สำนักงานการบินพลเรือนแห่งประเทศไทย
The Civil Aviation Authority of Thailand

Guidance Material for Mode Awareness and Energy State Management Aspects Of Flight Deck Automation

CAAT-GM-OPS-ENERGY

Revision: 00

Date: 4 January 2023

Approved by

Suttipong Kongpool

Director General of the Civil Aviation Authority of Thailand

Intentionally Left Blank

Table of Contents

0. Introduction

0.1 General

Automation in the flight deck has contributed substantially to the sustained improvement in air safety around the world. Automation increases the timeliness and precision of routine procedures, and greatly reduces the opportunity to introduce risks which could threaten safe flight operations.

Nevertheless, in complex and highly automated aircraft, automation has its limits. More critically, flight crew can lose situational awareness of the automation mode under which the aircraft is operating and/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 and/or to the aircraft deviating from the intended flight path.

0.2 Purpose

This guidance material is issued to alert air operators to the importance that flight crew is aware of the automation mode under which the aircraft is operating. It 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 through incident analysis.

0.3 Applicability

This GM is applicable for the Thai's Operator conducting operations under Thai AOCR.

0.4 Reference

(a) AOCR Issue 02 Revision 00 Eff. 30 April 2021

(b) CAAS - AC 121-2-6(Rev 0) 17 September 2018 Mode Awareness and Energy State Management Aspects of Flight Deck Automation

1. Acronyms and Abbreviations

1.1 Acronyms and Abbreviations

Acronyms / Abbreviations	*Meaning*
A/F	*Auto Flight*
AFS	*Automatic Flight System*
ALT	*Altitude*
AP	*Autopilot*
A/T	*Autothrottle*
ATC	*Air Traffic Control*
A/THR	*Autothrust*
CDU	*Control Display Unit*
FD	*Flight Director*
FCU	*Flight Control Unit*
FMA	*Flight Mode Annunciator*
FMGS	*Flight Management and Guidance System*
FMS	*Flight Management System*
LNAV	*Lateral Navigations*
MCP	*Mode Control Panel*
ND	*Navigation Display*
PF	*Pilot Flying*
PFD	*Primary Flight Display*
PM	*Pilot Monitor*

Acronyms / Abbreviations	*Meaning*
PNF	*Pilot Not Flying*
VMC	*Visual Meteorological Conditions*
VNAV	*Vertical Navigations*

2. DEVELOPING AN AUTOMATION POLICY

2.1 Philosophy and Approach to the Use of Automation

An Automation Policy should begin with a description of the organisation's philosophy and approach to the use of automation. Below is a recommended statement to be included in the operator's Automation Policy 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."

2.2 Fly the airplane

Though automation has brought major improvements to safety, an operator should promulgate and systematically reinforce the philosophy of "fly the airplane." If a pilot recognizes that he/she is uncertain about the autoflight modes or energy state, he/she should not allow the airplane to continue in an unstable 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 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.

As always, the Golden Rule of '**Aviate, Navigate, and Communicate**' should be internalised. Flight crew should be encouraged at all times to regain control if and when things do not go as planned, expected or commanded.

2.3 Adopt "CAMI" or "VVM" procedure

The operator should 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 pilots 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 autoflight system performs as desired.
- **I**ntervene if necessary.

VVM policy for both flight crew members:

- **V**erbalize
- **V**erify
- **M**onitor

2.4 Other topic

The operator should also consider including other statements on automation philosophy to provide operational guidance to pilots, such as:

- 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.

3. 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.

3.1 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.

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 must 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 FCU 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.

3.2 Ensure that pilots possess required skills and knowledge

The operator should consider including statements in his 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 the system is 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?

The operator should 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;

- Pilot-system interaction for:

(a) pilot-to-system communication (that is, for target selections and modes engagement) and;

(b) system-to-pilot feedback (that is, for cross-checking the status of modes and accuracy).

3.3 Autopilot (AP) – Automatic Thrust (A/THR or A/T) 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**

3.4 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 interact 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, 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 (VNAV) flight plan, speed profile, altitude targets/constraints.

3.5 Engaging, Disengaging and Reengaging Automation

Before engaging the AP, the pilot should ensure sure 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; and

- 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.

3.6 Other topics related to the choice of automation levels

The operator should include other statements such as the following 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).

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

4. Situation Awareness

Policies should include statements about the importance of maintaining situation awareness and, particularly, mode and energy awareness.

4.1 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.

4.2 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).

4.3 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.

5. 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 (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.

6. Verification

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

6.1 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 PNF (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 navigational display (ND) displays and scales (that is, for cross-checking guidance targets).

6.2 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 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) result 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.

7. 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 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 increases 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 operator 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 AP - 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 continuous lookout during ground movement & VMC flight;

- PF and PNF monitor each other's actions; and

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

8. 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 who controls Aircraft under what Conditions.

- Allow for switch of PF & PNF duties if control properly maintained PF and PNF monitor each other's actions.

- Designate one pilot to control (abnormal conditions).

9. Summary

For the optimum use of automation, the operator 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:

  (a) pilot-to-system communication (for mode engagement and target selections)

  (b) system-to-pilot feedback (i.e., for mode and target crosscheck)

- 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 carriers 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 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 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.