Air Transport Association (1997). *Towards an Operational Philosophy and Model Training Program for FMC-Generation Aircraft*. Air Transport Association.

Towards an Operational Philosophy and Model Training Program for FMC-Generation Aircraft

Human Factors Committee
Automation Task Force

Air Transport Association

Problem Statement from FAA Human Factors Team Report

The FAA Human Factors Team (1996) identified vulnerabilities in pilot management of automation and situation awareness. These included understanding the capabilities, limitations, modes, and operating principles of automated flightdeck systems, and choosing levels of automation appropriate to flight situations.

To rectify these problems, the Team recommended that individual carriers (1) communicate explicitly the carrier's automation philosophy to its pilots, (2) provide explicit guidance to crews concerning circumstances where autoflight should be engaged, disengaged, or engaged in modes with greater or lesser authority, conditions under which autoflight systems will not engage, will disengage, or revert to another mode, and appropriate combinations of automatic and manual control, (3) assess initial and recurrent training programs to ensure pilots are released with a satisfactory level of skills for managing and using automation, (4) assess the content and length of initial and recurrent training programs to ensure coverage of automation issues, basic airmanship, decision-making, CRM, and workload management, (5) increase crewmember understanding of situation awareness associated with mode and energy awareness, position awareness, and potential upsets while under autopilot control, and (6) assess initial and recurrent training and operating manuals to address energy awareness hazards and safety consequences of autoflight system design, and (7) ensure training to proficiency on FMS capabilities.

This paper represents an effort to assess the training implications of the Team's recommendations. Where are member carriers with regard to these recommendations as they apply to training?

Member Carrier Efforts to Communicate Operating Philosophy and Guidance

Some carriers have published in operating manuals and provided classroom training to communicate operational philosophies regarding aircraft automation. In most cases, this guidance has been in place for at least four years. Three major points have been emphasized in publications and training:

- *Levels of automation* -- Each carrier has emphasized that proficiency is required in each level of automation, and has explicitly authorized pilots to choose the most appropriate level for each flight situation. In general, three or four levels have been described, including manual control, intermediate or tactical modes represented on mode control or flight guidance panels (vertical speed, IAS, heading select, etc.), and strategic, lateral and vertical navigation modes represented in flight management systems. Some carriers have also distinguished manual control while using a flight director as a separate level of automation.

- *Confirmation of inputs* -- Each carrier has emphasized the need to confirm results of autoflight selections to prevent mode surprises and confusion. Some have even offered clever analogies to further make the point: An input to an autoflight system should be treated like a ***bid*** for a schedule or trip. It must be checked against its ***award*** presented on the Flight Mode Annuciator, to ensure that the request is carried out. And the aircraft must be monitored for a possible ***reassignment,*** so that the pilot remains aware of what the aircraft is doing and any subsequent mode change.

- Guidance for choosing among levels -- Some carriers have begun to offer guidance for when to choose what level, and this is a significant further step beyond simply authorizing such choices. For example, one carrier emphasizes that immediate control requires manual control, short-range tactical planning is appropriate for Mode Control or Flight Guidance inputs, and that long-range strategic planning is appropriate for Flight Management inputs.

Training to explain automation philosophy has been provided by each carrier, usually within ground school, either immediately prior to beginning a qualification course or in recurrent training provided to all pilots. At least one carrier has used advanced aircraft maneuvering training as a vehicle for providing guidance for choosing among levels. However, carrier operating philosophy has only recently begun to drive development or wholesale revision of training programs for FMC aircraft. That is, while operating philosophies have emerged since 1990, most qualification courses predate them. Only recently have carriers begun to revise qualification programs to teach operation of these aircraft by the carrier's published philosophy.

In addition, there is some evidence that philosophy statements need further clarification to meet the recommendations of the FAA Team. Specifically, their recommendation to carriers states:

> Provide guidance to crews concerning circumstances where autoflight should be engaged, disengaged, or engaged in modes with greater or lesser authority, conditions under which autoflight systems will not engage, will disengage, or revert to another mode, and appropriate combinations of automatic and manual control.

Guidance is incomplete *at this level* in both operator and manufacturer publications, and what does appear *at this level* is distributed throughout descriptions of specific functions and procedures rather than collected in a single location.

Assessing the Sufficiency of Efforts to Date

Significantly, several member carriers participated in the research conducted by the FAA Team in 1995. Despite the efforts described above, the Team found evidence leading to automation management and situation awareness concerns. Similarly, reports to ASRS and Partnership programs continue to reflect two tendencies consistent with the Team's concerns:

- *Tendency to choose an inappropriate level of automation* -- pilots often attempt to program when it creates additional workload, or alternatively, to turn automation completely off even though some intermediate mode would relieve workload.

- *Tendency to attempt to correct an "automation-induced" deviation by manipulating the automated system, rather than the controls of the aircraft* -- a situation where manual control is clearly most

appropriate, yet reports show preference for mode control over manual control. (The FAA Team pointed out that in some accidents, pilots have turned to an autoflight system to correct flight attitudes beyond the capability of the system -- in contrast to guidance published by member carriers that immediate control requires manual control.)

- *Feedback from Human Factors line audits*. A number of data sources identify situations where pilots failed to monitor or control the actions of an autoflight system in a timely manner. This may reflect both an inappropriate level of trust in the autopilot during critical flight modes such as altitude level-off and a tendency to "fly the aircraft through" a flight guidance or flight management system. But, the results of Safety Audits conducted on behalf of four de-identified carriers by the University of Texas Aerospace Crew Research Project may offer the clearest evidence that communication and training of automation philosophy have not been sufficient. Auditors conducted standardized evaluations during regularly scheduled line flights. Measures used by the auditors included "inputs into FMS or FGS confirmed between pilots," "guidelines established on how autoflight systems would be used," and "levels of automation used as appropriate to each situation." The audit team concluded that automation use remains an industry problem. Despite the fact that three of the four participating carriers clearly stated operating philosophies and provided training to communicate them to pilots, over 20% of observed crews on FMC aircraft still received substandard ratings on these items. And more importantly, in responses to surveys given to observed pilots, almost half believed that choosing a level of automation appropriate to each situation is inconsistent with their company's policy.

If carrier efforts to date to communicate operational philosophy have not been sufficient, what options exist to bring pilot performance in line with philosopy?

Inconsistency of First-Generation Training programs with Philosophical Statements

Most qualification training programs were not designed to be consistent with operating philosophy statements. Earl Wiener, who followed the introduction of the B-757 aircraft in the 1980s and documented some of the problems encountered, pointed out to the Task Force that the initial training programs for these aircraft were essentially adaptations or minor re-writes of training for previous generations of aircraft and resulted in failure rates approaching 20%. This led almost immediately to revised approaches unique to FMC aircraft -- the "first generation." Because pilots who did not succeed had difficulty mastering FMS and higher levels of automation, revisions were designed to ensure mastery of the highest levels of automation, biasing training time and focus toward those levels. Checking likewise became biased towards what was perceived to be most difficult on the aircraft. Both trends were to the detriment of operating at lower levels and demonstrating judgment. Most of these first-generation automated aircraft training programs remain in service today, with some updating.

If we accept carrier statements of operating philosophy, the principal flying tasks of a pilot operating these aircraft are competency in basic, intermediate, and flight management levels and judging how and when to apply each level. These represent at least two new skill areas for pilots transitioning from B-727 generation aircraft and one new skill area for pilots transitioning from MD-80 generation aircraft. Yet, the qualification training cycles for all three generations are very similar in length across fleets and carriers. It is unlikely that all three skills can be *taught* in this same timeframe, offering some explanation for both the bias toward the new and higher levels, and the FAA Team's concerns about level of knowledge and application of judgment.

Dr. Wiener concluded that checking at the highest levels, and training to the checkride, will miss problems at lower levels, will not check the most important criterion -- judgment -- and will reinforce beliefs that highest levels of automation are the most proper for line operations. Training failure rates have fallen dramatically, but the focus on higher levels has produced a mindset contrary to carrier operating goals and consistent with the problems identified by the FAA Team. *In a sense, we have taught the test, rather than our operational goals*.

Several carriers have come to similar conclusions in their own self-assessments. Assuming competency and de-emphasizing training events at the lower levels in favor of training and checking at the higher levels of automation may result in pilots biasing their skills and choices to the highest levels. From the pilot's perspective, how we train to fly these airplanes is centered on the FMS -- so flying becomes centered on the FMS.

Approaches toward Designing Training consistent with Philosophy

If first generation programs were inconsistent with carrier operational philosophy, how would training be designed to teach the way the carrier wants the aircraft flown? At least three approaches have been proposed, training the basic aircraft first, revising training by ongoing feedback, and most recently, training all levels and judgment.

Training the basic aircraft first

A case can be made for training the basic aircraft first. In this approach, pilots would attend a day of ground school overviewing systems unique to an FMC aircraft and explaining the airline's operating philosophy. However, further discussion of autoflight systems would be deliberately deferred for some number of days of ground school or device training, so that other systems and basic flight functions can be emphasized. The underlying philosophy is consistent with those described above -- if we expect pilots to revert to more basic levels or modes of operation, we must train them, rather than assume proficiency at those levels. What remains unresolved is whether this meets a second critical concern raised by the FAA Team -- ensuring pilot knowledge and proficiency in all modes and functions. It seems unlikely that pilots can absorb this full range of knowledge in a foreshortened subcourse when this is their area of least experience. First-generation programs were biased toward higher levels as a consequence of pilots failing to readily absorb these new skills. As a result, the Task Force views this approach as potentially trading *pilot proficiency across levels* for *proficiency at intervention* at low levels. We suspect that while the *consequences* of mode confusion might be reduced, the *incidence* might actually increase. Is it necessary to trade one set of problems for another, or can both goals be achieved in comparable-length courses?

Revision by ongoing feedback

A case can also be made for building upon existing training technology through feedback from line crewmembers and events. For example, one member carrier received comments from crewmembers completing IOE that they found visual approaches to be the most challenging task on the line, and they did not believe training for visuals was adequate. The carrier responded by building several visual approach maneuvers into the training program.

With the proliferation of partnership programs, it appears that feedback should increase in quantity and quality, and FOQA holds similar promise. Recurrent training data collected for Single-Visit Training or AQP can be analyzed or restructured to provide such feedback. Two key tests await such an approach -- the extent to which data can be gathered to ensure valid and systematic, rather than anecdotal, information and the extent to which pilot performance becomes congruent with the company's operational philosophy. The task force suspects that feedback will be a critical element in any approach, but is uncertain it will be adequate to accomplish the redesign necessary to address the concerns and recommendations of the FAA Team.

Training all levels and judgment

Most member carriers are moving toward this approach, which attempts to ensure that all levels of automation are presented and checked within a qualification program and that judgment tasks are represented within training and checking. We have selected one such program to describe this approach in some detail. Its designers deliberately chose not to assume proficiency in lower levels. Instead, they chose to train the FMC and autoflight systems as they would any other system on the aircraft -- determining which aspects are best taught in ground school, which in system trainers, and which in flight simulation. Knowledge and skills associated with autoflight systems were examined to determine where they could best be taught and checked. This allowed distributing different aspects of training among ground school, FMC trainers, and flight simulators. It can be described as spanning five phases:

1. **Overview and operational philosophy**

The first phase of automation training is included in indoctrination training and is provided the first time a pilot qualifies on an FMS-equipped aircraft. The course presents the airline's philosophy on use of automation, as well as a basic overview of cockpit instrumentation, displays, symbols, FMS, etc. The training focuses on what makes up an automated cockpit, the sources of information available, what to expect if one or more sources are lost, and why the automation systems are designed the way they are. The concepts of "managing" automation and various "levels" of automation also are introduced.

2. **Ground training of FMS pages**

The second phase is integrated into the ground training segment and consists of basic overviews of the specific aircraft's flight management system, its controls and indicators, CDU page format and design layout, descriptions of the functionality of each page, and system limitations and abnormalities. This phase lays the knowledge-based foundation that will be required to later use the FMS in an operational context. Selected basic FMS enabling objectives (EOs) are introduced each day during ground training in the self-study CBT lessons, followed by training with a ground school instructor on a flight management system part-task trainer (FMST). The process repeats itself each day during ground training until all basic FMS EOs are covered. The pilot's knowledge of these basic FMS EOs is tested during the oral evaluation.

3. **FMS procedures**

The third phase is conducted as the last module in the ground segment, and is taught by a simulator instructor using the FMST. This module builds upon the basics learned in the previous phase by teaching FMS procedures that are used in the simulator and on the line. Typical FMS functional EOs covered are initialization, flight plans, takeoff, departure/enroute, approach, and miscellaneous advanced

functions. The objective of phase three is to ensure the pilot understands and can properly use the FMS during most flight operations without the distractions of other aircraft systems and having to "fly" the aircraft. Before the pilot can progress beyond this module in ground training to the flight training segment, the instructor must verify proficiency in all basic FMS operational objectives.

4. Maneuvers at each applicable level of automation

The fourth phase is conducted during the flight training segment with simulator instructors. This phase integrates the previously learned FMS enabling objectives with Supporting and Terminal Performance Objectives (SPOs and TPOs) in flight simulator scenarios. It is important to note that the emphasis in this automation phase is on *maneuver proficiency* at various levels of automation. Literally, each required maneuver is demonstrated in each applicable level of automation. The level of automation to be used on each event is dictated by the syllabus. In addition, the same computer-based FMST used in ground training is available for use in the simulator briefing rooms. During the prebrief prior to simulator training, the instructors and pilots can set up and discuss various FMS scenarios, then automatically upload the initialization and scenario data to the simulator. During the debrief, any FMS problems that occurred during simulator training can be reconstructed for effective learning and correction of errors.

5. Applying judgment to problems and scenarios

The final phase is conducted in the flight training segment with a check airman. This phase emphasizes training *judgment* in the proper use of automation. The "level" of automation selected in any event is at the discretion of the pilot. As described above, the computer-based FMST is available in the simulator briefing rooms as an aid in learning.

Conclusion

The FAA Team identified vulnerabilities in pilot management of automation and situation awareness. The Team recommended that carriers provide guidance to crewmembers on when to use which levels, identify circumstances when functions will not engage or revert to other modes, and examine training to ensure that pilots begin line operations with sufficient skills for managing and using automation. Some carriers have published in operating manuals and provided classroom training to communicate operational philosophies regarding aircraft automation.

However, there is evidence that statements and training provided to date have not been sufficient. Operating philosophy statements need further explication to meet the recommendations of the FAA Team. First-Generation training programs were not designed to be consistent with operating philosophy statements. This has led several member carriers to identify alternative approaches toward designing training consistent with philosophy. Three such approaches have included training the basic aircraft first, revising training by ongoing feedback, and most recently, training all levels and judgment.

The Automation Task force finds substantial evidence supporting the FAA Human Factors Team recommendations. As a result, the Task Force recommends that each member carrier assess the extent to which its training and procedures address issues raised in the report. Specifically, each member carrier should:

(1) Review its statements of operating philosophy concerning aircraft automation. If published guidance is not provided at the level recommended by the FAA Team, work with the manufacturer and other member carriers to develop and communicate that guidance.

(2) Review its qualification and recurrent training, to determine whether concerns raised in this paper are valid within the carrier. If training is not consistent with operating philosophy, pursue modification or wholesale revision of these programs to train pilots to proficiency in all levels of automation and judgment in choosing among them.

(3) After completing those reviews, establish a process of revising training through ongoing feedback.