Aborted landing after thrust reverser selection

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Introduction

On the 8th of April 2022 around noon, the captain of an Airbus A320-214 (fitted with CFM56-5B4/3 engines) registration CS-TNV aborted a landing at Copenhagen airport (EKCH) after ground contact, and after thrust reversers had been selected.

Both engine thrust reversers started to deploy when the thrust levers were pulled to reverse, but the left thrust reverser did not stow when the thrust levers were moved forward. The aircraft got airborne, but controllability of the aircraft was significantly affected.

The Danish Accident Investigation Board (AIB) initiated a safety investigation to determine the factors involved in the serious incident. Accredited representatives from the French BEA, the Portuguese GPIAAF, the American NTSB and the UK AAIB supported the safety investigation together with technical advisors from EASA, Airbus, CFM and the thrust reverser hardware manufacturers.

Sequence of events

Based on data from the FDR, QAR (DAR) and CVR combined with airport CCTV recordings and crew interviews, the following sequence of events was uncovered:

Despite windy conditions, the ILS approach to runway 30 was stabilized. The aircraft was flared and the left main gear got contact with the runway. The captain initiated derotation and unlatched and moved the thrust levers to full reverse. During the touchdown, the captain felt uncomfortable with the aircraft attitude, and decided that the safest option was to abort the landing. The captain was not aware that he had selected reverse thrust.

Around the same time as the captain moved the thrust levers forward, the aircraft bounced slightly, and the Weight on Wheel (WoW)/ground signal was interrupted on the left main gear. The left thrust reverser system did not latch a stow command, and three out of four blocker doors on the left thrust reverser remained deployed.

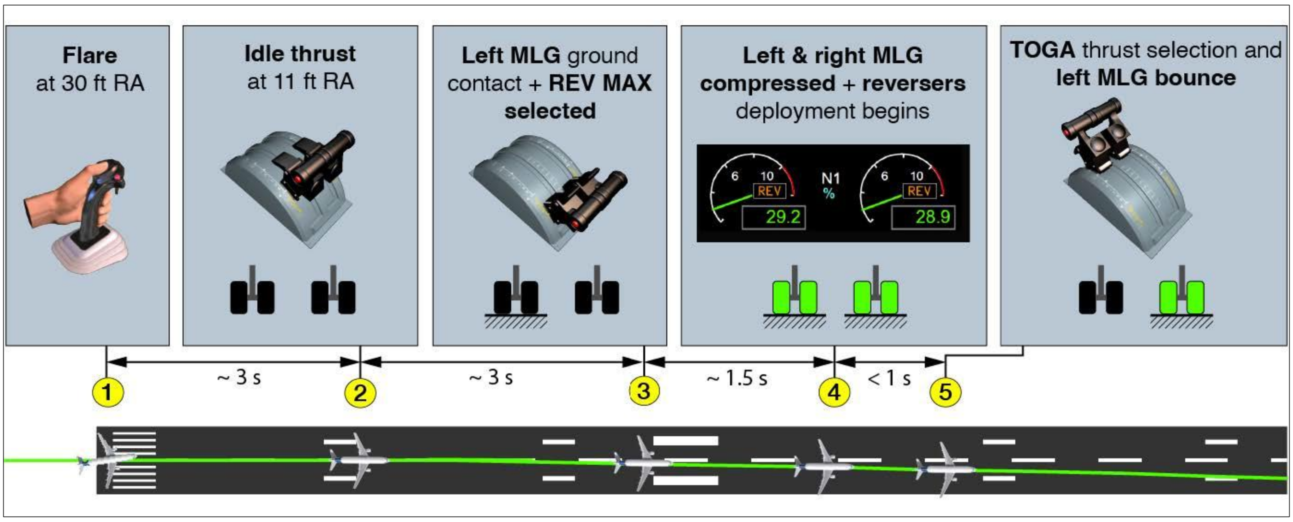

Figure 1. Illustration of the sequence of events, 1 of 2 (Source: Airbus)

The left engine remained at idle (due to the autoidle protection), and the right engine accelerated to Take Off and Go Around (TOGA) thrust. The captain struggled to maintain control of the aircraft. The aircraft veered to the left and vacated the left side of the runway with only a few feet of ground clearance.

The aircraft started climbing, and the first officer retracted the landing gear. The left engine was subsequently shut down, and the flight crew landed the aircraft safely at Copenhagen airport.

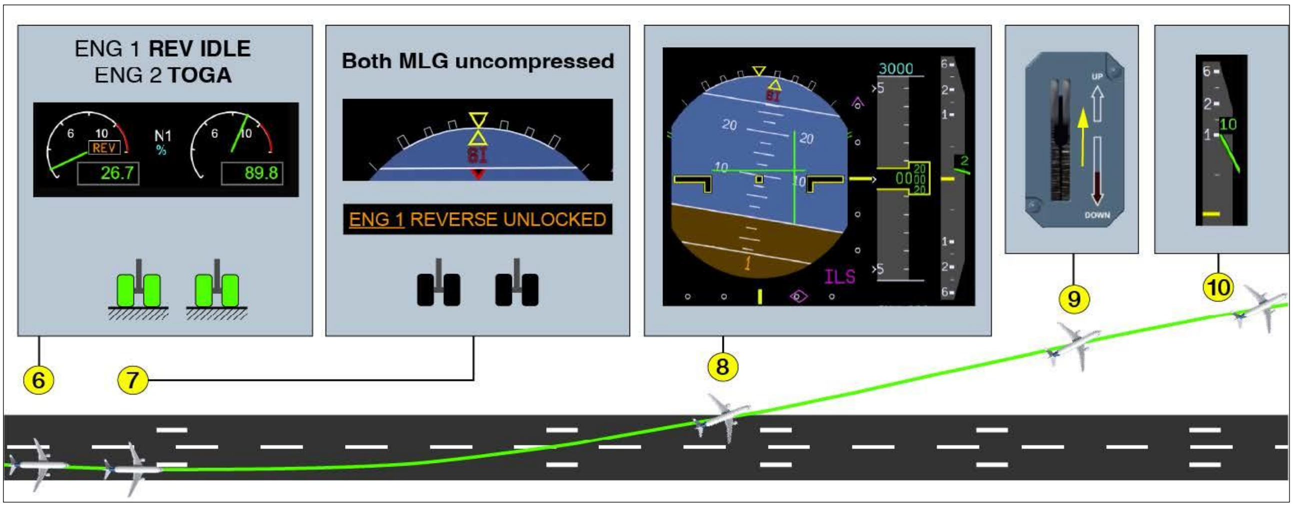

Figure 2. Illustration of the sequence of events 2 of 2 (Source: Airbus)

A320 thrust reverser system

The A320 family aircraft are available in four different engine/thrust reverser system configurations. The thrust reverser system designs have significant differences and have been independently designed. The thrust reverser system designed for the CFM56 engine is a blocker door type and the thrust reverser control logic is embedded into the Engine Control Unit (ECU).

The ECU receives input signals which are used to monitor, compute and command the thrust reverser position to either deploy or stow. The significant signals in this case are the thrust lever position signal and the ground signal. The ground signal is defined as WoW on both main landing gears at the same time.

In case the ECU receives a ground signal, at the same time as the thrust lever is moved from reverse to forward thrust, the ECU will latch (maintain) the stow command for several seconds regardless of a change in ground signal.

In case the ECU receives a flight signal, at the same time as the thrust lever is moved from reverse to forward thrust, the ECU will provide a stow command as soon as ground is sensed. But the signal is not latched, and the stow command is cancelled/interrupted, if the ECU receives a flight signal instead (due to a bounce). The blocker doors are pushed to deploy by air pressure, so when/if the ECU receives a ground signal again, the sequence must start over. Movement of blocker doors from deploy to stow position takes approximately two seconds.

The left and right thrust reverser systems are completely independent, and receives signals from different units. Since the signal pickup and processing is not synchronised between the two sides, it allows for a difference in timing of ground/air signals to the left ECU and the right ECU. As the left ECU did not receive a ground signal when forward thrust was selected, the stow command was not latched, the stow sequence was interrupted, and the left thrust reverser did not stow.

During the serious incident, the aircraft did not have firm ground contact (for two seconds) to allow for stowing of the left thrust reverser.

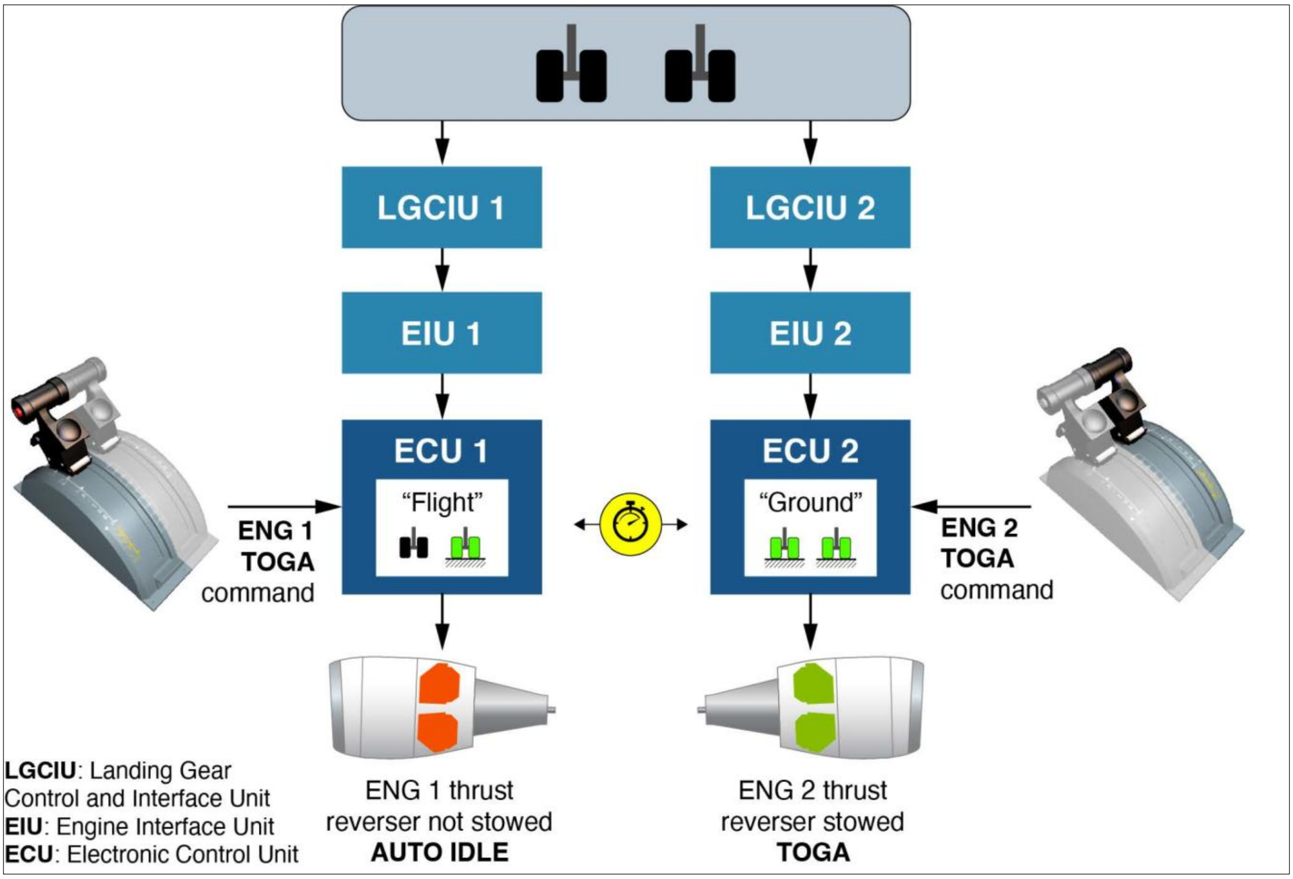

Figure 3. Thrust reverser system description with illustration of difference in signals acquisition (source: Airbus)

Factors

Aborting the landing after thrust reverser selection was not in adherence to the Standard Operating Procedures (SOPs) defined in the Flight Crew Operating Manual (FCOM). The captain was unaware that he had selected reverse thrust prior to aborting the landing. Human limitations and the fact that decisions and actions are executed in split-seconds in particular should be acknowledged for this scenario.

Airbus conducted a study into available flight data (approximately 3 million flights on different variants of A320 family aircraft) which indicated that the SOP non-adherence was not isolated to the specific captain. Other pilots also aborted landings after thrust reverser selection.

The aborted landing after thrust reverser selection occurred at a ratio of approximately one out of 1 million flights equal to once per month on the A320 family fleet. This was significantly more often than anyone anticipated, and it exposed a significant safety risk. It is not unlikely that the ratio and safety risk exposure is similar on other aircraft types.

The A320 family CFM56 thrust reverser control system design (software logic) did not stow the left thrust reverser. The thrust reverser design had however been sufficiently robust to stow the right thrust reverser during the serious incident, and also the thrust reversers on other identified events in the Airbus flight data study. This allowed the weakness of the software logic to remain undetected for more than 30 years, until it was combined with a bounce and thrust lever movement at exactly the wrong time.

Legislative requirements regarding aborted landings (AC525 for the Cranbrook scenario) were being developed around the time when the A320 CFM56 thrust reverser was designed. These requirements were taken into account in the A320 CFM56 thrust reverser design. However, the legislative requirements did not consider a bounce during selection of thrust reverser stowing/forward thrust.

However, other legislative requirements were effective in mitigating the consequences of the event. The engine autoidle feature reduced the yaw, and aircraft controllability with one thrust reverser deployed during flight was considered during the aircraft design phase.

Other significant thrust reverser events

The serious incident at Copenhagen had similarities to the Cranbrook accident (C-FPWC) involving a B737-200 in 1978 which also involved an aborted landing after thrust reverser selection. The significant difference was the timing of the forward thrust signal. In the Cranbrook accident, the forward thrust was applied while the aircraft was firm on ground. The stow sequence was interrupted when the aircraft lifted off again resulting in flight with a thrust reverser deployed. The A320 CFM56 thrust reverser logic was designed to prevent this stow interruption provided the forward thrust signal occurred while a ground signal was present.

Even though the previous event happened decades ago, accidents involving thrust reversers is still relevant. In 2019, a Cessna Citation Latitude (N8JR) crashed at Elizabethton, Tennessee. Following an unstable landing and not selecting spoilers after touchdown, the flight crew attempted a go-around after thrust reversers had been selected. Due to several bounces, the thrust reversers were late to deploy and eventually did not stow when the crew decided to abort the landing (behaviour was per design). The main landing gear collapsed, and the aircraft skidded off the runway and caught fire. Fortunately, all five persons on board was unharmed.

Conclusions, safety actions and lessons learned

Adherence to thrust reverser SOPs is important to ensure predictable thrust reverser behaviour. Using Flight Data Monitoring to track adherence to SOPs can be a valuable tool, to ensure landings are not aborted once the thrust reversers have been selected. Monitoring early selection of thrust reversers can also be beneficial, as early selection can be a precursor to actual aborted landings after thrust reverser selection. The Airbus study suggested that the exposure to aborted landings after thrust reverser selection is likely larger than anticipated, no matter which type of aircraft is being operated.

Keeping flight crews aware of the SOP for thrust reverser use is equally important, and transmission of safety messages (such as the Airbus Flight safety article) and focussing training on the subject can support mitigating the exposure to aborted landings after thrust reverser selection.

Even if mitigated, legislative requirements should ensure that thrust reverser system designs can cope with the aborted landing after thrust reverser selection scenario, even when bounces of different nature occurs. The AIB has issued a safety recommendation to EASA, who will revise thrust reverser certification legislation to ensure future aircraft designs can cope with this type of scenario.

Since legislative requirements only affects future aircraft designs, aircraft manufacturers should consider, how existing designs of the thrust reverser control system cope with the potential of non-adherence to thrust reverser SOPs, and how specific scenarios (such as runway incursions) can force a flight crew to abort a landing, after thrust reversers have been selected. Having a phrase in the operating manual that prohibits the use of thrust reverser during touch and goes and aborting landings after thrust reverser selections, might not be sufficient to ensure safe operation of the aircraft type.

The specific A320 CFM56 ECU software is being modified, and the modification will be mandated by EASA once ready for implementation. But it remains important to consider aborted landings after thrust reverser selection on a more global level.

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