TAXIWAY EXCURSION

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GENERAL INFORMATION

Number incident:	2009062
Classification:	Incident
Date, time[1] incident:	2 August 2009, 14.36 hour
Location incident:	Maastricht Aachen Airport
Registration of aircraft:	PH-AAY
Type of aircraft:	Airbus A320 – 232
Type of operation:	Commercial passenger flight
Phase of flight:	Taxi-out
Damage to aircraft:	Minor
Number of crew:	Two cockpit crew, four cabin crew
Number of passengers:	58
Personal injuries:	None
Other damage:	Runway edge light
Light conditions:	Daylight

SYNOPSIS

During a 90° right turn an Airbus A320 ran off the left side of a taxiway while taxiing at Maastricht Aachen Airport towards the runway. An intermittent failing main landing gear down and locked sensor caused the sensor to lose its near position. This resulted in the deactivation of the hydraulic pressure to the nose wheel steering hydraulic module, leaving the crew with no control over the nose wheel steering. The only way to steer the airplane was by differential braking.

[1] All time indications in this report are local times (LT) (LT = UTC + 2 hours) unless indicated otherwise.

FACTUAL INFORMATION

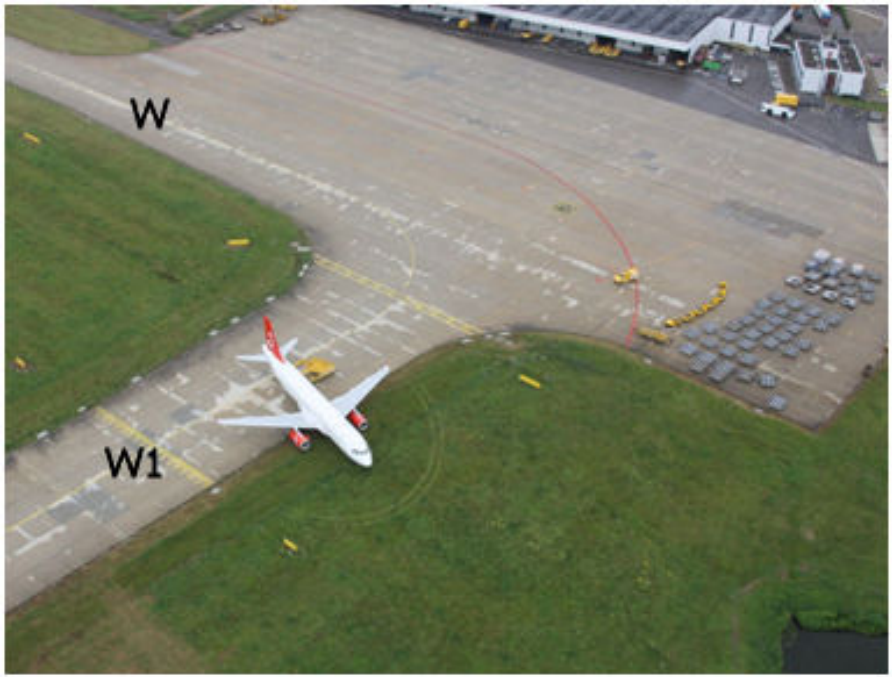
The flight

On 2 August 2009, 14.30 hours the Airbus A320-232 with registration PH-AAY received clearance for its flight from Maastricht Aachen Airport to Kayseri Erkilet Airport in Turkey (LTAU). During the flight the captain was to be pilot monitoring from the left seat, the first officer was to be pilot flying from the right seat. However, company procedures prescribe that during ground manoeuvres the captain is to perform the duties related to the taxiing of the aircraft, making him the pilot flying during taxi-out.

The aircraft was parked on the A apron. At 14.33:57 hours PH-AAY started to taxi to the runway 21 via the W taxiway. At the start of the turn towards the W1 taxiway the ground speed was approximately 18 knots.[2] At 14.36:16 hours a 90 degrees right turn towards the runway was initiated by the captain using the steering hand wheel. After completing approximately a ¾ right turn, the aircraft lost the nose wheel steering. An effort was made to reset the anti-skid and nose wheel steering. However, the nose wheel steering remained inoperative. The crew used differential braking, with more pressure on the left pedal, trying to steer the aircraft. Thereafter the aircraft ran-off the taxiway at the left side at an angle of approximately 30° with the taxiway edge. The left main gear sank 20 cm into the soft ground and came to a halt after 1 to 2 meters. The aircraft started to pivote to the left around the left main gear. The aircraft came to a standstill with the fuselage almost perpendicular to the taxiway with the right main gear just on the pavement edge. See picture 1.

The passengers and the crew disembarked after 20 minutes using an external stair at the left backside of the aircraft. None of the crew nor the passengers were injured.

The wheels of the left main gear sustained minor damage. A taxiway edge light was broken and the grass area next to the taxiway sustained some damage.



Picture 1: aerial picture after the incident (source: Aviation police)

[2] One knot is 1852 meter/hour.

Personnel information
The captain was a 38 year old man. He possessed a valid Airline Transport Pilot License (ATPL(A)) with instrument rating and the type ratings F50 and A320. He possessed a valid medical certificate class I.

	All types	*A320*
Total	7500	1800
Last 90 days	130	130
Last 24 hours	0	0

Table 1: flying experience captain in hours

The first officer was a 31 year old man. He possessed a valid Commercial Pilot License (CPL(A)) with instrument rating and type rating A320. He possessed a valid medical certificate class I.

	All types	*A320*
Total	472	290
Last 90 days	80	80
Last 24 hours	7	7

Table 2: flying experience first officer in hours

Aircraft
Registration: PH-AAY
Aircraft type: Airbus A320-232
Manufacturer serial number: 527
Date of manufacture: 1995
Certificate of Airworthiness: Valid from 18 June 2009 till 18 June 2010
Certificate of registration: issued on 10 June 2009

Meteorological Information
The weather at the time of the incident was: wind 250 degrees, 6 knots variable between 210 degrees and 290 degrees, scattered 400 ft, overcast 600 ft, visibility 8 kilometres, temperature 17 degrees Celsius, dew point 16 degrees Celsius, QNH 1011 HPa.

Airport Information
Maastricht Aachen Airport apron A is situated in front of the terminal building. Apron A has, parallel to runway 03-21, a taxiway (W) to runway 21. Runway 21 was assigned to PH-AAY for departure. Taxiway W has a width of 23 meters with a surface of concrete and asphalt.

Flight Recorders
The aircraft was equipped with a digital flight data recorder (DFDR) and a cockpit voice recorder (CVR). After the event the DFDR data was downloaded. Conversion to engineering units and subsequent analysis has been performed by Airbus Industries on behalf of the Dutch Safety Board. The CVR was not read out.

INVESTIGATION AND ANALYSIS

Aviation systems

Two aircraft systems are important in this occurrence:

- A320 Nose Wheel Steering
  This system enables to steer the aircraft while taxiing on the ground. It is operated by the cockpit crew using the hand wheel steering or the rudder pedals.
- A320 Braking and Steering Control Unit (BSCU)
  The BSCU has two identical electronic systems (system 1 and system 2). The BSCU has its own logic for activation, functioning and deactivation of these systems. When system 1 is active, system 2 is in the stand-by mode. When system 1 becomes ineffective it deactivates and system 2 will take over and becomes active. The BSCU is located in the aircraft's avionics bay. The BSCU computer controls the braking and nose wheel steering of the aircraft.

A more extensive description of these systems is contained in appendix A.

The aircraft was dispatched under a minimum equipment list (MEL) condition at time of the incident. Due to a fault in the BSCU system 1 the related circuit breaker for system 1 was pulled (open) as per master minimum equipment list (MMEL) procedure 32-42-03 since 22 July 2009. The aircraft was allowed to operate when one of the two BSCU systems was operative until the ultimate repair date of 1 August 2009. On this date extension until 11 August 2009 was granted.

The following messages have been retrieved from the maintenance post flight report, printed by the aircraft system:

<u>Warning/maintenance status messages</u>

Time (UTC)	
12.36	*Wheel N/W STRG fault*
12.36	*Brakes sys 1 fault*

<u>Failure messages</u>

Time (UTC)	
12.34	*No HF 1 Data*
12.34	*Check BSCU DC1PP circuit*
12.36	*No BSCU 2 DATA (INTM)*
12.36	*Steering Electro Hydraulic module 6GC*
12.41	*DMC3: No EEC1B Data*
12.41	*AFS: 28V PWR 11XU1*

Fault analysis

The PH-AAY was equipped with a Braking and Steering Control Unit (BSCU) manufactured by Messier-Bugatti. This BSCU was updated to Standard 10 software modification and consequently complied with the AD[3] 2008-0048. This AD was issued after nose wheel steering problems occurred with the Airbus type A319, A320 and A321. These problems were solved by the software Standard 10 modification.

Based on the Electronic Centralized Aircraft Monitor (ECAM) messages recorded after the incident a failure of the BSCU was suspected. BSCU, serial number 911, was removed and replaced with another BSCU, serial number 1450. Also the nose wheel steering servo control was changed. Both the BSCU and the servo unit which were replaced, were sent to the manufacturer for analysis. In addition the nose

[3] Airworthiness directive

landing gear wheels were replaced. Hereafter PH-AAY was to be released for a ferry flight to Oslo for maintenance. However, during a taxi trial on 5 August 2009 a left hand landing gear not down warning was triggered and the ECAM provided consequently a nose wheel steering fault message again.

Based on these fault messages an integrity test of the nose wheel steering was performed in accordance with AMM[4] 32-51-00 and found satisfying. The main landing gear oleos were found to be extended slightly too much. This was corrected as per procedure and judged to be of no relevance to the incident.

Wiring checks of all six proximity switches[5], fit on all gears were performed by the operator. The left hand system main landing gear extension proximity sensor 21GA and the right hand main landing gear extension proximity sensor 20GA were found short to ground. The target clearance of the proximity sensors were found to be within limits. After replacement the operator has performed functional test of the removed proximity sensors. The six proximity switches were found to be within limits when tested on resistance. After this the proximity switches were sent to Airbus Industries for further analysis.

Braking and Steering Control Unit tests
The removed BSCU serial number 911 was analyzed by the manufacturer. The BSCU data showed that an intermittent fault of BSCU system 1 led to an incorrect initialization of system 1 at power up. Consequently the BSCU transferred automatically control to BSCY system 2 which was found to be functioning correctly.

The data confirmed that BSCU System 1 circuit breaker was pulled (open) over the period of 22 July to 2 August. This was in accordance with MMEL procedure 32-42-03. The BSCU system 2 was found to be operational over this period, although system 2 experienced and detected six times an external fault comparable to the fault that initiated the incident.

Based on the data retrieved the BSCU system 2 was found to be functioning according to specification and was not the origin of the nose wheel steering power loss.

Steering Hydraulic Control Unit (HCU)
Steering Hydraulic Control Unit (serial number 1163) was investigated by the manufacturer. The unit was found to be in good condition. Some details on valve opening pressure and the nose wheel steering servo valve drift were noted. However, both deviations were considered minor issues and with no relevance to the incident.

Landing gear proximity sensors analysis by Airbus Industry
After inspection by the operator the resistance values of the proximity sensors were found to be within tolerance. Thereafter the six proximity sensors (model PN 8-484-01) were sent to Airbus Industries for further investigation. Since the malfunction was suspected in four specific sensors, these were extensively tested. The following results were obtained after this extensive testing:

[4] Aircraft maintenance manual

[5] A proximity switch measures the distance between two aircraft parts to check the right position of both parts compared to each other.

	Inductance target near (mH)	Inductance target far (mH)	Resistance (Ohm)	Test result
15GA (LH Downlock prox sensor)	5.07	4.72	11.2	OK
17GA (LH Downlock prox sensor)	4.65	4.36	11.2	Failed
20GA (RH extension prox sensor)	4.55	4.55	11	Failed
21GA (LH extension prox sensor)	5.08	4.72	11.6	OK

Table 3: investigation of PH-AAY landing gear proximity sensors

Note: Correct values for target near are 5.02-5.16 mH and for target far 4.68-4.81 mH.

Table 3 shows that the resistance values were within the limits and that using the resistance test, the malfunctioning of the proximity switches could not be identified. Only after performing inductance tests the malfunctioning of 17 GA and 20 GA could be determined. In this case the malfunctioning of sensor 17GA was considered relevant since this was a downlock proximity sensor that confirms that the gear is down and locked while 20 GA is an extension proximity sensor that is used for weight on wheels logic.

Proximity sensors that were installed on aircraft at time of the event were ferrite sensor (PN 8-484-01, specification ABS0121-10). Those proximity sensors are more prone to moisture ingress which in turn causes failure of the ferrite core. Alternative sensors are available (PN 8-933-01, specification ABS0121-40) which are all metal sensors with hermetically sealed titanium housing.

Digital Flight Data Recorder(DFDR) readout
The DFDR data was analysed by Airbus Industries. Based on the data the following relevant events were noted.

DFDR data analysis of initial conditions before the event:

	Aircraft was rolling on the taxiway at Maastricht Aachen Airport. Gross weight was 60.4t and centre of gravity was 26.5% (according to Load and Trim sheet).
From 12.26:10 to 12.32:33 UTC	All BSCU parameters from DFDR were recorded invalid from 12.26:10 to 12.32:33 UTC. The anti skid selector was on OFF. Parking brake was set ON, and removed at 12.29:28 UTC.
12.31:03 UTC	'Normal brake fault' Boolean triggered.
12.31:30 UTC	Parking brake was recorded ON.
12.32:33 UTC	Anti skid selector was ON. BSCU parameters became valid (except normal brake pressures on wheels 2 and 3. 'Normal brake fault' Boolean fell to 0. BSCU2 engaged.
12.32:56 UTC	Anti skid selector transiently recorded on OFF, BSCU parameters became invalid during that period. BSCU2 remained recorded engaged.
12.33:57 UTC	Parking brake was recorded OFF. Ground speed started to increase.
Van 12.34:25 tot 12.35:02 UTC	The aircraft performed its flight control check. Auto brake MAX was armed.
12.35:39 UTC	Ground speed increased up to 30 kt.
12.35:40 UTC	Left and right braking pedal was used.

12.35:56 UTC	Braking pedals were released, ground speed was 10 kt. Ground speed started to increase again.

DFDR data analysis of the event:

12.36:14 UTC	Just before the turn the ground speed was 18 kt. Pedal braking was initiated and the ground speed started to decrease. More pressure was put on the left pedal.
From 12.36:16 UTC	The magnetic heading started to increase, this corresponds with the start of a right turn.
12.36:20 UTC	The braking pedals were released in the turn. The ground speed was 14 kt.
12.36:26 UTC	The 'gear selected down and not locked' Boolean triggered from 0 to 1 for two seconds. This status relates to a landing gear being selected down, but not being down and locked. This corresponds with one of the downlock proximity sensors losing its near position. Two seconds later the 'gear selected down and not locked' Boolean was triggered twice again for one second.
12.36:27 UTC	The crew used differential braking with more pressure on the left pedal.
12.36:28 UTC	Maximum magnetic heading was reached (104°) before starting to decrease again. This corresponds with the left main gear sinking into soft ground next to the taxiway after which the aircraft starts to pivot to the left, reducing the magnetic heading.
12.36:29 UTC	Pedal braking was used and the longitudinal acceleration increased. The pedal brakes were released and then presses again one second later.
12.36:43 UTC	The aircraft was stopped.
12.37:05 UTC	The braking pedals were released.

During the event no electric or hydraulic power failures have been recorded.

Most likely chain of events based on functioning of the BSCU and the proximity switches
Since weather nor air traffic control services were considered to be a causal factor, the analysis of this incident will focus on the functioning of nose wheel steering.

Based on the above-mentioned information, the taxiway excursion by PH-AAY on August 2nd is considered to be the result of a loss of nose wheel steering most probably due to a faulty downlock proximity sensor. This is supported by the results of the inspection of the BSCU that concluded that the BSCU system 2 was functioning properly. Although also both electric and hydraulic systems were functioning normally, the BSCU did record a loss of NWS capability. Investigation of the proximity sensors removed from PH-AAY revealed that downlock proximity sensor 17GA (LH SYS1 downlock prox sensor) was faulty (inductance for *target near* and *target far* were out of tolerance). This downlock proximity sensor must have lost its "NEAR" position during taxi-out. This was also shown in the DFDR data were it was pointed out that the parameter GSND was triggered intermittently at the time of the event (starting at 12.36:26 UTC), probably due to failure of the downlock proximity sensor 17GA. Parameter GSND was linked to the configuration warning "LG NOT DOWN". This warning did NOT require confirmation time, and did only require one sensor in a "not downlocked" position to be activated.

This is reinforced by the results of the taxi test performed after the event were the warning LH L/G NOT DOWN was triggered. If at least one of the L/G downlock sensors indicates "NOT LOCKED DOWN", the nose doors selector valve (41GA) is de-energized. On A320 aircraft, before model modification 31152 the pressurization of the NWS system goes through the landing gear system and more especially through the landing gear doors closed position. Therefore, in such a configuration, the doors remain closed but the hydraulic supply to the doors actuators and the steering hydraulic module 6GC is cut off. This will be detected by the BSCU that will take the proper sanction to shut off the steering.

Based on the above, therefore the following scenario can be contemplated:

- MMEL 32-42-03 was applied due to BSCU System 1 failure. Consequently circuit breaker 2GG was opened to deactivate BSCU SYS1. This explains the post flight report (PFR) Message: *Check BSCU DC1PP circuit* from BSCU 1 and the *<<Brakes Sys 1 Fault>>* on the ECAM.
- At 12.36:26 UTC the GSND Boolean was triggered, meaning that at least one downlock proximity sensor was seen "not downlocked".
- Consequently the landing gear doors selector valve 41GA was de-energized and the hydraulic supply to the nose wheel steering was cut off as well.
- In case of steering demand the BSCU detected a disagreement between the theoretical position of the NWS spool and its actually commanded position (fault was noted).
- BSCU reset was performed by the pilot. NWS A/S switch was set to OFF. Associated status reports were recorded. When power was restored to BSCU "BSCU SYS 1 FAULT" was recorded due to pulled circuit breaker. Automatic control side change over to BSCU System 2 was noted.
- At 12.36:30 UTC: "NW STRG FAULT" was detected again by the BSCU since fault conditions were still fulfilled.

Actions Airbus Industries

In February 2000 Airbus released a Service Information Letter (SIL) to all customers with the purpose to inform operators of the availability of new landing gear proximity sensors. This SIL was revised in September 2006. The new landing gear proximity sensor is an all-metal sensor with hermetically sealed titanium housing. This type of sensor is less prone to moisture ingress than the older composite type. Replacement of the older type sensor into the all metal ones was not mandatory.

CONCLUSIONS

- The flight crew was properly licensed and qualified to conduct the flight.
- The aircraft had a valid certificate of airworthiness and a valid maintenance release for the flight.
- The weather and air traffic control were not a factor in the incident.
- While making the right hand turn during taxi the nose wheel steering failed due to loss of hydraulic power.
- The crew used differential braking with more pressure on the left pedal which caused the aircraft to turn to the left.
- A reset of A/SKID & N/W STRG did not restore the NWS.
- Electric and hydraulic systems were functioning according to specification.
- Braking power was available, however due to the limited time between failure of the NWS and the left main gear leaving the taxiway it proved impossible to stop the aircraft in time.
- The BSCU functioned correctly.
- Downlock proximity sensor 17GA failed in impedance tests. Very probably this failure was the origin of at least one of the L/G downlock sensors indicating "NOT LOCKED DOWN" resulting in the nose wheel doors selector valve (41GA) to be de-energized.
- When the landing gear doors selector valve 41GA was de-energized the hydraulic supply to the nose wheel steering was cut off.

PROBABLE CAUSE

The following causal factor was identified:
Faulty functioning proximity switch due to moisture ingress.

Contributing factors were the available response time to stop the aircraft on the taxiway and the differential braking with more pressure on the left pedal.

Note: This report has been published in the English and Dutch language. If there are differences in interpretation the Dutch text prevails.

APPENDIX A: NOSE WHEEL STEERING AND BSCU

A320 Nose Wheel Steering

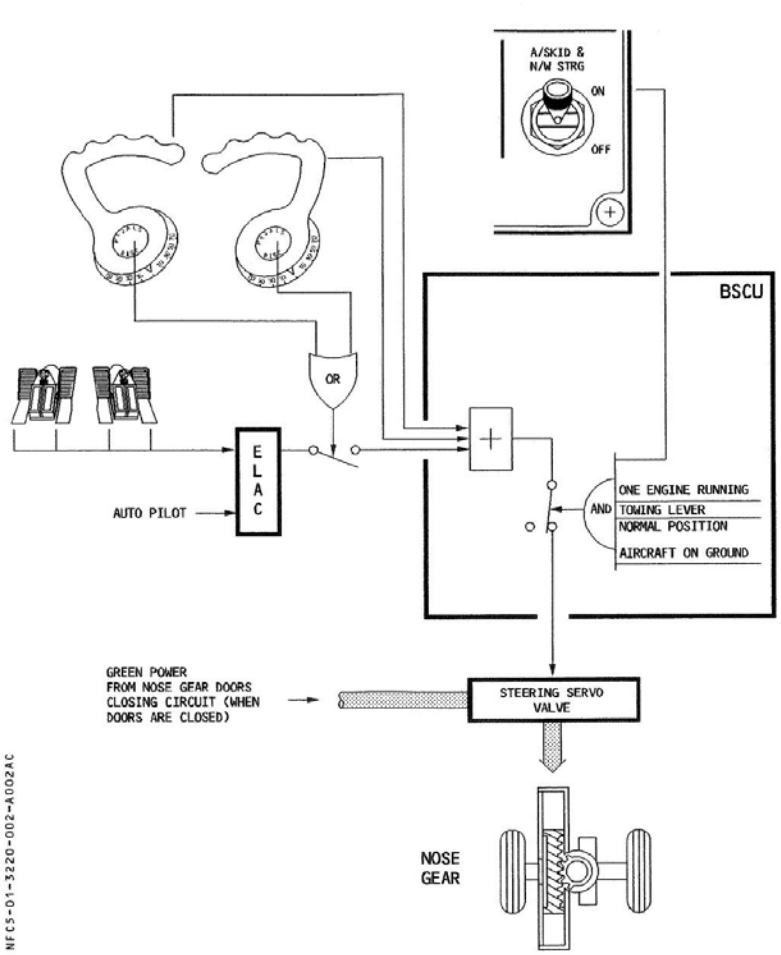
The A320 nose wheel is controlled by a hydraulic actuator cylinder that steers the nose wheel. The nose wheel steering (NWS) uses power from the green hydraulic system and is commanded by electric signals from the Brake and Steering Control Unit (BSCU). For the nose wheel steering function the BSCU receives orders from:

- the captain's and first officer steering hand wheels;
- the captain's and first officer rudder pedals;
- the auto pilot.

The nose wheel steering system receives actuating hydraulic pressure from the green hydraulic system when:

- the anti-skid and nose wheel steering (A/SKID & N/W STRG) switch is on and;
- the towing control lever is in normal position and;
- at least one engine is running and;
- the aircraft is on the ground.

All four conditions must be met before hydraulic pressure is applied to the steering actuating cylinder. The hydraulic pressure to the nose wheel steering actuator is rooted via the nose wheel door up lock assembly.



Picture 2: diagram of the nose wheel steering of a A320

A320 Braking and Steering Control Unit (BSCU)

The BSCU is located in the aircraft's avionics bay. The BSCU computer controls the braking and nose wheel steering of the aircraft. The BSCU uses input from: anti-skid and nose wheel steering ON/OFF switch (A/SKID & N/W STRG switch), auto brake mode, tachometers, brake pressure, brake temperature, landing down and locked sensors, nose gear door position sensors, and signals from the steering handwheels, rudder pedals and autopilot. Output is provided in form of electronic signals to the servo valves of the hydraulic brake pressure systems, to the nose wheel steering actuator and status information to the cockpit systems.

The BSCU has two identical electronic systems (system 1 and system 2). The BSCU has its own logic for activation, functioning and deactivation of these systems. When system 1 is active, system 2 is in the stand-by mode. When system 1 becomes ineffective it deactivates and system 2 will take over and becomes active. If both BSCU systems are inoperative, the BSCU is deactivated. The BSCU can be deactivated by switching the A/SKID & N/W STRG switch to the OFF position. The A/SKID & N/W STRG switch is located on the centre instrument panel in front of the pilots. One or both BSCU systems can also manually be deactivated by pulling the relevant BSCU circuit breakers. These circuit breakers are located on the wall behind right hand pilot's seat. With a complete deactivated BSCU, braking will be available through alternate braking without anti-skid and the parking brake remains available, but nose wheel steering will be lost when both BSCU systems are off-line.

At every BSCU power up, the BSCU software program will run a test through the different cards of each system. If there is no discrepancy, the system will be valid. Then a specific logic determines the active and "stand by" system. If there is a discrepancy on a system, this one won't start, a message will appear on the ECAM, and the other system takes over. Then, if a failure is detected in the remaining active system, specific sanctions will be taken with associated aural warning, master caution light and message on the WHEEL page of the Electronic Centralized Aircraft Monitor (ECAM).