The Take-Off Securing function

By: Stéphane PUIG
Project Leader, Safety Initiatives Engineering

1 | Introduction

The utilization of erroneous parameters, during the flight preparation, have resulted in tail strikes, high speed rejected take-offs and runway overruns.

This triggered the elaboration by Airbus of pack one of the Take-Off Securing function (TOS), which automatically checks the entered data for consistency.

The second pack, currently under development, will offer more safety enhancing functionalities. One of them is the real time Runway length / Remaining distance on runway function, whose objective is to reduce the probability of take-off runway excursions.

This article is a presentation of both packs of this new safety enhancing function.

2 | Possible errors and their consequences

The take-off preparation by the pilots entails the computation of the aircraft weights (Zero Fuel Weight, Take-Off Weight) and respective CG positions, as well as the calculation of the different Take-Off speeds (V_1, V_R, V_2) and thrust rating.

These data may be obtained either by using load sheets and take-off charts, or by means of non-aircraft software applications (i.e. flight operations laptops).

Three types of errors may be performed during this process:

- Parameters entered into the tables or into the programs may be wrong (carried load, outside temperature, runway length etc…)
- Computations may be inaccurate (wrong interpretation of charts, bug in the software etc…)
- The data entry process into the Flight Management System (FMS) may be incorrect (distraction, stress etc…).

Figure 1: Minimum Unstick Speed (VMU) determination during flight test

Each of these types of errors may have consequences on the Take-Off speeds:

- A too low V_R inserted through the Multipurpose Control & Display Unit (MCDU), may lead to a tail strike
- A too low V_2 may lead to the flight path not clearing the obstacles in an one engine out condition
- A set of too high Take-Off speeds may lead to a runway overrun or too high energy rejected take-off (RTO).

Other possible consequences:

- An error on the A/C configuration at take-off (CONF/TRIM setting) may lead to an "auto rotation" or a nose heavy condition
- A take-off from a different runway from the intended one, or even from a taxiway, may lead to:
  - A collision on ground with another aircraft, vehicle or obstacle
  - A collision in the air with an obstacle
  - An overrun if no lift-off before the end of the runway (even more so if combined with a high temperature FLEX take-off)
  - A low or high energy runaway overrun (in case of RTO)
- A wrong thrust rating may result in a tailstrike, a runway overrun or a shift of the climb path.

3 Description of the Take-Off Securing function (TOS)

The TOS has been developed to detect, to the best extend possible, wrong data entered into the FMS.

The aim of the function is to perform consistency checks between several take-off parameters.

The function is composed of two packages of modifications:

- The first one, TOS pack 1, is already implemented on the A320 family (except the PITCH TRIM / MCDU / CG disagree alert), and is under development for the A330/A340 and A380 (target 2011).
- For the A320 family, TOS pack 1 will be updated to include the PITCH TRIM / MCDU / CG disagree alert that already exists on the A330/A340 and A380
- The second package, TOS pack 2, is under development for the A350 and will later be applied on the A380.

3.1 TOS pack 1

The first Take-Off Securing package is implemented on the A320 family of aircraft equipped with FMS release 1A.

The Thales system checks:
- The Zero Fuel Weight (ZFW) range
- The Take-Off speeds consistency.

The Honeywell system checks:
- The Zero Fuel Weight (ZFW) range
- The Take-Off speeds consistency
- The Take-Off speeds limitations.

3.1.1 Zero Fuel Weight range

As soon as a ZFW value is entered, a range check is performed:

ZFW / ZFWCG
140.0 / 25.0

$ZFW_{MIN} \leq$ 140.0 $\leq ZFW_{MAX}$

The ZFW entry is rejected and an "**ENTRY OUT OF RANGE**" caution message appears on the MCDU scratchpad when the check is not fulfilled.

Figure 2: MCDU scratchpad message for ZFW range check

Note: The previous very broad range check has been refined, under TOS pack 1, to be more relevant to each aircraft type.

3.1.2. Take-Off speeds consistency

This check is performed as soon as all Take-Off speeds are inserted in the PERF take-off page, or each time a take-off speed is modified.
A "**V1/VR/V2 DISAGREE**" caution message will appear on the MCDU scratchpad when the following condition is not fulfilled:

$$V_1 \leq V_R \leq V_2$$

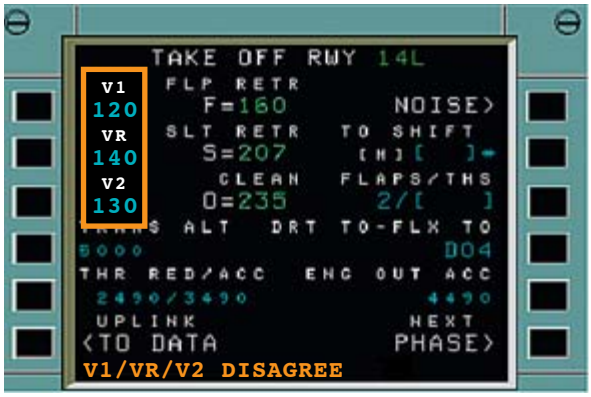


Figure 3: MCDU scratchpad message for TO speeds consistency check

3.1.3 Take-Off speeds limitations

V_{MC} and V_{S1G} limitations checks are launched when:
- ZFW, BLOCK and CONF are entered on the MCDU
- ZFW, BLOCK, CONF or take-off thrust setting are modified
- Engines are started.

V_{MC} limitation check:

$$V_1 \geq V_{MCG}$$
$$V_R \geq 1.05\ V_{MCA}$$
$$V_2 \geq 1.10\ V_{MCA}$$

V_{S1G} limitation check:

$$V_R \geq K_{VR} * V_{S1G}$$
$$V_2 \geq K_{V2} * V_{S1G}$$

(K_{VR} and K_{V2} are margin coefficients)

Minimum values are derived from V_{MC} and V_{S1G} and computations are based on pilot entered take-off data.

In case of an abnormal TO speed, the "**TO DATA/TOW DISAGREE**" caution message appears on the MCDU scratchpad.

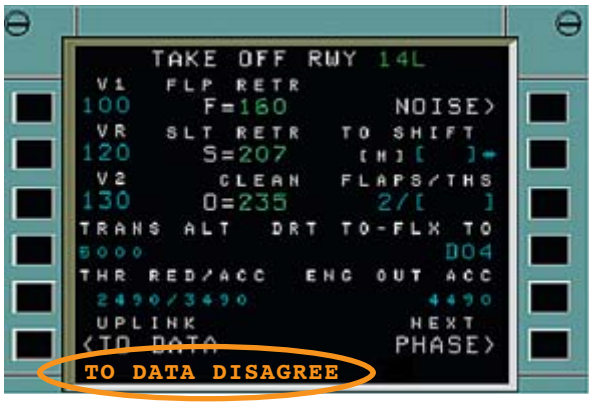


Figure 4: MCDU scratchpad message for TO speeds limitations check

3.1.4 *PITCH TRIM / MCDU / CG disagree alert (for A320 family)*

This check is performed when the TO Config Push Button is pressed, and during flight phase 3.

The following three parameters are checked for consistency:

- The Trimmable Horizontal Stabilizer (THS) setting (TRIM) entered in the FMS
- The theoretical TRIM calculated from the CG by the Flight Augmentation Computer (FAC)
- The real position of the TRIM from flight controls.

When one of these parameters differs from the two others by more than 1.3° of THS, the **PITCH TRIM / MCDU / CG DISAGREE** caution is displayed on the ECAM and a single chime aural alert is triggered.

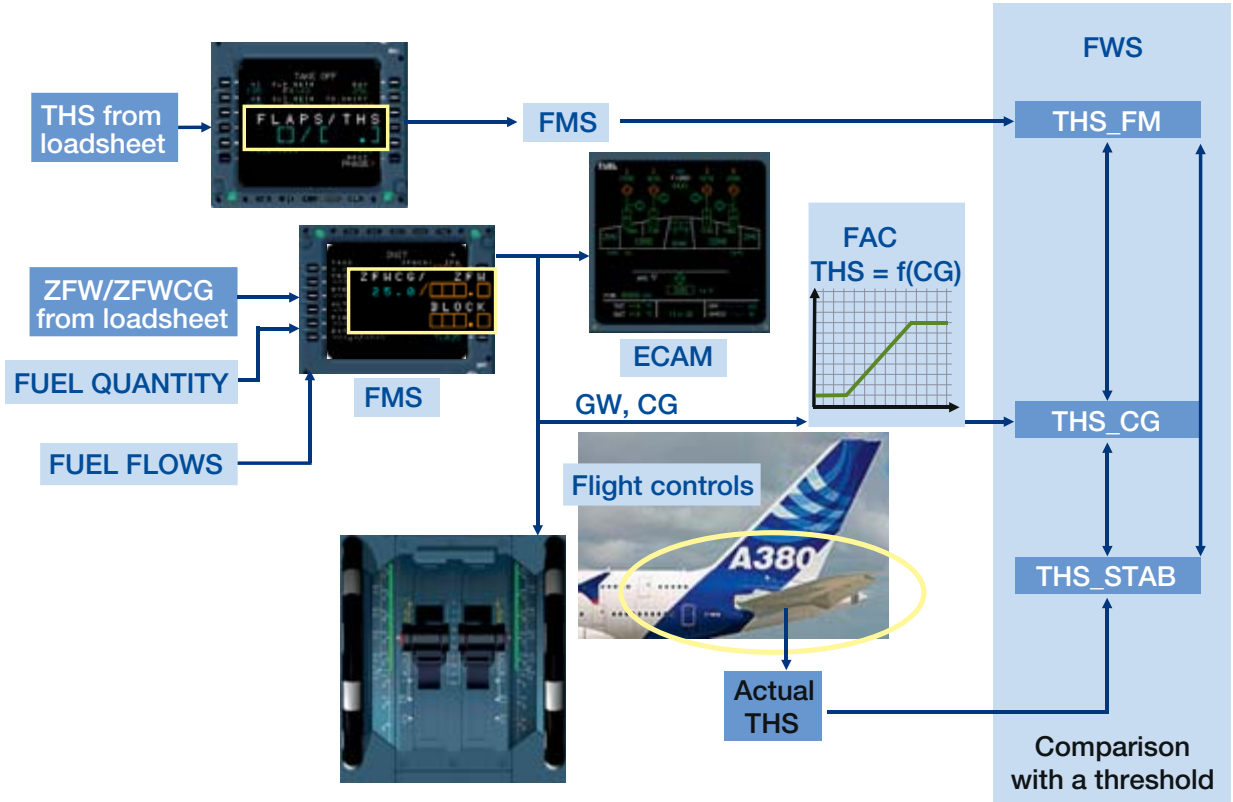
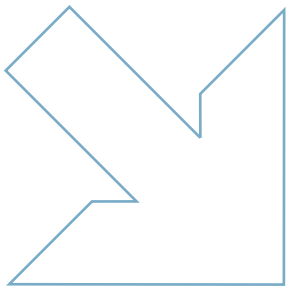


Figure 5: PITCH TRIM / MCDU / CG disagree check schematic



Summary of TOS pack 1 checks:

CHECKS	Risks covered	Implementation
TO speeds consistency	Inversion between two speeds and gross erroneous input of one TO speed	FMS release 1A THALES and HONEYWELL
ZFW refined range	Gross erroneous ZFW input in the FMS	
V_{S1G}/V_{MU} limitation ($V_2 > V_{2min}$ and $V_R > V_{Rmin}$	Erroneous input of too low V_2 and V_R in FMS and inconsistency between TO weight/CONF/THRUST and V_2/V_R for any weight. TO performances computation with erroneous parameters	FMS release 1A HONEYWELL
V_{MC} limitation ($V_1 > V_{1min}$, $V_2 > V_{2min}$ and $V_R > V_{Rmin}$	Erroneous input of a too low TO speed in FMS (taking into account thrust rating)	
PITCH TRIM / MCDU / CG DISAGREE alert on 320 family	Incorrect TRIM setting, Auto rotation, nose heavy	EIS S9.0, FAC 621 and FWS H2 F6 standards

Note:

V_{MU} *minimum unstick speed, is the calibrated airspeed at and above which the aeroplane can safely lift off the ground, and continue the take-off.*

V_{MCG} *minimum control speed on the ground. It is the calibrated airspeed during the take-off run, at which (when the critical engine is suddenly made inoperative) it is possible to minimize the deviation of the airplane by the use of the primary aerodynamic controls alone, to enable the take-off to be safely continued using normal piloting skill.*

V_{MCA} *minimum control speed in the air. It is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to minimize deviation of the airplane with that engine still inoperative, and maintain straight flight with an angle of bank of not more than 5 degrees.*

V_{S1G} *speed that corresponds to the maximum lift coefficient (i.e. just before the lift starts decreasing).*

3.3 TOS pack 2

TOS pack 2 will offer a more complete safety net against erroneous take-off parameters entered in the FMS. It will supplement the protection offered by TOS pack 1.

TOS pack 2 will offer the following additional checks:

- Take-Off speeds availability
- Runway limitation and remaining runway length
- Aircraft position on runway
- FLEX temperature setting.

3.3.1 *Take-Off speeds availability*

The objective is to avoid a take-off without Take-Off (TO) speeds (due to a last minute change, for example).
The system checks that the TO speeds have been inserted during the flight preparation.
It is launched when the crew checks the aircraft configuration before take-off.
It is relaunched automatically at take-off power application.
If the TO speeds are not available, the TO CONFIG test will be invalidated. This will trigger a "**NO FMS TO SPEEDS**" caution message on the ECAM and a single chime aural alert.

Figure 6: MCDU scratchpad message for runway limitation check (MCDU)

Figure 7: MCDU scratchpad message for runway limitation check (MFD)

3.3.2 *Runway length / Remaining distance on runway*

The objective is to reduce the probability of runway overruns.
To achieve this, the system performs the following:

- During the pre-flight phase, the system checks that the inserted TO data are consistent with the planned departure runway. The estimated lift-off run distance is compared with the distance available on the runway (including TO shift)
- During the take-off phase, the system compares the estimated lift-off run distance with the remaining distance on the runway, taking into account the real time position and speed of the aircraft.

If the system detects a risk of runway overrun during the pre-flight phase, a caution message is displayed on both the MCDU scratchpad and the ECAM.

Figure 8: ECAM alarm when the Lift-off run check detects a risk of overrun at take-off (take-off power condition is false)

If the system detects a risk of runway overrun during the take-off phase (thrust levers set in a position higher than the Climb (CLB) detent), a "**RWY TOO SHORT**" warning is displayed on the ECAM and a single chime aural alert is triggered.

Figure 9: ECAM alarm when the Lift-off Run check detects a risk of overrun at take-off (take-off power condition is true)

3.3.3 Aircraft position on airport

The objective is to prevent a take-off from:
- A taxiway
- A wrong runway.

As soon as the thrust levers are set in a position higher than the CLB detent, the system compares the position of the aircraft with the FMS navigation database.

If the aircraft is not on a runway, an "**ON TAXIWAY**" warning is displayed on the Navigation Display (ND) (all the ranges are concerned) and an "ON TAXIWAY!" specific aural alert is triggered.

Figure 10: ON TAXIWAY message on ND.

If the aircraft is not on the runway selected by the pilot, a "**NOT ON FMS RWY**" caution message is displayed on the ND (all the range are concerned) and a "NOT ON FMS RWY!" aural alert is triggered.

3.3.4 Take-off FLEX temperature setting

The objective is to check the FLEX temperature setting upon selection of FLEX take-off.
On current aircraft, when the thrust levers are set on the MCT/FLX detent, the FADEC compares the entered FLEX setting with the outside temperature.
In case of incompatibility, the "**ENG THR LEVERS NOT SET**" caution, as well as the procedure to follow, are displayed on the ECAM and a single chime aural alert is triggered.
In the frame of TOS2, the above ECAM caution message will be changed to indicate "**SAT ABOVE FLX TEMP**".

4 | Conclusion

The Take-Off Securing function performs automatic consistency checks between several take-off parameters.

The function is composed of two packs for FMS inputs consolidation:
- The first one, TOS pack 1, is already implemented on the A320 family (except the PITCH TRIM / MCDU / CG disagree alert) and is under development (target 2011) for the A330/A340 and A380.
  For the A320 family, TOS pack 1 will be updated to include the PITCH TRIM / MCDU / CG disagree alert that already exists on the A330/A340 and A380.
- The second package, TOS pack 2, is under development for the A350 and will later be applied on the A380.

The TOS function represents a safety net against erroneous take-off parameters, and is expected to reduce the number of experienced tail strikes, runway overruns and loss of control during take-off.

Two more packs are under study, which will be dedicated respectively to the take-off monitoring and weight & CG estimations.

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Airbus
Product Safety department (GS)
1, rond point Maurice Bellonte
31707 Blagnac Cedex - France
Fax: +33(0)5 61 93 44 29
safetycommunication@airbus.com

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