180° turns on runway

Performing a 180° turn or U-turn on a runway may seem an ordinary maneuver compared to other phases of the flight. However, operational experience over the past 10 years shows that unintentionally leaving the runway while completing a U-turn can happen, even to experienced pilots, in any conditions, even on dry runway, on any aircraft type including the A320 family aircraft. A specific technique exists for such U-turns to avoid runway excursions.

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U-TURNS ON RUNWAY: A SIGNIFICANT CONTRIBUTOR TO RUNWAY EXCURSIONS

Who would naturally think about U-turns on runways when referring to aviation accidents? Although not intuitive, this relationship does exist. Indeed, operational experience shows that a number of runway excursions resulted from a failure to manage such a maneuver correctly. In less than 10 years, more than 20 runway excursions with some incidents leading to an ICAO Annex 13 investigation have been reported to Airbus.

Beyond the potential for significant aircraft damage or time for inspection and repairs, the consequences of such events translate mainly into operational disturbance. They lead to flight cancellation, the need to off-load and defuel the aircraft when it has to be returned to the pavement, not to mention the impact on airport operations with the potential closure of the runway and its associated safety implications. The airline involved is often put in an embarrassing position from a brand point of view due to the speed of modern visual communications.

The number of recent events may be growing due to a reporting bias, but the issue has now drawn attention from a safety vantage point.

Thanks to the reported events, Airbus was able to analyze and understand the conditions of occurrence.

Lessons from in-service events

Some possible preconceived ideas are dismissed by facts especially concerning the runway contamination, the pilot's experience or the type of aircraft. Let's review the 21 events reported to Airbus over the past 10 years in figures:

Aircraft type Runway state	A320 family	A330 family	A300/A310 family	A350	Total
Contaminated	5	4	0	1	10
Dry	2	6	0	0	8
No information	0	1	2	0	3
Total	7	11	2	1	21

> “Any runway excursion, as smooth as it may seem, requires the aircraft to be checked prior to the next flight.”

> “To ensure the aircraft integrity for the next flight, to allow safety lessons to be learnt and to be able to take appropriate mitigation measures from analyzing all events of similar nature, all runway excursion events need to be reported.”

Beyond these two dimensions, a thorough analysis of the events shows that the runway surface quality is also an important parameter. Indeed, a degraded or damaged runway surface may have as much influence on the performance of a U-turn as a contaminated runway.

As for the pilot’s background, it turns out that it was extremely variable from one event to the other. In other words, a runway excursion when performing a U-turn on a runway is not the preserve of the least experienced pilots…

Reporting: the most precious input to enhancing safety

In one surprising event, although the crew had experienced a runway excursion, they realigned the aircraft and took off. Damage on the gear was observed at arrival. Even at low speed, a runway excursion can damage the aircraft in a way that can affect the safety of the following flights. Any runway excursion, as smooth as it may seem, requires the aircraft to be checked prior to the next flight in accordance with the AMM guidelines.

Moreover, to ensure the aircraft integrity for the next flight, to allow safety lessons to be learnt and to be able to take appropriate mitigation measures from analyzing all events of similar nature, all runway excursion events need to be reported.

As of today, the analysis of the events made available to Airbus through reporting allowed us to dismiss possible preconceived ideas, such as: it only occurs to the least experienced pilots or only on contaminated runways or with large aircraft. It also allows us to highlight the key points or parameters that need to be checked before initiating the turn and executing the maneuver, as well as to emphasize the best technique and tips to perform such turns safely.

Eventually, thanks to airlines reporting, the technique available today in the FCOM is going to be revisited and improved as part of the FCTM. Key values relating to the recommended runway width will be kept in the FCOM. These updates will be available by the end of 2016. ■

TECHNIQUE AND TIPS TO PERFORM A SAFE U-TURN ON THE RUNWAY

The analysis of in-service events allowed the technique for U-turns in the FCOM to be revisited. The philosophy of the new revision will align with the existing content and emphasize the key steps of the technique for performing successful and safe U-turns. The technique was initially developed for U-turns on a runway, where there are standard markings at the borders of the runway.

As far as possible, a U-turn on the runway needs to be prepared before arriving on the runway. The preparation includes a discussion on who will be PF and in which direction should the turn be performed in accordance with the airline policy.

Performing a safe U-turn on a runway is not just a matter of managing the turn itself. It starts before initiating the turn…

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Before initiating the turn

Initiating the turn in good conditions relies on a number of complementary aspects beyond the ones mentioned before.

Suitability of runway width with the conditions of the day

Performing a safe U-turn on a runway requires anticipating the space required for the safe completion of the maneuver. The minimum runway width for a given aircraft type is provided in the FCOM. However, it is important to keep in mind that this value is based on the following assumptions: the runway is dry, the runway surface quality is good and the technique recommended by Airbus is used. Therefore, it may be necessary to add some margins if these conditions are not met (e.g. contaminated runway).

In summary, before considering a U-turn on a runway, check that the runway width is sufficient with respect to the minimum published in the FCOM possibly adjusted to the anticipated conditions of the day.

> “The minimum required runway width to carry out a U-turn is based on the following assumptions: a dry runway, a good runway surface and the application of the correct technique.”

Consider the actual runway surface quality

As previously mentioned, the state of the runway may require the margins provided by the FCOM to be adapted. The maneuver is to be performed with the maximum available steering of the nose wheels and in such a configuration, a poor surface may make the wheels slip and increase the turn radius.

It is important to keep in mind that painted areas such as runway threshold markings can be significantly more slippery than the rest of the runway. Indeed, some investigations highlighted that the repainting of the white strips tended to fill the runway’s textured surface. In other instances, pieces of multiple layers of painted surface became detached over time, thus generating depressions likely to retain rain water even though the remainder of the runway had already dried up.

As a consequence, special care must be taken when the trajectory requires taxiing the aircraft over a painted surface. A good friction coefficient experienced while still on the unpainted area is not necessarily representative of the one when on the painted marks. The crew must be ready to reassess the situation if any unexpected skidding during the turn is experienced.

Control the ground speed and adapt it to the conditions of the day

Remaining on the runway while performing a U-turn requires control of the trajectory at all times. This involves before initiating the turn:

» Stabilizing the trajectory
Stabilizing the initial trajectory before the turn is key in many respects. It allows for:
- optimization of the point of initiation of the turn
- compliancy with the assumptions used to determine the minimum runway width required, i.e. the maneuver is properly performed (initial recommended divergence angle)
- reduction of the number of parameters to be managed during the turn itself.

In order to optimize the turn initiation point and the distance required to complete the turn, it is recommended to adopt a divergence angle from the runway axis. The advisable divergence angle varies depending on the aircraft type but it typically ranges between 15° and 25°.

As illustrated in **Figure 1,** increasing the divergence angle leads to an increase in the turn radius. For example, adopting a divergence angle of 40° instead of the recommended 20° for an A330-300 leads to an increase of about 2 meters. Decreasing the divergence angle by too large an amount would result in the main landing gear possibly exiting the runway at initiation of the turn.

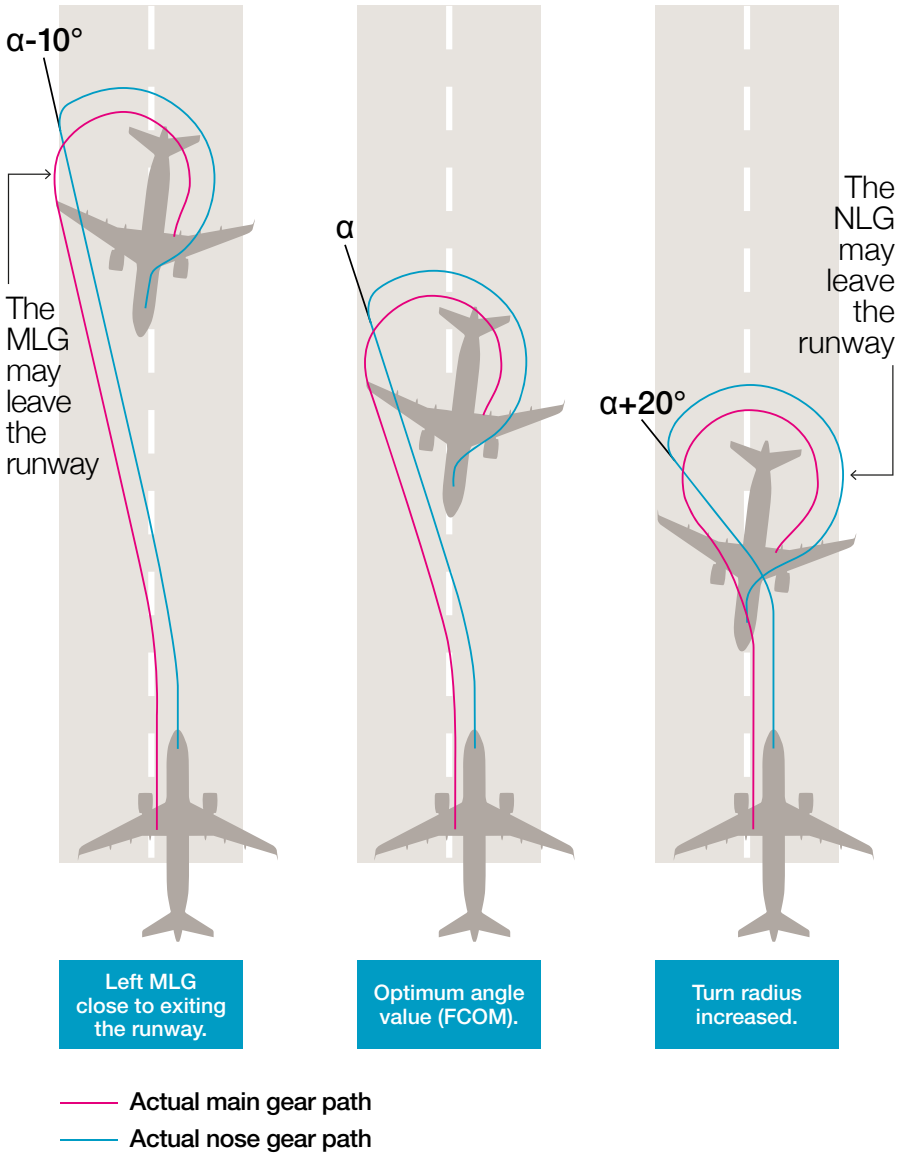
A330-300	Divergence angle	Measure of necessary width Nose Wheel Steering Angle (NWSA) 95% (m)	Difference compared with FCOM recommended value of 20° (m)	Measure of necessary width NWSA 80% (m)	Difference between 80 and 95% NWSA (m)
	10°	56.2	-0.17	65.6	9.4
	Recommended 20°	56.4	0	65.7	9.3
	40°	58.1	1.7	67.4	9.3

» Stabilizing the ground speed
The recommended ground speed for the 180° maneuver should be between 5 and 10 kt on most aircraft. If the speed is not stabilized before the turn, larger thrust adjustments may be needed during the turn. However, these adjustments can lead to an increase beyond the recommended speed, and may be a contributor to a runway excursion.

As mentioned earlier, any degradation of the runway state either due to runway surface condition or contamination requires additional precautions and margins. In terms of speed, it is safer to target the lower boundary of the recommended speed window, namely 5 kt, to perform a U-turn on a degraded runway.

BEST PRACTICE

On A300/A310, A330/A340 and A350 families, on dry runways, the use of differential braking to stop one gear (Braked Pivot Turn technique) may induce stress on this gear and could have fatigue effects over time on the gear. Such a technique is therefore not recommended. However, on a wet or contaminated runway, the lower friction coefficient reduces the induced stresses and differential braking, whilst avoiding pivot braking, could help to manage the turn.
This recommendation does not apply to A320 family and A380 aircraft, for which the Braked Pivot Turn technique is usually used without adverse effect on the gears.



(fig.1)
Turn radius evolution as a function of the divergence angle α

Performing the turn

During the maneuver, the ground speed is a key parameter to manage: the objective is to maintain a low (5 to 10 kt) but steady ground speed. If too much speed is lost, turning the aircraft will become more difficult to manage and it may eventually come to a complete stop. To avoid stopping, applying some additional thrust may be necessary. However, gaining too much speed could increase the chances of the aircraft exiting the runway. Maintaining a continuous speed before and during the turn is therefore of paramount importance.

Initiating the turn

For field of view reasons, the turn is recommended to be performed by the crew member sitting on the seat opposite to the direction of the U-turn. This means that to turn right, the flight crew member on the left hand side of the cockpit is PF; respectively to turn left, the flight crew member on the right hand side is PF.

The visual reference to initiate the turn depends on the aircraft type. On most Airbus aircraft, the turn is to be initiated when the PF assesses that he/she is physically directly over the runway edge.

Once the PF reaches the appropriate initiation point, he/she needs to progressively use up to full tiller deflection to turn the aircraft.

During this initial maneuver, due to the aircraft inertia the nose wheels are not fully aligned with the aircraft trajectory. This misalignment reduces the grip of the nose wheels onto the runway and may lead the aircraft to skid if the nose wheels are not turned smoothly and progressively. This is why an aggressive application of full nose wheel steering should not be done.

The speed can be maintained by applying small amounts of asymmetric thrust and keeping idle thrust on the engine on the inside of the turn. As explained before, maintaining a continuous speed is key and after any adjustment to the thrust, the speed must be carefully monitored.

During the turn

As shown in **Figure 1**, if the divergence angle affects the required turning distance, then the steering value is a parameter even more significant. The minimum distance published in the operation documentation considers a full steering order throughout the whole maneuver.

Throughout the turn, the PF is focused on the dynamics of the maneuver. He/she is looking outside in the direction of the expected aircraft trajectory, and adjusting the aircraft speed accordingly.

The role of the PM is at all times to monitor not only the aircraft trajectory but also the aircraft ground speed and to call out any deviation. The PM can monitor the heading, the ground speed indication as well as the ETACS when available. Indeed, by focusing on the outside, the PF cannot closely monitor these parameters and especially the aircraft ground speed to detect any excursion outside the recommended speed range; therefore, the role of the PM is essential.

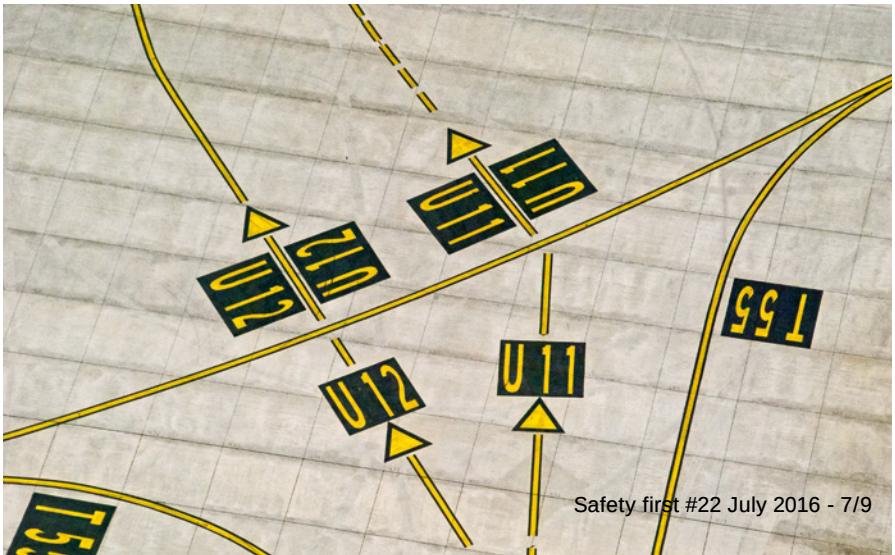
Finishing the turn

In this phase of the turn, the main challenge is to get the aircraft aligned on the centre of the runway without jeopardizing the remaining runway length or the planned take-off distance available.

When the aircraft is aligned with the runway, the tiller is to be released smoothly before stopping the aircraft to make sure that the nose wheel is aligned with the aircraft and therefore ready to initiate the take-off roll in good conditions.

At any stage before or during the maneuver, should any problem arise, stop and call the tower to get support from a tug. Keep in mind that it is most preferable to call a tractor to finish the maneuver, rather than to recover the aircraft with a landing gear off of the runway. ■

> “At any stage before or during the maneuver, should any problem arise, stop and call the tower to get support from a tug.”



Performing a U-turn on a runway is not an insignificant maneuver. Safely performing it starts with good preparation and a precise initiation of the turn as well as implementing the technique properly at the right speed.
Whether it has to be performed before taking-off or at the end of the flight, some key aspects are to be kept in mind:

- Carefully check the minimum distance published in the operational manual versus the available runway width, keeping in mind that the minimum 180° turning distance published values correspond to a dry runway
- Pay attention to the runway condition, both surface quality and contamination, as they may induce skid and may increase the turn width. Add reasonable margins accordingly
- Adapt the speed to the runway condition (within the recommended speed range)
- In case of a problem at any stage of the overall maneuver, stop the aircraft and call for support
- Should the crew become aware that the aircraft has left the runway surface, even slightly, report the occurrence and inspect the aircraft before taking-off

Some simple advice to avoid big problems!

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