AC 121-2-6(Rev 0)
17 September 2018

Civil Aviation Authority of Singapore

Advisory Circular

MODE AWARENESS AND ENERGY STATE MANAGEMENT ASPECTS OF FLIGHT DECK AUTOMATION

GENERAL
Advisory Circulars (ACs) are issued by the Director-General of Civil Aviation (DGCA) from time to time to provide practical guidance or certainty in respect of the statutory requirements for aviation safety. ACs contain information about standards, practices and procedures acceptable to CAAS. An AC may be used, in accordance with section 3C of the Air Navigation Act (Cap. 6) (ANA), to demonstrate compliance with a statutory requirement. The revision number of the AC is indicated in parenthesis in the suffix of the AC number.

PURPOSE
This AC provides to demonstrate compliance with, and information for an AOC holder in developing procedures to enhance the awareness and proficiency of the flight crew regarding the automation mode under which the aircraft is operating.

APPLICABILITY
This AC is applicable for an AOC holder operating an aeroplane in accordance with ANR-121.

RELATED REGULATIONS
This AC relates specifically to Regulation 21 of ANR-121.

RELATED ADVISORY CIRCULARS
- AC 121-2-1 Guidance on Operational Procedures for ANR-121 Operations
- AC 121-2-3 Standard Operating Procedures for Flight Crew Members

CANCELLATION
This AC supersedes AC AOC-29.

EFFECTIVE DATE
This AC is effective from 1 October 2018.

OTHER REFERENCES

- CAST Safety Enhancement 30 Rev 5
- COSCAP-NA AC CNA 020 (issue 1)
- EASA SIB 2010-33

1 INTRODUCTION

1.1 Automation has contributed substantially to the sustained 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.

1.2 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.

1.3 The Commercial Aviation Safety Team (CAST) has identified these issues as factors or problems in several major accidents in the United States and around the world. Subsequently, a prototype automation policy for operators was developed.

1.4 This AC provides guidance to the AOC holder in reviewing its automation policy with respect to the management of aircraft in-flight to enhance the awareness of flight crew regarding the automation mode under which the aircraft is operating.

2 SAMPLE POLICY

2.1 In almost all cases reviewed, 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, they often aggravated the situation when the crew attempt to correct the automation errors. This problem exists for all automation modes, regardless of whether the crew induced the event or the event was precipitated by a problem with the automation system. In all 50 cases reviewed, 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;
- 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.

2.2 Yet, among the 16 air operator automation policies reviewed by CAST, 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 applicable if the crew understands the functions of the automation mode at the onset of the problem, 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 a function of the automation system, pilots did not understand what and how the aircraft automation function, or did not know how to use the automation to eliminate an error. Consequently, the recommendations emphasise specific elements that should be incorporated into automation policies and then systematically reinforced.

2.3 A core philosophy of *"fly the airplane"* should permeate any AOC holder's policy on employing aircraft automation in flight. While acknowledging that automation has

brought major improvements to safety, the AOC holder should require and systematically reinforce a philosophy of "*fly the airplane*." If the pilot recognises that he does not understand the nature of an anomaly and does not precisely understand the solution, he should not continue in an undesirable or unpredictable flight path or energy state while attempting to correct an anomaly.

2.4 The sample policy is developed based on this core philosophy. The objective of the sample policy is to help minimise the frequency with which pilots experience aircraft automation mode confusions and undesirable aircraft energy states. This, in turn, requires that crew members understand the functions of various modes of aircraft automation. The sample policy is based on a set of common industry practices that are known to be effective. It is presented in **Appendix A**.

3 RECOMMENDATIONS

3.1 The AOC holder should review this guidance and ensure that its policy, procedures and training reflect the industry's best practices. The AOC holder is advised to compare this to its existing policies and identify any necessary changes. In addition, the sample policy includes practical guidance that the AOC holder may include in its policies to help pilots respond effectively to particular types of automation anomalies. The developed policies, procedures and training should be incorporated into the operation manual, including training programmes, etc., as appropriate.

3.2 This guidance is intended only as examples of effective responses to selected circumstances. It does not necessarily identify the only proper response.

Note: The terminology used in this document and in the examples are consistent with the terminology for Airbus and Boeing aircraft. The AOC holder may need to amend the terminology to apply this document to its own fleet mixes for a consistent language within a single, or other unique characteristics.

APPENDIX A SAMPLE POLICY ON EMPLOYMENT OF AIRCRAFT AUTOMATION INFLIGHT

1 **Philosophy and Approach to the Use of Aircraft Automation:** An automation policy should begin with a description of the organisation's philosophy and approach to the use of automation.

1.1 **Fly the airplane**: First and foremost, though aircraft automation has brought major improvements to safety, the operator should promulgate and systematically reinforce the philosophy of "fly the airplane." If the pilot recognises that he/she is uncertain about the auto flight modes or energy state, he/she should not allow the airplane to continue in an undesirable or unpredictable flight path or energy state while attempting to correct the situation. Instead, the pilot should revert to a better understood level or combination of automation modes until the aircraft resumes the desired flight path and/or airspeed. This may ultimately require that the pilot turn off all automation systems and fly the aircraft manually. When the aircraft again is flying the desired flight path and/or airspeed, the pilot can begin to reengage the automation as appropriate. This type of statement in the automation policy would help the pilot know how to correctly interact with the automation to reduce workload and increase safety and efficiency.

1.2 Adopt "CAMI" or "VVM" procedure: Include references to and descriptions of generalised procedures, such as the CAMI or VVM, that have been developed by various air carriers as effective means for the pilot to validate the arming/engagement of the AFS and to monitor functions/mode changes.

CAMI procedure for the pilot flying:

- **C**onfirm airborne (or ground) inputs to the FMS with the other pilot.
- **A**ctivate inputs.
- ***M***onitor mode annunciations to ensure the auto flight system performs as desired.
- ***I***ntervene if necessary.

VVM policy for both flight crew members:

- **Verbalise.**
- **Verify.**
- **Monitor.**

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

1.3 **Other topics:** The AOC holder also should consider including other statements on automation philosophy to provide operational guidance to pilots.

- Appreciate specified capability, limitations, and failure susceptibility of 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.
- 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 on the combinations and use of automated systems. Some AOC holders 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 Appropriate Aircraft 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, the task should be accomplished in the FCU/MCP; this allows the crew to maintain a 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 may also 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 may be the most appropriate, depending on the 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, and thrust.

2.2 **Ensure that pilots possess required skills and knowledge:** Some AOC holders have also included statements in their automation policies about the requirement for the pilot 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 auto flight system ideally require answering the following fundamental questions:

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

Ensure that the pilot fully understands 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 transitions and reversion sequences;

- Pilot-system interaction for
    - o pilot-to-system communication (that is, for target selections and modes engagement) and;
    - o 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 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 a 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 interaction 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 aircrafts equipped with either a flight management guidance system (FMGS) or flight management computer (FMC), featuring both lateral and vertical navigation, i.e.:

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 (LNAV) flight plan, speed profile, altitude targets/constraints.

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

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.
- Prioritise correctly (e.g. avoid programming during critical flight phases).

3 **Situation Awareness:** Policies should include statements about the importance of maintaining situation awareness and, particularly, mode and energy awareness.

3.1 **Mode and Energy Awareness:** Situation 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 PNF 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 situation 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.
- 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:** Consider topics related to communication and coordination in developing the automation policy are statements to help flight crew:

- 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 (verbalise) before executing any inputs which alter the aircraft flight profile.
- Make callout 1,000 feet before clearance altitude and verbally acknowledge.
- Utilise the “point and acknowledge” procedure with any ATC clearance.
- Brief special automation duties & responsibilities.
- 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 generalised 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 the pilot performs an action on the FCU/MCP or FMS CDU to give a command, he 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, the pilot 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 navigational display (ND) displays and scales (that is, for cross-checking guidance targets).

5.2 **Specific topics related to verification:** Include statements to help the pilot 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 printed charts.
- Maintain an effective cross-check of system performance with the desired flight path.
- Verify programming that alters route, track, or altitude, and cross-check proper mode annunciation.
- Cross-check (verify) result of selections, settings, and changes.
- If a transition is selected or built, verify among 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 the 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 localiser and glideslope capture). This enhances the supervision of automation during capture phases and cross-check with raw data, as applicable, to enable the 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 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. The AOC holder should also consider the following types of statements to help provide operational guidance to the pilot.

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

- Do not use any navigational system displaying an inoperative flag or some other failure indication.

7 **Workload and System Use:** Consider including statements on workload 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 control (abnormal conditions).
- Intervene if the flight status is not "as desired"; revert to lower automation level; disengage any A/F system not operating "as expected".
- Encourage manual flying for maintaining proficiency when flight conditions permit,
- Clearly establish the conditions under which a designated pilot controls the aircraft
- Allow for a switch of PF & PM duties if control is properly maintained whilst PF and PM monitor each other's actions.
- Designate one pilot to control (abnormal conditions).

8 **Summary:** The SE-30 Data Review Team has identified seven broad topics that should be addressed in automation policies. Only a specific AOC holder knows what is best for its own circumstances, but the seven topics provide a basic exemplar, based on current practices that are known to be effective and incident analysis by an expert panel.

For the optimum use of automation, the AOC holder 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 transitions 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 AOC holder’s SOPs.
- If doubt exists regarding the aircraft flight path or speed control, do not attempt to reprogramme the automated systems.
- Selected guidance or hand flying together with the use of raw data from navigation aids should be used until the 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 disconnection push button(s), and 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.