ACT ARC Recommendation 17-8:

Management of Automated Systems

I. Submission

The recommendation(s) below were submitted by the Flight Path Management Workgroup (FPM WG) for consideration by the Air Carrier Training Aviation Rulemaking Committee (ACT ARC) Steering Committee at F2F-15. The ACT ARC Steering Committee adopted the recommendations with unanimous consent, and they are submitted to the Federal Aviation Administration as ACT ARC Recommendation 17-8.

II. Statement of the Issue

Training on how to manage automated systems for flight path management has been addressed by various prior recommendations of this workgroup. However, during further dialog and completion of ongoing recommendations, the workgroup identified that some items discussed in industry reports and past incidents were not completely addressed:

- While previous recommendations addressed the use of flight path management systems and combinations of flight guidance and flight control automation, an increased awareness is needed for addressing when these systems (e.g., autoflight, autothrust) do not engage as expected or disengage unexpectedly.
- Flight crews routinely input data and use automated systems properly to maintain the desired flight path. However, industry studies note that input or usage errors occur and result in flight path deviations, and one report sampling noted that "44% of…these errors went unnoticed by the pilots…"[1] Training to provide further guidance in preventing and recognizing these errors is needed.
- Finally, automated system failures and failure of those units that provide inputs to the automated system, although rare, create potentially confusing indications and alerts. Some of these aspects (e.g. loss of reliable airspeed) are addressed in extended envelope and upset prevention and recovery training. However, industry reports[1] note multiple varieties of automation failures that may not be a part of those events. Training should include how to mitigate and recover from operationally relevant[2] automation anomalies[3] that are appropriate to various fleets and identified in data collection systems.

III. Recommendations

The ACT ARC proposes the following recommendations for FAA consideration:

[1] International Air Transport Association (IATA), FMS Data Entry Error Prevention Best Practices, 1st Edition, 2015.
[2] As noted in prior FPM WG recommendations, operationally relevant issues can be identified through an operator's Safety Management System (SMS) program, including safety data programs such as Line Operations Safety Audit (LOSA), Aviation Safety Action Program (ASAP), Flight Operational Quality Assurance (FOQA), and industry programs.
[3] The phrase "automation anomaly" refers to an unexpected automated system behavior that may be caused with or without crew input.

The ACT ARC recommends that the Federal Aviation Administration (FAA) publish guidance to operators advising the following:

(a) Operators should provide flight crews with recommended strategies on the use of automated systems in normal, rare normal,[4] and non-normal operations. Training these strategies should be scenario-based and operationally relevant.

(b) Operators should develop procedures for flight crew action when an automated system does not engage as expected or disengages unexpectedly.

(c) Operators should train flight crews on how to manage automated systems after input errors (crew or system generated).

(d) Operators should train flight crews on how to manage automated system failures. This should include failures of systems that affect the operation of automated systems.

IV. Rationale and Discussion

Recommendation 17-8(a): Operators should provide flight crews with recommended strategies on the use of automated systems in normal, rare normal and non-normal operations. Training these strategies should be scenario-based and operationally relevant.

Rationale: The use of flight path management systems on modern aircraft has significantly contributed to the impressive safety record of the air transportation system. Aircraft and avionics manufacturers have provided flight crews with automated FPM tools that enhance accuracy and reduce workload across all phases of flight. System descriptions and training manuals provide information on the application and use of individual systems or combinations of systems during flight. However, flight crews could also benefit from guidance on the application of the automated system or combination of systems, when not to use them, and which system or combinations are best suited to the desired operational scenario.

Strategies on the use and application of the respective system(s) is obviously situation-dependent, and operators should provide training on automated system use for normal operations, rare normal and known non-normal scenarios. The training should reflect actual events captured from the various data sources. Strategies for automation use, commonly referred to as levels of automation, go beyond the recommendations in ACT ARC Recommendation 16-4 to provide flight crews with the best use options that match the specific operationally relevant scenario, but also allow flexibility for those unusual operations that occur in the real world of flight. Equipping flight crews with such practical strategies may also equip them with the knowledge to select the appropriate mix of automated systems (or none at all) for those unexpected events that require informed and timely decisions (e.g. those events which may not be addressed in flight crew checklists). See ACT ARC Recommendation 16-10, *Flight Path Management Philosophy, Policy and Procedures*,[5] which should be viewed as complementary to this training.

[4] The use of "rare normal" in this recommendation refers to environmental conditions that are experienced infrequently but considered to be operationally relevant. Examples may include significant winds/gusts, windshear/microburst, severe turbulence, and asymmetric icing.

[5] Numerous recommendations in ACT ARC Recommendation 16-10 are complementary, specifically Item #3: "Policies and procedures should include guidance for the appropriate use of automated systems recognizing they provide a set of tools (but are not the only available tools) to effectively manage the flight path."

Instructors providing training on these strategies must have a thorough understanding of flight path management and automated systems. Operators should provide instructors training on the recommended strategies, including scenarios that can be used to incorporate these learning objectives.

Recommendation 17-8(b): Operators should develop procedures for flight crew action when an automated system does not engage as expected or disengages unexpectedly.

Rationale: The Performance-Based Operations Aviation Rulemaking Committee (PARC)/Commercial Aviation Safety Team (CAST) Flight Deck Automation Working Group report, Operational Use of Flight Path Management Systems (FltDAWG), identified that flight crews were found to be vulnerable with respect to the understanding and use of automated systems. ACT ARC Recommendation 15-11 recommended that the FAA develop advisory guidance for stakeholders to train flight crews on autoflight modes, specifically on correct interpretation of the modes and the effects on other systems and aircraft performance. The goal is to develop an understanding of the automated system, its integration with other aircraft systems, and what might affect the automated systems' ability to function as expected. This recommendation supplements ACT ARC Recommendation 15-11 by training flight crews on the operation and actions to be taken when the automated system does not function as expected. This recommendation addresses those systems that engage into a control mode, such as components of the autoflight system (flight control, autopilot, autothrottle/autothrust, and flight director).

It is critical to correctly interpret the system's engagement mode and whether the aircraft is responding as intended. If a system is not responding as intended, whoever detects an anomaly must communicate with other members of the flightcrew to ensure a shared understanding. Should the system not engage as desired, engage into an undesired mode, or disengage unexpectedly, flight crews should be capable of returning to the previous state or manually disengaging the system in accordance with established aircraft operating procedures. Subsequently, flight crews should be capable of analyzing the anomaly and selecting alternative options and/or corrective actions.

Augmenting the training with engage/disengage conditions[6] may prevent continued attempts to engage a system that is not capable of engagement under the existing conditions.

Flight crews should also receive training for operational situations in which it is not appropriate to engage an automated system such as when known system failures/anomalies exist that may adversely affect aircraft control or when the aircraft is in an undesired state (upset). An exception to the latter is when the aircraft is specifically designed with a recovery system to facilitate an upset recovery. In this case, flight crews should be thoroughly trained on the use of the recovery system.

Instructors providing training on these operational situations must have a thorough understanding of flight path management and automated systems. Operators should provide instructors training on the recommended actions, including scenarios that can be used to incorporate these learning objectives.

[6] The conditions referenced here are those determined to be operationally relevant by each operator and are not necessarily referring to the engineering conditions required for every engagement/disengagement.

Recommendation 17-8(c): Operators should train flight crews on how to manage automated systems after input errors (crew or system generated).

Rationale: The FltDAWG report submitted in 2013 identified Data Entry and Cross Verification Errors as a finding, noting that these errors can cause significant deviations to the flight path and have led to incidents and accidents. Several examples that involved mis-entry of data into the flight management system (FMS) (such as aircraft weight) have resulted in incidents that could have resulted in loss of life (e.g. Emirates 407, A340-500, Melbourne Airport, 20 March 2009 (tailstrike)). The International Air Transport Association (IATA) recently documented a study of such data entry errors. Additionally, the National Transportation Safety Board (NTSB) has made several safety recommendations on this topic.[7]

To reduce the likelihood of automated system input and usage errors, flight crews must first be trained on what to look for, and then be given procedures, tools, and techniques to crosscheck each other and the automated system in a combined effort to trap potential errors. The IATA FMS Data Entry Error Prevention Best Practices document from 2015 lists some common error categories: Mass/Balance, Flight Plan, Load/Trim, Nav Database, FMS limitations, configuration errors, data calculation, and data transcription. Given the remarkable reliability of automated systems, and inherently poor human vigilance performance (ability to detect infrequent events), instructors should offer methods for prioritizing the specific errors that are most likely to have significant negative consequences. Gross error checks (sometimes known as reasonableness assessments, as referenced in Proposed Recommendation FPM-10) are important characteristics to instill, because automated systems have a tendency to be precisely right in the majority of cases, but otherwise grossly wrong. Crews should back each other up so errors with a potential for significant negative consequences are detected and mitigated.

This training[8] should include but not be limited to:

1) Strategies to detect and identify input or usage errors;[9]
2) Training pilots on operationally relevant input and usage errors and their consequences (see Attachment A for example scenarios);
3) Methods for flight crews to correct the input or usage error;
4) Methods to ensure the intended flight path is maintained.[10]

At present, it is a challenge for operators to effectively simulate automation-related input errors with current generation simulators. Training devices today do not permit instructors to easily introduce routine error-making scenarios at the frequency needed to replicate problems experienced in flight operations. This leaves instructors waiting for errors to occur or forces discussion-only training of many hazards associated with highly automated cockpits. These challenges are exacerbated when considering automation anomalies (e.g., the inability to select a desired vertical mode) that cannot be synthesized in a simulator without prior flight crew knowledge. Therefore, after proper detection and recovery methods have been taught to the flight crew, instructors should have methods to subtly introduce automation-related input and pilot errors without the crew's awareness for training purposes only. These unexpected events are an important aspect of crew training because, in addition to recognition that the error exists,

[7] Including but not limited to NTSB recommendations A-05-07 and A-14-52.
[8] Training elements listed relate to both Recommendation 17-8(c) and (d).
[9] See ACT ARC Recommendation 15-11 for complementary guidance.
[10] See ACT ARC Recommendations 15-10 and 16-10 for complementary guidance.

flight crews must be taught techniques for intervening as an effective team to mitigate a threat or error while ensuring safe flight.

The FPM WG acknowledges that intentionally introducing error conditions risks a negative transfer of learning unless there is a reasonable representation provided to the crew. Introducing pilot-induced errors that the flight crew has not made is valuable for training but inappropriate for evaluation events. Although beyond the scope of the FPM WG, consideration should be given to developing/redeveloping simulators and flight training devices that permit the introduction of automation-related pilot errors. Lastly, it is important to underscore that, while the aforementioned concept may not be practicable with current generation simulators, this truism should not be deployed as an excuse for inaction in the near term. Until simulators are able to accomplish these tasks, attempts should be made to leverage existing training devices and revise instructor procedures to produce the enhanced learning environment noted above.

Recommendation 17-8(d): Operators should train flight crews on how to manage automated system failures. This should include failures of integrated systems that affect the operation of automated systems.

Rationale: Previous working group recommendations indicate the need to train a thorough understanding of flight guidance and flight control systems. This provides a foundation to properly recognize and resolve issues when encountering "gotchas" that can lead to flight path related errors. However, the FAA 1996 Human Factors report and the FltDAWG report both note a need to increase pilots' ability to respond to failure situations more complex than guidance mode changes/selections.

Training on failures should consider operationally relevant issues and should also include failures of items that provide input to the automated systems. The FltDAWG report noted a few possible failure issues to address: situations where assessment is difficult; situations where recovery is difficult if not properly recognized; and conditions that do not have a checklist.

For these training sessions, it is appropriate to note a FltDAWG report summary: "It is not possible to train pilots in all possible malfunctions or failure scenarios, nor is it possible (or desirable) for line pilots to perform functions as test pilots. However, pilots must be prepared to recognize the results of both complete and partial system failures (including sensor failures) and intervene appropriately."

Previous ACT ARC Recommendation 16-4 properly identified this required knowledge for instructors. Their understanding of the failure and accepted recovery techniques must be clear before training other crewmembers and should be viewed as complementary guidance with this recommendation. This is also an enhancement to ACT ARC Recommendation 17-1 that discusses procedures to accomplish if the automated system failure requires manual recovery.

V. Background Information

Recommendation 17-8 addresses item 2(b) in the FPM WG Scope of Work and

ACT ARC Initiative #35 (see below):

FPM WG Scope of Work:

2. Recommend guidance for developing training for flight path management policy and procedures.
   b. Management of automated systems for flight path management, especially autoflight mode awareness.

ACT ARC Initiatives:

- Initiative #35: Develop training/qualification to improve knowledge and skills for successful flight path management, to include:
  a. Management of automated systems for flight path management, especially autoflight mode awareness.

Source Reports:

- Operational Use of Flight Path Management Systems, Final Report of the Performance-Based Operations Aviation Rulemaking Committee/ Commercial Aviation Safety Team Flight Deck Automation Working Group, September 5, 2013.
- FAA Human Factors Team, The Interfaces Between Flightcrews and Modern Flight Deck Systems, June 18, 1996.
- IATA, FMS Data Entry Error Prevention Best Practices, 1st Edition, 2015.

Attachment A: Examples of Input Errors (crew or system generated)

The following are representative errors occasionally encountered during line operations, which crews should be trained to recognize and mitigate. The intent in listing examples is not to imply that each must be covered during initial or recurrent training. Rather, they are intended to serve as general types of errors that, once made, crews need to be trained to handle.

Uplink Errors

- A weight & balance sheet for another aircraft and containing unreasonable numbers for the intended flight is mistakenly transmitted;
- An uplinked route of flight contains fix omissions that do not match the issued clearance.

Automation Management Errors

- A managed descent to a crossing restriction is intended, but one of the crew members unwittingly selects open descent/flight level change instead;
- When a heading is assigned, the pilot flying (PF) dials the assigned heading into the speed window;
- During a go-around (Boeing), the PF fails to hit the throttle go-around button;
- During takeoff (Airbus), the PF selects the climb detent rather than flex or Takeoff/Go-around (TOGA).

Automation Programming Errors

- During taxi, the crew receives a runway change but does not accomplish all of the required re-programming steps;
- One crew member mistypes a data entry and enters the data without first verifying its accuracy.

Pilot-induced Errors

- Autopilot inadvertently bumped off-line while both crew members are momentarily distracted;
- Dual stick input (Airbus).