

Automation Training Practitioners' Guide

Elizabeth A. Lyall
Research Integrations, Inc.

Deborah A. Boehm-Davis
George Mason University

Florian Jentsch
University of Central Florida

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Introduction

This document serves to provide a concise review of research addressing pilot training for automated aircraft, (“automation training” for short) and to make the research results accessible to those in the field. This document is an updated version of Lyall, Vint, Niemczyk, Wilson, and Funk (1998).

For the convenience of the reader, the document has been divided into eight sections addressing broad concepts that integrate the research being covered. Each section begins with a brief summary of the concept followed by two subsections: *Best Practices* and *More Information*. In the *Best Practices* subsection, recommendations based on the research in automation training are made for improving automation training. In addition, each ‘best practice’ is followed by a description of the rationale behind the practice and, when appropriate, a concrete example of how the best practice might be applied. The *More Information* subsection provides further sources and articles for the interested reader. At the end of the document are Glossary and References sections.

1. Check Available Sources for Data and Information Related to Flight Deck Automation Issues Prior to Developing a Training Program

Much information is already available regarding training for automation issues. In developing a new training program, it makes sense to take advantage of that information. Research Integrations, Inc. has compiled and summarized this information in a database which is continually updated and made available at www.flightdeckautomation.com. This website describes 94 human factors (HF) issues related to the design, training, and operation of automated airplanes. These HF issues have been identified on the basis of accidents, incidents, and research experiments and studies. The goal was to provide an organization and means to allow operators, regulators, researchers, and others a resource for finding data and information in a way that would allow users to apply this data and information for their own needs. The HF issues and all related research and safety information are housed in a searchable database. Excerpts of research or safety reports (e.g., accidents and incidents) are available on the web site to support the recommendations made. Table 1 shows a number of issues specifically related to pilot training for automated airplanes. The table indicates the number of surveys, observational studies, accident reports, incident studies and experiments that are described and captured on the website for each individual issue raised.

Table 1
Flight Deck Automation Human Factors (HF) Issues Related to Training

Issue	Evidence				
	Surveys	Observational Studies	Accident Reports	Incident Studies	Experiments
Understanding of automation may be	5	1	5	1	2

inadequate					
Training may be inadequate	5	1	3	3	1
Deficiencies in basic aircraft training may exist	6	1			
Manual skills may not be acquired	3				
Automation may be over-emphasized in pilot evaluation	2	1			
Instructor training requirements may be inadequate	1				
Transitioning between aircraft may increase training requirements	1				

Best Practice

Use the Flight Deck Automation Issues Database as a resource to identify research and safety information that may be helpful in developing training objectives and training program elements related to particular human factors issues for automated airplanes.

More Information: For more information see reference 8 or visit the Flight Deck Automation Issues Database website at <http://www.flightdeckautomation.com>.

2. Ensure Basic Aircraft Skills are Included in Training Objectives

Although special attention should be paid to the unique complexities of automated aircraft, the basic principles for flying the aircraft must also be addressed.

Best Practice

Ensure that the information for flying the basic aircraft is effectively included in the training program.

Rationale

- The first general lesson learned is that automated aircraft have complexities that are not present on traditional aircraft. These complexities create challenges for training development and implementation. Training managers and developers must carefully determine how to design training programs to present the complex systems while still teaching the necessary information to fly the basic aircraft without the automation.

More Information: For more information see reference 15.

3. Recognize that Automation Training Should Follow General Training Principles

Instructors and evaluators must keep in mind that principles for training pilots how to use an automated system are no different than principles for training pilots how to use any cockpit system. Thus, training for automated systems should take advantage of principles for good training. That is, certain techniques that have been found useful for training in other domains are likely also applicable to automation training. The following is a listing of the most important of these for automation training.

Best Practice

Present material in a consistent and standardized way.

Rationale

- Repetition reinforces the material being presented. Thus, presenting information in a consistent or standardized manner will allow for stronger learning of the material.

Best Practice

Adapt the training based on individual needs.

Rationale

- Individuals learn at different speeds; they may also have different needs at unique points during training. An effective training program is sufficiently flexible to meet the current needs of each pilot.
- Individuals also react differently to the stress associated with accomplishing these programs. Effective instructors appreciate the difficulty of learning the automated aircraft, are nurturing, pay attention to the details of each pilot's concerns, and are able to identify and respond to the needs of individual students.

Best Practice

During training, establish a comfortable atmosphere that clearly communicates training objectives and provides opportunities for pilots to ask questions and develop their own understanding of the automated systems.

Rationale

- The training environment is important. Treating pilots as professionals and clearly indicating what is expected of them results in the pilots working hard and achieving high performance.
- Negative responses to performance such as yelling or intimidation are not effective, especially in this already high stress situation. Observing the use of the automated systems is helpful. An environment in which the pilots are not afraid to make mistakes on the training equipment should be created. Allowing pilots to make mistakes and discussing them later helps the pilots learn from their

mistakes. Along with learning from their own mistakes, learning from the mistakes of other crew members can be very instructive..

Best Practice

Use crew-based training for automation where possible.

Rationale

- Individuals should train in the same environment where they will perform. In aviation, teamwork is critical. Thus, it is important to train in a crew environment.
- Learning with others may raise questions and/or issues that may not have been addressed in an individual training environment.
- The complexities of the automated systems and the procedures requiring interaction with those systems make it especially important to have crew-based training for the automated aircraft.

Best Practice

Teach CRM (Crew Resource Management)-related topics throughout the training program and especially when addressing operation of the automation.

Rationale

- The building block approach to automated aircraft training program structure seems to be effective. CRM-related topics are important in training for the automated aircraft. Incidents and accidents have repeatedly shown that good CRM is especially important in automated aircraft. Therefore, CRM should be integrated and used throughout training, rather than being taught as a separate module.
- See <http://www.hf.faa.gov/docs/DACRMT.pdf>.

Best Practice

Develop and use Computer-Based Training (CBT) in the training programs for automated aircraft so that it includes those characteristics that have been shown to be effective. In particular, create interactive CBT exercises and present information in a manner that facilitates use of the automated systems later in line operations.

Rationale

- Well-designed CBT can be effective in presenting automated systems and automation concepts. However, in order for it to be effective, CBT should be interactive, self-paced, and non-threatening. It should provide immediate feedback, tie together the modules it teaches, and present information in a manner that is relevant to use during line operations. CBT is not as effective when an instructor is not available for answering questions and monitoring the pilots' performance. CBT also must present accurate information and do so in a manner that keeps the pilot engaged. CBT can effectively augment automation training but should not be the only way automation is trained.

Best Practice

Include scenario-based training exercises and events throughout the training program.

Rationale

- A realistic and consistent scenario-based presentation of the information is important when teaching automated systems because it makes the information easier for the pilot to learn and will not require the pilot to unlearn unrealistic information. The training experience should be based on real-world line operations. Providing the pilots with scenario-based training allows them to relate their training experience to their experience in line operations. This helps build their confidence for performing well on the line. Pilots should see the big picture and understand what their goals are.
- One way to make scenario-based training very effective is to apply it in a way that combines the building-block approach to training with scenario-based training in CBTs, especially when using computer-based simulations of the autoflight or FMS system. For example, when discussing how to set up flight plans, provide trainees with a scenario for a line flight and let them practice in the computer-based FMS simulator by inputting the flight plan. Then, use the stored flight plan when discussing descent management or holding later.

Best Practice

Do not add information and requirements to the training program unnecessarily.

Rationale

- The amount of information included in the training program should be carefully decided. Attempting to present too much information and rushing can be overwhelming and confusing.
- Information should be presented in related and manageable chunks (see also the discussion of scenario-based training above).
- Care should be taken to only add items to the syllabus that are necessary. Modern autoflight systems contain many functions that are seldom, if at all, used on the line. It is typically better if pilots understand 80% of the FMS's available functionalities at 100% comprehension than if they understand 100% of the available functionalities, but only at 80% comprehension.

Best Practice

Use multiple knowledge assessment techniques to evaluate automation knowledge and skills.

Rationale

- Pilots need to have many types of knowledge, and any given form of evaluation can only assess a portion of overall understanding. To ensure safety, it is necessary to evaluate different forms of performance.
 - Declarative knowledge concerns facts (e.g., what does the abbreviation "FLCH" stand for?)

- Procedural knowledge concerns step-by-step procedures or sequences of actions (e.g., what are the steps needed to enter a holding pattern?)
- Strategic knowledge concerns the conditions and circumstances under which declarative and procedural knowledge should be used or applied.
- Perceptual knowledge concerns the availability, in memory, of templates and images of, for example, the instrument indications during descent
- Conceptual knowledge concerns the understanding and linking of declarative, procedural, perceptual, and strategic knowledge.

Types of Assessments

- **Paper and pencil evaluations** are easy to administer and score. It is possible to assess both procedural and conceptual knowledge with this method, but these evaluations are typically better at identifying declarative knowledge about the system. They tend not to be very good at predicting performance in a live setting.
- **Simulator evaluation** is a more effective method of assessing what an individual can do and/or will do in a given situation. Although high-fidelity simulators are often considered the gold standard for training, lower cost PC-based simulators and procedures trainers have been found to effectively evaluate certain characteristics pertinent to crew performance, such as fundamental FMS operations like setting up flight plans, entering holding patterns, etc. Simulators are particularly effective in allowing for an assessment of emergency or abnormal conditions, since there is no actual danger.
- **Line checks** go one step beyond simulator evaluations (LOFTs and LOEs) in that they take place in the actual flight environment. These evaluations capture routine performance and are more likely to show what an individual typically will do in a particular situation, but may not provide much insight into performance under unusual circumstances (such as emergencies).
- **Conceptual knowledge assessment techniques** such as card sorting or concept mapping provide an effective method of assessing how individuals organize their knowledge within a domain. The advent of computerized methods of administering and scoring these options make it a more feasible option in knowledge assessment. These techniques are particularly effective in identifying the extent to which an individual pilot has acquired a conceptual and strategic knowledge that is consistent with those of other experts.

How to Do It

- **Paper and Pencil Assessments.** Most airlines have produced a set of questions that cover the knowledge needed to perform successfully. Assessments typically draw some number of these questions for presentation to pilots as a test. Some of these questions come from manufacturers; others are developed by the training department at the airline. Table 2 provides example questions drawn from one airline's chapter on autoflight-related flight instruments.
- **Simulator assessments** should be made on the basis of actions that can be observed (observable behaviors). Further, structuring the assessment through the

use of a form will provide the instructors with more standardized information on what should be assessed during a simulator assessment. A sample assessment form using observable behaviors can be found in Table 3.

- Rapidly-Reconfigurable LOEs (RRLOE) developed by the University of Central Florida is useful for developing LOEs. These modules allow you to quickly build an LOE from individual building blocks, which is particularly useful when a pilot fails a training event and is required to do an additional LOE. See <http://www.tpl.ucf.edu/downloads.htm>.
- Instructor/evaluators who are assessing pilots on the line may want to take advantage of a standardized form that outlines what to look for during the flight. This can take the form of a line check audit, such as those used by George Mason University (see reference 19) or in the form of a LOSA (see references 20 & 21).
- Conceptual Knowledge Assessment. The Team Performance Lab-Knowledge Assessment Training Suite (TPL-KATS, a.k.a. TPL Intelligent Training Suite-ITS) was developed as a free, easily-deployable, efficient knowledge elicitation software program that includes both concept mapping and card sorting options. Individuals are prompted to think about and make visual representations of how they believe domain concepts are related. See <http://www.tpl.ucf.edu/downloads.htm>.

Best Practice

Require pilots to adhere to the same standards at all times. That is, pilots should be required to perform in the same way during training and on the line.

Rationale

- If the criterion required in training is higher than that required when a pilot is evaluated in a LOFT, LOE, or on the line, performance will deteriorate after initial training. If the criterion in training is lower than that required when a pilot is evaluated or flying the line, pilots will be unable to perform successfully. It is critical to maintain the same high standards in all evaluation settings.

Table 2
Sample questions from the section on flight instruments.

1. In the event of a PFD failure, the PFD format may be displayed on the adjacent MFD by actuation of the:
 - a. MFD format selector on Display Control Panel
 - b. Display select switch on the Display Reversionary Panel
 - c. TCAS
 - d. None of the above

2. Normally, the flight compartment's clocks are the time base source for the airplane avionics equipment.
 - a. True
 - b. False

3. Where is the standby compass located in the flight compartment?
 - a. Below the overhead panel
 - b. On the center pedestal
 - c. On the observer's station
 - d. On primary flight display

Table 3
Sample standardized worksheet for assessing observable behaviors.

J32 LOE 96 Worksheet				Leg 1 Event Set 1			
Month/Year	<input type="text"/>	<input type="text"/>		CRM/TECH CODES	REASON CODES		
INST PIN#	<input type="text"/>	<input type="text"/>	<input type="text"/>	1 = Unsatisfactory	A = Aircraft Control		
PIC PIN #	<input type="text"/>	<input type="text"/>	<input type="text"/>	2 = Satisfactory	J = Judgment		
SIC PIN#	<input type="text"/>	<input type="text"/>	<input type="text"/>	3 = Standard	K = Knowledge Systems		
				4 = Above Standard	P = SOP/Procedure		
ACRM training	PIC	<input type="checkbox"/> yes <input type="checkbox"/> no	SIC		T = Team Management		
					C = Crew Communication		
					S = Situational Awareness		
					D = Decision Making		
LEG 1 EVENT SET 1 (Pre Departure through Taxi)							
CRM OBSERVABLE BEHAVIORS CHECK ✓ ONLY ONE BOX FOR EACH BEHAVIOR BELOW	FULLY OBSERVED	PARTIALLY OBSERVED	NOT OBSERVED	TECHNICAL AND CRM RATINGS RATE FROM 1 to 4 EACH TECHNICAL AND CRM ITEM	REASON CODE	PIC	CREW
TEAM MANAGEMENT OBSERVABLE BEHAVIORS				TECH: Complex with deicing procedures			
Crew plans and discusses winter operations to include deicing procedures				TECH: Winter operations SOP			
				CRM: Preflight and Clearance briefing			
BRIEFING OBSERVABLE BEHAVIORS				OVERALL Event Set 1 RATE PIC, SIC & CREW 1-4			
Crew discusses Preflight Briefing items				REASON CODE (as above) FOR ANY OVERALL RATING NOT A 3			
Crew discusses clearance brief items to include runway conditions, wind and turbulence				REPEATS REQUIRED?			
				CHECK ✓ BOX OF PILOT FLYING			
COMMENTS							

4. Recognize That Automation Training May Not Always Transfer

All automation is not the same; therefore, automation knowledge may not always transfer between systems. Although certain types of automation may have similarities with other systems that can be capitalized upon in training, in other cases different automated systems work in very different ways that end up surprising pilots. Careful analysis is essential to determine how training for a given system should relate to previous training on other systems.

Best Practice

Evaluate whether knowledge acquired from experiences with other autoflight systems can be applied. If yes, create a transfer matrix that lays out what credit can be given for prior autoflight experience and when extra training may be required because prior autoflight experience was sufficiently different..

Rationale

- Careful analysis may lead to a realization that there are similarities between systems (either an automated and a manual system or two automated systems) that can be leveraged to reduce the associated time and cost. However, generalizations based on a previous system must be accurate and should lead to safe and effective performance.

Best Practice

Do not assume that automation knowledge transfers automatically.

Rationale

- Not all automated aircraft are the same. The fact that a pilot has experience in a particular area of automation or with a specific system does not mean that the information previously learned will transfer seamlessly or fulfill all learning needs of the new system.

More Information: For more information see references 1, 2, 3, 4, 5, 7, 14, 20, and 22.

5. Structure the Training Program to Best Address Automation

Training for automated systems should be integrated throughout the entire training program. This is more effective than training automation as a separate issue or module. Automation should be introduced as early in the training program as possible so that pilots can get a general idea of how the pieces in the system work together. Hands-on learning is the best way for pilots to become familiar with automation. Computer-Based Training, Crew-Based Training, and Scenario-Based Training should be utilized throughout the training program.

Proper guidance in the early learning stages will prevent pilot confusion and learning of improper techniques. A comfortable learning environment and the availability of instructor feedback are important elements of a successful training program.

Best Practice

Teach the setup, function, and operation of automated systems throughout the training program. Integrate training for automation into multiple modules of the program, rather than teaching it as a stand-alone module.

Rationale

- Pilots should be able to build their conception of the automation as the training progresses. The most effective method is to present the automated systems throughout the training program as the knowledge and understanding of their complexities is built. Covering a concept in more than one way and using a variety of methods to train helps the pilots integrate the information and develop an accurate mental model. Pilots should be taught how the components work together in the overall system.
- See also the Best Practice on *scenario-based training* in **Section 3** above.

Best Practice

Provide pilots with as much hands-on experience with the automation as possible, and do so as early in the program as possible.

Rationale

- Because of its complexity, automation is difficult to teach with static displays (slides and text) and lecture alone. Hands-on experience is very important for learning dynamic and complex systems. Each student needs to be able to perform the tasks on high fidelity equipment or devices with enough realism that they provide the appropriate feedback to the pilot's inputs. This allows the pilots to begin to integrate the information and understand the systems.

Best Practice

Structure hands-on interaction with the automated systems (by whatever means) in a manner that ensures effective progression through the training program. Evaluate critically whether the training inadvertently encourages the learning of improper practices or leads to improper understanding of the automated systems.

Rationale

- Hands-on free-play interaction with the automated systems can be very effective by allowing the pilot to explore and learn the system. However, this free-play must have some structure so that the complexity of the systems is not overwhelming. The program should only allow the pilots to learn correct information and procedures. Having to unlearn incorrect information wastes valuable training time. Thus, experimentation should be encouraged, but with guidance so that pilots do not teach themselves incorrect information.

Best Practice

Consider using a building block approach to integrating the training programs for automated aircraft. Ensure that the objectives of each block of the program are defined along with how the pilots will accomplish that block using particular training devices. Also include the specific training objectives and approach to integration in the instructor-training program.

Rationale

- Research has shown that integrating the training program using a building block approach to choosing training devices and the topics addressed with each device is effective in training the complexities of automated systems. It also has been effective to integrate the use of devices within a one or two-day training block in which topics are taught through the different methods of classroom, CBT, and FBS to help pilots fully understand different aspects of the automation. When using this approach, however, the student must understand one block before moving on to the next. It is also critical for the instructor to follow the syllabus closely and not introduce information prematurely. (See also the *best practice on scenario-based training* in **Section 3** above).

Best Practice

Make sure that instructors are available during all training events, and especially when the pilots are learning about or interacting with the automated systems.

Rationale

- Instructor availability when the pilots are learning or practicing the automation is also important. As mentioned previously, the complex and dynamic nature of the automated systems cannot be effectively taught using traditional training aids such as static slides and rote memorization. However, it is also not effective to have pilots interact with devices or computer-based training (CBT) without an instructor available to lead the session by providing feedback and guidance. Hands-on experience coupled with extensive interaction with an instructor is much more effective for teaching the complexities and dynamic nature of the automated systems.
- If using off-site training methods, such as the use of self-paced CBT before pilots report to the training center, consider making instructors available for trainees' questions via e-mail, on-line chat, etc.

Other Best Practices

See Section 3 above.

More Information: For more information see references 8, 10, 15, 16 and 19

6. Simulate Responsibly (A simulator is a piece of hardware, not a training program)

Simulators are a vital tool for safe and effective training within the aviation domain. Simply exposing trainees to a simulated environment does not ensure proper training. Instead, trainers should carefully consider how the simulation is implemented within a training program to make sure that it is utilized for optimal training effectiveness.

Best Practice

Use scenario-based training throughout the program: in the classroom, as well as in PC-based trainers, part-task trainers, flight training devices, and simulators.

Rationale

- Preparation for unlikely situations can be extremely valuable in emergency cases. Implementing scenario-based training aids should be used for this sort of preparation.
- Scenario-based training promotes hands-on, critical thinking for unique situations that can be very helpful when an individual is placed in a new situation.
- See also the best practice on *scenario-based training* in **Section 3** above.

Best Practice

Create as many practice opportunities as possible.

Rationale

- Repeated exposure to event-based training scenarios promotes skill development in highly dynamic environments and improvement in reactions to novel or unexpected events.

Best Practice

Use multiple event-based/scenario-based/line-oriented approaches created from data collected from aviation safety organizations (FOQA, ASAP, etc.).

Rationale

- Use of multiple scenarios in the training facility will reduce the pilots' ability to predict the content of their assessments. This allows for successive training to build on previous knowledge.

Best Practice

Use alternative methods to manual development of Line Oriented Simulation (LOS) training and evaluation opportunities (i.e., LOFT, SPOT, LOE).

Rationale

- Development of LOSs manually can be very time consuming, which leads to increased cost for LOS development personnel.

- Software programs, such as the Rapidly Reconfigurable Event-based Line Oriented Evaluation (RRLOE), exist, which do the following:
 - Automate the LOS development process using a database of phase-based events combined with computer assistance into a logical flight to pair it with appropriate route and weather data, providing an efficient means of scenario development.
 - Adapt to meet the continually evolving flight system requirements within the flight deck.
- See <http://www.tpl.ucf.edu/downloads.htm>.

Best Practice

Provide pilots with as much hands-on experience with the automation as possible, and do so as early in the program as possible.

Rationale

- Because of its complexity, automation is difficult to teach with static displays (slides and text) and lecture alone. Hands-on experience is very important for learning dynamic and complex systems. Each student needs to be able to perform the tasks on high fidelity equipment or devices with enough realism that they provide the appropriate feedback to the pilot's inputs. This allows the pilots to begin to integrate the information and understand the systems.

Best Practice

Avoid unstructured “free play,” especially early-on in the training program. Consider removing/blocking certain system functions initially to set up a simplified interface that focuses the trainee on the primary training goals.

Rationale

- Lack of structured scenarios can lead to slower user progress, a focus on inappropriate or less useful issues, or the development of bad habits or poor mental models about the system.
- By limiting the functions used in simulated training exercises, especially in the early phases, emphasis can be placed on specific training goals with less influence from system features that are unrelated to current training goals.

Best Practice

Ensure that all training devices used to teach the automated systems include full functionality of those systems and allow pilots to use them in all the ways that they would be able to use them in the aircraft.

Rationale

- Training devices used to teach the automated systems must include the full functionality of those systems. Using part task trainers for training specific topics is effective for interactive exploration when the device used has the functionality of the system it represents. Devices that lack the functionality to explore the

systems they represent or require one specific set or path of responses are not effective.

More Information: For more information see references 10, 15, 16, and 21.

7. Perform Reliable Assessments to Ensure Successful Automation Training

Instructor/evaluators (I/Es) have the difficult job of evaluating pilot performance. Most I/Es base their ratings on company norms but interpret them based on their experiences: of flying and evaluating the current group of pilots in a given fleet. Because I/Es have unique experiences, they can rate pilots differently from their colleagues. As a result, a given pilot may pass or fail as a function of the biases of the I/E rather than the pilot's level of proficiency. Thus, steps must be taken to ensure reliability in evaluations of pilot performance. As suggested below, a number of steps can be taken to improve reliability.

Best Practice

Discuss company philosophies, practices, and procedures on automation with I/Es.

Rationale

- I/Es who are aware of the concepts and reasoning behind automation procedures will be more consistent in training and evaluating pilot performance.

Best Practice

Bring line experiences back to I/Es at regular intervals. This can be done during I/E meetings using ASAP data and feedback from line evaluations, for example.

Rationale

- The best indicator of a problem in training is seeing a recurrent problem on the line. Thus, providing feedback to I/Es about problems that are seen either during line checks or in ASAP reports is the most concrete way to make instructors and evaluators aware of problems that they should be looking for when they evaluate performance (whether in a LOFT, an LOE, or line check).
- Other sources of line data include Initial Operating Experiences (IOEs), Line-Oriented Safety Audits (LOSAs), FOQA data, and NASA Aviation Safety Reporting System (ASRS) reports.

Best Practice

Hold regular instructor meetings to evaluate and improve the reliability of assessments. Although there is no set frequency for such meetings, it is recommended that they be at least semi-annual.

Rationale

- Over time, I/Es see and evaluate a number of pilots. The experiences they have with these pilots may influence their distribution of ratings and the ratings themselves. Thus, it is important to re-calibrate against other instructors (Inter-

rater reliability, or IRR) or experts (Referent rater reliability, or RRR) on a regular basis.

- The cadre of I/Es changes considerably over time. Therefore, new I/Es should be brought into any discussions of standards (IRR).

Best Practice

Emphasize the development of high-quality training programs for instructors on automated aircraft. Enhance training for instructors to teach them techniques for consistently recognizing and responding to pilot needs as they arise during the program.

Rationale

- Pilots in training to fly automated aircraft have a wide variety of individual needs. Each student, even those with prior automation experience, has individual needs as he or she tries to effectively understand and use the automation. Each crew in training seems to have unique challenges to overcome. An effective training program allows for individual pilot experiences and attitudes and is able to adapt given the current needs of each pilot. To do this, the program must train the instructors to identify these needs and respond to them consistently.
- Instructor training is especially important on the automated aircraft because it is critical for the material to be presented in a consistent and standardized way throughout the program. Interaction between the instructors and the pilots is particularly important because of the stress associated with accomplishing these programs.
- Effective instructors appreciate the difficulty of learning the automated aircraft, are nurturing, pay attention to the details of each pilot's concerns, and are able to identify and respond to the needs of individual students. Effective instructors are careful not to ignore the needs of pilots with automation experience while being responsive to the needs of those without that experience.

Best Practice

Incorporate observable conditions into procedures.

Rationale

- It is easier to evaluate something that can be seen (observed) than something that must be inferred. Thus, actions that pilots must perform should be defined as a SOP (standard operating procedure) so that a pilot can be held to that standard in evaluations. For example, imagine that you want to evaluate crew resource management performance (CRM). One indicator of good CRM performance is whether the pilots work well together when faced with an emergency (e.g., alarm in the cockpit). In this situation, the airline might define a procedure that includes a requirement for the captain and first officer to discuss who will fly the aircraft and who will diagnose the problem. This action is something that can be observed by an evaluator and thus is less subject to interpretation by a given I/E.
- See <http://www.hf.faa.gov/docs/DACRMT.pdf>.

Best Practice

Use either inter-rater (IRR) or referent rater reliability (RRR) techniques to reduce variability in instructor/evaluator (I/E) ratings.

Rationale

- Variability in instructor/evaluator ratings has implications for cost and safety.
 - Allowing unqualified pilots to fly increases the risk of an accident.
 - Forcing qualified pilots to undergo unnecessary training wastes money and resources.

How to Do It

- IRR focuses on developing agreement among the set of I/Es who are currently performing the evaluations. This technique allows I/Es to rate videotaped performance and then discuss amongst themselves reasons for differences in ratings and come to an agreement on how behavior should be rated. See references 24 and 25 for more information.
- RRR focuses on developing agreement between an individual I/E and a “gold standard” developed by asking expert I/Es to evaluate videotaped behavior. An overview of the technique is available here: http://www.faa.gov/education_research/training/aqp/training/media/rhotlpap.pdf. Furthermore, a software tool that allows carriers to carry out individualized calibration sessions, enter data from group sessions, calculate statistics, and print out reports is available from Tim Goldsmith (contact information can be found here: http://www.unm.edu/~psych/faculty/lg_goldsmith.html).

More Information: For more information see references 7, 12 and 23.

8. Know and test the “why,” not just the “how” (Evaluation is not limited to written tests and simulator scenarios)

Training and evaluation in the aviation domain focuses on making sure that pilots are able to safely operate in a dynamic environment. Much of flight involves routine procedures that pilots will experience many times. However, in scenarios where there are rare or unexpected occurrences, simply knowing how to fly might not be sufficient to safely address the situation. In these situations a deeper conceptual understanding of how different aspects of the system interact can aid in safe navigation. This section provides recommendations for including conceptual knowledge training and evaluation along with procedural and declarative knowledge training for automated aircraft.

Best Practice

Carefully analyze the task structure that is taught and provide training that includes monitoring of the automation and a deeper understanding of the concepts that work.

Rationale

- Both procedural knowledge and conceptual understanding are important for a pilot using an automated system. It is easy to focus on how to use a specific automated function; however, without an understanding of the underlying concepts behind the automation, the pilot will be at a disadvantage if the situation strays from standard procedure.

Best Practice

Have pilots explain the flight physics of a particular maneuver and how it is realized in the automation

Rationale

- By forcing pilots to explain a particular aspect of flight physics and its relation to a specific automated function, the pilot will gain better conceptual understanding of the way automation works.

Best Practice

To the extent possible, explicitly teach the logic underlying the automation and cover its limitations.

Rationale

- The pilots should be trained (to an appropriate degree) about the underlying logic of the automation. Complex details should be simplified to make them understandable, but care should be taken so that this simplification does not obscure the underlying logic of the system.
- Pilots should also be taught explicitly about the limitations of the automation, specifically where its failings are and how to cope with them. Giving the pilots specific examples and exposing them to subtle failures are effective ways to equip them to deal with unexpected situations when they arise later in line operations.

Best Practice

Use multiple knowledge assessment techniques to evaluate automation knowledge and skills.

Rationale

- See the best practice on *multiple knowledge assessment techniques* in **Section 3** above.

More Information: For more information see references 6, 9, and 11.

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 - This paper offers a set of practical guidelines for guiding and conducting RRR sessions.
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 - This paper discusses how to use the card sorting tool on the TPL-KATS software. It provides descriptions of features of the software and theoretical support for its use.
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 - ACRM is a proceduralized form of CRM developed to help pilots utilize CRM techniques. This paper provides evidence that performance of ACRM trained crews is superior to performance of non-ACRM trained crews.
 14. *Instructions for Facilitating an IRR Training Session*. Unpublished manuscript, George Mason University, Fairfax, VA.
 - Contains step-by-step instructions on how to conduct a training session to improve reliability of instructor and evaluator ratings.
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 - This paper gives a set of guidelines for training people to use IRR.

Glossary

Aviation Safety Action Program (ASAP)

Federal Aviation program that collects voluntary reports of safety issues that occur in flight.

Computer Based Training (CBT)

This term refers to "the use of computers to provide an interactive instructional experience" in which the computer is seen "as the primary mode of instruction".

Crew Resource Management (CRM)

A strategy that focuses on making the best use of all available experience and skills in the cockpit.

Flight Operational Quality Assurance (FOQA)

Program designated to collection and analysis in flight recordings to help identify areas where flight safety can be improved.

Inter-Rater Reliability (IRR)

A consensus in ratings among different parties, so that all parties use the same system for making assessments, making the ratings themselves more reliable.

Rapidly Reconfigurable Event-based Line Oriented Evaluation (RRLOE)

Software program that automates the LOE development process using a database of phase-based events combined with computer assistance into a logical flight to pair it with appropriate route and weather data, providing an efficient means of scenario development.

Referent-Rater Reliability (RRR)

Synonymous with inter-rater reliability.

Standard Operating Procedure (SOP)

Established or prescribed methods to be followed routinely for the performance of designated operations or in designated situations.

Team Performance Lab- Knowledge Assessment Training Suite (TPL-KATS)

An example of computer developed knowledge elicitation software that was developed as a free, easily-deployable, efficient knowledge elicitation software program that includes both concept mapping and card sorting options.

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