Safety First

The Airbus Safety Magazine

7

FEBRUARY 2009

AIRBUS

Editorial

 # 07 | February 2009

Yannick MALINGE
Vice President
Flight Safety

Dear Customers and Aviation Safety colleagues,

Despite the worldwide economic environment, the increased operator participation in the last Airbus Flight Safety Conference (last October 08) is a positive illustration that our Safety Community remained focussed on our mutual objectives. You were indeed 20% more operators compared to the previous conference.

The articles included in this issue 7 of Safety First underline once more that aviation safety is a global issue that requires the 4 key elements: design enhancement, maintenance & operational procedures, training, and compliance to Standard Operating Procedures (both in operational and maintenance fields).

The World witnessed the USA1549 Hudson river ditching, illustrating the essential role of safety preparedness, even for extremely rare events. This serves as an excellent reminder to all of us that good airmanship and crew resource management will always remain essential for a positive outcome.

To the cockpit and cabin crew of USA1549: “Well done!”

Yannick MALINGE

Vice President Flight Safety

Content

Safety First

The Airbus Safety Magazine
For the enhancement of safe flight through
increased knowledge and communications.

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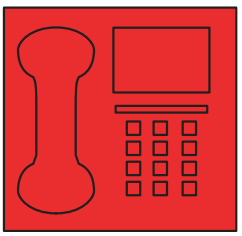
Safety Information on the Airbus websites

On the different Airbus websites we are building up more and more safety relevant information for you to use.

The present and previous issues of Safety First can be accessed to in the Flight Operations Community, Safety and Operational Materials chapter, at https://w3.airbusworld.com

If you do not yet have access rights, please contact your IT administrator.

Other safety and operational expertise publications, like the Flight Operation Briefing Notes (FOBN), Getting to Grips with …brochures, e-briefings etc… are regularly released as well in the Flight Operations Community at the above sites.



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Airbus AP/FD TCAS mode:
a new step towards safety Improvement

By: Paule BOTARGUES
Engineer, Automatic Flight Systems, Engineering

1 | Introduction

The Traffic Collision Avoidance System (TCAS) has been introduced to reduce the risks associated with mid-air collision threats. Today this safety goal has globally been reached.

However, surprise and stress created by TCAS Resolution Advisories may lead to non-optimum crew response, resulting in a lack of proper communication with ATC, undue aircraft altitude deviations, injuries in the cabin and the jeopardizing of the aircraft's safety.
This article will review the current TCAS interface and procedures. It will then present the Auto Pilot/ Flight Director (AP/FD) TCAS mode function developed by Airbus, and its numerous operational benefits, which further enhance the pilot interfaces.

2 | Current TCAS interface and procedures

Traffic Advisory (TA)

When the TCAS considers an intruder to be a potential threat, it generates a TA.
This advisory aims at alerting crews to the intruder's position. TAs are indicated to the crew by:

- An aural message, "Traffic, Traffic"
- Specific amber cues on the Navigation Display, which highlight the intruder's position.

No specific action is expected from the crew following a TA.

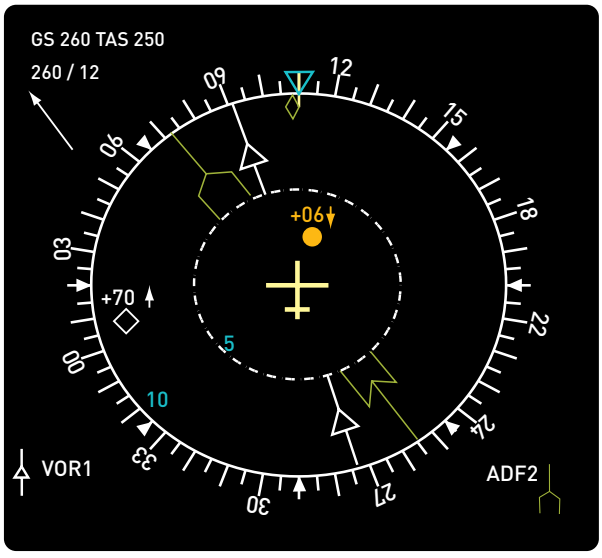


Figure 1: Navigation Display in case of TCAS TA

Resolution Advisory (RA)

If the TCAS considers an intruder to be a real collision threat, it generates an RA.

In most cases, the TCAS will trigger a Traffic Advisory before a Resolution Advisory.

RAs are indicated to the pilots by:

- An aural message specifying the type of vertical order (Climb, Descent, Monitor, Adjust…)
- Specific red cues on the Navigation Display materializing the intruder
- Green / red zones on the Vertical Speed Indicator (VSI) specifying the type of maneuver the pilot has to perform.

In order to fly the required maneuver, the pilot selects both the Auto Pilot (AP) and Flight Directors (FD) to OFF, and adjusts the pitch attitude of the aircraft as required, so as to reach the proper Vertical Speed (V/S). This unfamiliar flying technique increases the stress level already induced by the triggering of the Resolution Advisory.

"Adjust V/S, Adjust"

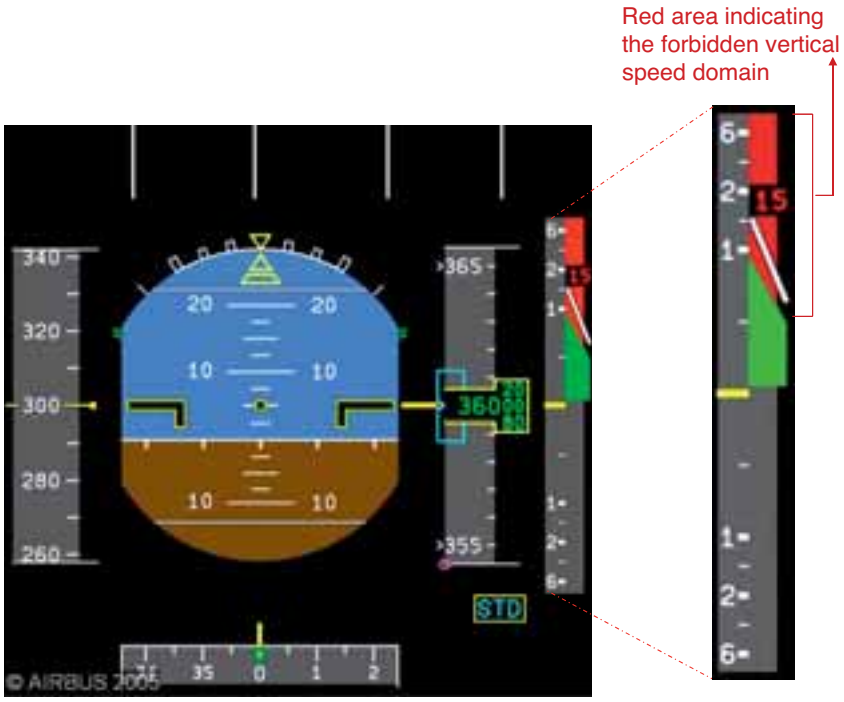


Figure 2: TCAS RA HMI without AP/FD TCAS mode

3 AP/FD TCAS mode concept

Airbus has carried out an in-depth analysis of:
- Needs expressed by airline pilots
- Human factor studies linked to the TCAS system
- Recommendations given by airworthiness authorities.

This resulted in the development of a new concept called AP/FD TCAS guidance, via the Auto Flight System (AFS), to support pilots flying TCAS RAs.

The AP/FD TCAS mode is a vertical guidance mode built into the Auto Flight computer. It controls the vertical speed (V/S) of the aircraft on a vertical speed target adapted to each RA, which is acquired from TCAS.
With the Auto Pilot engaged, it allows the pilot to fly the TCAS RA maneuvre automatically.
With the Auto Pilot disengaged, the pilot can fly the TCAS RA maneuvre manually, by following the TCAS Flight Director pitch bar guidance.
It has to be considered as an add-on to the existing TCAS features (traffic on Navigation Display, aural alerts, vertical speed green / red zones materializing the RA on the Vertical Speed Indicator).

In case of a TCAS RA, the AP/FD TCAS mode automatically triggers the following:
- If both AP and FDs are engaged, the AP/FD vertical mode reverts to TCAS mode, which provides the necessary guidance for the Auto Pilot to automatically fly the TCAS maneuver
- If the AP is disengaged and FDs are engaged, the TCAS mode automatically engages as the new FD guidance. The FD pitch bar provides an unambiguous order to the pilot, who simply has to centre the pitch bar, to bring the V/S of the aircraft on the V/S target (green zone)
- If both AP and FDs are OFF, the FD bars will automatically reappear with TCAS mode guiding as above.

Note: At any time, the crew keeps the possibility to disconnect the AP and the FDs, and is capable to respond manually to a TCAS RA by flying according to the "conventional" TCAS procedure (i.e. flying the vertical speed out of the red band).

The AP/FD TCAS mode will behave differently depending on the kind of alert triggered by the TCAS:
- In case of Traffic Advisory (TA), the AP/FD TCAS mode is automatically armed, in order to bring crew awareness on the TCAS mode engagement if the TA turned into an RA.

- In case of Corrective RA ("CLIMB", "DESCEND", "ADJUST", etc aural alerts), the aircraft vertical speed is initially within the red VSI zone. The requirement is to fly out of this red zone to reach the boundary of the red / green V/S zone.
  Consequently:
  – The TCAS longitudinal mode engages. It ensures a vertical guidance to a vertical speed target equal to the red / green boundary value (to minimize altitude deviation) ± 200 ft/min within the green vertical speed zone, with a pitch authority increased to 0.3g
  – All previously armed longitudinal modes are automatically disarmed, except the altitude capture mode (ALT*) in case of an "ADJUST V/S" alert. This prevents an undue altitude excursion: indeed, in this type of RA, reaching 0 ft/min is always safe, as this value is never within the red vertical speed zone. Therefore, if the altitude capture conditions are met, the TCAS mode will safely allow to capture the targeted flight level
  – The Auto Thrust engages in speed control mode (SPEED/MACH) to ensure a safe speed during the maneuver
  – The current engaged lateral mode remains unchanged.

"Adjust V/S, Adjust"

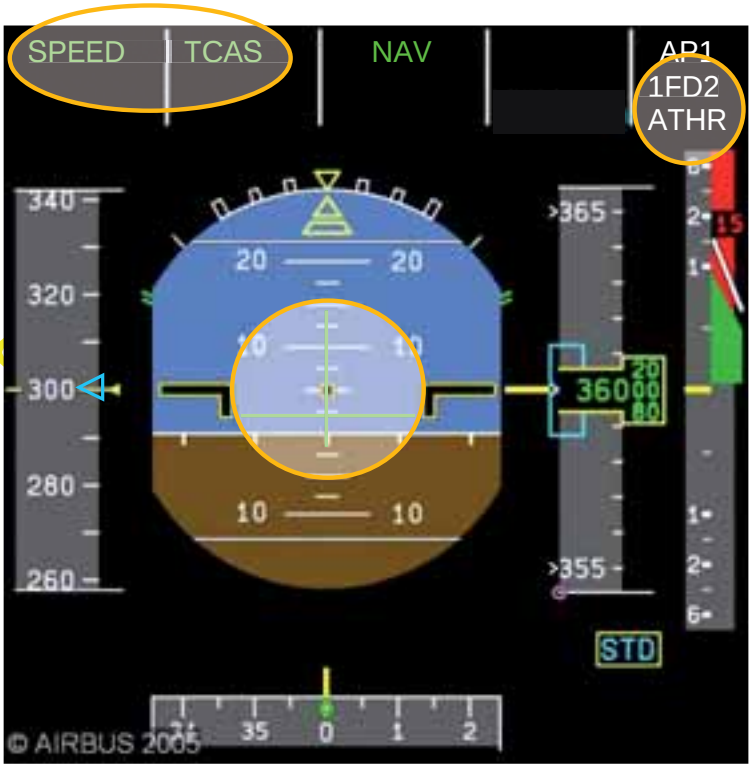


Figure 3: PFD upon a Corrective TCAS RA with AP/FD TCAS mode

- In case of Preventive RA (*e.g.*" MONITOR V/S" aural alert), the aircraft vertical speed is initially out of the red VSI zone. The requirement is to maintain the current vertical speed
  Consequently:
  – The TCAS longitudinal mode engages to maintain the current safe aircraft vertical speed target
  – All previously armed longitudinal modes are automatically disarmed, except the altitude capture mode (ALT*). Indeed, as for an "ADJUST V/S" RA, levelling-off during a Preventive RA will always maintain the vertical speed outside of the red area. So if the altitude capture conditions are met, the TCAS mode will allow to safely capture the targeted level, thus preventing an undue altitude excursion
  – The Auto Thrust engages in speed control mode (SPEED/MACH) to ensure a safe speed during the maneuver
  – The current engaged lateral mode remains unchanged.

- Once Clear of Conflict, vertical navigation is resumed as follows :
  – The AP/FD longitudinal mode reverts to the "vertical speed" (V/S) mode, with a smooth vertical speed target towards the FCU target altitude. The ALT mode is armed to reach the FCU target altitude (ATC cleared altitude)
  – If an altitude capture occurred in the course of a TCAS RA event, once Clear of Conflict, the AP/FD longitudinal mode reverts to the altitude capture (ALT*) or to the altitude hold (ALT) mode
  – The lateral mode remains unchanged.

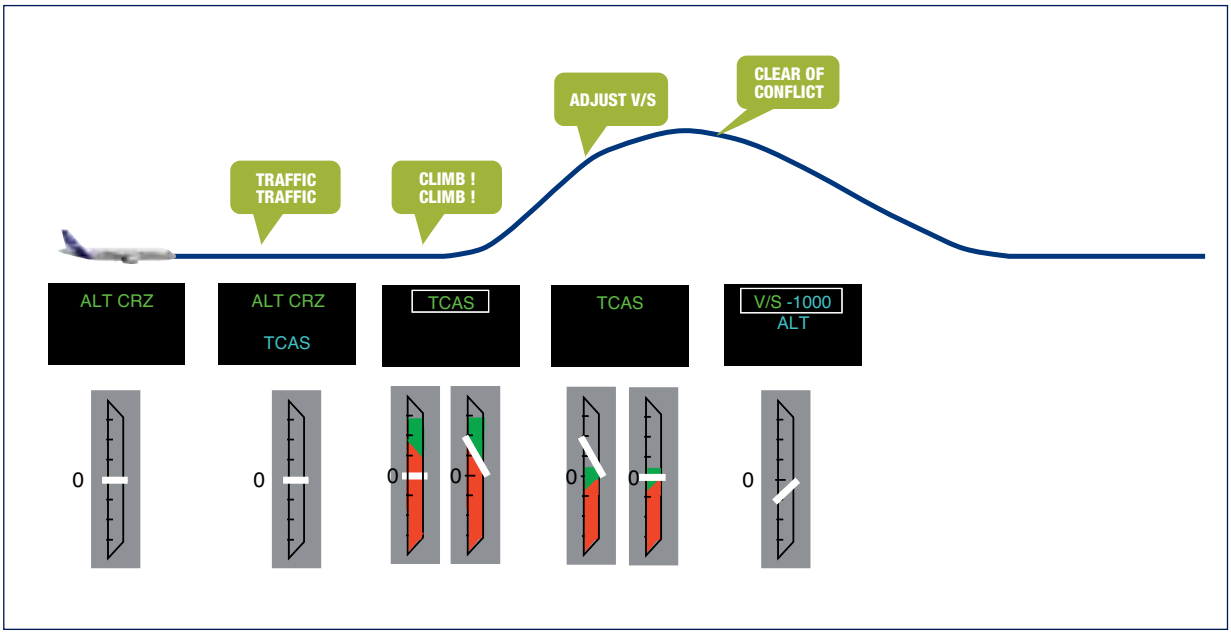


Figure 4: FMA and VSI during a TCAS sequence with AP/FD TCAS mode

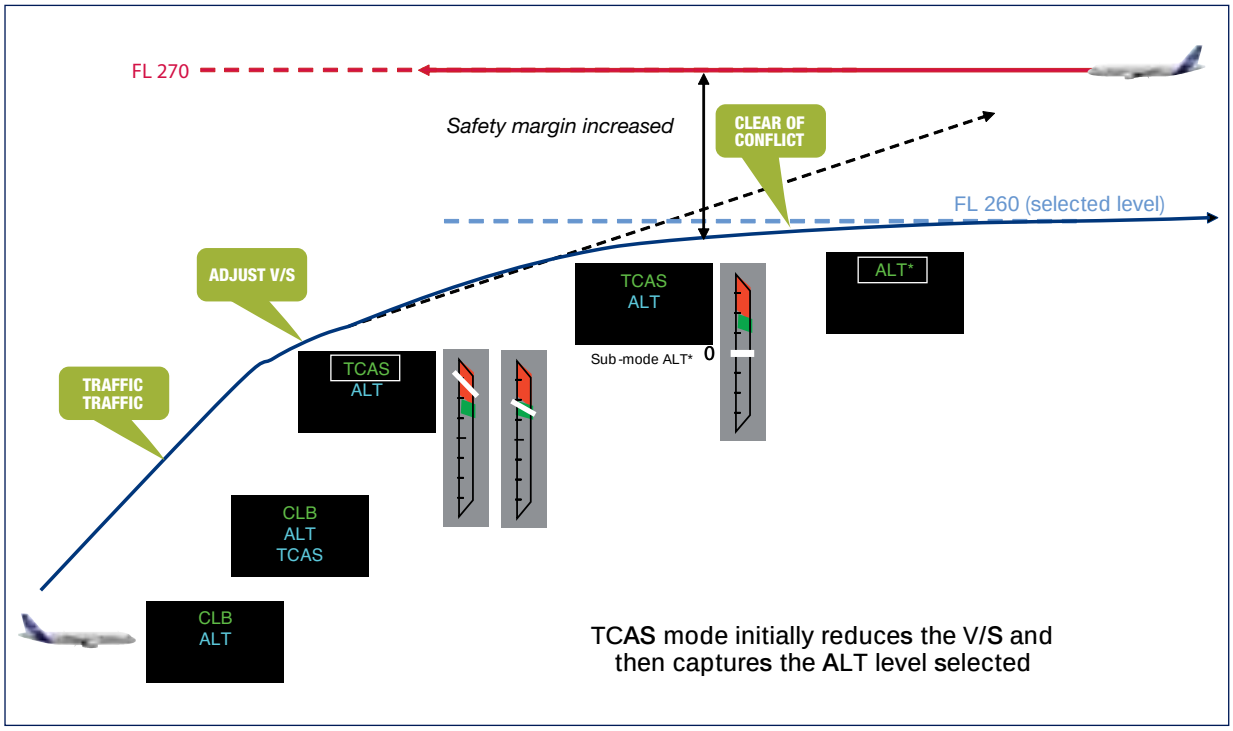


Figure 5: Safe altitude capture in TCAS mode

4 | Operational benefits

The operational benefits of the AP/FD TCAS mode solution are numerous; the system addresses most of the concerns raised by in-line experience feedbacks:

- It provides an unambiguous flying order to the pilot
- The flying order is adjusted to the severity of the RA; it thus reduces the risks of overreaction by the crew, minimizes the deviations from trajectories initially cleared by ATC, and adapts the load factor of the maneuvre
- The availability of the AP/FD TCAS mode makes it possible to define simple procedures for the aircrews, eliminating any disruption in their flying technique: the procedure is simply to monitor the AP, or to manually fly the FD bars, when the TCAS mode engages, while monitoring the VSI.

By reducing the crews' workload and stress level, the AP/FD TCAS mode should therefore significantly reduce:

- Inappropriate reactions in case of Resolution Advisory (late, over or opposite reactions)
- Misbehaviours when Clear of Conflict
- Lack of adequate communications with ATC.

Note: For ATC controllers, the AP/FD TCAS mode is totally transparent in terms of expected aircraft reactions.

The AP/FD TCAS mode was demonstrated to a large panel of pilots from various airlines, and was perceived by them as a very simple and intuitive solution. It was deemed to be consistent with the Airbus cockpit philosophy and Auto Flight system.

All agree that the AP/FD TCAS mode represents a safety improvement.

5 | Certification schedule

The certification of the AP/FD TCAS mode function is expected:

- On the A380: by May 2009
- On the A320 family:
  - with CFM engines, by end 2009
  - with IAE engines, by July 2010
- On the A330/A340, depending on the aircraft type, from the beginning of 2010 (A330 PW/RR) to the end of 2011 (A340-500/600).

The certifcation dates for all required retrofit standards are not yet frozen.

Braking system cross connections

By: Thierry THOREAU
Director, Flight Safety

1 | Introduction

The braking system cross connections have generated a few incidents over the years. The worst case experienced on the Airbus fleet further to a case of braking system cross connections, led the airplane to stop around 150 feet from the extended runway centerline. An emergency evacuation was initiated and everybody escaped safely, without serious injuries. The aircraft sustained some damages.

This document will present:

- The two types of cross connections reported and their consequences
- The existing prevention measures
- The operational procedure to mitigate them
- And finally the improvements already implemented, or contemplated.

Increased awareness on these possible maintenance errors should help avoiding or mitigating further events.

2 | Type of events reported on the Single Aisle aircraft family

- A few cases of Main Landing Gear — MLG — tachometer cross connections have been reported. These cross connections were done at the level of the wheels axis, as shown on figure 1.

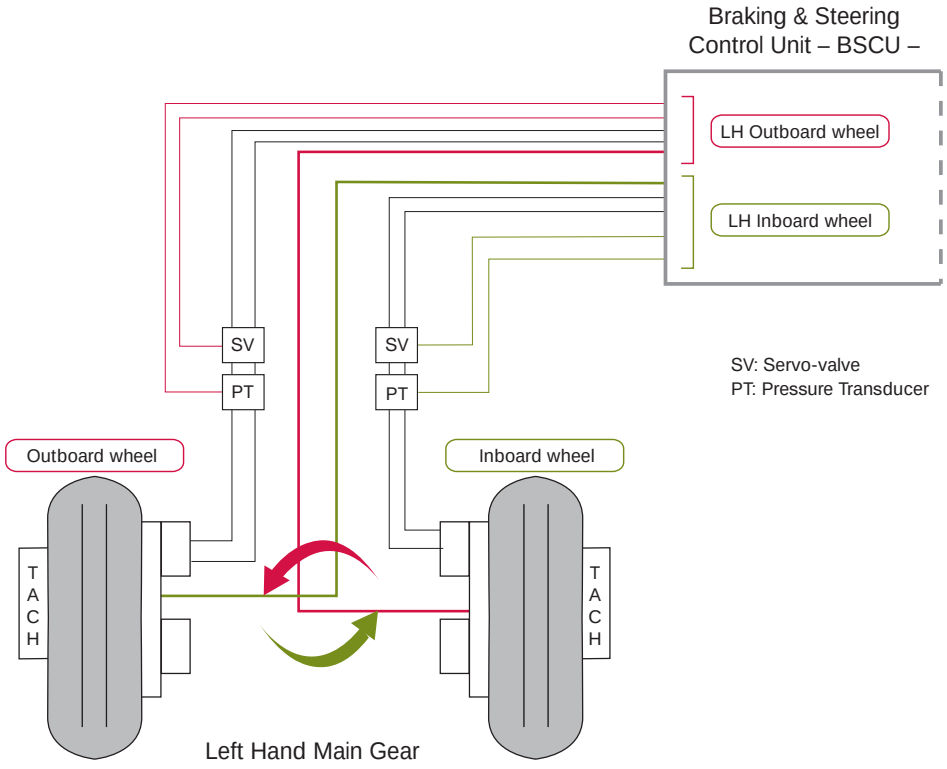


Figure 1: Schematic of tachometer cross connections

Figure 2 shows an actual cross connection on the right hand side main gear. The cable labelled 19GG-A/22GG-A connected to the tachometer (the blue cylindrical equipment which can be partially seen on the right hand side of the picture), should in fact have been the cable 20GG-A/21GG-A.

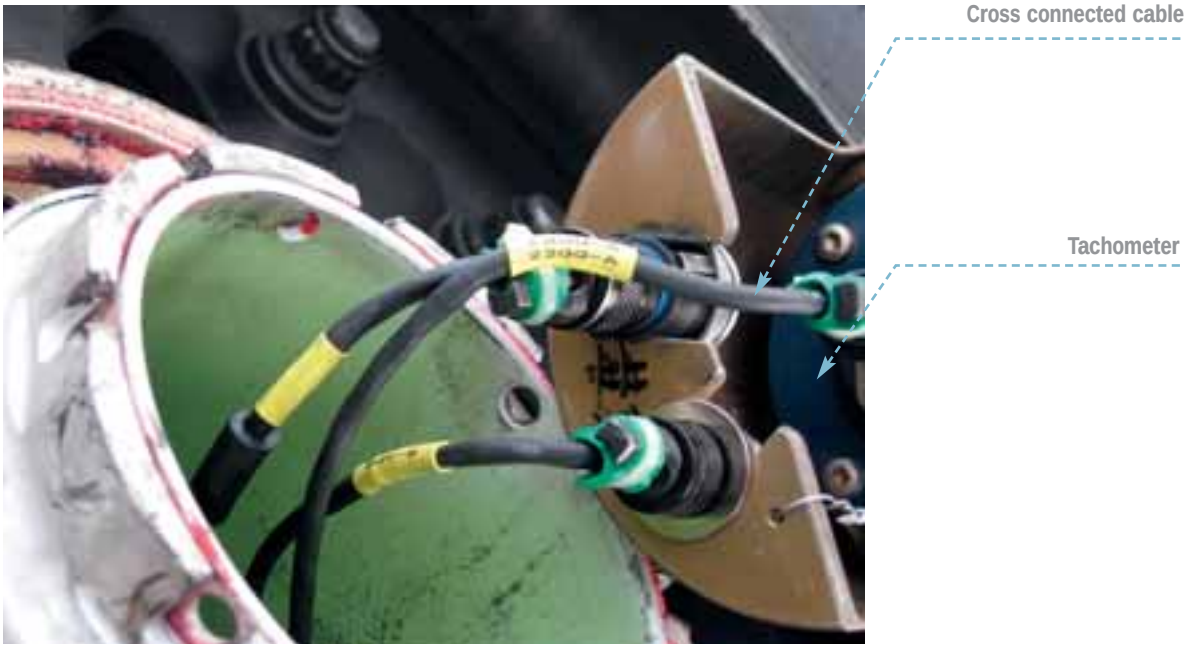


Figure 2: Picture of tachometer cross connections

- Even if only two cases have been reported to Airbus, it is worth mentioning the other type of cross connections experienced so far.

It involves the connections to the servo-valves, as shown on figure 3.

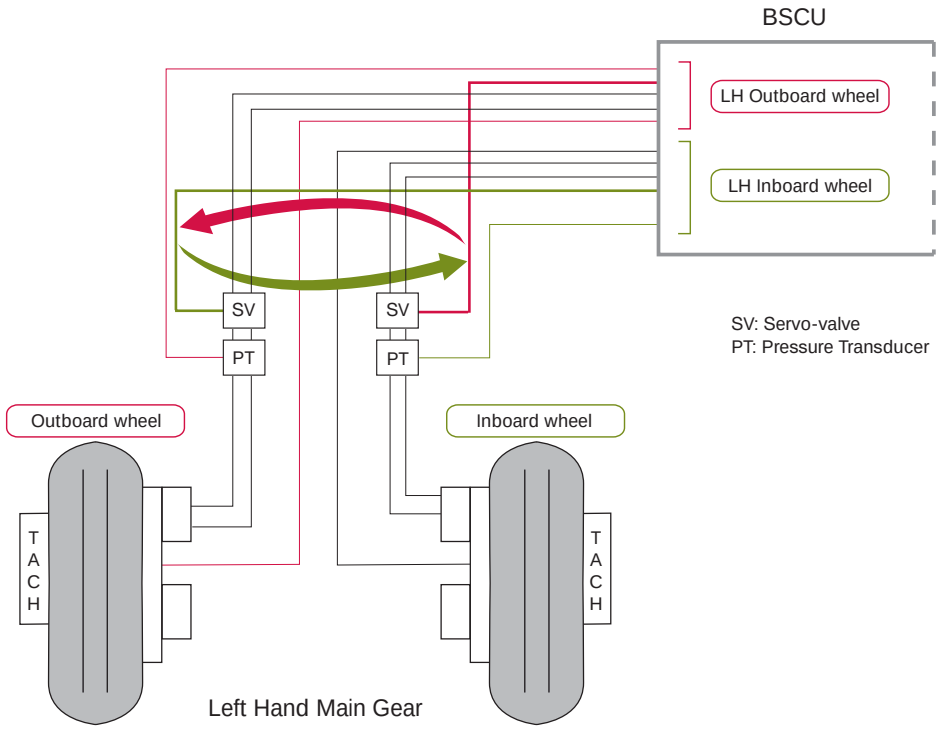


Figure 3: Schematic of servo-valve cross connections

The lower number of cases that have been reported can be explained by the fact that the flanges supporting the servo-valve cables have different lengths. This type of cross connections are thus more difficult to realize.

Figure 4 shows an example of servo-valve cross connections.

It shows that the flange supporting the cable to the lower servo-valve allows an easy connection only on the lower servo-valve.
In this case, the flange forced the cable wrongly connected to the upper servo-valve to make an excessively sharp bend.

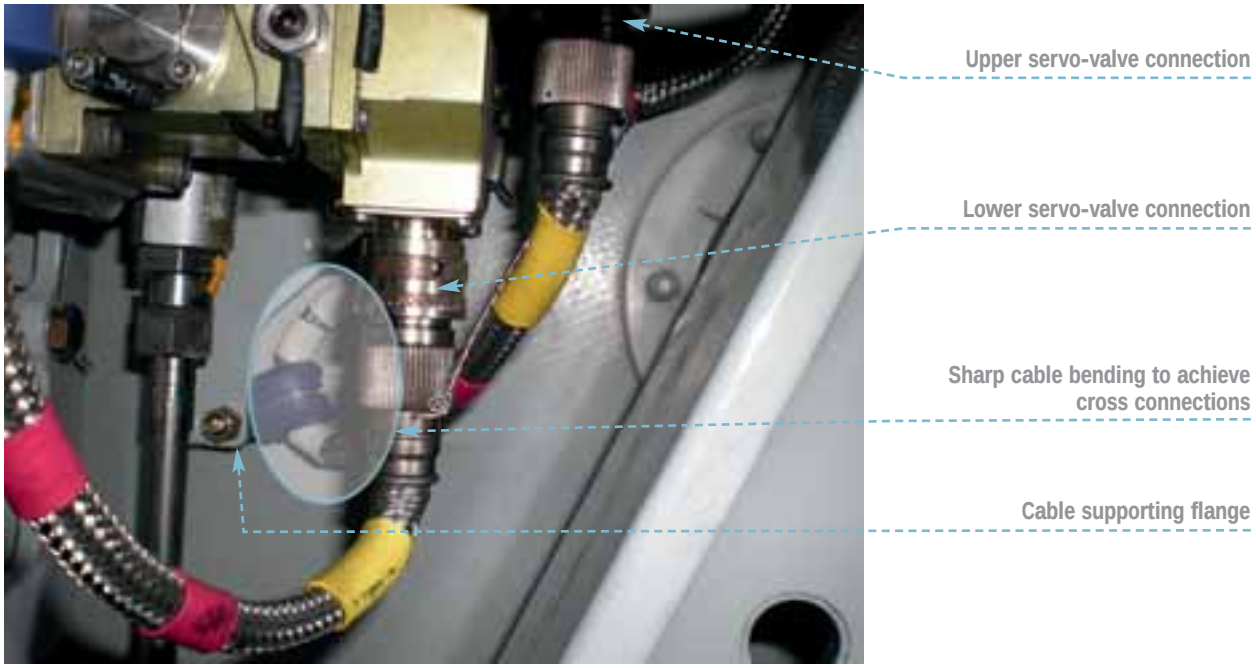


Figure 4: Picture of servo-valve cross connections

3 Existing measures on the Single Aisle aircraft family

The Braking & Steering Control Unit – BSCU – (3GG), the servo-valves (15 GG, 16 GG, 17GG, 18GG) and the tachometers (19GG, 20GG, 21GG, 22GG) are the key components of the braking system. They must be properly connected to ensure efficient braking.

The BSCU compares each wheel speed to a computed reference speed and releases associated brake pressure if need be.

In case of cross connections, the braking performance will not be impacted as long as the anti-skid function is not activated. If the anti-skid function is activated, the BSCU will release the brake pressure on the opposite wheel, while maintaining the brake pressure on the already skidding wheel. The braking performance will then be significantly affected.

Note: Use of differential braking to correct the yaw tendency might be useless in this case, as the anti-skid system still provides braking orders to the wrong wheel.

In the majority of the reported cases, cross connections were evidenced further to tyres abnormal wear (flat spots) or bursts, and did not lead to serious incidents. However in a few cases these cross connections led to runway excursions.

This is why it is important to keep in mind existing measures.

Maintenance

The Aircraft Maintenance Manual *– AMM – task 32-42-00-720-002* is specifically designed to detect cross connections.

AMM indicates in a specific note that:
"You must do this test if there is a risk of wiring cross connections between two tachometers (replacement of the MLG or of the electrical harness of the MLG)".

AIRBUS TRAINING A320 SIMULATOR

EMERGENCY PROCEDURES

REV 36 | SEQ 001 | 1.13

LOSS OF BRAKING

- **IF AUTOBRAKE IS SELECTED:**
  - BRAKE PEDALS . . . . . PRESS
- **IF NO BRAKING AVAILABLE:**
  - REV . . . . . MAX
  - BRAKE PEDALS . . . . . .RELEASE
  - A/SKID & N/W STRG . . . . . .OFF
  - BRAKE PEDALS . . . . . PRESS
  - MAX BRK PR . . . . . .1000 PSI
  - **IF STILL NO BRAKING:**
    - PARKING BRAKE . . . . . .SHORT AND SUCCESSIVE APPLICATIONS

Figure 5: Loss of braking "memory item" procedure

Operations

Should there be cross connections and an anti-skid function activation during the landing roll, the crew will perceive two things:

- A yawing tendency, and
- An unusually small deceleration.

While controlling the lateral trajectory, if the aircraft's deceleration rate is perceived as significantly below expectation, the crew must apply the Loss of Braking "memory item" procedure shown on figure 5.

The procedure calls for the anti-skid function to be turned OFF, thereby eliminating the major consequence of the cross connections.

It is worth mentioning that in these circumstances, it might be appropriate for the flight crew to maintain full reverse thrust below the SOP minimum recommended speed for full reverse use. The Standard Operating Procedure for Landing will be updated accordingly at the next general revision to indicate that, in case of emergency, maximum reverse thrust might be used until a complete stop.

4 | Maintenance documentation improvements

Recently, the AMM task 32-42-00-720-002 has been amended to include the monitoring of the brake's wear pin and brake unit deflection, in addition to the previous monitoring of the brake's piston movements, as additional means to determine proper brake operation.

This task is now also required further to the installation of servo-valves.

5 | Future improvements

- The Trouble Shooting Manual (TSM) will be enhanced to include an entry point in case of tyre flat spot(s), to look for possible cross connections
- On the Single Aisle (SA) family, cable colour coding is currently under review to avoid crossing cables.

Note: All SA family changes
- *introduced (addition of warnings in AMM, monitoring of the brake's wear pin and brake unit deflection to determine brake operation)*
- *planned (TSM entry in case of tyre flat spots)*
- *or under review (cable colour coding)*

are being considered as well on the other families of Airbus aircraft fitted with boogie gears. On these types of landing gear, the consequences of cross connections are reduced compared to the diabolo versions.

6 | Conclusion

Crossed cables in the braking system have, in the past, caused incidents. It is therefore important to comply strictly with the published maintenance procedure.

Pilots facing a situation where the airplane yaws to one side and the aircraft's deceleration rate is perceived as significantly below normal, may suspect brake cross connections. They should apply the Loss of Braking "memory item", which calls for the anti-skid function to be turned OFF.

REFERENCE
Operator Information Telex (OIT) ref 999.0133/07/LB Rev 01 issued on the 30th of April 2008, reminds the operators to strictly adhere to the AMM task 32-42-00-720-002 "Functional Test of Tachometers" whenever it needs to be applied.

Upset Recovery Training Aid, Revision 2

By: Larry ROCKLIFF
V.P., Training and Flt. Ops Support, Customer Services, Airbus Americas

1 | Introduction

The original industry upset recovery training was delivered to the aviation community ten years ago. The genesis of this reference was a discovery that many pilots had progressed along their career and had never been educated in recognition and recover from upsets or unusual attitudes. Ten years later, the accident/incident rate due to failure to recover from an upset, remains among the top statistics to work on. There are various reasons for this, not the least of which is a regulatory base that allows to add training modules to an operator's program, but is less agreeable to remove modules that have much less significance in the operating environment of today.

In recent years, there have been several accidents and incidents that have occurred in the high altitude environment. Odd as it may seem, causal factors from several investigations have been a lack of understanding of phenomena associated with operating a jet aircraft in the high altitude environment. To respond to this shortfall in a pilot education, the FAA asked Airbus and Boeing to convene an industry group to define a training aid specific to high altitude operations. The result has been a collaborative effort that consisted of manufacturer, airline, safety, regulatory, industry trade, and educational organizational representatives both domestic, within the United States, and international in scope to arrive at a document that addresses the problem.

Consensus from the group was to amplify information and guidance vis a vis high altitude already embedded in the existing Industry Upset Recovery Training Aid and deliver it as Revision 2. This is now available to operators on *https://w3.airbusworld.com*.

In addition, because the FAA requested a specific reference for high altitude to respond to NTSB recommendations, it was decided to also provide a separate stand alone supplement to specifically address high altitude phenomena. This is a separate appendix, which is contained in the back of the Training Aid.

2 | Goal

The goal of Revision 2 is to focus on specific education for pilots so they have the knowledge and skill to adequately operate their airplanes and prevent upsets in a high altitude environment. This includes educating pilots so they can develop the ability to recognize and prevent an impending high altitude problem and increase the likelihood of a successful recovery from a high altitude upset situation should it occur.

As surprised as regulators and industry was to discover in the 1990s that many pilots did not have the knowledge and skills to recognize and recover from any upset or unusual attitude, it came equally as baffling to learn that pilots had exceedingly limited knowledge and abilities to handle their airplanes in the high altitude environment in spite of the fact they operate in this area over 98% of their flight time experience. Indeed, many pilots have never had the opportunity (or requirement) to operate their aircraft in the high altitude environment with an Auto Pilot off to experience the differences.

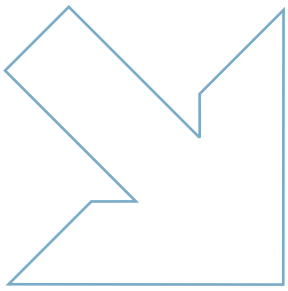
3 | Take Away

There is considerable content within the Training Aid Revision 2 and Airbus recommends that operators refresh their knowledge and skills with a view to introduce primary and/or refresher training for their crews. With all the information available to the training departments, the take away to each and every pilot has been distilled into three simple guidelines:

- Contain The Startle Factor
- Recognize and Confirm the Situation
- Very Small Control Inputs

Containing the startle factor applies to every situation a pilot may encounter, regardless of high altitude or sea level operating environment. It is a natural reaction; perhaps even reflex action, to want to do something when one is startled. Reactively, disconnecting an Auto Pilot and making un-calibrated open loop rudder and/or control yoke or sidestick inputs will never be the correct reaction and will almost always lead to an amplified abnormal situation. It is in this area that pilots must develop skills to discipline themselves from putting their hands and/or feet into motion, without first understanding what is going on and what the potential consequences of their actions will be. Disconnecting the Auto Pilot under effort in a reflex action is particularly significant as it generally results in a large control input. Indeed, many high altitude upsets would never have become upsets had pilots contained the startle factor. This is a critical area of human factor development that cannot be overstated.

Recognize and confirm the situation is essential for the pilot to determine what recovery action is necessary. Some situations develop quite slowly in which case, the crew will have ample time to assess and decide upon a course of action. However, some may occur nearly instantly, and in these cases the pilot/crew must determine what is happening to their energy state and what is happening to their trajectory. It may not be easy, but it is critical in order for the crew to decide what response they will need to take. In the same way that many engines have been un-necessarily shutdown before sufficient information had been considered, so too, have high altitude upsets been created, due to reacting to only part of the available information. This is a broad area that cannot be distilled into the scope of this article, but sufficient to say that a corrective action cannot be contemplated without consideration of what the pilot/crew is responding to. The link between containing the startle factor, recognizing and confirming the situation, can be fused together to allow the pilot to apply the third and always essential take away point.



Very small control inputs cannot be overstated. Open loop, or arbitrary large scale deflections must be avoided at any altitude. The relationship between control surface deflection and trajectory change is amplified at high altitude.

- The airspeed at high altitude is generally higher than the one pilots are used to fly at manually. Therefore, a reflex action giving the same control surface deflection will result in a much higher load factor than initially expected.
- For the same control surface movement at constant airspeed, an airplane at 35,000 ft experiences a higher pitch change than an airplane at 5,000 ft because there is less aerodynamic damping. Therefore, the change in angle of attack is greater, creating more lift and a higher load factor.
- Moreover, if the input is large enough, pitch up may happen, amplifying the formerly described effect and buffeting may occur, creating a second startle factor that may trigger another large reaction in the opposite direction.

If the control system is designed to provide a fixed ratio of control force to elevator deflection, it will take less force to generate the same load factor as altitude increases.
On many modern airplanes with classical, non reversible flight controls, the control force to elevator ratio is varying with airspeed so as to give roughly a constant force for the same load factor all over the flight envelope. This is even more true for fly-by-wire airplanes flying with C* pitch control law where sidestick deflection is actually a load factor demand.

A similar discussion could be held for the yaw axis with rudder inputs.

Nevertheless, and whatever the flight control system, an additional effect is that, for a given attitude change, the change in rate of climb is proportional to the true airspeed. Thus, for an attitude change for 500 ft per minute (fpm) at 290 knots indicated air speed (KIAS) at sea level, the same change in attitude at 290 KIAS (490 knots true air speed) at 35,000 ft would be almost 900 fpm. This characteristic is essentially true for small attitude changes, such as the kind used to hold altitude. It is also why smooth and small control inputs are required at high altitude, particularly when disconnecting the Auto Pilot (an Auto Pilot disconnection by overriding it on the yoke or sidestick controller will very likely cause large and excessive control inputs). Put in fundamental piloting terms, inappropriate control inputs due to un-contained startle factor without consideration for what is actually occurring, can almost certainly cause an upset to become exaggerated, or indeed precipitate one that didn't exist in the first place. Simply stated, all control inputs must be in the form of control pressures versus control deflections. Incidentally, this is identical to the relationship in the larger movements on an automobile steering wheel when nearly stopped as opposed to the tiny pressures warranted while at high speeds. Imagine the result of a large steering wheel deflection at highway speeds…

4 Airbus Policy toward Upset Recovery Training

Airbus policy has been consistent since the original Industry Upset Recovery Training Aid was offered in 1998. Airbus believes it is practical and encouraged to educate all pilots to understand the principles of airplane upsets and how to avoid them. The dynamics of airplane upsets at low altitude or high altitude are so broad that defining simplistic procedures or techniques are not appropriate. To that end, upset recovery training is encouraged in the context of awareness training versus procedure training.

Moreover, Airbus does not support the use of full flight simulators to conduct upset recovery training. Although excellent training tools within the normal operating environment and envelope the pilot/crew experiences in his/her duties, simulators have many limitations that create enormous opportunities for negative training. Airbus believes the risk of producing significant negative training far outweighs the possible benefit that might be achieved.

High altitude exercises as proposed in the most recent Revision 2 of the Industry aid, is consistent with Airbus training policy. Because the scenarios recommended are focused towards recognizing a developing situation so the pilot/crew can arrive at a solution prior to entering an upset, the use of simulators in these scenarios are appropriate.

Some operators may still decide to use simulators to conduct upset recovery training. In these cases, Airbus recommends to only use the simulators with the motion systems selected off. This is not to protect the serviceability of the equipment due to large motion movements toward the stops. Rather, it is an attempt to minimize the likelihood of negative training due to incorrect motion cues and lack of accelerations. Indeed, positive re-enforcement derived from negative training, is the most difficult situation to manage. A pilot/crew should walk away from a training event with positive re-enforcement. However, if similar conditions taught in a simulator are experienced in an airplane, there could be large differences in how the airplane responds to the pilot inputs and consequences can be severe and unrecoverable. Finally, Airbus does not support intentionally suppressing normal law in order to facilitate upset conditions.

5 | Summary

Airbus has been a supporter of educating pilots to recognize and avoid airplane upsets. Though this knowledge and associated skills should have been acquired during earlier pilot training and not airplane type rating training, it is important to recognize that a knowledge gap exists within the pilot community and Airbus has been a leader in working with industry to arrive at a solution.

Contain the startle factor, recognize and confirm the situation and correct making the smallest control inputs/pressures possible to arrest any divergence in order to recover. These three points are powerful, positive “take aways”…

Fuel pumps left in OFF position

By: Frédéric COMBES
Director, Flight Safety

1 | Introduction

An A320 encountered a dual engine rollback, after the aircraft levelled off at Flight Level 380, as a result of fuel starvation.
The aircraft was dispatched with the center tank empty. Both wing tank fuel pushbutton switches had been left in the OFF position from engine start.
Interesting lessons may be learned from this event.

2 | Investigation

An official investigation was conducted with the concerned Investigations Board, the airline, engine supplier and Airbus.

Five different hypothesis have been examined:
- Adverse weather conditions
- Fuel contamination
- Aircraft fuel system anomaly
- Engine misbehaviour
- Fuel pumps left in the OFF position.

The following data have been investigated:
- Engines Full Authority Digital Engine Control (FADEC) Non Volatile Memories
- Digital Flight data Recorder (DFDR) engine main parameters
- Post Flight Report (PFR).

Analysis of all the available data allowed to rule out the first four hypothesis.
Indeed:
- There was no indication that inclement weather condition could have contributed to the event
- The fuel sampling analysis confirmed that the fuel was not contaminated
- The data recorded within the engine computer allowed to rule out any control system/engine issue
- The aircraft's recorded data and troubleshooting performed on the aircraft, did not highlight any evidence of failure in the following systems:
  – Fuel
  – Electrical generation and distribution
  – Autoflight.

The only remaining scenario was therefore that all fuel pumps had remained switched-off from the engine start until the time of the dual engine rollback.

The available data allowed to confirm the following:

1) During the engine start sequence all fuel pumps were left in the OFF position, leading to the triggering of the following ECAM Cautions:

FUEL L TK PUMP 1+2 LO PR
FUEL R TK PUMP 1+2 LO PR

The crew cleared both Cautions but left the fuel pumps in the OFF position.
As a consequence, both engines were being gravity fed during the engine start, take-off and climb phases of the flight.

2) The behaviour of the engines was normal until the aircraft reached FL380, some 23 minutes after take-off. At that point, both engines rolled back, leading to:
   - The Mach Number to decrease from M0.78 to M0.63
   - The disconnection of the Electrical Generators 1&2 (Engines 1&2 N2 being below 53%)
   - The Ram Air Turbine deployment (Emergency Electrical Configuration).

3) The aircraft started to descend and the crew declared an Emergency.
   At FL 320, the engines were recovered leading to an automatic re-connection of both Electrical Generators. The crew then decided to turn back to the departure airport where an uneventful landing was performed.
   This scenario was confirmed through a flight test done on an Airbus A320 production aircraft.

3 | Analysis of the event

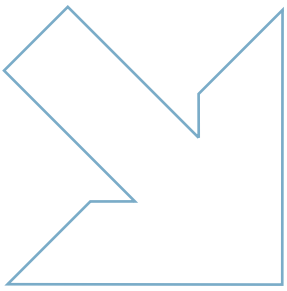
Operations Engineering Bulletin 178 "OPERATION OF CENTER TANK PUMPS"

The OEB was applicable to the aircraft concerned by this event. During the refuelling, all fuel pumps were set to OFF, in accordance with OEB 178.

This OEB was issued to avoid having the center tank pump in operation if not fully immersed.
It calls for:
- All fuel pumps to be in the OFF position before and during the refuelling
- The wing tank pumps to be set ON after the refuelling
- The center tank pumps to be left OFF, if the total fuel on board is less or equal than 12 000 kg.

Note: 1. OEB 178 is applicable to some A318/A319/A320 aircraft with a center tank.

2. OEB 180 "OPERATION OF FUEL PUMPS", applicable to some A321 aircraft, was also issued to avoid having wing fuel pumps running if not fully immersed during fuel loading operation: It notably calls for all wing fuel pumps to be turned OFF before refuelling.



A318 A319 A320 A321	OEB PROC N° 178/1	FEB 08	6.00

PAGE 3 OF 6

OPERATION OF CENTER TANK PUMPS (cont'd)

PROCEDURE A (CONT'D)

CENTER TANK PUMPS OPERATION

WARNING

Do not turn on the center tank pumps, if the center tank contains less than 2 000 kg (4 500 lb) of fuel, even if it is requested by another procedure.

Before and during refueling:

ALL TK PUMPS . . . . . OFF

■ **IF THE TOTAL FOB AFTER REFUELING IS LESS THAN OR EQUAL TO 12 000 KG (26 500 LB)**

After refueling:

- CTR TK . . . . . CHECK EMPTY

It fuel remains in the center tank, it must be considered unusable

- L and R TK PUMP 1 and 2 . . . . . ON
- CTR TK PUMP 1 and 2 . . . . . MAINTAIN OFF
- FUEL MODE SEL . . . . . MAN

Note : The QRH OEB PROC N° 178 gives a quick access to the OEB procedure, which is also covered in AFM TR - 4.03.00/28 issue 2.

Limitations of fuel gravity feed

The altitude limitations linked to gravity feed are due to the application of Henry's law. The law states that the concentration of a solute gas in a liquid is directly proportional to the partial pressure of that gas.

Therefore, as the airplane climbs and as the atmospheric pressure decreases, so does the amount of air dissolved in the aircraft's fuel.

The excess air vents into the fuel tanks and engine fuel lines.

At some point, the quantity of vapour present in the fuel, when it reaches the engine, may exceed the engine inlet maximum allowable vapour / liquid ratio and the operation of the engines is compromised. In the example illustrated in this article, the airplane was able to reach FL380 before the engines eventually rolled back.

However, the precise altitude at which engines will experience fuel starvation depends on a number of factors, including saturation level of air in the fuel, temperature and rate of climb.

Considering the worst case operating conditions, the A320 FCOM 3.02.28/QRH 2.09 paper procedure has retained three different scenarios:

- The airplane is on gravity feed shortly after take-off, in which case the gravity fuel feed ceiling is limited to FL150 or 7 000 feet above the airport
- The airplane switches to gravity feed with a Flight time above FL300 being less than 30 minutes, in which case the ceiling is limited to FL300
- The airplane switches to gravity feed with a Flight time above FL300 exceeding 30 minutes, in which case the ceiling is the current FL.

4 | Standard Operating Procedures

ECAM task sharing rules

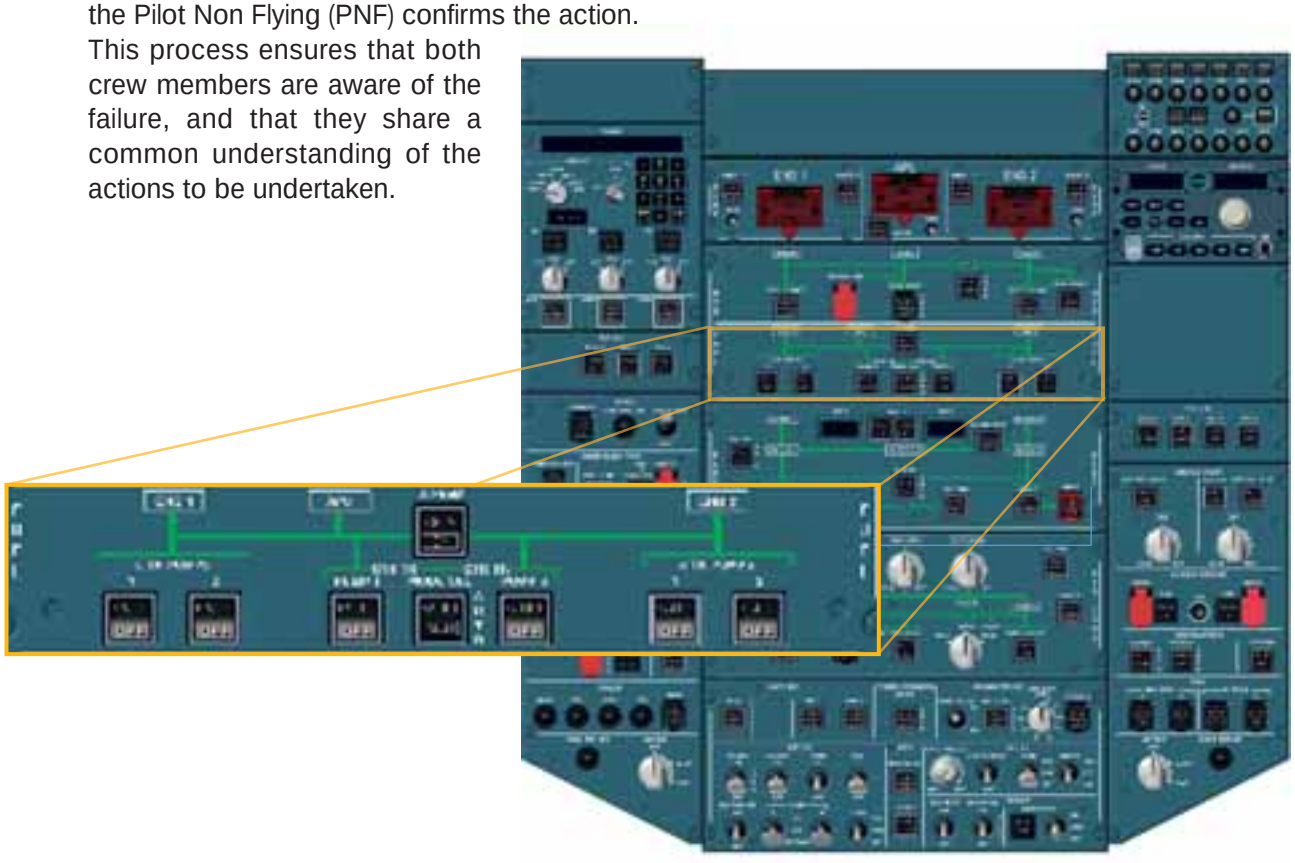
This event serves to highlight the importance of adhering to the ECAM operational philosophy. The first pilot, who notices an ECAM Caution or Warning, announces the title of the failure. The Pilot Flying (PF) then orders “ECAM Action”, and the Pilot Non Flying (PNF) confirms the action. This process ensures that both crew members are aware of the failure, and that they share a common understanding of the actions to be undertaken.

The PNF then performs the action and requests permission to clear the failure.
The PF will first check to ensure that the action has been completed, then announce, “Clear ECAM”.

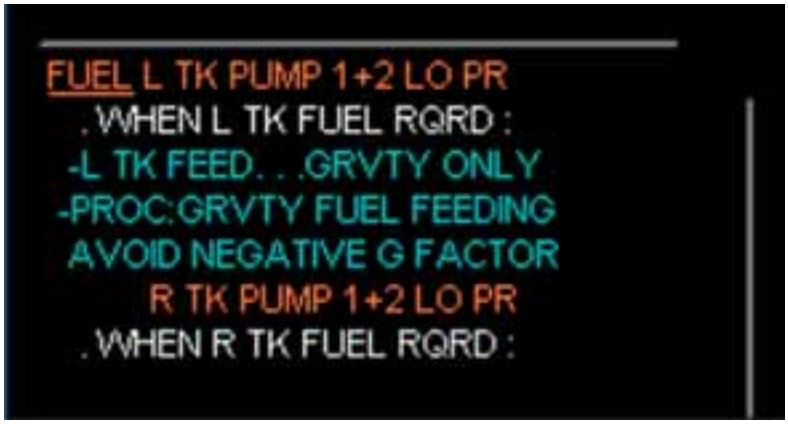
Fuel pumps left in OFF position

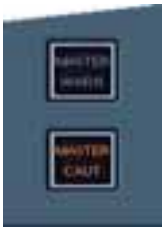
The following three barriers were available to alert the crew of the abnormal configuration they were flying in:

- First barrier:
  At the beginning of the Cockpit Preparation checklist for the Overhead Panel, the SOPs request the crew to extinguish all white lights (pushbutton switches) on the overhead panel, as applicable during the scan sequence. This ensures that both the center tank and wing tank pushbutton switches are selected to the ON position prior to flight, except for the center tank if OEB 178 applies.
  With the center tank and wing tank fuel pumps l in the OFF position, this is how the overhead panel would look like; notice the six illuminated white pushbutton lights:



- Second barrier:
  30 seconds after the first engine start (flight phase 2), if the wing tank fuel pumps are still in the OFF position, the dedicated ECAM Caution will trigger, and the FUEL page will be displayed:





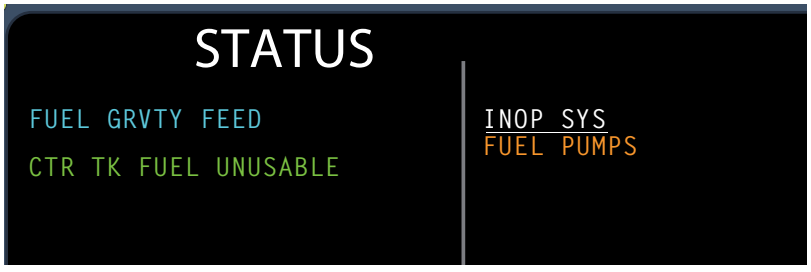
(ECAM upper display – E/WD – Warning part)

Symbol  means:

PUMPS OFF

(ECAM lower display SD)

- Third barrier:
  Clearance of an ECAM Caution leads to the display of the STATUS page:



5 | Enhancements

Flight warning Computer (FWC)

Airbus is working on future enhancements in the next FWC standard H2F5 (certification planned by mid 2009). Indeed, the TAKE OFF CONFIG will be improved to monitor as well the fuel pumps, hydraulic pressure, IDG disconnection, and electrical generators.
For example, if the fuel pumps are left in the OFF position, this new FWC standard will recall the following ECAM Caution :

FUEL L TK PUMP 1+2 LO PR
FUEL R TK PUMP 1+2 LO PR

Information concerning OEB 178 and OEB 180:

Operators for which OEB 178 and/or OEB 180 apply, may cancel them by the accomplishment of the mandated Service Bulletin 28-1159-00 (this SB involves only 2 hours of elapsed time).

6 | Conclusion

Existing barriers (white lights on the overhead panel, ECAM Caution, audio warning, status page display on the System Display) were available to prevent the crew overlooking the fuel pumps in the OFF position.

Further barriers will be included with the proposed enhancements:

- Addition of some system monitoring within FWC standard H2F5
- Cancellation of OEB 178 and OEB 180 with the implementation of the modification referenced in SB 28-1159-00.

Additionally, the following more general lessons may be learned from this event:

- ECAM task sharing rules should be followed before clearing Cautions or Warnings
- Design features are not meant, and never will, to replace effective briefings.

Avoiding Dual Bleed Loss

By: Patrick GRAVE
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Pneumatics, Ice and
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Christophe MATHE
Engineer A320/A330/A340
Operational Standards
Customer Services

1 | Introduction

Over the past years, the A320 family fleet experienced a significant number of dual air engine bleed losses. The consequences of these losses ranged from in-flight turn backs shortly after take-off, to full blown cabin depressurization events and flight diversions.
The aim of this article is to present the typical causes of the dual bleed losses and to explain how:

- The crew may mitigate the operational consequences of this type of occurrence by applying the pertinent procedures
- New maintenance and design improvements should reduce the number of such events in the future.

We are confident that the correct application of the above procedures and improvements should help airlines to limit occurrences of dual bleed loss incidents.

2 | Description of the pneumatic system

The main purpose of the dual bleed air system is to provide the air conditioning system with air regulated in both pressure and temperature.
They also supply various air system consumers such as :

- Wing anti-ice protection
- Engine starter
- Hydraulic reservoir and water tank pressurization.

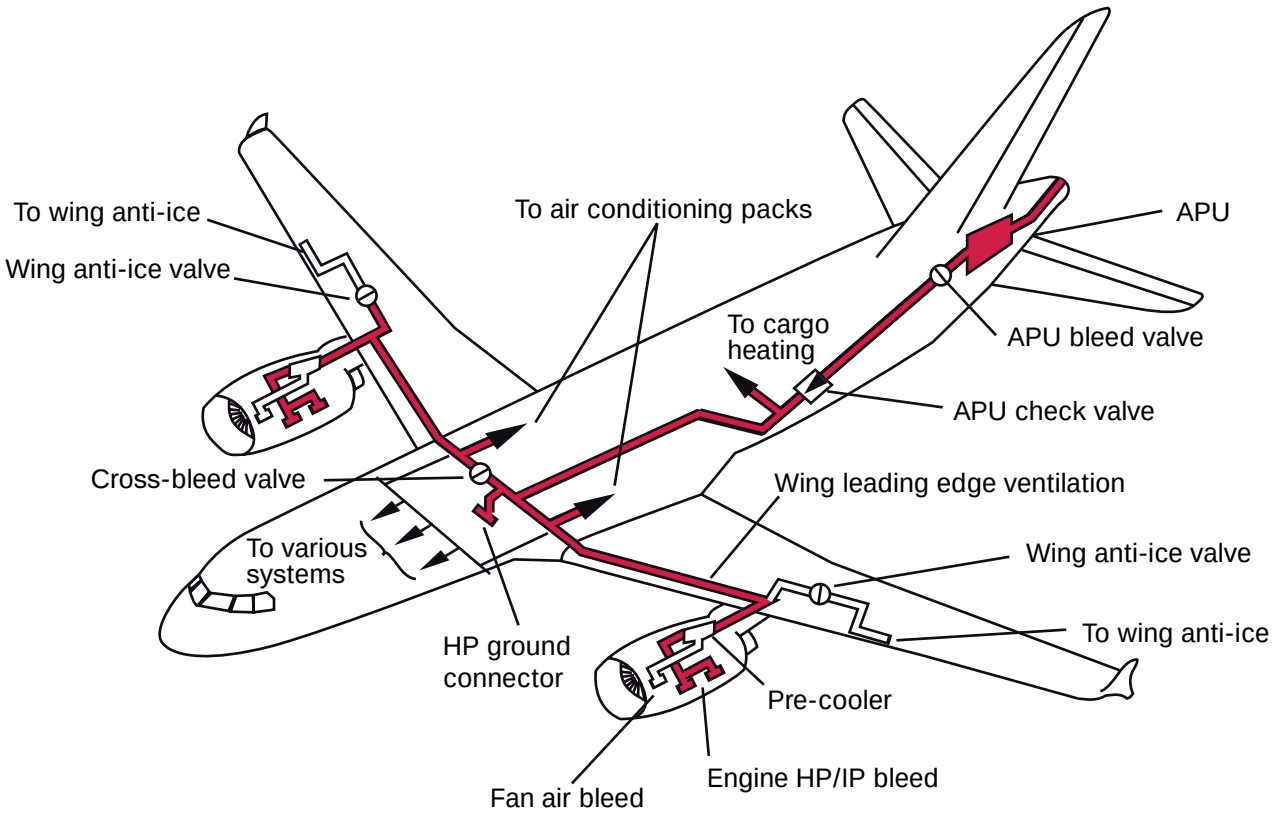


Figure 1: Pneumatic system layout

The bleed air system is installed in the nacelle and pylon of each engine and includes:

- For the pressure regulation:
  - An Intermediate Pressure Bleed Check Valve (IPCV)
  - A High Pressure Bleed Valve (HPV)
  - An Over Pressure Valve (OPV)
  - A Pressure Regulator Bleed Valve (PRV), which is commanded by a Temperature Limitation Thermostat (TLT).
    The TLT will order the PRV to reduce the pressure in the system in case of over-temperature.
- For the temperature regulation:
  - A precooler exchanger (PCE)
  - A Fan Air Valve (FAV), which is commanded by a Temperature Control Thermostat (TCT)
  - The TCT will order the FAV to increase air flow from the fan in case of over-temperature.
- For the system monitoring:
  - A Bleed Monitoring Computer (BMC).

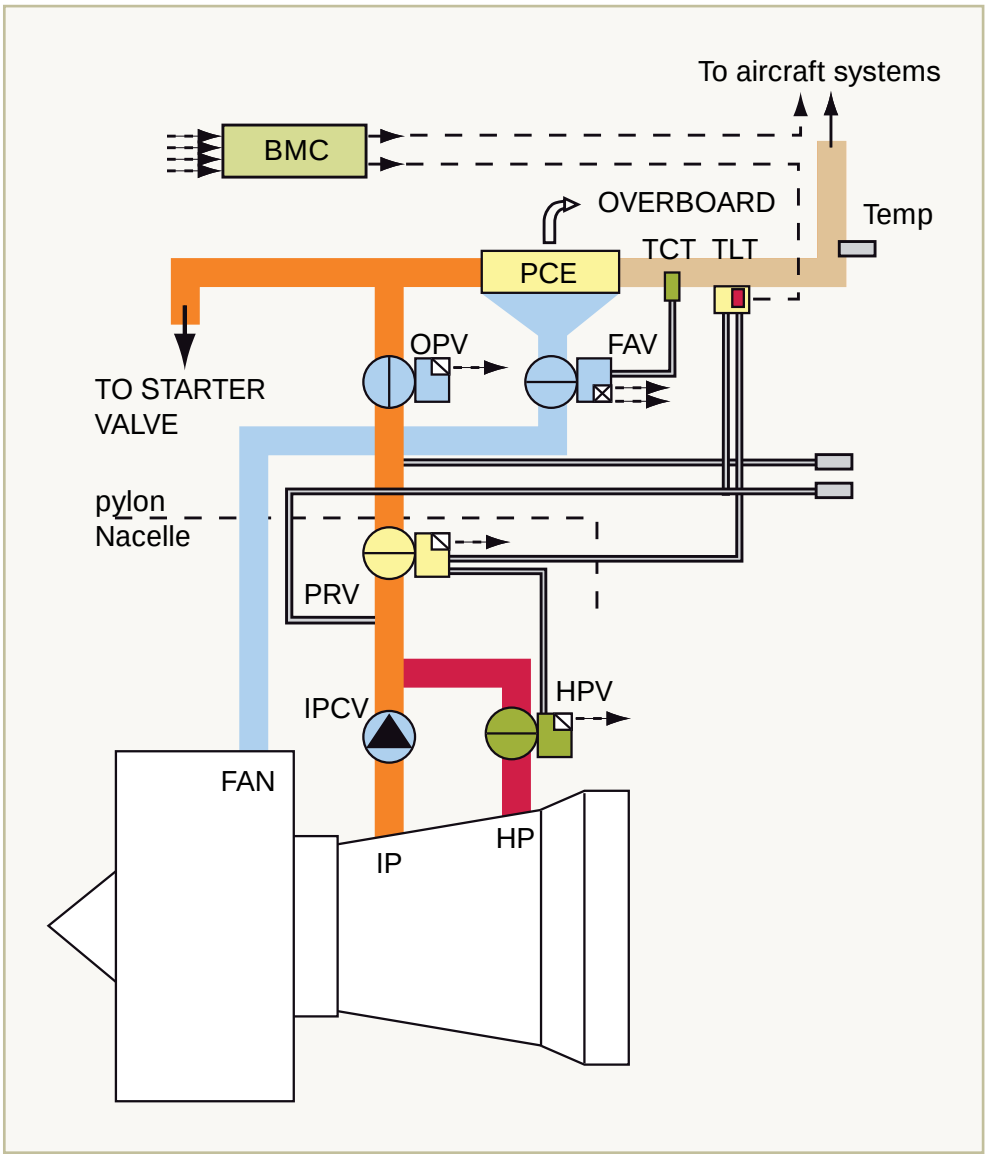


Figure 2: Main components description

3 Typical failure scenario

The dual bleed loss events usually happen when one bleed fails, resulting in the remaining bleed on the other engine to compensate for it.

The augmented flow of warm air from the engine core leads to a corresponding increase in the flow of cold air from the Fan to the Precooler.

In case of one engine bleed loss, the remaining bleed fails when the Fan Air Valve (FAV) does not let enough cold air reach the Precooler (PCE). This causes the temperature downstream of the PCE to reach the 260°C (500°F) over-temperature threshold, which induces the automatic closure of the bleed system.

This excessive rise in temperature is caused mainly by either:
- Leakage of the TCT to FAV sense line
- TCT drift / failure
- Or FAV leakage / failure.

NOTE: In-service experience has shown that the root cause of over-temperature is often linked to a combination of the above factors.

Other possible causes are:
- Temperature sensor failure
- Wiring failure.

4 Operational procedure to be applied

In the above scenario, the failure of the first bleed system leaves the second engine bleed to supply all the aircraft consumers. This bleed, in turn, is lost due to excessive demand.
After the failure of both bleed systems, the AIR DUAL BLEED FAULT paper procedure (QRH page 2.02 and FCOM 3.02.36 page 3) therefore recommends to initiate a rapid descent to FL200 and to reduce air demand, before attempting the recovery of the second bleed system.

Assuming that both PACKS are operative, the air demand is reduced by shutting OFF the PACK on the side of the first affected bleed system.
The flight crew should then press twice the ENG BLEED pushbutton on the overhead panel associated to the second engine bleed, in order to reset it.

– DESCENT . . . . . INITIATE
Descend rapidity to FL200 so that the bleed supply may be supplied by the APU, if the bleed system recovery is not successful.*

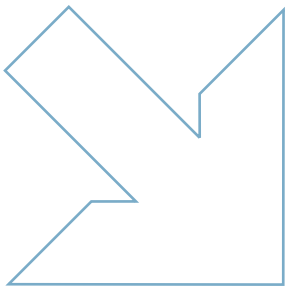
- **If both packs are available:**
If both packs are operative, it can be suspected that the second bleed system failed due to excessive demand. Recovery of the second failed engine bleed may be attempted.

■ **IF ENG 1 BLEED is lost first:**
- PACK 1 . . . . . OFF
- ENGINE 2 BLEED . . . . . ON

■ **IF ENG 2 BLEED is lost first:**
- PACK 2 . . . . . OFF
- ENGINE 1 BLEED . . . . . ON

* FL225 for APU Honeywell 131-9 (A)

Figure 3: Extract of Quick Reference Handbook page 2.02



The bleed should recover, and the flight should be able to resume to the destination airport with one engine bleed supplying one PACK (that automatically delivers high flow).

5 | Maintenance and design improvements

Following laboratory and flight tests, enhancements have been introduced in the domains of maintenance and design.

- Maintenance
  - Improved FAV leak check procedure in the Aircraft Maintenance Manual (AMM) (ref A)
  - Test of the engine bleed system performance. The AMM includes a new test of the capacity of the bleed system to function properly in a one bleed/two packs configuration (ref B)
  - Periodic cleaning of the TCT filter
    As the clogging of the filter is considered to be a major contributor to the TCT temperature drift, a new mandatory MPD task has been introduced (ref C).

NOTE: The Aircraft Condition Monitoring System (ACMS) may be customized to monitor bleed temperature levels. This allows preventive troubleshooting to be performed before the bleed actually fails.

- Design
  - The TCT has been modified to react faster to excessive temperatures, thereby ordering the FAV to increase the cold air supply earlier than before (ref D)
  - In order to address the leakage issue, the FAV has been modified to include a seal between the actuator and actuator cover (ref E)
  - The pressure limitation function has been shifted. Even though the TLT function is not a root cause of bleed failure, it is considered to be an aggravating factor for an already degraded system (ref F)
  - New tooling is being developed to allow bleed air system health checks and to improve trouble shooting efficiency.
    These tools are expected to be available by the end of 2009.

6 | Conclusion

The root causes of the dual bleed loss scenario have been identified. Necessary prevention and design improvements have been put in place to address this issue.

Incorporation of the below enhancements should address the large majority of dual bleed loss occurrences. This will have a positive impact on our customer airlines' operations. We therefore highly recommend their timely application.

REFERENCES
A) AMM task 36-11-54-720-001-01
B) AMM task 36-11-00-710-003
C) MPD Task 361143-01-1
D) AIRBUS SB A320-36-1061 and LIEBHERR VSB 342-36-08
E) LIEBHERR VSB 6730F-36-01 & 6730-36-03
F) LIEBHERR VSB 341-36-06

Please consult the Retrofit Information Letter (ref. SEOT2 916.0468/08) issued in July 2008 for logistical advice on the completion of the A320 family dual bleed loss improvement action plan.

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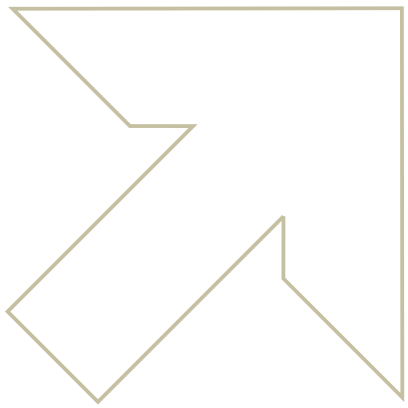

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