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1.0 INTRODUCTION

This Advisory Circular (AC) is provided for information and guidance purposes. It may describe an example of an acceptable means, but not the only means, of demonstrating compliance with regulations and standards. This AC on its own does not change, create, amend or permit deviations from regulatory requirements, nor does it establish minimum standards. This AC is issued in accordance with [applicable national regulatory framework.]

This AC may use mandatory terms such as “must”, “shall” and “is/are required” so as to convey the intent of the regulatory requirements where applicable. The term “should” is to be understood to mean that the proposed method of compliance is strongly recommended, unless an alternative method of safety protection is implemented that would meet or exceed the intent of the recommendation.

1.1 Purpose

This Advisory Circular is issued to alert air operators to the importance that air crews are aware of the automation mode under which the aircraft is operating. It provides a sample automation policy to support the use of aircraft automation.

1.2 Applicability

This document is applicable to all air operators.

All air operators should review this guidance and ensure that their policy, procedures and training reflect these industry best practices. Consideration by air operators of the findings and guidance contained in the Advisory Circular will be a positive contribution to flight safety.

1.3 Description of Changes

Not applicable

2.0 REFERENCES AND REQUIREMENTS

2.1 Reference Documents

The following reference material may be consulted for information purposes:

(1) Commercial Aviation Safety Team – Final Report – Mode Awareness and Energy State Management Aspects of Flight Deck Automation. August 2008

http://www.skybrary.aero/bookshelf/books/1581.pdf

2.2 Cancelled Documents

(1) Not applicable

(2) By default, it is understood that the publication of a new issue of a document automatically renders any earlier issues of the same document null and void.

2.3 Definitions and Abbreviations

(1) The following **definitions** are used in this document:

Not applicable

(2) The following **abbreviations** are used in this document:

(a) **AC:** Advisory Circular;

(b) **CAST:** Commercial Aviation Safety Team

(c) **CDU:** Control and Display Unit

(d) **FCU:** Flight Control Unit

(e) **FMA:** Flight Modes Annunciator

(f) **FMC:** Flight Management Computer

(g) **FMGS:** Flight Management Guidance System

(h) **FMS:** Flight Management System

(i) **LNAV:** Lateral Navigation

(j) **MCP:** Mode Control Panel

(k) **NCAA:** National Civil Aviation Administration

(l) **RASG-APAC:** Regional Aviation Safety Group – Asia and Pacific Regions

(m) **VNAV:** Vertical Navigation

3.0 BACKGROUND

The material described in this Advisory Circular (AC) is based on a report by the Commercial Aviation Safety Team – Mode Awareness and Energy State Management Aspects of Flight Deck Automation, Final Report, August 2008.

Automation has contributed substantially to the improvement in air operator safety around the world. Automation increases the timeliness and precision of routine procedures, and greatly reduces the opportunity to introduce risks and threatening flight regimes.

Nevertheless, in complex and highly automated aircraft, automation has its limits. More critically, flight crews can lose situational awareness of the automation mode under which the aircraft is operating or may not understand the interaction between a mode of automation and a particular phase of flight or pilot input. These and other examples of mode confusion often lead to mismanaging the energy state of the aircraft or to the aircraft deviating from the intended flight path for other reasons. These issues have been identified as factors in several major accidents around the world.

This AC provides a guidance and sample policy on the use of automation (Attachment I). The objective of the guidance and sample policy is to help minimize the frequency with which pilots experience mode confusion and undesirable energy states. This, in turn, requires that crews understand the functions of the various modes of automation. The guidance and sample policy is based on a set of common industry practices that are known to be effective. Operators should compare this to their existing policies and identify any needed changes. In addition, the sample policy includes practical guidance that air operators may include in their policies in order to help pilots respond effectively to particular types of automation anomalies. The suggested guidance is intended only as examples of effective responses to selected circumstances. The suggested guidance does not necessarily identify the only proper response.

> *Note: The terminology used in this document and in the examples reflects terminology for Airbus and Boeing aircraft. Air operators may need to amend the terminology to apply this document to their own fleet mixes, the need for consistent language within a single air operator, or other unique characteristics.*

Findings

In almost all cases the flight crew did not understand what the automation was doing, or did not know how to manipulate the automation to eliminate the error. In such cases, when the

crew changed automation levels they often made the problem worse. This problem applied to all automation modes and it applied regardless of whether the crew induced the event or the event was precipitated by a problem with the automation system. *In all 50 cases studied by the Commercial Aviation Safety Team (CAST), pilots were unable to return the aircraft to the desired flight path in a timely manner*.

This was due to two root causes:

- inadequate training and system knowledge; and,
- the unexpected incompatibility of the automation system with the flight regime confronting pilots in their normal duties.

For example, the crew may have made a manual input to the flight controls that would have been appropriate with the autopilot disengaged. However, if the auto thrust system was still engaged and was in a mode that did not support the flight control input, the resulting flight path or energy state was often undesirable.

Yet, among the 16 air operator automation policies reviewed, the most common concept simply directs crews to "*use the level of automation that will best support the desired operation of the aircraft.*" This concept is fine if the crew understands what the automation is doing at the time of the problem onset, and is then able to determine if the current or another automation level will better suit the operation. However, nearly all incident reports shared one common factor: regardless of whether an error was pilot-induced or was a function of the automation system, pilots did not understand what the automation was doing, or did not know how to use the automation to eliminate an error. Consequently, the recommendations emphasize specific elements that should be incorporated into automation policies and then systematically reinforced.

A core philosophy of *"fly the airplane"* should permeate any air operator's policy on automation. While recognizing that automation has brought major improvements to safety, air operators should require and systematically reinforce a philosophy of "*fly the airplane*." If pilots recognize that they do not understand the nature of an anomaly and do not precisely understand the solution, pilots should not continue in an unstable or unpredictable flight path or energy state while attempting to correct an anomaly. Instead, crews should revert to a more direct level of automation until the aircraft resumes the desired flight path and/or airspeed. This may ultimately require the crew to turn off all automation systems and flying the aircraft manually. When the aircraft once again is flying the desired flight path and/or airspeed, the crew can begin to reengage the automation, as appropriate. Below is a recommended statement to be included in operators' automation policies and which should be systematically reinforced.

> *At any time, if the aircraft does not follow the desired vertical flight path, lateral flight path or airspeed, do not hesitate to revert to a more direct level of automation. For example, revert from FMS guidance to*

non-FMS guidance, or when operating in a non-FMS guidance but with A/THR or A/T engaged, disengage and set thrust manually.

In addition to this recommended philosophical foundation, Air Operators are recommended to prepare, in cooperation with their respective airplane manufacturers, an Automation Policy which should in particular address the following topics:

- Philosophy;
- Levels of Automation;
- Situational Awareness;
- Communication and Coordination;
- Verification;
- System and Crew Monitoring; and,
- Workload sharing and System Use (Command and Control)

Operators should assess their policies against these seven categories, fill any identified gaps, and ensure that each element is regularly reinforced in operating procedures and training programs.

4.0 INFORMATION MANAGEMENT

(1) Not applicable.

5.0 DOCUMENT HISTORY

(1) Not applicable. This is the original issue.

6.0 CONTACT OFFICE

Issued under the authority of:

[Name and Title of the person with authority to issue this AC on behalf of the National Civil Aviation Administration. Typically, this would be the Director General]

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Recommended Automation Policy Sample

1. Philosophy and Approach to the Use of Automation

An automation policy should begin with a description of the organization's philosophy and approach to the use of automation.

1.1 Fly the airplane

First and foremost, though automation has brought major improvements to safety, air operators should promulgate and systematically reinforce the philosophy of "fly the airplane." If pilots recognize that they are uncertain about the autoflight modes or energy state, they should not allow the airplane to continue in an unstable or unpredictable flight path or energy state while attempting to correct the situation. Instead, pilots should revert to a better (usually lower) understood level or combination of automation until the aircraft resumes the desired flight path and/or airspeed. This may ultimately require that pilots turn off all automation systems and fly the aircraft manually. When the aircraft again is flying the desired flight path and/or airspeed, pilots can begin to reengage the automation as appropriate.

As always, the old Golden Rule of 'Aviate, Navigate, and Communicate' should be persevered. Flight crews should be encouraged at all times to attain control if/when things do not go as planned, expected or commanded.

> *Note: This type of statement in the automation policy would help the pilot to know how to correctly interact with automation to reduce workload and increase safety and efficiency.*

1.2 Adopt "CAMI" or "VVM" procedure

Include references to and descriptions of generalized procedures, such as the CAMI or VVM, that have been developed by various air operators as effective means for pilots to validate the arming/engagement of the AFS and to monitor functions/mode changes.

- CAMI procedure for the pilot flying:

Confirm airborne (or ground) inputs to the FMS with the other pilot.

Activate inputs.

Monitor mode annunciations to ensure the autoflight system performs as desired.

Intervene if necessary.

or

- VVM policy for both flight crew members:

Verbalize.

Verify.

Monitor.

General approaches like these are easy to train and review on the line and have been shown to help flight crews in their overall approach to the use of automation.

1.3 Other topics

Operators also should consider including other statements on automation philosophy to provide operational guidance to pilots.

- Appreciate specified capability, limitations, and failure susceptibility of the automation,
- Be wary of autoflight states when crew coordination, communication, and monitoring of automation is more important.
- Resist situations when automation can increase pilot workload or degrade performance, and
- Avoid over-reliance on automation to the detriment of manual flying skills.

2. Choice of Systems or "Levels" of Automation

Automation policy should include information to guide pilots on making choices about how to combine and use automated systems. Some airlines have defined "levels of automation" to help with this. However, a definition alone is not adequate for this topic. Below is a list of

recommended topics that could add substance to a definition and that could provide practical guidance for pilots.

2.1 Use the Appropriate Automation for the Task.

On highly automated and integrated aircraft, several combinations, or levels, of automation may be available to perform a given task in either FMS modes and guidance or non-FMS modes and guidance.

- The most appropriate level of automation depends on the task to be performed, the phase of flight and the amount of time available to manage a task. A short-term or tactical task, such as responding to an ATC direction to go briefly to a different altitude or heading, should be accomplished in the FCU/MCP. This allows the crew to maintain head-up flight. A long-term or strategic task that changes most or all of the remaining flight should be accomplished in the FMS CDU, which requires more head-down time by one pilot.

- The most appropriate level also may depend on the level with which the pilot feels most comfortable for the task or for the prevailing conditions, depending on his/her knowledge and experience operating the aircraft and systems. Reverting to hand-flying and manual thrust control actually may be most appropriate, depending on conditions.

- The PF should retain the authority and capability to select the most appropriate level of automation and guidance for the task. Making this selection includes adopting a more direct level of automation by reverting from FMS guidance to selected guidance (that is, selected modes and targets through the use of either the FCP or MCP); selecting a more appropriate lateral or vertical mode; or reverting to hand-flying (with or without FD guidance, with or without A/THR or A/T), for direct control of aircraft vertical trajectory, lateral trajectory, thrust and airspeed.

2.2 Ensure that pilots possess required skills and knowledge.

Some airlines have also included statements in their automation policies about the requirement for pilots to be skilled in and knowledgeable about the use of certain combinations of automated systems or all possible combinations of systems. Understanding and interacting with any autoflight system ideally requires answering the following fundamental questions:

- How is the system designed?
- Why is the system designed that way?
- How does the system interact and communicate with the pilot?
- How does the pilot operate the system in normal and abnormal situations?

Ensure that pilots fully understand the following aspects in the use of automation:

- Integration of AP/FD and A/THR or A/T modes (that is, pairing of modes), if applicable;
- Mode transition and reversion sequences; Integration of AP/FD and A/THR or A/T modes (that is, pairing of modes), if applicable; and,
- Pilot-system interaction for
    - pilot-to-system communication (that is, for target selections and modes engagement) and
    - system-to-pilot feedback (that is, for cross-checking the status of modes and accuracy).

2.3 AP - A/THR Integration:

Integrated AP-A/THR or AP-A/T systems pair AP pitch modes (elevator control) with the A/THR or A/T modes (thrust levers/throttle levers). Integrated AP - A/THR or AP-A/T systems operate in the same way as a pilot who hand-flies with manual thrust.

- Elevator is used to control pitch attitude, airspeed, vertical speed, altitude, flight-path-angle, and vertical navigation profile or to capture and track a glideslope beam.
- Thrust levers or throttle levers are used to maintain a given thrust or a given airspeed.

Throughout the flight, the pilot's objective is to fly either:

- Performance segments at constant thrust or at idle, as on takeoff, climb or descent; or
- Trajectory segments at constant speed (as in cruise or on approach).

Depending on the task to be accomplished, airspeed is maintained either by the AP (elevators) or the A/THR (thrust levers) or A/T (throttles levers), as shown in **Table 1** below.

Table 1
AP – A/THR & A/T Mode Integration

	A/THR or A/T	*A/P*
	Thrust levers/ Throttle levers	**Elevators**
Aircraft Performance is controlled by:	**Thrust or idle**	**Speed**
Aircraft Trajectory is controlled by	**Speed**	**V/S Vertical profile Altitude Glide slope**

2.4 Automation Design Objectives:

The AFS provides guidance to capture and maintain the selected targets and the defined flight path, in accordance with the modes engaged and the targets set by the flight crew on either the flight control unit (FCU)/mode control panel (MCP) or on the flight management system (FMS) control and display unit (CDU).

The FCU/MCP constitutes the main interface between the pilot and the autoflight system for *short-term guidance* (i.e., for immediate guidance such as radar vectors).

The FMS CDU constitutes the main interface between the pilot and the autoflight system for *long-term guidance* (i.e., for the current and subsequent flight phases).

Two types of guidance (modes and associated targets) are available on aircraft equipped with either a flight management guidance system (FMGS) or flight management computer (FMC), featuring both lateral and vertical navigation:

- Selected guidance:

  The aircraft is guided to acquire and maintain the targets set by the crew, using the modes engaged or armed by the crew (i.e., using either the FCU or MCP target setting knobs and mode arming/engagement pushbuttons)

- FMS guidance:

  The aircraft is guided along a pilot-defined FMS lateral navigation (LNAV) and a vertical navigation (VNAV) flight plan, speed profile, altitude targets/constraints

2.5 Engaging,Disengaging and Reengaging Automation:

Before engaging the AP, ensure that:

- Modes engaged (check FMA annunciations) for FD guidance are the correct modes for the intended flight phase and task;
- Select the appropriate mode(s), as required; and confirm;
- FD command bars do not display any large displacements; if large displacements are commanded, continue to hand fly until FD bars are centered prior to engaging the AP.

Engaging the AP while large commands are required to achieve the intended flight path may result in the AP overshooting the intended vertical target or lateral target, and surprise the pilot due to the resulting large pitch / roll changes and thrust variations.

If situations require the flight crews to disengage automation, they are expected to be equally aware so as to decide when to reengage the appropriate levels of automation once the precursor/s which trigerred the disengagement of automation is/are eliminated. This will help in stabilizing the aircraft flight mode/path,especially during approaches so, as to obtain maximum utilization of the available means of automation.

2.6 Other topics related to the choice of automation levels

Include other statements to help pilots choose the appropriate level of automation.

- Use optimum automation combination or "level" for comfortable workload, high situation awareness, and improved operations capability (passenger comfort, schedule, and economy).
- Do not try to solve automation problems with conditioned responses from the same level of automation.
- Prioritize correctly (e.g. avoid programming during critical flight phases).

3. Situational Awareness

Operators' training policies should include statements about the importance of maintaining situational awareness, particularly regarding 'mode and energy awareness'.

3.1 Mode and Energy Awareness

Situational awareness requires that pilots know the available guidance at all times. The FCU/MCP and the FMS CDU are the primary interfaces for pilots to set targets and arm or engage modes. Any action on the FCU/MCP or on the FMS keyboard and line-select keys should be confirmed by crosschecking the corresponding annunciation or data on the PFD and/or ND (and on the FMS CDU). At all times, the PF and PM should be aware of the status of the guidance modes being armed or engaged and of any mode changes throughout mode transitions and reversions.

3.2 Monitor the use and operation of the automated systems.

- Check and announce the status of the FMA, such as the status of AP/FD modes and A/THR or A/T mode.
- Observe and announce the result of any target setting or change (on the FCU/MCP) on the related PFD and/or ND scales; and
- Supervise the AP/FD guidance and A/THR or A/T operation on the PFD and ND (pitch attitude and bank angle, speed and speed trend, altitude, vertical speed, heading, or track).

3.3 Other topics on situational awareness.

- Remain alert for signs of deteriorating flying skills, excessive workload, stress, or fatigue (avert complacency).
- Ensure at least one crewmember monitors the actual flight path at all times.
- Consider “hand flying” in manual mode for immediate change of flight path.
- Brief the plan for using automation before takeoff and rebrief in flight as the situation dictates.

4. Communication and Coordination

Topics related to communication and coordination to consider in developing the automation policy are statements to help flight crews:

- Announce automatic or manual changes to autoflight status (or update other pilot at first opportunity),
- Brief and compare programmed flight path with charted procedure/ active routing,
- Coordinate (verbalize) before executing any inputs which alter aircraft flight

profile,
- Make callout 1,000 feet before clearance altitude and verbally acknowledge,
- Utilize the "point and acknowledge" procedure with any ATC clearance.
- Brief special automation duties & responsibilities, and
- Actively listen for traffic, communication & clearances.

5. Verification

Include statements about verifying and cross-checking automation selections and anticipating subsequent aircraft performance in an automation policy.

5.1 Know Your Modes and Targets.

At a high level, the goal of verification can be generalized as "know your modes and targets." The AP control panel and FMS control display unit/keyboard are the prime interactions for pilots to communicate with aircraft systems (to arm modes or engage modes, and to set targets). The PFD, particularly the FMA section and target symbols on the speed scale and altitude scale, and ND are the primary interactions for the aircraft to communicate with pilots. These interfaces confirm that aircraft systems have correctly accepted the pilot's mode selections and target entries.

Any action on the autopilot control panel or on FMS keyboard/line-select keys should be confirmed by cross-checking the corresponding annunciation or data on the PFD and/or the ND. The PF and PM should be aware of the following:

- Modes armed or engaged;
- Guidance targets set;
- Aircraft response in terms of attitude, speed, and trajectory; and
- Mode transitions or reversions.

When flight crews perform an action on the FCU/MCP or FMS CDU to give a command, the pilot expects a particular aircraft reaction and, therefore, must have in mind the following questions:

- Which mode did I engage and which target did I set for the aircraft to fly now?
- Is the aircraft following intended vertical and lateral flight path and targets?
- Which mode did I arm and which target did I preset for the aircraft to fly next?

To answer such questions, pilots must understand the certain controls and displays:

- FCU/MCP mode selection keys, target-setting knobs, and display windows;
- FMS CDU keyboard, line-select keys, display pages, and messages;
- Flight modes annunciator (FMA) on the PFD; and
- PFD and ND displays and scales (that is, for cross-checking guidance targets).

5.2 Specific topics related to verification

Include statements to help pilots verify and cross-check inputs and aircraft responses.

- Cross-check raw data and computed data, as appropriate.
- Verify (both pilots) entered waypoints and confirm FMS data against published charts.
- Maintain effective cross-check of system performance with desired flight path,
- Verify programming that alters route, track, or altitude, and cross-check proper mode annunciation,
- Cross-Check (verify) results of selections, settings, and changes.
- If a transition is selected or built, verify between pilots that it matches clearance and that it produces desired track.

6. System and Crew Monitoring

Monitoring automation is simply carefully observing flight deck displays and indications to ensure the aircraft response matches your mode selections and guidance target entries, and the aircraft attitude, speed, and trajectory match expectations.

- During the capture phase, observe the progressive centering of FD bars and the progressive centering of deviation symbols (during localizer and glideslope capture). This enhances supervision of automation during capture phases and cross-check with raw data, as applicable, to enable early detection of a false capture or capture of an incorrect beam.

- If the aircraft does not follow the desired flight path or airspeed, do not hesitate to revert to a more direct level of automation, as recommended by the airplane manufacturer or as required by the operator's SOPs.

- In the event of an uncommanded AP disconnection, engage the second AP immediately to reduce pilot workload.

The effective monitoring of these controls and displays promotes increased pilot awareness of the modes being engaged or armed and the available guidance (flight path and speed control).

Active monitoring of controls and displays also enables the pilot to anticipate the sequence of flight modes annunciations throughout successive mode transitions or mode reversions. Operators should also consider the following types of statements to help provide operational guidance to pilots.

- Scan indications to ensure aircraft performs "as expected;"
- Monitor Status (indications and mode annunciations);
- Monitor ALT capture mode to ensure commands for smooth level-off at assigned altitude are followed when using ALT capture mode of A/P - F/D, or VNAV;
- Maintain One "head up" at all times at low altitude;
- Avoid distraction from duties;
- Do not let automation interfere with outside vigilance;
- Maintain continuous lookout during ground movement & VMC flight
- PF and PM monitor each other's actions; and;
- Do not use any system displaying an inoperative flag or some other failure indication.

7. Workload Sharing and System Use

Consider including statements on workload sharing and system use to provide some operational guidance to pilots, such as the following:

- Ensure PF has responsibility for flight path; remain prepared to assume manual control (abnormal conditions).

- Intervene if the flight status is not "as desired"; revert to better understood (usually lower) automation level; disengage any A/F system not operating "as expected."

- Encourage manual flying for maintaining proficiency when flight conditions permit,

- Clearly establish who controls Aircraft under what Conditions.

- Allow for switch of PF & PM duties providing that control is properly maintained. PF andPM monitor each other's actions.

- Ensure to designate one pilot to control during abnormal conditions.

8. Summary

This Advisory Circular identifies the above seven broad topics that should be addressed in automation policies. Only a specific air operator and the respective aeroplane manufacturer knows what is best for particular circumstances. This advisory circular provides a suggested baseline for developing an operator-specific mode awareness and emergency state management policy based on practices that are known to be effective and incident analysis by an expert panel.

For the optimum use of automation, operators should promote the following, in which the central point remains "fly the airplane."

- Understanding the integration of AP/FD and A/THR-A/T modes (pairing of modes).
- Understanding all mode transition and reversion sequences.
- Understanding pilot-system interfaces for:
  - pilot-to-system communication (for mode engagement and target selections)
  - system-to-pilot feedback (i.e., for mode and target cross-check)
- Awareness of available guidance (AP/FD and A/THR or A/T status and which modes are armed or engaged, active targets).
- Alertness to adapt the level of automation to the task and/or circumstances, or to revert to hand flying or manual thrust/throttle control, if required.
- Adherence to the aircraft specific design and operating philosophy and the air operators SOPs.
- If doubt exists regarding the aircraft flight path or speed control, do not attempt to reprogram the automated systems.
- Selected guidance or hand flying together with the use of navaids raw data should be used until time and conditions permit reprogramming the AP/FD or FMS.
- If the aircraft does not follow the intended flight path, check the AP and A/THR or A/T engagement status:
  - If engaged, disconnect the AP and/or A/THR or A/T using the associated disconnect push button(s), to revert to hand flying (with FD guidance or with reference to raw data) and/or to manual thrust control.
  - In hand flying, the FD commands should be followed. Otherwise, the FD bars should be cleared from display, AP and A/THR or A/T.

~~ END ~~