Aircraft automation

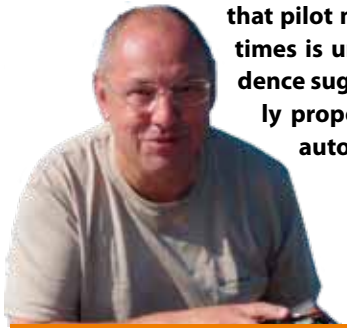
by Michel Tremaud

It is very useful for air traffic controllers to have some understanding of the pilot's working environment. This includes the fundamentals of aircraft automation (understood in this article as automatic flight guidance), how pilots interface with automated systems and how optimal use of automation can contribute to the overall management of the aircraft flight path.

Although the extent to which automation is used has grown a great deal over the past 50 years, and many different levels of systems integration and automation remain in the skies today, the guiding principles which underlie automation have remained essentially the same.

Providing an aircraft is functioning normally, the high levels of automation which may be available are able to provide pilots with an increasing number of solutions to the task which they must accomplish, such as complying with ATC requirements.

I will try and describe some of the fundamental aspects of the use and monitoring of automation. Designers of automated aircraft systems envisage that strict adherence to the following guiding principles and golden rules of operation will enhance pilot situational awareness and prevent so called "automation surprises". Of course this model has humans in charge and so controllers should recognise that pilot mismanagement of automation at times is unfortunately a fact – and the evidence suggests that the risk of this is directly proportional to the complexity of the automation or procedure involved!



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Understanding Automation

The design objective of an automatic flight system (AFS) is to provide assistance to the crew throughout the flight (within the normal flight envelope and with normal operation of all the systems it depends on), by:

- relieving the pilot-flying (PF) from routine handling tasks and thus allowing time and resources to enhance his/her situational awareness or for problem-solving tasks; or,
- providing the PF with attitude and flight path guidance through the flight director (FD), for hand flying.

Basically, 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 the flight guidance control panel (usually referred to as the flight control unit – FCU – or mode control panel – MCP) or on the flight management system control and display unit (FMS CDU).

When seeking an understanding of any automated system, but particularly the AFS and FMS, it helps if the following questions are considered:

- How is the system designed?
- How does the system interface and communicate with the pilot?
- How can the system be operated in normal and abnormal situations?

The following are both important for optimal use of automatic flight guidance:

- The integration of autopilot/flight director (AP/FD) and autothrottle/autothrust (A/THR) modes (i.e. the pairing of modes);
- Mode transition sequences; and,
- Pilot-system interfaces for both:
  - Pilot-to-system communication (i.e. for selecting guidance targets and arming/engaging AP/FD - A/THR modes); and,
  - System-to-pilot feedback (i.e. for checking the status of modes armed or engaged and the correctness of active guidance targets).

made simple

AP - A/THR Integration

Integrated AP - A/THR systems feature an association (pairing) of AP pitch modes (elevator or stabiliser control) and A/THR modes (throttle or thrust levers).

An integrated AP - A/THR operates in the exact same way as a human pilot:

- The elevator/stabiliser is used to control pitch attitude, airspeed, vertical speed, altitude, flight- path-angle, vertical navigation profile or to capture and track a glide slope beam.
- The throttle/thrust levers are used to maintain a given thrust or a given airspeed.

Indeed, throughout the flight, the pilot's objective can be seen as to fly either:

- performance segments at constant thrust/power (e.g., take-off, climb or descent); or
- trajectory segments at constant speed (e.g., cruise or approach).

Depending on the task to be accomplished, maintaining the airspeed is assigned – automatically – either to the AP (elevators) or to the A/THR (throttles levers/thrust control), as shown in Figure 1.

	A/THR	AP / FD
	Throttles/ Thrust levers	Elevators
Performance Segment	Given thrust or idle	Speed
Trajectory Segment	Speed	Vertical speed Altitude Vertical profile Glide slope

Figure 1 - The AP / FD – A/THR Modes Pairing

Flight crew/system interface

The FCU constitutes the main interface between the pilot and the autoflight system for short term guidance (i.e. for immediate guidance).

Figure 2 - A340 FCU (typical)

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).

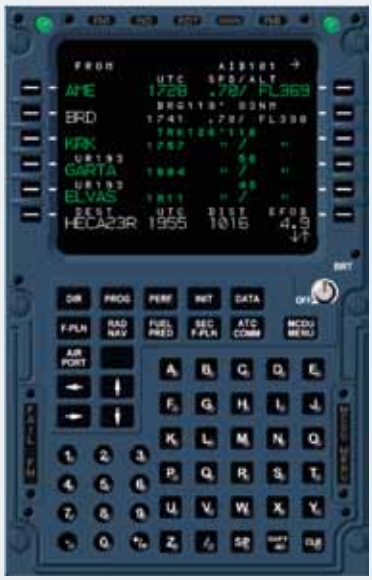

Figure 3 - A340 FMS CDU (typical)

When performing an action on the FCU or FMS CDU to give a command to the AFS, the pilot has an expectation of the aircraft reaction and, therefore, must bear in mind the following questions:

- What do I want the aircraft to fly now?
- What do I want the aircraft to fly next?

Aircraft automation made simple (cont'd)

This implies an awareness and understanding of the following aspects:

- Which mode did I engage and which target did I set for the aircraft to fly now?
- Is the aircraft following the 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 these questions, the roles of the following controls and displays need to be understood:

- FCU (mode selection-keys, target-setting knobs and display windows);
- FMS CDU (keyboard, line-select keys, display pages and messages);
- FMA (Flight Mode Annunciator) on PFD; and,
- PFD and ND (Navigation Display) displays and scales (i.e., for cross-checking active guidance targets).

Figure 4 - A340 PFD and ND (typical)

Effective monitoring of these controls and displays promotes and increases flight crew awareness of the available/active guidance for flight path and speed control. This includes:

- modes (i.e. AP/FD modes being engaged or armed); and,
- targets (i.e. altitude, speed or vertical speed or vertical navigation, heading or lateral navigation).

The safe use of the AP, A/THR and FMS needs a three-step approach:

- **Anticipate:**
  - Understand system operation and the results of any action.
  - Be aware of the modes being engaged or armed.
  - Understand mode transitions or reversions.
- **Execute:**
  - Perform action(s) on FCU or on FMS CDU.
- **Confirm:**
  - Crosscheck and announce the effective arming or engagement of modes and the correctness of active guidance targets (on FMA, PFD and/or ND scales and/or FMS CDU);
  - Observe the aircraft response and resulting trajectory.

User Strategy

The following principles should guide the operation and supervision of automation so that pilots can stay ahead of the aircraft and be prepared for possible contingencies.

Taking advantage of automation to reduce workload

The use of automated systems is intended to reduce workload and significantly improve the time pilots need to respond to unanticipated changes such as ATC instructions or adverse weather conditions. Some unplanned, abnormal or emergency conditions can also be best dealt with by the use of automation – but controllers should be aware that significant failures often lead to a reduction in the extent to which automation can assist.

Most aircraft operators expect both AP and A/THR to be routinely engaged, especially in marginal weather conditions or when operating into an unfamiliar airport.

Using the AP and the A/THR enables pilots to pay more attention to ATC communications and enhances their overall situational awareness, particularly in congested terminal areas and busy airport environments.

Of course, pilots need to maintain their manual flying skills too because they never know when they might be required. Training sessions in the full flight simulator are important for this but, in appropriate circumstances, pilots can be expected to periodically elect to control the aircraft manually or perhaps to select a lower level of automation than they usually use, to maintain all round proficiency.

Using the correct level of automation for the task

On the latest highly automated and integrated aircraft, several levels of automation are available to perform a given task.

The optimum level of automation depends on:

- The task to be performed:
  - short-term task (i.e. tactical choice, short and head-up action(s) on FCU, immediate aircraft response); or,
  - long-term task (i.e. strategic choice, longer and head-down action(s) on FMS CDU, longer term aircraft response);
- The flight phase:
  - departure;
  - en-route climb/cruise/descent;
  - terminal area; or,
  - approach; and,
- The time available:
  - pre-planned selection or entry or 'last-minute change';
  - normal selection or entry; or,

Once automated systems have been programmed, the pilot always retains the ability to change the level of automation and guidance for the task. This might include:

- adopting a more direct level of automation by reverting from FMS-managed guidance to non-FMS guidance (i.e., using the FCU for modes selections and targets entries);
- selecting a more appropriate lateral or vertical mode; or,
- reverting to hand flying (with or without FD guidance, with or without A/THR), for direct control of aircraft vertical trajectory, lateral trajectory and thrust.

Ultimately, the optimal level of automation likely to be the one the pilots feel comfortable with for a task in the prevailing conditions, which will be dependent on their knowledge and experience of the aircraft and its systems.

It has been noted that pilots with significant levels of experience on an aircraft type tend to use automation in a simpler way than pilots who are recently qualified on a type, who tend to explore higher levels of automation ... with the resulting risk of error or loss of mode awareness.

Being aware of available guidance at all times

The FCU and the FMS CDU are the prime interfaces for the flight crew to communicate with the aircraft systems (i.e. to set targets and arm or engage modes).

The PFD and ND are the prime interfaces for the aircraft to communicate with the flight crew, to confirm that the aircraft systems have correctly accepted the mode selections and the target entries:

- PFD (FMA, speed scale and altitude scale):
  - guidance modes, speed and altitude targets;
- ND (heading / track scale or FMS flight plan):
  - lateral guidance.

Any action on the FCU or on the FMS CDU (keyboard and line-select keys) should be confirmed by cross-checking the corresponding annunciation or target on the PFD and/or ND, and on the FMS CDU display.

The use and operation of the AFS must be evident to both pilots at all times by:

- announcement of changes made or observed to the status of AP/FD modes and A/THR mode on the FMA (i.e. mode arming or engagement, mode changeovers);
- announcement of the result of any change of guidance target on the related PFD and/or ND scales; and,
- supervision of the resulting AP/FD guidance and A/THR operation on the PFD and ND (i.e. pitch attitude and bank angle, speed and speed trend, altitude, vertical speed, heading or track …).

Both pilots must always be aware of the status of the modes armed or engaged and of the selected and active guidance targets.

Being ready and alert to take over, if required

Supervising automation can be summed up as simply "Flying with your eyes" - observing cockpit displays and indications to ensure that the aircraft response matches your mode selections and guidance target entries, and that the aircraft attitude, speed and trajectory match your expectations.

If any doubt exists regarding the aircraft flight path or speed control, pilots are encouraged to revert to a lower level or automation rather than attempt to re-programme automated systems unless an obvious entry error is detected.

Whilst there are routine ways to disconnect automation, if an AP or A/THR operation needs to be overridden following a malfunction such as a flight control runaway, pilots are expected to use the immediate disconnection methods provided. Only in emergency situations is it expected that pilots will manually override an engaged AP or A/THR.

Conclusions

Automation should match the pilot's mental model for flying the aircraft from gate to gate and should therefore be intuitive. However, effective use of automation requires that proper pilot understanding of it is achieved through ground training followed by supervised use during line training and finally consolidation in normal operations.

It should be acknowledged that automation may malfunction and that pilots may mismanage automation but it should equally be recognised that complex procedures (approach or go-around/missed-approach) or challenging ATC instructions may complicate the pilot task and his/her use of automation.

As an air traffic controller, you may have an idea of the level of automation which a particular aircraft type provides but you will not usually know the extent to which it is being used and how your instruction may affect this use. However, perhaps this article has opened your eyes to the scope and pilot use of automation in the flight deck and prepared you a little to appreciate both its potential and its pitfalls for pilots.