



Takeoff Surveillance & Monitoring Functions

Airbus has continuously improved takeoff safety since the “TO CONFIG TEST” pushbutton was first introduced on A300 and A310 aircraft, and with the development of the Takeoff Surveillance (TOS1 & TOS2) and Takeoff Monitoring (TOM) functions.

The TOS2 package that was initially developed for the A350 is now available for A320 family and A330 aircraft. This is an opportunity to review the checks that are performed by each function, from cockpit preparation to takeoff.

This article supersedes “The Takeoff Securing function” article published in the Safety first issue #8 (July 2009).

SECURING THE TAKEOFF



There have been several events during takeoff over this last decade. In certain cases, the aircraft took off with incorrect trim or flaps settings, which increases the risk of runway overrun or tail strike event. Erroneous parameters were sometimes used for the performance calculation, leading to incorrect takeoff speeds or Flex thrust computation. On other occasions takeoff data was not updated in the FMS following a late runway change, leading to takeoff without the correct performance data in the FMS. A number of aircraft started takeoff from a taxiway intersection when the computed performance was for the entire length of runway. There were also takeoffs starting on a taxiway or from the opposite QFU. Finally, few cases of residual braking leading to an abnormal aircraft acceleration were reported during takeoff roll.

Most of these events can be avoided by complying with the FCOM Standard Operating Procedures (SOP). Indeed, several crosschecks enable the flight crew to identify discrepancies. These examples however show that errors can still be made, which typically occur when there are stressful situations, high crew workload, last minute changes or demanding ATC requests.

Airbus developed Takeoff Surveillance and Monitoring functions to provide additional safety-nets to support the flight crew during takeoff preparation and takeoff roll.

Evolution of the Takeoff Surveillance & Monitoring functions on Airbus aircraft

The “TO CONFIG TEST” pushbutton was first introduced on A300/A310 aircraft. When pressed, it checks the correct aircraft configuration for takeoff. If the aircraft configuration is not correct, the CONFIG light comes on the Master Warning Panel (A300) or an ECAM alert triggers (A300-600/A310).

Airbus introduced the first step of the Takeoff Surveillance functions (TOS1) on A320 family aircraft in 2009 and then on A330/A340 aircraft in 2013. TOS1 improves the checks performed on flaps and trim settings and adds a check of the performance parameters entered in the FMS (aircraft weight and takeoff speeds).

The second step of the Takeoff Surveillance functions (TOS2) was introduced on A350 aircraft in 2018 and is now available on A320 family and A330 aircraft. TOS2 checks that the aircraft is positioned on the intended runway and that the expected takeoff performance – based on data entered in the FMS by the crew – is compatible with the runway distance available.

The Takeoff Monitoring function (TOM) was first developed on A380 in 2018 and is now also available on A350. TOM monitors the acceleration of the aircraft during the takeoff phase and warns the flight crew if a lower-than-expected acceleration is detected. ■

TOS CHECKS DURING COCKPIT PREPARATION

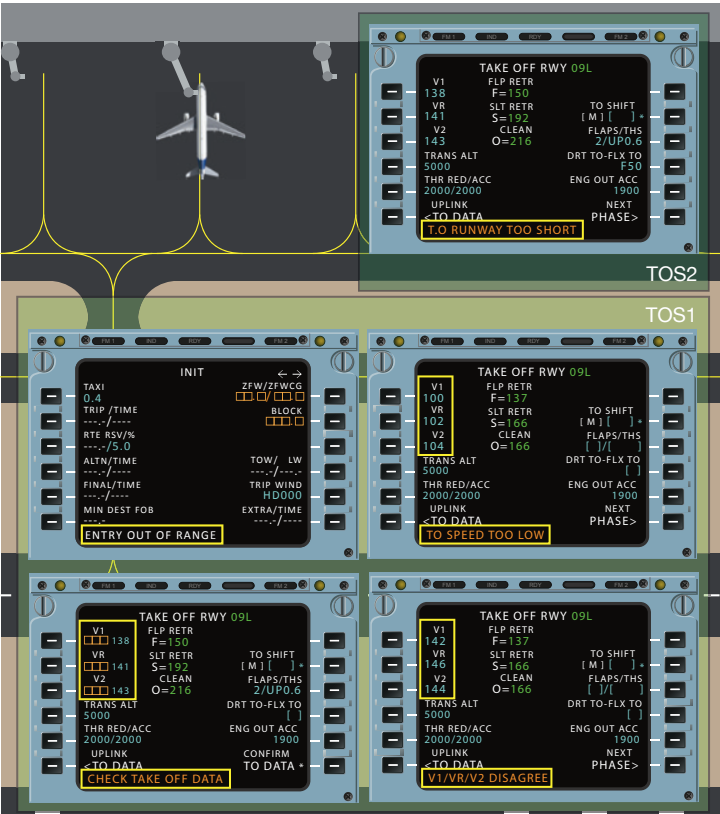
ZFW and takeoff speeds check (TOS1)

During the cockpit preparation, TOS1 checks for gross errors on weight or takeoff speeds inserted into the FMS. The MCDU/MFD can display the below scratchpad messages (fig. 1).

- ENTRY OUT OF RANGE**: Inserted Zero Fuel Weight value is outside of the correct range.
- TO SPEED TOO LOW** (A320/A330) or **T.O SPEED TOO LOW CHECK TOW AND T.O DATA** (A380/A350): Inserted takeoff speeds do not respect the required margins with minimum control (VMCG, VMCA) or stall (VS1G) speeds.
- V1/VR/V2 DISAGREE**: Inserted takeoff speeds do not respect the rule $V1 \leq VR \leq V2$.
- CHECK TAKE OFF DATA**: The flight crew changed the takeoff runway but takeoff speeds that were entered are applicable for another runway. The takeoff speeds are therefore invalidated and must be either re-entered or re-validated.

Lift-off distance check (TOS2)

TOS2 computes the Lift Off Distance (LOD) expected with the performance dataset entered by the crew (weight, thrust, Flaps, OAT and VR/V2) and compares it with the available runway length of the takeoff runway selected in the FMS. The LOD computation takes into account any takeoff shift entered in the MCDU/MFD. If the available runway length is lower than the LOD, the MCDU/MFD scratchpad displays a **T.O RUNWAY TOO SHORT** message (fig. 1).

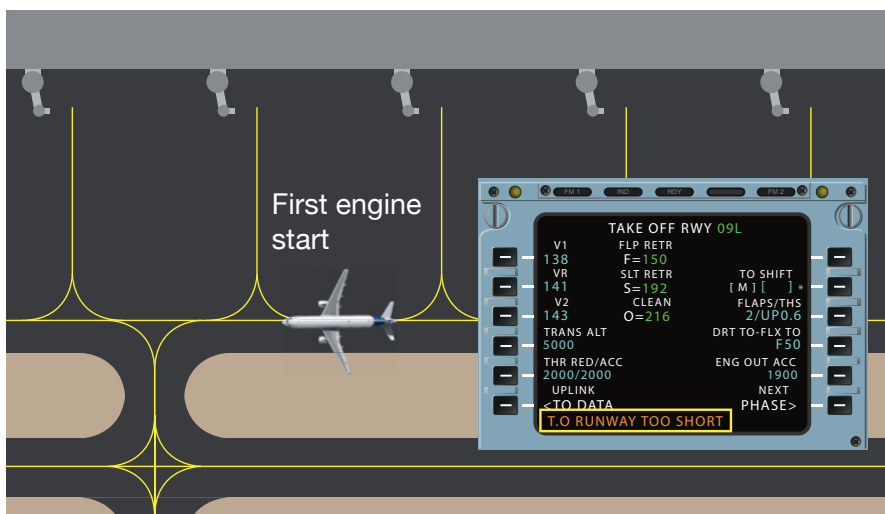


(fig.1)
TOS1 and TOS2 potential scratchpad messages during cockpit preparation

TOS CHECKS AT ENGINE START

Lift-off distance check (TOS2)

TOS2 re-performs a LOD check at engine start, using actual fuel quantity data now available from the fuel system. If the available runway length is lower than the LOD, the MCDU/MFD scratchpad displays a **T.O RWY TOO SHORT** message (fig.2). ■



(fig.2)

TOS2 potential alert at first engine start

TOS CHECKS DURING TAXI PHASE (T.O CONFIG PUSHBUTTON PRESSED)

During taxi, the SOP request the flight crew to press the T.O CONFIG pushbutton. TOS functions then perform the following checks:

Flaps check (TOS1)

TOS1 checks consistency between the Flaps setting inserted by the crew in the Takeoff PERF page and the actual flaps setting. If there is an inconsistency, this will trigger the **F/CTL FLAP/MCDU DISAGREE** (A320/A330/A340) (fig.3) or **F/CTL FLAP/FMS DISAGREE** (A350/A380) ECAM message.

Trim Check (TOS1)

TOS1 also compares the trim setting entered by the crew into the Takeoff PERF page with the actual Trimmable Horizontal Stabilizer (THS) position and with the trim computed by the FAC/FMGEC/FE based on the CG value provided by the fuel management system. If an inconsistency is detected, this will trigger the **F/CTL PITCH TRIM/MCDU/CG DISAGREE** (A320/A330/A340) (fig.3) or **F/CTL PITCH TRIM/FMS/CG DISAGREE** (A350/A380) ECAM message.

Takeoff speeds check (TOS1)

TOS1 performs an additional takeoff speeds check in the same way as it was done during the cockpit preparation phase. If one of the checks fails, the Flight Warning System triggers an ECAM alert and displays the associated MCDU/MFD scratchpad message **(fig.3)**:

- **T.O SPEEDS TOO LOW**
- **T.O V1/VR/V2 DISAGREE**
- **T.O SPEEDS NOT INSERTED**

Lift-off distance check (TOS2)

TOS2 performs an additional LOD check. If the available runway length is lower than LOD, the Flight Warning System triggers the ECAM alert **T.O RWY TOO SHORT** **(fig.3)** and displays the associated scratchpad message. ■



(fig.3)

TOS1 and TOS2 potential alerts when the T.O CONFIG pushbutton is pressed

TOS CHECKS AT TAKEOFF THRUST APPLICATION

When the flight crew initiates the takeoff roll by setting the thrust levers to takeoff thrust, TOS2 provides additional safety nets by checking that the aircraft is on the intended runway and that the required liftoff distance is compatible with the available runway distance, taking into account the real aircraft position on the runway.

Check of takeoff start position (TOS2)

When the crew applies takeoff thrust, TOS2 checks if the aircraft is positioned within an area that contains the takeoff runway entered in the FMS **(fig.4)**.

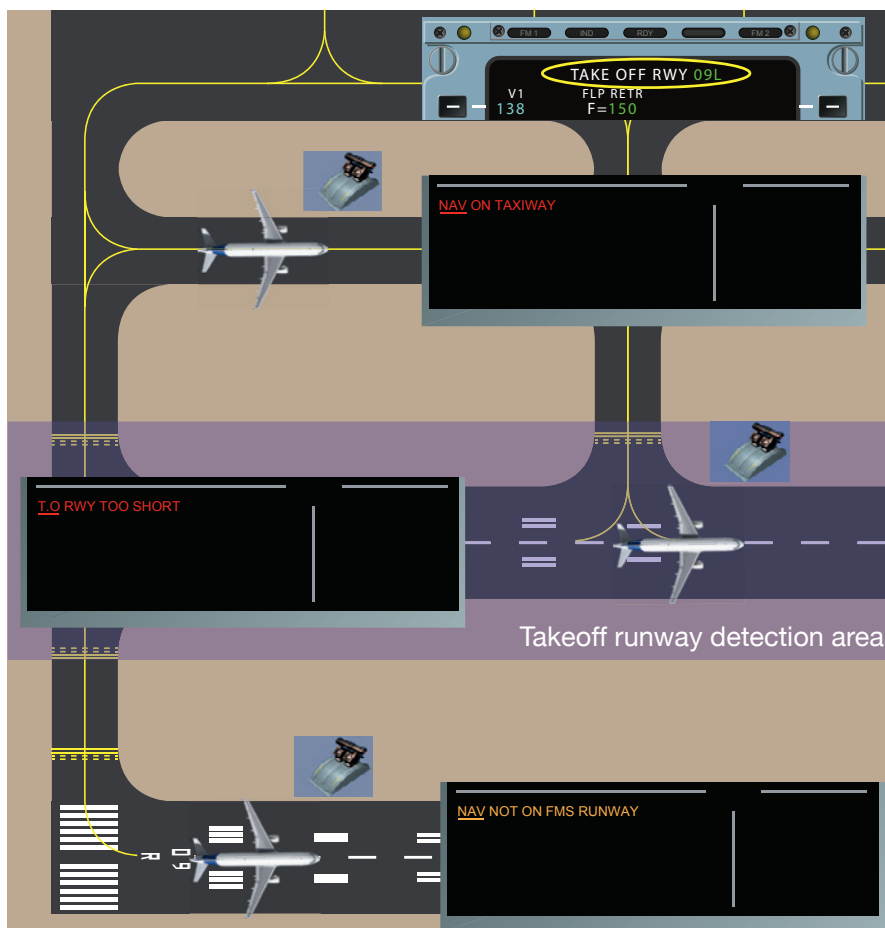
If the flight crew applies takeoff thrust when the aircraft is still on a taxiway and outside the runway area, this will trigger the red ECAM warning **NAV ON TAXIWAY**.

The alert can also be an amber caution depending on the FWS standard.

If the flight crew applies takeoff thrust while the aircraft is positioned on a different runway from the one entered into the FMS, this will trigger the ECAM caution **NAV NOT ON FMS RUNWAY**.

Lift-off distance check (TOS2)

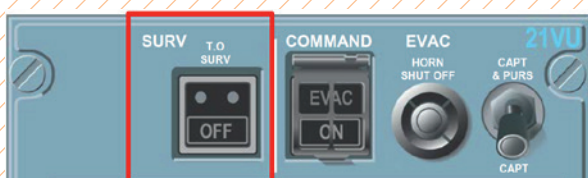
When the flight crew applies takeoff thrust, TOS2 performs a final LOD check based on the real aircraft position. If the runway distance available in front of the aircraft is lower than the computed LOD (e.g. an aircraft commencing takeoff from a wrong runway intersection or from an incorrect runway with an insufficient length), this will trigger the red ECAM warning **T.O RWY TOO SHORT** (fig.4). ■



(fig.4)
TOS2 potential alerts at takeoff thrust application

De-activation of TOS 2 function

The T.O SURV pushbutton switch de-activates TOS2 function to avoid spurious alerts if the Navigation/Airport database information for a particular airport is not up-to-date. This pushbutton switch is installed on A320/A330 aircraft equipped with the TOS2 and can be installed on A350 as an option.



(fig.5)
Example of the T.O SURV pushbutton switch on A320 aircraft

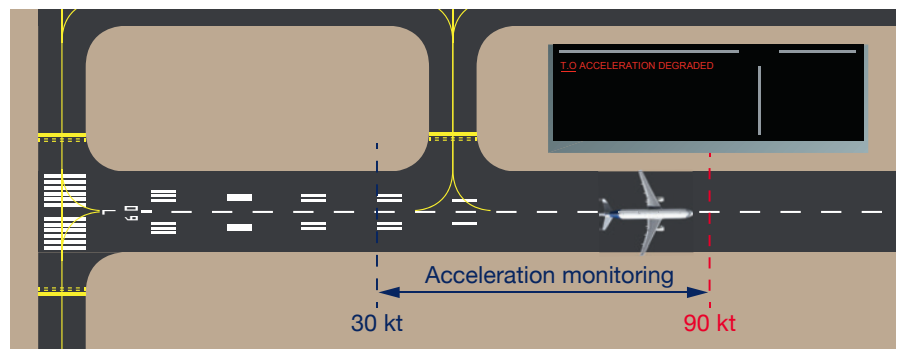
TAKEOFF MONITORING (TOM)

TOM provides an additional safety-net during the takeoff roll. From 30 kt, it compares the expected acceleration with the real acceleration of the aircraft. If the difference between the real aircraft acceleration and its expected acceleration is more than 15 % when the aircraft reaches 90 kt, TOM will trigger the red ECAM warning **T.O ACCELERATION DEGRADED**.

TOM can be de-activated on A350 aircraft using the T.O SURV pushbutton switch (if installed). ■

(fig.6)

TOM alert displayed if the difference between the aircraft's actual acceleration and its expected acceleration is more than 15 % when the aircraft reaches 90 kt



OPERATIONAL CONSIDERATIONS

SOP ensure correct takeoff preparation and request checks for error identification

Adherence to SOP ensures takeoff preparation is completed correctly regardless of whether an aircraft is equipped with the Takeoff Surveillance and Monitoring functions. Correct takeoff preparation by the crew is ensured by promoting the following:

- A takeoff briefing should be relevant, concise and chronological
- The takeoff performance computation should be independently performed by both flight crew members and crosschecked
- Ensure accurate aircraft positioning data by systematically inserting T.O SHIFT during the departure phase when the takeoff will start from an intersection.

The Takeoff Surveillance and Monitoring functions must be considered as a safety net and are not replacements for full application of SOP actions.

An up-to-date Navigation/Airport database is key

TOS2 function relies on the FMS Navigation Database (for A320/A330/A380) and on the Airport database (for A350). Therefore the database must be up-to-date to fully take advantage of the TOS2 function. An outdated database may lead to spurious TOS2 ECAM alerts or non-triggering of an alert.

NOTAMs impacting the TOS2 function

NOTAMs that modify the runway length available may not always be incorporated into the Navigation/Airport database. Airbus recommends that Operators evaluate the impact on TOS2 of these NOTAMs and request that their flight crew deactivates the function to avoid spurious alerts if necessary **(fig.5)**.

Takeoff Surveillance alerts and RTO

Airbus recommends to reject the takeoff if TOS2 ECAM alerts are triggered at takeoff thrust application – including:

- NAV ON TAXIWAY
- NAV NOT ON FMS RUNWAY
- T.O RWY TOO SHORT

Takeoff Monitoring alert and RTO

Many ECAM alerts are inhibited between 80 kt and 400 ft (takeoff inhibition phase). Any warning received during this period must be considered as significant. For this reason, Airbus recommends to reject the takeoff if the **T.O ACCELERATION DEGRADED** warning is triggered. The TOM function is designed so that if this warning appears when the aircraft reaches 90 kt, the flight crew can safely perform a rejected takeoff before V1. ■

SUMMARY & AVAILABILITY OF TOS AND TOM FUNCTIONS

Focusing on the types of event that were reported to Airbus in the last ten years shows that the takeoff surveillance and monitoring functions would detect the majority of them and alert the flight crew.

(fig.7)

Summary of the potential occurrences addressed by TOS and TOM functions

Potential Occurrences / Design Mitigation	T.O Configuration P/B	TOS1	TOS2	TOM
Wrong CG/trim setting	Yes (Trim inside green band)	Yes (check of Trim vs FMS and computed CG)		
Wrong flaps setting	Yes (Flap not in CLEAN or FULL)	Yes (Actual Flaps vs FMS Flaps)		
Erroneous FMS Takeoff Speeds		Yes		
Runway too short for takeoff			Yes	
Incorrect aircraft position at takeoff			Yes	
Degraded acceleration at takeoff				Yes

The table below summarizes the availability of the TOS and TOM functions on the various aircraft types. The availability for retrofit depends on the exact aircraft configuration (FMS, EIS, ADIRU, and FWS standards). For more details on the system pre-requisites, operators are invited to contact Airbus customer support. ■

Aircraft Type	T.O CONFIG P/B	TOS1	TOS2	TOM
A300	Basic	No	No	No
A310	Basic	No	No	No
A300-600	Basic	No	No	No
A320	Basic	FMS R1A*	Option	Under feasibility study
A330	Basic	FMS R1A*	Option	Under feasibility study
A340	Basic	FMS R1A*	No	No
A350	Basic	Basic	Basic	Basic**
A380	Basic	Basic	Under feasibility study	Basic

* TOS1 is basically activated on all aircraft fitted with FMS2 release 1a and later standards (see below table for availability)

**Available on A350-1000 in 2020

(fig.8)

Availability of the Takeoff Surveillance and Monitoring functions

Aircraft Types & Engines	HONEYWELL FMS		THALES FMS	
	MSN*	Delivery Date	MSN*	Delivery Date
A320 CFM56	4379	Aug-10	4030	Sep-09
A320 IAE	4066	Oct-09	4110	Dec-09
A320neo	All aircraft			
A330 GE	1458	Nov-13	1276	Jan-12
A330 PW/RR	1425	Jun-13	1627	May-15
A330neo	All aircraft			
A340	Retrofit only			

* Manufacturer Serial Number: first aircraft with FMS release 1a or later standard installed in production line

(fig.9)

Availability of the TOS1 (Release 1A FMS standard or later standards) for A320/A330/A340 aircraft

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Airbus developed the Takeoff Surveillance TOS 1 & TOS 2 and Takeoff Monitoring (TOM) functions to provide an additional safety-net against the risks of runway overrun or tailstrike at takeoff that may occur due to:

- Errors in takeoff performance computation, or errors when entering takeoff data
- Takeoff starting from an incorrect position
- A degraded acceleration condition, where the aircraft's actual acceleration is lower than the expected acceleration during the takeoff roll.

The TOS2 was initially developed for the A350 aircraft and it is now available for the A320 family and on A330 aircraft.

It is important to remember that these Takeoff Surveillance functions are enhancements that act as an additional safety-net. They do not replace the correct application of SOP by the flight crew.

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