Flight Operations Briefing Notes

Standard Operating Procedures

Optimum Use of Automation

I Introduction

The term "optimum use of automation" refers to the integrated and coordinated use of the following systems:

- Autopilot / flight director (AP / FD);
- Autothrottle / autothrust (A/THR); and,
- Flight management system (FMS).

Three generations of flight guidance systems are currently in airline service, providing different levels of integration and automation:

- A300B2/B4 and A300 FFCC families:
  - Partial integration (pairing) of the AP/FD and A/THR modes;
  - Selected vertical and lateral modes; and,
  - Lateral navigation only (i.e., inertial navigation system [INS] or FMS/GPS).

- A310 and A300-600 families:
  - Full integration of AP/FD and A/THR modes;
  - Selected vertical and lateral modes; and,
  - Vertical and lateral navigation (FMS NAV and PROFILE modes),

- A320 / A330 / A340 / A380 families:
  - Full integration of AP/FD - A/THR – FMS modes (FMGS);
  - Selected vertical and lateral modes; and,
  - Managed vertical and lateral navigation in all flight phases.

Higher levels of automation provide flight crews with an increasing number of options and strategies to choose for the task to be accomplished (e.g., to comply with ATC requirements, …).

The applicable Flight Crew Operating Manual (FCOM) provides specific information and operational recommendations for each aircraft type.

II Statistical Data

Errors in using and managing the automatic flight system and the lack of awareness of the operating modes are causal factors in more than 20 % of approach-and-landing accidents (source : Flight Safety Foundation – 1998-1999).

III AP - A/THR Integration

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

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

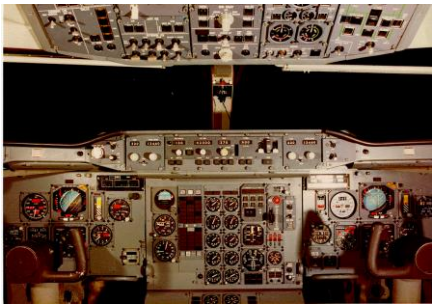
- Elevator is used to control pitch attitude, airspeed, vertical speed, altitude, flight-path-angle, vertical navigation profile or to capture and track a glideslope beam;
- Throttle / thrust levers are used to maintain a given thrust or a given airspeed.

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

- Performance segments at constant thrust or at idle (e.g., takeoff, 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 either to the AP (elevators) or to the A/THR (throttles levers / thrust control), as shown in **Table 1**.

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

Table 1

AP – A/THR Modes Integration

IV Design Objective

The design objective of the automatic flight system (AFS) is to provide assistance to the crew throughout the flight (within the normal flight envelope), by :

- Relieving the 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 adequate attitude and flight path guidance through the FD, for hand flying.

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 FCU or on the FMS CDU.

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

The FMS multi-purpose control and display unit (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).

On aircraft equipped with a Flight Management and Guidance System (FMGS), featuring both lateral and vertical navigation, two types of guidance (modes and associated targets) are available:

- **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 the FCU target setting knobs and mode arming / engagement pushbuttons).
- **Managed guidance:**
  - The aircraft is guided along the pilot-defined FMS lateral and vertical flight plan, speed profile and altitude targets, as managed by the FMS (accounting for altitude and speed constraints, as applicable).

V Understanding Automated Systems

Understanding any automated system, but particularly the AFS and FMS, ideally would require answering the following fundamental questions:

- How is the system designed ?
- Why is the system designed this way ?
- How does the system interface and communicate with the pilot ?
- How to operate the system in normal and abnormal situations ?

The following aspects should be fully understood for an optimum use of automation:

- Integration of AP/FD and A/THR modes (i.e., pairing of modes);
- Mode transition and reversion sequences; and,
- Pilot-system interfaces for:
  - Pilot-to-system communication (i.e., for target selections and modes engagement); and,
  - System-to-pilot feedback (i.e., for cross-checking status of modes and correctness of guidance targets).

This *Flight Operations Briefing Note* is intended to enhance the reader's understanding of the interface and communication between the flight crew and the autoflight system.

VI Flight Crew / System Interface

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 have in mind the following questions:

- What do I want the aircraft to fly now ?

- What do I want the aircraft to fly next ?

This implies answering also the following questions :

- 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 enable answering the above questions, the key role of the following controls and displays must be understood:

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

The effective monitoring of these controls and displays promotes and increases the flight crew awareness of the available guidance for flight path and speed control:

- Status of the autoflight system (i.e., modes being engaged or armed); and,
- Active guidance targets.

The active monitoring of controls and displays also enables the pilot to predict and anticipate the entire sequence of flight modes annunciations (FMA) throughout successive flight phases (i.e., throughout mode transitions or mode reversions).

VII Operating Philosophy and Golden Rules

Optimum use of automation requires strict adherence to the aircraft-type-related design philosophy and operating philosophy, and to the general Golden Rules for Pilots (refer to the Flight Crew Training Manual – Operational Philosophy - Golden Rules for Pilots).

VII.1 Use the appropriate level of automation at all times

This is the Golden Rule number 2. On highly automated and integrated aircraft, several levels of automation are available to perform a given task:

- FMS-managed modes and guidance; or,
- Selected modes and guidance.

The appropriate 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;
  - enroute climb / cruise / descent;
  - terminal area; or,
  - approach; and,

- The time available:
  - normal selection or entry; or,
  - last-minute change.

The appropriate level of automation is usually the one the pilot feels comfortable with for the task or for the prevailing conditions, depending on his/her own knowledge and experience of the aircraft and systems.

Reversion to hand flying and manual thrust control actually may be the appropriate level of automation, depending on the prevailing conditions.

FMS or selected guidance can be used in succession or in combination (e.g., FMS lateral guidance together with selected vertical guidance) as best suited for the flight phase and prevailing operational conditions.

The PF always retain the authority and capability to select the most appropriate level of automation and guidance for the task, this includes:

- Adopting a more direct level of automation by reverting from FMS-managed guidance to selected guidance (i.e., selected modes and targets);
- 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.

VII.2 Understand your available guidance at all times

This is the Golden Rule number 3. 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 target entries:

- PFD (FMA, speed scale and altitude scale):
  - guidance modes, speed and altitude targets; and,

- ND :
  - lateral guidance (heading or track or FMS flight plan).

Any action on the FCU or on the FMS keyboard and line-select keys should be confirmed by cross-checking 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 changeover throughout mode transitions and reversions.

The use and operation of the AFS must be monitored / supervised at all times by:

- Checking and announcing the status of AP/FD modes and A/THR mode on the FMA (i.e., arming or engagement);
- Observing and announcing the result of any target setting or change (on the FCU) on the related PFD and/or ND scales; and,
- Supervising the resulting AP/FD guidance and A/THR operation on the PFD and ND (pitch attitude and bank angle, speed and speed trend, altitude, vertical speed, heading or track, …).

VII.3 Take actions if things do not go as expected

This is the Golden Rule number 4. If doubt exists regarding the aircraft flight path or speed control, the flight crew should not try to reprogram the automated systems.

The flight crew should use Selected Guidance or hand flying together with the use of navaids raw data, until time and conditions permit a reprogramming of the AP/FD or FMS.

If the aircraft does not follow the intended flight path, check the AP and A/THR engagement status.

If engaged, disconnect the AP and/or A/THR using the associated instinctive 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 PF must follow FD commands; otherwise the flight crew must remove the FD from the PFD.

AP and A/THR must not be overridden manually.

If AP or A/THR operation needs to be overridden (i.e., following a runaway or hardover), immediately disconnect the affected system by pressing the associated instinctive disconnect push button.

VIII Operational and Human Factors Affecting the Optimum Use of Automation

The following operational and human factors are often observed in incidents and accidents in which the use of automation is identified as a causal factor (with reference to various industry sources):

- Intimidation (i.e., non-interference with or late takeover from automation when needed);
- Overconfidence / overreliance (i.e., excessive delegation);
- Complacency (i.e., passive attitude, lack of active supervision);
- Inadvertent arming or engagement of an incorrect mode;
- Failure to verify the effective arming / engagement (on the FMA) of the modes armed or engaged;
- Selection of an incorrect target (altitude, speed, heading, radial, course, track, fligh-path angle, …) on the FCU and failure to confirm the selected target by cross-checking the related target symbol on the PFD and/or ND;
- Selection of the FCU altitude to any altitude below the MEA / MORA, MSA, approach-segment safe altitude or final approach intercept altitude;
- Insertion of an erroneous waypoint;
- Arming of the lateral navigation mode with an incorrect active waypoint (i.e., an incorrect TO waypoint);
- Preoccupation with FMS programming during a critical flight phase, with consequent loss of situational awareness;
- Insufficient understanding of mode transitions and mode reversions (i.e., mode confusion, automation surprise);
- Inadequate task sharing and/or CRM practices preventing the PF from monitoring the flight path and airspeed (e.g., both pilots being engaged in the management of automation or in solving an unanticipated situation or abnormal condition);
- Engaging the AP with the FD bars largely not-centered (i.e., after hand flying the aircraft without following FD orders);
- Engaging the AP with the aircraft in an out-of-trim condition (conventional aircraft models only);
- Failure to arm the approach mode;
- Failure to set the correct final approach course; and/or,
- Failure to set the correct go-around altitude.

IX Recommendations for Optimum Use of Automation

IX.1 Using Automation - General

Correct use of automated systems reduces workload and significantly improves the flight crew time and resources for responding to:

- An unanticipated change (e.g., ATC instruction, weather conditions, …); or,
- An abnormal or emergency condition.

During line operations, AP and A/THR should be engaged throughout the flight, especially in marginal weather conditions or when operating into an unfamiliar airport.

When operating in fair environmental conditions and at low-density airports, flight crew can elect to fly the departure or arrival manually to maintain flying skills.

Using AP and A/THR also enables flight crew to pay more attention to ATC communications and to other aircraft, particularly in congested terminal areas and at high-density airports.

AP and A/THR should be used during a go-around and missed-approach to reduce workload.

FMS lateral navigation should be used to reduce workload and risk of CFIT during go-around if :

- Applicable missed-approach procedure is included in the FMS flight plan; and,
- FMS navigation accuracy has been confirmed (unless the aircraft is GPS-equipped and the GPS availability / performance allow its use for primary lateral navigation).

The safe and efficient use and management of AP, A/THR and FMS are based on the following three-step technique:

- **Anticipate:**
  - Understand system operation and the results of any action,
  - Be aware of modes being engaged or armed (seek concurrence of other crewmember, if deemed necessary); and,
  - Understand mode transitions or reversions,
- **Execute:**
  - Perform action on FCU or on FMS CDU; and,
- **Confirm:**
  - Crosscheck and announce the effective arming or engagement of modes and the active guidance targets (on FMA, PFD and/or ND scales and/or FMS CDU).

The optimum use of automation enables the flight crew to stay ahead of the aircraft and be prepared for possible contingencies.

IX.2 Engaging Automation

Before engaging the AP, make sure that:

- Modes engaged for FD guidance (check FMA annunciations) are the correct modes for the intended flight phase and task; if not, select the appropriate mode(s); and,
- FD command bars do not show large orders; if large commands are given, maintain hand flying to center the bars before 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/or,

  – May surprise the pilot due to the resulting large pitch / roll changes and thrust variations.

IX.3 Interfacing with Automation

When interfacing with automation, for modes arming / selection and for guidance targets entries, adhere to the following rules-of-use (rules derived from the lessons-learned from the operational and human factors analysis of operational events) :

- Before any action on FCU, check that the knob or push button is the correct one for the desired function;
- After each action on FCU, verify the result of this action on :

  – FMA (i.e., for arming or engagement of modes); and/or,

  – PFD/ND data (i.e., for selected targets); and,

  by reference to the aircraft flight path and airspeed response;

- Announce all changes in accordance with Standard Calls defined in SOPs;
- When changing the selected altitude on FCU, cross-check the selected altitude indication on PFD;

  During descent, ensure that the selected altitude is not to below the MEA or MSA (or be aware of the applicable minimum-vectoring-altitude);

  During final approach, set the go-around altitude on FCU (i.e., the MDA/H or DA/H should not be set on the FCU);

- Prepare FMS for arrival before starting the descent;

An alternative arrival routing, another runway or circling approach, can be prepared on the secondary flight plan (SEC F-PLN), as anticipated;

- In case of a routing change (e.g., DIR TO), cross-check the new TO waypoint before activating the DIR TO (i.e., making sure that the intended TO waypoint is not already behind the aircraft);

  Caution is essential during descent in mountainous areas; ensure that the new track and assigned altitude are not below the sector safe altitude;

  If under radar vectors, be aware of the sector minimum vectoring-altitude;

  If necessary, the selected heading mode can be used with reference to navaids raw data, while verifying the new route and/or requesting confirmation from ATC;

- Before arming the NAV mode, ensure that the correct active waypoint (i.e., TO waypoint) is displayed on the FMS CDU and ND;

  If the displayed TO waypoint on the ND is not correct, the desired TO waypoint can be restored by either:

  – Clearing an undue intermediate waypoint; or,
  – Performing a DIR TO [desired TO waypoint];

  Monitor the correct interception of the FMS lateral flight plan;

- In case of a late routing or runway change, a reversion to AP selected modes and raw data may be considered;

  Reprogramming the FMS during a critical flight phase (e.g., in terminal area, on final approach or go-around) is not recommended, except to activate the secondary flight plan, if prepared, or for selecting a new approach;

  Priority tasks are, in that order :

  – Horizontal and vertical flight path control;
  – Altitude and traffic awareness; and,
  – ATC communications;

- If cleared to exit a holding pattern on a radar vector, the holding exit prompt should be pressed (or the holding pattern cleared) to allow the correct sequencing of the FMS flight plan;

- Under radar vectors, when intercepting the final approach course in a selected heading or track mode (i.e., not in NAV mode), flight crew should ensure that FMS flight plan sequences normally by checking that the TO waypoint is correct (on ND and FMS CDU);

Ensuring that FMS flight plan sequences correctly with a correct TO waypoint is essential, in readiness for re-engaging the NAV mode, in case of a go-around;

If FMS flight plan does not sequence correctly, correct sequencing can be restored by either:

- Performing a DIR TO [a waypoint ahead in the approach] or a DIR TO INTCPT (as available); or,
- Clearing an undue intermediate waypoint (be cautious not to clear the desired TO waypoint);

If a correct TO waypoint cannot be restored, the NAV mode should not be used for the rest of the approach or for go-around;

- Before arming the APPR mode, ensure that the ILS has been correctly tuned and identified, and that the aircraft:
  - Is within the ILS capture envelope (LOC and G/S deviation symbols correctly displayed);
  - Is on a LOC intercept heading; and,
  - Has been cleared for approach.

IX.4 Supervising Automation

Supervising automation is 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, i.e. :

- During capture phases, observe the progressive centering of FD bars and the progressive centering of deviation symbols (i.e., during localizer and glideslope capture);

  Enhancing the supervision of automation during capture phases – and crosscheck with raw data, as applicable - enables the early detection of a false capture or of the capture of an incorrect beam (e.g., ILS in maintenance mode emitting a permanent on-glideslope signal);

- Do not attempt to analyze or rectify an anomaly by reprogramming the AFS or FMS, until the desired flight path and/or airspeed are restored;

- In case of AP uncommanded disconnection, engage the second AP immediately to reduce PF's workload (i.e., only dual or multiple failures may affect both APs simultaneously); or fly the aircraft manually until the aircraft is maintained / re-established on the correct flight path and time allows for trouble-shooting and re-programming;

- At any time, if the aircraft does not follow the desired flight path and/or airspeed, do not hesitate to revert to a more direct level of automation, i.e.:
  - Revert from FMS-managed modes to selected modes;

  or,

  - Disconnect AP and follow FD guidance (if correct);

  or,

  - Disengage FD, select FPV (as available) and hand fly the aircraft, using raw data or visually (if in VMC);

  and/or,

  - Disengage the A/THR and control the thrust manually.

X Summary of Key Points

For optimum use of automation, the following should be promoted:

- Understanding the integration of AP/FD and A/THR modes (i.e., pairing of modes);
- Understanding all mode transition and reversion sequences;
- Understanding pilot-system interfaces for:
  - Pilot-to-system communication (i.e., for modes engagement and target selections);
  - System-to-pilot feedback (i.e., for modes and targets cross-check);
- Awareness of available guidance (AP/FD and A/THR status, modes armed or engaged, active targets);
- Alertness to adapt the level of automation to the task and/or circumstances, or to revert to hand flying / manual thrust control, if required;
- Adherence to design philosophy and operating philosophy, SOPs and Golden Rules for Pilots.

XI Associated Flight Operations Briefing Notes

The following *Flight Operations Briefing Notes* should be reviewed along with the above information to complement this overview on the use of automation:

- **Operating Philosophy,**
- **Standard Calls.**

XII Regulatory References

- ICAO – Annex 6 Operation of Aircraft, part I – International Commercial transport – Aeroplanes, Appendix 2, 5.14.
- ICAO – Human Factors Training Manual (Doc 9683).
- ICAO – Human Factors Digest No 5 – Operational Implications of Automation in Advanced Technology Flight Decks (Circular 234).
- FAR 121-579 - Minimum altitudes for the use of the autopilot.

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FOBN Reference : FLT_OPS – SOP – SEQ 02 – REV 03 – JUL. 2006