve industry practices.

### Author's Description
*From the 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" (p. 1).

Bürki-Cohen, J., Boothe, E. M., Soja N. N., DiSario, R., Go, T., & Longridge T. (2000). Simulator fidelity: The effect of platform motion. *Proceedings of the International Conference Flight Simulation - The Next Decade, Royal Aeronautical Society, 10-12 May 2000, London, UK*, 23.1-23.7.

### Training-Related Highlights

This study investigated the effect of simulator motion on the transfer of training performance. Data from this work was intended to help the FAA evaluate air carrier proposals for the use of training devices in place of full-flight simulators.

### Authors' Description
*From the Abstract*

"This research is part of the Federal Aviation Administration's (FAA) initiative towards promoting affordable flight simulators for U.S. commuter airline training. This initiative becomes even more important as the FAA is considering regulatory action that will mandate the use of simulators for all air carrier flight-crew training and qualification. Consequently, sound scientific data on the relationship between certain simulator features such as platform motion and their effect on the transfer of pilot performance and behavior to and from the respective airplane become very important. The present study examined the effect of platform motion (i.e., FAA qualified Level C six-degree-of-freedom synergistic motion) in the presence of a high-quality wide-angle visual system on 1) pilot performance and behavior for *evaluation* prior to any repeated practice or training, 2) *the course of training* in the simulator, and 3) the *transfer of skills* acquired during training in the simulator with or without motion to the simulator with motion as a stand-in for the airplane (quasi-transfer design). Every effort was made to avoid deficiencies in the research design identified in a review of prior studies, by measuring pilot stimulation *and* response, testing both maneuvers and pilots that are *diagnostic* of a need of motion, avoiding pilot and instructor *bias*, and ensuring sufficient statistical *power* to capture operationally relevant effects. Results of the analyses and their implications are presented in this paper" (p.1).

Bürki-Cohen, J. & Go, T.H. (2005). The effect of simulator motion cues on initial training of airline pilots. In *Proceedings of the AIAA Modeling and Simulation Technologies Conference, 15-18 August 2005, San Francisco, CA*, AIAA-2005-6109.

### Training-Related Highlights

This work describes preliminary results from an experimental study addressing the effects of simulator platform motion on the training of pilots who have never before flown the airplane for which they are being trained. Recommendations for further study are made.

### Authors' Description
*From the Abstract*

"Two earlier studies conducted in the framework of the Federal Aviation Administration/Volpe Flight Simulator Human Factors Program examining the effect of simulator motion on *recurrent* training and evaluation of airline pilots have found that in the presence of a state-of-the-art visual systems, motion provided by a six-degree-of-freedom platform-motion system only minimally affected evaluation, and did not benefit training, of pilots that were familiar with the airplane. This paper

gives preliminary results of a study on the effect of simulator platform motion on initial training of airline pilots that have never flown the simulated airplane" (p. 1).

Bürki-Cohen, J., Go, T. H., Chung, W. W., & Schroeder, J. A. (2004). *Simulator platform motion requirements for recurrent airline pilot training and evaluation*. Final report.

### Training-Related Highlights

This report recaps the study on simulator motion in initial training described earlier in Bürki-Cohen, J., Boothe, E. M., Soja N. N., DiSario, R., Go, T., & Longridge T. (2000). The report builds on those results with a second study that used a simulator on which the motion was optimized based on the results of the first study. This second study looked at the effect of the enhanced motion on recurrent training. Some differences were found between the groups trained with motion or no-motion, but those effects did not last through the transfer phase of the study in which the performance of pilots was equivalent.

### Authors' Description
*From the Executive Summary*

"This report presents the results of two studies that examined the effect of enhanced hexapod-simulator motion on recurrent evaluation in the simulator, on the course of recurrent training in the simulator, and on "quasi-transfer" of this recurrent training to the simulator with motion as a stand-in for the airplane. These studies were conducted in the framework of the Volpe Center's Flight Simulator Fidelity Requirements Research Program and sponsored by the Federal Aviation Administration.

Today, airline pilots are almost exclusively trained and evaluated in flight simulators. That means that the first time a pilot flies a particular airplane or in a particular capacity in the air, the airplane is carrying paying passengers. It is therefore critical that, when evaluating a pilot in the simulator, the skills and behaviors comprising the expertise of this pilot when flying the airplane are accurately reflected in the simulator. Similarly, the skills and behaviors a pilot acquires in the simulator must transfer to the airplane. The definition of an effective simulator is therefore one that allows full transfer of performance and behavior from the airplane to the simulator for evaluation and from the simulator to the airplane for training.

The Federal Aviation Administration, who regulates simulator use for total training and evaluation of airline pilots, is responsible for ensuring that simulator requirements are sufficient for transfer of performance and behavior between airplane and simulator. To prevent simulator rental, acquisition, and maintenance costs from excluding smaller airlines from the benefits of simulator training and evaluation, however, requirements must also be necessary.

One requirement that remains controversial is the need for platform motion. Of course, the airplane does move; however, there are inherent limitations to the fidelity of the hexapod-motion platforms used for airline-pilot training. These motion platforms have been shown to be useful in some aerospace applications, but there is currently no empirical research that shows that platform motion improves transfer for airline-pilot training and evaluation. Studies to date have been limited by factors such as: (1) the quality of the available visual and motion systems, (2) the experience level of the subject population (e.g., studies often used novice pilots that may not yet have learned to capitalize on motion cues), (3) the number of subjects

used, (4) the choice of maneuver selection (e.g., using tracking maneuvers that may not require motion cues), (5) individual differences in the pilot population, and (6) combinations of these factors (e.g., the number of pilots was not sufficient to wash out individual differences between pilots that could have masked the effects of motion).

Volpe was attempting to overcome these limitations by adopting a design philosophy using a simulator with a wide field-of-view visual system known to induce the illusion of motion (vection); testing experienced and highly motivated pilots that were asked to perform diagnostic pilot-in-the-loop maneuvers with asymmetric disturbances and high workload; and measuring at a high-sampling rate the motion-performance of the simulator, pilot flight-path precision, and pilot-control inputs. Also, any factors that could mask an effect of motion, such as between-group differences in experience, were minimized by calibrating the simulator, choosing a homogenous group of pilots, and counterbalancing across groups anything else that could not be controlled. A so-called quasi-transfer design was used to control many nuisance variables such as weather or traffic. In this design, pilots that came fresh from an airplane (to prevent adaptation to the simulator) were divided into two groups, a Motion and a No-Motion group. Pilots in both groups were first evaluated to measure transfer from the airplane. Pilots in the *Motion* group were then trained in the simulator *with motion* whereas pilots in the *No-Motion* group were trained in the simulator *without motion*. Following the training session, both groups were quasi-transferred to the simulator with motion as a stand-in for the airplane in order to compare the effect of the two training methods on transfer of training. Impostor effects that might masquerade as an effect of motion, such as rater or pilot bias, were avoided by concealing the purpose of the experiment and the motion condition (on or off) of the simulator from participants.

The first Volpe study (First Study) was aimed at testing the effect of "as is" motion, i.e., the motion provided by a qualified Level C simulator that is used around the clock for airline-pilot training and checking (Bürki-Cohen, Boothe, Soja, DiSario, Go, and Longridge, 2000; Go, Bürki-Cohen, and Soja, 2000). Because the initial concern was with the affordability of simulators for regional airlines, regional-airline crews were tested on a simulator of a 30 passenger turboprop airplane with wing-mounted engines. The data was collected from approximately 40 Captains flying engine failures on takeoff before their recurrent evaluation ($V_1$ cuts and rejected takeoffs).

No systematic differences between the two groups were found, during Evaluation, Training, and Quasi Transfer to all motion. This was true for the measurements from the simulator and for the grades provided by instructor/evaluators, and also for the crew and instructor opinions collected in extensive questionnaires. Power analyses showed that the number of pilots was sufficient to wash out individual differences between pilots, so that even small effects of motion could have been found.

Does this mean that "as is" motion is equivalent to having no motion with regard to transfer between simulator and airplane for recurrent evaluation and training? The failure-induced lateral acceleration of the "as is" motion simulator, which was supposed to serve as an alerting cue for the pilot that there was an engine problem, was found to be very mild, certainly milder than the one recommended based on the flight data. It was unclear whether this is typical for other simulators used in airline-pilot evaluation and training, and a comparison with eight airline simulators showed that it might be. This would lead to the conclusion that the requirements for airplane simulators used for airline-pilot training and checking should be tightened, and such efforts are currently being discussed by regulators and industry. Given the burden to

the simulator operators to provide such motion and to the Federal Aviation Administration to enforce it, however, and the fact that airline pilots have been successfully trained and evaluated in simulators qualified under the current requirements for over twenty years, it seemed necessary to document that motion that was improved with tighter standards would result in improved transfer for airline-pilot simulator checking (evaluation) and training. This was the purpose of the Second Study, which is described in this report.

For this Second Study, the motion of a CAE Level D simulator was re-engineered to optimize the motion stimulation for the planned test maneuvers in collaboration with the National Aeronautics and Space Administration's Ames Research Center. The device simulates a Boeing 747-400 airplane with four wing-mounted engines. Its lateral acceleration and heave were enhanced trading off rotational motion (mainly yaw) based on findings in the literature. Forty current B747-400 Captains and First Officers participated, aided by two cohort pilots performing non-flying duties. The participants departed with an engine failure either just before ($V_1$ cut) or just after takeoff ($V_2$ cut), and then continued with either a precision instrument approach and landing with shifting crosswinds or a sidestep landing with a vertical upward gust just after sidestepping to a parallel runway. To make the maneuvers even more difficult (and participants subjective comments suggested that they did find them very difficult!), the autopilot and autothrottle were inoperative throughout and the flight director was inoperative during the landings only, so they had to be hand flown. These maneuvers were chosen to 1) replicate the $V_1$ cut tested in the First Study and 2) reduce any visual reference to the runway and require control in multiple axes compared to the First Study.

The results obtained with enhanced motion were very different from the First Study with "as is" motion. Several differences between the Motion and the No-Motion groups were found, and a fairly clear picture of the effect of motion emerges. First, motion did appear to alert pilots of a disturbance, as stipulated in the literature, but only for the $V_1$ cut. This may be because the $V_1$ cut occurs close to the ground and any delay in response would result in scraping the wings or the tail (which did happen, but equally rarely in the two groups, and usually because of applying the wrong rudder). Due to the motion alert, the Motion group had a faster pedal response and tracked heading slightly better, but the latter showed only during Evaluation. The No-Motion pilots, as long as they did not have the motion cue, were unable to significantly improve their pedal-response time, even during Training when they were told what failure to expect. Once they quasi-transferred to motion for Quasi-Transfer Testing however, their pedal-response time was identical to the one of the Motion group. Hence, the No-Motion pilots did not seem to need recurrent training with motion to be able to sense and appropriately respond to motion cues.

Second, training with motion cues clearly increased the control activity of the Motion pilots, especially for wheel inputs. However, this reduced their flight precision, at least for the landing maneuvers. These performance decrements in localizer, heading, or airspeed tracking were in fact the largest effects found in the study, and may be operationally relevant. Most importantly, the performance deficit of the Motion group persisted even when both groups had motion during Quasi-Transfer Testing.

Perhaps inherent to the increased control activity of the Motion group was a curious result found for the $V_2$ cut during Quasi-Transfer Testing, namely, that the Motion group responded slower to the engine failure than the No-Motion group, with apparently no effect on flight precision. One hypothesis is that the Motion group was

fatigued. An alternative explanation is that both groups were equally fatigued and that the emergence of the motion cues may have had "stimulating" effect on the No-Motion group. Overall, the $V_2$ cut does appear to have been especially fatiguing for both groups, with several variables that had significantly improved during Training compared to Evaluation significantly deteriorating between Training and Quasi-Transfer Testing for both groups.

Third, motion affected the sidestep-landing strategy in a predictable manner. When motion was available, pilots landed softer. However, pilots also landed slightly farther from the runway threshold, but still well within the landing box. Like all effects on the landing maneuvers, this effect seems to have been consolidated during Training, because it persisted even during Quasi-Transfer Testing.

Finally, the results show that both groups improved their performance for all maneuvers in the course of the experiment, regardless of whether they were trained with or without motion. Initial Evaluation, however, was subject to motion effects for all four maneuvers, as discussed above.

These results were reflected in Pilot-Flying (PF) and Pilot-Not-Flying (PNF) opinions. The PFs found the simulator equally acceptable than their company simulator regardless of group. They were also equally comfortable in it. Moreover, there was no difference between groups with respect to their comparisons of the simulator to the airplane for Control Sensitivity and Control Strategy and Technique.

For all the in-depth probing, there were only four questions on which the two PF groups disagreed, and for one of these it was the No-Motion pilots that answered more favorably: After Training, the No-Motion group gave the simulator higher handling-quality ratings than the ones given by the Motion group. The ratings of the Motion group were higher than the ones of the No-Motion group for Control Feel (even at Quasi Transfer, when the No-Motion group also had motion), Other Cues (the majority of No-Motion pilots did recognize that something was amiss) and Performance (only after Evaluation).

The PNFs ratings always were in favor of the No-Motion group, but sometimes this was due to one of the two PNFs, while the other didn't always see a difference. They felt that the No-Motion pilots were more similar to the average pilot than the motion pilots with respect to Control Strategy and Technique (but not during Evaluation). They gave higher performance and lower workload ratings to the No-Motion pilots, except during Training. For Quasi Transfer only, they gave better Gaining Proficiency ratings to the No-Motion pilots.

In conclusion, this study showed that enhanced hexapod motion, configured based on the guidelines in the literature, does have an effect. It appears to affect the accuracy of recurrent evaluation. However, the benefits for recurrent training remain questionable.

Results of these studies and the previous hexapod motion research should assist the FAA in determining future research directions in the effort to develop improved motion standards. It also may contribute to finding a cost-effective solution to today's airline evaluation and training needs via an appropriate combination of fixed-base and motion-base simulators" (pp.13-16).

Bürki-Cohen, J., Go, T. H., Chung, W. W., Schroeder, J., Jacobs, S., & Longridge, T. (2003). Simulator fidelity requirements for airline pilot training and evaluation continued: An update on motion requirements research. *Proceedings of the 12th International Symposium on Aviation Psychology, April 2003, Dayton, OH*.

### Training-Related Highlights

This is a conference proceedings paper that describes the preliminary results from the study described earlier in Bürki-Cohen, J., Go, T. H., Chung, W. W., & Schroeder, J. A. (2004) addressing the effect of enhanced simulator motion on airline pilot recurrent training.

### Author's Description
*From the Abstract*

"Preliminary results are presented on the effect of enhanced hexapod motion on airline pilot recurrent evaluation, training, and transfer of training to the simulator with motion as a stand-in for the airplane (quasi-transfer). A first study, which tested "as is" motion in an FAA qualified full flight simulator, had not found any effect of motion. Under the enhanced motion conditions of the present study many effects of motion emerged that have not been previously shown in the airline-pilot training and evaluation context, indicating that motion may be required at least for pilot evaluation purposes. The implications of the results for recurrent training are also discussed" (p.1).

Bürki-Cohen, J., Go, T.H., & Longridge, T. (2001). Flight simulator fidelity considerations for total airline training and evaluation. In *Proceedings of the AIAA Modeling and Simulation Technology Conference, August 2001, Montréal, Canada*, AIAA-2001-4425.

### Training-Related Highlights

This conference paper describes findings of the study described earlier in Bürki-Cohen, J., Boothe, E. M., Soja N. N., DiSario, R., Go, T., & Longridge T. (2000) addressing the effect of simulator motion on initial pilot training and later in the list in Bürki-Cohen, J. & Kendra, A.J. (2001) concluding that improvements in radio communications realism are needed.

### Authors' Description
*From the Abstract*

"This paper presents the FAA/Volpe Center's Flight Simulator Fidelity Research Program, which is part of the Federal Aviation Administration's effort to promote the effectiveness, availability and affordability of flight simulators. This initiative will become increasingly critical with the anticipated regulatory changes mandating the use of simulators in airline pilot training and evaluation, dramatically reduced pilot new-hire experience levels and growing operational complexity. Two research areas with high pay-off potential for this effort are radio communications and platform motion simulation. Initial results suggest that for fully effective training and evaluation of the cognitive and workload management skills associated with radio communications, significant improvements in radio communications realism are needed. Initial research on the training effectiveness of a fixed-base simulator with a wide field-of-view visual system compared to a like system having platform motion failed to find an operationally significant effect of motion. Follow-up work will examine whether this result was a function of the motion characteristics or the

maneuvers tested. No changes in regulatory requirements can be expected without absolute confidence in the reliability and validity of the results, requiring considerable additional research in both areas" (p. 1).

Bürki-Cohen, J. & Kendra, A.J. (2001). Air traffic control in airline pilot simulator training and evaluation. *Air Traffic Control Quarterly*, Vol. 9(3), 229-253.

### Training-Related Highlights

This resource provides a summary of research related to the value and use of realistic radio communications during airline pilot training and evaluation events conducted in simulators. This work includes the first year of work that is also described in Bürki-Cohen, J., Kendra, A.J., Kanki, B.G., & Lee, A.T. (2000) and comprises several elements including a review of current practices through a survey of pilot instructors and evaluators, a literature review, an ASRS incident study, and a review of current efforts to improve industry practices.

### Authors' Description
*From the Abstract*

"Much airline pilot training and checking occurs entirely in the simulator, and the first time a pilot flies a particular airplane, it may carry passengers. Simulator qualification standards, however, focus on the simulation of the airplane without reference to the air traffic environment. This paper describes research examining the question of whether simulator pilot training and evaluation would benefit from improved simulation of radio communications. First, existing radio communication simulation practices were investigated. Second, opinions from instructors/evaluators were solicited. Third, the pertinent literature was reviewed. Fourth, the effectiveness of current practices was evaluated by surveying the Aviation Safety Reporting System. Finally, recent efforts to improve radio communication simulation were examined. The paper concludes that there is much evidence that increasing the realism of radio communications would improve simulator training and evaluation of airline pilots, but that finding effective ways to do so will depend on collaboration of government, industry, military and academia" (p. 1).

Bürki-Cohen, J., Kendra, A.J., Kanki, B.G., & Lee, A.T. (2000). *Realistic radio communications in pilot simulator training*. Washington, DC: DOT/FAA/AR-00/13.

### Training-Related Highlights

This report provides results from the first year of research that examined the effectiveness of simulating radio communications during pilot simulator training and evaluation. This work includes a review of current practices through a survey of pilot instructors and evaluators, a literature review focusing on AQP and CRM/CTM (cockpit task management), and a review of technologies that could support radio communications simulation. The research presented here is also included with its follow-on work in Bürki-Cohen, J. & Kendra, A.J. (2001) described earlier.

### Authors' Description
*From the Abstract*

"Simulators used for total training and evaluation of airline pilots must satisfy stringent criteria in order to assure their adequacy for training and checking

maneuvers. Air traffic control and company radio communications simulation, however, may still be left to role-play by the already taxed instructor/evaluators in spite of their central importance in every aspect of the flight environment. The underlying premise of this research is that providing a realistic radio communications environment would increase safety by enhancing pilot training and evaluation.

This report summarizes the first-year efforts of assessing the requirement and feasibility of simulating radio communications automatically. A review of the training and crew resource/task management literature showed both practical and theoretical support for the need for realistic radio communications simulation. A survey of 29 instructor/evaluators from 14 airlines revealed that radio communications are mainly role-played by the instructor/evaluators. This increases instructor/evaluators' own workload while unrealistically lowering pilot communications load compared to actual operations, with a concomitant loss in training/evaluation effectiveness. A technology review searching for an automated means of providing radio communications to and from aircraft with minimal human effort showed that while promising, the technology is still immature. Further research and the need for establishing a proof-of-concept are also discussed" (p. ii).

Bürki-Cohen, J., Soja, N. N., & Longridge, T. (1998a). Simulator fidelity requirements: The case of platform motion. *Proceedings of the 9th ITEC International Training and Education Conference (ITEC 98), Lausanne, Switzerland*, 216-231.

### Training-Related Highlights

This conference proceedings paper describes the work presented in the journal article in Bürki-Cohen, J., Soja, N. N., & Longridge, T. (1998). This work reviews past research on simulator motion along with a research strategy and an experimental study to be conducted that revisits the effects of simulator motion in training and evaluating pilots. The goal of the study is to help determine whether motion in simulators plays a necessary role in training and evaluation. Specifically, this experiment will help answer the following three questions of interest to the FAA:

Broadly, does the training conducted in a fixed-base simulator with a wide FOV, cross-cockpit-view visual system produce results equivalent to those produced in a like system having platform-motion cueing? Regarding disturbance tasks, does recurrent training that is accomplished without motion cueing have any measurable effect on the pilot's ability to respond in the airplane? And finally, from a regulatory perspective, do recurrent proficiency checks conducted in a visually equipped fixed-base simulator verify the line-operational readiness of airline pilots without compromising the safety of the flying public?

### Authors' Description
No abstract, executive summary, or other short descriptions were included in the document.

Bürki-Cohen, J., Soja, N. N., & Longridge, T. (1998b). Simulator platform motion: The need revisited. *International Journal of Aviation Psychology, 8*(3), 293-317.

### Training-Related Highlights

This paper reviews literature on the effectiveness of platform motion in full-flight simulators to clarify the need for them at regional airlines. The conclusion was that

more research is needed to assess whether changes to current qualification requirements for motion in simulators are warranted. A research approach to begin addressing the issues is described.

### Authors' Description
*From the Abstract*

"The need to provide increased access to flight simulator training for U.S. regional airlines, which historically have been limited by cost considerations in the use of such equipment for pilot recurrent training, is discussed. In light of that need, the issue of whether more affordable fixed-base simulators, identical to full flight simulators in all respects except for absence of platform motion, might provide an equivalent level of safety when employed for recurrent training, is examined. Pertinent literature from the past two decades is reviewed. The paper observes that no definitive conclusion can be drawn that would warrant modification of current qualification requirements for platform motion in full flight simulators. The article concludes that this situation will remain unchanged unless new research is undertaken, which takes into account the lessons learned from past research, and the opportunities engendered by new technology. Broad guidelines for an appropriate research design are discussed" (p. 1).

Bürki-Cohen, J., Sparko, A. L., and Go, T. H. (2007). Training value of a fixed-base flight simulator with a dynamic seat. *Proceedings of the AIAA Modeling and Simulation Technologies Conference, August 20-23, Hilton Head, SC.,* AIAA 2007-6564.

### Training-Related Highlights

This conference paper describes cueing requirements applied to flight simulators and their contribution to improving the transfer of performance between simulator and airplane for effective training and evaluation. A proof-of-concept is described for an approach providing cueing primarily generated by visual cues and a dynamic seat.

### Authors' Description
*From the Abstract*

"In this paper, we first explain that pilots experience airplane motion via multiple perceptual systems, which makes motion a candidate for simulation via stimulation of only a subset of these systems. Next, we discuss the relative merit of vestibular cues when piloting an airplane. This is followed by a comparison of the vestibular cues received in the airplane and those possible, or practicable, in an airline-pilot training simulator, considering also the history of flight-simulator motion and alternative technologies. We conclude that a vast body of research has shown that accurate cues are not achievable at present, and that those available have not been shown to improve transfer between airplane and simulator. We then examine the cost of motion, and posit that it may prohibit some airline pilots from reaping the benefits of simulator training, with a concomitant loss in passenger safety. This consideration is especially pertinent given the world-wide training needs. Moreover, the equipment, facility, and maintenance costs associated with hexapod-platform motion systems may serve to discourage operators from upgrading the simulator's fidelity in other important areas, such as assuring that the simulator cockpit does in fact match the equipment in the target aircraft, and that the simulation includes realistic operational representation of the national air space, including the air-traffic-control environment. We describe current and planned research on the training effectiveness of an alternative approach, which provides trainees with visual motion

and heave-onset cues in what otherwise corresponds to an FAA Level D Full Flight Simulator in terms of data fidelity. This includes the results of a "proof-of-concept" phase that culminated in the successful type-rating of six pilots on a twin-engine turboprop airplane" (pg. 1).

Bürki-Cohen, J., Sparko, A. L., Go, T. H., & Jo, Y. J. (2009). Effects of visual, seat, and platform motion during flight simulator air transport pilot training and evaluation. *Proceedings of the 15th International Symposium on Aviation Psychology, April 27-30, 2009, Dayton, OH*.

### Training-Related Highlights

This conference paper describes previous results in this ongoing research program addressing simulator fidelity as described earlier Bürki-Cohen, J., Sparko, A. L., and Go, T. H. (2007) and adds initial findings about the effectiveness of using seat motion for cueing.

### Authors' Description
*From the Abstract*

"Access to affordable and effective flight-simulation training devices (FSTDs) is critical to safely train airline crews in aviating, navigating, communicating, making decisions, and managing flight-deck and crew resources. This paper provides an overview of the Federal Aviation Administration-Volpe Center Flight Simulator Human Factors Program examining the requirements for the qualification and use of FSTDs. We will summarize past research investigating the need for a full hexapod-platform motion system, describe regulatory and industry developments, and report on current activities" (p. 1).

Cannon-Bowers, J.A., Tannenbaum, S.I., Salas, E., & Converse, S.A. (1991). Toward an integration of training theory and technique. R. W. Swezey and D. H. Andrews (Eds.), *Readings in Training and Simulation: A 30-Year Perspective* (pp. 74-85). Santa Monica, CA: Human Factors and Ergonomics Society.

### Training-Related Highlights

The objective of this paper is to illustrate gaps between training theory and practice, to provide examples of how they relate to each other, and to offer approaches for research that could be designed to bridge the gaps in a pragmatic way.

### Authors' Description
*From the Abstract*

"Reviewers of the training literature have generally concluded that training theory and practice are not well integrated, and that research findings are not often translated into useful training methods. In an effort to bridge the gap between training theory and practice, an organizing framework for conceptualizing training research is presented. The purpose of the framework is to highlight the linkages between training-related theory and technique in the areas of training analysis, design, and evaluation. The linkages are described in detail, and illustrated via consideration of research into mental models. We hope that the framework will lead to future research programs that enhance the transition of training research from theory into practice, and integrate more fully these two perspectives" (p. 74).

Caro, P.W. (1973). Aircraft simulators and pilot training. In R.W. Swezey and D. H. Andrews (Eds.), *Readings in Training and Simulation: A 30-Year Perspective* (pp. 225-232). Santa Monica, CA: Human Factors and Ergonomics Society.

### Training-Related Highlights

The paper provides a historical perspective on the use of simulators in training. It presents a discussion of simulator training from its pre-1970's role in pilot training, in which simulators were used less than actual aircraft, to an emerging role, in which simulators with increased capabilities are part of a more holistic training program. The article describes positive attributes of emerging pilot training programs including training to a functional context, training to the pace of the individual, sequencing the instruction to be effective, minimizing over-training, crew training, and more. The author emphasizes that it is essential to develop an appropriate training program and then consider the value of using training devices in that program.

### Author's Description
*From the Abstract*

"Flight simulators are built as realistically as possible, presumably to enhance their training value. Yet, their training value is determined by the way they are used. Traditionally, simulators have been less important for training than have aircraft, but they are currently emerging as primary pilot training vehicles. This new emphasis is an outgrowth of systems engineering of flight training programs, and a characteristic of the resultant training is the employment of techniques developed through applied research in a variety of training settings. These techniques include functional context training, minimizing over-training, effective utilization of personnel, use of incentive awards, peer training, and objective performance measurement. Programs employing these and other techniques, with training equipment ranging from highly-realistic simulators to reduced scale paper mock ups, have resulted in impressive transfer of training. The conclusion is drawn that a proper training program is essential to realizing the potential training value of a device, regardless of its realism" (p. 225).

Caro, P. W. (1979). The relationship between flight simulator motion and training requirements. *Human Factors*, 21(4), 493-501.

### Training-Related Highlights

This article provides background information on the evolution of flight simulators for training. Studies that attempted to correlate motion cues with transfer of training are also described. Two types of motion cues are examined: those associated with maneuvers and those associated with disturbances. Additional study is recommended to examine the relationship between motion cues in a simulated environment and the transfer of training that results from these cues to the aircraft.

### Author's Description
*From the Abstract*

"Flight simulator motion has been demonstrated to affect performance in the simulator, but recent transfer of training studies have failed to demonstrate an effect upon in-flight performance. However, these transfer studies examined the effects of motion in experimental designs that did not permit a dependency relationship to be established between the characteristics of the motion simulated and the training objectives or the performance measured. Another investigator has suggested that

motion cues which occur in flight can be dichotomized as maneuver and disturbance cues, i.e., as resulting from pilot control action or from external forces. This paper examines each type cue and relates it analytically to training requirements. The need to establish such relationships in simulator design is emphasized. Future transfer studies should examine specific training objectives that can be expected to be effected by motion" (p. 233).

Carretta, T. R. & Dunlap, R. D. (1998). *Transfer of training effectiveness in flight simulation: 1986 to 1997.* Technical Report AFRL-HE-AZ-TR-1998-0078, U.S. Air Force Research Laboratory, Mesa, AZ.

### Training-Related Highlights

This report reviews studies addressing the effectiveness of flight simulators as augmentation for "hands-on" flying training, many of which focus on military flight training. The authors examined pilot training literature for two time periods: early studies conducted between 1957 and 1986 and recent (as of 1998) studies conducted between 1987 and 1997. The work provides a description of the findings for each period.

### Authors' Description
*From the Abstract*

"The purpose of this report was to review recent studies regarding the effectiveness of flight simulators as augmentation for "hands-on" flying training. Simulation-based training has been proposed to reduce costs, extend aircraft life, maintain flying proficiency, and provide more effective training, especially in areas difficult to train in operational aircraft. A review of the literature from 1986 to 1997 identified 67 articles, conference papers, and technical reports regarding simulator flying training and transfer. Of these, only 13 were related directly to transfer of training from the simulator to the aircraft. Studies of simulator effectiveness for training landing skills constituted a majority of the transfer studies, although a few examined other flying skills such as radial bombing accuracy and instrument and flight control. Results indicate that simulators are useful for training landing skills, bombing accuracy, and instrument and flight control. Generally, as the number of simulated sorties increases, performance improves, but this gain levels off after approximately 25 missions. Further, several studies indicate that successful transfer may not require high-fidelity simulators or whole-task training, thus reducing simulator development costs. Evaluation of this literature is difficult for many reasons. Typically, researchers fail to report sufficient detail regarding research methods, training characteristics, and simulator fidelity. In addition to these methodological concerns, there is a lack of true simulator-to-aircraft transfer studies involving complex pilot skills. This may be due to problems such as inadequate simulator design, cost, and availability, and access to simulators in operational flying units. Future directions in simulator transfer of training are discussed" (p.3).

Casner, S.M. (1995, May). Laptop applies new concepts in computer-based learning to flight deck automation training. *ICAO Journal, 50(*4), 18-19.

**Training-Related Highlights**

This article describes a NASA prototype FMS training system for helping pilots transition to glass cockpits. The system is PC-based, and the article also discusses the advantages of PC-based training systems.

**Author's Description**
*From the Abstract*

"A NASA research project is exploring the feasibility and effectiveness of using portable computers, higher-fidelity equipment emulation and interactive multimedia to help pilots learn about modern flight deck automation" (p. 18).

Casner, S.M. (2003a). *Learning about cockpit automation: From piston trainer to jet transport* (NASA/TM-2003-212260). Moffett Field, CA: NASA Ames Research Center.

**Training-Related Highlights**

This technical report describes two studies that evaluated the effectiveness of providing early hands-on learning and experience with flight-deck automation in small airplanes to allow pilots to more easily transition to the use of automation in transport airplanes. The results showed a positive effect of the use of small-airplane automation.

**Author's Description**
*From the Abstract*

"Two experiments explored the idea of providing cockpit automation training to airline-bound student pilots using cockpit automation equipment commonly found in small training airplanes. In a first experiment, pilots mastered a set of tasks and maneuvers using a GPS navigation computer, autopilot, and flight director system installed in a small training airplane. Students were then tested on their ability to complete a similar set of tasks using the cockpit automation systems found in a popular jet transport aircraft. Pilots were able to successfully complete 77% of all tasks in the jet transport on their first attempt. An analysis of a control group suggests that the pilots' success was attributable to the application of automation principles they had learned in the small airplane. A second experiment looked at two different ways of delivering small-airplane cockpit automation training: a self-study method, and a dual instruction method. The results showed a slight advantage for the self-study method. Overall, the results of the two studies cast a strong vote for the incorporation of cockpit automation training in curricula designed for pilots who will later transition to the jet fleet" (p.25).

Casner, S.M. (2003b). *Teaching cockpit automation in the classroom* (NASA/TM-2003-211865). Moffett Field, CA: NASA Ames Research Center.

**Training-Related Highlights**

This experimental study looked at teaching the fundamentals of flight-deck automation in a classroom, without any hands-on training or the use of training devices. The training materials used in the study strongly emphasized the

importance of maintaining an understanding of what pilot tasks are delegated to the automation, how the automation works to achieve those tasks, and what the airplane is configured to do at all times. The results suggest that the approach is viable.

## Author's Description
*From the Summary*

"This study explores the idea of teaching fundamental cockpit automation concepts and skills to aspiring professional pilots in a classroom setting, without the use of sophisticated aircraft or equipment simulators. Pilot participants from a local professional pilot academy completed eighteen hours of classroom instruction that placed a strong emphasis on understanding the underlying principles of cockpit automation systems and their use in a multi-crew cockpit. The instructional materials consisted solely of a single textbook. Pilots received no hands-on instruction or practice during their training. At the conclusion of the classroom instruction, pilots completed a written examination testing their mastery of what had been taught during the classroom meetings. Following the written exam, each pilot was given a check flight in a full-mission Level D simulator of a Boeing 747-400 aircraft. Pilots were given the opportunity to fly one practice leg, and were then tested on all concepts and skills covered in the class during a second leg. The results of the written exam and simulator checks strongly suggest that instruction delivered in a traditional classroom setting can lead to high levels of preparation without the need for expensive airplane or equipment simulators" (p. 3).

Chung, W. W., Bürki-Cohen, J., & Go, T. H. (2004). Task and vehicle dynamics based assessment of motion cueing requirements. *Proceedings of the AIAA Modeling and Simulation Technologies Conference, 16-19 August 2004, Providence, Rhode Island*, AIAA 2004-5154.

## Training-Related Highlights

This paper presents a particular analytical approach for the review of studies related to motion cueing. The approach was applied to four previous studies to demonstrate the concepts and make recommendations for future elaboration. Detailed descriptions of task and vehicle dynamics, visual cues, motion-drive algorithms and platform dynamics, and experimental validity and reliability are given.

## Authors' Description
*From the Abstract*

"One significant difference between real and simulated flight on the ground are the stimuli or cues provided to the pilot. Due to physical and/or cost constraints, it is nearly impossible to match all the cues experienced in the air in ground-based simulators. Motion cues, in particular, are severely affected by the limits imposed on the ground, such as the extent of travel and the dynamics bandwidth. Researchers have been struggling for decades to develop a better understanding on how pilots' behavior and performance in the simulator are affected by these limitations, and to determine the motion-cueing requirements appropriate to the purposes of the simulation. It has been demonstrated that motion cues can affect pilot-vehicle performance and pilot behavior in ground-based simulators. However, whether motion cues affect behavior and performance appears to be a function of pilot task, vehicle dynamics, and cueing quality (of motion and other cues). The experimental design also greatly affects the validity (whether the data answer the research question) and reliability (whether the results can be replicated) of a study. This

paper is developing a systematic approach to re-examine past studies in an effort to develop a comprehensive understanding of the effects of motion in ground-based flight simulators" (p.1).

Clark, R. C., & Mayer, R. E. 2008. *E-learning and the science of instruction: proven guidelines for consumers and designers of multimedia learning*. 2nd Ed. San Francisco, CA: John Wiley and Sons, Inc.

### Training-Related Highlights

This book provides research-based design principles for the development of e-learning. The organization and integration of text, graphics, audio, video, and the like are covered along with guidelines for navigation, pacing, and language usage. Games and simulations are also addressed. Advantages and disadvantages of e-learning are presented along with information on what still needs to be discovered about e-learning.

### Authors' Description
*From the Purpose section*

"The training field is undergoing an evolution from a craft based on fads and fold wisdom to a profession rates evidence into the design and development of its products. Part of the training revolution had been driven by the use of digital technology to manage and deliver instructional solutions. This book provides you with evidence-based guidelines for both self-study (asynchronous) and virtual classroom (synchronous) forms of e-learning. Here you will learn the guidelines, the evidence, and examples to shape your decisions about the design, development, and evaluation of e-learning" (p. 1).

Covelli, J.M., Rolland J.P., & Hancock P. A. (2007). A quantitative measurement of presence in flight simulators. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC 2007).*

### Training-Related Highlights

This conference paper describes work aimed at providing a foundation to address the challenges found in implementing head-worn displays (HWDs) as simulation devices for pilot training. One purpose of the study was to estimate the optimum field of view (FOV) necessary for HWD systems to allow pilots to perform specific tasks. Head and eye movement measures were used to understand the effects on task performance with changes in FOV. Results indicated that pilots change their scan patterns with limited effective FOV. Also, it was concluded that an effective FOV of 40% or more is required for the pilots to accomplish the types of tasks included in the experiment, implying minimum FOV requirements for HWDs.

### Authors' Description
*From the Abstract*

"Virtual Reality (VR) and Augmented Reality (AR) Head Worn Display (HWD) technology is being considered as a novel alternative for low cost, wide Field of Regard (FOR), deployable simulators. There are inherent differences in display characteristics among different HWDs and between HWDs in general with conventional displays. For example, the effective Field of View (FOV) in most HWDs

is no more than 60º horizontal and 45º vertical, which is far narrower than the human eye's 200º horizontal and 135º vertical FOV. Developing a HWD with a wide 200º horizontal FOV is expensive. Current HWD flight simulator implementations provide limited effective FOV that reduces the pilot's visual stimulus, perception, sense of presence and overall training effectiveness. To successfully utilize a VR or AR HWD in a simulator, we hypothesize the user must have the same or even a higher mental immersion experience as compared with the conventional simulator experience with unrestricted FOV. Attempts to measure mental immersion or presence from VR simulations were normally conducted with questionnaires. Although more convenient, the validity of measuring the continuous experience of presence with post experience questionnaires has been challenged (e.g., Slater, 2004). Here, a quantitative approach to measure presence in relation to mental image processing and performance is proposed. This paper presents experimental methods involving measurement and analysis of normal head and eye movement patterns of experienced pilots while accomplishing specific tasks in a conventional flight simulator with a 170° horizontal x 75° vertical FOR. The paper outlines metrics taken using head and eye tracking equipment, and results of pilot head and eye movement patterns between different Areas of Interest (AOIs) inside and outside the cockpit. The experimental results are analyzed with regard to task performance and five different pilot effective FOV conditions. A summary of findings, experiment limitations, lessons learned and potential areas for future research are also presented" (p. 1).

Craig, P., Bertrand, J., Dornan, W., Gossett, S., & Thorsby, K. (2005). Ab initio training in the glass cockpit era: New technology meets new pilots. *Proceedings of the 13th International Symposium on Aviation Psychology.* Available: https://www.faa.gov/training_testing/training/fits/research/media/Ab Inito.pdf

### Training-Related Highlights

This conference paper describes work that is part of NASA's Small Aircraft Transportation System (SATS) program called SAFER (SATS Aerospace Flight Education Research). The project compared the performance of university student pilots trained in advanced technology airplanes using a new curriculum developed for SAFER with those trained in the traditional university program. The average number of flight hours required to accomplish similar lessons in each program were compared. Preliminary findings showed that SAFER students had more setbacks in the pre-solo phase of the program than the traditional students, and that the number of setbacks for the traditional students continued to rise throughout the program where they decreased for the SAFER students. Additional data were being collected as the research continued.

### Authors' Description
*From the Abstract*

"The Aerospace Department at Middle Tennessee State University and the NASA Langley Research Center entered into a cooperative agreement in 2003. The project is named the SATS Aerospace Flight Education Research (SAFER) and is part of NASA's Small Aircraft Transportation System (SATS) initiative. The SATS project envisions a future flight environment that employs small aircraft to transport people and cargo from point to point using smaller, under utilized airports instead of major gridlocked airports. The aircraft used in the SATS vision would take advantage of a range of emerging technologies including glass cockpits, new structures, and new

engines. But with the understanding that the best aircraft and the best systems are still only as good as its operator, MTSU Aerospace set out to explore how pilot training might be different in the SATS environment. The SAFER project therefore takes beginner pilots and completes their initial Visual Flight (VFR) and Instrument Flight (IFR) flight training in technically advanced aircraft to determine how best to educate the next generation of pilots in the next generation of aircraft" (p. 1).

Dahlström, N. (2008). *Pilot training in our time—use of flight training devices and simulators.* Lund University School of Aviation, Sweden, Aviation. 12(1), 22-27.

### Training-Related Highlights

This paper describes two studies that evaluated the use of simulators in training cognitive and collaborative skills. The first study followed ab-initio students up to their first solo; the students used TAA instrumentation and controls from the beginning of their training. The second study observed students participating in an exercise in which they developed individual and team roles meant to transfer to flight-deck operations in an airline. The studies found that successful training of technically advanced concepts can be done through careful instructional preparation and delivery and that flight crews can develop CRM skills in other than high fidelity simulators. Further study is recommended.

### Author's Description
*From the Abstract*

"The challenge of pilot training include adapting to an industry in which the environment is formed by steep upturns and downturns, cut-throat competition, and advanced technology that continues to change the role of the pilot and in which safety always must match the continuously increasing demands of efficiency. The pilot training performed at flight training organisations (FTOs) is the fundament in the education of captains and first officers who will be able to manage the operational "sharp end" of this environment.

The response from the training industry in adapting to this environment has to a large extent been to increasingly rely on various levels of simulation in training, as seen with the current introduction of the multi-crew pilot license (MPL). Simulation can play an important role in acquiring the skills needed for a pilot, but it is also necessary to focus on the cognitive and collaborative skills that are to be developed by the training. The increasing technological sophistication seen in flight training devices and simulators today does however not seem to be matched by systematic validation of the value of different levels of simulation on cognitive and collaborative skills, which means that educational resources can go underutilised or get misapplied.

This paper will describe and discuss some aspects of the challenge for pilot training, especially regarding the use of flight training devices and simulators. The framework within which FTOs exist and perform their training will be presented to add context to the overall situation for pilot training. And in particular, recent Lund University School of Aviation research projects on pilot training, introduction of technically advanced aircraft (TAA), and use of midfidelity simulation for CRM-training will be presented and connected to the discussion" (p. 22).

Dahlström, N., Dekker, S. W. A., & Nählinder, S. (2006). Introduction of technically advanced aircraft in ab-initio flight training. *International Journal of Applied Aviation Studies*, 6(1), 131-144.

### Training-Related Highlights

This study collected pilot-training information during the introduction of technically advanced airplanes (TAAs) using interviews and questionnaires with ab-initio instructors and pilots as participants. Findings showed that some initial expectations of training challenges were not evident in actual training. The training was seen as successful, but additional research was suggested to understand potential gaps in the training approach.

### Authors' Description
*From the Abstract*

"The transition of pilots from a traditional cockpit to a modern glass-cockpit has been a training challenge for the last two decades. The arrival of Technically Advanced Aircraft (TAA) during the last decade has brought the opportunity to introduce this technology from the beginning of airline pilot training. In this project, three flight instructors responsible for the introduction of TAAs in ab-initio training at a flight school were interviewed on their initial experiences and concerns regarding the introduction. Subsequently, questionnaires were collected from the familiarization training of instructors on the new aircraft and from ab-initio students and instructors after three of the 18 flights leading up to the first solo. Finally, flight instructors involved in the introduction were interviewed. The results show that anticipated problems with use of displays, aircraft speed and use of side control proved to have limited impact on the training. The conclusion is that with extensive preparation, introduction of TAA in ab-initio training can be accomplished successfully. However, the expected benefits of this on training and questions on what might be lost in the process need to be addressed by further research" (p. 2).

D'Alessandro, N. (2007). *Transference of PC-based simulation to aviation training: Issues in learning - a review of the literature 1997-2007*. Walnut Creek, Tasmania: InSite Solution (Tas.) Pty Ltd.

### Training-Related Highlights

This paper is a literature review related to PC-based simulation devices and their use in aviation training. Fifty-seven studies, papers, reviews, and articles from 1997 through 2007 were considered for this review. The review found that PC-based simulators are effective for certain aspects of pilot training and potentially detrimental to others. They suggest that there is a peak transfer-of-training efficiency after which the effectiveness as well as the time and cost efficiency decreases. The authors emphasize that focus should still be placed on the quality of the application of learning principles, and devices such as PC-based simulators should be used as tools to support the objectives of the training.

### Author's Description
*From the Executive Summary*

"The use of flight simulation devices as learning tools for aviation training is well established – particularly in the training of commercial pilots and airline flight crew. The emphasis within this field has largely been on sophisticated and costly cockpit simulators that provide high-fidelity, highly-immersive learning environments.

With the rapid emergence of the personal computer and the Internet, the computing power to run reasonably sophisticated simulation software has become available and continues to grow exponentially. Feature-rich simulation software and compatible hardware devices have become prevalent, providing the general public with low-cost access to flight experiences. This has led to individuals using PC-based simulators as introductions to, and pre-training for, real-life flying training. Some already licensed pilots, flight instructors and training institutions have also taken up the tool for use in part-task, self-directed and classroom-based training.

With the rapid uptake of PC-based simulators, the aviation industry and regulators have posed questions regarding the validity, effectiveness and risks associated with the use of the tool in formal training. Various research studies and reviews have been conducted and there is a relatively small but growing body of literature on this topic.

PC-based simulators have a positive role to play within aviation training at all levels. The literature reveals that there is a positive transfer-of-training from the simulator to real aircraft and in-flight-training for part-task training, procedural training, to teach underlying cognitive principles, and for tasks that are new and/or sequenced early in training programs. They are also effective for recurrent training and advanced instrument flight procedure training and ongoing pilot proficiency / practice. PC-based simulators offer a superior learning environment to an airplane in some contexts, and there are significant time and cost savings to be realised. However they are not as effective, and sometimes detrimental, to the teaching of basic flight handling and maneuvers. Their relative lack of fidelity can mean poor habit formation and increased training time due to skills and procedures needing to be relearned.

A key finding is that PC-based simulators have a peak transfer-of-training efficiency, and using them beyond this level in training will mean decreasing effectiveness and time/cost inefficiency. Finding the peak level and a balance between simulated and in-flight training for each major area of flight training is critical. So too is the continuing role of flight instructors who provide a fundamental coordination and supervision role, and can assist in the integration of various training tools and methods.

Balance is also required in how PC-based simulators are used within training programs. They should be creatively used as multipurpose tools for relevant aspects of training, rather than as fully-fledged flight simulators – which clearly they are not.

To find this balance and to improve the design of PC-based simulators and the curricula that they are used within, more focus needs to be given to educational theory, design and practice. There is a largely unchallenged focus in the aviation industry on improving the technical and fidelity aspects of simulators as the answer to improving training, rather than upon learning outcomes and the learning process itself. To support this, aviation educators, instructors, and software designers need to work in partnership with educational practitioners to produce more creative, innovative and informed learning designs that leverage technical and educational advances. It is these designs that can realise the further potential that PC-based simulators offer the aviation training field" (pp. 3-4).

Damos, D. L. (1988). Determining transfer of training using curve fitting. R.W. Swezey and D. H. Andrews (Eds.), *Readings in Training and Simulation: A 30-Year Perspective* (pp. 51-55). Santa Monica, CA: Human Factors and Ergonomics Society.

### Training-Related Highlights

This paper describes a study focused on evaluating an analytic technique for measuring transfer of training. The technique was applied to an experimental study to determine whether rotation skills used to distinguish between a shape and its mirror image can become automated with practice and whether the skills can transfer between stimuli. Results showed that the curve-fitting technique may be more sensitive to transfer-of-training effects that standard calculations.

### Author's Description
*From the Abstract*

"The purpose of this paper is to demonstrate the measurement of learning and transfer using a curve-fitting technique discussed in a 1985 Human Factors article by Spears. The data were collected during an experiment that determined if rotation skills could become automated with practice and if the skills could transfer between stimuli. The dependent variables of interest were the slope and intercept of the regression equation relating correct reaction time and degrees of rotation. Curve fitting was accomplished using a common statistical package, BMDP, and an IBM-XT. The curve-fitting technique showed large initial transfer of training on several variables that did not affect the asymptotic level of performance. In contrast standard transfer of training calculations indicated small positive transfer" (p. 51).

DeRouin, R.E., Fritzsche, B.A., Salas, E. (2005). E-learning in organizations. *Journal of Management, 31*(6), 920-940.

### Training-Related Highlights

This article is a comprehensive review of e-learning methods by organizations and the literature available on the use of e-learning. The article critiques the quality of the literature in its ability to enhance the practice of e-learning. The authors conclude that many research needs still exist and describe potential approaches that can produce the information necessary for the future.

### Authors' Description
*From the Abstract*

"E-learning, an instructional strategy for imparting needed knowledge, skills, and attitudes in organizations, is here to stay. Its viability, effectiveness, and potential to return tangible benefits to organizations depend largely on how it is designed, delivered, and evaluated. This article provides a comprehensive review of the state of the art of e-learning methods in organizations. The authors also critically examine e-learning's effectiveness by reviewing the current literature on the outcomes of e-learning. Finally, they offer a research agenda designed to bridge the gap between the practice and science of e-learning" (p. 920).

Dismukes, R. K., McDonnell, L. K., & Jobe, K. K. (2000). Facilitating LOFT debriefings: Instructor techniques and crew participation. *The International Journal of Aviation Psychology*, 10, 35-57.

### Training-Related Highlights

This study examined the effectiveness of instructor pilot use of crew facilitation to analyze and evaluate line-oriented flight training (LOFT) performance by reviewing facilitation and crew participation in actual airline pilot training debriefing sessions. Findings showed that specific training in facilitation is necessary to improve debriefing performance and suggest methods to accomplish such training.

### Authors' Description
*From the Abstract*

"This study analyzes techniques instructor pilots (IPs) use to facilitate crew analysis and evaluation of LOFT performance. We analyzed IP facilitation and crew participation for 36 debriefing sessions conducted at five U.S. airlines. For this analysis we developed a rating instrument called the Debriefing Assessment Battery (DAB) and demonstrated that it can be used reliably. IP facilitation skill varied dramatically, suggesting a need for concrete hands-on training in facilitation techniques. All measures of crew participation correlated significantly with IP effectiveness in facilitation. Crews responded to IP guidance but did not lead their own debriefings. We suggest ways to improve debriefing effectiveness" (p.2).

Dismukes, R. K., McDonnell, L. K., Jobe, K. K., & Smith, G. M. (2001). What is facilitation and why use it? In R. K. Dismukes & G. M. Smith (Eds.) *Facilitation and debriefing in aviation training and operations*. Aldershot, UK: Ashgate.

### Training-Related Highlights

This book chapter defines facilitation and compares it to traditional instruction in aviation training. The chapter promotes the use of facilitation in pilot training debriefings, describes when it is best used, and provides a resource for how to use facilitation and avoid mistakes.

### Authors' Description
No abstract, executive summary, or other short descriptions were included in the document.

Dismukes, K. & Nowinski, J. (in press). Prospective memory, concurrent task management, and pilot error. To appear in A. Kramer, D. Wiegmann, & A. Kirlik (Eds.) *Attention: from theory to practice*. New York, NY: Oxford.)

### Training-Related Highlights

In this book chapter, the author's drew from the combined results of three previous studies on prospective memory in aviation, and on an experiment that they conducted to support their theories on the sources of prospective memory error. They examined ethnographic studies, analyses of accident and incident reports, and laboratory studies to define the prospective memory demands of the cockpit, and to describe a theoretical framework that connects real-world prospective memory phenomena with the growing understanding of associated cognitive processes.

Implications, countermeasures, and practical strategies to reduce prospective memory error are also offered.

### Authors' Description

No abstract, executive summary, or other short descriptions were included in the document.

Dornan, W. A., Beckman, W., Gossett, S., Craig, P. A., & Mosey, P. (2007). The implementation of the FAA industry training program in technically advanced aircraft (TAA): Lessons learned. *Proceedings of the 14th International Symposium on Aviation Psychology*, Dayton, Ohio.

### Training-Related Highlights

This article reviews the FAA-Industry Training Standards (FITS) program for TAA training. The article discusses lessons learned, including the need for early maneuver-based lessons for some tasks; the importance of consequences in flight scenarios; and the requirement for intensive flight instructor training.

### Authors' Description
*From the Abstract*

"The proliferation of aircraft with extensive automation, collectively known as Technically Advanced Aircraft (TAA) within the last 10 years in the General Aviation industry has led to a novel approach in flight training. The FAA implemented the FAA-Industry Training Standards (FITS) program that emphasizes the importance of "real world" training exercises in the form of scenario training. The FITS curriculum, which was first empirically tested by Middle Tennessee State University (MTSU), was developed by Embry-Riddle Aeronautical University and the University of North Dakota through the FAA Air Transportation Center of Excellence for General Aviation. Over the last four years MTSU has evaluated the FITS training approach with students in a FAR 141 accepted, combined Private Certificate/Instrument Rating syllabus in TAA. Our findings indicate the need for inclusion of several maneuver-based lessons that facilitate the physical skills training required for some tasks (e.g. landing), early in the FITS syllabus. The importance of consequences in the flight scenarios, the intensive flight instructor training required prior to FITS implementation, and the incorporation of new elements into the ground school portion of the curriculum are all "lessons learned" over the last several years of FITS implementation at MTSU" (p. 1).

Estock, J. L., Alexander, A. L, Gildea, K. M., Nash, M., & Blueggel, B. (2006). A model-based approach to simulator fidelity and training effectiveness. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC 2006)*. Paper No. 2794.

### Training-Related Highlights

This conference paper describes research focused on developing methods for measuring and predicting the effects of aspects of simulator fidelity on pilot training effectiveness. The approach evaluated is called Relating Effective Learning to Attributes of the Training Environment (RELATE). It is a systematic method for modeling the relationship between fidelity attributes and training requirements. The

paper demonstrates the use of RELATE using one project and describes the value of the predictive modeling that can result.

### Authors' Description
*From the Abstract*

"Although there is a commonly held belief that high-fidelity simulators provide a high degree of transfer, some evidence indicates that lower-fidelity simulators can provide benefits without the added expense and complexity of high-fidelity simulators (Wickens & Hollands, 2000). The civilian flight simulator market contains inexpensive systems for training procedures and operations. A plethora of force-cueing devices can augment the lower-fidelity simulators. However, the effect of force-cueing devices on performance and training is a heavily debated topic (e.g., Heintzman, 1997). Furthermore, the available information regarding the impact of fidelity on training effectiveness is documented in a disparate and fragmented literature. The ability to assemble this information in a common location and to establish quantitative, predictive relationships between simulator fidelity and training effectiveness would greatly enhance the value of training programs that utilize simulators to train operators.

In this paper, we will describe the Relating Effective Learning to Attributes of the Training Environment (RELATE) approach, a process designed and applied in the Performance Effects Related to FORce-cueing Manipulation (PERFORM) project. The purpose of the RELATE approach is to establish quantitative, predictive relationships between the attributes of a training environment and training effectiveness. In the PERFORM project, the training attribute of interest is simulator fidelity. The RELATE approach consists of six steps: (1) identifying the relevant dimensions of simulator fidelity, (2) identifying the knowledge and skills (K&S) necessary in the specific domain, (3) determining whether a relationship exists between the fidelity dimensions and the K&S, (4) developing functions that define the relationships between fidelity dimensions and K&S, (5) developing algorithms that predict training effectiveness, and (6) empirically validating the functions and algorithms. We will walk through the steps as they were applied in the PERFORM project, which aimed at determining the level of fidelity required for effective air-to-air combat training in F-16 simulators" (p. 1).

Fanjoy, R. O. & Young, J. P. (2005). Flight deck automation: Line pilot insight for improved initial pilots training. *International Journal of Applied Aviation Studies*, 5 (1), 13-24.

### Training-Related Highlights

This journal article describes a study to identify factors useful in college-curriculum development based on line pilot perspectives of their glass-cockpit training. Issues associated with transitioning to automated flight-deck operations as they relate to advanced flight training curricula were addressed, and recommendations for training development were provided.

### Authors' Description
*From the Abstract*

"The difficulty associated with transition from round-dial to glass cockpit flight instrumentation has received significant airline attention over the past decade. Collegiate aviation curriculum designers have carefully monitored airline training in this area for insights to automation course development. This paper address glass

cockpit training from the perspective of line pilots in an attempt to identify factors useful to a college curriculum development. Study participants included one hundred and ten highly experienced airline, cooperate, and military pilots who were surveyed before and after a flight simulator training session conducted in preparation for an employment interview with a major airline. Although only a few study participants reported problems in completing automated flight deck training, most reported ongoing concern with line operation of such systems, particularly during the approach and landing phases of flight. Although pilots in the study sample reported regular use of automated flight modes during most phases of flight, they expressed concern over a perceived deterioration in psychomotor skills essential to manual flight operations. Issues related to old and new technology aircraft are discussed in this paper, as well as recommendations for glass cockpit training course development" (p.13).

Feary, M., Alkin, M., Palmer, P., Sherry, L., McCrobie, D., & Polson, P. (1997). Behavior-based vs. system-based training and displays for automated vertical guidance. *Proceedings of the 9th International Symposium on Aviation Psychology, Columbus, OH.* Available: http://humansystems.arc.nasa.gov/IHpersonnel/feary/files/osu_feary97.pdf

### Training-Related Highlights

This conference paper details an experimental study that examined changing a system-based design to a behavior-based design for the vertical guidance portion of the flight mode annunciator in an MD-11 aircraft. The results showed that training for normal operations can be successfully delivered through computer-based training and began to show a trend in favor of the new display.

### Authors' Description
*From the Abstract*

"Aircraft automation, particularly the automation surrounding vertical navigation has been cited as an area of training difficulty and a source of confusion during operation. A number of incidents and accidents have been attributed to a lack of crew understanding of what the automation is doing. This paper describes an experiment which tested a new display for automated vertical guidance. The study utilized a training package designed to teach the vertical guidance portion of the Flight Mode Annunciator (FMA), as seen in normal operations of the McDonnell Douglas MD-11. The results of the study showed that this type of training can be successfully delivered via a computer based training device. Additionally, the results began to show a trend in favor of the new display, although without reaching statistical significance. This study is part of a larger project to improve the recognition and understanding of the "objectives and behaviors" of automated systems through a formal methodology. The formal methodology, referred to as the operational procedures methodology, integrates the design of the system with the design of the training and display information requirements for that system (Sherry, 1995)" (p. 1).

Feary, M., McCrobie, D., Alkin, M., Sherry, L., Polson, P., Palmer, E. & McQuinn, N. (1998). *Aiding vertical guidance understanding* (NASA/TM-1998-112217). Moffett Field, CA: NASA Ames Research Center.

### Training-Related Highlights

This study evaluated the effects on pilot performance of specific training based on vertical guidance logic or the use of a new display that gives guidance based on aircraft behaviors instead of control modes. The training was developed using the operations procedures methodology. Results showed a reduction of automation surprises after they were given the training and a further reduction if they used the new display.

### Authors' Description
*From the Summary*

"A two-part study was conducted to evaluate modern flight deck automation and interfaces. In the first part, a survey was performed to validate the existence of automation surprises with current pilots. Results indicated that pilots were often surprised by the behavior of the automation. There were several surprises that were reported more frequently than others. An experimental study was then performed to evaluate (1) the reduction of automation surprises through training specifically for the vertical guidance logic, and (2) a new display that describes the flight guidance in terms of aircraft behaviors instead of control modes. The study was performed in a simulator that was used to run a complete flight with actual airline pilots. Three groups were used to evaluate the guidance display and training. In the training condition, participants went through a training program for vertical guidance before flying the simulation. In the display condition, participants ran through the same training program and then flew the experimental scenario with the new Guidance–Flight Mode Annunciator (G-FMA). Results showed improved pilot performance when given training specifically for the vertical guidance logic and greater improvements when given the training and the new G-FMA. Using actual behavior of the avionics to design pilot training and FMA is feasible, and when the automated vertical guidance mode of the Flight Management System is engaged, the display of the guidance mode and targets yields improved pilot performance" (p. 8).

Feary, M. & Sherry, L. (1998). Evaluation of a formal methodology for developing aircraft vertical flight guidance training material. In *Proceedings of the 42nd Annual Meeting of the Human Factors and Ergonomics Society*, Chicago, Il, USA, 5-9 Oct 1998. pp. 72-76.

### Training-Related Highlights

This study described both the translation of information from an operational procedures methodology to a training package and an experiment that tested the new training. The methodology was used to design a new automated vertical guidance portion of the FMA in an MD-11 aircraft. The results showed that the training can be successfully delivered through CBT and that the new display resulted in significantly fewer errors on a simulated flight.

### Authors' Description
*From the Abstract*

"Aircraft automation, particularly the automation surrounding vertical navigation, has been cited as an area of training difficulty and a source of confusion during

operation. A number of incidents have been attributed to a lack of crew understanding of what the automation is doing. This paper describes the translation of information from a formal methodology used in design of an automated vertical guidance system to a training package, and an experiment that tested the new training. This study is part of a larger project to improve the recognition and understanding of the "objectives and behaviors" of automated systems through a formal methodology. The formal method, referred to as the operational procedures methodology, integrates the design of the system with the design of the training and display information requirements for that system (Sherry, 1995). The study utilized a training package designed to teach the vertical guidance portion of the Flight Mode Annunciator (FMA), as seen in normal operations of the Boeing MD-11. The results of the study showed that this type of training can be successfully delivered via a computer based training device. Additionally, a study in a full cockpit simulator showed that the training, coupled with the new display, provided significantly less errors on a simulated flight, although the training alone did not provide significantly better performance" (p. 1).

Federal Aviation Administration (1994). Takeoff safety training aid. *Section 2, Pilot Guide to Takeoff Safety*. Available: http://www.faa.gov/pilots/training/.

### Training-Related Highlights

This training aid describes factors that affect the go/no-go decision during take off and training methods and topics to increase rejected-takeoff safety margins, including topics related to CRM.

### Author's Description
No abstract, executive summary, or other short descriptions were included in the document.

Federal Aviation Administration. (1996). *Human factors team report on: The interfaces between flight crews and modern flight deck systems*. Federal Aviation Administration. Washington DC.

### Training-Related Highlights

This study reviewed information on the interfaces between the flight crew and highly automated systems, primarily interfaces that affect flight-path management. Human factors issues were identified related to training, as well as design, flightcrew qualifications, and operations; and recommendations were made to address those issues.

### Authors' Description
*From the Executive Summary*

"Advances in technology have enabled increasingly sophisticated automation to be introduced into the flight decks of modern airplanes. Generally, this automation was added to accomplish worthy objectives such as reducing flightcrew workload, adding additional capability, or increasing fuel economy. To a large extent, these objectives have been achieved. Safety also stood to benefit from the increasing amounts of highly reliable automation. Indeed, the current generation of highly automated transport category airplanes has generally demonstrated an improved safety record relative to the previous generation of airplanes. Vulnerabilities do exist, though, and

further safety improvements should be made. To provide a safety target to guide the aviation industry, the Secretary of Transportation and others have expressed the view that the aviation industry should strive for the goal of zero accidents.

On April 26, 1994, an Airbus A300-600 operated by China Airlines crashed at Nagoya, Japan, killing 264 passengers and flightcrew members. Contributing to the accident were conflicting actions taken by the flightcrew and the airplane's autopilot. The crash provided a stark example of how a breakdown in the flightcrew/automation interface can affect flight safety. Although this particular accident involved an A300-600, other accidents, incidents, and safety indicators demonstrate that this problem is not confined to any one airplane type, airplane manufacturer, operator, or geographical region. This point was tragically demonstrated by the crash of a Boeing 757 operated by American Airlines near Cali, Columbia on December 20, 1995, and a November 12, 1995 incident (very nearly a fatal accident) in which a American Airlines Douglas MD-80 descended below the minimum descent altitude on approach to Bradley International Airport, CT, clipped the tops of trees, and landed short of the runway.

As a result of the Nagoya accident as well as other incidents and accidents that appear to highlight difficulties in flightcrews interacting with the increasing flight deck automation, the Federal Aviation Administration's (FAA) Transport Airplane Directorate, under the approval of the Director, Aircraft Certification Service, launched a study to evaluate the flightcrew/flight deck automation interfaces of current generation transport category airplanes. The following airplane types were included in the evaluation:

Boeing: Models 737/757/767/747-400/777
Airbus: Models A300-600/A310/A320/A330/A340
McDonnell Douglas: Models MD-80/MD-90/MD-11
Fokker: Model F28-0100/-0070

The FAA chartered a human factors (HF) team to address these human factors issues, with representatives from the FAA Aircraft Certification and Flight Standards Services, the National Aeronautics and Space Administration, and the Joint Aviation Authorities (JAA), assisted by technical advisors from the Ohio State University, the University of Illinois, and the University of Texas. The HF Team was asked to identify specific or generic problems in design, training, flight crew qualifications, and operations, and to recommend appropriate means to address these problems. In addition, the HF Team was specifically directed to identify those concerns that should be the subject of new or revised Federal Aviation Regulations (FAR), Advisory Circulars (AC), or policies" (pp. 1-2).

Gawron, V. J., Berman, B. A., Dismukes, R. K., & Peer, J. H. (2003). New airline pilots may not receive sufficient training to cope with airplane upsets. *Flight Safety Foundation's Flight Safety Digest*, July-August 2003, 19-32.

### Training-Related Highlights

This article describes a study conducted for NASA that evaluated the flying performance of pilots in eight scenarios that were developed based on the details of upset accidents. The study had 40 new-hire airline pilots perform the upset-recovery scenarios in a Learjet equipped to replicate characteristics of large transport aircraft. Most pilots did not recover control in most of the scenarios. They recovered most reliably from upset scenarios that were straightforward, uncomplicated, and similar

to specific training they had received. The study results provide information about the types of errors made while attempting to recover from upsets and suggest methods to improve upset recovery training.

### Authors' Description
No abstract, executive summary, or other short descriptions were included in the document.


Gipson, T., Bowman, D., & BraynSmith, I. (2006). Next generation aircraft training; Good pilot - good instructor? *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC 2006).*

### Training-Related Highlights

This conference paper describes two studies addressing requirements for future aircraft instructor pilots. One study includes information about the knowledge, skills, and attitudes needed by pilot instructors. The other study reviews literature and develops a description of how instructors should consider the personalities and learning styles of their student pilots during training. Conclusions are drawn about how to effectively train instructor pilots.

### Authors' Description
*From the Abstract*

"The failure to fully consider the requirements of instructor pilots imposes an unacceptable risk on the quality of training and the success of student pilots. The skills required to 'fly' an aircraft are only a sub-set of the skills required to ''instruct' and evidence indicates that highly competent pilots do not necessarily make competent instructors.

Instructor pilots need to be given training on how to create the most effective learning environment from which students can achieve their highest possible standard. With the introduction of next generation aircraft, the instructor pilot also needs to have the ability to analyse and assess a student's psychomotor and cognitive skills performance.

This paper draws on two separate studies undertaken to investigate the selection, training and development requirements of next generation aircraft instructor pilots.

Study one, conducted by Air Affairs (UK) Ltd., analysed the human-human and human-equipment interfaces of instructor pilots, as part of a UK Ministry of Defence (MoD) Training Needs Analysis (TNA) process. This included the development of an Operational Task List (OTL), together with the identification of associated knowledge, technical skills, instructional skills and behavioural attributes of instructor pilots. This analysis also considered issues associated with ongoing instructional development.

Study two discussed research into methods of improving the quality of flying training, carried out by the Flying Training Development Wing (FTDW), Central Flying School (CFS), Royal Air Force (RAF). This work included an assessment of the application of learning styles and personality types in the aviation environment, instructor/student communication patterns, the effect that stress and over-stress has on student success and how an instructor's behaviour can directly affect the performance of a student pilot.

This paper identifies the requirements of, and some of the challenges facing, an instructor pilot training students for next generation aircraft" (p. 1).

Go, T. H., Bürki-Cohen, J., Chung, W. W., Schroeder, J., Saillant, G., Jacobs, S., & Longridge, T. (2003). The effects of enhanced hexapod motion on airline pilot recurrent training and evaluation. *Proceedings of the AIAA Modeling and Simulation Technology Conference, 11-14 August 2003 Austin, Texas*, AIAA-2003-5678.

### Training-Related Highlights

This conference proceedings document describes an experimental study that tested whether improved motion cueing affects recurrent training and evaluation of pilots flying the NASA B747-400 simulator. The study found an effect of motion on evaluation but not on training. Results from landing maneuvers showed that training without motion may improve pilot performance.

### Authors' Description
*From the Abstract*

"A quasi-transfer experiment tested the effect of simulator motion on recurrent evaluation and training of airline pilots. Two groups of twenty B747-400 pilots were randomly assigned to a flight simulator with or without platform motion. In three phases, they flew four maneuvers designed to reveal differences due to motion. In the first phase, termed Evaluation, the two groups flew the maneuvers as they would in a check ride. In the second phase, termed Training, the two groups flew the maneuvers repetitively and were given feedback on their performance. In the third phase, termed Quasi-Transfer, both groups flew the tasks again, but both in the simulator with motion (quasi-transfer instead of real transfer to the airplane). This was to determine whether or not their previous training with or without motion made any difference. Statistically significant effects of both motion and the phase of experiment were found for all four maneuvers. Platform motion was shown to make a difference in Evaluation, but was not found to be of benefit in Training. Results of this study and the previous hexapod motion research should assist the FAA in determining future research directions in the effort to develop motion requirements for today's airline evaluation and training needs" (p. 1).

Go, T. H.; Bürki-Cohen, J., & Soja, N.N. (2000). The effect of simulator motion on pilot training and evaluation. *Proceedings of the AIAA Modeling and Simulation Technologies Conference, August 14-17, 2000, Denver, Colorado,* AIAA-2000-4296.

### Training-Related Highlights

This conference proceedings paper describes the research that is also presented earlier in Bürki-Cohen, J., Boothe, E. M., Soja N. N., DiSario, R., Go, T., & Longridge T. (2000). This experimental study examined the effect of platform motion and a high-level visual system on pilot training and evaluation. The results indicated that, with caveats, the test simulator did not significantly affect first-look evaluation, training progress, transfer of training, subjective perception of pilot performance, or the acceptability of the simulator to pilots.

### Authors' Description
*From the Abstract*

"This study empirically examined the effect of simulator platform motion on airline pilot recurrent training and evaluation. It is driven by the need for sound scientific data on the relationship between certain key modern device features and their effect on the transfer of pilot performance and behavior to and from the respective airplane. The experiment utilized an FAA qualified Level C simulator with six-degree-of-freedom synergistic motion and a wide angle high quality visual system. Experienced airline pilots were evaluated and trained in the simulator, half of them with and the other half without motion. Then the transfer of skills acquired by both groups during this training was tested in the simulator with the motion system turned on as a stand-in for the airplane (quasi-transfer). Every effort was made to avoid deficiencies in the research design identified in a review of prior studies, by measuring pilot stimulation and response, testing both maneuvers and pilots that are diagnostic of a need of motion, avoiding pilot and instructor bias, and ensuring sufficient statistical power to capture operationally relevant effects. The results of the analyses as well as their implications are presented in this paper" (p. 1).


Hamman, W. R., Beaubien, J. M., & Holt, R. W. (1999). Evaluating instructor/evaluator inter-rater reliability from performance database information. *Proceedings of the Tenth International Symposium on Aviation Psychology.* Columbus, OH: The Ohio State University Press.

### Training-Related Highlights

This conference paper outlines the steps needed to develop an inter-rater reliability training program for instructors and evaluators.

### Authors' Description
*From the Abstract*

"Carriers operating under the FAA's Advanced Qualification Program are required to assess individual and crew performance via Line Oriented Evaluations (LOEs). LOEs take place in a full-motion simulator, and involve a full crew performing a simulated flight from take-off to landing. Evaluating crew performance in the LOE is an arduous task, even for highly-trained professionals. Therefore, techniques are needed for training Instructor/Evaluators (I/Es), and for maintaining I/E calibration indefinitely. This paper describes the major steps involved in the development of Inter-Rater Reliability (IRR) training programs, as well as the usefulness of LOE performance database information for assessing I/E calibration between IRR training sessions" (p. 1).


Harris, D. (2009). A design and training agenda for the next generation of commercial aircraft flight deck. *Proceedings of the 8th International Conference on Engineering Psychology and Cognitive Ergonomics: Held as Part of HCI International 2009 (EPCE'09).* Springer-Verlag, Berlin, Heidelberg, 529-536.

### Training-Related Highlights

This analytical paper addresses historical, current, and future issues with flight-deck design, operations, and related pilot training. As flight decks are redesigned, the pilot training syllabus should also be redesigned to ensure congruency. The paper also

discusses the human-factors integration/human-system integration approach to the design of equipment and training.

### Author's Description
*From the Abstract*

"To maximize cost efficiencies the design of the modern commercial airliner flight deck must change quite radically. However, these efficiencies cannot be realized unless there are concomitant changes in the rest of the system, and in particular, the training aspect. This paper proposes a radical design agenda for the flight deck and outlines how efficiencies can be gained through a careful re-alignment and re-appraisal of the training requirements to operate this aircraft" (p. 1).

Helmreich, R. L., Klinect, J. R., & Wilhelm, J. A. (1999). Models of threat, error, and CRM in flight operations. In *Proceedings of the Tenth International Symposium on Aviation Psychology* (pp. 677-682). Columbus, OH: The Ohio State University.

### Training-Related Highlights

This paper outlines and discusses two models of threat and error management that were developed based on LOSA data from three airlines. The first model is a general model of threat and error in aviation, and the second model is a full error-management model. The authors suggest that the two models can be used to provide a structure for training and recommend that training should acknowledge that errors will happen and focus on providing specific strategies for mitigating and managing threat and error. Discussion regarding the benefits of the use of LOSA data is provided.

In addition, the authors provide discussion related to defining CRM, understanding the goals of CRM training, and specifically discuss that CRM should still be considered a separate and continually ongoing part of training that is driven by data that reflects operational issues.

### Author's Description
*From the Abstract*

"Issues in Crew Resource Management (CRM) are discussed, including its definition and primary goals of recognizing and managing threat and error. CRM is a component of an organization's safety efforts and must be driven by valid data on operational issues. Data requirements for a safety culture include proactive information on crew behavior. The use of non-jeopardy, Line Operational Safety Audits (LOSA) to document threat, error, and crew behavior in line operations is discussed. Models of threat and error in the aviation system are presented, based on data from LOSA in three airlines" (p. 1).

Holder, B & Hutchins, E. (2001). What pilots learn about autoflight while flying on the line. *Proceedings of the 11th International Symposium on Aviation Psychology, Columbus Ohio, 2001.*

### Training-Related Highlights

This study examined how pilots transitioning to the A320 develop an understanding of flight-deck automation through the early stages of operating experience based on extensive interviews and observations. Findings showed that pilots use simple

conceptual models to interpret the behavior of the automated systems. The researchers apply their findings and develop an approach to training to provide pilots the conceptual elements needed for understanding the managed descent mode, which proved to be the most difficult according to the interviews. These are the same interview and observation data also described in Hutchins (2007) and Hutchins and Holder (2001).

### Authors' Description
*From the Abstract*

"We are conducting a longitudinal study to investigate how pilots acquire expertise in the operation of the autoflight and flight management computer systems in the Airbus A320 airplane. We interview and observe pilots in the first stages of their line experience to discover how pilot's understanding of flight deck automation develops. Pilots appear to use a small set of simple conceptual models to understand how the automation controls aircraft behavior. These basic models are not presented to pilots in training. Pilots appear to use their conceptual models as resources for constructing an understanding of how the automation controls airplane behavior. We discuss the models and our efforts to incorporate them into training" (p. 1).

Holt, R., Boehm-Davis, D., & Beaubien, M., 2001. Evaluating resource management training. In E. Salas, C. Bowers, & E. Edens (Eds.), *Improving Teamwork in Organizations: Applications of Resource Management Training.* Lawrence Erlbaum Associates, New Jersey, pp. 165–190.

### Training-Related Highlights

This book chapter describes several methods that can be used to evaluate resource-management training programs and describes the advantages and disadvantages of each method. It also describes individual- and crew-based measures of program effectiveness and outlines the steps needed to develop an evaluation. The chapter also provides an overview of a study in which the authors worked with a regional air carrier to develop and evaluate a resource-management training program for pilots. They concluded that the methods for developing and evaluating the program were effective. The pilots who were trained with the new resource-management program showed significantly improved performance on the multiple measures used for evaluation.

### Author Description
*From the Introduction*

"Resource management is a critical component of job performance in a number of domains. Although a fair amount of research has been devoted to the development of resource management training programs (Helmreich & Foushee, 1993; Wiener, Kanki, & Helmreich 1993), much less effort has been devoted to their evaluation.

The evaluation of a training program is important for a number of reasons, not the least of which is to ascertain whether the organization's investment pays off in terms of performance improvements (Goldstein, 1993). From a cost-benefit perspective, if performance does not improve relative to the cost of implementation, then the training program should be discontinued or modified. In many domains, however, performance changes are difficult to measure because of uncontrollable factors that exist within the larger organizational context. Therefore, it is critical to develop a list of *targeted* changes in knowledge, skills, and/or attitudes that are expected to occur

after training, and to investigate these *systematically* in order to weigh the costs and benefits of training (Kraiger, Ford, & Salas, 1993).

It is also important to determine where to look for changes in performance. Kirkpatrick (1976) suggested that there are different levels of analysis at which training effectiveness can be manifest: the individual, the team or crew, and the organization. A majority of the resource management literature focuses exclusively on the transfer of trained material at the individual or team level. This is quite reasonable, as individual/team *behaviors* are most directly under the control of the trainees. However, aggregate *performance* data, for example at the department or organizational level, are also important to the organization. Unfortunately, performance data, unlike measures of behavior, are frequently beyond the control of the individuals or team. For example, an aircrew may manage a crisis situation perfectly, yet factors beyond their control, such as faulty equipment, can nonetheless lead to a disaster. As such, performance data are subject to extensive confounds, and extreme care must be used when interpreting these results as evidence for or against the effectiveness of training (Campbell, 1990). For these reasons, the effects of resource management training should be evaluated in a systematic, step-by-step fashion.

This chapter will outline the steps needed to evaluate the effectiveness of a resource management training program and highlight both practical and theoretical issues that arise during this process. We will first cover general requirements for defining, implementing, and evaluating resource management training. Then we will illustrate these principles by applying them to Crew Resource Management (CRM) in the aviation domain. This chapter will focus on the application of statistical techniques and research methodology in this domain. For a more comprehensive treatment of these subjects, interested readers should consult Campbell and Stanley (1963), Cook and Campbell (1979), Howell (1997), and Pedhazur and Pedhazur Schmelkin (1991)" (pp. 1-2).


Hopkins, C.O. (1975). How much should you pay for that box? Presented in *Human Factors Society at the Eighteenth Annual Meeting in October, 1975*, 17(6), 533-541.

### Training-Related Highlights

This paper provides foundational material on the issues related to understanding the effectiveness of the use of simulators and whether they should have motion. The issues described are still applicable to the questions currently being addressed about simulator fidelity and motion in spite of the fact that the technology has significantly advanced since it was written.

### Author's Description
*From the Abstract*

"Some claimed cost, safety, efficiency, and effectiveness advantages of aircraft simulators for training are equivocal. Effectiveness of simulator training depends mostly upon the training procedures. Other factors alleged to influence the effectiveness of simulators vary in their demonstrated importance. These are considered in the contexts of physical simulation vs. psychological simulation, simulator fidelity and motivation, and pilot acceptance. One of the more costly areas of engineering development to increase fidelity of physical simulation is motion systems. No experimental evidence is available to show that simulator motion enhances transfer of training. Cost effectiveness has not been demonstrated for

many interesting and attractive features that are standard trimmings on flight training simulators. The acquisition of simulators costing several times as much to own and operate as their counterpart airplanes may produce a backlash that will set back the desirable use of cost-effective simulators in reasonable research and training programs" (p.533).

Hutchins, E. (2007). Measuring change in pilots' conceptual understanding of autoflight. In *Proceedings of the 14th International Symposium on Aviation Psychology*, *Dayton, Ohio, April 2007,* (ISAP 2007), (pp.475-480).

### Training-Related Highlights

This study examined how pilots' understanding of flight-deck automation develops from initial training through the first 18 months of line experience. The researchers interviewed and observed pilots at regular intervals during those 18 months and then conducted a content analysis of the language used by the pilots during the interviews to understand the changes in their conceptual structures across time. This is the same content analysis presented in Holder and Hutchins (2000) and Hutchins and Holder (2001). This paper adds details of a quantitative analyses conducted on the interview data using frequency of terms and co-occurrence of terms. Findings include that pilots with a year of experience still talk more about simple "selected" modes that they do about the more complex "managed" modes, and that at 18 months of experience they talk more about the "managed" modes but it appears that they still have not gained a full understanding of those modes.

### Author's Description
*From the Abstract*

"Pilots transitioning to the Airbus A320 were observed in flight and interviewed at four sample points during their first 18 months on the airplane. The interview data were analyzed by examining changes in both the relative frequencies of automation terms and the similarity of pairs of terms over time. The results show that pilots master selected modes before managed modes, and that even after 18 months of experience, their models of complex managed modes are still changing" (p.1).

Hutchins, E. (2009, August). Expectation and surprise. In C. Hogeman (Chair), *Feeling trapped by automation?* Panel discussion conducted at the ALPA Air Safety Forum, Washington, D.C.

### Training-Related Highlights

This paper outlines possible causes of automation surprise and presents evidence that automation surprises mostly occur as a result of gaps in the allocation of pilot attention. The author makes the point that "while training can always be improved, most automation surprises are probably not the result of deficiencies in pilot knowledge about the operation of autoflight systems. Therefore, we should not expect changes to training on autoflight systems to have large effects of the occurrence of automation surprises." (p.15)

### Author's Description
*From the Abstract*

"Automation surprises have occurred since the introduction of the first automated systems. Earl Weiner's 1989 study of automation use elevated automation surprise to the status of core concern in the commercial aviation industry. In spite of two decades of studies, interface upgrades, and new procedures, recent evidence[1] indicates that automation surprises continue to occur. What causes pilots to be surprised by the automation in their aircraft? Are automation surprises caused by lack of pilot knowledge? Are they due to events that are so rare that they could not be anticipated? In this paper, I will present and support an alternative explanation; that automation surprises mostly occur as a result of the gaps in the allocation of pilot attention" (p.1).

Hutchins, E. & Holder, B. (2000). Conceptual models for understanding an encounter with a mountain wave. In *Proceedings of HCI-Aero 2000, Toulouse, France, September, 2000*.

### Training-Related Highlights

This study examined how pilots' conceptual models are formed though operational experience on the line and how they differ from those presented in training. If characteristics of models used on the line were understood, models used in training could be restructured to be more effective in preparing pilots to deal with problems they might encounter. The interviews and observations described here are the same as those described in Hutchins (2007) and Holder and Hutchins (2000).

### Authors' Description
*From the Abstract*

"Conceptual models are one of many resources available to pilots for making sense of the flight environment. In this paper we describe the conceptual models a pilot uses, in interviews, to explicate his encounter with a mountain wave while flying an Airbus airplane on the line. In the discourse four models emerge: mountain wave, thrust to control speed, pitch to control speed, and climb-descend to control speed. The models he utilizes in his descriptions have a different conceptual structure from models presented in training materials. The analysis suggests that the pilot's conceptual models have an operational organization, and this structure is somehow adapted for managing specific flight situations" (p.1).

Hutchins, E., Middleton, C., & Newsome, W. (2009). Conceptualizing spatial relations in flight training. *Proceedings of the 15th International Symposium on Aviation Psychology*, *Dayton, OH*. (pp. 384-389).

### Training-Related Highlights

This study examined how pilots and flight instructors use their bodies and the relationship of their bodies to surrounding space in order to construct, remember, and reason about situation awareness.

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### Authors' Description
*From the Abstract*

"In the aviation human factors literature, situation awareness (SA) is usually described as arising from disembodied mental processes. Action has virtually no role in current theories of SA. This disembodied view is out of step with contemporary theories that take cognitive processes to be distributed, situated, and above all, embodied. This shift in theory suggests that SA ought to be an embodied phenomenon, and given the highly spatial nature of SA, it would be quite surprising to discover that the body did not play a key role in the construction, elaboration, and maintenance of SA. In this paper we examine the construction of elements of SA in ongoing flight training conducted in a light jet. We show that flight instructors and students make extensive use of their bodies and the relations of their bodies to surrounding space while constructing, remembering, and reasoning about the situation of the airplane" (p.1).

Kearns, S.K. (2008). *E-Learning: The future of pilot safety training*. London, ON, Canada: University of Western Ontario. Retrieved from http://osrm.ssc.uwo.ca/docs/Kearns - Full Paper Submission for EAAP Conference.pdf.

### Training-Related Highlights

In this study the author developed a computer-based single-pilot resource management (SRM) training program and then performed an experiment to assess the program's feasibility for developing improved situation awareness. The study compared two approaches for the computer-based SRM training. Both approaches included modeling of expert pilot behavior and tips based on coaching, and asked learners to articulate their thought processes and reflect on their behavior as it compared with the expert behavior. The two approaches differed in that one practices the concepts using a PC-based flight simulator with cockpit controls (yoke, throttle, and rudder pedals) and the other practiced by using guided mental practice. For the latter, pilots watched a video of a flight scenario and imagined themselves as the pilot. Three groups of pilots were compared in the study: one using each of the two approaches for SRM training and the other without any training used as a control group. The measurement used after training was the Situation Awareness Global Assessment Technique (SAGAT). The results showed that both of the SRM-trained groups performed better than the control group and there was no difference between the trained groups. The author concludes that SRM can be taught using computer-based training and that guided mental practice is a promising instructional strategy.

### Author's Description
No abstract, executive summary, or other short descriptions were included in the document.

Kleiss, J. A. (1995). Visual scene properties relevant for simulating low-altitude flight: A multidimensional scaling approach. In R.W. Swezey and D. H. Andrews (Eds.), *Readings in Training and Simulation: A 30-Year Perspective* (pp. 242-265). Santa Monica, CA: Human Factors and Ergonomics Society.

### Training-Related Highlights

This experimental study examined the design of visual imagery used in simulating low-altitude flight. Results showed two relevant properties for videotapes: variation

in terrain shape and variation in object size or spacing. Results for still photographs were less interpretable.

### Author's Description
*From the Abstract*

"In the present experiments I sought to identify the properties of visual scenes relevant for simulating low-altitude flight. The approach was first to identify the relevant properties of real-world scenes. The stimuli were videotape segments or still photographs of real-world scenes exhibiting a variety of scene properties. Ratings of similarity between stimulus pairs were submitted to multidimensional scaling analyses . Results using videotape segments provided consistent evidence for two relevant scene properties: variation in terrain shape and variation in object size or spacing. Results using still photographs were less interpretable, supporting the argument that motion information is important. Results suggest that designers of flight simulator visual scenes should focus specifically on rendering elements of terrain shape and objects in scenes" (p. 242).

Kleiss, J.A. & Hubbard, D.C. (1993). Effects of three types of flight simulator visual scene detail on detection of altitude change. *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 35(4), 653-671.

### Training-Related Highlights

This experimental study evaluated the effects of visual scene detail in a simulator on the detection of altitude change. The results indicated that increasing the density of objects in scenes had a more consistent effect in improving detection of altitude changes than increasing the detail of individual objects.

### Authors' Description
*From the Abstract*

"The effects of three types of flight simulator visual scene detail on detection of altitude change were evaluated in three experiments. Across all experiments and with a variety of tasks and display conditions, speed and accuracy of detecting altitude change improved with increases in the density of vertical objects in scenes. Adding detail to individual objects to increase their natural appearance produced no consistent effects on performance. In Experiment 3 complex texture distributed globally on terrain surfaces improved detection of altitude change but did not alleviate the need for high object density. These results indicate that available computer image generator processing capacity would be used more effectively by increasing the density of objects in scenes, rather than by increasing the complexity and detail of individual objects. Complex texture is used more effectively when distributed globally on terrain surfaces, rather than when allocated to individual objects" (p. 653).

Kosarzycki, M. P., Salas, E., DeRouin, R., & Fiore, S. M. (2003). Distance learning in organizations: A review and assessment of future needs. In E. Salas (Series Ed.) & D. Stone (Vol. Ed.), *Advances in Human Performance and Cognitive Engineering Research: Vol 3. Human Resources Technology* (pp. 69-98). Boston: JAI.

### Training-Related Highlights

This chapter describes distance learning in context of the many forms of terminology that are used for similar and related concepts, including distance education, e-learning, and computer-based training. The authors describe the benefits of distance learning and provide a critical review of distance learning research. They describe the prevalence of distance learning and its effects from a business perspective, as well as the types of skills and knowledge that can be addressed. The authors conclude with a concise description of what is known about distance learning, including the conclusion that the most effective distance-learning programs are based on proven instructional design principles. They also emphasize that much knowledge still needs to be developed to make the most effective use of distance learning, including how to use distance learning to address higher-order skills like problem solving.

### Authors' Description
*From the Abstract*

"Many organizations have implemented distance-learning (DL) courses and programs as an economical, efficient way to deliver training. The purpose of this chapter is to summarize some of the major considerations that are associated with distance-learning programs. We describe a number of the issues surrounding DL, ranging from how organizations use DL to the differing forms of training being delivered and how organizations are reacting to DL. We close with a discussion of issues in practice and suggest directions for future research" (p. 69).


Longridge, T., Bürki-Cohen, J., Go, T. H., & Kendra, A. J. (2001). Simulator fidelity considerations for training and evaluation of today's airline pilots. *Proceedings of the 11th International Symposium on Aviation Psychology, March 2001, Columbus, OH*.

### Training-Related Highlights

This conference paper reviewed previous work by the authors that addressed the effects of simulator motion and realistic radio communications. It also describes two studies that are in progress building on the previous work. One study to determine whether the previous findings can be applied to other simulators and the other to continue to eliminate potential reasons that could account for the previous study not finding an effect of simulator motion.

### Authors' Description
*From the Abstract*

"Regulatory changes in response to today's airline pilot training and evaluation needs push the twin issues of effectiveness and affordability of flight simulators for use by U.S. airlines to the forefront. The Federal Aviation Administration (FAA) is sponsoring two research programs with high pay-off potential in this area, namely, platform motion and realistic radio communications. This paper describes the rationale and the initial results of this work" (p.1).

Lyall, B., Vint, R., Niemczyk, M., Wilson, J., Funk, K. (1998). *Training approaches and considerations for automated aircraft: A summary of training development experiences* (1998). Retrieved from http://www.researchintegrations.com/publications/training-report-1998.pdf

### Training-Related Highlights

This report describes automation-training methods used by major U.S. airlines and aircraft manufacturers. It covers effective approaches and those the airlines and manufacturers found not to be effective.

### Author's Description
*From the Abstract*

"This report is the result of a project that was initiated to gather information about the current state of airline training for automated aircraft. Prior to the initiation of this project many training developers and researchers had identified challenges associated with creating training programs for automated aircraft. Though the challenges inherent in developing effective training for the automated aircraft were recognized, it was also recognized that, despite the challenges, the airlines and other training organizations were developing and implementing these types of training programs every day based on their own experiences and needs. In other words, training departments and personnel address the challenges of training development in their jobs daily, as well as face new challenges that have not previously been recognized. Therefore, the objective of this project was to gather information about current knowledge related to developing these programs from those who are creating them at the airlines and aircraft manufacturers. The project was not meant to be an exhaustive review of all training methods and, therefore, this report does not address all of the methods available. This report summarizes the training methods currently being used to develop and deliver training for automated aircraft at the major US airlines and aircraft manufacturers. Information is presented about the training methods and approaches that have been found effective by organizations developing training programs for automated aircraft along with descriptions of methods that were abandoned or modified because they did not prove to be effective. The intent of this project was to gather information that would be valuable to organizations modifying their training programs or developing new programs for automated aircraft. Therefore, this report is not meant to be a scientific research paper, but instead it is meant to be a reference document for developers and managers of training programs for automated aircraft" (p. 1).


McCauley, M.E. (2006). *Do army helicopter training simulators need motion bases?* Technical report 1176. US Army Research Institute for the Behavioral and Social Sciences. Document 20060324010.

### Training-Related Highlights

In this literature review, the authors examined the need for simulator motion in training helicopter pilots. The review focused on transfer-of-training experiments where motion was an independent variable. Other topics included in-simulator learning, pilot preferences, force-cueing systems, simulator sickness, and perceptual control theory. It is concluded that there is very little evidence to suggest that simulator motion adds to training effectiveness.

### Author's Description
*From the Abstract*

"This report reviews the arguments and the evidence regarding the need for simulator motion bases in training helicopter pilots. It discusses flight simulators, perceptual fidelity, history of motion bases, disturbance versus maneuver motion, human motion sensation, and reviews the empirical evidence for the training effectiveness of motion bases. The section on training effectiveness reviews research from relevant sources, including: Military helicopter, military transport, commercial airlines, general aviation, fighter, and attack aircraft. In addition the author describes a Perceptual Control Theory approach to determining the information requirements for simulator-based training. The author concludes that there is a substantial body of data to support the training effectiveness of flight simulation in general; that there is virtually no evidence to support the training effectiveness of motion platforms; that motion contributes to in-simulator performance, particularly for experienced pilots; that motion cues may be beneficial for flight training in unstable aircraft and in tasks involving disturbance cues, although the evidence is weak; and that motion, noise, and vibration contribute to the realism of the simulation and, therefore, strongly influence the acceptance of a simulator by the pilot community. There is no reliable evidence that a motion base prevents simulator sickness. Instructional design is more important than physical fidelity for training effectiveness"" (p. i).

McDonnell, L. K., Jobe, K. K., & Dismukes, R. K. (1997). *Facilitating LOS debriefings: A training manual*. (NASA Technical Memorandum 112192). Moffett Field, CA: NASA Ames Research Center.

### Training-Related Highlights

This manual assists airline instructors in effectively facilitating debriefings of LOS. It describes facilitation tools instructors can use to achieve debriefing objectives.

### Authors' Description
*From the Summary*

"This manual is a practical guide to help airline instructors effectively facilitate debriefings of Line Oriented Simulations (LOS). It is based on a recently completed study of Line Oriented Flight Training (LOFT) debriefings at several U.S. airlines. As a companion piece to the published report of that study (LOFT Debriefings: An Analysis of Instructor Techniques and Crew Participation, by R.K. Dismukes, K.K. Jobe, and L.K. McDonnell, NASA Technical Memorandum 110442, March 1997), this manual presents specific facilitation tools instructors can use to achieve debriefing objectives. The approach of the manual is to be flexible so it can be tailored to the individual needs of each airline. Part One clarifies the purpose and objectives of facilitation in the LOS setting. Part Two provides recommendations for clarifying roles and expectations and presents a model for organizing discussion. Part Three suggests techniques for eliciting active crew participation and in-depth analysis and evaluation. Finally, in Part Four, these techniques are organized according to the facilitation model. Examples of how to effectively use the techniques are provided throughout, including strategies to try when the debriefing objectives are not being fully achieved" (p.1).

Mitchell, C.M., Chappell, A.R., Gray, W.M., Quinn, A., & Thurman, D.A. (2000). Intelligent tutoring systems for aviation automation. Report Number: 2000-01-5545. Warrendale, PA: Society of Automotive Engineers (SAE).

### Training-Related Highlights

This experimental study evaluated the effectiveness of two intelligent tutoring systems for operational control of safety-critical systems in MD-11 aircraft. The design of the systems was based on the operator function model (OFM) and its computational implementation. Results showed that the intelligent tutors were effective in increasing pilot proficiency in the experimental conditions used.

### Authors' Description
*From the Abstract*

"This paper begins with a discussion of a cognitive engineering model, the operator function model (OFM), to guide design of artifacts for human interaction with complex systems. Such artifacts include operator aids, associates, and tutors. The paper presents an overview of the current implementation and evolution of the operator function model (OFM) and OFMspert, its computational implementation. It describes how OFMspert has been extended to support the design of two intelligent tutoring systems (ITS) for operational control of safety-critical systems. Proof-of-concept demonstrations and evaluation teaching MD-11 transition pilots vertical navigation and a case-based tutor teaching currently certified MD-11 pilots new procedures, adapted since their certification training" (p. 3).


Moroney, W.F. & Lilienthal, M.G. (2008). Chapter 1: Human factors in simulation and training: An overview. *Human Factors in Simulation and Training*. D.A. Vincenzi, J.A. Wise, M. Mouloua, & P.A. Hancock (eds.). Boca Raton, London, New York: CRC Press.

### Training-Related Highlights

This book chapter provides an overview of information related to human factors and simulation. The chapter includes historical information related to simulation, a comparison of simulation and modeling, advantages and disadvantages of simulation, and information on the simulation-development process. Much of the information emphasizes the human factors perspective. Future requirements and challenges related to human factors and simulation are also discussed.

### Authors' Description
*From the Introduction*

"This chapter provides a broad overview of human factors and simulation with an emphasis on areas that will not be addressed in subsequent chapters; it addresses more global issues. It begins with a discussion of the pervasiveness of simulation, and delineates differences between simulation and modeling. This is followed by a section titled "Why Simulate?" that describes the advantages and disadvantages of simulation from a human factors perspective. Following this is a brief history of simulation that focuses on war gaming and aviation and includes a section on 21st-century simulators. Then the simulation development process is addressed, with particular emphasis on the often neglected area of Verification, Validation, and Accreditation (VV&A). This is followed by a section on simulating human behaviors in systems—a topic that will not be addressed in other chapters. This chapter closes with the authors' perceptions of future challenges in the areas of human factors and simulation" (p. 4).

Mulqueen C., Baker D., & Dismukes R.K. (2002). Pilot instructor rater training: The utility of the Multifacet Item Response Theory model. *The International Journal of Aviation Psychology, 12(3),* 87-303.

### Training-Related Highlights

This journal article describes research addressing the effectiveness of the multifacet Rasch model as a tool to help train pilot instructors to consistently evaluate flight-crew CRM and technical skills. The study compared the multifacet Rasch model with other tools for evaluating the ability of pilot instructors' to objectively rate flight crews. Strengths of using the model for understanding instructor-rating bias are described, including that it is the only model that provides information on individual instructor performance. The authors use data from instructor inter-rater reliability training sessions to demonstrate the usefulness of the model by identifying individual instructors who were rating inconsistently. It was described how the information can be used as feedback for the instructors. The drawbacks of the using the model were also described.

### Authors' Description
*From the Abstract*

"A multifacet 1-parameter item response theory (i.e., Rasch) model was used to examine interrater reliability training for pilot instructors. This model provides a means for examining individual instructor leniency or severity in ratings, difficulty of grade-sheet items, skill levels of flight crews, and interactions among these components. It was found that pilot instructor trainees differed in their levels of rating severity, and that higher crew resource management scores were easier to achieve than technical scores. Interaction analyses identified several pilot instructors who were evaluating crews in an unexpected manner, which is useful when providing feedback during training" (p. 287).

Nikolic, M.I. & Sarter, N.B. (2007). Flight deck disturbance management: A simulator study of diagnosis and recovery from breakdowns in pilot-automation coordination. *Human Factors*, 49(4), 553-563.

### Training-Related Highlights

This journal article describes an exploratory study focused on the behavior of pilots to diagnose and respond to automation-related problems. Data were gathered about pilot diagnosis and recovery during three complex automation-related scenarios in a 747-400 simulator. Results confirmed that there are significant gaps in pilot mental models of the automation and noted the strategies used by pilots in responding to the scenarios. The conclusion was that automation training requires improvements that will allow pilots to achieve quicker error detection, to receive more accurate explanations of errors, and to recover more effectively from errors and disturbances. The authors suggest a need for new forms of exploratory and error management training to support the development of accurate mental models.

### Authors' Description
*From the Abstract*

"Objective: To examine operator strategies for diagnosing and recovering from errors and disturbances as well as the impact of automation design and time pressure on these processes. Background: Considerable efforts have been directed at error prevention through training and design. However, because errors cannot be

eliminated completely, their detection, diagnosis, and recovery must also be supported. Research has focused almost exclusively on error detection. Little is known about error diagnosis and recovery, especially in the context of event-driven tasks and domains. Method: With a confederate pilot, 12 airline pilots flew a 1-hr simulator scenario that involved three challenging automation-related tasks and events that were likely to produce erroneous actions or assessments. Behavioral data were compared with a canonical path to examine pilots' error and disturbance management strategies. Debriefings were conducted to probe pilots' system knowledge. Results: Pilots seldom followed the canonical path to cope with the scenario events. Detection of a disturbance was often delayed. Diagnostic episodes were rare because of pilots' knowledge gaps and time criticality. In many cases, generic inefficient recovery strategies were observed, and pilots relied on high levels of automation to manage the consequences of an error. Conclusion. Our findings describe and explain the nature and shortcomings of pilots' error management activities. They highlight the need for improved automation training and design to achieve more timely detection, accurate explanation, and effective recovery from errors and disturbances. Application: Our findings can inform the design of tools and techniques that support disturbance management in various complex, event-driven environments" (p. 553).

Nullmeyer, R. T., Spiker, V. A., Golas, K. C., Logan, R. C., & Clemons, L. (2006). The effectiveness of a PC-based C-130: Crew resource management aircrew training device. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC 2006).*

### Training-Related Highlights

This conference paper describes an experimental study that evaluated the use of a PC-based simulator for CRM training for C-130 pilots. Results showed that students and instructors found the training effective and that the instructors reported it as a good use of instructor and student time.

### Authors' Description
*From the Abstract*

"Inadequate crew resource management (CRM) behaviors are still cited as causal factors in most military and commercial aircraft mishaps despite mandatory CRM training in virtually all aviator training programs, suggesting a need to explore alternative approaches. A low-cost, PC-based simulator was designed to elicit the communication and crew coordination behaviors associated with instrument and visual airdrop missions. These targeted behaviors were frequently addressed in instructor comments from earlier C-130 student training records, especially for navigators and copilots. The effectiveness of instruction using this device was evaluated. Treatment group students received a four hour training profile before their first airdrop flight while control group students did not. Multiple measures of effectiveness were tracked. Instructors and students rated training effectiveness using 5-point Likert scales. Ratings from both groups were significantly greater than "3" (neutral) for task management, communication, and crew coordination. In addition, instructors reported that the experience was a good use of instructor and student time. Detailed CRM proficiency data were collected during the first subsequent airdrop flight. Positive transfer of training was substantiated by a multivariate analysis of variance. CRM performance ratings during this flight were significantly higher for treatment group students than their for control group peers.

Higher performance grades in training records were also observed for treatment group students in all CRM skill areas through subsequent flights, with fewer sorties to criterion for communication, crew coordination, task management, and decision making for both navigators and copilots.

Empirical CRM training effectiveness data are rare. This paper addresses the effectiveness of instruction using a PC-based simulator to develop teamwork skills and provides a template for measuring "soft skills" in operational environments using a combination of focused, study-specific data collection instruments and existing student training records. Each provided unique insights regarding benefits and limitations of PC-based CRM training" (p. 1).

Regional Airline Association (2008). *Regional airline industry white paper RAA recommends operational testing of training effectiveness without the use of full simulator motion.* Available: http://www.raa.org/Portals/0/CommitteePages/FlightTraining/2-20_RAA_Sim-Motion_PP_Final_Draft_v1-0.pdf.

### Training-Related Highlights

This white paper was released to draw attention to the issue that there is increasing scientific evidence that suggests that flight simulator motion does not enhance pilot training effectiveness when compared with fixed-based simulators that are equipped with state-of-the-art visual systems with a wide field of view. The RAA suggests that the regional airlines are a very important party in the discussion of the issue of requiring simulator motion for pilot training and produced the white paper to be a part of the ongoing debate. Specifically the RAA recommends to the FAA that operational testing is conducted and states that (1) the RAA opposes any decisions by U.S. or international bodies that will permanently close the door to alternatives to full platform motion, and (2) based on the evidence cited, RAA recommends a proof-of-concept operational test of the effectiveness of flight training and checking, up to and including ATP certification and aircraft type rating, without the use of full platform motion.

### Author's Description
No abstract, executive summary, or other short descriptions were included in the document.

Salas, E., Bowers, C. A., Rhodenizer, L. (1998). It is not how much you have but how you use it: Toward a rational use of simulation to support aviation training. *International Journal of Aviation Psychology,* 8, 197-208.

### Training-Related Highlights

This journal article describes three misguided assumptions present in the aviation-training industry related to the use of simulation, and the authors contend they must be addressed and turned around to improve training effectiveness. The ill-conceived assumptions state that (1) simulation is all that is needed to produce effective training, (2) the more simulation the better, (3) if pilots like it then it is good training. The authors refute each of these assumptions by summarizing available research findings. They conclude that the emphasis must be taken off of simulator technology and place on the application of learning principles and the measured effectiveness of the resulting training.

### Authors' Description
*From the Abstract*

"One of the most remarkable changes in aviation training over the past few decades is the use of simulation. The capabilities now offered by simulation have created unlimited opportunities for aviation training. In fact, aviation training is now more realistic, safe, cost-effective, and flexible than ever before. However, we believe that a number of misconceptions—or invalid assumptions—exist in the simulation community that prevent us from fully exploiting and utilizing recent scientific advances in a number of related fields in order to further enhance aviation training. These assumptions relate to the overreliance on high-fidelity simulation and to the misuse of simulation to enhance learning of complex skills. The purpose of this article is to discuss these assumptions in the hope of initiating a dialogue between behavioral scientists and engineers" (p. 197).

Salas, E., Prince, C., Bowers, C., Stout, R., Oser, R. L., & Cannon-Bowers, J. A. (1999). A methodology for enhancing crew resource management training. *Human Factors, 41,* 161–172.

### Training-Related Highlights

This journal article describes a research program that addressed the teamwork elements of crew resource management training. The program built on the available research and tried to answer several questions about how best to approach CRM training. After several studies in which CRM skill training was successfully applied in different areas of naval operations, the authors developed a description of the overall process and methodology used for training development and suggested that it can be used for development of any CRM training program.

### Authors' Description
*From the Abstract*

"Human error is an ever-present threat to the safe conduct of flight. Recently, applied psychologists have developed an intervention, crew resource management (CRM) training, designed to help prevent human error in the cockpit. However, as it is commonly applied within the aviation community, CRM lacks standardization in content, design, delivery, and evaluation. This paper presents a discussion of an applied program of research aimed at developing a methodology for the design and delivery of CRM training within the Navy. This long-term, theoretically based program of aviation team research included identification of skills to be trained, development of performance measures, application of instructional design principles, and evaluation of the training delivery. Our conclusion indicates that a systematic methodology for developing CRM training can result in better performance in the cockpit. Actual or potential applications of this research include any task environment in which teams are interdependent" (p. 159).

Salas, E., Wilson, K. A., Burke, C. S., & Bowers, C. A. (2002). Myths about crew resource management training. *Ergonomics in Design, 10(*4), 20–24.

### Training-Related Highlights

This article outlines the evolution and development of CRM training, and it details eight training myths that hinder the development and administration of this type of

training. The authors describe the reality related to each of the myths in an effort to raise the awareness of the aviation training and research communities and encourage heavier reliance on the science related to training for the development and evaluation of training programs.

### Authors' Description
*From the Introduction*

"It has been frequently documented that a contributing factor in 60%-80% of commercial aviation accidents is human error (e.g., Federal Aviation Administration, 1998). As a result, commercial airlines spend millions of dollars training crewmembers to work effectively as a team. Helmreich and colleagues (1993) stated that commercial aviation is the largest user (and supporter) of team training.

Within the aviation community, the most common type of team training is crew resource management (CRM). To reduce the number of human-err or-related accidents, CRM was introduced to train crewmembers to utilize all available resources: information, people, and equipment. Specifically, CRM training has been conceived as a way to prevent aviation accidents by improving crew performance through better crew coordination' (FAA, 1998, p. 4).

Because the purpose of CRM training is to maximize the use of all available resources so that crewmembers can avoid and manage errors, it is imperative that the crew be able to work together as a team. Although CRM training has been around for 20 years, a recent review of its effectiveness indicated that it is not yet clear whether the aviation community is getting the most out of this training method (see Salas, Burke, Bowers, & Wilson, 2001). Why, after all these years, has CRM training not reached its potential? One possible reason might be the myths or misconceptions prevailing in some organizations about the design and delivery of training and team training.

The purpose of this article is to highlight a few of the myths to which the aviation community might (like many others) fall prey when implementing CRM training. Our hope is to raise awareness of the need to rely on the science of training to design, deliver, and evaluate CRM training" (p. 20).

Salas, E., Wilson, K.A., Burke, C.S., Wightman, D.C., & Howse, W.R. (2006). A Checklist for crew resource management training. *Ergonomics in Design,* 14(2), 6-15.

### Training-Related Highlights

This article describes a need for CRM training to be guided by training and learning science. To facilitate this effort, the authors describe a checklist tool that illustrates the steps to be taken in the development, delivery, and evaluation of a CRM training program. The article also lists and defines several potential CRM skills and learning principles as the details of each of the steps of the checklist are described. It is concluded that such a systematic approach can be applied to the development of any training program and that its implementation will maximize the impact that the training can have on the organizational goals.

### Authors' Description
*From the Abstract*

"Teams are a way of life in organizations. Many industries, organizations, and agencies seek, promote, and encourage teamwork. Teams are dispatched to solve

complex problems, handle stressful tasks, and promote productivity and better service. But not all teams succeed - some derail, fail, or don't produce the desired outcomes. As such, organizations rely on team training to solve these problems. Organizations, especially the aviation and medical communities, seek team training to enhance team performance and safety in cockpits and to manage errors in operating rooms. And so CRM (crew resource management) training was born.

In this article, we provide a checklist to help CRM training designers systematically think about the design, delivery, implementation, and evaluation of CRM training" (p. 6).

Salas, E., Wilson, K.A., Burke, C.S., & Priest, H.A. (August, 2006). *What is simulation-based training?* Crico CRF Forum, 24 (2).

### Training-Related Highlights

This short article aimed at the medical community describes the seven steps required to effectively develop and implement simulation-based training.

### Authors' Description
No abstract, executive summary, or other short descriptions were included in the document.

Salas, E., Wilson, K.A., Lazzara, E.H., King, H.B., Augenstein, J.S., Robinson, D., & Birnbach, D.J. (2008). Simulation-based training for patient safety: Ten principles that matter. *Journal of Patient Safety.* 4, 3-8.

### Training-Related Highlights

This journal article focuses on simulation-based training in health care and patient safety, but the information is applicable to any use of simulation-based training. Ten principles are described to support the implementation of effective simulation-based training. Each of the principles are described in detail.

### Authors' Description
*From the Abstract*

"Simulation-based training can improve patient care when factors influencing its design, delivery, evaluation, and transfer are taken into consideration. In this paper, we provide a number of principles and practical tips that organizations in health care can use to begin implementing effective simulation-based training as a way to enhance patient safety. We commend the health care community for their efforts thus far. We hope that the information provided in this paper will encourage thinking beyond the bells and whistles of the simulation and bring to light full potential of simulation-based training in health care and patient safety" (p. 3).

Salas, E., Wilson, K. A., Priest, H. A., & Guthrie, J. W. (2006). Design, delivery, and evaluation of training systems. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics, Third Edition* (pp. 472–512). Hoboken, New Jersey: John Wiley & Sons, Inc.

### Training-Related Highlights

This book chapter provides a detailed review of training literature primarily published before 2000 and highlights scientifically derived information necessary for designing and delivering an effective training system. Detailed descriptions are provided for the areas of training analysis, training design, training development, training implementation, training evaluation, and transfer of training assessment.

### Authors' Description
No abstract, executive summary, or other short descriptions were included in the document.


Sarter, N.B., Wickens, C.D., Mumaw, R., Kimball, S., Marsh, R., Nikolic, M., and Xu, W. (2003). Modern flight deck automation: Pilot's mental model and monitoring patterns and performance. In *12th International Symposium on Aviation Psychology*, *Dayton, OH*, 2003

### Training-Related Highlights

This conference article provides data that show the types of monitoring behavior of flight crews in glass-cockpit aircraft. A wide-range of pilot behavior was found regarding the frequency, duration, and pattern of scanning automation indications. The debriefing results also showed that pilots do not have a full understanding of how the automation works. The authors suggest that the gaps in knowledge could be addressed by an exploratory approach to training that improves attention allocation and increased processing of flight deck information.

### Authors' Description
*From the Abstract*

"Substantial empirical evidence from surveys and simulator studies indicates that "glass cockpit" pilots sometimes lose track of the status and behavior of automated flight deck systems and, as a result, experience "automation surprises." A number of related factors are assumed to contribute to these problems, including the nature of current automation feedback and gaps and misconceptions in pilots' understanding of the automation. To date, most research on pilot-automation interaction has focused on subjective accounts and on performance outcome measures. Little is known about underlying processes, including how pilots monitor the automation and at what stages their information processing tends to break down. To fill this gap, a simulator study was conducted where twenty 747-400 pilots flew a routine one-hour flight on a fixed-base 747-400 simulator. Several scenario events were introduced to assess pilots' monitoring behavior and their awareness of automation status and behavior. Throughout the scenario, behavioral and performance data as well as eye fixations were recorded. After the scenario was complete, pilots' mental model of the automation was probed based on a predefined set of questions. Overall, the findings from this research confirm that pilots experience considerable problems with monitoring the automation on modern glass cockpit aircraft. There is considerable diversity across pilots in terms of the frequency, duration, and pattern of scanning automation indications. Also, during the debriefing, pilots revealed significant gaps in their understanding of some of the automation features. The results from this study – both in terms of process and outcome measures – will be discussed in terms of their implications for improving training and design for effective pilot-automation collaboration" (p. 1).

Schneider, W. (1985). Training high-performance skills: Fallacies and guidelines. In R. W. Swezey and D. H. Andrews (Eds.), *Readings in Training and Simulation: A 30-Year Perspective* (pp. 285-300). Santa Monica, CA: Human Factors and Ergonomics Society.

### Training-Related Highlights

This foundational article reviewed empirical characteristics of high-performance skill acquisition and describes training fallacies. Training guidelines for facilitating the acquisition of high-performance skills are presented.

### Author's Description
*From the Abstract*

"A high-performance skill is defined as one for which (1) more than 100 hours of training are required, (2) substantial numbers of individuals fail to develop proficiency, and (3) the performance of the expert is qualitatively different from that of the novice. Training programs for developing high-performance skills are often based on assumptions that may be appropriate for simple skills. These assumptions can be fallacious when extended to high-performance skills. Six fallacies of training are described. Empirical characteristics of high-performance skill acquisition are reviewed. These include long acquisition periods, heterogeneity of component learning, development of inappropriate strategies, and training of timesharing skills. A tentative set of working guidelines for the acquisition of high-performance skills is described" (p. 285).

Seamster, T. L., Boehm-Davis, D. A., Holt, R. W., & Schultz, K. (1998). *Developing advanced crew resource management (ACRM) training: A training manual.* Washington DC: FAA, Office of the Chief Scientific and Technical Advisor for Human Factors.

### Training-Related Highlights

This resource provides comprehensive guidance and recommendations for the development of an advanced crew resource management (ACRM) program, including considerations for training at major and regional airlines. The manual is divided into sections that provide a sequence and examples for developing and implementing ACRM.

### Authors' Description
*From the Summary*

*"CRM and the Need for ACRM Training*

U.S. airlines have implemented Crew Resource Management (CRM) training with an emphasis on principles and concepts that improve crew performance and flight safety. This has resulted in crew requirements that have been trained and assessed as additions to, rather than as part of, Standard Operating Procedure (SOP). Advanced Crew Resource Management (ACRM) provides a more integrated form of CRM by incorporating CRM practices with normal and emergency SOP.

ACRM is a comprehensive implementation package including the CRM procedures, training of the instructor/evaluators, training of the crews, a standardized assessment of crew performance, and an ongoing implementation process. ACRM has been designed and developed through a collaborative effort between the airline

and research community. ACRM training is an ongoing development process that provides airlines with unique CRM solutions tailored to their operational demands. Design of CRM procedures is based on critical CRM principles that require emphasis in airline's specific operational environment. Procedures were developed to emphasize these CRM elements by incorporating them into SOPs for normal as well as abnormal and emergency flight situations.

As can be seen in this Manual, ACRM is an ongoing, dynamic, development process and should not be confused with a single set of products. The Manual does present some products of the ACRM training development process, but these are to be used as examples only and should not be used as a substitute for the process. Reproducing a briefing card from another airline will not, by itself, produce the type of organization change that the ACRM training development process can.

*FAA Evaluation of* ACRM *Training*

The Federal Aviation Administration (FAA) has sponsored a Grant, Analysis of CRM Procedures in a Regional Air Carrier, conducted by a team including George Mason University and Subject Matter Experts (SMEs) from a regional airline, a major airline, and other research organizations. The Grant is in the process of evaluating the effectiveness of CRM procedures in a regional airline environment. Both the airline and the FAA are interested in determining whether the implementation of CRM procedures can improve overall crew performance. Under the Grant, the regional airline's key CRM principles were translated into procedures that have been implemented through ACRM training. The regional airline involved in this Grant was authorized to develop an innovative approach to crew training and assessment under the Advanced Qualification Program (AQP).

The results of this Grant have significant ramifications for flight crew training, specifically in the area of integrated CRM and technical skill training. The airlines have not had the capability to perform detailed assessments of CRM skill training, nor have they had the ability to assess different forms of CRM training. The results of this Grant provide guidelines for the training of CRM procedures (see Appendix A for a complete list of the guidelines) as well as a framework for the assessment of skill-based crew performance. With this capability to train and assess CRM performance, airlines can become proactive and improve training based on the assessment data rather than having to rely exclusively on accident and incident information.

*Key Elements of* ACRM *Training*

Key elements of an ACRM program are the development of CRM procedures, training of the instructor/evaluators, training of the fleet crews, and assessment of crew performance based on the airline's operational environment. Supporting elements to the development of ACRM training include the survey forms, changes to the Flight Operations Manual (FOM), Flight Standards Manual (FSM), and Quick Reference Handbook (QRH), the Line Oriented Flight Training/Line Operational Environment (LOFT/LOE) development process, and the Inter-Rater Reliability (IRR) process to standardize crew assessment. These are important supplements and examples are presented in the appendices " (pp. ix-x).

Sherman, P. J. (1997). *Aircrews evaluation of flight deck automation training and use: Measuring and ameliorating threats to safety* (No. Technical Report 97-2). Washington, D.C.: Federal Aviation Administration.

### Training-Related Highlights

This technical report describes the conduct and results of the University of Texas Aviation Automation Survey. The purpose of the survey was to gather information from pilots who fly automated airplanes about their perceptions of the quality of their initial and recurrent training among other topics. It used hypothesis testing and descriptive techniques to determine how pilots view training for automation, the automation itself, and how and when pilots use the automation. One result indicated that pilot perceptions were that training did not adequately prepare them for line operations and they did not develop an adequate understanding of the automation. The report describes all of the results in detail and describes implications of the results on training, flight deck design, and safety.

### Author's Description
*From the Abstract*

"The present study examined 1,718 commercial airline pilots' evaluations of the training they received for use of aircraft automation, automated systems on their current aircraft, and their attitudes toward the use and management of automation. Examination of training ratings showed that, overall, roughly one-quarter of pilots felt that initial training did not adequately prepare them for operating their aircraft. Substantial differences in ratings of training efficacy were found across airlines, aircraft types, experience level, and exposure to discretionary opportunities for practice during training. Examination of automated equipment evaluations revealed that ratings of automation usability are related to ratings of training efficacy, implying that any evaluations of automated equipment must take training efficacy into account. Analyses also demonstrated differences across aircraft types on automation usability, quality of troubleshooting and problem solving, and awareness of aircraft energy state; some of these differences seem to be related to differences across aircraft manufacturers and some to differences in automation generation. Finally, analyses of pilots' attitudes toward management of automation showed relationships between the scales and measures of experience, perceptions of company policies regarding automation use, and a measure of respondents' need to avoid uncertain, ambiguous situations. Overall, these results allow identification of some potential threats to safety that reside in the crew-automation interface. They also suggest that crew-automation interaction can be conceptualized from the systems viewpoint – i.e., that crew-automation interaction is determined by multiple factors, including training quality, the automated equipment itself, and the organization's policies and procedures regarding automation use" (p.1)*.


Sherry, L., Feary, M., Fennell, K., & Polson, P. (2009). Estimating the benefits of human factors engineering in NextGen development: Towards a formal definition of pilot proficiency. *Proceedings of the 9th AIAA Aviation Technology, Integration, and Operations Conference (ATIO) and Air 21 - 23 September 2009, Hilton Head, South Carolina.* Report AIAA 2009-6974.

### Training-Related Highlights

This conference paper discusses the challenges of flight-deck human-computer interaction in the proposed and increasingly complex NextGen airspace. In addition

to providing "a quantifiable definition of human-computer interaction performance", a formal definition of flight-crew proficiency, a framework for evaluating these proficiencies, and an examination of the relationship between individual proficiency and flight-crew proficiency are provided.

### Authors' Description
*From the Abstract*

"The concepts-of-operation proposed for the Next Generation Air Transportation System (NextGen) implicitly require a significant improvement over existing standards for flightdeck human-computer interaction. Whereas in today's airspace operations there is no routing penalty for delayed response to a required ATC maneuver, flights in high density NextGen airspace that are unable to respond to off-nominal situations in a timely manner, will lose their slot and be shifted to a downgraded level of airspace resulting in flight delays and/or increased route distance.

Current design and certification processes for avionics, aircraft, and pilots prove the reliability of the "deterministic" automated functions in a comprehensive manner. The design and certification requirements for ensuring and testing the reliability of the inherently "non-deterministic" operator interaction with the automation are not rigorous and are the source of operational inefficiencies and reduced safety margins. Unless the design and certification process are radically modified and refocused, pilots will find themselves with the same types of issues that researchers documented with the introduction of the "glass cockpit" in the 1980s and 1990's.

This paper provides a quantifiable definition of Human Computer Interaction performance and explicit measures of individual and crew proficiency. A method for estimating revenue-service cost savings generated by improved proficiency is described along with an example of the cost savings benefits accrued by a hypothetical large U.S. domestic carrier experiencing improved proficiency in response to FMS error messages ($45M per year). A discussion of the implications and limitations of the definition of proficiency and the cost savings model is provided" (p. 1).

Sherry, L., Feary, M., Polson, P., & Fennell, K. (2003). Drinking from the fire hose: Why the flight management system can be hard to train and difficult to use. *Technical Memorandum No. NASA/TM-2003-212274*. NASA Ames Research Center.

### Training-Related Highlights

This technical report describes an analytical study using the RAFIV that reviewed pilot tasks in using the flight management computer and found that a large number of tasks required memorized action sequences. The authors state that this result may help explain difficulties in training automation. They provide four recommendations for training programs indicating that training programs should (1) provide explicit models of the skills required to perform tasks using the automation, (2) provide schemas that organize and make comprehensible these skills, (3) provide schemas that support the transfer of training from one skill to the next, and (4) train the required memorized action sequences. Other implications for training and design are also described.

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### Authors' Description
*From the Summary*

"The Flight Management Computer (FMC) and its interface, the Multi-function Control and Display Unit (MCDU) have been identified by researchers and airlines as difficult to train and use. Specifically, airline pilots have described the "drinking from the fire-hose" effect during training. Previous research has identified memorized action sequences as a major factor in a user's ability to learn and operate complex devices.

This paper discusses the use of a method to examine the quantity of memorized *action* sequences required to perform a sample of 102 tasks, using features of the Boeing 777 Flight Management Computer Interface. The analysis identified a large number of memorized action sequences that must be learned during training and then recalled during line operations. Seventy-five percent of the tasks examined require recall of at least one memorized action sequence. Forty-five percent of the tasks require recall of a memorized action sequence and occur infrequently. The large number of memorized action sequences may provide an explanation for the difficulties in training and usage of the automation. Based on these findings, implications for training and the design of new user-interfaces are discussed" (p. 5).

Sherry, L., Feary, M., Polson, P., & Palmer, E. (2001). *Autopilot tutor: Building and maintaining autopilot skills.* Unpublished paper. Retrieved February 25, 2011 from http://humansystems.arc.nasa.gov/IHpersonnel/feary/files/AutopilotTutor1.pdf.

### Training-Related Highlights

This paper describes the development of a web-based cognitive tutor to train pilots flying large aircraft with autopilots and FMAs. The tutor is a part-task trainer that defines the knowledge needed to recognize autopilot behavior from information on primary flight displays and to convert pilot goals into actions using the mode control panel. The authors state that a study is planned to test the effectiveness of the tutor.

### Authors' Description
*From the Abstract*

"This paper describes a web-based tutor used to build and maintain pilot skills in operating a modern autopilot. The tutor, based on a goal-based model derived from the actual autopilot code, explicitly defines: (1) knowledge to recognize all unique autopilot behaviors from information on the flight mode annunciation (FMA) and other primary flight display (PFD) cues, (2) knowledge to convert pilot goals into pilot actions on the mode control panel (MCP). The tutor builds and maintains pilot skills by requiring the pilot to "solve problems" by executing Air Traffic Control instructions. The tutor provides immediate feedback to reinforce correct pilot behavior and rectify incorrect pilot behavior" (p. 1).

Sherry, L., Fennell, K., Feary, M., & Polson, P. (2006). Human–computer interaction analysis of flight management system messages. *Journal of Aircraft*. Vol. 43, No. 5, September–October 2006.

### Training-Related Highlights

This journal article describes an analysis of the human-computer interaction required to respond to scratchpad error messages of a modern FMS. The results of the study

demonstrated that these error messages require deliberate design that considers the properties of human–computer interaction. Based on the results of the study, recommendations related to training materials and training opportunities are made.

### Authors' Description
*From the Abstract*

Researchers have identified low proficiency in pilot response to flight management system error messages and have documented pilot perceptions that the messages contribute to the overall difficulty in learning and using the flight management system. It is well known that sharp reductions in pilot proficiency occur when pilots are asked to perform tasks that are time-critical, occur very infrequently, and are not guided by salient visual cues on the user-interface. This paper describes the results of an analysis of the pilot human–computer interaction required to respond to 67 flight management system error messages from a representative modern flight management system. Thirty-six percent of the messages require prompt pilot response, occur very infrequently, and are not guided by visual cues. These results explain, in part, issues with pilot proficiency, and demonstrate the need for deliberate design of the messages to account for the properties of human–computer interaction. Guidelines for improved training and design of the error messages are discussed" (p. 1).

Sherry, L., Medina, M., Feary, M. & Otiker, J. (2008). Automated tool for task analysis of NextGen automation. Presented in *Integrated Communications, Navigation and Surveillance Conference*, *2008*. ICNS (pp. 1-9).

### Training-Related Highlights

This conference paper describes an automated tool developed to be used for airline training or procedure development. The tool uses human-performance models combined with human computer interaction process analysis (HCIPA) to predict the usability of tasks and procedures while they are being developed. A case study is described that assessed the usefulness of the tool.

### Authors' Description
*From the Abstract*

"The realization of NextGen capabilities will require rapid deployment of revised airline cockpit procedures and the pre-requisite training and proficiency checks. Traditional approaches for the evaluation of the re-designed procedures and training, such as expert reviews and human-in-the-loop tests, cannot provide comprehensive analysis, cannot be performed until after the procedures and training are developed, and are cost and time prohibitive.

This paper describes the emergence of a new class of tools to automate the evaluation of procedures and training. The tools capture the procedures and tasks to be trained in a formal model that is stored in a data-base. Human performance models are executed to estimate the ease-of-learning, ease-of-use and likelihood of failure of each of the tasks. The procedures and tasks can be defined rapidly, and modified and run repeatedly throughout the development cycle. The underlying models and tools are described in this paper. A case study and the implications of these tools are also discussed" (p. 1).

Simon, C.W. & Roscoe, S.N. (1984). Application of a multifactor approach to transfer of training research. Human Factors, 26(5), 591-612.

### Training-Related Highlights

This journal article describes a foundational experimental study that examined relationships among training and transfer scores for a computer-generated horizontal-tracking task. Transfer-of-training studies would be simplified if the transfer of simulator training to actual flight could be predicted from performance in the simulator. The primary objective of the study was to describe and demonstrate a practical way to inexpensively conduct transfer experiments.

### Authors' Description
*From the Abstract*

"A multifactor, multicriterion transfer of training experiment involving a computer-generated horizontal tracking task was conducted to establish relationships among training and transfer scores for manual control of a maneuvering vehicle, to determine the response surfaces for training and transfer, and to demonstrate a new transfer research paradigm that makes economically feasible the simultaneous investigation of the effects of a large number of training-equipment and use variables on transfer to multiple-criterion vehicle configurations. There were 80 experimental participants, 48 of whom were trained and tested on individually unique combinations of training and transfer conditions. This study was the first to measure the training and transfer effects of as many as' six training equipment and use factors in a single experiment, to examine as many as 25 training-vehicle configurations in the same experiment, to train a single individual on each of 48 training conditions, to employ multiple (3) transfer vehicle configurations, and to provide data suitable for deriving multiple-regression equations for estimating the transfer effectiveness of configurations not directly studied" (p. 13).

Sumwalt, R. L. III, Thomas, R. J., & Dismukes, R. K. (2002). Enhancing flight-crew monitoring skills can increase flight safety. *Proceedings of the 55th International Air Safety Seminar, Flight Safety Foundation, Dublin, Ireland, 4-7 November 2002,* 175-206. Available: http://human-factors.arc.nasa.gov/flightcognition/Publications/Holbrookcopy.pdf

### Training-Related Highlights

This conference paper identifies the underlying causes of poor pilot monitoring of aircraft systems and flight paths. It introduces the idea of the "active-monitoring concept", and offers a conceptual framework for the development of a program to address these issues through improved training and policy changes.

### Authors' Description
*From the Introduction*

"To ensure the highest levels of safety each flight crewmember must carefully monitor the aircraft's flight path and systems, as well as actively cross-check the actions of each other. Effective crew monitoring and cross-checking can literally be the last line of defense; when a crewmember can catch an error or unsafe act, this detection may break the chain of events leading to an accident scenario. Conversely, when this layer of defense is absent the error may go undetected, leading to adverse safety consequences.

Following a fatal controlled flight into terrain (CFIT) approach and landing accident (ALA) involving a corporate turbo-prop the surviving pilot (who was the Pilot Not Flying) told one of the authors of this paper, "If I had been watching the instruments I could have prevented the accident." This pilot's poignant statement is quite telling; in essence, he is stating that if he had better monitored the flight instruments he could have detected the aircraft's descent below the minimum descent altitude (MDA) before it struck terrain.

This pilot's statement is eerily similar to a conclusion reached by the U.S. National Transportation Safety Board (NTSB) after an airliner descended through the MDA and impacted terrain during a nighttime instrument approach. "If the First Officer had monitored the approach on the instruments...he would have been better able to notice and immediately call the Captain's attention to the altitude deviation below the minimum descent altitude" (p. 1).

Taylor, H.L. & Emanuel, T.W. (2000). A civil aviation view of aircrew training. In Harold F. O'Neil, Dee H. Andrews (Eds.), *Aircrew Training and Assessment* (pp. 17-36). Mahwah, NJ: Lawrence Erlbaum Associates. Training-Related Highlights.

### Training-Related Highlights
This book chapter describes various civil-aviation organizations and the important trends that are shaping aircrew training.

### Authors' Description
No abstract, executive summary, or other short descriptions were included in the document.

Taylor, H. L., Talleur, D. A., Bradshaw, G. L., Emanuel Jr., T. W., Rantanen, E., Hulin, C. L., & Lendrum, L. (2003). *Effectiveness of personal computers to meet recency of experience requirements* (No. DOT/FAA/AM-03/3). Savoy, Illinois: University of Illinois at Urbana-Champaign.

### Training-Related Highlights

This resource presents a study that tested the effectiveness of personal computer aviation training devices (PCATDs) and FTDs to meet FAA recency-of-experience requirements for instrument flight. An overview of PC technology compared to FTDs is presented, and PCATDs are shown to be just as accurate as, and less costly than, FTDs. Specific studies related to PCATDs are discussed. A follow-on study concerning incremental transfer of training effectiveness is also discussed.

### Authors' Description
*From the Abstract*

"The purpose of the current study was to investigate the effectiveness of Personal Computer Aviation Training Devises (PCATDs) and Flight Training Devices (FTDs) to meet FAA recency of experience requirements for instrument flight. Two types of training devices were tested: 1) an FAA approved PCATD; and 2), Frasca 141 FTD. An Instrument Proficiency Check (I PC) was given to all subjects in the airplane to establish a performance baseline (IPC #1). After the completion of IPC #1 in the airplane, the subjects were randomly assigned to one of four groups: the PCA TD, the FTD, the aircraft or the control group with a balancing constraint so that the

subjects successfully completing IPC #1 were equally distributed among the four groups. During the six-month period, each subject received two recency of experience flights of about 1.8 hours each in either the PCATD, the FTD or the aircraft; the control group received no recency training. These recency of experience flights included three instrument approaches, holding procedures, and intercepting and tracking navigation radials and courses. After the six-month period, performance on an IPC in the airplane (IPC #2) compared pilots who received recency of experience in the training devices to a control group. The subjects in the PCATD and FTD group were also compared to the aircraft group who received recency of experience in the airplane. A comparison of the three training groups with the control group performance on the final instrument proficiency check indicated that the training groups performed significantly better than the control group. The study also indicated that PCATDs are effective in maintaining recency of experience for instrument rated pilots over a period of six months. The two recency of experience practice sessions resulted in significantly better performance for the PCATD group on an IPC compared to the control group. Practice in either the PCA TD or the FTD resulted in higher pass rates compared to the control group and practice in the PCATD and the FTD was found to be at least as effective as practice in the airplane. Finally, the performance of the PCATD group was statistically indistinguishable from the FTD group. These findings present compelling evidence that the FAA should permit the use of PCATDs to maintain recency of experience for instrument pilots" (p. i).

Thomas, M. J. W. (2003a). Improving organisational safety through the integrated evaluation of operational and training performance: An adaptation of the line operations safety audit (LOSA) methodology. *Human Factors and Aerospace Safety*, 3, 25–45.

### Training-Related Highlights

This journal article describes an experimental study using a methodology adapted from the LOSA observational process with additions that allowed the evaluation of the training systems along with operational performance. The results indicated several areas in which training did not adequately prepare pilots for effectively performing in line operations, including effectively managing errors. Implications for improving training are presented.

### Author's Description
*From the Abstract*

"The development of effective feedback mechanisms between operations and training is an essential predicate to enhancing safety and improving efficiency in any organisation. With the constant demands to streamline training, the design of training programs that adequately reflect operational needs is paramount. This paper describes the use of new observational methodologies in the integrated evaluation of an airlines' operational and training systems performance. This approach not only complements the traditional check and training systems, but provides a new mechanism by which airlines can pro-actively unmask deficiencies and possible latent failures in both their training and line operations. Building upon the Line Operations Safety Audit (LOSA) methodology, an integrated evaluation of operations and training was undertaken on two fleets of an airline operating both short-haul domestic and medium-haul international routes. The findings of this research lend strong support for the adoption of organisational approaches to performance

evaluation as a necessary part of an airline's commitment to safety and efficiency in its operations" (p. 1).

Thomas, M.J.W. (2003b). Operational fidelity in simulation-based training: The use of data from threat and error management analysis in instructional systems design. *Proceedings of SimTecT 2003: Simulation Conference, 26-29 May, Adelaide, Australia,* 91-95*.*

### Training-Related Highlights

This conference paper describes a model of a threat-and-error-management LOSA-observation methodology used as a task analysis tool to increase the operational fidelity of training events.

### Author's Description
*From the Abstract*

"A crucial aspect of the effectiveness of simulation-based training is the notion of fidelity. Typically, research and development in relation to simulation fidelity has focussed on achieving high levels of visual, kinaesthetic and functional realism. While this approach has lead to significant advancements in simulator-based training, there remains a need to develop mechanisms to ensure that training is responsive to the real operational needs of an organisation. This approach is termed "operational fidelity" and can be defined as ensuring the simulation is an authentic representation of the complex operational environment of an organisation. Methods currently used for understanding the operation of complex systems, such as modern aircraft, frequently adopt an abstracted approach to data acquisition. For instance, Cognitive Task Analysis is used to inform Instructional Systems Design through the decomposition and analysis of individual work elements. While these approaches to Instructional Systems Design provide a robust empirical method for the detailed analysis of system operation, they do not provide sufficient information to an organisation about the complex contextual factors that influence everyday operatoional performance. Accordingly, new tools need to be utilised in order to adopt a data-driven approach to simulator-based training. This paper describes in detail a new methodology to ensure enhanced simulator-based training through increased operational fidelity. Focussing on an example from the commercial aviation setting, the study details how data from the analysis of Threat and Error Management actions undertaken by flight crew during normal operations can be utilised in the development of scenario-based training. The paper outlines a four-stage process in scenario development and highlights the potential for such an approach to Instructional Systems Design in a variety of training environments" (p. 1).

Thomas, M. J. W. (2004a). *Error Management training: Defining best practice.* ATSB
Aviation Safety Research Grant Scheme Project 2004/0050. Retrieved February 2,
2011 from
http://www.atsb.gov.au/media/36711/error_management_training_best_practice.pd
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### Training-Related Highlights

This work describes two different studies related to error management and error-
management training. The first study was a series of interviews that collected data
on the core components of effective error management and error-management
training currently existing in commercial airlines. The second study relied on
observations during simulator training sessions to determine the best practices for
error-management training.

### Authors' Description
*From the Executive Summary*

"Human error remains a significant causal factor in the majority of aviation incidents
and accidents. In response to the ubiquity of human error, it has been suggested
that a key to maintaining safety in high-risk industries lies in the development of
specific error management training programs. However, we are still some way from
defining best practice in error management training.

Error management training refers to the structured development of error
management competencies through a formal process of training. A critical premise
for error management training is that it should not form a separate element of a
training curriculum, but rather elements of error management training should be
integrated into ground, simulator and line training.

Due to the lack of a strong scientific foundation to the design and specification of
error management training programs, a major research project was initiated in order
to provide an empirical foundation for error management training programs in the
commercial aviation setting. The primary objective of this research project was to
provide the Australian aviation industry with a concrete curriculum package for error
management training for flight crew.

A curriculum typically specifies the major aspects of training, including: 1) a
specification of the core knowledge and skills that form the instructional objectives of
training and the content of the syllabus; and 2) the instructional approaches adopted
in the implementation of the training. This report provides an overview of both of
these aspects of an error management training curriculum" (p. 1)

Thomas, M. J. W. (2004b). Predictors of Threat and Error Management: Identification of
core non-technical skills and implications for training systems design. *International
Journal of Aviation Psychology, 14*(2), 207-231.

### Training-Related Highlights

This descriptive study uses observations of a crew's performance during normal flight
operations to gather data related to a set of contextual factors and nontechnical
skills. Afterward, the crews' threat-and-error management skills were analyzed in
relation to the data collected. For each phase of flight, predictive models of threat
and error management were developed. The study shows how a specific type of data

analysis can demonstrate strengths and weaknesses of operational performance and improve training systems by the use of further developed scenario-based training.

### Authors' Description
*From the Abstract*

"In normal flight operations, crews are faced with a variety of external threats and commit a range of errors that have the potential to impact negatively on the safety of airline operations. The effective management of these threats and errors therefore forms an essential element of enhancing performance and minimizing risk. Recent research has reinforced the need to examine a range of nontechnical or crew resource management skills that form threat and error countermeasures. This article provides an analysis of the predictors of threat and error management in normal flight operations within the context of a Southeast Asian airline. Through the structured observation of crews' performance during normal flight operations, data were collected in relation to a set of contextual factors and nontechnical skills. Crews' threat and error management actions were then analyzed in relation to these factors, and predictive models of threat and error management at various phases of flight were developed. The results of this study demonstrate the ways in which this type of data analysis can highlight the strengths and weaknesses of operational performance and suggest that this type of performance evaluation can offer individual organizations invaluable information for enhanced training system design through the further development of scenario-based training" (p. 207).

Thurman, R. A., & Dunlap, R. D. (1999). Assessing the effectiveness of simulator-based training. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC 1999)*.

### Training-Related Highlights

This conference paper describes a review of literature from several domains, including flight training, to determine the effectiveness of simulator-based training. The study found that little has been done to determine the effectiveness of simulators or of the tactics and strategies for using them.

### Authors' Description
*From the Abstract*

"The digital revolution has sparked a worldwide movement toward the use of simulators to enhance training and accelerate learning. As simulator-based training grows, the concern of trainers should increasingly turn to determining if effective training is taking place, rather than merely using simulators more extensively. We reviewed the simulator training literature to see just what literature exists as well as the effect simulation is having in terms of training effectiveness. The review concentrated on the literature from several different domains/perspectives, including the NASA space program, commercial aviation training, medical procedures training, and nuclear power plant operation training. The objective of the review was to focus on prototypical studies which showed utility in determining the effects of simulator-based training of highly complex tasks. Unfortunately, our review showed that little attention is being directed toward determining the effectiveness of these training devices and research on the effective tactics and strategies for utilizing simulation are almost nonexistent. We then put forward a brief explanation for the lack of motivation to assess simulator-based training, along with a plea to move forward in

this area. Finally, we review a model, first outlined by Lewis (1996), for assessing the effectiveness of simulator-based training" (p. 1).

Turney, M.A, Henley, I., Niemczyk, M., & McCurry, W.K. (2001). Inclusive strategies versus exclusive strategies in aviation training: Focusing attention on aviation safety. *Proceedings of the 11th International Symposium on Aviation Psychology, Columbus, Ohio, USA, March 5-8, 2001.*

### Training-Related Highlights

This conference paper emphasizes the importance of focusing on the instructional needs of diverse students in aviation training and education programs and provides guidance for the development of training curriculums that meet those needs. A case is made for addressing cross-cultural, racioethnic, and gender differences in making aviation education and training more inclusive. Computer-based instruction and distance learning are promoted to create aviation programs that are applicable to a multicultural environment.

### Authors' Description
*From the Abstract*

"Successful training and education programs focus on the instructional needs of diverse students. Important differences related to learning exist universally and these have broad implications in the aviation industry, an industry that must compete for the talent of the increasingly diverse worldwide workforce. The ability to address cross-cultural (e.g., Asian-Anglo) differences, racioethnic, and gender differences is essential in making aviation education and training more inclusive. The increased use of computer-based instruction and distance learning technologies are key factors in aviation program development that is applicable to a multicultural environment. Guidelines for Inclusive Course/Model Development provide the specific focus for inclusive strategies and offer the organization an opportunity to define learning and training environments that are inclusive" (p.1).

Volpe, C.E., Cannon-Bowers, J.A., Sales, E. & Spector, P.E. (1996). The impact of cross-training on team functioning: An empirical investigation. *Human Factors,* 38(1*)*, 87-100.

### Training-Related Highlights

This journal article describes work that examined the effects of cross-training and workload on team processes, communications, and task performance. The results of the study suggest that cross-training may be one way of preventing problems that may occur as a result of lack of interpositional knowledge (IPK). However, the study concludes that more research is needed to determine the approach, format, and specificity required for cross-training, depending on the type of task and team.

### Authors' Description
*From the Abstract*

"The effects of cross-training (presence vs. absence) and workload (high vs. low) on team processes, communication, and task performance were examined. Eighty male undergraduate students were randomly assigned to one of four training conditions: cross-training, low workload; cross-training, high workload; no cross-training, low

workload; and no cross-training, high workload. Results indicated that cross-training was an important determinant of effective teamwork process, communication, and performance. Predicted interactions between cross-training and workload were not supported. Implications for the design and implementation of cross-training as a means to improve team functioning are discussed" (p. 1).

Wallace, J. W., & Hannibal, B.J. (2008). What is realism?: Navigating the obstacles and forging a path to achievement. P*roceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC 2008).*

### Training-Related Highlights

This conference paper describes work focused on defining realism, fidelity, and related terms used in training modeling and simulation. The study described a scheme to characterize realism in a way that provides insight into its significance, the obstacles to achieving it, and methods to enhance it.

### Authors' Description
*From the Abstract*

"At last year's (2007) Interservice/Industry Training, Simulation & Education Conference (I/ITSEC) Flag Panel, many leaders mentioned the need for improving realism, and that it was a topic of interest for their service or organization. However, a community-wide agreement or consensus understanding as to how realism is defined seems to be lacking. For example, realism may be defined as high-definition graphics in some cases, as realistic environmental factors (e.g., simulation of strong winds) in other cases, or even as culturally-sensitive battle and negotiation tactics in others. So precisely, what does someone mean when they use the term realism, and is the meaning consistent across disciplines and across services and organizations? In a related vein, there is wide community agreement regarding the need to advance the practice of non-kinetic effects representation to the same level as our abilities in kinetic effects. As such, it would be useful to understand the relationship between realism and the concepts and practices in the modeling and simulation of kinetic and non-kinetic effects. The paper provides some examples of how these concepts are related, and also addresses the concepts of fidelity, resolution, and verification, validation, and accreditation (VV&A). The objective of this paper is to systematically describe a scheme to characterize realism in a way that provides insight into its significance, the obstacles to achieving it, and methods to enhance it, with regard to modeling and simulation efforts employed in training and education curricula and programs. Principally, this paper intends to begin the discussion of representation primitives required to support the improvement of realism in order to enhance warfighter readiness, and to ultimately understand how to build more effective training and education products to maximize the Government's return on investment" (p. 1).

Whaley, C.J. & Fisk, A. D. (2001). Readings in training and simulation: A 30-year perspective. *Effects of Part-Task Training on Memory Set Unitization and Retention of Memory Dependent Skilled Search* (pp. 101-114) Santa Monica, CA: Human Factors and Ergonomics Society.

### Training-Related Highlights

This journal article describes foundational experimental studies that compared the effects of part-task training and whole-task training on skill acquisition and retention. The experiments specifically addressed memory-dependent skills. The results support the use of part-task training in similar situations.

### Authors' Description
*From the Abstract*

"Two experiments were conducted to examine the effects of part-task training on the acquisition and retention of a memory-dependent skill. Participants received extensive practice on a semantic category, memory/visual search task in one of three training conditions. To assess the effects of part-task training on memory element unitization, subjects trained on one third, one half, or all of the memory set elements during any given training session. Transfer tests requiring whole-task performance provided one index of training effectiveness. The results suggest that consistent memory sets can be unitized even if part-task training is used. Indeed, part-task training was as effective as whole-task training when immediate transfer was assessed. Part-task training produced retention performance equivalent to whole-task training when retention performance was determined by both target and distractor learning. Retention performance was superior for part-task training compared with whole-task training when performance was based on only target learning" (p. 101).

Wiener, E.L., Chute, R.D., & Moses, J.H. (1999, June-August). Transition to glass: Pilot training for high-technology transport aircraft. *Flight Safety Digest, 18*(6-8),1-136. Available: http://flightsafety.org/fsd/fsd_jun_aug99.pdf

### Training-Related Highlights

This longitudinal study collected questionnaire data on flight training, technical support, and pilot management from pilots transitioning to a glass cockpit. The study found that generally the pilots had a positive attitude toward their training and toward flight-deck automation. The study also reported pilot concerns about losing basic airmanship skills.

### Authors' Description
*From the Summary*

"This report examines and details the activities of a major U.S. airline during the period of late 1993 to late1997,as it acquired two fleets of advanced-technology aircraft, the Boeing 757 and the 737-500. The host airline had planned to purchase 767s during the period of the study, but delivery was delayed for economic reasons. The 767 and 757 are considered a single fleet due to the commonality of their cockpits.

All three aircraft were equipped with electronic flight instrument systems (EFIS), colloquially known as "glass cockpits." There are aircraft with flight management systems (FMSs), but with traditional instrumentation (e.g., some models of the B-

737-300). But generally, the glass aircraft have both FMSs and instrument panels that are driven by computer-based color graphics. These are not simply electronic replications of traditional aircraft instruments, but are highly versatile displays that can do what traditional instruments cannot (e.g., the horizontal situation indicator (HSI) moving map display, the display of radar returns on the map, the display of the wind vector and the position predictor vector).

Prior to the delivery of the first 737-500 in January 1994, the airline had no glass airplanes. The most modern aircraft was the 737-300 non-EFIS ("round dial"), with a modern FMS (see above).

Although the primary focus of the study was upon flight training, we examined as well the technical support and management of the pilots in these fleets, in some cases very detailed matters, such as checklist and procedure design.

Questionnaire data were collected in three phases:

Phase1-thefirstdayoftransitiontraining

Phase 2 -approximately 3-4 months after transition training

Phase 3 -approximately 12-14 months after initial operating experience (IOE)

A total of 150 pilots who were entering 757 transition training volunteered for the study. Three were dropped during data analysis for the first stage due to incomplete data records. Of the remaining 147, 102 returned data forms in Phase II of the study, and of these, 99 pilot volunteers also completed the forms in the third phase.

Face-to-face and telephone interviews were conducted with a sample of20 line pilots, as well as with flight instructors, check airmen, management pilots and ground school instructors.

As a side activity, at the request of the company, a sample of volunteers going through transition to the 737-300/500 was selected and given the questionnaires, before and after a change in the training program. The company wished to have an independent assessment of the effect of the change. This study will be reported in a subsequent publication authored by Rebecca Chute.

The 757 study found that, by and large, pilots transitioning to the B-757, most of whom were going to their first glass cockpit, had high morale, low levels of apprehension about the transition and a generally positive attitude toward their training and toward cockpit automation. They also shared some concerns, such as what they perceived as a potential for a loss of basic airmanship skills, and an apprehension about having sufficient time for extra-cockpit scanning ("head outside"). These concerns will be addressed in this report" (p. 4).

Wiggins, M. E., Hampton, S., Morin, D., Larssen, A., & Troncoso, A. (2002). *A study of training devices used by flight training organizations.* Unpublished report prepared for the University Aviation Association under FAA contract No. DTFA 01-01-X-02051. Daytona Beach, FL: Embry-Riddle Aeronautical University. Available: http://www.hf.faa.gov/docs/508/docs/FTDphaseI.pdf

### Training-Related Highlights

This resource describes the types of training devices currently used in GA flight-training programs.

### Authors' Description
*From the Executive Summary*

"Recent advances in computer technology have created many new devices and computer programs that are being used throughout the flight training industry. Little is known about the exact number and nature of training devices currently in use and there is no central repository of data regarding these various training devices. A survey of 354 flight training organizations was conducted to gain insight into how training organizations use different types of training devices. These organizations included 99 universities, 153 Part 141 flight schools, and 102 Part 61 flight schools. The data revealed that 381 flight training devices (FTDs), 224 Personal Computer Aviation-Training Devices (PCATDs), and 99 other types of training aids (OTAs) are being used in various combinations in private and commercial pilot certificate programs and instrument and multi-engine rating programs. The data revealed that university programs make more use of these devices on average than do non-university Part 141 and Part 61 schools. Flight training devices are still the largest number of devices in use and instrument rating programs use these devices more than do the other types of training. A large number of universities are making use of a computer program that is available to the general public even though no credit is allowed under current regulations for its use. Most FTDs are certificated as Level 1 devices under the guidelines of Advisory Circular AC120- 45A, Airplane Flight Training Device Qualification (FAA, 1992). The data also reveals several demographic data about the responding schools, manufacturers and models of the devices reported, numbers of schools using various devices, and amounts of use" (p. iv).

Wood, S.J. and Huddlestone, J. (2006). Requirements for a revised syllabus to train pilots in the use of advanced flight deck automation. *Human Factors and Aerospace Safety*, 6(4), 359-370.

### Training-Related Highlights

This journal article describes research on the possibility that pilots of modem aircraft may be unable to deal with failures of automated systems and wrongly programmed systems. An automation training syllabus is proposed to address the problem.

### Authors' Description
*From the Abstract*

"This paper reviews research that has been conducted on behalf of the UK CAA into the possibility of inappropriate response by pilots to problems with automation. The research identified a gap between the procedural knowledge required to operate highly automated aircraft and that which is delivered by current training processes. The requirements to address this gap are identified, and a proposed structure for type rating training on highly automated aircraft is presented" (p. 359).

Wright, R. A. (2002). *Changes in general aviation flight operations and their impact on system safety and flight training.* Washington, DC: FAA Flight Standards White Paper.

### Training-Related Highlights

This paper reviews changes in general aviation and the need for adaptable flight-training tools and standards that maintain or improve safety. The integration of general aviation in the national airspace system is also discussed.

### Author's Description
*From the Introduction*

"The purpose of this white paper is to identify recent and impending changes in general aviation flight operations that may require new approaches to pilot training and related activities. This paper will identify such changes within the framework of current regulatory and system safety metrics as well as new system safety models. It will then identify the elements needed to apply these concepts to new flight training tools and Federal Aviation Administration (FAA)/ industry training standards to maintain or improve system safety and maintain or increase general aviation's integration in the National Airspace System (NAS).

This paper is NOT a precursor to major regulatory proposals but rather will suggest approaches adaptable to partnership with the general aviation community. The approaches suggested will focus on risk management and aeronautical decision making techniques, training and education, and appropriate use of new cockpit and other flight technologies. They will focus on incentives for compliance rather than mandates" (p. 2).

Young, J.P., Fanjoy, R.O., & Suckow, M.W. (2006). Impact of glass cockpit experience on manual flight skills. *Journal of Aviation/Aerospace Education and Research, 15*(2), 27-32.

### Training-Related Highlights

This journal article discusses issues related to advanced flight-deck operations and training and includes an experimental study. The experimental study addressed concerns with a reduction in manual flight skills as a result of regular operation in automated modes. The study found that pilots who are more likely to use automation have a less effective cross-check and reduced manual flight skills.

### Authors' Description
*From the Abstract*

"Modern aircraft employ a wide variety of advanced flight instrument systems that have been designed to reduce pilot workload and promote safe, efficient flight operations. Research to date on advanced flight instrumentation has primarily focused on mode confusion or pilot misinterpretation of system information. A few studies have also identified pilot concern with a reduction in manual flight skills as a result of regular operation in automated modes. This paper addresses that concern in an attempt to identify factors useful to flight curriculum development. Study participants included 110 experienced airline, corporate, and military pilots who were surveyed before and after a training session in a transport category flight training device with round dial instrumentation. An experienced instructor rated participant flight skills during the simulator activity. Study findings suggest that pilots who are more likely to use automated modes of modern "glass cockpit" aircraft have a less effective crosscheck and reduced manual flight skills. Issues related to advanced flight deck operations and training are discussed" (p. 27).

# Current Training Practices Interviews

## Introduction

Interviews of 24 pilot training organizations were conducted to understand their current training programs and practices, the training methods and tools they have found effective and those that have not been effective, along with the successes and challenges they have had. The interview participants were selected to provide a broad representation of the industry including 15 US carriers (7 mainline, 8 regional), 6 non-US carriers (4 mainline, 2 regional), and 3 other training organizations. The interviews were conducted by telephone. Our intention was to learn about the training department as a whole and not to focus on one particular fleet or program. There was typically one interview per organization that included the leader of the pilot training department (e.g., Director) and other managers and instructors, as they deemed appropriate based on the purpose of our interview. Many times someone else was brought in to the interview to answer questions when those already participating thought they did not have the best information. If the training department leaders were not available for the interview, they designated someone else to be the point person for their participation. The interviews were scheduled for two hours and often exceeded the allotted time due to desired continued conversation by the participants. The interviews were conducted in a structured manner based on a set of questions prepared for our purposes; however, we intended to have a conversation with the participants and allow them the freedom to share their experiences with us in a relaxed atmosphere. If some questions were naturally answered before they came up on the interview question list, those were not asked again and the answers previously given were recorded for those questions in post-processing of the interview data. The following description of our results is organized by the questions that we asked with the responses summarized for each one. The full set of questions is included in an appendix to this report.

## I. Overall what would you say are the biggest strengths of your training programs?

Participant responses to this question were largely about the structure and process of training delivery, the curriculum, and the training tools used. Other significant themes that described training program strengths included training personnel, leadership support, and pilot selection. A number of program specific components were also mentioned. Details are presented below starting with the comments heard most frequently.

**Standardization**—7 responses
Standardization was cited as a strength by seven participants. Standardization includes training materials, equipment, and content created for multiple delivery systems. Participants mentioned that standardized training needs to account for differences in aircraft and operations, and that it requires extensive coordination and facilitates maintenance. Three participants mentioned SOPs in relation to standardization. One of them said that standardized policies and operating procedures are easier to train.

**Flexibility**—6 responses
Six participants emphasized flexibility, from quickly reacting to incidents, to scheduling on weekends or holidays, to adapting training to a pilot group or an individual pilot.

**Training instructors/check program personnel**—6 responses
Six participants discussed training personnel. Three specifically mentioned the importance of the selection process for trainers. Trainers at those organizations were variously portrayed as being experienced, capable, dedicated, passionate, and having a can-do attitude. A cross-section of personnel was also mentioned as a strength (e.g., check airmen, ground instructors, part-time instructors from the ranks of the line pilots, and retired instructors from the military or from commercial cargo transport).

**Equipment/delivery systems**—6 responses
Six participants talked about their equipment and/or delivery systems as strengths in their training programs. Equipment included simulators, FTDs, virtual flight decks, and other advanced devices. Delivery systems included CBT, e-learning, distance learning, instructor-led briefings, and blended learning.

**Curriculum**—6 responses
Six participants brought up the curriculum or content of their training programs. Four thought that a curriculum customized to the airline was important, while one found value in a manufacturer-developed program based on the testing behind the program.

**AQP**—5 responses
AQP was specifically acknowledged by five participants, many of them because of its flexibility and some because of its reliance on data collection.

**Data collection and reporting**—5 responses
Five participants thought the data they collect was a strength. One stated that the goal was to use operational experience and feedback from the line into training, including data from flight-data monitoring tools. Sometimes data collection and reporting were discussed as part of AQP and sometimes not. The data collection was mentioned once as being part of a manufacturer-developed training program

**Management/financial support**—5 responses
Five participants talked about the support of their leadership, especially financial support. Two specifically mentioned "training to proficiency" [possibly as part of AQP]. One brought up a view of training as an investment instead of an expense and also said that the company pays for training during off hours.

**Pilot selection**—3 responses
Three participants acknowledged their pilot-selection process as a strength. Two participants cited ab-initio programs. One participant said that ab-initio makes it easier to anticipate the difficulties students will have. One mentioned that hiring only pilots averaging over 6,000 hours of flight time, including 1,000 hours as pilot in command resulted in a strength for the training department.

**Training beyond regulatory requirements**—2 responses
Two participants said that they go "above and beyond" regulatory requirements in their training.

**Other**
Each of the following was cited once as a strength of training programs:

- Recurrent program
- Small class size
- Automation training/scenarios
- Airport familiarization program
- CRM
- Check ride
- Command training
- Systematic/holistic approach
- Culture

- Human factors
- Cutting edge
- One type of airplane to train

## II. What are your biggest challenges?

Responses to this question focused on the challenges of training within a regulatory framework, the diversity of pilot populations, and the ongoing changes of aircraft technology and training devices. Additional topics said to be challenging included budgetary constraints, program standardization, and the volume of training required. A number of other program specific challenges were also mentioned. Details are presented below starting with the comments heard most frequently.

**Regulations/FAA**—7 responses
Seven participants discussed challenges with regulations and the FAA or international regulatory agencies. Two participants also included Congress. One participant said that highly regulated training is increasing, but it is justified by more sophisticated aircraft. Another said successes would be diminished without the FAA. But all the participants who answered the question talked about challenges:

- Barrage of regulations
- Impending changes to regulations
- Lack of science to back up regulations
- Single data points leading to FAA overreaction
- Setbacks: going back to doing things that do not work
- Meeting all the needs of the regulators
- Little time left to meet other needs(e.g., to teach pilots the unexpected prescriptive/one size fits all approach to programs)
- Multiplicity of international regulations

**Pilot backgrounds**—5 responses
Five participants described pilot diversity as a challenge: cultural diversity and differences in experience, backgrounds, personalities, and expectations. One participant discussed long-term problems in training former commuter pilots and training flight engineers to become pilots. Another participant said that training pilots who do not have enough hours is the biggest challenge. A manufacturer stated that considering the full diversity of pilots from all companies that may purchase their airplanes was a challenge.

**Hiring pilots**—4 responses
One participant mentioned recruitment as a challenge. Another said that the peaks and valleys in hiring presented difficulties in keeping instructors busy when hiring is down and allowing instructors to catch up when hiring picks up. At another, lack of opportunity to get a command was mentioned as a problem.

**Technology changes in aircraft and training devices**—4 responses
Four participants discussed the rapid pace of technology change. One participant said that training is always a challenge for a new airplane.

Several participants also found challenges with training devices. One participant has not caught up with training devices. Another participant had to discontinue using a device that had issues and will have to retrain when the issues are resolved; the device manufacturer was not keeping up with necessary changes. According to one participant, the changes also

cause time pressures in simulators. Getting management to see the advantages of having the right equipment was mentioned by another participant.

**Budget**—4 responses
Budgets were discussed as a challenge by four participants. One participant has difficulties justifying training beyond regulatory minimums; another has budgetary issues but does have management support to train above the minimums.

**Automation**—3 responses
Three participants brought up automation as a challenge. One participant stated that automation is complex and leads to challenges with less frequent scenarios. Two said that automation led to changes in their training philosophy. One of those participants has made a big change because of NextGen. This participant is moving away from manual flying operations to a greater use of automation. Procedures development was the most challenging aspect of the change.

**Standardization**—2 responses
Three participants discussed challenges related to standardization. Two of them attested to the difficulties in maintaining standards across fleets. One participant talked about standardization in relation to a merger, including curriculums that are too similar and do not take advantage of knowledge carried from fleet to fleet. Another participant talked about instructors teaching techniques that do not necessarily follow an SOP, and a lack of guidance for the FTD, along with inconsistent types of instructors.

**Realistic situations in simulators**—2 responses
Two participants face challenges in using the simulator only for realistic situations. One participant is moving some of the training out of the simulator. That participant also mentioned negative training associated with pilot decisions in a scenario not matching the instructor's expectation.

**Aging pilots**—2 responses
Older pilots are a challenge according to two participants. One participant said that some pilots no longer perform as well. The other brought up older pilots having to adapt to automation.

**Diverse operational environment**—2 responses
Two participants said that diverse operational environments are a challenge. One participant specified tailoring an approach for all crews as problematic. Another participant talked about the demands of operating under different regulatory systems.

**Quick response to required changes**—2 responses
Two participants mentioned difficulties in responding to necessary changes quickly, one in relation to regulatory changes and the other in relation to safety reports.

**Too much to train**—2 responses
Two participants said that fitting in everything that needs to be trained is a challenge. One of them included meeting the needs of the regulators as part of the challenge.

**Other**
Each of the following was cited once as a challenge:
- Flexibility and responsiveness
- Short staff/too many students per class

- Getting metrics in place
- Manual flying skills
- Logistical issues, structural pieces, instructor calibration
- Unions issues with evaluation and grading
- Ground school instructors not line qualified

## III. Because the vision for NextGen operations includes using more automation than we do now, our next questions will focus on automation.

### A. Automation

### 1. What have you found are the most effective methods of training for the use or understanding of automation?

Participants focused mostly on their use of simulators or training devices as what has been the most effective for automation-related training. Some mentioned them in general and some brought up particular devices. Also mentioned were effective approaches to training, with the most frequently mentioned being building the automation concepts from simple to complex to help pilots understand most effectively. In addition, some particular content was mentioned such as general automation concepts, procedures, and automation "gotchas." Details are presented below starting with the comments heard most frequently.

**Training devices**—20 responses
Twenty participants talked about their training devices. The different types of devices discussed are listed below. Terminology is not necessarily used consistently; therefore, some of the types listed most likely overlap.

**Simulators**—12 responses
Twelve participants discussed their use of simulators for automation training. Five of them talked about using other types of training before going into in the simulator (i.e., procedures training, flat panel, classroom, and laptop FMS). Other points were also made in the interviews:

- One participant uses a step-learning process in the simulator.
- One participant said that the simulator adds different value to the training for different aircraft.
- One participant uses the simulator to focus on the "gotchas" in automation

**Build from the simple to the complex**—7 responses
Seven participants discussed automation training in terms of building from the simple and moving to the more complex.

Six of the participants talked about the progressive complexity of tools or devices:

- CBT through LOFT
- Ground school to interactive training to the simulator to OE
- Lower fidelity devices first, then the rest of the curriculum
- Cockpit procedures trainer, stair step approach in simulator, to full automation in LOFT

- Simple (low fidelity) to complex (higher fidelity)(i.e., reading/lecture, CBT, simulator, then actual aircraft)
- Right tools at the right time in the program
- Three airlines brought up increasing complexity in the subject matter:
- Normal conditions to failures; manual flying to increases in automation
- General knowledge to applications to normal/abnormal procedures

**Automation Concepts**—7 responses
Seven participants discussed educating pilots on specific automation concepts:

- What automation will or will not do for the pilot
- What automation is or is not doing
- When to use and when not to use automation, including not using automation even when it is functioning correctly
- Information/indicators automation provides
- Relationships among systems
- Understanding of the components of automation
- Mode changes
- Think about the best way to use the automation, rather than flying by habit
- When instructing in the simulator ask "why" questions

**Levels of automation**—6 responses
Six participants discussed teaching levels of automation, including which level is appropriate for which situation. Three participants brought up how to back out of automation and why. One said there is a "no fault" policy that includes the use of automation: Pilots should get out of the automation if they are not comfortable with it for any reason. One participant leverages international regulatory requirements to justify backing out.

**Desktop trainers/PCs**—6 responses
Six participants talked about using desktop trainers or PCs for automation training. Three specified using them for flight management. Another uses them for procedures.

**Hands-on training**—5 responses
Five participants focused on the necessity to provide hands-on training when mentioning why they use training devices. Two airlines said that learning automation by reading about it is not the best way to learn.

**Classroom**—5 responses
Five participants discussed covering automation training topics in the classroom. Two brought up using the classroom to teach the basics before using a simulator. Another covers topics in the classroom using a training device.

**General comments about training devices**—4 responses
Four participants talked about training devices without specifying any particular devices. One participant emphasized automation tools for "NowGen" in relation to FMS. One participant cautioned against tools that do not match the equipment and cautioned against ending up with a hodgepodge of computer tools.

**Distance learning/online training**—4 responses
Four participants discussed distance learning or online training. As a side effect of the effectiveness of distance learning for systems training, one participant can spend more time on managing automation in FTDs. This participant uses distance learning on a desktop simulator for training procedural issues, including automation. One participant has an electronic library pilots can access from home, and another provides online courses to be completed before ground school.

**Procedures training**—4 responses
Four participants said they cover procedures in association with automation training. Two brought up their procedures trainers, and another a desktop simulator used for procedures training. One of the participants talked about training procedures and not just systems in relation to automation. Another talked about covering both normal and non-normal procedures.

**Ground school**—4 participants
Four participants brought up teaching automation in ground school.

**Recurrent training/LOFT**—4 responses
Four participants talked about using automation during LOFT; in one session students are introduced to full automation.

**Documentation**—3 responses
Three participants mentioned reading materials. Two of them talked about documentation provided outside of training classes.

**Line experience** —3 responses
Three airlines said they continue to train automation on the line.

**CBT**—3 responses
Three participants mentioned using CBT.

**Flat panels/touch screens**—3 responses
Three participants talked about their flat panels. A benefit that one of them mentioned is the ability to push buttons without breaking the device.

**Part task trainers**—2 responses
Two participants said they use part-task trainers. One participant could use more of them.

**Cardboard/paper tigers**—2 responses
Two participants talked about paper mockups. One participant uses "paper tigers" for procedures training.

**Other simulation tools**—2 responses
Two participants said they use other simulation tools for automation training.

**Initial qualification training**—2 responses
Two participants stated that they cover automation in initial qualification.

**Blended learning**—2 responses
Although many participants imply they use a blended approach (see "Build from the simple to the complex"), two specifically mentioned the term.

**Other**
Each of the following was cited once as an effective method of training for the use or understanding of automation:

- Continuing qualification
- Drill and practice
- ISD
- Automation "gotchas"

## 2. What challenges do you have with training the use or understanding of automation?

The majority of participants described challenges with training pilots to a sufficient level of understanding of the automated systems, either from the perspective of challenges with the amount or variation in backgrounds of the pilots or from the perspective of the complexity of the automated systems that need to be trained. These are both related to the challenge of getting the pilots trained in a within the time allotted, which was explicitly mentioned . Participants also mentioned challenges with having the right tools and devices that effectively represent the automated systems, and the lack of standardization of design across manufacturers that require multiple approaches and specific operations that need to be taught. The general challenge of knowing how best to train automated systems was also mentioned. All responses are listed below beginning with those most frequently mentioned.

**Experience/expertise pilots**—10 responses
Ten participants discussed difficulties caused by the experience or expertise of the pilots they train. Some of the challenges appear to be changing over time.

Three participants said that new hires have lacked experience with advanced technology. Two of those participants said that the problem is much less of an issue now than it was in the past. The problem continues at the other because training airplanes have no automation. One participant said that depending on the pilots' expertise, they might either turn off automation or let the automation control them. One participant said that differences in background or ability are a challenge. Two said training older pilots is more difficult. Two participants said that the generational differences themselves cause training challenges.

**In depth understanding of automation**—9 responses
Nine participants talked about challenges with fully understanding the complexities of automation:

- Mental models of how systems interact
- Understanding why pilots sometimes do the right thing for the wrong reasons
- Levels of automation and how automation works
- What the system is doing and how it is providing protection, and pilot recognition of when some protections have been lost
- Management of automation/being in sync with automation
- Interface between automation and the pilot
- Automation modes
  - Awareness
  - With malfunctions, in normal/non-normal situations,
  - Sub-modes
- Aberrations (e.g., automation not programmed to do what is needed)

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**Flight Crew Training for NextGen Automation**

- Applications, options, pitfalls, traps, and best techniques for particular circumstances

**Change from one aircraft to another**—5 responses
Five participants said they face challenges with automation when changing from one aircraft to another. Although one said the young have difficulties, another said that pilots over 50 have a harder time. One cited the lack of human factors standardization of automation. Another mentioned the repetition required to prevent reverting to old habits when the workload is high.

**Quality of technology in training devices/sim**—5 responses
Five participants brought up the technology of their training devices as a challenge. One participant said the simulators do not match the real equipment. Another said that the training technologies are not keeping up. According to two other participants, the simulators are not updated as rapidly as the aircraft.

One participant mentioned challenges with the visuals in fixed training devices. Two said flight plans cannot be uploaded.

**How to train automation**—5 responses
Five participants said they struggle with how to train automation; two of them said training programs have not kept up with automation. One participant said it is hard to train if you don't know how the system works. Two participants have had problems assessing pilot understanding of automation; one of them has started grade automation proficiency as a separate item. Two participants said old habits are a problem. One participant mentioned information automation as a challenge. One participant differentiated training and education; training on which button to push is insufficient when there is more than one right answer.

**Time pressure**—4 responses
Four participants mentioned lack of time as a training challenge. One participant was concerned about sufficient pilot exposure to automation during line training. One talked about the amount of repetition required to transition to a new fleet. Another talked about the time it takes to assimilate how systems interact. And another talked about limited time in the simulator to demonstrate different ways to accomplish a task.

**Manufacturers**—3 responses
According to three participants, manufacturers create challenges. Specifically, they mentioned guidance that always keeps them in automation, lack of human factors standardization among manufacturers, and/or inadequate training provided by manufacturers.

**Manual flying vs. automation**—3 responses
Three participants talked about challenges with manual flying and automation. Another said managing automation is difficult for pilots trained in planes with no automation.

Three participants talked about challenges with manual flying and automation. One said that balancing the training of automation with maintaining manual skills is difficult. Another participant spends 75% of the time training on automation, but training aircraft has no automation.

**Instructors**—2 responses
Two participants mentioned difficulties with instructors. At one, the ground school instructors are not line qualified and the application of automation is a challenge for them. At the other, instructors train one right way to do something when there are multiple ways.

**Other**
Each of the following was cited once as an automation training challenge:

- Complicated aircraft
- Collecting data about automation
- FAA
- Policy indoctrination
- Flying simulators instead of learn automation
- Third-party facilities
- Trust in automation
- Class size

## 3. What could be done to improve training for automation?

The most frequently mentioned area that could improve training for automation is to have more time for covering the topics and for practicing. Several strategies were mentioned that could help with creating more time, like reallocating training time, using more distance training and self-study. Also mentioned was the need to make improvements to training devices and a few other items. All are presented below beginning with that most frequently mentioned.

**More training or reallocated training**—8 responses
Eight participants talked about improving automation training by increasing training time or reallocating it. One participant who would like to provide more training said that training departments always want more and pointed out the economic ramifications, including hiring more pilots.

Five participants said they would like to deliver more automation training through self-study. Four specified home (or offsite) study; one said such study would be especially useful for long-haul pilots who don't fly with a variety of modes. One participant said that cockpit distractions cannot be replicated on a computer. Three brought up independent study about FMS on a personal computer, one with CBT and two with desktop simulators. One of those participants pointed out that a desktop simulator does not replace an instructor in a full-flight simulator.

One participant said it is increasing the initial exposure to automation and the time spent on automation in other phases of training. This participant also wants to deemphasize the checking component of recurrent training to better use time spent in the simulator.

Another participant said there should be more classroom training on automation or better knowledge building.

**Improve training devices or their use**—7 responses
Seven participants discussed improving devices or their use to improve automation training.

Four participants would like to spend more time in the simulators addressing automation. One talked about spending more time in the simulator to make tasks become more automatic. Another participant said they want to spend more time in the simulator but pointed out the resulting increased headcount. This participant has not formally studied

whether more simulator time would have a significant impact on safety. One participant wants to spend more simulator time on important issues such as engine go-arounds and more positions where pilots have to make decisions. One participant wants to spend the most time in the simulator during recurrent training doing an LOE and maneuver validations

Two participants talked about part-task trainers. One of them brought up using part-task trainers and then using simulators as "finishing school." One participant is evaluating a new device IPT– mock-up trainer that has the same logic and tactile feel of the FMC and flight mode panel. Lessons that include explanations of increased automation are integrated into the software.

**Realistic training**—3 responses
Three airlines want to improve the realism of their training. Two airlines mentioned integrating real-world scenarios into training.

**Training already adequate**—3 responses
Three participants seem to feel their automation training is adequate.

**Drill, practice, repetition**—3 responses
Three participants said that they would like to see more drill, practice, or repetition. One of them specified more drill and practice in lower fidelity devices.

**Demonstrate skill before proceeding**—2 responses
Two participants brought up the need to evaluate pilots' skills before allowing them to move on.

**Entry level pilots with better backgrounds**—2 responses
Two participants said their training would be improved by hiring pilots with more background knowledge. One said they are hiring more low-time pilots lacking knowledge of energy management and how to deal with ATC.

**Automation philosophy**—2 responses
Two participants said that pilots need to better understand automation philosophy. One participant said more training is needed on how automation philosophies rose from the manufacturer's and the company's perspectives along with how that drives policies, practices, and procedures. The other participant specified HF logic as part of the manufacturer's philosophy, which pilots need to understand.

**Incorporate data captured on automation problem areas**—2 responses
Two participants said that data they have captured should be used in their training programs to address automation issues.

**Other**
Each of the following was cited once as a way to improve training for automation:

- Evaluate automation skills separately
- Better planning of technology suite in an aircraft
- Improve training on crossing restrictions, including when automation is being used
- Better follow-up on questions from pilots
- Train pilots not to fixate on automation

- Improve mode awareness
- Improve pilot understanding of automation tools and procedures in the airplane

## B. Manual Flying Skills

## 1. Do you include elements of your training program to specifically address the development and maintenance of manual flying skills?

All the participants who answered this question said that they address manual-flying skills in their training and evaluation programs. The types of maneuvers or abnormal situations trained manually were mentioned, and several participants specified automation failures and degradation, or approaches and landings. Equipment used for the training was also discussed with simulators being the most frequently mentioned. Regulatory considerations were also discussed. Details are presented below starting with the comments heard most frequently.

**Yes**—21 responses
Of the 24 participants who answered the question, 21 gave a definite answer of "yes." Of the 21, four did not provide any other details.

**Types of training**—9 responses
Nine participants discussed the types of training in which manual flying is covered. One said manual flying is included in all lesson plans. Another said the amount of manual flying to be covered depends on the stage of training, and another said manual flying is included in some portions of training.

Two participants mentioned initial training. One of them said that after initial training, pilots need to take the initiative to fly manually to keep their skills up.

Six participants include manual flying in recurrent training. One participant said manual flying is formally evaluated. Another participant said manual flying is not formally evaluated. One said manual flying is currently being reintroduced in recurrent training. One participant said the emphasis on manual flying in the last year has been increased to focus on manual skills every two years, and another participant said the emphasis on manual flying has been increased over the last couple of years.

One participant talked about qualification (which has one week on manual flying)/requalification and said the manual flying training is standardized across fleets. Another participant said manual flying is covered in both phases of the transition course.

**Maneuvers/unusual attitudes**—9 responses
Nine participants discussed training on manually flying maneuvers or unusual attitudes.

Five participants talked about training on manual approaches: Two participants said their program requires a single-engine ILS. One of them requires a raw-data ILS, and another has the pilot do a normal ILS to minimums with a miss, and as the pilot comes out of the miss, the autopilot fails. Two participants said they train on manually flying a visual pattern/approach. One provides the training every few years. Two participants said they train on non-precision approaches. One of those participants said that students manually fly a missed approach followed by a visual pattern. One participant talked about having data on unstable approaches and tailoring a program to address them.

Three participants brought up landings. One has extended its landing class curriculum; one of three approaches is flown manually. The other participant talked about a high-altitude approach to landing and a 0 flaps landing. One participant does circuits and bumps.

Three participants said they train departures without the use of automation, including the participant who does circuits and bumps.

Two participants said they train on stalls and steep turns; one of them mentioned steep turns through stalls. Another participant no longer trains steep turns and stalls because of a lack of time.

Two participants mentioned manually flying with unusual attitudes.

### Simulators—8 responses
Eight participants talked about training manual flying in a simulator. One brought up that after initial training, pilots will go back in the simulator for only three days every year. One participant has ten simulations divided into two phases. One talked about training manual flying procedures in a simulator. In the last year, one participant has added additional simulator training every two years that focuses on manual flying. One mentioned zero flight time training for the A330.

### Automaton levels/degradation, autopilot failure—7 responses
Seven participants talked about training manual flying in relation to automation. One said pilots are trained through full automation – both instrument and visual flying are in the syllabus. One participant mentioned moving up and down the levels of automation. One participant said getting out of the automation modes (transitioning out of LNAV, VNAV or both) is trained. Another participant said three levels of automation, including a level that includes raw data and no flight director/autopilot, are trained. Three participants said they train with the autopilot turned off, or they have autopilot fail. One talked about automation degradation training; a study at that organization showed that multiple automation failures occur.

### Amount of emphasis—7 responses
Seven participants discussed the amount of emphasis placed on manual flying. Three participants talked about encouraging manual flying in general. One said manual flying is the foundation of the training program. Another participant discussed an increasing emphasis on manual flying because of automation policy that encourages pilots to be automation driven.

Two participants do not seem to have a major focus on training manual flying. One expects new hires to have that skill. The other does not assess manual flying and expressed a concern about manual flying in challenging conditions.

### FAA mandates—5 responses
Five participants discussed FAA requirements for manual flying. Four of them said that the FAA mandates training on manual flying. One of those four said that flying without the autopilot was an FAA mandate. A fifth participant discussed a battle with the FAA over the FAA's belief that having the autopilot on at 600 ft reduces task saturation and increases situational awareness. One participant said that current FAA requirements on manual flying are not relevant to current operations and aircraft.

One participant talked about manual flying during checking events. One participant pointed out that in general the FAA continues to add more requirements.

### Manual flying in actual aircraft—5 responses
Five participants use actual aircraft to help pilots keep up their manual skills (or encourage manual flying on the line). Two participants have pilots fly empty planes. One participant has pilots spend OJT time on manual training during IOE, with an instructor check airman in the left seat.

**Procedures**—2 responses
Two participants talked about training manual flying procedures. One participant mentioned being gratified to hear crews talking on the line about the procedures he has documented.

**Wind conditions**—2 responses
Two participants talked about training manual flying in wind. One mentioned down winds and wind shear and the other mentioned cross-winds.

**Single engine**—2 responses
Two airlines talked about training manual flying under single-engine operations. One specified engine failures.

**Other**
Each of the following was cited once in regard to training programs specifically addressing the development and maintenance of manual flying skills

- Non-normal
- Airbus (fly by wire)
- DC9 (has no automation)
- Fleet captains
- Future training/lack of negative effects of HUD on manual flying

## 2. What has been most effective for training or maintaining manual flying skills?

As with answers to the previous question, many participants talked about the use of simulators in training manual flying. Training on the instruments was discussed, and hand flying a single-engine ILS was mentioned several times. Data-driven approaches to training were also discussed. Details are presented below starting with the comments heard most frequently.

**Types of training programs**—12 responses
Twelve participants discussed their training programs' coverage of manual flying.

Four participants discussed manual flying in their training programs in general. One said manual flying is integrated into almost every level of training through a building block methodology. One participant said both manual flying and automated flying are trained. Another said its program just started training manual flying and has had no feedback yet.

Two participants talked about manual flying as part of initial training. One said quite a bit of time is spent on manual flying in initial training, and the other said at least one or two events require manual flying.

Eight participants discussed the manual flying part of recurrent training. One said that training manual flying is limited during recurrent because of European regulations. A third party said limited recurrent training is provided on manual flying for its customers. One emphasizes turning off automation when appropriate. This participant had noticed a trend of pilots who cannot fly a single-engine ILS. Another participant requires flying a single-engine ILS in recurrent training. One mentioned fly and orient evaluation. One participant said quite a bit of time is spent on manual flying in recurrent training, and another said recurrent training is repeated every three months.

One third party discussed its transition training, which includes several events and exercises that require manual flying. The assumption is that pilots already have some ability, and if not, manual-flying courses are provided to those pilots.

One participant mentioned providing a session on manual flying in the type rating.

**Maneuvers**—12 responses
Twelve participants brought up hand flying maneuvers.

Seven participants discussed manual approaches and landings. One of them discussed an ILS. Two brought up single-engine ILSs: One had pilots who could not manually fly a single-engine ILS and now trains pilots to turn off automation when appropriate, and the other said hand flying a single-engine ILS during training is required. One participant uses simulators for visual approaches and landings without any automation. Another participant mentioned unstable approaches, and another mentioned cross-wind landings and touch and go. One participant is required to train manual landings to proficiency for ab-initio pilots. One has pilots do circuits and bumps. Another animates "ugly approaches of the month," distributes the animations, and uses them in training.

Two participants talked about training on manually flying steep turns. One of them asks pilots what they anticipate with greater wing loading.

Two participants train on stalls.

**Flight instruments**—12 responses
Four participants talked about manually flying using the instruments. One participant includes pitch attitudes for critical airspeeds and configuration in handbooks and expects pilots to know them and have a feel for the airplane, including typical landing speed and power setting. This participant adds automation later on and has found that to be effective.

Another participant said that pilots only need to look at pitch attitude at the point of takeoff, assuming the rotation started at the right speed and the rotation is at the right rate. That participant also said that instruction must be specific about what pilots should view at any point in the flight profile.

One participant said that using unreliable airspeed indicators is the best training aid for manual flying skills and that understanding pitch and power allows pilots to fly without the airspeed indicator. Another reinforces the scan on the artificial horizon and how it is presented in an automated aircraft.

**Simulator**—10 responses
Ten participants talked about using simulators for training manual flying.

One of the participants said it has added simulator sessions to train manual flying. Another participant said that in the simulator all lesson plans have at least one manual-flying event. Another includes four simulator sessions per year for long-haul fleets because long-haul pilots do relatively few landings.

Two participants said they use a full-flight simulator. One of those participants mentioned its Level D simulators. The other participant uses a full-flight simulator without the automation for visual approaches and landings; its integrated proc trainers do not have a control column. Another said for the 777 fleet, easy maneuvers are difficult to simulate because the 777 simulator has to be "dumbed down."

One participant said simulators are used for "fly and orient evaluation," and addition training (cross-wind landings, touch and go) is provided in leftover simulator time.

**Policy/philosophy**—3 responses
Three participants discussed their manual flying policy or philosophy. One participant said hybrid flying is not allowed; that is, if the autopilot is off, then the auto-throttle also needs

to be off. Another participant said the philosophy has changed from using the most automation to using the appropriate level of automation.

**Data driven**—3 responses
Three participants said that training needs to respond to real world data. One participant talked about training in response to data on incidents and accidents. Another guessed that manual flying is done well in AQP programs that provide operational data. A third participant talked about insights from the flight safety group, including trends, based on data from ASAP and ADAP (FOQA). The participant gets the information from event review team meetings, the union, flight training and standards, and the FAA. The participants also mentioned exceedances.

**Practice and repetition**—3 responses
Three participants talked about practice or repetition.

**Levels of automation**—2 responses
Two participants said pilots are trained to operate at the appropriate level of automation. One of them said that if the airplane does not act as expected when the autopilot is disconnected, the pilot should take control manually. That participant also grades pilots not flying on pilot monitoring skills; pilot monitoring is their primary defense against automation-related pilot errors.

**Unknown**—2 responses
Two participants said they do not know how to effectively train manual flying skills. One is a third party that provides limited training on manual flying. Another guessed the training goes well in AQP programs.

**Other**
Each of the following was cited once as what has been most effective for training or maintaining manual flying skills:

- Manufacturer training
- DC9 fleet, credit for experience and airmanship in advanced fleets
- Pilot intellectual capacity
- Realistic scenarios
- Pilot's competitive nature
- Additional training after a leave

## 3. What improvements do you think need to be made in this area?

Almost half of the participants feel their manual-flying training need no improvement. Many others are guided by safety data when determining whether improvements are needed. A few participants do not know how to improve their training. Details are presented below starting with the comments heard most frequently.

**No improvements needed**—9 responses
Nine participants said that they currently do not need to improve their manual flying training. Five of those participants also said or implied that if or when necessary they would work on improvements (see "If data shows weaknesses," "Maintaining skill," "Knowledge, skill,""Regulations," and "Not sure.")

One participant pointed out that manual skills have already been trained for a long time, another pointed out that the fundamentals of hand flying have not changed, and another

mentioned FAA mandates. Another participant said -failure rates are extremely low, and its organization is considering extending check rides out to every 18 months. One participant added that no trends from continuing qualifications indicate a need to add anything to manual training. One participant said its pilots are highly qualified and hand flying is not an issue

One participant added that automation is preferred because it is safer.

### If data shows weaknesses—7 responses
Seven participants discussed improving training if data indicates weaknesses. Three participants said their trends/data do not indicate that improvements are needed. One of them talked about AQP measurements on currency.

One participant said its organization's data indicates a need to train go-arounds on unstable approaches. Another participant thought long-haul pilots might need more manual flying training, but a second participant from that organization said the data shows no issue.

One participant said evidence-based training should be used to decide what to train.

### Maintaining skill—6 responses
Six participants discussed maintaining manual flying skill. One participant said that the need for demonstrations of manual proficiency will continue even as the focus on automation and other areas increase. Another participant said that buy-in from some line pilots on maintaining their manual flying skills is needed. One participant said that some pilots turn off the flight director after 10,000 feet to maintain proficiency. Another recommends flying up to 10,000 feet before turning on the automation. This participant also said that maintaining the skills depends on individual professionalism.

One participant said there are weaknesses in manual flying and the scan. This participant also mentioned -that the weaknesses are apparent when a pilot returns from leave or is transitioning aircraft, but the weaknesses are not about automation dependency.

### Knowledge, skill—4 responses
Four participants said training on manual flying knowledge or skills needs improvement. One said that problems that initially appear to be with skill are actually problems with system/procedural knowledge. Two said that pilots need to be trained on how to properly intervene manually.

Two participants brought up technology issues; one of them also mentioned automation issues and management issues. That participant differentiated between manual flying skills and piloting skills.

Two participants said that pilots need to be taught good skills up front. One of them also said that pilots need to be able to process information rapidly and convert it into motor skills.

### Regulations—4 responses
Four participants talked about regulatory requirements in relation to improving training on manual flying.

One participant said that regulators must test more manual flying skills, and that because of budgets, the first focus is on current regulatory requirements. Another said that the regulatory requirements may not be realistic

**Not sure**—4 responses
Four participants said they do not know what to do about improving training manual flying. One does not know what needs to be demonstrated in the training environments and where to draw the line between training automation and manual flying. Another participant said more guidance from researchers is needed on the best way to train manual flying and what the retention periods are. One participant said its organization does not know how to improve maintaining manual skills.

**Approach/landing**—2 responses
Two participants talked about improving training on approaches or landings. One participant said the simulators cannot adequately replicate a real-world visual approach and landing. Another said its training program needs to improve go-arounds on unstable approaches after an automated approach.

**Other**
Each of the following was cited once as what improvements need to be made in training manual flying:

- Focus more attention on manual flying in future A350 program
- Manual flying against a competency
- Build a TCAS trainer
- Procedural changes
- Pitch/power relationship

## C. CRM

## 1. What CRM topics are included in your training programs?

Participants mentioned a variety of topics that they cover in their CRM programs. Decision-making, threat and error management, and communication were cited the most. Details are presented below starting with the comments heard most frequently. Some of the participants also provided information about the methods they use in the CRM courses and those are described below the list of CRM topics.

**Decision-making skills**—19 responses
Nineteen of the 24 participants interviewed stated that decision-making was taught as part of their CRM training program. Note: The participants were specifically asked if this topic was taught in the following question and more details are presented there.

**Threat and error management**—13 responses
Thirteen of the participants interviewed specifically cited that Threat and Error Management topics were included in their training program. Seven participants stated that they either have or are moving from traditional CRM training toward the Threat and Error Management model. One participant mentioned that included in the training related to threat and error management is providing pilots with tools they need to identify treats early, generate a plan, and address the threats promptly. Another participant stated that threat and error management is defined as the operational threats that occur, the errors that are made, and the process for trapping and fixing the errors.

**Communication**—12 responses
Twelve of the participants interviewed specifically cited that communication skills were taught as part of their CRM training program. One participant stated that good communication is the cornerstone of CRM, and since good communication is often lacking in

the cockpit, it is important to teach the pilots how to effectively communicate. Another participant stated that training related to communication included addressing methods for communicating, how to communicate changes, and how to clarify meaning. Three participants stated that communication between the flight crew and the cabin crew is addressed in the CRM training program.

**Working effectively with cabin crew**—8 responses
Eight of the participants interviewed specifically cited that working effectively with the cabin crew was taught as part of their CRM training program. Three participants mentioned that effective communication between the flight crew and the cabin crew is addressed in the CRM training program. Six participants cited that training sessions in which the flight crew and the cabin crew participate together are included in their CRM training program.

**Leadership**—7 responses
Seven of the participants interviewed specifically cited that leadership skills were taught as part of their CRM training program. Four of the participants mentioned that leadership skills for a captain (or pilot-in-command) were taught as part of their upgrade course. Three participants cited that the leadership relationship between the pilot-in-command and the second-in-command was addressed in training to ensure that the pilot-in-command was a good leader and the second-in-command was a good follower as well as a being a fully participating crew member who displays respectful assertion. One participant mentioned that leadership and decision-making skills with respect to automation were also addressed in the CRM training. An eighth participant stated that while the topic of leadership is not currently included, it is being added back into the training program.

**Situation awareness**—6 responses
Six of the participants interviewed specifically cited that situation awareness was taught as part of their CRM training program.

**Monitoring**—5 responses
Five of the participants specifically cited that monitoring skills were taught as part of their CRM training program. Two participants also mentioned that their training related to monitoring included addressing how to monitor the status of fellow crew member and how to effectively question about status.

**Crew coordination**—5 responses
Five of the participants interviewed specifically cited that crew coordination skills were taught as part of the CRM training program. One participant mentioned that training includes highlighting real life incidents that illustrate the crew working effectively together and other incidents that illustrate the crew not working effectively together. Another participant stated that both team building and the maintenance of the team relationship are included in the training program.

**Conflict management**—4 responses
Four of the participants interviewed specifically cited that conflict management related skills were taught as part of their CRM training program. One participant also mentioned that training related to conflict management included addressing how to handle conflict resolution and how to address disagreements. Three participants cited that professional, non-confrontational, respectful assertiveness and "speaking up" was taught in their CRM training. Another participant mentioned that conflict recognition and resolution was addressed in the CRM training program.

**Workload management**—3 responses
Three of the participants interviewed cited that workload management related topics were taught as part of their CRM training program. One participant mentioned that automation management (i.e., managing workload to include automation) was addressed in the training program. Another participant mentioned that such topics as how time management, task prioritization, and understanding the need to report that self or other crew members are experiencing overload are each addressed as advanced CRM topics in the training program.

**Fatigue management**—3 responses
Three of the participants specifically cited that fatigue management was taught as part of their CRM training program. One participant cited that fatigue management training includes identifying the dangers of fatigue, recognizing fatigue, and learning fatigue preventative measures.

**Briefings**—2 responses
Two of the participants specifically cited that briefing skills were taught as part of their CRM training program. One participant mentioned that both flight crew briefings and cabin crew briefings were addressed in the CRM training.

**Problem solving**—2 responses
Two of the participants specifically cited that problem-solving skills were taught as part of their CRM training program. One participant also mentioned that how to diagnose warning signs and anomalies was also addressed as an advanced CRM topic =.

**Human factors**—2 responses
Two of the participants specifically cited that human factors were taught as part of their CRM training program. One participant mentioned that the topic of human factors from the technical side was included in the CRM program.

**Other**
Each of the following was cited once as what CRM topics are included in training programs:

- introduction to CRM and an awareness of CRM issues
- flight discipline skills
- professionalism
- stress management
- distraction management
- emergency procedures
- knowing manuals and procedures
- mentoring skills
- behavioral markers related to CRM-related issues
- incapacitation
- runway incursions and excursions
- standardization
- man-machine automation training

**How CRM topics and content is identified**—8 responses total
The following means by which CRM topics and content are identified for inclusion in the training program were explicitly mentioned:

### Standard or classic CRM program topics—*2 responses*
Two of the participants interviewed specifically stated that at least a portion of their CRM program is based on a standard or classic CRM program.

### Safety data driven—*2 responses*
Two of the participants interviewed specifically stated that at least some topics for CRM training are identified through safety data that the organization collects and analyzes.

### Determined by regulations—*4 responses*
Four of the participants interviewed specifically stated that CRM topics in their training program are determined by complying with their governing aviation authority's regulations.

### CRM topics are fluid—*2 responses*
Two of the participants specifically stated that CRM topics in their training program are fluid, and the CRM training program is frequently modified based on needs that have been identified.

## a. Do you specifically teach decision-making skills If so, how do you teach decision-making skills?

We specifically asked whether decision-making skills are addressed in the CRM courses because of the increased criticality of decision-making that will come with NextGen. Details of the responses are given below along with information shared about how decision-making is taught.

**Yes**—19 responses
Nineteen of the 24 participants interviewed stated that they do specifically teach decision-making skills in their training program. One participant stated that it is important to build fundamental decision-making skills so pilots can handle unexpected situations.

**No**—5 responses
Five of the 24 participants interviewed stated that decision-making skills are not currently being taught in their training program. Of these, three participants said their organizations plan on incorporating decision-making skills in their training program in the future. One participant stated that decision-making skills had been taught in the past, but this topic is no longer a focus in their training program. Another participant stated that while they do not specifically include decision-making as a module in their program, pilots are exposed to decision-making instruction as a product of scenario based training, and decision-making is discussed during the debrief.

**Decision-making training methods**—21 responses total
The following are training methods that the participants specifically stated are being used to teach decision-making skills to their pilots.

### Scenario-based training—*10 responses*
Ten of the participants interviewed stated that they train decision-making skills using scenario-driven training methods. Seven organizations use scenarios to lead discussions related to decision-making including topics such as the decision-making process, how to make decisions, why one decision is better than another, and prioritizing decisions. Five participants stated that they use real or realistic examples in their decision-making training. Two participants said they use incidents or

scenarios representing examples of good and poor decision-making in their training. One participant stated that a lot of decision-making opportunities are included in their training program.

### Tools to aid in decision-making—*8 responses*
Eight of the participants stated that their organization provides tools to aid in decision-making as part of their training program. Four participants stated that pilots are provided with a decision-making model to aid in decision-making. Two of these participants said pilots are given the DODAR decision-making model comprised of: Diagnose problem, generate Options, Decide which one to use, Assign the tasks, Review the decision you made and make sure it was the right one. Another participant said pilots are given the FORDEC decision-making model comprised of Facts, Options, Risks and benefits, Decision, Execution, and Check. This participant also stated that pilots are provided with a decision-making model used within their organization.

Two participants stated that they have created procedural responses or developed memory items to many situations that require decisions to be made. Procedures have been developed for tasks such as performing briefings, day-to-day activities, and for responding to various emergencies.

One participant said pilots are given a decision-making matrix that illustrates the relationship between the criticality of an event and how much time is available for making a decision. This participant also said that training information includes how to overcome decision-making errors such as premature anchoring, expectation bias, and decision rigidity.

### Skills taught during debrief—*1 response*
One of the participants stated that the decision-making topics including why and how certain decisions are made are covered during the pilots' debriefing.

### Teaching directly and indirectly—*1 response*
One of the participants stated that decision-making skills are taught in both direct and indirect ways. The direct teaching methods include profiling incidents and talking directly about decision-making. The indirect teaching methods include putting the message out there in the course of the training sessions without overtly talking about decision-making.

### Integrated with other topics—*1 response*
One of the participants stated that instead of teaching decision-making skills as its own separate course, it is taught by integrating it with other training topics.

## Training courses—7 responses total
The following identify the training courses in which decision-making skills are taught:

### Upgrade course—*4 responses*
Four of the participants stated that decision-making skills are taught during transition training. Two participants stated that decision-making is taught as part of the captain leadership module.

### 2$^{nd}$ in command course—*2 responses*
Two of the participants stated that decision-making skills are taught during second-in-command or first officer training courses. One participant said that first officers

are encouraged to practice their decision-making skills in the simulator when they are performing the pilot flying duties.

### Transition training—*1 response*
One of the participants stated that decision-making skills are taught during transition training.

### Taught in classroom—5 responses
Four of the participants stated that at least part of decision-making training occurs in the classroom. One participant said a comprehensive decision-making module is used in initial training that includes such topics as physiology, fatigue, pressure, expectations, embarrassment, fear of failure, and fear of looking like a fool related to decision-making.

### Taught in the classroom and reinforced in Simulator—3 responses
Three of the participants stated that the decision-making skills training the pilots receive in the classroom is then reinforced in the simulator.

### Other topics—9 responses total
The following is other information that the participants shared about the topic of teaching decision-making skills in their training program.

#### Learning objectives—*4 responses*
Four of the participants stated that learning objectives, triggers, or markers are assigned to decision-making skills in their training program.

#### Room for improvement in decision-making training—*2 responses*
Two of the participants interviewed believed that there was room for improvement in their decision-making training. One participant stated that the instructors did not have the decision-making tools they needed to give to pilots to help address a weakness in certain types of decision-making and are currently developing a toolkit of decision-making tools to give to the instructors to share with the pilots.

#### Decision-making is a core component of CRM—*2 responses*
Two of the participants interviewed stated that they believed that decision-making is a core component of CRM.

#### Decision-making is part of AQP—*1 response*
One of the participants stated that decision-making is part of the AQP.

## 2. What methods have you found to be most effective for training of CRM?

A variety of approaches being used that result in effective CRM training was mentioned by participants. The most frequently mentioned were use of the threat and error management model and scenario-based training. Details of all approaches are presented below followed by other topics mentioned like descriptions of the training devices used, the curricula in which CRM is taught, and the use of instructor/evaluators.

### Threat and error management paradigm (TEM)—13 responses
Thirteen of the participants cited that using the Threat and Error Management (TEM) paradigm is an effective method to train the CRM-related skills. One organization stated that their training focuses on making the pilot aware of threats and on managing these threats as they arise. They felt that this approach takes advantage of a pilot's natural tendency to

manage a threat once the pilot becomes aware of it. Another participant stated that TEM is used as a framework for teaching such CRM-related topics as threat recognition, error recognition, and threat and error management.

**Scenario-driven training**—13 responses
Thirteen of the participants stated that scenario-driven training methods are effective for teaching CRM skills. Eight participants said they use scenarios to lead discussions related to decision-making, including topics such as the decision-making process, how to make decisions, why one decision is better than another, and prioritizing decisions. Eight participants stated that their organization uses real or realistic examples in their CRM training including those based on current industry events, in-house safety data, and/or accidents. Two participants specifically cited that they use incidents or scenarios representing examples of good and poor decision-making in their training. One participant stated that an advantage of scenario-driven training is that it allows the trainee to spend time working on the process of performing the desired skills instead of simply analyzing the outcome.

**Debriefings**—6 responses
Six of the participants stated that debriefings can be effective in teaching CRM skills. Two participants believe that a facilitated debrief in which the student does most of the debriefing is a very effective method for allowing the pilots to gain CRM skills. One participant that self-critique in debriefing is effective because it allows crews to "say it and own it," instead of the instructor telling them about it. Another participant stated that the decision-making topics including why and how certain decisions are made are covered during the pilots' debriefing. One other participant stated that a CRM skills matrix is used during the debriefing process.

**Briefings**—6 responses
Two of the participants stated that briefings can be effectively used to teach CRM topics. One of the participants stated that providing briefing cards to pilots that on one side provides the pilot briefing for departure/arrival and the other side provides the flight attendant briefing is an effective method to enable pilots to demonstrate effective CRM skills. The other participant stated that briefings can be effective by making training comfortable.

**CRM integrated throughout training program**—6 organizations
Six of the participants stated that integrating CRM throughout the training program is an effective method to train CRM skills.

**Providing SOPs**—1 response
One of the participants stated that providing standard operating procedures for the smallest task to the biggest task is an effective method to enable pilots to demonstrate effective CRM skills.

**Provide tangible tools**—1 response
One of the participants stated that it is important to provide the pilots with tangible tools for CRM rather than only providing pilots with theoretical presentations. The tangible tools can help pilots do such things as identify threats early, create a plan, and promptly address errors.

**Training devices to teach CRM skills**—20 responses total
The following training devices or places (e.g., classroom) to train CRM skills were explicitly mentioned:

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***Teaching CRM in the classroom is effective***—*8 responses*
Eight of the participants stated that teaching (at least some) CRM skills in the classroom is an effective method. One organization stated that based on data from the line, the most effective CRM training methods are those in which students are forced to participate in classroom activity. They stated that this method is effective for training the threat awareness management model and CRM skills. Another participant stated that providing a mixture of theory and practical training with a moderator with flying background and a psychologist with expertise in social aspects is effective. One of the participants stated that the use of a system that allows interactive feedback while in the classroom setting can be effective in training CRM. In such a system, all students are able to provide answers by means of a clicker, and the student results can be used to prompt discussions and to identify the areas where additional instruction may be needed. Another participant stated that while there is a challenge with ensuring that CRM training information is fresh and that it doesn't become redundant in the classroom, this challenge is addressed by having skilled instructors bring real life experiences into the classroom.

***Using simulator***—*7 responses*
Seven of the participants stated that using the simulator to train, reinforce, and/or practice CRM skills are effective. Five of the participants stated that including CRM skills during LOFT is effective. Three of the participants stated that the decision-making skills training the pilots receive in the classroom is then reinforced in the simulator. One of the participants stated that all of the scenarios rolled out into the training have CRM in them.

***Using mockups***—*2 responses*
Two of the participants stated that using mockups can be effective in training CRM skills. One participant stated that one CRM training module was developed using a mockup of an aircraft and PowerPoint slides to show the status of the aircraft, and the crew acted out the scenario in real time. They found this was an effective training method.

***Video presentations***—*2 responses*
Two of the participants specifically stated that the use of video presentations can be effective in training CRM. One participant stated that a lot of video presentations that were created from training scenarios flown in the simulators are used. The participant said that presenting those videos is effective because it is easier for students to relate to and brings the lesson home. The participant said that other types of in-house developed videos are effective for training CRM skills. Another participant stated that they use video in the simulator during refresher sessions, and the recorded video session is used in the debriefing specifically to review interpersonal CRM aspects.

***Teaching CRM in the classroom is not effective***—*1 response*
One of the participants stated that while CRM is currently taught in the classroom, it is an effective method.

**Training courses**—15 responses total
The following identify the training courses in which CRM skills are taught:

***Taught in recurrent***—*8 responses*
Eight of the participants specifically stated that CRM topics are taught in recurrent training.

### *Taught in upgrade training*—*4 responses*
Four of the participants specifically stated that CRM topics are taught in upgrade training.

### *Taught in initial / ground training*—*3 responses*
Three of the participants specifically stated that CRM topics are taught in initial or ground training.

## Integrating training with others—9 responses total
The following was explicitly mentioned regarding integrating pilot training with those who play other roles at the organization:

### *CRM training integrated with the cabin crew*—*6 responses*
Six of the participants specifically cited that integrating some of the CRM training with the cabin crew is effective. Two participants said that pilot and cabin crew training for emergency situations is performed in conjunction with one another.

### *CRM training integrated with the dispatchers*—*3 responses*
Three of the participants said that integrating some of the CRM training with the dispatchers is effective.

## Instructor/Evaluators and Facilitators—8 responses total
The following methods for effectively utilizing the Instructor/Evaluators and Facilitators to train CRM skills were explicitly mentioned:

### *Perspective and behavior of Instructor/Evaluators*—*4 responses*
Four of the participants specifically stated that instructors' perspective and behavior can be used to effectively in teach CRM skills. One participant said that it is effective to have the Instructor/Evaluators (I/Es) teach from the perspective of facilitating the pilot passing instead of being there to fail them and that the I/E should ask questions in order to facilitate the trainees to verbalize what they should focus on. According to the participant, this is a more effective method than simply telling the trainee what they want them to know. One of the participants stated that all their instructors are certified as CRM I/Es. Another participant stated that it is effective to have the instructors model the behavior that the organization wants the pilot to perform.

### *Calibrate Instructors*—*2 responses*
Two of the participants specifically stated that it is important to calibrate instructors so that their focus and judgments are equivalent across all instructors at the training organization. One participant said that using Inter-Rater Reliability (IRR) is a best practice. The other participant said that it is important to calibrate the instructors, that CRM is a core element, and that CRM skills should be treated with the same importance as any other skill that is being trained.

### *Use of Facilitators*—*2 responses*
Two of the participants specifically stated that facilitators can be used to effectively in teach CRM topics. One participant stated that the use of skilled facilitators, especially when they have strong operational knowledge including current events in the company and can build a rapport with the pilots, is effective in training CRM skills. This participant also stated that in the course of facilitating a discussion, facilitators can teach human factors information. The other participant stated that full-time CRM facilitators are employed for training programs.

**Training design elements**—*6 responses total*
The following elements related to how the training is designed to teach CRM skills were explicitly mentioned:

    ***Learning objectives defined for CRM skills***—*2 responses*
    Five of the participants stated that it is important to define learning objectives or behavioral markers for CRM to effectively train CRM skills. Two participants stated that CRM skills should be evaluated with the same importance as other skills that are trained, and one of these participants pointed out that pilots can 'bust' by failing to adequately perform CRM skills

    ***Repetition***—*1 response*
    One of the participants specifically stated that the use of repetition can be effective in training CRM.

    ***Tailor information to a crew perspective***—*1 response*
    One of the participants specifically stated that it is effective to tailor the information to a crew's perspective.

    ***Using layering effect***—*1 response*
    One of the participants stated that using the layering effect is a fundamental concept of learning and is effective in training. In this method, the knowledge and cognitive aspects of a skill are trained first in the classroom and then are carried through into the simulator where the motor skills are trained. A strength of this method is that in the classroom session, the pilots have a chance to think about and discuss things without the panic of being in the middle of a situation. When pilots see the same situation in the simulator, they can recognize the situation they have already thought through and can make an appropriate response.

    ***Using alternative non-CRM terminology***—*1 response*
    One of the participants stated that traditional CRM terminology is no longer used. This participant said that using the terms Human Factors and safety for these concepts is more effective.

**Effective methods to identify CRM topics and content**—*4 responses total*
The following methods by which CRM topics and content are identified for inclusion in the training program were explicitly mentioned:

    ***Allowing CRM Topics to be fluid or frequently modified***—*2 responses*
    Two of the participants specifically stated that CRM topics in their training program are fluid, and the CRM training program is frequently modified based on needs that have been identified.

    ***Safety data driven***—*2 responses*
    Two of the participants specifically stated that at least some topics for CRM training are identified through safety data that the organization collects and analyzes.

# 3. What challenges do you have with training CRM?

Most of the challenges with training CRM mentioned by the participants were related to communicating well what CRM is and the effectiveness of instructors and evaluators. Details are presented below starting with the comments heard most frequently.

**CRM soft skills are difficult to define and measure**—4 responses
Four of the participants specifically stated that CRM is a soft skill and, therefore, difficult to define and measure. One participant stated that some of CRM is theory, which makes it more difficult to get the pilots in the right mindset to teach. It is a challenge to teach because pilots cannot touch or feel it, and currently it does not have standards tied to it. Another participant stated that pilots are more comfortable with hard skills. One participant stated that it is difficult to measure effectiveness of CRM training to determine if it has had a positive effect on safety.

**Pilots don't buy-in**—4 responses
Four of the participants said that it is a challenge to have some of the pilots buy in to CRM. A subset of the pilot population believes that CRM is too touchy feely referring to it with such phrases like "Charm School" or "Hot Tub Harmony." One participant stated that there are still a few captains who want to be a very authoritative captain who makes all the decisions on their own. The participant said that it is difficult to change the mind and behaviors of these pilots. Another participant stated that CRM can be a tough sell for a FO to speak up when they have come from a military background where there was a command of responsibility that was not questioned.

**Getting good Instructor/Evaluators and Facilitators**—2 responses
Two of the participants specifically stated that one challenge is having qualified Instructor/Evaluators and/or Facilitators. One participant stated that with budget changes in the Flight Operations department, any instructors who are available for doing CRM have to be used because that is what the VP of Flight Operations allows. Another participant stated that is challenging to get all the qualities needed for an instructor in one person.

**Keeping CRM fresh and interesting**—2 responses
Two of the participants specifically stated it is a challenge to keep CRM training fresh and interesting while still emphasizing the appropriate key points. One participant stated that this challenge is addressed by having skilled instructors bring real life experiences related to CRM into the classroom.

**No challenges**—2 responses
Two of the participants specifically stated that they do not have any challenges training CRM.

**Defining CRM as a whole**—1 response
One of the participants specifically stated that defining what CRM really means is a challenge. They said that it has evolved over the years and because of this pilots look at it as if it is the latest academic fad. It has been difficult to build a consistent message in terms of focus and terminology; however they cited that recently it has stabilized with a focus of threat and error management.

**CRM is different from other training in program**—1 response
One of the participants specifically stated that challenges arise because CRM training is different from other training that pilots receive. This participant stated that day-to-day

frustrations tend to come up because CRM is one of the only facilitated sessions that pilots are in.

**Standardizing Instructor/Evaluators**—1 responses
One of the participants specifically stated that one challenge is standardizing Instructor/Evaluators on CRM skills. This participant said that because it is difficult to define CRM skills, it is more difficult to get these skills embedded in instructors in a standardized way so that all instructors teach and evaluate students in a consistent manner.

## IV. Training Simulators and Devices

## A. Full-Flight Simulation

## 1. When do you use full-flight simulators?

> *(Note: Responses given are what the participants thought were important enough to mention and are not necessarily a full account of their organization's use of full-flight simulators. Also, the omission of full-flight simulator use in certain categories should not be considered as an indication that they are not used for that purpose.)*

Participants focused mostly on the type of training program in which they use full-flight simulators and included examples of their use such as LOFT and check rides. The amount that full-flight simulators were used in training also varied widely between participants. Participants also noted several specific types of training in which they used full-flight simulators. The details for uses of full-flight simulators are presented below beginning with the types of training in which they are most used.

**Recurrent training/continuing qualification training**—11 responses
Most of the participants noted that they use full-flight simulators in their recurrent training and indicated that recurrent training events last two, three, or four days and may occur from two to four times a year. While some carriers were noted to use the full-flight simulator for all of their recurrent training, we learned that others do not. We also learned that some operators will use the full-flight simulator to accomplish other types of training but without the motion activated.

**Initial training**—8 responses
Participants noted that they also used full-flight simulators in their initial training. Usage varied among participants between four to ten sessions and might include a check ride and/or LOFT

**After use of other devices—**8 responses
Of particular note were comments about the sequence in which full-flight simulators were used relative to the use of lower fidelity training devices including fixed-based simulators and laptop simulators, with full-flight simulators being used later in the training. The cost associated with using full-flight simulators was a significant factor in this thinking.

**All training courses**—5 responses
Participants also noted without specificity that they use full-flight simulators in all of their pilot training programs.

**Use without motion or visual operating**—4 responses
Using a full-flight simulator with the motion or visuals turned off was also an option used in place of using a fixed-based simulator.

**Type rating/endorsement training**—3 responses
Another use for full-flight simulators was noted for training normal and abnormal flying procedures, for LOFT, and during type rating training.

**Other unspecified training**—2 responses
Other times that full flight simulation is used includes when it is requested by the pilot and on an ad hoc basis and that they could be used anytime that they are requested.

**Transition/conversion training**—2 responses
Full-flight simulators were also noted as being used during the latter portion of transition training.

**Specific motor skills**—3 responses
Pilots noted that a particular use for full-flight simulation was to develop motor skill coordination in pilot training. Specifically, full-flight simulation is used for building skill in take offs, landings, and emergency procedures; as preparation for maneuvers training; and when motor skills are complicated by the need for complex thought processes.

**Upgrade training**—1 response
In upgrade training, participants noted that full-flight simulators were used for proficiency checks and LOFT exercises.

## 2. What is most effective about your use of full-flight simulators?

Participants focused mostly on the realism that full-flight simulators provide during training that made their use particularly effective. Other effective uses of full-flight simulators were noted as training for non-normal procedures, learning reinforcement and a variety of other tasks. Details are presented below in the order of how participants thought full-flight simulators were most effective.

**Realism**—12 responses
Operating the controls in a fully replicated cockpit, feeling the response, and seeing the high-fidelity visuals, while being immersed in scenarios that are based on real line operation experiences and real locations (airports) were key attributes used to describe this realism.

**Training pilots on non-normal procedures**—4 responses
Being able to expose and train pilots to manage conditions that would be otherwise unsafe in real flight was thought to be another particularly effective use of full-flight simulators.

**Reinforces previous learning**—2 responses
In addition, it was mentioned that using full-flight simulators was a good tool to reinforce concepts and skills learned in the classroom and/or lower level devices.

**Other**
Each of the following was also cited as effective uses of full-flight simulators:

- Can license pilots without real aircraft experience
- Data capture and evaluation
- Identification of problems
- On the ground scenarios
- Debriefing after simulator training
- Use in ground school

### 3. What could be improved about how you use full-flight simulators?

Participants most notably cited improvements to the realism of full-flight simulators as being key to improving their use. Other considerations to improve the use of full flight simulators included maintenance of the simulator software and hardware and keeping the equipment in the simulator current with the equipment installed on the aircraft. Also mentioned was the use of full-flight simulators at the correct time during the training cycle, when their use would have the most beneficial effect to learning. There was also some mention about constraints and regulations that could be improved to facilitate more effective use of full-flight simulators. Details are listed below in the order of the frequency of responses.

**More and better scenarios based on real flight data/experience**—6 responses
Creating a real flight environment that includes the actual distractions and complications likely to be encountered, better ground handling models, the use of scenarios outside of the checklist, and expanding the use of real flight data were all suggested improvements to providing a more realistic experience in full-flight simulators for pilots.

**Keeping simulator software/hardware up to date**—4 responses
Keeping pace with the technological advances in the aircraft that they serve (making sure that the simulator equipment matches the aircraft equipment), providing better software updates, and improving communications and navigation simulations were cited as improvements for the technical side of full-flight simulators to improve their effectiveness in training.

**Using at the right time, not using it when unneeded**—3 responses
It was also noted that in order to avoid the distraction of motion and visuals when not needed and to use time more efficiently (set up is time consuming), full-flight simulators should not be used until after other forms of training were used to their full effectiveness.

**Constraints of the regulations/regulators**—2 responses
There was some general concern among participants that regulations were a constraining factor in the effective use of full-flight simulators, but no specific examples were given.

**Other**
Each of the following was cited as strategies to effect improvements to the use of full-flight simulators in pilot training:

- More funding
- Streamlining of simulator setup and operation
- Use of playback system
- Reliability of the simulator
- More flexibility training sessions
- Use simulator more
- Drop N&O and go to APQ
- More use of non-motion simulation

## B. Other Training Devices

### 1. What other types of simulation devices do you use?

In this section, participants address the variety of training devices that they use in their pilot training programs that are not classified as full-flight simulators. Examples

of the devices noted include fixed-base simulators, laptop and desktop computers, cardboard mockups, FMS trainers and more. Also noted in this section are some of the ways in which these devices are employed. The details for these devices are presented starting with the comments heard most frequently.

**Computer-based Learning**—26 responses total

> ***Desktop/laptop***—*18 responses*
> Participants use personal computer systems in a variety of ways including solo learning with take home laptops or discs, and classroom use with or without instructor participation. Applications of computer–based learning mentioned include the use of mockups of controls (electronic posters), part-task training, training of flight management computer/systems, automation control training, procedures training, The use of a heads-up guidance system for desktop flight simulation controlled by a joystick was also mentioned.

> ***Internet learning***—*8 responses*
> Mentioned in the category of desktop/laptop training devices was students' ability to access internet-based training for learning to use flight management computers, learn emergency procedures,, systems, and cockpit equipment layout. Having the ability to free play on these systems was also noted.

**Flight training devices (FTD)**—9 responses
> *(Note: Typically, flight training devices are considered any type of training device that presents a full representation of the entire aircraft flight deck. Although paper and cardboard flight deck mock ups and digital flight deck mock ups are technically FTDs, for the purpose of this summary they are listed separately. Please see the CBT Posters/cardboard cutouts and Computer-based training sections below.)*

Participants noted the use of flight deck simulators comprised of an array of flat panel displays. These were noted as often having touch-screen capability and either traditional computer-based controls such as a mouse or trackball or augmented controls that used actual aircraft equipment to manipulate the displays.

**Fixed-base simulators**—7 responses
Participants noted the use of fixed-based simulators for high fidelity replication of the aircraft cockpit including the full array of controls and the entire flight management system. They also noted that these simulators may or may not have visual systems and do not have motion capabilities. Participants noted that in some instances, full-flight simulators were used without the motion turned on in place of fixed-based simulators.

**Part-task trainers/cockpit procedures trainers**—6 responses
Participants noted the use of part-task trainers, systems that were not full representations of the flight deck, for systems and procedures training. They noted that these devices typically did not include a full representation of the flight deck and could be either computer-based or comprised of actual controls used in the aircraft.

**Posters/cardboard cutouts**—5 responses
Participants also noted the use of low-tech devices such as cardboard mockups and paper posters which are typically used to familiarize trainees with the layout of the cockpit, for the practice check lists and flows, and to illustrate questions.

**The aircraft itself**—5 responses

In some cases, actual aircraft was characterized as training devices, typically being used for aircraft familiarization. Other uses of real aircraft equipment (e.g. cabin trainers), if not the aircraft itself, was noted for evacuation and ditch training.

**Other**
Other simulation devices that were noted for use in pilot training include basic charts and a flight safety panel.

## 2. Where is each type of training device most effective?

Participants focused mostly on the effectiveness of computer-based training and flight training devices to teach systems and procedures.

**Computer-based training (CBT)**—6 responses
CBT was noted as being most effective when used for systems training (e.g. FMS automation), and systems integration training. CBT was also seen as being effective for procedures training and for training procedural changes.

**Flight training devices (FTD**)—6 responses
FTDs were also thought to be most effective when training systems and procedures, the integration of systems knowledge into procedural tasks, and crew coordination. Participants noted that FTDs offer pilots the opportunity to find and take their seat in the cockpit and practice fundamental, heads down skills and scanning. It was also stated that FTDs are most effective for preparing pilots to fly the simulators and use their simulator time most efficiently.

**Other**
Other uses of flight training devices thought to be effective include:

- Using Part-task trainers for training the use of flight management computers
- Putting all the pieces together in fixed-base simulators and the on the flight deck
- Challenging students in ways that you cannot in other devices.

## 3. What challenges do you have in using the training devices?

Participants expressed a broad range of challenges in using training devices including maintaining their devices as accurate representations of their aircraft in terms of hardware and software. Some mentioned the regulatory requirements/constraints for using certain types of training devices and their associated cost. Also mentioned as challenges were having access to additional devices, and the limitations of some devices to accurately represent the controls that they are supposed to depict.

**Matching training device equipment/software the actual aircraft equipment**—4 responses
Participants thought that trying to keep training devices accurately representing the equipment and software on their aircraft was a big challenge, in particular because of the rapid pace of changes to flight deck technology. This typically requires instructors to create work-arounds while training pilots because their simulated systems do not match those on the aircraft. Simulating the variation of customized equipment installations and the 18 month lag time to create simulation of new technology were also noted as challenges.

**Spending too much time in simulators**—3 responses
There was some concern among participants that regulations required the use of higher fidelity simulators than the trainers thought were appropriate for the task being trained,

also noting that this was often accompanied by a significantly higher cost. Another concern was not having access to an intermediate device such as an FTD.

**Only one pilot at a time can operate device controls at a time**—2 responses
Using lower fidelity training devices in which only one crew member could use the mouse or trackball to affect a control input was seen as a challenge.

**Other**
Each of the following was cited once as challenges to the use of training devices:

- Inflexibility of simulator location and cost of use
- Cannot do full smoke drill in simulator
- Making training realistic and engaging
- Investment required to train instructors in FMSTS
- Adapting current training to integrate new training
- Maintaining the value of instructor interaction while using CBT
- Optimizing the device to learning outcome
- Training CRM and aircraft operation skills

## 4. What could be done to improve the training devices that you use?

Wide array of responses were given to this question with no real focus on one particular topic. They are listed below. In addition, ten participants answered this question as "What could be done to improve *how you use* training devices". Those responses are listed in the section label **other** below.

Participants expressed a number of ideas about how to improve the training devices that they use. Details are included below. No single idea held significant weight over another.

**Keeping up with evolving technology**—2 responses
Keeping software current with technology updates on board the aircraft was expressed as a needed improvement in training devices. The addition of new devices and version updates are currently "tacked on" and are not well integrated in the devices.

**Reduce software costs**—1 response
Training devices could be improved by reducing the costs created when there is a need for different vendors to each supply different software packages. The ability to do set up and programming before entering the simulator was also mentioned as a cost-saving improvement.

**Improved fidelity**—1 response
Participants thought that the fidelity of simulators could be improved, in particular for improving the simulation of taxiing and turbulence. Having better visuals and sharper responsiveness were also thought to be potential valuable improvements.

**Improve teaching environment of simulator**—1 response
Some noted that they thought simulator environments could be better designed for training but did not give specific recommendations.

**Integrate teaching devices**—1 response
said it was suggested that training devices could be improved to integrate their functionality. It was also suggested that data could be transferred from a low-cost device to a simulator to save costs.

**More interactive CBT**—1 response
It was suggested that computer based training that was more interactive, to recognize flying patterns for example, would be an improvement.

**More realistic controls (hardware)**—1 response
said it was also suggested that training devices could be improved with more realistic controls instead of computer touch screens.

**Other**
Each of the following was cited once as what could be done to improve *how you use* training devices (see note above).

- More interactive system that allows for home study.
- Need an FTD for less time in FFS
- Need structural design analysis of training program
- Same level of automation and interface across devices
- Greater use of part-task trainers
- Integrating a debriefing tool
- Greater use of management training exercises
- Update CBT for older aircraft
- Less use of CBT
- Greater use of FBS and less use of flat panel trainers
- Need interactive CBT
- Right balance of technology and instructors
- Build trainee confidence in training with devices

## C  New Training Technologies

## 1.  Are there any new training technologies that you would like to implement to help you train?

Participants focused their ideas on using new technologies to help them train fairly evenly across three broad areas. These include the training delivery technologies associated with distance learning, adding training devices to their existing programs and making the training technology more interactive. Details are presented below starting with the comments heard most frequently.

**Training delivery technologies**—6 responses
Some mentioned that they would like to enhance their training operation through new training delivery methods and technologies. Participants mentioned the addition of distance learning through the internet, compact discs, thumb drives and iPads. It was also noted that the internet is too slow for the volume of data needed for training. There was also a suggestion to use a system that keeps statistics on pilot performance of distance learning skills and to use that information to customize training and define training emphasizes.

**Adding new devices**—6 responses
Some thought that adding additional devices to their training programs that incorporated touch screen display technology, adding fixed-base simulators with visuals, desktop simulation, part-task trainers, and iPads would all be technological improvements to help them with their training.

**More interactive technology**—5 responses
Adding technology for more interactivity in their training devices was also thought to be a method for improving their use of training devices. The use of several creative new technologies was proposed, including 3D modeling, first person gaming technology, and flight-scape animation (built from real flight data and actual incidents and accidents). Having real G forces in the simulator was also suggested.

**Other**—1 response
Having a new device (unspecified) to improve metrics of evaluation of simulator training performance was also suggested as a way to improve the use of training devices.

## 2. How do you see these training technologies improving training effectiveness?

Participants noted that training technologies could improve training effectiveness in several ways, including overall training program enhancement, lower costs, and greater efficiency. Details are given below starting with the comments heard most frequently.

**Training program enhancement**—3 responses
Participants thought that the addition of an initial procedures trainer (type of FTD) would make the building block training method more effective and that the use of touch screen technology would enhance the initiative to fly manually at the edge of the envelope and help with ground school.

**Lower training costs**—2 responses
The lower cost of operating fixed-base simulators with visuals instead of full flight simulators was thought to be a way to improve training, noting also that the lower cost of the devices might allow more devices to be purchased therefore creating more availability (time in simulator).

**Appropriate use of device**—2 responses
It was also noted that using training devices (both current and new acquisitions) appropriately for their intended purposes would improve training effectiveness.

**Greater efficiency**—1 response
It was suggested that better training could be provided in less amount of time by using a fixed-base simulator with visuals rather than a flight simulator.

## D. Training Scenarios

## 1. What methods have you found to be most effective in developing training scenarios?

Participants focused mostly on line experience and the use of safety data as effective tools in developing training scenarios. Also mentioned as being effective were the use of systematic methods to create scenarios. In addition, pilot performance feedback, and subject matter expert input was thought to be effective. Details are given below starting with the comments heard most frequently.

**Line experience**—11 responses
Using the real world experience of pilots working the line was cited as an effective method for developing training scenarios. Incidents, mistakes, and other things that happen on a regular basis, and how pilots coped with them are combined with other elements, such as safety data, to address problems and add realism to the scenarios.

**Safety data**—9 responses
Using safety data was noted as being an effective method for developing scenarios with data being accessed from a variety of sources including Flight Operational Quality Assurance (FOQA), Aviation Safety Action Program (ASAP), Advanced Qualification Program (APQ) feedback loops, hazard reports, event review committees, audit teams, and industry sources. These data help participants to determine levels of risk, and identify deficiencies, trends, and recurring issues. Participants stated that the use of safety data is important in helping them to determine what to train, how to best train, and what are the best devices to use in training. They also find that using safety data creates credibility and realism noting that safety data is used in combination with line experience, practical test standards, and Line Operational Evaluation (LOE) to develop training scenarios.

**Systematic methodology**—8 responses
It was noted that using a specific procedural method was an effective way develop training scenarios. Although no overlap is present among the responses, a clear methodical process for developing scenarios was stated. Methods were described as using risk ratings, matrices, storyboards, branched learning, event sets, periodic emphasis, 2-leg LOE, and pre-testing.

**Pilot performance**—6 responses
Pilot performance data such as proficiency checks, Line Oriented Evaluations (LOE), and Advanced Qualification Program (AQP) feedback loops and task proficiency data were noted as important tools to be used in training scenario development. These performance measures are used to evaluate pilot flying skills as well as pilot monitoring. This information shows the most common areas where students are having difficulty and are used in combination with line experience and safety data to create training scenarios.

**Experts**—2 responses
Using subject area experts who develop scenarios based on prioritized flight safety data and different topical areas during different times of year was thought to be an effective method for developing training scenarios.

**Other**
- New procedures and regulatory prescriptions were cited as methods that could be used effectively in developing scenarios.

## 2. What challenges do you have in developing training scenarios?

Participants noted that time and resources were the greatest challenge to developing training scenarios. Some mentioned regulations/regulators, maintaining the element of surprise, and device limitations as challenges. Details are given below based on the frequency of the responses.

**Time and resources**—7 responses
Participants noted that is challenging to have enough staff resources available for training scenario development, that creativity is diminished by the limitation of time and resources, and that high priority issues must be addressed first. Participants also mentioned that they are increasingly challenged to complete all the required training in the time allotted. In

addition, participants said that lead time for FAA approval is challenging. Working closely with FAA counterparts was a strategy noted that helped to reduce approval time.

**Regulations/regulators**—3 responses
Constraints created by the prescriptive and descriptive requirements of the regulations were cited as a challenge to developing scenarios. These constraints cause the organization to lag behind customer needs. It was noted that trying to convince the FAA that their desired AQP scenarios were the right thing to do was particularly challenging.

**Maintaining element of surprise**—3 responses
Participants noted that trying to create scenarios that are not predictable, or lack the element of surprise that mimics real line operation was a challenge. This also causes instructors to anticipate student reactions and expect certain responses. said it was also noted that the cost of scenario development inhibits the ability to maintain the element of surprise.

**Device limitations**—2 responses
Participants noted that devices that come with pre-programmed limitations that are mechanical, data driven, or from regulation requirements are problematic for developing scenarios. These limitations make it hard to recreate the complexity of what is actually happening on the line. More unpredictable and compounded malfunctions are occurring, and the devices are not easily operated to simulate them. Work-arounds are necessary.

**Other**
The following were each cited once as challenges in developing training scenarios:

- Agreement on how to achieve desired learning
- Limited access to simulators
- Using available data
- Using trainers and evaluators knowledge
- Appropriate level of pilot challenge
- Keeping scenarios informative, fresh and challenging, but non-threatening.

## V. Training Methods

## A. Classroom

## 1. What topics do you include in classroom training?

Most of the interview participants use the classroom for systems training, and many cover emergency equipment/procedures and other safety considerations. CRM is often taught in the classroom as well, as is routing information and airline-specific information. Details are presented below starting with the comments heard most frequently.

**Systems**—18 responses
Eighteen participants talked about their systems training in their answers to the question. One of them said training is done on systems using the classroom and CBT, and another said training takes place in the classroom and at home. Two use only non-classroom training for systems training (one said systems are trained at home, and another said systems are trained using CBT.) One participant was unclear about whether the training was given in a classroom or the actual aircraft.

One participant talked about training classic knowledge areas, such as systems, in the classroom. Another participant said that systems can be learned at home alone but that other (human) subjects are better taught with an instructor.

One participant includes generic non-aircraft systems in its training. One said it covers architecture, controls, and indicators. One participant said "why" needs to be answered for system function and design, not just "how." One participant said systems integration, hydraulics, and electrics are included.

**Safety/security**—15 responses
Fifteen participants discussed various aspects of safety and security in their answers to the question:

- CRM—8 responses total
- Security—5 responses total
  - Four levels of threat
  - Self-defense
- Safety/emergencies—11 responses total
  - Emergency equipment
  - Safety equipment
  - Hazardous materials
  - Safety briefings
  - Safety events
  - Safety equipment procedures
  - Medical procedures
  - Evacuate and ditch, swim/ditch
  - Fire
  - Practice putting out fires
  - Fire extinguishers
  - Emergency procedures
  - Emergency situations, drills
- Threat and error management—1 response

**Training programs**—15 responses
Fifteen participants discussed training programs in their answers to the question.

One participant discussed "new hire" training: the training starts with over a week of indoctrination. Three participants discussed "initial training." One said topics from the flight operations manual are covered. Another said its initial training consists of 20 to 25 modules.

Three participants talked about "qualification." One said the training is about half instructor led and half CBT, covering thousands of objectives.

One participant said that its ground school has to be visual. One participant talked about type ratings and said computers are used very little in the training.

Eleven participants talked about recurrent training. One said a half day is spent in meetings with management. One participant said the same objectives are covered in ground school (on a rotational basis) as are covered in recurrent. Another participant said that everything new hires are trained on in a distance portion and in a classroom portion (two-year

program, or 18 months under AQP) is covered. One participant said a little bit of everything is covered. Another participant said every two years all systems are addressed in training. Another participant said that in a three-year period, all subjects required by the FAA are covered. Two participants said they do technical refreshers. One of them is done in one day every year, under a lot of pressure. Another participant said that recurrent training is done in the classroom every six months.

Two participants talked about transition/conversion training.

### Policies/procedures/indoctrination—12 responses
Twelve participants talked about indoctrinating pilots or training policies, procedures, or check lists in their answers to the question.

Five participants mentioned indoctrination. One participant said economic considerations and company paperwork are covered. Four mentioned policies.

Nine participants talked about training on procedures and checklists. One participant mentioned SOPs. One participant said company procedures, general procedures, and cockpit procedures are covered. One brought up emergency procedures, and another, medical procedures. One participant said safety equipment procedures are trained every 12 months. One participant said operational procedures are trained. One mentioned instrument, approach, and dispatch procedures. Three participants talked about checklists; one in association with flows and another in association with profiles. The latter also said that abnormal checklists are supposed to be a precursor to going to fixed devices.

### Environment/weather—8 responses total
Eight participants talked about environmental conditions or weather in their answers to the question:

- Low Visibility Procedures
- Environmental
- Weather/ meteorology
  - Weather scenarios
  - Weather avoidance
  - Icing
  - Hot and cold operations
- High altitude operations
- Oceanic

### Routes/theaters/charts/flight plans—8 responses
Eight participants talked about training on routes and the like in their answers to this question. One participant said the only unique training provided is information particular to the flown routes. One participant mentioned ETOPS. Another participant covers international operations. Two participants said they cover special or unique theaters including oceanic and the North Atlantic. One participant covers charting. Two participants train on dispatch releases or procedures. One of these participants also covers flight planning, while the other one trains on reading takeoff and landing reports.

### Performance—7 responses
Seven participants talked about training on performance in their answers to this question. One of them said that normally performance is the only subject trained in a classroom. Two said they train weight and balance; one of them also mentioned power.

**Topics required by regulators**—6 responses
Six participants brought up regulatory requirements in their answers to this question. Three participants said they teach FAA or regulation required topics. One covers topics required by DOD.

One company with international operations mentioned aerospace regulations. One company with operations in the US, Canada, and Mexico has some training driven by regulations, which includes why certain things are done they way they are.

**Approach/landing**—4 responses
Four participants talked about approaches or landings. One brought up stabilized approaches and RNP approaches. One mentioned CATII approaches, and another mentioned approach procedures. Two said they train on runway incursions/excursions; one of them also mentioned hot spots.

**Personnel trained in classroom**—4 responses
Four participants mentioned the types of personnel they train in the classroom. One participant said new hires are trained. One participant mentioned First Officer development training, which includes decision-making. Another participant brought up command training for those being promoted to Captain. Another participant mentioned instructor/examiner training.

**Human factors/human centered**—4 responses
Four participants brought up human-centered training when answering this question; three of them mentioned human factors. One of them said CFIT is included in HF training.

**Documentation**—4 responses
Four participants brought up manuals or specs in their answers to this question: Flight manual, ops training manual, ops spec, and Flight Operations Training Manual.

**Types of Incidents**—3 responses
Three participants talked about dangerous situations including the following:

- Runway incursions/excursions
- Mach tuck
- CFIT
- Flap over speed
- Upset recovery

**Abnormals**—3 responses
Three participants talked about abnormals when answering this question. One of them said that abnormal checklists are a precursor to going to the fixed training devices.

**Automation**—3 responses
Three participants talked about automation training in their answers to this question. One talked about human centered automation training. One participant said pilots have to understand the fundamentals, including what the automation is doing and why. One said automation is integrated into the technical part of ground training.

**CBT and instructor led**—3 responses
Three participants brought up combining instructor-led or classroom training with CBT. One said its ground school is about half instructor led training and half CBT. One said stand-up

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instruction/training in the device along with CBT for the next day's topics is used. One participant said technical subjects using CBT and the classroom are covered.

**Classroom equipment**—3 responses
Three participants brought up classroom equipment in answering this question. One participant said computers are used very little in training. Another said the classrooms are well-equipped with computers and graphic displays.

**Knowledge**—3 responses
Three participants talked about knowledge training in their answers to this question.

**Hot topics**—2 responses
Two participants brought up hot items in their answers to this question.

**Simulator briefings**—2 responses
Two participants mentioned simulator briefings when answering this question.

**Other topics included in classroom training**—1 response
One participant discussed air traffic control in response to this question.

## 2. What training methods have been effective in your classroom training?

A major benefit of classroom instruction is the interactivity with the instructor that leads to effective training, according to a large number of participants. Although classroom training is often blended with other methods, especially CBT, instructor involvement in the other methods is valued. Many participants feel classroom training should reflect the real world, and discussing scenarios is an effective way of doing so. Graphical information was also talked about as being effectively used in the classroom. Details are presented below starting with the comments heard most frequently.

**Blended learning**—12 responses
Twelve participants talked about using a mix of training methods.

One participant said lectures are blended with a facilitation-based approach. Another participant has tried all classroom lecture and 75% CBT, settling on 40% CBT and 60% guided discussion/lecture/cockpit trainer. One participant said about half of the classroom training is done with the available computers. One participant said web-based training is used: eight hours at home and 16 hours in a classroom. One participant said CBT is used in a classroom. One participant said that for its qualification course, one third is stand-up instruction, one third is in a device, and one third is CBT.

One participant said CBT facilitated by an instructor is used. Another said some CBT led by an instructor is used. One participant said both CBT and an instructor are used. One talked about e-learning for rote learning followed by classroom discussion. Another participant said students are exposed to CBT first and then provided with instructor interaction.

Another participant uses PowerPoint and movies followed by group discussions.

**Interactivity**—10 responses
Ten participants talked about the effectiveness of interactivity, with instructors, computers, or both. One participant said that interactivity is important even without an instructor, but an instructor is important for reinforcing information.

Four participants said they find interactive CBT effective (see also the "Delivery media" section). One said that for systems training, interactive CBT (instead of static diagrams) can be facilitated by an instructor, but for scenario-based training, the technology would be secondary; either way, interchanging ideas is the purpose of having trainees and a facilitator in the same room. Another participant said interactive CBT can be instructor-led or not. One participant said that students use CBT first, and then instructors answer questions and put the training in context. That participant also said that the organization returned to having instructors involved in scenario training to discuss why different crews might do things differently.

Five participants talked about interactive lectures or discussions. One of them said that rote learning should be provided through e-learning now, but the application of what is learned should be discussed in class. Another participant said that dialog with instructors is needed and that the industry is going too far with computer training; unique questions from students need to be asked in a classroom to get an answer.

One participant said that web-based training consists of eight hours at home followed by 16 hours in a classroom and that the organization is trying to make the training more interactive.

### Realistic training—8 responses
Eight participants said that training should be realistic. One participant said that the more realistic the training, the better the value. Another participant said systems training needs to cover what happens in the real world, and scenario discussions need to cover different crew approaches.

Four participants talked about graphics in their answers to this question. Two of them said that they use schematics showing movement (fluids, hydraulics). One of them said that it dynamic CBT simulation is now used instead of static wiring diagrams.

Six participants talked about scenario training as being effective in the classroom. One participant said the more realistic the training, the better, and implied scenario training is an example of that. One mentioned the real world and then talked about scenarios. One said systems are taught through talking about how real-world scenarios unfold in a real flight, including what the crew did well and what the crew should not have done.

### Small class size—3 responses
Three participants said that small class sizes are effective. One said that having two students to one instructor ratio is a big positive, and another said the ideal class size is ten students

### Delivery media—2 responses
Twelve participants brought up the media used to deliver training, including in the classroom. Ten of those participants talked about CBT or computerized training.

One said that CBT is used in the classroom as a dynamic piece instead of using static diagrams. Another said pilots use CBT to study material for the next day. Another said web-based training is used for continuing quality but not for additions or upgrades.

One participant said some instructor-led CBT is used. At another, instructors answer questions students had from systems training on CBT. Another participant said CBT is used in the classroom for teaching advanced information. One participant said that most of its training is done with CBT. Another tried 75% CBT and then settled on 40% CBT. One said that in the industry students read and answer questions in front of a computer and that a lot is lost if students do not have a dialog.

One participant said it uses Simfinity. One uses PowerPoint and movies, but another said it replaced PowerPoint and slide projectors with schematics that show motion. One participant said the use of videos is planned. One said the Audience Response System, which is integrated with PowerPoint, is used to keep students engaged.

**People learn in different ways**—2 responses
Two participants brought up students learning in different ways. One said that instructors need to use the tool that that works best for an audience. Another likes CBT because students can learn at their own speed.

**Monitor student responses**—2 responses
Two participants said they monitor student responses. One uses the Audience Response System, and the other has instructors monitor student test answers via a console so that the direction of training can be changed if necessary.

**Other**
Each of the following was cited once as methods that are effective in classroom training:

- Knowledgeable instructors
- Instructors open to feedback
- Challenge students
- Team teaching

## 3. What challenges have you had in classroom training?

Although participants indicated in answers to the previous question that interaction with instructors is valuable, instructors also bring challenges from standardizing them to keeping them current. Pilot trainees also bring challenges to the classroom, particularly in attempts to hold their interest, as in information required by regulations that is outdated or not applicable to an airline's operations. The expense of classroom training was also mentioned. Details are presented below starting with the comments heard most frequently.

**Keeping students engaged**—5 responses
Five participants said that keeping students engaged is a challenge. One participant mentioned that pilots would rather fly than go to training. Another said that keeping students involved when lecturing on information required by regulations is challenging.

Two participants pointed out that subjects like hydraulics or CRM can only be talked about in so many ways. One of them added that pilots are now from more of a computer-based generation. The other added that new safety information can keep CRM training from becoming boring.

See also the "Rote learning" and "Length of time in class" sections.

**Challenges with instructors**—5 responses
Five participants talked about various challenges they face with instructors. Two participants said they face challenges in standardization of instructors. Both mentioned that instructors bring personal flying/war stories to the curriculum. One participant said that keeping instructors current is a challenge, in equipping good flight instructors with classroom skills and in keeping dedicated classroom instructors current with line practices.

One participant faces challenges when many students have to be trained because instead of having two instructors normally used in team teaching, there is only one. One participant said the biggest challenge is instructors who lack experience operating the equipment. One

participant said finding the right people to be trainers is challenging. They must be people the pilots will listen to.

**PowerPoint**—4 responses
Four participants talked about PowerPoint. Three said that PowerPoint is a challenge, but one said it uses PowerPoint to help keep instruction standardized. Of the three, one participant mentioned "death by PowerPoint," another mentioned too much PowerPoint, and another mentioned the loss of dialog when people read a PowerPoint.

**Few challenges or none**—3 responses
Three participants said that they do not face serious challenges with classroom training. However, one of them also mentioned that standardization will always be a challenge as long as humans are involved.

**Budget**—3 responses
Three participants talked about budgetary challenges. One participant said that instructor-led classes cost more, but pilots love the instant feedback and personal attention. Another brought up having financial constraints.

**Curriculum**—3 responses
Three participants cited curriculum challenges. One said instructors use PowerPoint presentations to ensure topics are covered, and observations and standardization meetings are used to keep training standardized. One participant said that he fights syllabus creep among line pilot instructors. The third participant said the organization does not have the answer to all of the curriculum challenges.

**Regulatory requirements**—3 responses
Three participants brought up challenges with regulatory requirements. One said that videos the FAA requires are 15 years old and that dry securities materials from the FAA have to be seen annually for 25 to 30 years. Another said that information required by regulations may not be directly applicable. The third said that as new requirements such as information on incidents and accidents come from the FAA, old requirements do not go away; a tradeoff point is needed.

One of the participants said that AQP is nice because many limitations come from the FAA.

**Other**
Each of the following was cited once a challenge in classroom training:

- More challenges than strengths
- Older technology
- Too much lecture
- Different learning styles
- Keeping devices updated
- Rote learning
- Adapting training to technology on aircraft
- Length of time in class

## B. Distance Training

## 1. What topics do you train through distance training?

Participants noted a variety of topics that are covered in their distance training programs mostly focusing on systems or procedures knowledge. Details are provides below beginning with the most frequent response.

**Topics for Recurrent Training**—7 responses
Four participants stated that they use distance training during recurrent training. Three participants noted that they use distance training for the flight operating systems portion of their recurrent training program. One of these participants stated that distance training is used to provide optional preview materials for the recurrent training program.

**Safety-related topics**—5 responses
Five participants stated that they use distance training for some form of safety-related training.

**Specialized topics**—4 responses
Two participants stated that they use distance training to address specialized topics. This includes winter operations, Class II Navigation, over-water navigation, topics generated by industry, and professional development. Another participant said that laptops are used to deliver training on airport familiarization and dangerous goods training.

**Company Procedures and Operations**—3 responses
Three participants stated that they use distance training for demonstrating company procedures by sending out DVDs of the procedures (e.g., general approach to procedures for verifying callouts or checklists, specific normals or non-normals, use of heads-up display, special airport operations).

**Systems training**—3 responses
Three participants stated that they use distance training specifically for systems training.

**No distance training provided**—2 responses
Two participants stated that they do not currently provide any form of distance training.

**Security training**—2 responses
Two participants stated that they use distance training for security-related training.

**Other**
Each of the following was cited once as topics trained through distance training:

- As many topics as possible
- Knowledge-based content
- Transition training
- Hazardous materials training
- Safety programs
- Airport familiarization
- FAA required topics
- In response to an event

- Quarterly bulletin
- Electronic library

## 2. How effective has this been?

Most participants who stated that they use distance training said that it is effective, but several are having challenges with it being effective. Details are provided below.

**Distance training has been effective**—9 responses
Nine participants responded that their use of distance training has been effective.

**Distance training has been moderately effective**—2 responses
Two participants responded that their use of distance training has been moderately effective.

**Other**
Each of the following was cited once regarding the effectiveness of distance training:

- Initially effective with emerging limitations
- Effectiveness of distance training unknown
- Effectiveness of distance training has improved

## 3. What could be done to improve your distance training?

The most frequently mentioned improvement that could be made to distance training programs is to increase the interactivity of the training materials. Also mentioned were improvements to the content, methods by which it is provided, or tools for management of the distance training. Details are provided below beginning with the most frequent response.

**Increase interactive nature**—5 responses
Five participants responded that distance training could be improved by increasing or ensuring the interactive nature of training materials.

**Improve content**—4 responses
Four participants responded that certain improvements could be made to the content of distance training materials. Two of the four participants responded that the training content needed to be updated in a timely manner to ensure currency, relevancy and the engaging nature of the material. One participant responded that the writing and presentation of training materials could be improved. One participant responded that the structure of the content could be improved and additional content could be added.

**Tracking capabilities**—2 responses
One participant responded that adding a Learning Management System (LMS) would improve the use of distance learning. Another participant responded that providing the capability to ensure pilots have viewed the training material would improve the use of distance learning.

**More robust training development system**—1 response
One participant responded that having a more robust system for developing training would allow the ability to enhance reading materials with videos, and this would improve his use of distance training.

**Moving to online training**—1 response
One participant responded that moving to online training would improve distance training. The participant noted that this method would provide an easier format in which to update material as well as the ability to provide interactive training elements and links to other online training aids.

**Standardized platform**—1 response
One participant responded that distance training could be improved by providing trainees with a standardized platform. The participant noted that this would avoid compatibility problems and likely provide well-received, user-friendly training.

**Other**
Each of the following was cited once as ways to improve distance training:

- Better integration with classroom training
- Free-play simulation
- Internet connection speed
- instant feedback
- Quizzes and test out feature
- Collecting answer data
- Measuring training effectiveness with a survey
- More scenario-based training
- Adding requirements for training completion
- Developing prerequisites that need to be completed prior to in-house training
- Adding a classroom for self-study

## C. Debriefings

## 1. How do you use debriefings in your training?

Major themes that emerged from the responses to this question include the specific debriefing methods and approaches used, types of debriefings used, and the relationship of debriefings to the use of simulators and training devices. Instructor training and learning, length of debriefings, and the use of video recording were also mentioned. Details are presented below starting with the comments heard most frequently.

**Methods and approaches used**—12 responses
Twelve participants talked about the methods used in their debriefings. Two participants said they use debriefings to assess performance, and one participant said the instructors/check pilots praise or critique crews. One participant said that students critique themselves and go over what they learned and what they could do better. Two participants said students talk about what went well and what did not go well, and then at one of the organizations, any holes are filled in. One participant said the instructor/check pilot talks about what went well and what did not go well. One participant said both the good and the bad points are highlighted and pilots are harder on themselves than the instructors are.

Two participants said they use debriefings to reinforce good behaviors. One of these participants also said that properly executed maneuvers are reinforced and that a debriefing is not a list of what was done wrong.

Three participants said they use debriefings for the crew to understand why something went wrong. One participant also includes why things went right. One participant's LOE scenarios

can have multiple endings; the debriefings go over the decision made and why different decisions might have been better.

One participant said debriefings are used to discuss how things worked out and what the pilots were thinking about. Debriefings are also used for the check airman to provide additional insights and to understand whether the pilots knew what they were doing. In training-in-lieu debriefings, one participant goes back to the procedure manual.

One participant said that after a flat panel or simulator session, the instructor focuses on technical issues, but at the end of the simulator debriefing, a different instructor focuses on human factors and overall performance levels. One participant focuses on threat and error management. In LOFT debriefs, one participant includes what is coming up in line observational evaluations. This participant also links debriefings back to briefings. One participant discusses anything that needs to be included in the next lesson. Another participant focuses on CRM during refresher training.

### Types of debrief: Lecture, facilitated, self-debriefs—11 responses
Eleven participants discussed the types of debriefings they hold. One participant said its debriefings are between the pilot and the instructor. One participant uses traditional face-to-face debriefings, one-to-one or one-to-two, but they are becoming more facilitated, particularly towards the end of the debriefing. This participant also said that debriefings are simple and nothing radical has been tried; there is currently not a focus on debriefings.

Nine of the participants talked about facilitated debriefings, self-debriefings, or both. One participant uses facilitated debriefings for LOFT and lecture-style debriefings for standards-based flight training. Two participants said they use facilitated debriefs. One participant mentioned facilitated debriefs as presented by R. Key Dismukes and Guy Smith.

One participant holds oral debriefs and some facilitated self-debriefs. This participant said self-debriefs may be more appropriate in certain situations. One participant said facilitated self-debriefings are used. Another participant holds facilitated debriefs and is making crew self-debriefings part of its crew procedures. One participant is encouraging pilot self-critiques after every flight. This participant uses facilitated debriefings with self-debriefings in which students take ownership. This participant also said that ownership leads to more effective learning because of the behavior modification.

Two other participants also talked about self-debriefing. One of these mentioned self-critiques in association with AQP, and one said that student-led debriefings take longer.

Two participants said they include written versions of the debriefings.

### Training devices and simulators—7 responses
Seven participants talked about debriefings after sessions in training devices.

Six participants talked about simulators. One of these participants said debriefings are held after all LOFTS and most other simulator sessions. Another participant said that the debriefing is just as important as the simulator session.

Three participants brought up other devices:

- Any device training
- Flat panel trainers

### Length of debrief—6 responses
Six participants talked about the length of their debriefings. Two participants said their debriefings are 30 minutes. One of these participants added that a debriefing could go longer if there were a large problem.

Three participants said their simulator debriefings are one hour long. One participant said for a four-hour simulator session briefings and debriefs are two and a half hours long.

**Debrief instructor/facilitator/check airman training**—5 responses
Five participants talked about instructor learning experiences.

Four participants talked about debrief training. One participant said instructors are trained to debrief in a non-threatening manner. Another participant said its training program is fairly extensive and focuses on what debriefings are to achieve and how to link them back to briefings. Another participant said instructors and check airmen are trained to praise and critique.

One participant said the debriefings are a good learning experience for instructors; they can learn what they could do better.

**Type of training followed by debriefings**—4 responses
Four participants mentioned the types of training that are followed by debriefings. One participant said every training module has time for pre and post briefs and that more time might be needed after validation/checking events based on student performance. One participant said the style of the debriefing depends on the flight training module (see " Types of debrief: Lecture, facilitated, self-debriefs"). One participant mentioned refresher training. Another participant said more debriefings are held for initial, upgrade, and special than for recurrent.

**Safety**—3 responses
Three participants talked about safety. One participant said that CRM instructors debrief crews on issues reported through ASAP, operations reports, and data from the safety department. One participant said debriefings should be encouraged to enhance safety.

**Video debriefing**—3 responses
Three participants talked about videotaping debriefings. Two of them were positive about video: One of the participants is an advocate, and the other participant recommends video for refresher training in the simulator. One participant said debriefings are done without the video (unlike LOFT).

**After flights on the line**—2 responses
Two participants talked about debriefings after flights on the line. One participant is considering adding a debriefing process after every flight. One participant said that for new line operations, students have debriefings, but there are limitations because the training occurs during the flight.

**Other ways debriefings are used in your training**—1 response
One participant said that debriefing certification by regulatory authorities is used in training.

## 2. What has been effective in the use of debriefings?

Participant responses to this question centered on the use of training tools, the use of self-critique methods, instructor learning and improvement, facilitated debriefings, and the debriefing environment. Additional program specific comments were also made. Details are presented below starting with the comments heard most frequently.

**Tools: recordings, white board, written summaries**—5 responses
Five participants talked about tools that help make debriefings effective. Three mentioned that some way of recording and playing back the simulator session is effective. One also said that graphic displays in the simulator can be downloaded. One participant said that the

white board can be used if facts are in dispute and that the same training aides used in briefings can be used in debriefings. One participant provides written summaries that students and instructors sign.

**Self-critique**—4 responses
Four participants said that self-critiques are effective. One participant said that pilots who self-critique are probably harder on themselves than the instructors are. One participant said that when crews take ownership through self-critiques, more effective learning takes place, and another participant said that when pilots come to their own conclusions, they retain the information longer and are more likely to follow through. One participant said self-critiques have been partially successful.

**Instructor debrief training/learning**—4 responses
Four participants talked about training instructors on how to conduct debriefings or what instructors can learn from them. One participant trains LOFT facilitators to use the right phrases in debriefings to draw information from the pilot, including how a situation made a pilot feel.

One participant said that the pilot debriefings are a good learning experience for instructors. This participant also talked about I/E training, which includes a check airman in I/E training sessions and the debriefings that follow that the FAA has approved. No one else is allowed in. This participant said it has gotten good feedback on the process.

One participant trains instructors/evaluators in giving debriefings. Captains watch I/E training/checking events twice each year to take I/Es through ways to improve.

**Facilitated/two-way debriefings**—4 responses
Four participants talked about facilitated debriefings in their answers to this question. One participant said that two-way debriefings are important. Another participant said that facilitated debriefings are a good learning experience for pilots and instructors. A third participant said that in a facilitated debriefing, if one pilot asks why something happened, the facilitator asks another pilot for ideas, which leads to more participation and buy in.

**Nonthreatening debriefs**—3 responses
Three participants said that debriefings should be nonthreatening and should not belittle pilots. Two participants also mentioned talking about what crews did well in debriefings. One participant added that how questions or statements are phrased can help draw information from pilots.

**Use as a teaching/learning opportunity**—3 responses
Three participants said that debriefings are effectively used as teaching opportunities. One participant included instructors as having a good learning experience.

**Rating scales/IRR**—3 responses
Three participants talked about the effectiveness of ratings. Two participants said they use inter-rate reliability. One participant said inter-rate reliability (IRR) is a best practice. One participant said IRR is used to get everyone on the same page. Another participant said that rating scales and task rankings go beyond pass/fail and lead to positive debriefings.

**Other**

Each of the following was cited once as effective debriefing techniques:

- Fixing errors
- Student control of debriefing

- Highlight both good and bad
- Time before debriefing for instructors to collect their thoughts
- Reinforce what was done in simulator
- CRM/threat and error management perspective in debriefings

## 3.  What challenges do you have with using debriefings?

Answers to this question centered on issues of pilot engagement, pilot culture, the use of video recording and standardization. Additional issues including instructor training and issues of procedures and practices were also mentioned. Details are presented below starting with the comments heard most frequently.

**Pilot engagement**—3 responses
Three participants said that pilots want to leave after the training session but before the debriefing. One participant said that some pilots understand the big picture, but other pilots are not engaged.

**Culture**—3 responses
Three participants talked about how culture affects debriefings. One participant said that debriefs are not a challenge because of the culture: Pilots know what to expect. One participant said that debriefings are an ongoing cultural issue. This participant's organization is focusing on the four P's (philosophy, policies, procedures, practices). Another participant said the increase of human-factors-based feedback is becoming a problem area in some cultures.

**Video**—3 responses
Three participants talked about video. One participant uses video in recurrent training, but not in qualification training. This participant would like a quick way to index the recordings. One participant would like simulator videos that work well.

One participant said it has to delete videos after the debriefing because of the labor perspective. One participant said that the union has to buy in to what is going to be recorded.

**Standardization: tools, language, training**—3 responses
Three participants said they face challenges in standardization. One participant said that standardizing tools is always a challenge. This participant also talked about getting instructors to use the language of threat and error management before teaching crews to be comfortable with that language. Another participant uses IRR each month at instructor meetings and said an effort is being made to get everyone to use the same tools and criteria. One participant said training departments should be more standardized.

**Facilitating debriefings**—2 responses
Two participants said that facilitating debriefings is hard.

**Debrief/facilitator training**—2 responses
Two participants said that they face challenges in training how to debrief. One would like to boost the debrief training given to I/Es. This participant said debriefings have become a "litany of crimes," which can lead to the loss of the developmental benefits of debriefings. One participant mentioned the attention people have to pay to each other in facilitator training.

**Pilot's recall**—2 responses

Two participants said that after four hours of training, pilots cannot necessarily recall details. One participant said that it comes down to instructor skill. Another participant said that video (used in recurrent training only) helps. This participant is considering debriefing immediately after certain maneuvers or at the two-hour break but believes post-training debriefs have the least impact.

**Inaccurate written records of debriefings**—2 responses

Two participants said that written records are a weakness. The quality of written records varies at one of these organizations, and this participant said that is true in most training organizations. Another participant said the written record is not the same as what the instructor told students in debriefings, but accurate records are needed to plan future training.

**Lack of time**—2 responses

Two participants talked about time challenges. One participant said that there is not enough time in the footprint. Another participant brought up travel restraints, which are time constraints.

**Other**

Each of the following was cited once as challenges with using debriefings:

- Timing and debrief content
- Debriefing line ops
- Pilot's willingness to listen to certain instructors
- Knowing whether skills transfer to the line
- Willingness to talk
- Pilot contesting the debrief (infrequent)
- Two captains in training events
- Older pilots
- Quality of debriefings

## 4. How could the use of debriefings in training be improved?

Responses to this question focused on the improvement of Instructor/Evaluator training and the use of recordings as ways to improve debriefings. A number of additional comments were made on the debriefing process and procedures. Details are presented below starting with the comments heard most frequently.

**Recordings**—4 responses

Four participants brought up recordings as a way to improve debriefings. One participant would like to build on debrief recordings and mentioned the filming of LOFT events. Another participant said that ab-initio pilots should analyze the video and then present to the instructor the next day. One participant said that simulator video tools and how they are used need improvement. Another participant said that video recording is not used because of finances but would like to.

**Instructor debrief training—4 responses**

Three participants said that improving instructor or I/E debrief training would improve debriefings. Two participants said that teaching instructors how to debrief would improve the benefit to pilots. One of these participants also talked about basic instructional

techniques and the use of the white board. The other participants talked about how instructors grade scenarios, including how pilots trap errors and determine outcomes.

**Other**

Each of the following was cited once as how debriefings in training could be improved:

- Improve quality of written records
- Increase focus on human factors based feedback
- Have an interactive focus
- Address three issues max per pilot during new type ratings
- Take time before debrief to think and to determine training objectives for debrief
- Standardize the process

# VI. Use of Safety Data

## A  What safety data do you have access to?

Many different sources of large volumes of safety data were discussed in the responses to this question by the participants in the training interview. ASAP data was mentioned the most frequently, closely followed by FOQA data. Details are presented below starting with the comments heard most frequently.

**FOQA—**12 responses

Twelve participants said they use FOQA data. One participant's organization has "volumes" of FOQA data. Another participant's organization said that FOQA is one of its two biggest sources of data (although it has not quite been integrated yet). One participant said FOQA is the biggest.

**Flight data recording**—4 responses

Four participants talked about flight data recording. One participant said flights have been recorded for 40 or 50 years. One participant said instructors have direct access to the recorder line monitoring program. Another participant gets near real-time flight data from the aircraft.

**Aviation Safety Action Program (ASAP)**—14 responses

Fourteen participants talked about ASAP. One participant analyzes ASAP data regularly. According to one participant, ASAP is one of the two biggest sources of data. Another participant pointed out that ASAP data is de-identified, and some of the data is minor (e.g., it's about misunderstandings). One participant said ASAP data is safety reporting, not just "screw ups." Another participant said a less robust analysis of ASAP data is done; the data includes maintenance and dispatch information.

**Line operations safety audits (LOSA)**—7 responses

Seven participants talked about LOSA. One participant said one LOSA has been done and the ground work for the second has been laid. One participant said a couple of LOSAs have been done, and another participant said LOSA data has been collected. One participant said the LOSA program is extensive.

**Training data/AQP data**—6 responses

Six participants talked about having access to training data. Three participants brought up AQP data. One participant mentioned using the previous year's AQP reports. One participant said AQP training reports are done monthly, and this participant's organization participates

in joint meetings about training issues that also cover issues from other data. One participant said its instructors use electronic check sheets to record training outcomes, and the check sheets provide statistical information. One participant gets feedback from 29 training facilities worldwide.

**Safety reports/data**—4 responses
Four participants talked about access to safety reports or data without specifying the source. One participant discussed having safety department data that is separate from ASAP. Another participant said flight safety investigations into unique events are conducted.

**Operations reports/communications**—3 responses
Three participants said they have access to operations communications. Two participants brought up reports. One participant mentioned a lot of communication between ops and training.

**Line check data**—3 responses
Three participants said they have access to data from check airmen. One participant mentioned information on threats, errors, and "scenarios of what's going on."

**Large amounts of data**—3 responses
Three participants said they have access to large amounts of data. One participant talked about enormous amounts of information that his organization collects, from companies that supply data voluntarily, and from targeted information. Another participant said flights have been recorded for 40 or 50 years. One participant mentioned volumes of AQP data.

**Pilot reports**—2 responses
Two participants talked about using captain's irregularity reports. The third participant mentioned their internal incident reporting program.

**Information from the FAA**—2 responses
Two participants brought up safety information from the FAA (without specifying the type of information). (See also "ACs.")

**Safety alerts for operations (SAFOs)**—2 responses
Two participants said they have access to SAFOs data.

**Manufacturer information**—2 responses
Two participants talked about accessing safety information from manufacturers. One participant uses bulletins from manufacturers during training (e.g., a bulletin about fuel compressors causing stalls.

**Aviation Safety Reports**—2 responses
Two participants said they access Aviation Safety Reports. One participant said the organization's culture ensures a high level of safety reporting. (See also "Safety reports/data")

**Pilot reports**—2 responses
Two participants said they have access to pilot reports. One participant specified P2 reports. (See also "Captains irregularity reports")

**NTSB**—2 responses
Two participants said they access data from the NTSB.

**Bulletins (e.g., fuel compressor, volcano)**—2 responses
Two participants talked about bulletins. One participant incorporates bulletins into training (
e.g., a fuel compressor causing stalls that pilots thought were caused by engine failure).
Another participant talked about short notice bulletins on events (e.g., a volcano).

**Other**
Each of the following was cited once by participants as accessible safety data:

- Data from customers
- Hazard reports
- Corporate reporting
- Fleet analysis
- Internal reporting
- Ab-initio safety data
- TSA
- FAA InFOs
- Work with government
- Maneuvers validation and initial/continuing qualification feedback
- Unique reports (e.g., Rejected Takeoffs)
- Reviews of accidents at other operators
- International data
- Safety recording system
- FAA Runway safety action team recommendations
- Flight Safety Foundation
- Air Transport Association
- Other Industry resources
- Safety auditors, FAA evaluators
- ACs
- Other publications
- Flight Data Analysis Program (FDAP), includes FOQA and ASAP

## B.  How do you use safety data in training development?

Safety data, from more than one source according to many participants, is used to target
areas for training, sometimes based on a risk or trend analysis. The source of issues can be
the training itself or operational issues such as procedures that need improvement.
Participants also discussed intervals between safety reviews, ranging from one month to
one year, or as needed based on events. The use of safety data in scenario development
was mentioned. Details are presented below starting with the comments heard most
frequently.

**Identify issues/risks**—8 responses
Eight participants said they use safety data to identify issues or risks. One participant
identifies issues affecting training based on data from operators. One participant uses safety
data to determine whether issues are related to training, knowledge, or procedures. This
participant also said hot items from line checks are used. One participant changes
procedures based on issues identified through ASAP. Another participant said safety data is

used to target important issues and areas for improvement. One participant said joint meetings about training issues include issues from other data. Another participant said SMS is beginning to be used to identify issues.

One participant uses safety data to identify operational issues, and then applies a weighted risk analysis to the issues; for example, this participant looks for areas with low standards ratings in its AQP data and correlates them to safety data to assign a risk rating. Another participant said risk assessments on key hazards are used to mitigate the risks. APF (advanced performance factors) was implemented to provide weighting and drill down to key drivers. This participant also said measurements outside of set boundaries indicate an issue that needs to be investigated. One participant discussed trying to look at safety data though a risk management process.

**Blend safety data from multiple sources**—7 responses
Seven participants combine safety data from multiple sources. One participant looks for trends in FOQA and ASAP data. According to one participant, a full-time department runs FOQA and ASAP. This participant also commended the organization on integrating safety data. Two participants compare safety data, including FOQA, ASAP, and AQP data, to determine areas for improvement. One participant blends data from multiple sources and because every source presents a different perspective, his organization also maps the safety data against operations data (e.g., on-time performance and fuel). One participant said the pilot reports/ASRs are coordinated. Another participant said all data streams are looked at holistically.

**Procedural changes**—5 responses
One participant said safety data is used to identify changes needed to procedures. In training, the differences in the performance of pilots in the simulators can be seen. One participant said safety data is used to determine whether an issue is related to training or to procedures. One participant said procedures are being changed based on safety data on lateral deviations, altitude deviations, and landing issues. One participant changes SOPs based on key hazards. Another participant conducts flight safety investigations that result in changes to procedures/training. Also see "Altitude changes based on ASAP."

**Frequency of safety data reviews**—4 responses
Four participants discussed the frequency of their reviews of safety data. Two participants hold reviews on multiple schedules:

- Monthly
- Every two months or when triggered by events
- Quarterly
- Yearly

**Develop scenarios**—4 responses
Four participants said they use safety data in developing scenarios. One participant relates operational issues to specific systems to develop themes for scenarios. One participant noted that training managers work with other groups to look for trends in safety data from their organization and in the industry. This participant then develops objectives and a storyboard. One participant said that all LOFT scenarios are built on safety data. Another participant also uses safety data to create scenarios, often using specific events as the basis.

**Incorporate incidents/events into training**—4 responses
One of the participants said the training manager ensures incidents are covered in training and changes the curriculum based on safety reports. Another participant integrates events into the training program and said event data goes through a two or three day process to determine whether it should be treated as an advisory or a warning. One of the participant's event review team provides input to training, and performance exceedances are highlighted. This participant also animates an "ugly approach of the month" for use in training. Another participant investigates unique events that can change procedures training.

**Safety Management System (SMS) process**—3 responses
Three participants talked about their SMS processes. One participant said the SMS process is extensive. This participant described a Safe Ops group that uses safety data to identify trends and make recommendations. For example, one participant reinstalled cockpit lights after feedback and minor events. Another participant said SMS is key to tying safety data to training. One participant is starting to implement an SMS to identify issues and make changes.

**Recurrent training**—3 responses
Two participants said they use safety data in recurrent training. One of these participants uses the data to identify real operation issues and later relates the data to the systems to be trained that year. One participant said safety data is discussed in recurrent ground school. See also "Develop scenarios."

**Management/Executive involvement**—2 responses
Two participants said VPs are involved with the safety data. One of these participants presents safety round table data to the VP and above. The other participant said that the flight safety action team includes flight standards managers up to the VP level.

**Target training**—2 responses
Two participants said they use safety data to target training. One participant uses safety data to target training in order to make better use of resources. The other participant said it uses safety data to target areas for improvement in training.

**Metrics**—2 responses
Two participants talked about their metrics. One of these participants has quantifiable results showing whether procedures changes lead to improvements in pilot performance. Another of these participants puts boundaries around specific measures of operations and investigates when the measurements stray out of the boundaries. This participant also creates new metrics to ensure the desired output, which feeds back into safety assurance.

**Safety data de-identifed**—2 responses
Two participants talked about de-identified safety data. One of these participants mentioned that ASAP data is de-identified. The other participant said that both FOQA and ASAP data given to training are de-identified.

**Address hazards**—2 responses
Two participants talked about hazards. One participant correlates AQP task proficiency data to any hazard reports. The other participant addresses hazards by first providing the information to pilots, or by training the pilots, or by changing an SOP, in that order.

**CRM**—2 responses
Two participants brought up CRM. One of these participants said that CRM instructors use safety issues from ASAP to debrief crews. The other participant uses safety data to identify

holes in CRM training and to adjust CRM procedures. For example, this participant used ASAP data to identify problems with lateral and vertical deviations and then encouraged division of duties between pilot monitoring and pilot flying in FMS entries.

**Use safety data for realism**—2 responses
Two participants said they use safety data to add realism to training. One participant said credibility and realism in training are effective. The other participant said instructors use real safety data during curriculum development to lend credibility to reasons for doing things.

**Altitude changes based on ASAP**—3 responses
Two participants talked about altitude changes made based on ASAP data. One participant changed procedures based on altitude deviations identified through ASAP. One participant said ASAP showed pilots having difficulties making altitude restrictions at intersections in New York so the altitudes were changed.

**Other**
Each of the following was cited once in terms of how safety data is used in training development:

- Given directly to pilots
- Use for human factors
- Structure training based on client data
- Use FOQA data in training programs
- Use quarterly training to get information to pilots while it is relevant
- Present data from safety round tables to FAA and ALPA
- Tie safety round table output to e-learning/CQ simulator training
- Use ASAP data, safety auditor data, data from the line, bulletin to modify training programs
- Use near real-time flight data to run virtual flights on a PC
- use ATQP to tailor training to individuals rather than to the group
- Conduct regulator meetings/debriefs about use of safety data
- FOQA data is analyzed more robustly than ASAP data
- Used for policy changes
- Used for temporary short-term solutions

## C. What has been most effective about your use of safety data for training development and evaluation?

The use of safety data to determine where improvements can be made in training and in other areas was cited most often by participants. The fact that safety data comes from the real world helps make its use in training valuable. Details are presented below starting with the comments heard most frequently

**Trends/target areas for improvement**—6 responses
Six participants talked about effectively using safety data to identify trends and areas for improvement. One participant talked about doing a good job of collecting, analyzing, and presenting multiple streams of safety data, and this participant targets areas for improvement. Another participant looks for trends in data from multiple sources to change

policies, procedures, and technology. This participant then measures again and sees good results. One participant said good results have been gotten from incorporating trend data from ASAP into the training program. One participant incorporates consistent activities (e.g., automation activities) into evaluations and training. Another participant applies trends to specific individuals and crews.

One participant watches the operation of the aircraft and uses data from customers to identify areas for improvement. For example, after being approached by a few operators, this participant developed training to reduce hard landings and then observed a reduction.

### Realistic training—5 responses
Five participants talked about the effectiveness of realistic training. Three participants said that safety data makes training realistic and credible. One participant said that real safety data explains why things are done the way they are. This participant also said that pilots take notice of real problems that are happening at their company.

One participant watches aircraft in the real operational environment to validate procedures and training.

### Events/incidents—4 responses
Four participants said that data on events and incidents is used effectively. One participant is proud of the reconstruction of events based on aircraft data points: software turns the data into visuals for use in safety briefings. One participant said that incorporating incidents from ASAP (e.g., FMS errors, altitude deviations) into scenarios for recurrent training is effective. This participant also keeps a database of recurring flight issues. One participant said that the Event Review Committee sees the effects of training in fluctuations in data, and another participant is involved in the Event Review Team.

### Flight data—3 responses
Three participants said they use flight data effectively. Two participants reconstruct flights based on flight data. One participant reviews the virtual flights with individual pilots to help them learn from their actions. This participant uses the reconstructed flights in safety briefings. Except for variations in parameters, one participant finds flight data powerful and useful.

### Timely use of safety data—2 responses
Two participants talked about the effectiveness of using safety data quickly. One participant has made great strides in timeliness. This participant has gotten away from lawyer impediments and can now train on incidents within 30 days. Pilots have given positive feedback on this procedure. One participant rapidly updates LOFT scenarios based on safety data and quickly informs pilots of current issues. This participant has also has gotten positive feedback from pilots. This participant changed stall recognition and recovery procedures based on safety data about a year before the Colgan accident.

### Improve CRM—2 responses
Two participants said they have used safety data to improve CRM. One of these participants reviewed CRM using AQP, FOQA, and ASAP data as a result of a merger and updated CRM procedures. The other participant identified the ability to command as a CRM issue.

### Other
Each of the following was cited once as effective uses of safety data for training development:

- Fleet analysis
- Better data from LOSA: how pilot performs without check airman onboard
- Justify increased spending
- Present animations based on aircraft data in classroom so questions can be addressed
- Good information flow from and rapport with safety department
- Regular review process for reports from the line results in fewer incidents/accidents
- ASAP data improved safety with process for determining current cleared path using ACARS
- Built different CQ system in the simulator to adapt more quickly
- SMS
- Identified need for specific training for non-normal procedures
- Automation and requirements for unique situations
- Identified manual flying as a risk
- Pilots leave training knowing they have needed skills (e.g., engine out on climb)
- Articles in flight ops magazine about events/recurrent training
- Integrating FOQA and ASAP/full-time department runs FOQA and ASAP
- Communications tool for hot items

# D  What challenges do you have with including safety data in training?

As a whole, participants did not focus on any one type of challenge with using safety data in training. Practical issues such as timeliness and confidentiality were discussed, along with difficulties in determining what data to use or how to use the data effectively. Details are presented below.

**Not using data effectively**—3 responses
Three participants said they do not use their safety data effectively. One of these participants discussed doing a good job of collecting the data, but does not take action based on the data.

**Timeliness of safety data**—3 responses
Three participants talked about challenges with the timeliness of the safety data they receive. One participant said that every year there are difficulties getting data for recurrent training. One participant said that FOQA data important to training is not always received in a timely manner. Another participant is trying to use a risk-based approach to look at safety data earlier.

**Labor issues**—3 responses
One participant said that agreements with the labor group affect what can be done with FOQA data, but the legal issues are improving. One participant talked about fighting with the union regarding ensuring de-identification. Another participant said the union group was positive about FOQA and ASAP, but the union at an organization the participant worked for previously was opposed. See also "Confidentiality."

**Process not challenging**—3 responses

Three participants said they do not have many challenges including safety data in training. One participant said the safety data process is not difficult, but it is complex. One participant does not have too many challenges because this participant is open with information. One participant's answer to the question began with "no."

**Prioritize safety data**—2 responses

Two participants talked about challenges with prioritizing data. One participant is determining where to focus efforts in using safety data. Another participant is challenged by keeping all hot topics visible to pilots, including old ones.

**Timeliness in updating training**—2 responses

Two participants said they face challenges in quickly updating training with safety data. One of those participants said that 18 months are needed from identifying a safety issue to training pilots. The other participant spends 5 months putting together the next 6 months of training, but in the last month something else needs to be added.

**ASAP**—2 responses

Two participants are challenged by ASAP. One of these participants is still developing ASAP and getting everyone on the same page. The other participant said that ASAP data is hard to decipher. This participant also has difficulties determining what the problem is from ASAP CRM data.

**Confidentiality**—2 responses

One participant faces challenges in keeping customer data confidential when making suggestions to participants Telling other customers to do something without telling them why breeds skepticism. Another participant said that ensuring anonymity to pilots who come forward with information about events is a challenge. See also "labor issues."

**Other**

Each of the following was cited once as challenges with including safety data in training:

- Variations in parameter data (e.g., to trigger a speed exceedance)
- Sufficient staffing to analyze safety data; priority is not training
- Data analysis tools needed
- Not all airplanes are FOQA equipped
- Irrelevant data (e.g., recent SAFO on icing from accident in 1996)
- Too much data
- Time pressure in manual handling exercises
- Simulator scenarios that don't fit manufacturer's check list
- Safety implications of changes are transparent to pilot
- Different groups for standards and SMS/policy

## E  What improvements could be made with regard to using safety data in training?

No one clear area for improvement in the use of safety data arose from responses to this question. Facilitating access to the data, possibly through a main point of contact, was mentioned a few times. Details are presented below.

**Greater access to safety data**—3 responses
Three participants would like to improve their access to safety data. One participant said that safety data does not go directly to the training department. Two participants said they would like greater access to safety data.

**FOQA data**—2 responses
Two participants talked about improvements with the use of FOQA data. One participant counts on a FOQA gatekeeper to dig deeper into the data but thinks FOQA data will become more helpful than check airman data. One participant would also like to see more FOQA-equipped aircraft. One participant said FOQA has not quite been integrated yet, but it, FOQA, along with ASAP data, will directly drive what is being trained and how it is being trained. One participant thinks more FOQA data analysis mechanisms are needed and they could be used to drive training development and to address issues more quickly.

**Primary source of safety information needed**—2 responses
Two participants would like a main source for safety data. One participant hopes that ATQP will drive a partnership between safety and training. This participant also said that at another organization, one person ensures that flight data and safety are taken into account for training. One participant would like a primary source of information and someone dedicated to recent occurrences.

**Include reasons for doing things**—2 responses
Two participants talked about improving training by including the reasons for doing things. One participant said pilots should be shown what you are doing, how you are doing it, and why you are doing it.

**Other**
Each of the following was cited once as ways to improve the use of safety data in training:

- Don't change for the sake of change
- Improve timely distribution to pilots via quarterly training
- Add metrics when necessary
- Look at safety data earlier with a risk-based approach
- Risk management process
- Refine systems for capturing safety data, especially on an industry level
- Realism in the safety program
- Dedicated curriculum developers
- Track aircraft data by individual pilot
- Nothing
- Tailor scenarios to meet needs (i.e., hot topics from the line)

## VII. Instructor and Evaluator Training

### A. What do you find to be the most effective methods for selecting and training your instructors and evaluators?

While many participants did not directly respond to the question, related information was provided that included current practices for selecting, training, and calibrating I/Es. Responses that addressed I/E selection practices were varied and included the I/E selection process, how I/Es are selected and what characteristics are required of candidates.

Responses that addressed I/E training primarily focused on process and events in I/E training. Responses that addressed I/E calibration were varied discussing such methods as observations, feedback, classes and data collection. Details are presented below starting with the comments most frequently heard.

**Selecting Instructors and Evaluators (I/E)**—10 responses total
Participants had varied responses when asked what the most effective methods were for selecting their instructors and evaluators. Responses were as follows:

- Familiarity with piloting experience and personality traits—3 responses
- Recommendations from current instructors and check airman—1 response
- Use of detailed instructor and evaluator requirements that go beyond the FAA requirements—1 response
- Requiring candidates to have a passion for teaching, noting that a good pilot does not necessarily make a good teacher—1 response
- An interview process—1 response
- Having qualification standards written down—1 response
- On the job training—1 response
- Have not found the most effective method yet—1 response

**Summary of current practices for I/E Selection**—21 responses total
While not directly asked, some participants offered information regarding their current practices for selecting instructors and evaluators.

*Selection process*—4 responses
Some participants noted various stages of the process for selecting instructors and evaluators:

- Job opening is posted
- Applications and resumes are submitted and reviewed by various departments and people at the organization
- Candidates are interviewed (may include instructional tasks, knowledge test, or simulator evaluations)
- Candidate training records are reviewed and assessed

*How I/Es are selected*—4 responses
- Some participants noted how instructors and evaluators are selected and who is involved in the selection:
- Recommendations and/or feedback from others with direct knowledge of the candidate (current instructors, management, line pilots, check airman, chief pilots, and others)
- Hired from within the organization and then moved across fleets
- Requirements developed by the organization that are more detailed than the FAA requirements
- Qualification standards

*Desirable I/E characteristics*—7 responses
- Some participants noted various instructor and evaluator characteristics that are required of candidates:

- Maturity
- Passion for teaching
- Good communicator
- Engaging
- Well-respected
- Good role model
- Empathy for trainees

***Experience and background requirements***—*5 responses*
Some participants noted various experience and background requirements when selecting instructors or evaluators:

- Background in aviation
- Experience in same aircraft
- Minimum amount of flight time
- Previous instructional/evaluation experience
- Strong understanding of the philosophy of the airplane and of training.

Summary of current practices for instructor and evaluator training—22 responses total
While not directly asked, some participants offered information regarding their current practices related to training instructors and evaluators.

***Process and events in I/E Training***—*18 responses*
Some participants noted various stages and events that take place during the training of instructors and evaluators.

*Training related to flying—4 responses*

- Ground School is taught
- Basic instruction skills through specific skill sets are taught
- Complete scenario is presented that includes specific threat and error management and CRM for instructors
- All maneuvers, both normal and abnormal, are presented

*Training related to instructing methods and techniques—2 responses*

- How to use automation used in teaching
- How to instruct, including how people learn and how to facilitate behavioral changes.

*Simulator training—3 responses*

- I/E observes lessons in the simulator
- I/E conducts simulator lessons while being observed by experienced instructor
- I/E uses simulator (both right and left seat), teaching other I/E's

*Types of observations that take place during training—3 responses*

- I/E observes other instructors teaching
- I/E observes simulator sessions

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- I/E rides in aircraft jump-seat

*Types of practice that take place during training—2 responses*
- I/E practices teaching in front of coordinators
- I/E is given guided practice with instructor on lessons

*Process for approval of trainee—3 responses*
- Check of I/E before conducting training
- Sign-off on training prior to becoming I/E
- Reviewed by standards before released

*Other training—1 response*
- Drug and alcohol awareness training

**Methods for training I/Es**—*4 responses*
Some participants noted various methods used in the training of instructors and evaluators.

- On the job training
- Use of role play
- Hands-on training
- Invest in training up front

**Summary of current practices for I/E calibration**—12 responses
While not directly asked, some participants offered information regarding their current practices for improving and maintaining the effectiveness and quality of training by calibrating their instructors and evaluators.

- Scheduled and unscheduled observations with feedback
- Feedback program that captures data from pilot training
- Calibration classes
- Measurement twice within first twelve months of becoming an instructor
- Annual quality control observations
- Gather and review of feedback from pilots
- Measure deviations in assessment standards
- Data collection of grades (compare to peers)
- Annual in-house observation
- FAA observation every other year
- Quarterly subject area question and answer sessions conducted with management specialists of trainers
- Simulator data compiled and reviewed

## B.  What challenges do you have in selecting and training your instructors and evaluators?

The majority of participants described challenges with hiring I/Es, focusing primarily on problems with finding candidates who are qualified for the position. Participants also

mentioned challenges related to training I/Es including issues with training enough I/Es in a timely manner to keep up with demand. Details are presented below that include all of the varied responses, starting with the comments heard most frequently.

**Hiring**—9 responses total

### Selecting qualified I/Es—*6 responses*
Two participants responded that finding I/Es who are suited for the position is a challenge, noting that oftentimes this does not become apparent until the person has been on the job for some time. One participant responded that selecting instructors who are good at decision-making is a challenge. One participant responded that selecting instructors who are both above average pilots and can also convey information effectively is a challenge. One participant responded that finding candidate I/Es who meet all of the qualifications standards is a challenge. One participant responded that the candidates available to select I/Es from is limited due to the location of the organization.

### Motivation—*2 responses*
Two participants responded that finding candidates with the appropriate motivation to become an instructor or evaluator is a challenge.

### Monetary challenges—*1 response*
One participant responded that hiring I/Es is expensive, resulting in the use of current employees.

**Training**—5 responses total

### Keeping up with growth—*2 responses*
Two participants responded that keeping up with company growth is a challenge. Specifically, one participant responded that training a sufficient number of I/Es quickly enough is a challenge. Another participant noted that the temptation is to outsource during periods of growth, but this was not effective in the past.

### Teaching decision-making—*1 response*
One participant responded that training instructors in decision-making is a challenge.

### Monetary Challenges—1 response
One participant responded that it is expensive to effectively train an instructor.

### Sufficient time to train—*1 response*
One participant responded that having sufficient time to train I/Es is a challenge.

**Standardization**—4 responses
Four participants responded that standardization of training for I/Es and the content they instruct and evaluate is a challenge.

**Retention**—3 responses
Three participants responded that retaining qualified I/Es during periods of growth is a challenge.

**Instructor union**—1 response
One participant responded that instructor unions are a challenge, hindering the ability to get rid of instructors who are not performing adequately.

**Aging I/Es**—1 response
One participant responded that the aging population of I/Es is a challenge.

## VIII. Training Development

## A. How often do you modify your training programs? –

The intervals at which training programs are modified range from constantly to rarely, or as different participants put it, from too often to as needed. As needed was the most frequent response, followed by annual modifications. Reasons for modifications were also offered, from changes caused by turnover or lack of proficiency to changes in technology or policies and procedures. When particular programs or methods are modified was also discussed. Details are presented below starting with the comments heard most frequently.

**As needed**—11 responses
Eleven participants said they modify training as needed. Two participants gave a new SAFO as an example of when training would be modified. One participant said refresher and conversion are modified "as identified," and another participant said ground school is modified as needed. One participant said personnel turnover can lead to modifications. One participant said that earlier programs are modified when a new aircraft is developed.

One participant updates training as required (e.g., by the addition of a new system or because of a lack of proficiency in pilots.) One participant said systems (e.g., EFB in Q400), regulation changes, or policy changes drive training modifications.

One participant updates initial training within a couple of weeks when regulations or procedures change. One participant modifies flight training when procedures or policies change. One participant modifies initial training only when procedures change, and it makes modifications when indicated by data.

**Every 12 months**—10 responses
Ten participants talked about annual changes to training. In the past, one participant needed nearly one year to change type ratings. Three participants change scenarios every year; one participant mentioned LOEs, and two participants mentioned continuing qualification training. One participant makes yearly changes to ground school. Two participants change CRM once per year. One participant said that with AQP, fairly big changes to recurrent ground school will be made once per year. One participant changes its recurrent annually (AQP will allow for a nine month rotating cycle). One participant said changes include meeting N&O requirements.

**Constant change**—6 responses
Six participants talked about changing training constantly. Two participants said they change their training every day, but one of those participants said there are added constraints to make changes no more than three times per year. One participant can develop and deliver changes based on safety trends in one day.

One participant said it continuously reviews scripts and captain training. One participant is in a constant state of change. This participant is using evidence-based training. Another participant said a constant-change program based on feedback and measures from real operations is needed. One participant said its instructors make ongoing changes to training based primarily on FOQA and ASAP data.

**Every 6 months**—4 responses
Four participants said they change training every six months. One participant changes programs every six months. Another participant, depending on the fleet, changes training

about twice per year. Two participants said they modify recurrent training every 6 months. One of those participants also said the changes are based on organizational and regulatory requirements.

**Every few years**—2 responses
Two participants discussed modifying training every couple of years. One participant changes qualifications for LOEs every few years, and another participant reviews initial training for changes every two to three years.

**Major changes done infrequently**—2 responses
Two participants said that they make major changes infrequently. One of these participants said large shifts in philosophy, which are relatively rare, cause modifications to training. The other participant said the basic footprint has not been modified in a long time.

**Too often**—2 responses
One participant said that training was modified often for the wrong reasons (e.g., to compete in sales). One participant said that it adds to conversion training from manufacturers, probably too often.

**Modifications of training by type**—31 responses total
Many of the participants mentioned the frequency of their training modifications in relationship to types of training.

### Recurrent
- Six months —3 responses
- 12 months—3 responses
- 12 months/nine months with AQP—1 response
- 12 months or as needed—1 response

### Initial
- As needed—3 responses
- Too often—1 response
- Every two to three years—1 response

### Qualification
- 12 months—1 response
- Every few years/12 months for scenarios—1 response
- As needed—1 response

### Ground schools
- 12 months—2 responses
- As needed —2 responses

### Type rating
- 12 months—1 response
- Two to Three years—1 response

### Refresher/conversion

- Six months—1 response
- As needed (refresher and conversion) —1 response

### Flight training

- As needed—1 response

### HF/CRM

- 12 months—1 response

### Maneuvers

- Possibly every three months—1 response
- Every one to three years—1 response

### Captains training

- Constant—1 response

### New type of Airbus

- As needed—1 response

### Other
Each of the following was cited once in regard to how often training is modified:

- About every two months on a schedule
- Individual programs modified at least every 18 months
- Every four months maximum
- Every 24 months with ATQP
- Every nine months with AQP
- Not often enough: constrained by budget and regulations
- Significant changes every four to six months
- Maneuvers validation every 12 to 36 months on a continuing basis
- Minor changes about every three months

## B.  How often do you develop new programs?

New training programs are developed as needed, according to the most participants. Other answers ranged from continuous to yearly or, according to one participant, every five years for major new programs. Reasons for new programs were also mentioned. Details are presented below starting with the comments heard most frequently.

**As needed or required**—7 responses
Seven participants talked about developing new training as required by new or updated equipment or procedures. The following reasons were cited as factors that prompt the development of new programs:

- Operation/external factors
- New equipment
- New/changed technology

- FAA requirements/regulations
- Improvements to airplane
- Procedures, including for acquired pilots
- RNP or RNAV or closely spaced approaches
- Incidents/events/accidents
- Customer driven
- Acquisition (merger)

**For new aircraft**—3 responses
Three participants said they develop new training when a new aircraft is introduced. One participant said there is no reason for new training otherwise. Another participant said that the commonality of aircraft types limited new training somewhat.

**Every 12 months**—2 responses
Two participants talked about yearly cycles for new programs. One of these participants creates new ground instruction yearly, half of all systems in one year and the other half in the next year. One participant said its FO development course runs for one year.

**Continuously**—2 responses
Two participants said they continuously develop new training. One of these participants said keeping up with new technology is a full-time job. and this participant developed about 12 new courses this year (2010). One participant is constantly changing training because of new aircraft types.

**Other**
Each of the following was cited once regarding the timing of new training development:

- Big changes on an average of every five years
- Fresh recurrent training every six months

## C. What steps do you take when this happens and who is involved?

No one process for training development was indicated in the interview. AQP was discussed by some of the participants. Much of the discussion revolved around the people who are involved in the process. Details are presented below starting with the comments heard most frequently.

**AQP not mentioned in answers to this question**—7 responses
Seven participants discussed their process without mentioning AQP.

**AQP mentioned in answer to this question**—5 responses
Five participants said AQP is involved in their training development steps.

**Involvement with manufacturers**—3 responses
Three participants talked about the involvement of manufacturers in their training development. One participant said it is manufacturer centric; it adds to manufacturer conversion courses. One participant looks at what other organizations are doing and adds to that. One participant said it works with the manufacturer when developing training for a new procedure or flight deck technology.

**It depends**—2 responses
Two participants said that training development steps depend on the circumstances. One participant said that the steps taken to develop training depend on the nature and urgency of the project. One participant said the steps depend on the source of the initiative.

**Who is involved in training development?**
The following lists who are involved in training development as mentioned in the interview answers for this question.

### Management—20 responses
- Senior director training policy
- Director of training
- Head of standards training
- Manager technical training
- Training Manager
- Managers of ground, flight, recurrent programs
- Supervisors of recurrent training group
- Fleet training manager
- Manager of operations (each fleet)
- Flight operations
- CEO
- Project Manager
- Program managers
- Manager of program or department
- Project leader within management team

### Instructors—11 responses
- Flight training procedures instructors
- Senior/seniority list instructors
- Retired and other highly experienced pilots
- All instructors
- Instructor-developers
- Instructor pilot/check airman

### Policy and Standards—7 responses
- Standards
- Standards group
- Flight standards
- Standards department (check airmen)
- Groups that deal with standards

### Safety—7 responses
- Head of Safety performance
- Flight safety

*Training staff*—5 responses

*Check airmen*—3 responses

*Regulators*—4 responses
- Regulations
- FAA
- FAA, aircrew program manager (APMs)

*Pilots*—2 responses

*Other*—1 response each
- ACS ground personnel
- ALPA union rep
- AQP developer
- Company-wide
- Fleet captains
- Flight divisions
- Flight test
- Flight training
- Grand staff
- Lots of committees
- Maintenance
- Manufacturers/OEM rep
- Person to research regulations and ACs
- Resource production group
- Saab person/jet person
- Simulator coordinator
- Simulator engineer
- SME
- Students(for feedback)

**Input to training development**—5 responses
Five participants discussed where training gets its input. One participant receives a paper that says what is to be done. One participant's sources of input include instructors and line check airmen. One participant said that operations supplies a draft document (e.g., on procedures), and standards supplies the concrete version. One participant said that changes come from instructors/student feedback. One participant said that training plans are created for development tasks, such as researching ACs and regulations.

**Review and approvals**—5 responses
One participant said that Standards reviews training, and the FAA reviews and approves it. Another participant also brought up FAA approval. One participant does interim reviews of delivered training. Another participant said the AQP developer ensures requirements from regulations, task analysis, and quality standards are met, and instructors ensure the training meets training standards and flight test requirements.

**Leader of training development**—3 responses
One participant said that a project leader from the management team oversees the development of new training. Another participant said the director of training directs the development of training. One participant takes time to find a group with a leader.

**Request to change training**—2 responses
Two participants talked about who requests changes to training. One participant said that requests come from any department, including flight safety, or from management. One participant said requests come from the safety department, an authority figure, customers, an internal process for an obvious need (e.g., new aircraft), or the training policy department.

**Timelines**—2 responses
Two participants mentioned timelines for training development. One participant reviews whether the training can be developed in the allocated time and, if not, discusses what to leave out. One participant said that timelines are long when committees are involved and short when development is contained within the training organization.

**Costs**—2 responses
Two participants talked about costs. One participant said that the training department is usually checked first for cuts, and that the senior instructors are the most highly paid. Another participant said that training is well- funded. This participant named regulations and the competition as being constraints.

## D. How often do you use task analysis methods during development?

Participants focused primarily on their use of task analysis as part of AQP requirements. Several participants answered that they do not do task analysis. Other responses were varied including the use of task analysis as it relates to identifying cognitive skills, simulator curriculum, and automation training. Details are presented below that include all of the varied responses, starting with the comments heard most frequently.

**AQP**—8 responses
Eight participants talked about task analysis as part of AQP. One participant has a person dedicated to the AQP joint task analysis and the task analysis is 2000 pages long. One participant said that task analyses are limited in civilian aviation, except with AQP. One participant will do more task analyses with ATQP. One participant is changing from a prescriptive N&O program to AQP, and has completed the task analysis on all its procedures. One participant said it did not do task analyses before AQP, but that with AQP everything is driven by the task analysis. One participant said that an AQP task analysis was done for the A320 and other aircraft. One participant plans to use a task analysis in its upcoming AQP.

**Don't do task analyses**—4 responses
Four participants said that they do not do task analyses. One participant said they may be done informally or intuitively.

**Cognitive skills**—2 responses
Two participants talked about cognitive skills in relation to task analyses. One participant specifically identifies tasks that have complex cognitive aspects. Another participant said they do not have the expertise to do a cognitive task analysis.

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**Task analysis for the simulator**—2 responses
Two participants talked about their task analysis leading to training in the simulator. One of these participants identifies tasks requiring motor skills and those with complex cognitive aspects that are made more difficult by flying a plane. This participant assigns those tasks to the simulator.

**Task analysis for automation—**2 responses
One participant uses a building block approach of taking everything apart and breaking material into smaller pieces when addressing training for automated systems. Another participant said a cognitive task analysis would be a critical part of a man-machine-interface task analysis, especially for automation, but this participant does not have the expertise to do that.

**Building block approach**—2 responses
Two participants said they use a building block approach. One participant talked about breaking down tasks into their component parts and building on a foundation.

**Other**
Each of the following was cited once as how often task analysis methods are used during development:

- Training needs analysis team does task analysis
- Check with manufacturers, then add experience of flight safety and training departments
- Depends on who is involved in the program
- Few changes need a task analysis; depends on the severity of the change
- Fleet SMEs and AQP developer make sure task analysis standards are met
- Limited by budget and regulations
- Must be used with operational measures/feedback
- Pilot involvement/Authority says pilots should not be involved
- Regularly audit the task analysis
- Several ways to do task analysis
- Special individual likes task analysis
- Systems integration in FTDs, flat panel, cardboard
- Task analysis done by SMEs
- Task analysis done for type rating
- Task analysis of training development
- Tasks analysis used about 25% of the time
- To add new skill sets, including NextGen
- To match training content to a training tool
- Training analyzes data on established procedures; therefore, no task analysis needed
- When add/change procedures or systems
- Where appropriate when changing programs

## E. How do you match training content to a particular training tool like a training device or simulator?

Participants focused mostly on cost considerations when matching training content to a particular training tool with some mentioning selection based on the most economical or cost-effective tool that will meet training needs. Participants also mentioned that decisions related to training tool selection are based on what is being training and what tools are available. Additional responses were varied and included the selection of training tools based on regulations or other guidance documents, a training needs assessment, managerial decisions and other answers. Details are presented below that include all of the varied responses, starting with the comments heard most frequently.

**Cost considerations**—5 responses
Five participants brought up costs. One participant said the most cost effective tool that can teach the required skills should be used. Another participant said the most economical tool should be used when the FAA does not provide guidance. One participant uses the highest possible fidelity, balanced against cost effectiveness and availability. Another participant considers whether new tools can be cost justified. One participant spends to meet the training need.

**It depends**—4 responses
Four participants said that the choice of a tool depends on either what is being trained or what tools are available. Three participants said that matching training to a tool or delivery system depends on what is being trained.

One participant gave two examples: A new approach would be handled in ground school and simulator briefing and an FAA performance issue would be handled in a ground school classroom. This participant said that several people are involved in the decision.

One participant starts with the minimum level necessary and then works up to full comprehension (e.g., train systems first with lecture, then in simulators).

One participant said methods of delivery depend on the content, from a bulletin for simple content, to the classroom (e.g., new vendor for performance data) to the (e.g., non-precision approach or CATII)

One participant said that matching training to a tool or delivery system depends on what is available or what can be cost justified. This participant also said that making do can have negative ramifications, pointing to ongoing problems with the way FMS it is trained on hardware with no display.

**Training needs assessment/analysis**—2 responses
One participant conducts a training needs assessment, a long process that includes considering whether the training is about information or a skill and considering the level needed. One participant said the needs analysis does not happen as well as it should; either managers specify the tool or the project team tests its ideas.

**Based on regulations**—2 responses
Two participants talked about regulatory requirements for training tools. One participant said that tool choices are based on regulations. Another participant said they are based on specific guidance from regulations and ACs, when available.

**Availability considerations**—2 responses
Two participants said they consider the tools that are available. One participant uses the highest fidelity possible, balanced against availability and cost. One participant determines which tools are available (or can be cost justified).

**Managers decide**—2 responses
One participant said that managers review training objectives and device capabilities to decide which tools to use. One participant said that, apart from regulatory requirements, managers (or the project team) try out ideas.

**Other**
Each of the following was cited once regarding how training content is matched to a particular training tool like a training device or simulator:

- Operator difference requirement (expert analysis of hardware, procedures, tasks); computerized version loses subjective assessment
- Part of task analysis, work with SMEs, ISD staff
- Several people involved in the decision
- Match training equipment to what is on the line to ensure FAA approval
- Systems integration in FTD, flight training in full flight simulator, interactive software in ground school, distance learning for review and testing
- If necessary, say it cannot be done or make do
- Limited training tool capabilities
- Matches are natural and obvious
- Not sure beyond using training devices/simulators for pilot training
- Development team SMEs, procedures development team determine hands-on time needed in lessons

## F. New flight deck technology and procedures

## 1. What methods have you found to be effective in developing training for the introduction of new flight deck technologies or procedures?

Participants focused on using a team approach, increasing the time spent on course development, and understanding the strengths and limitations of training methods as effective means for developing training for new flight deck technologies. Several specific training methods as well as having information on new technology in advance of developing training were also stated. Details are presented below starting with the comments heard most frequently.

**Team approach**—7 responses
Seven participants said that a team approach using input from several different sources and drawing on their expertise is effective for developing training for the introduction of new flight deck technologies or procedures.

**Increasing time**—6 responses
Six participants found that increasing the amount of time that can be spent on course development, including time familiarizing trainers with the system to be taught, was

effective in developing training for the introduction of new flight deck technologies or procedures.

**Understanding the limitations of the methods used**—6 responses
Six participants stated it is key to understand the limitations of methods used and to make sure that the training gets delivered through the best training method available.

**Example of technology in advance**—2 responses
Two participants reported that they like having first-hand knowledge of the specific technology that they are going to teach. They want the specific information (actual equipment rather than just a screen-shot of the faceplate) and specific analysis of what they are likely to experience in advance of training development.

**Integrated method**—2 responses
Two participants reported that they liked using an integrated method to balance the complexity of the material to be trained with all of the training aids available.

**Staying informed on current technology**—2 responses
Two participants said that it is effective to keep current on the latest technologies and do early assessments of how it will impact the training.

**Building block approach**—2 responses
Two participants stated that training development works best if there is a building block approach where the new training is built on existing knowledge and skills. An analysis must also be done of the current regulations to develop an understanding of how the new training fits in with existing training.

**Match procedures to airspace**—1 response
One participant said the procedures being trained should be specific to the airspace. There are different procedures that need to be addressed so that pilots can quickly understand what procedure to use at the right time and place.

## 2. What challenges have you had when developing and implementing training for new technologies or procedures?

Getting the right information about new technologies soon enough, timing training with equipment installations and receiving timely feedback for the FAA ranked as the top challenges in response to this question. Other issues regarding coordination and program development were also mentioned. Details are presented below starting with the comments heard most frequently.

**Having the right information in advance**—5 responses
Five participants said that having the right information about the design of the new technology and procedures before they begin training development challenged their organizations

**Timely response from the FAA**—3 responses
Three participants stated that they were challenged by their efforts to get cooperation and timely feedback from the FAA regarding procedures and new technology.

**Timing**—3 responses
Three participants stated that they are challenged by the time that it takes to get the entire fleet of pilots trained, and coordinating the training effort so that it is timed correctly with the installation of new equipment

**Selecting the correct training device**—3 responses
Three participants said that they are challenged by how to determine the correct training device to use for a given new technology.

**Politics**—2 responses
Two participants described their challenges with getting everyone to agree on the training program and negotiating the political waters associated with regulatory agencies.

**Timely coordination**—2 responses
Two participants said that they are challenged by getting everyone's inputs to the training in a timely manner and coordinating the training effort between the airline, OEM, and regulatory agencies.

**Regional specific procedures**—1 response
One participant is challenged by the negotiating with regional-specific procedures that make it impossible to teach a procedure just one way without exceptions.

**Other**
Each of the following was cited once as challenges when developing and implementing training for new technologies or procedures:

- Determining the correct level of training
- Getting the instructors trained
- Developing dual training for the seasoned and new pilot
- Getting pilots to class on time
- Making the information understandable
- Using task-analysis

## 3. How could the training or the process used to develop the training have been improved?

As in the questions above, the issue of getting enough information far enough in advance was again one of the most frequent responses. Improvements in training methods and FAA relationships were also stated by several participants as important. Details are presented below starting with the comments heard most frequently.

**More information before developing training**—5 responses
Five participants commented on the need to get more information before training development begins. This will help them understand the technology better so they can develop more effective procedures and implement training that matches the way that the airplane really works. One participant also said that designers need to do a better job considering training during the design of the equipment so that it is not an after-thought.

**Training methods**—5 responses
Five participants commented that training methods needed to be changed to improve the overall training provided.

**FAA relations**—3 responses
Three participants stated that the FAA is a key driver in determining what gets trained and how often. Participants also mentioned that the FAA needs to be more proactive in standardizing procedures across the airspace; must work with carriers to offer specific feedback into how they can design procedures that meet FAA requirements; and must address the length of time that the application process for FAA approval takes and its impact on the training.

**Keeping up with technology**—2 responses
Two participants said that technology is leaps ahead of current procedures, which causes training problems in the timing of training delivery.

**Long training schedules**—2 responses
Two participants stated that training could be improved by addressing the issue of keeping all of the pilots in the fleet up-to-date on all procedures and technology due to long training schedules.

**Other**
Each of the following was cited once as ways on how training or the process used to develop the training have been improved:

- More simulators
- Additional training devices
- balance economic and training choices

## IX. Programs

Eleven of the 24 participants stated that all of their training programs are under AQP. Twelve stated that they have one or more of their training programs under AQP or the European ATQP. One organization stated that they have training programs currently under AQP and are in the process of moving the rest of their training programs to AQP.

## A. If operating under AQP

## 1. What improvements have you seen in your training since implementing AQP?

In general, participants indicated positive results from the use of AQP, although several participants have not used AQP long enough to determine whether it has improved training. Details are presented below starting with the comments heard most frequently.

**Too early to tell**—5 responses
Five of the participants interviewed report that it is still too early to tell if there is an improvement from AQP

**Data collection**—4 responses
Four participants stated that AQP programs are inherently more data driven, which has focused pilot training on collecting the metrics to support training programs.

**Overall improvement**—3 responses
Three participants believe that the AQP results in a better training program overall. They have seen improvements with instructors developing better overall facilitation skills and teaching resource management

An improvement to the training has been a better focus on training the crews, rather than the individual to improve communications and briefings.

**Customized training**—2 responses
Two participants mentioned that customized training programs are a benefit of AQP.

**Other**
Each of the following was cited once as improvements seen in training since implementing AQP:

- Performance
- Customer satisfaction

## 2. What challenges do you have in training under AQP?

The customization of training brought about by AQP causes time challenges for some participants interviewed. Challenges with the FAA were also mentioned. Details are presented below starting with the comments heard most frequently.

**Change**—4 responses
Four participants said that dealing with change was a challenge that affected the creativity of new training methods, keeping current, and changing the way that evaluations are performed.

**FAA relations**—3 responses
Three participants stated that dealing with the FAA was challenging and that  the FAA was having a problem getting away from the 121 regulations.

**Lack of ability to share course materials**—2 responses
Two participants said that because AQP creates a tailored, airline specific program design, they are unable to benefit from the sharing of data or course materials.

**Time intensive**—3 responses
Three participants commented on how AQP has created challenges for them because of the much more time-intense commitments to scenario development, reporting, and customize coursework.

**Other**
Each of the following was cited once as challenges training under AQP:

- Keeping trainers up to speed
- providing program modifications
- Record keeping and reporting

## 3. What could be done to improve AQP?

Several participants felt that improvements at the FAA are needed make APQ better. Details are presented below.

**FFA relations**—4 responses
Four interview participants commented on FAA relations as a means to improving AQP. Standardized approvals, better trained inspectors, recommendations based on data, and

leaving the Appendix H requirements behind were suggested as ways to improve FAA relations with pilot training programs.

**FOQA data**—1 response
One participant suggested the use of FOQA data to continually improve the AQP training.

## B. If not operating under AQP

### 1. Why have you not developed an AQP?

The responses from the participants did not give insight into why AQP is not being used by some training organizations. Those responses that were given are detailed below.

**In progress**—1 response
One participant indicated AQP development is in progress, but not yet complete.

**Focusing attention on other priorities**—1 response
One participant indicated that they have not yet developed an AQP because they have been focusing on priorities unique to their organization.

**Cost-benefit analysis did not justify change**—1 response
One participant indicated that the company was not interested in AQP after analyzing the time and costs associated with the implementation process and the ensuing benefits. Also, the participant still benefits from some features of AQP (such as FOQA and ASAP, and modification of training programs) without actually incurring the full cost to implement AQP. Another cost consideration is the requirement to develop a separate AQP for each unique aircraft type in the company's fleet.

**Reduced training frequency not desired**—1 response
One participant indicated that the perceived benefit of single visit training afforded by AQP is not an actual benefit for the company because they have found it advantageous to bring the pilots in twice a year.

### 2. What challenges have you had working under the current regulations?

Responses from the participants did not indicate common challenges with the current regulations. The array of responses that were given is detailed below.

**Training time must be spent on less important topics**—2 responses
Two participants indicated that compliance with N&O requires training of some items that may not be as important as other items that are not included in the regulations.

**Integration of threat and error management and CRM**—1 response
One participant indicated that integrating threat and error management and CRM has been a challenge, requiring a shift in mindset from the prescriptive, black and white nature of the traditional training program.

**"One size fits all" mentality**—1 response
One participant indicated a challenge related to getting approval for initiatives that would improve safety but may not align directly with the regulations. This participant acknowledged his local FAA office for helping break down some barriers to getting some of these safety enhancements approved.

**Pass/fail vs. train to proficiency**—1 response
One participant indicated that the pass/fail system for check rides imposed by the current regulations is a challenge in providing appropriate training.

**Some requirements need updating**—1 response
One participant indicated that training of steep turns is not applicable to current operations and that the current stall training requirements need to be improved.

**Not conducive to building block training approach**—1 response
One participant commented that the content required under Part 121 Regulations is not conducive to using a building block approach to training pilots.

## 3. Have you reviewed the draft revision of the regulations? If so, what is your opinion of the changes?

Opinions on the revised regulations were mostly negative. The revisions impose increases in simulator sessions, instructor involvement, and record keeping, and the 1500-hour rule was described as simplistic. Some participants indicated that the revised regulations may provide an impetus to implement AQP. Details are presented below starting with the comments heard most frequently

**Difficult implementation**—3 responses
Three participants indicated that the proposed regulation could present implementation challenges in terms of the amount of restrictions included and the increased amount of training required. One participant cited an excessive number of proposed simulator sessions. Another cited, as an example of the restrictions, the requirement to have a complete qualified flight crew in simulator training. When training a large group of new First Officers, this would require simulator sessions to be conducted by two instructors for one student (one instructor in the Captain's seat and one in the instructor seat). This would also eliminate early exposure of First Officers to time in the Captain role during simulator sessions. This participant also noted the record keeping requirements as being an implementation challenge, calling these requirements "astounding".

**Looks similar to AQP**—2 responses
Two participants said that the proposed regulation is more similar to AQP than the existing regulation.

**Prompted consideration of AQP**—2 responses
Two participants indicated that they made the decision to pursue or consider AQP after participating in the proposed rulemaking sessions for the new regulation.

**Political influences are driving some overly simplistic solutions**—1 response
One participant indicated that the regulation is too heavily influenced by political concerns and is causing overly simplistic solutions such as the 1500-hour rule to be proposed to satisfy the broader public.

**1500 hours rule needs to consider military and aviation university experience**—1 response
One participant indicated that there is a need to provide some additional credit towards the 1500 hours requirement for those who have been trained as military pilots or through accredited aviation universities.

**9-month cycle is a positive change**—1 response
One participant indicated that the proposal of a nine month training cycle for both crew members would be a positive change.

## X. Regulatory Factors That Affect Training

## A. What is your relationship with your local FAA (or regulatory) office?

By far the majority of responses to this question were that relationships with regulatory offices were positive. This was attributed to open communications, availability of staff, and the staff being former pilots. Participants that rated their relationships as fair or poor described regulators as inexperienced, inflexible, and slow to respond. Details are presented below starting with the comments heard most frequently.

**Good/Excellent Relationship**—13 responses
Thirteen participants stated that their relationship with their local FAA (regulatory office) is good or excellent. Of these, four of the participants explicitly attributed the good relationship with the fact that the regulatory office employed retired airline pilots/personnel. Other factors contributing to good or excellent relations that were cited were open communication, availability of managers, and focus on doing what is right as opposed to determining who is right.

**Fair relationship**—4 responses
Four participants stated that their relationship with their local FAA (regulatory office) is fair. In one case, the "fair" relationship is attributed to being in a transition period. Other factors that contribute to neither a positive nor a negative experience are that the local regulator does not have a lot of experience, the general personality of the local FAA people, and the lack of a POI.

**Problematic/challenging relationship**—3 responses
Three participants stated that their relationship with their local FAA (regulatory office) is challenging and/or problematic. One organization attributed the challenging relationship to the fact that the inspectors are young with little experience, and they frequently focus on the "letter of the law" versus the "spirit of the law." Other factors that were attributed to problematic relationships are the differing views between the organizations and governing bodies, inflexibility of the governing body, and the duration of time it takes to get things approved.

## B. What resources does the FAA provide that help you with your training program?

Participant responses to this question focused mostly on the oversight and advice provided by the FFA and their participation in training program development. Participants stated that, among other things, their local FAA or other regulatory agencies are partners, and they are supportive in helping to find creative ways to make training work. Details are presented below starting with the comments heard most frequently.

**Oversight and advice**–10 responses
Ten participants stated that their local FAA or regulatory agency provided them with oversight of their training program and advice or feedback. One organization said that their local FAA or regulatory office is knowledgeable in ISD methodologies and is helpful in

providing benchmarks. One participant said the local FAA gives great feedback, while one of the participants complained that the feedback provided lacked quality and objectivity.

**Developing training program**—7 responses
Seven of the participants interviewed stated that their local FAA or regulatory agency is involved in developing their training program. One participant discussed the Condor (Construct Dynamic Observation Reports) program that involved riding with pilots, observing line and training events, and listing deficiencies. Other participants stated that their local FAA or regulatory agency are partners and supportive in helping them find creative ways to make the training work, in helping them develop evaluation scenarios, in providing money for training and equipment, in providing certified instructors, by auditing training devices, and by providing examples of "best practices" for conduct. One participant stated that the FAA Office of Voluntary Safety Programs (AFS 230) is helpful with AQP and that their local FAA works closely with them.

**Written guidance**—4 responses
Three participants stated that their local FAA or regulatory agency provides them with written guidance (e.g., bulletins, AC's, advisories).

## C.  What Improvements could be made in your relationship with the FAA?

Greater flexibility was strongly stated as a way for the FAA to improve relationships with interview participants. More stability, consistency, and experience in staff, along with streamlined recordkeeping and approval processes were also cited. Details are presented below starting with the comments heard most frequently.

**More flexibility**—8 responses
Eight participants indicated that the local FAA or regulatory office needs to be more flexible and/or less rigid. One participant indicated a desire to going back to being a customer of the FAA instead of being overseen by the FAA. One participant would like to see the local regulatory office be more supportive and share a common goal. One participant stated that the local FAA or regulatory office needs to be more available. One participant said that the relationship is better when there is a shared confidence.

**No improvements needed**—5 responses
Five participants stated that they recommend no improvements in their relationship with the local FAA or regulatory office.

**Impact of Principal Operations Inspectors (POIs)**—3 responses
Three participants specifically cited the importance of the POI in maintaining a good relationship with the local FAA (regulatory office). Specifically, they stated the need for more stability and experience in this area. One organization mentioned that ideally all members of Aviation Authority should have airline experience.

**Streamline record-keeping and approval process**—2 responses
Two participants discussed the need for the local FAA (regulatory office) to work toward streamlining record-keeping.  Along with that, one participant specifically cited the need for the approval process to be better managed.

**Improve consistency**—3 responses
Three participants stated that the local FAA (regulatory office) needs to be more consistent. Specifically, they cited that regulators need to be "on the same page" and rules need to be standardized and applied evenly to all carriers.

**Other**
Each of the following was cited once as ways to improve relationships with the FAA:

- Need help in getting information from other participants
- FISDO needs to be local
- Right seat training issue needs to be corrected

# XI. Training Program Evaluations

## A. How do you measure training program effectiveness?

Participants mentioned measuring training effectiveness with common methods such as test results and performance comparisons over time. Information from safety data was discussed as often as information based on the opinions of trainees and instructor/evaluators. Details are presented below starting with the comments heard most frequently.

**Training performance measures**—8 responses
Eight participants stated that they use training assessment tools such as written tests and performance evaluations to measure their program's effectiveness. Participants specifically mentioned comparing first look (pre-training simulator session) performance to end of recurrent training performance, pass rates, and number of repetitions to proficiency in qualifications training.

**Safety data trends**—6 responses
Six participants said that they use FOQUA, ASAP, and AQP data to assess the effectiveness of training outcomes. In addition, one participant uses training council meetings – standards, FAA, labor, and ALPA data in a monthly and annual review cycles.

**Informal feedback**—6 responses
Six participants said that some sort of information exchange between trainees and their instructors and evaluators helps them to evaluate their training program effectiveness. They use information on the trainee's likes and dislikes, sense of preparedness, and what is working or not working in the program content and methodology. Feedback is also exchanged between instructors/evaluators and given by instructors to training program leadership

**Surveys**—3 responses
Two participants said that they use a survey to gauge training program effectiveness. One participant surveys both trainees and the training airline staff.

**Dropout/failure/promotion rates**—2 responses
Two participants stated that they use failures and dropout rates as measures of training effectiveness. In addition, the advancement of first officers to captains was cited by one participant as an indication of training effectiveness.

**Line operations monitoring**—2 responses
Line checks, standard orders and line operations monitoring were said to be tools for measuring training effectiveness by two participants.

## B.  How do you define proficiency for your pilot's effectiveness?

Many of the responses to this question indicate that participants define pilot proficiency as required by regulations, and others said their organizations set their own objectives. Pilot preparedness and consistent adherence to safe practices were also mentioned. Details are presented below starting with the comments heard most frequently.

**Regulations**—8 responses
Eight participants said that they define pilot proficiency by the book. That is, their standard is set by the governing regulations of the FAA, CAA, etc. One participant stated that these regulations are satisfactory, and one said that they expect a bit more (than regulated standards). One participant said that most (95%) of their students proficiency for pilot effectiveness is defined by a final simulator evaluation with examiners for these sessions working for their individual national authorities and up holding their respective regulated standards.

**Internal standards**—6 responses
A number of participants to this question said that internal policies, procedures and standards define proficiency in their pilot's effectiveness. They set their own objectives and criteria for evaluating them. Only one participant specifically stated that the organization's current standards exceed the regulations.

**Judgment**—3 responses
Three participants said that they judge whether a pilot is proficient and effective by whether they do a safe and standard job, are studied, prepared, and do a good job day after day. One holds quarterly meetings to discuss instructor experiences in the simulators to define proficiency for pilot effectiveness.

**Customer standards**—1 response
One participant said that customers may require the use of their own standards of performance to define proficiency for pilot effectiveness.

**Line performance**—1 response
The participant looks at trends on the line and the type and number of ASAPs to determine proficiency.

## XII.  NextGen

## A.  What do you know about the plans for NextGen operations?

The majority of participants responded that they had little or no awareness of the plans for NextGen operations. Several participants mentioned that they were aware of specific technologies related to NextGen operations, while several others had a conceptual awareness, but were not clear on the details of the plans. Details are presented below that include all of the varied responses, starting with the comments heard most frequently.

**Have little or no awareness of NextGen plans**—5 responses
Five participants indicated that they had little or no awareness of FAA NextGen plans.

**Made reference to specific technologies**—4 responses
Four participants made reference to specific technologies when asked about plans for NextGen Operations. These technologies included:

- RNP
- ADS-B
- Electronic Flight Bag

**Conceptual awareness, fuzzy on details**—3 responses
Three participants indicated that they have a general conceptual awareness of plans for NextGen operations but are not really clear on the details of the plans.

**Become aware of emerging technologies from manufacturers**—2 responses
Two participants indicated that they are aware (or become aware) of some emerging technologies through interaction with the manufacturers. They will take the lead from the manufacturer as new technology is developed.

**NextGen currently being addressed by other areas of their organization**—2 responses
Two participants indicated that within their organizations NextGen plans were being addressed by other departments (for one a technical/technology group and the other by Flight Ops).

**Other**
Each of the following responses was cited once as knowledge about the plans for NextGen operations:

- NextGen plans involve increased use/sophistication of automation
- Aware, but not yet dedicating training resources – will do so as more detailed implementation timelines are determined
- Attended conferences where NextGen plans discussed
- Familiar with FAA plans/timeline for next 8-10 years
- Awareness through RAA Flight Tech committee meetings with updates provided by FAA
- Aware of pilot programs for some ATC centers
- Aware, and responsible for, new technology going into new aircraft, and have a department working on training for the next wave of new aircraft
- An American initiative, not currently a focus

## B. What challenges do you foresee with training NextGen Operations?

The majority of participants anticipated challenges related to the pilot's level of understanding of the new systems required for NextGen operations. This included potential challenges in adequately training systems management. Other responses were varied and included the potential for pilots to experience information overload, requiring additional training of information management skills, changes in how the pilot interacts with automation, challenges with FAA relations, and other answers. Details are presented below that include all of the varied responses, starting with the comments heard most frequently.

**Level of understanding of aircraft and systems, system management**—5 responses
Five participants expressed concerns about the pilot's having an adequate understanding of the new systems prior to initiating NextGen operations. Concerns included having the necessary time and resources to adequately train pilots and instructors. Three of these participants indicated that a challenge in training NextGen operations will be related to systems management and the integration of new systems as the new technology is phased in. One of these participants indicated that with NextGen operations, the number and complexity of the aircraft systems may necessitate a radical change in teaching philosophy. Such that the focus is on understanding and awareness of how the systems work, but more detailed knowledge of the mechanics may not be desired or possible.

**Information Overload**—1 response
One participant commented on the proliferation of information in the NextGen Flight Deck indicating that information overload could be a challenge for the pilots possibly requiring development of new information management skills while flying the aircraft. These new skills will have to somehow be trained and assessed.

**Pilot-Automation interaction role changes**—1 response
One participant commented that the pilot's role in interacting with the automation will shift to even more of a monitoring role in separation and routing tasks.

**FAA relations**—1 response
One participant expressed that the more significant challenges would be related to operational issues and decision-making to address possible disparity between company focus and FAA direction. Also, this participant has concerns about FAA changing course in the future after significant investments in training and technology may be made.

**Other**
Each of the following was cited once as challenges that are foreseen with training NextGen Operations:

- Similar to transition to Fly-by-wire aircraft
- Pilot knowledge of benefits
- Need more details before identifying specific challenges

## C. How do you anticipate that NextGen training might differ from the training programs and or methods that you are using today?

Participant responses to this question were limited and varied, ranging from not anticipating the need to make any changes to anticipating the need for different training tools and additional training time. All responses are listed below.

**Need different tools and additional time**—1 response
One participant expects a need for different tools and additional training time to adequately train for NextGen operations.

**Need to wait for more details**—1 response
One participant indicated a "wait and see" approach to see what changes will be mandated by the FAA. Once changes are known, his organization will have to determine how to make room for new content by possibly eliminating some current training material.

**Not anticipating any changes**—1 response
One participant did not anticipate any changes at this time.

## XIII.  Other

## A.  Are there topics that you train now that you don't think should be required? Why?

Participants identified 27 discrete topics that they feel do not need to be trained, but are required by regulations. Topics included specific maneuvers, and safety and security subjects. Redundancy and over training were also mentioned. Details are presented below starting with the comments heard most frequently.

**Antiquated requirements/ Regulatory constraints—12 responses**
Twelve interview participants identified 27 discrete topics that they thought did not need to be trained but were required by regulations.

- Some indoctrination subjects
- No-flap landings with no visual glide path guidance
- Speed turns
- The whole checking and training of stall training
- NDB approaches
- Windshear
- Video tape on Security/high jacking
- Some elements of type rating training for experienced pilots
- Hour on potable water
- Non precision approaches – tasks that are going away
- Legacy issues
- Maneuver validation
- Engine failure on takeoff
- Dangerous goods
- Replace training on old unused procedures with training that is appropriate to current requirements
- Regulations drive repeated training on same subjects
- Some recurrent topics trained too frequently (prescriptive) and lead to boredom and waste of time
- Self-defense moves
- Basic indoctrination topics (e.g., meteorology and airspace)
- Too much time on basic topics for which pilots should already be knowledgeable based on their training to become commercial pilots
- time requirements - mandated length of training
- Security
- Watching outdated videos
- Donning life vests in simulator

- Materials in seat-back pockets
- Time requirements on ground school

**None—7 responses**

Seven participants indicated that they either did not have any topics that they train now and think that they should not be required or the interview session ended before reaching this question.

**Indoctrination topics/new hire and recurrent training—2 responses**

One participant characterized having to do training that should not be required as "not making sense." This includes indoctrination training topics for new hires that address basic airmanship subjects such as high altitude physiology, weather phenomenon, and ditching. Topics that did not make sense for this participant in recurrent training include emergency training in which pilots must don life vests and open all of the doors in the aircraft. This participant also thought it more appropriate to not have to train so many different types of approaches. Instead, this participant suggests training only two types of approaches. A second interview participant thought it more important to train underlying skills than the maneuvers themselves.

**Automation—1 response**

One participant noted that younger pilots wanted less automation training. They further speculated that pilots in their fifties would probably want the opposite.

**Having flexibility with AQP—1 response**

One participant credited the AQP program for allowing his organization to eliminate unnecessary training topics.

## B. Are there topics that you would like to train but cannot? Why?

Responses to this question included the use of simulators for training environmental factors such as wind shear and icing, and uncommon maneuvers such as upset recovery, steep turns and stalls. Participants also spoke of training normal daily operations and other topics. Details are presented below starting with the comments heard most frequently.

**Training in simulators**—4 responses

Four participants noted a desire to train different topics including how to address that which we are trained to avoid (e.g.: wind shear, upset etc), integrated EFBs on the flight deck, and all engine go-arounds. One participant expressed a desire for better simulator models to more effectively train in the simulator for icing. Similarly, another participant expressed a desire to have the correct simulator software to train current operations without requiring regulatory modification to the simulator's certification, and to have enough time in the simulator to train normal operations in addition to the steep turns and stalls that regulations require.

**Current operations**—2 responses

Two participants expressed an interest in being able to train normal daily operations and what is of value to them but may not be included in the regulatory requirements for training.

**Manual flying and CRM**—1 response

One participant noted that younger pilots seemed to want more training on manual flying skills and CRM than on the automation systems. The carrier also speculated that their older

pilots would want the opposite: more training on automation, less on manual flying and CRM.

**Other than normal**—1 response
One participant noted that we need to focus on training for failures that have a higher probability of occurring in daily operations and thus a deeper impact to the flying public. One carrier expressed an interest in being able to train for emergencies and abnormalities, the things that happen in daily operations but are not covered by regulatory training requirements.

**Other**
Each of the following was cited once as topics that participants would like to train but cannot:

- Human Factors
- Unique incidents
- Individualized pilot training based on flight data
- Airline specific proprietary training

## C. Is there anything else that you think would be important for us to know that we haven't asked about?

An array of topics was addressed in response to this question. In general, they concerned pilot characteristics and capabilities, budgetary trade-offs, the need for data management and sharing. Details are presented below starting with the comments heard most frequently.

**General pilot characteristics and capabilities**—4 responses
Four interview participants had general comments with regards to pilot characteristics and capabilities. One participant noted concern over the pilot selection process in some countries in which a pilot candidates' "ability" is not a consideration. As long as the candidate could pay for the training, he or she would be accepted into flight training. This participant noted that the global demand for pilots has outstripped the supply and that the industry needs to carefully consider this shortage. One participant noted that there should be more emphasis on training pilots to be "aviators" rather than "automation managers." Similarly, two participants noted that there needs to be more training on situational awareness in light of increased automation on the flight deck. One participant noted that many of the malfunctions and failures that pilots see are limited to their time and experience in a simulator rather than the aircraft. Another participant indicated a need to develop risk management capabilities in their pilots. One participant noted that there is a significant difference in the requirements of pilot training between regional and mainline carriers that is due to the experience level (or lack of) of new hire pilots with jet aircraft, suggesting that the requirements for training are different also.

**User groups and information Sharing**—2 responses
Two participants had somewhat differing views on information sharing. One participant noted that that the RAA (Regional Airline Association) Flight Technology Committee provides member organizations a forum in which to discuss advancing technology issues and their implications for training and operations. Another participant noted that a fear of liability restricts some organizations from sharing information that could be useful to the industry.

**Flight deck manning**—1 response
One participant noted that their organization has formed a team to explore the possibilities of one-pilot flight crews.

**Changes in technology**—1 response
One participant said that while training new technologies will be a challenge, it will be helpful to carriers to have the flexibility of AQP to meet their training goals and requirements.

**Instructor training**—1 response
One participant praised the recurrent instructor-training program, noting a concentrated and comprehensive, hands-on, team-based approach to developing solid and effective training and evaluation skills.

**Managing Data**—1 response
One participant noted that there needs to be a way to manage all of the information that requires training and suggested developing a database from which organizations could easily access this information. This participant also noted that internal groups that monitor research, AQP and other development have proven to be essential in training programs.

**Budget**—1 response
One interview participant noted that the challenges of managing a training budget often require tradeoffs between the things that they have to train and the things that they would like to train.

## Appendix A:  Interview Questions

I.  Overall what would you say are the biggest strengths of your training programs?

II.  What are your biggest challenges?

III.  Because the vision for NextGen operations includes using more automation than we do now, our next questions will focus on automation.

    A.  Automation

        1.  What have you found are the most effective methods of training for the use or understanding of automation?

        2.  What challenges do you have with training the use or understanding of automation?

        3.  What could be done to improve training for automation?

    B.  Manual Flying Skills

        1.  Do you include elements of your training program to specifically address the development and maintenance of manual flying skills?

        2.  What has been most effective for training or maintaining manual flying skills?

        3.  What improvements do you think need to be made in this area?

    C.  CRM

        1.  What CRM topics are included in your training programs?

            a.  [If not already mentioned] Do you specifically teach decision making skills? If so, how?

        2.  What methods have you found to be most effective for training of CRM?

        3.  What challenges do you have with training CRM?

IV.  Training Simulators and Devices

    A.  Full-Flight Simulation

        1.  When do you use full-flight simulators?

        2.  What is most effective about your use of full-flight simulators?

        3.  What could be improved about how you use full-flight simulators?

    B.  Other Training Devices

1.    What other types of simulation or training devices do you use?

2.    Where has each type of training device been most effective?

3.    What challenges do you have in using the training devices?

4.    What could be done to improve the training devices you use?

C.  New Training Technologies

1.    Are there any new training technologies that you would like to implement to help you train?

2.    How do you see these training technologies improving training effectiveness?

D.  Training Scenarios

1.  What methods have you found to be most effective in developing training scenarios?

2.  What challenges do you have in developing training scenarios?

V.  Training Methods

A.  Classroom

1.  What topics do you include in classroom training?

2.  What training methods have been effective in your classroom training?

3.  What challenges have you had in classroom training?

B.  Distance Training

1.  What topics do you train through distance training?

2.  How effective has this been?

3.  What could be done to improve your distance training?

C.  Debriefings

1.  How do you use debriefings in your training?

2.  What has been effective in the use of debriefings?

3.  What challenges do you have with using debriefings?

4.  How could the use of debriefings in training be improved?

VI.  Use of Safety Data

    A.  What safety data do you have access to?

    B.  How do you use safety data in training development?

    C.  What has been most effective about your use of safety data for training development and evaluation?

    D.  What challenges do you have with including safety data in training?

    E.  What improvements could be made with regard to using safety data in training?

VII.  Instructor and Evaluator Training

    A.  What do you find to be the most effective methods for selecting and training your instructors and evaluators?

    B.  What challenges do you have in selecting and training your instructors and evaluators?

VIII.  Training Development

    A.  How often do you modify your training programs?

    B.  How often do you develop new programs?

    C.  What steps do you take when this happens and who is involved?

    D.  How often do you use task analysis methods during development?

    E.  How do you match training content to a particular training tool like a training device or simulator?

    F.  New flight deck technology and procedures

        1.  What methods have you found to be effective in developing training for the introduction of new flight deck technologies or procedures?

        2.  What challenges have you had when developing and implementing training for new technologies or procedures?

        3.  How could the training or the process used to develop the training have been improved?

IX.  Programs

    A.  If an AQP program:

        1.  What improvements have you seen in your training since implementing AQP?

        2.  What challenges do you have in training under AQP?

        3.  What could be done to improve AQP?

B. If not an AQP program:

    1. Why have you not developed an AQP?

    2. What challenges have you had working under the current regulations?

    3. Have you reviewed the draft revision of the regulations? If so, what is your opinion of the changes?

X. Regulatory Factors That Affect Training

    A. What is your relationship with your local FAA office?

    B. What resources does the FAA provide that help you with your training program?

    C. What improvements could be made in your relationship with the FAA?

XI. Training Program Evaluations

    A. How do you measure training program effectiveness?

    B. How do you define proficiency for your pilots?

XII. NextGen

    A. What do you know about the plans for NextGen operations?

    B. What challenges do you foresee with training NextGen Operations?

    C. How do you anticipate that NextGen training might differ from the training programs and or methods that you are using today?

XIII. Other

    A. Are there topics that you train now that you don't think should be required? Why?

    B. Are there topics that you would like to train but cannot? Why?

    C. Is there anything else that you think would be important for us to know that we haven't asked about?

# Pilot Training Vision Workshops and Gap Analysis

## Contents

# Introduction and Overview

This chapter presents the information that was discussed in our Pilot Training Vision workshops and the resulting findings from a gap analysis in which we compared current pilot training practices with workshop participants' vision for the future of pilot training in a NextGen operational environment.

# Workshop Planning

## Our Vision for the Pilot Training Vision Workshop

The purpose of our Pilot Training Vision Workshop was to have our participants consider future pilot training needs as impacted by the operational changes introduced in the NextGen environment and discuss the training implications they envision when those changes are introduced. For this reason we consulted with the FAA and selected three operational changes that are planned for NextGen on which to focus our discussions. These include broad use of RNAV/RNP, 4D Trajectory, and Self-Separation. We also included a session at the end of each workshop to discuss topics raised by the workshop participants.

## Participant Selection

We determined that to achieve the best representation of visionary thinking for the future of pilot training and have enough time to adequately address our key topics, we would need to limit our discussion to an invitation-only selection of participants.

We selected our participants through experience with individuals from our previous training survey, referrals from airline and industry professionals, referrals from ALPA, RAA, ATA, ICAO and other relevant sources. We focused our recruitment on airline and industry professionals who have been involved in pilot training for a long time and, through their experience, have developed an ability to think broadly about training and the factors that impact it. All participants currently hold position where they either in the business of actively train pilots, manage training, or direct training organizations.

## Resources

In addition to the question format and process developed by our team, the FAA kindly provided us time with two representatives knowledgeable on the areas of focus for our workshop to help us introduce the session. They provided presentations that included background information on the NextGen technologies and concepts that would be the basis for discussion throughout the day.

## Conditions of Participation

All workshop participants

- Agreed enthusiastically to participation in our research
- Agreed to anonymity in their responses

All participants were offered compensation for lodging and meals. Most but not all participants accepted.

We had ten participants in our first workshop and eight participants in our second workshop.

## Workshop Structure and Conduct

In order to make the most effective use of our time with the limited availability of participants, the workshops were

- Conducted on two different days with different participants in each workshop
- Designed to last approximately eight hours and divided as follow:
  - First two hours: Introduction and FAA presentation on key NextGen Technologies/Concepts
  - Discussion periods lasting approximately one and one half hours per technology topic
- Facilitated by an experienced facilitator who was familiar with the industry
- Guided by a pre-established set of questions meant to promote discussion that was focused on the future of pilot training

# Primary Gap Analysis

We analyzed the information we gathered in the workshops along with the results of the training survey to perform a gap analysis. We gathered a lot of insightful information and it is all represented in the report as a whole. For the gap analysis we focused on the primary areas that will change related to pilot training as we move toward NextGen operations. Many points were made in the training survey and in the workshops about current challenges that exist with all aspects of pilot training. Those are described in other sections of our project results. Here we present the pilot training challenges that are expected to be new because of the introduction of NextGen or will become more critical as changes related to NextGen operations are implemented.

## Training time

One overarching gap that became apparent is that more training will need to be accomplished. Even if some training is determined as no longer relevant, the amount of changes and increase in systems and information will require additional training. There will be needs to be creative about how to accomplish all the training in an effective, but still cost-efficient manner.

# Automation knowledge, awareness, management

It's no surprise that the increase in automation is the primary source of some of the gaps we identified.

- There will be more automated systems for the pilots to understand and, therefore, will need to be addressed in training.
- There will be more opportunities for automated system failures and this, along with the increased interactions of the systems, will increase training requirements for knowledge, tools, and techniques to monitor and manage the automated systems.
- Similarly, the depth of information provided to pilots may need to be increased to allow them to understand, anticipate, and make decisions in the use of the automated systems when they are working normally and when they fail.

# Information management

- The addition of automated systems will primarily be those systems that provide and process information for the pilots to use. This will drastically increase the need for training on information management for the pilots, including explicit tools and techniques for how to gather, monitor, manage, and assess the value of the appropriate information.
- Another specific requirement related to information management is the understanding and methods to use to determine if an information automation system has failed. Failures in information automation systems are often not quite as evident as other types of automated systems.
- Management of multiple sources of information that are similar will become more important as well. The pilots will need to be able to know how to compare the information from different sources and how to manage it and act upon it appropriately.
- The increase in automation availability and use will also increase the need for different approaches to decision making creating a more critical need for enhanced decision making training.

# Managing the unexpected and unplanned

- The move to NextGen operations will increase the interdependence of operations and the associated systems. As a result, there will be more challenges with anticipating all aspects that may be encountered in operations. These elements will combine to make it more crucial for pilots to be given the knowledge and skills to manage unexpected and unplanned situations and events.

# Discussion Focus Area Results

Within each focus area, key points summarize the discussion items addressed for that area. While each discussion segment focused on an overall vision of pilot training for the intended NextGen operational change, the responses are presented in the form of key points that are further divided into training topic categories that are also analogous to the topics addressed in the training survey conducted for this research project. This provides a ready reference to potential training gaps between what we learned in the training survey and the pilot training vision workshops. Gaps in pilot training that were specifically noted by one or more participants are explicitly noted.

Training survey topic areas that did not have a corresponding discussion point in the workshop are not included in the results.

# RNAV/RNP

## Introduction

We chose RNAV/RNP as our first discussion area. It was the most familiar because some of our participants have extensive experience with training and operating RNAV/RNP in specific areas over the last several years.

While workshop participants understood the concept of RNAV/RNP, we arranged for a presentation that provided an overview of how it is envisioned to be a part of NextGen to provide a common starting point for the discussions. Some basic definitions for RNAV and RNP respectively are provided here for reference.

RNAV, or Area Navigation, is a method of air navigation that permits user-defined flight paths defined by geographic waypoints of latitude and longitude rather than requiring the aircraft to overfly ground-based navigation aids.

RNP, or Required Navigation Performance, is a concept that defines navigation performance accuracy within a particular airspace. RNP performance is dependent upon several broad factors, including navigation infrastructure, aircraft capabilities, and approved procedures. The combination of RNAV/RNP, for capably equipped aircraft intends to bring greater precision and efficiency to overall flight planning, execution, and management.

RNAV/RNP infrastructure is not uniformly established across the National Airspace System, nor are all aircraft equipped or certified to fly RNAV/RNP procedures.

RNAV/RNP falls within the broader NextGen area of arrival and departure control services. Full realization of RNAV/RNP infrastructure and operations is still several years away.

The key points identified for this area are as follows.

## Training for Automation

- Participants noted that they would need a better understanding of automation at the system level, including how to manage automation failures.
- Pilots will have more information to process.
- Differences in equipment will pose challenges for training. Subtle variations in symbology and functionality for the same type of systems from different manufacturers may require unique procedures and subsequently unique training for each equipment variation.

- Participants noted that they would need to develop rules to address similarities among related systems that may provide similar information but for somewhat different purposes (e.g., ADSB-In compared with TCAS)
- Automation may increase workload in the high-workload phases of flight rather than reduce it.
- There will be an increased need to maintain situational awareness in the use of automation.

## CRM/TEM

- For RNAV, RNP operations, it will be important for ATC to be more cognizant of the operational differences and capabilities of the aircraft that they are handling.
- Since pilots will be working with much new information in NextGen operations and tasked to interpret it perhaps differently than they do now, it will be important to consider how to train information management and decision-making in the context of how pilots will use the information to manage interruptions in flight.
- With regard to managing disruptions to RNAV/RNP approaches, TEM (Threat and Error Management) skills may need to be better defined and trained in order to adequately prepare pilots for line operations in the NextGen environment, particularly for major metropolitan airports where interrupted RNAV/RNP approaches are common, as well as mountainous regions. While it will be important to train pilots how to fly RNAV approaches, it will be more important to train pilots how to manage the deviations from these approaches.
- It will be important for pilots to be adequately trained to manage non-normal situations, including problems with automation.

## Full-Flight Simulators

- Full-flight simulators should be equipped and capable of operating with the intended technologies to be used in NextGen (e.g., EFBs, real-time communications with the appropriate technology).
- Currently, there are some limitations in operational fidelity with air traffic, communications, and weather that need to improve to make the simulation more realistic and consistent with what happens in line operations.

## New Training Technologies

- Lower-level training devices will likely play a significant role in training NextGen technologies.
- Training media, such as tablet computers, could be considered as a means to 'refresh' pilot knowledge on-the-line. For example, a refresher training video on a unique approach could be reviewed during the cruise phase of flight.

## Training Scenarios

- When developing new training scenarios related to NextGen operations, care should be taken to avoid building LOEs that are over-contrived with an excessive amount of triggers and events packed into a single session.

# Training Methods (Classroom, Distance Learning, Debriefings etc)

- Graphic depictions of training information can be more effective than text-based information in fostering understanding and proper mental constructs of training material. Use of graphic information to communicate training content should be further developed as a means to effectively train NextGen operational changes.
- Stand-alone training should be provided for the release of new procedures or technology. Some elements of the training for new procedures or technology may be covered in distance training.
- Content should be trained from simple to complex and the core features of the equipment should be emphasized.
- Recognize that training is not effective if delivered during the same event as an evaluation because the pilots cannot focus on the training at that time.

# Use of Safety Data

- SMS Data is increasingly being used as a basis for new and revised training and new procedures. It will be important for training developers to have access to the right information for effective use in training development and improvement.
- One airline is looking at ways to aggregate the data into easy-to-understand and actionable results.
- SMS data should be aggregated across carriers for a larger-picture analysis. This would require some standardization across the industry.

# Instructor and Evaluator Training

- Instructors need to be better at teaching the cognitive skills that are used for interpreting data and providing specific situational awareness.
- Training for NextGen will likely be costly.
- There are a lot of instructors to train in preparation for training NextGen.
- Trainers must have access to, and an understanding of, all of the elements that need to be trained for NextGen.

# Training Content/Development

- Training should provide pilots with a deeper understanding of why different tasks are done differently on different airplanes.
- Training content should be provided that addresses a high-level view of systems, including how to manage system failures.
- Training information management should be added to the basic flying tasks training content. NextGen will require increased emphasis on cognitive skills and learning how to interpret data to find the right piece of data for the right situation.
- Training should provide a way to connect up the pieces of learned information to better translate to the real-world environment. Training should teach how to integrate information.

- Pilots should not be trained on only the events that are to be evaluated; systems training should address how pilots will use the system in actual operations.
- Training should be designed to be competency-based rather than evaluation-based.
- Standardized terminology is needed to support the training.
- Speed intervention will be an essential topic when training RNAV/RNP approaches.
- A phased-in approach should be used to deliver training so new capabilities are gradually added to the pilot tasks, rather than being added all at once.
- Equipment designers should consider training in the development process of the technology.
- Stand-alone training should be used for the release of new procedures or technology.
- Training should be designed from data taken on the line to understand potential pitfalls and traps.
- Training should be developed based on what the pilot has learned previously and how the new system will be different.
- Training should be customized to the specific skill and knowledge base of the pilot.
- Participants felt the FAA should mandate that manufacturers bundle training with new technologies, believing that by combining the training and software with the devices, this would ease the burden on the airlines from having to develop the training.

## Pilot Training Programs (AQP, N&O)

- The training footprint should be revisited to make room for new technology and operations and put more emphasis on real-world operational complexity.
- Airlines need to be open to adding more training time to meet the needs of training new technology.

## Training Program Evaluations

- There has to be an evaluation strategy to decide what is going to be trained and what is going to be evaluated, such that not everything that is trained is subject to evaluation.

## Other

- The FAA needs to provide the rules and guidance on NextGen operational changes before training development can be initiated.
- For RNAV/RNP to be successful, the infrastructure development needs to reach the point where RNAV/RNP is being implemented across the airspace and at all airports, so that airport-specific training is not needed.
- Air Traffic Controllers need to be trained to work seamlessly with different airplanes. ATC needs to have a better understanding of pilot demands and operations to better manage traffic.

- Carriers have different ideas about the sequence of training and checking. Some participants suggested doing the evaluation before training, others thought that the pilots would be uncomfortable doing the evaluation first, without having time to prepare.
- To minimize training requirements, design of equipment needs to be pilot-centered with standard symbology and display formats. Equipment should be designed to simplify mode transitions and contingencies.
- Participants expressed a lack of confidence in regulatory authority (FAA) driving the technology change, noting opportunities for improvement in the time required to implement NextGen and general working relationships on various projects.
- With regard to having the equipment to support RNAV/RNP, carriers agreed that those who cannot keep up with the technology should have a penalty, citing the FAA stated motto of "best equipped – best served." The participants further noted that this would be a great incentive for carriers to get the needed equipment to operate in the NextGen environment.
- Incorporate lessons learned from those that do the technology testing or demonstrations. Pilots who are doing demonstrations and trials probably know a lot more about the systems and common errors that will need to be trained.
- Training effectiveness may be improved by installing all RNAV/RNP equipment on the aircraft before training has been completed and by ensuring the NAS has the infrastructure for a significant number of RNAV approaches that are approved in operations so that pilots may use their training in the real-world environment before the learning has time to degrade.
- Repetition and refresher modules should be provided to ensure initial proficiency and competency will be lasting and translate to long term retention and effective use in operations.

## Challenges to Training

- Differences in manufacturer equipment cause challenges in training. Industry standardization would help to minimize training requirements among aircraft/carriers.
- Updates of simulator equipment represent a big challenge to keep up with the technology. An example was cited of the simulator visual system not aligning with other data because of disconnects in the simulator caused by incorrect flight management updates. These updates can be costly in terms of both time and budget. Airlines may need to have lead time of up to two years just to get the simulator working properly with integrated new systems.
- The ADSB-IN signals are similar to TCAS in that pilots are seeing signals generated by other aircraft showing position. Participants noted that they would need to develop rules to address similarities in these systems to ensure that the appropriate pilot actions are triggered by each system.
- There is a fear that the amount of training content to be addressed in a fixed training footprint will continue to expand as newer technologies will add on more quickly than older layers of technology drop off, especially with the push for NextGen initiatives.
- Other RNAV/RNP concerns are the interpretation of the approach plate, the initial briefing, and how to deal with contingencies. Interpretation of displays relative to RNP and limiting head-down time will be two of the biggest challenges. Focusing

training on integrating new technology into real world operations after basic knowledge is learned will be a big challenge.

- The number of instructors to be trained for NextGen and the associated costs will be a challenge.
- Developing a core of effective training that bridges the learning styles of multiple demographics will be a challenge.

# 4D Trajectory

## Introduction

Our second topic of discussion focused on the concept of 4D trajectory flight. Again, a basic definition/explanation follows.

4-D trajectory flight is the relatively precise management of an aircraft's flight path from gate-to-gate with an aircraft's flight position at any given time accounted for in terms of latitude, longitude, altitude, and time. The process is planned and managed by multiple resources including, but not limited to, flight planners, air traffic control, pilots, and automated systems both on the ground and on the flight deck. 4-D trajectory flight planning also accounts for those times when an aircraft must divert from its intended flight path through updates to changes in the condition of the airspace and agreed-upon procedures.

An electronic representation of the aircraft's flight path will be available to both air traffic control and the pilots in real time over a secure network and updated with changes that might affect the aircraft's flight path.

The design of this system includes improved situational awareness for both the pilots and air traffic control, the ability to predict conflicts and manage them appropriately, and the ability for air traffic control to more efficiently manage airport arrivals, departures, and throughput.

At the time of the workshops, there was not much information about the specifics of the system or how it would work.

## Training for Automation

- Pilots may need to learn new procedures for monitoring the automated systems (e.g., VNAV path to VNAV speed is a very subtle mode change that they know can catch pilots off guard.).
- New pilots will need more work in automation and information management to attain proficiency.
- Carriers already teach the Required Time of Arrival (RTA) function in the FMS training. Training for 4D operations will build more complexity on the base of RTA function knowledge that is currently trained.
- Pilots need to be trained on how to monitor and impact the relevant variables to maintain the appropriate 4D flight path.

## Manual Flying Skills

- With NextGen, there will be more focus on automation and a vulnerability for less emphasis and opportunity in training the development and maintenance of manual flying skills.

## Full-Flight Simulators

- The level of fidelity (for training devices intended to train NextGen) will have to be very realistic to effectively train pilots.

- The 4D training will have to start back at cruise altitude. Currently, pilots do not spend time in the high-priced simulator in the cruise phase of flight (more done in LOSs and LOEs). That will be a change to how the simulator is currently used in training.

- The fidelity of the simulator is good for teaching basic flying skills.

## Other Training Devices

- The level of fidelity (for training devices intended to train NextGen) will have to be very realistic to effectively train pilots.

## Training Methods (Classroom, Distance Learning, Debriefings etc)

- The potential higher cost of training for NextGen, particularly for regional carriers, may drive more training to be administered in a blended learning approach via distance education.

- Pilot compensation, with respect to training via distance education, may require greater consideration when training NextGen.

- Considering industry-wide compensation issues, motivation, and fatigue, distance education modules might be a cost-effective and training-effective solution. Using at-home or distance training can be effective for the introduction of new material.

## Use of Safety Data

- SMS data is a good source of information from which to develop training. A LOSA provided one carrier an opportunity to identify a line-performance deficiency then apply a training solution to it. LOSA was then used to monitor post-training performance.

## Instructor and Evaluator Training

- Instructors will have much to learn to become competent with a variety of training media used to administer NextGen training.

- Instructors must have the desire to want to train and be familiar with NextGen line operations.

# Training Development/Content

- 4D training should focus on teaching what the computer (FMS) is doing, how to monitor the progress and recognition of being above or below the path and what to do at those points. Training will be easier if pilots know they will have accurate wind and other information in the box and if other systems are in place to ensure that accurate environmental information is fed into the 4D navigation equations.

- Pilots will also need to know the background of the technology and why it is important to do the job. Teaching these parts of the puzzle helps pilots integrate the information and understand the systems better.

- Several topics were mentioned during this session as great topics to include with the next gen training.

  1. Partial Failures are more difficult to spot, and the pilot may be under the impression that everything is working. These interdependencies should be explored and added to the training program.

  2. Energy management will be a necessary technique to teach with the new systems, especially 4D.

  3. ATC changes/unscripted changes are significant threats in a 4D world and should be considered as training topics.

  4. Mode awareness may require additional emphasis to ensure pilots know the proper tools and modes to use.

  5. Pilots should be trained how to do the in-trail procedures when there is a problem with their aircraft or another aircraft (i.e., a wind shear).

  6. Training should address all the potential threats and teach intervention techniques that assure a high probability of successful intervention. There should also be an evaluation to make sure that pilots can do the correct techniques.

  7. Pilots should be trained to appropriately interact with ATC and should be able to say "unable to comply" without being penalized when a conflict with ATC instructions is recognized.

- Universal training material can be packaged with the purchase of the device or new technology so pilots heading from one airline to another will have had some commonality of training.

- Training should be organized to take the pilots from the known to the unknown, leveraging the skills that they have using a building block approach.

- Lessons learned and known threats from actual flight operations should be considered when developing training examples and scenarios.

- Training developers should consider multi-user, on-line games for ideas on how to design training.

# Other

- The proposed 1500 hour rule with respect to new hire pilots is a concern. While universities do a good job of training automation, graduates will not have enough flight hours to be considered, even by regional carriers. A solution that is more holistic and considers the needs of regional carriers as well as the progression of pilots through this system should be considered.

- The effect of the high cost of pilot training on recruiting talented new hires is a concern.
- Transitioning pilots with a lot of automation experience to an aircraft with lower levels of automation can be a training challenge.
- The new generation of pilots is believed to be more technologically savvy and better prepared for computerized flight.
- Pilots will need additional time in training to address foundational deficiencies.
- Pilots with less experience in actual flight and much of their training in a simulator lack situational awareness skills as they tend to stay too focused on areas of the displays.
- Air Traffic Controllers need to understand the capabilities and limitations of specific aircraft so that they can provide direction that makes it easy for the crew to follow. There are clearances that are easy and difficult for certain types of airplanes. When controllers advise of restrictions, then they should do so with a high probability that the airplane can do it without forcing extreme actions on part of the flight crew to comply.

# Self-Separation

## Introduction

Self-separation is a NextGen technology concept whose development is still in progress; therefore, the information presented to the workshop participants could give only a broad view of this technology.

In essence, the current concept for self-separation is a combination of performance-based equipment and procedures that delegate some of the responsibility for maintaining separation from other aircraft in cruise to the pilots. This would only occur between aircraft that are equipped to maintain separation with other like-equipped aircraft and must be maintained within certain performance standards.

Here are the key points from our workshop discussions regarding self-separation.

## Manual Flying Skills

- A concern was expressed regarding over-reliance on automation and how pilots will be able to be trained to maintain basic flying skills as all of this new technology is introduced.
- The industry needs to set standards for maintaining manual flying skills.

## Training Methods (Classroom, Distance Learning, Debriefings etc)

- Students should spend some time actually observing the pilot tasks to allow them to learn in a situation where they are not responsible for making decisions, but they can see what is going on. This helps to develop a mental model of the airplane tasks.
- Students should observe the air traffic controllers doing their tasks to get an appreciation for what is happening in the airspace and the controller's tasks.

- For self-separation concept awareness and training, a video or some other gestalt view of the technology could be used. A pilot has no control or understanding of other aircraft intentions, so the training has to provide specific practice with self-separation. Self separation is a foreign concept to pilots as they have always been told how to separate.
- Training developers may need to create new methods, such as visual games, for teaching spatial orientation skills to pilots as they prepare for self separation.

## Use of Safety Data

- Transitioning to self separation may create new challenges in collecting adequate FOQA data to analyze pilot performance of self separation. To analyze trends, it will be necessary to have adequate data to understand the airplane's position in relation to the other planes in the airspace.

## Training Development

- Training should include specific techniques for dealing effectively with a startle or surprise response when something happens that is not expected.
- Pilots will need training to identify system malfunctions or inaccuracies.

## Training Program/Pilot Evaluations

- For these NextGen operational changes, enhanced cognitive skills such as information management and understanding of potential failure modes will need to be evaluated.

## Other

- The participants strongly advocated cross training of controllers and pilots. All pilots and controllers also need basics on what different aircraft are capable of to help predict actions and reactions. Pilots should also be trained and aware of how all airports and procedures fit together.
- Participants found it difficult to describe the NextGen training for self separation without knowing more about what the pilot's roles and responsibilities will be and what displays will actually render. The group, in general, was confident that these techniques can be trained and trained well. They felt it would just be a matter of sitting down and working the training out as the technology is defined.
- Participants would like greater commitment from the FAA before investing in NextGen technologies that they are not certain will be realized. Carriers would like to know that they have a relatively short period for return-on-investment with NextGen technologies.
- There should be some prioritization schemes trained so that if there are several different squawks in the airplane, it should be obvious which takes priority.

- Delegating self-separation to pilots will most likely increase workloads and overtax already busy flight crews. Participants' concern focused primarily on the approach/arrival phase of flight, and they stated that self-separation may be more appropriate in the cruise phase.
- With regard to self-separation, we might have to change how pilots manage their workload and tasks during high workload times like when they are in a pattern. Pilots already have problems with monitoring automation, and they will take on the added task of monitoring other airplanes.

# Other

## Introduction

This section summarizes discussion key points from various NextGen-related topics of interest to the workshop participants. As in the prior NextGen technology-based discussion summaries, the key points from this discussion period are divided among topic areas that correspond to those in our training survey. Topics that do not fit within a specific area are included in the "other" category at the end of this section.

## Training for Automation

- As NextGen initiatives are introduced, pilots will have to learn how the new systems are integrated with other systems.

## Full-Flight Simulators

- The design of new simulators should anticipate updates and be designed to be robust enough to make updating the simulator an easy task to perform.
- A viable strategy is needed to optimize the use of simulators for the appropriate training.
- Updating older simulators is challenging.

## Other Training Devices

- Manufactures have to provide the code for their avionics to allow more of the desktop trainers to be successful.
- Computer-based training has to be interactive.
- The choice of the correct training device will be key to optimizing training for different content. It will be critical to get the right device to match specific training objectives.

## Training Methods (Classroom, Distance Learning, Debriefings etc)

- There may be a shift to a LOFT training environment to handle the increase in the training footprint.
- Experimentation with free-play in a trainer has been ineffective.

# Instructor and Evaluator Training

- NextGen trainers will need to be flexible and capable of operating various types of trainers, including being able to program the scenarios.
- Ideal profile for NextGen Instructor
  - Instructors need to know their audience and the diversity of pilots.
  - Instructors should be able to read the students and recognize what the students need. The focus needs to be on teaching, not just checking the boxes.
  - Instructors need to be able to see what students are doing incorrectly, and then make those corrections. Currently, for some airlines the approach to preparing instructor is "watch one, do one, be one". Many instructors are just simulator operators who rely on students learning on their own and through manuals. This approach will not be adequate in the NextGen era. NextGen instruction will require teaching first. Instructors will need to know ATC operations better than the pilots.
  - Instructors will need to be line operation pilots as well.
  - Younger generation instructors will need to be included on the training team to teach the gaming or computer skills. Younger instructors could work with the older instructors in a tag team approach so that students get the best of both worlds.
  - Instructors will need to be skilled in decision-making and teaching decision-making.
  - Instructors will need to be skilled in automation management.
  - A team of instructors who have the appropriate combination of skills could be considered.

# Training Development

- A building block approach was suggested where the systems are trained one at a time, building on the previous knowledge acquired.

# Pilot Training Programs (AQP, N&O)

- A change to the footprint will require new regulatory requirements to increase training time or the airlines will not spend more money on training to expand the footprint. The increased footprint would need to cover new material without losing current material as well as provide more in depth training to bring improvements in pilot understanding.
- Operators want to be able to streamline their AQP (all have taken regulatory exception) and train on a different interval than what 121 prescribes. When they get an exemption for a specific area of training, they would like to see that shared with other carriers as applicable.

- The FAA needs to look for enhancements to further the AQP process by providing more latitude to carriers. Examples are designations of airmen or line check airmen so that the interval between check rides are extended for pilots doing a great job. This would enhance airline abilities under subpart Y for AQP. This might link to an airline's SMS (FOQA, ASAP, voluntary disclosure) and using this to enhance the AQP with feedback. A mature airline that has all of these programs should be rewarded for their diligence.

## Other

- New skills needed for NextGen
  - Mode awareness is going to be an even more important skill in the future with this technology. Flight Path Management, Flight Path Awareness, and Performance Management will be essential to maintaining situation awareness.
- Management of new systems and training is easier to do one fleet at a time, so the slower the implementation, the easier to teach.
- NextGen research funding should be on-going, and the report on the training gaps should drive additional research and activities.
- Operators have a high-level of interest in safety and training excellence, and they would like to be able to define their own training, rather than deal with a pre-defined training from the FAA.
- Airlines need more information sharing and best practices with other airlines to find out what they are doing and how they can leverage those programs.
  - Airlines have hosted round-tables to discuss specific problems that they are having and how they are dealing with them. This is not prevalent among the regional airlines as there might be monetary reasons for not attending.
  - There are several different groups and ARCs that are feeding information back to the airlines based on their research or acknowledgment of best practices.
  - Currently, there is really no reluctance among carriers to talk between their organizations.
  - Upper management has to be aware of the benefits of collaboration and provide support to allow trainers to participate.
  - There are 6-10 safety and training ARCs currently organizing best practices. This information has to be integrated into rulemaking processes and cannot be ignored if NextGen will be successful.
- Suggested composition of the Training Development Team:
  - The team will have to have a blending of different skill sets. One team is needed to work with the designers and also to develop curriculum to support the new technology.
  - Someone with Human Factors qualifications and aptitude
  - Line Pilot
  - Test Pilot
  - Curriculum developers
  - Simulator Instructor
  - ATC

- System engineer
- FAA representation
- The training department should be involved in the aircraft equipment acquisition process to facilitate timely and effective training development for new equipment. (#191)
- Ad hoc training and staffing pilot lounges with instructors to field questions is not an effective model for training and is limited in its capacity to communicate to the pilot population at large. (#47)

# Summary of Ongoing and Planned Research Applicable to Airline Pilot Training

This chapter describes the results of a task accomplished as part of our project addressing flight crew training for NextGen operations. The purpose of the task was to gather information about ongoing or planned research that has or may have implications for training airline pilots for current or future (NextGen) operations. This chapter summarizes our findings.

## Methodology

Our goal was to identify researchers with the potential to be actively involved in pilot training research and to find out about the research they had on going or planned. We primarily used the list of researchers identified in our literature review as being involved in pilot training research. We supplemented this list throughout the course of the project through the contacts made in our survey, workshops, and attendance at various aviation-related conferences and working groups. We contacted 101 researchers by email, direct phone calls, and/or visits to their research facilities. If more than one researcher on our list worked in the same research group, we designated one of them as primary and contacted them for information about the work of the group rather than asking the same questions of several group researchers.

Forty-five researchers responded to our request to share information. Most of the researchers responded that they are no longer working on projects that have implications for pilot training, or that they have moved to other research fields. Eleven researchers responded with descriptive information about their current or planned research projects. We were able to meet with three of them to further discuss and view their work. The information that they shared is described below.

Unless otherwise noted, responses were received by email.

## Summary of Ongoing or Planned Research

### Dee Andrews, Ph.D. (AFRL, ASU)

Dr. Andrews, in conjunction with the Air Force Research Lab and Arizona State University, has ongoing work in which the researchers seek to examine "better ways to train instructor pilots/flight instructors [IPs]." Their "theory is that IP training can be improved by helping IP candidates see how often they manifest certain behaviors (e.g., questioning, directing, inquiring, etc.)." The researchers use a commercially available cataloging tool to observe Instructor Pilot candidates as they instruct novice trainees to see how often they manifest certain behaviors (e.g., questioning, directing, inquiring, etc.). The researchers then show the candidate IPs how their observed behaviors compare to those of expert IPs and assess whether the candidates modify their behavior after they have the feedback. In addition, the researchers have expert IPs rate the videos of the IPs while instructing.

Dr. Andrews did not give a completion date for their work and noted that their research team expects to submit an article to the *International Journal of Aviation Psychology* soon. They will also likely publish a technical report.

### Paul A. Craig, Ph.D. (MTSU, NASA)

Dr. Craig conveyed that he is "currently working on a NASA funded project that not only involves scenario-based pilot training, but also incorporates maintenance technicians, flight dispatchers, ATC and weather briefers into the scenario." He did not provide a timeline for his work.

### Missy Cummings, Ph.D. (MIT – Humans and Automation Lab)

Dr. Cummings and her researchers provided us with an opportunity to visit and view their work. They have ongoing work in which they are trying to determine the predictability of students' success or failure in post-training operational environments based on their performance in distance education training. She expects their work to be completed sometime before the end of 2011.

### Barbara Holder, Ph.D. (Boeing)

Dr. Holder provided us with an opportunity to visit and discuss her work on pilot training. She is conducting a multi-year project to determine "What it means to be a trained pilot" through a process of ethnographic studies among US-based and global air carriers (US carriers were non-AQP).

Her work will result in a pilot training program that is focused on pilot competencies divided among three broad categories. These include basic flying skills, managing expected variability, and managing unexpected variability. In a broad sense her work defines these categories as follows:

- Basic flying skills include tasks that are both technical and non-technical, radio communications, and the use of checklists.
- Managing expected variability addresses how pilots use basic flying skills in day-to-day operations.
- Managing unexpected variability addresses tasks and conditions that are other-than-normal.

Dr. Holder's project also addresses several other topics related to pilot training that include the following:

- Building a framework for training flight instructors and defining grading standards
- Examining device usage (fixed-base training devices and full flight simulators) to determine the most effective application of each device within the training program
- Exploring various considerations with regard to the social aspect of learning and how this might be applied to pilot training

An additional area being explored in her work is on the use of video to train skills through observation.

> The training program implementation is expected for late 2011 or early 2012.

### William Howse, Ph.D. (Human Resources Research Organization, Army)

Dr. Howse is "currently consulting with Human Resources Research Organization (HumRRO) on an Army contract involving determination of collective training requirements and performance measures for manned and unmanned aircraft teams. This project is projected to reach completion in September of this year [2011]."

### Ed Hutchins, Ph.D. (UCSD)

Dr. Hutchins is working "with a major airframe manufacturer to develop digital tools to accelerate the analysis of flight deck behavior." He anticipates that the system they "are building will have applications in flight training." He did not specify a timeline for the project.

### Suzanne Kearns, Ph.D. (University of Western Ontario)

Dr. Kearns describes her work as "Hangar talk: Analyzing how nontechnical skills develop naturalistically during the course of the hours-building phase of a pilot's career."

Her research questions include the following:

1. "What types of scenarios (based on the 'critical threats and/or errors' within each scenario) are most commonly encountered during the hours-building phase of a pilot's career?
   a. How does the distribution of scenario types at the GA level compare to those at the airline level (as reported in Thomas 2004)?
2. What types of nontechnical skills were most commonly applied within the scenarios?
   a. Does the type of nontechnical skill used within the scenario (as indicated by the respondent) relate to that pilot's perceived impact of the scenario?
   b. Is there variance between the type of nontechnical skill, as chosen by the respondent, and the type of nontechnical skill identified by the expert reviewers?
      i. Does variance decrease with increased hours of flight experience?
3. Are pilots more or less likely to be exposed to scenarios requiring specific nontechnical skills, depending upon the type of operation they are involved in?
4. Do more experienced pilots (with more total hours) react more appropriately than pilots with less experience (as self-reported in whether they would react differently if they encountered the scenario again)?
   a. Do pilots with more hours on-type react more appropriately than those with less time on type?
   b. Do pilots with more hours in the type of operation react more appropriately than those with less time in type of operation?"

"This investigation will provide information regarding the types of threats and errors pilots experience naturalistically during the hours-building phase of their careers. In addition, data regarding the types and application of nontechnical skills will be collected."

Dr. Kearns did not give a time frame for the completion of her study.

### Adrian Rycroft (UK CFS)

Mr. Rycroft had two projects nearing completion when responding to our request for information, one that addresses advanced debriefing techniques, completed in July 2011. The other addresses performance coaching in aircrew training – continuing assessment and development. This work focuses on the crew skills required before pilots join their squadrons on the front lines after their training. "Most of the work at the moment is turning the research from the last 2 to 3 years into usable training regimes."

### Thomas L. Seamster, Ph.D. (Cognitive and Human Factors)

Dr. Seamster noted that he is "currently working on an operation evaluation of an Airport Moving Map (AMM) system that includes its training. This project is a 12 month project that should be finished in the first quarter of 2012."

### Mary Stearns, Ph.D. and Volpe Human Factors Research Program (Volpe National Transportation Systems Center)

Dr. Stearns (Chief, Behavioral Safety Research and Demonstration Division) hosted a site visit to discuss the relevant research being accomplished in the aviation-related projects of her division. Several human factors projects related to NextGen are in progress, though not all have implications for flight crew training.

The most relevant program is lead by Dr. Judith Bürke-Cohen. This work continues to assess the effects of simulator motion on pilot training. Her work examines the effects of flight simulator requirements on skill transfer and measures the effectiveness of platform motion versus fixed-base operational simulator training of regional airline pilots targeting manual, cognitive, team, and emergency skills.

# Acronyms and Abbreviations

| | |
|---|---|
| AC | Advisory Circular |
| ACARS | Aircraft Communications Addressing and Reporting System |
| ACRM | Advanced Crew Resource Management |
| ADS-B | Automatic Dependant Surveillance—Broadcast |
| AIAA | American Institute of Aeronautics and Astronautics |
| AIR | American Institutes for Research |
| ALA | Approach and Landing Accident |
| ALPA | Air Line Pilots Association, International |
| AOPA | Aircraft Owners and Pilots Association |
| APM | Aircrew Program Manager |
| AQP | Advanced Qualification Program |
| AR | Augmented Reality |
| ASAP | Aviation Safety Action Program |
| ASP | Advanced Simulation Program |
| ASR | Automated Speech Recognition |
| ASRS | Aviation Safety Reporting System |
| ATA | Air Transport Association |
| ATC | Air Traffic Control |
| ATP | Airline Transport Pilot |
| ATQP | Alternative Training and Qualification Programme |
| CAA | Civil Aviation Authority |
| CBT | Computer-Based Training |
| CDU | Control Display Unit |
| CFIT | Controlled Flight Into Terrain |
| CFR | Code of Federal Regulations |
| CPDLC | Controller-Pilot Data Link Communications |
| CQ | Continuing Qualification |
| CRM | Crew Resource Management |
| CTM | Cockpit Task Management |
| DL | Distance Learning |
| DOD | U.S. Department of Defense |
| DOT | U.S. Department of Transportation |

| | |
|---|---|
| DRM | Dispatch Resource management |
| EAAP | European Association for Aviation Psychology |
| EFB | Electronic Flight Bag |
| EFIS | Electronic Flight Instrument Systems |
| ETOPS | Extended-Range Twin-Engine Operations |
| FAA | Federal Aviation Administration |
| FBS | Fixed Base Simulator |
| FFS | Full Flight Simulator |
| FFT | Full Flight Trainer |
| FITS | FAA Industry Training Standards |
| FMA | Flight Mode Annunciator |
| FMC | Flight Management Computer |
| FMS | Flight Management System |
| FMST | Flight Management System Trainer |
| FO | First Officer |
| FOM | Flight Operations Manual |
| FOQA | Flight Operational Quality Assurance |
| FOR | Field of Regard |
| FOV | Field Of View |
| FTD | Flight Training Device |
| GA | General Aviation |
| GMP | Guided Mental Practice |
| GPS | Global Positioning System |
| GRADE | Gather, Review, Analyze, Decide, Evaluate |
| GUI | Graphical User Interface |
| HCI | Human Computer Interaction |
| HCIPA | Human Computer Interaction Process Analysis |
| HF | Human Factors |
| HSI | Horizontal Situation Indicator |
| HUD | Head-Up Display |
| HWD | Head Worn Display |
| I/E | Instructor/Evaluator |
| IACP | Independent Association of Continental Pilots |
| ICAO | International Civil Aviation Organization |
| IFR | Instrument Flight Rules |

| | |
|---|---|
| ILS | Instrument Landing System |
| IOE | Initial Operating Experience |
| IP | Instructor Pilot |
| IPC | Instrument Proficiency Check |
| IPT | Integrated Procedures Trainer |
| IRAS | Interactive Real Time Audio System |
| IRR | Inter-Rater Reliability |
| ISD | Instructional Systems Design |
| ITS | Intelligent Tutoring System |
| JAA | Joint Aviation Authorities (EU) |
| LNAV | Lateral Navigation |
| LOE | Line Operational Evaluation |
| LOFT | Line Oriented Flight Training |
| LOS | Line Operational Simulation |
| LOSA | Line Operations Safety Audit |
| MCDU | Multi-function Control and Display Unit |
| MCP | Mode Control Panel |
| MDA | Minimum Descent Altitude |
| MPL | Multi-crew Pilot License |
| MV | Maneuver Validation |
| N&O | 14 CFR, Part 121, subparts N and O |
| NAS | National Airspace System |
| NASA | National Aeronautics and Space Administration |
| NAVAID | Navigational Aid |
| NDB | Non-Directional Beacon |
| NTSB | National Transportation Safety Board |
| OEM | Original Equipment Manufacturer |
| PC | Personal Computer |
| PCATD | Personal Computer Aviation Training Device |
| PERFORM | Performance Effects Related to FORce-cueing Manipulation |
| PFD | Primary Flight Display |
| POI | Principle Operations Inspector |
| QRH | Quick Reference Handbook |
| RAA | Regional Airline Association |
| RAF | Royal Air Force (UK) |

| | |
|---|---|
| RAFIV | Reformulating the task, Accessing the user interface, Formatting data, Inserting data, Verifying and monitoring the automation |
| RELATE | Relating Effective Learning to Attributes of the Training Environment |
| RNAV | Area Navigation |
| RNP | Required Navigation Performance |
| RTA | Required Time of Arrival |
| RTO | Rejected Take Off |
| SA | Situation Awareness |
| SAFER | SATS Aerospace Flight Education Research (NASA) |
| SAFO | Safety Alerts For Operations |
| SAGAT | Situation Awareness Global Assessment Technique |
| SATS | Small Aircraft Transportation System (NASA) |
| SESAR | Single European Sky ATM (Air Traffic Management) Research |
| SET | Stress Exposure Training |
| SME | Subject Matter Expert |
| SMS | Safety Management System |
| SOP | Standard Operating Procedure |
| SPOT | Special Purpose Operational Training |
| SRM | Single-Pilot Resource Management |
| SVT | Single Visit Training |
| TAA | Technically Advanced Aircraft |
| TCAS | Traffic Alert and Collision Avoidance System |
| TEM | Threat and Error Management |
| TSA | Transportation Safety Administration |
| VFR | Visual Flight Rules |
| VNAV | Vertical Navigation |