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INVESTIGATION REPORT

Serious incident to the ATR 42-500
Registered F-GPYF
Operated by HOP!

On 25 March 2018
At beginning of descent to Aurillac airport (Cantal)

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

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BEA2018-0151.en/February 2021

Safety investigations

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The BEA investigations are independent, separate and conducted without prejudice to any judicial or administrative action that may be taken to determine blame or liability.

SPECIAL FOREWORD TO ENGLISH EDITION

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation published in February 2021. As accurate as the translation may be, the original text in French is the work of reference.

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Glossary

Acronyms	
AFNOR	French Standards Association
AIA	Aerospace Industries Association (US)
ALT P/N	Alternative Part Number listed in the SRM or SPET
AMASIS	Aircraft Maintenance And Spares Information System
AMM	Aircraft Maintenance Manual
AMOS	Airline Maintenance & Operational Systems
AOA	Angle Of Attack
AOM	All Operators Message
APM	Aircraft Performance Monitoring
ATA	Air Transport Association
BEA	Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile (French Civil Aviation Safety Investigation Authority)
BFU	Bundesstelle für Flugunfalluntersuchung (German Federal Bureau of Aircraft Accident Investigation)
CARI	Continuing Airworthiness Review Item
CRES	Corrosion Resistant Steel
CRNA/SO	En-route Control Center (South-West)
CVR	Cockpit Voice Recorder
Cx	Drag coefficient
DM	Data Module
DOA	Design Organisation Approval
EASA	European Aviation Safety Agency
EDS	Energy Dispersive X-ray Spectroscopy
FAA	Federal Aviation Administration
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
FL	Flight Level
FO	First Officer
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization
IPC	Illustrated Parts Catalogue

Acronyms	
IPC OPT P/N	Optional Part Number listed in the IPC
IPC P/N	Part Number listed in the IPC
JAR	Joint Aviation Requirements
JIC	Job Instruction Card
L MLG	Left Main Landing Gear
MLG	Main Landing Gear
MPD	Maintenance Planning Document
MRO	Maintenance Repair Organisation
MSN	Manufacturing Serial Number
OOM	On-duty Operational Manager
P/N	Part Number
PF	Pilot Flying
PM	Pilot Monitoring
QRH	Quick Reference Handbook
R MLG	Right Main Landing Gear
RAS	Rheinland Air Service
SEM	Scanning Electron Microscope
SPET	Standard Part Equivalence Table
SRM	Structural Repair Manual
TCU	Tower Cumulus
TLB	Technical Log Book

Synopsis

Time	19:18[1]
Operator	HOP!
Type of flight	Commercial air transport
Persons on board	Captain (PM); First Officer (PF); 1 cabin crew; 48 passengers
Consequences and damage	Aircraft damaged

[1] Unless otherwise stated, all times in this report are in Coordinated Universal Time (UTC). Two hours must be added to this time to obtain the time in metropolitan France on the day of the occurrence.

In-flight loss of the left main landing gear door, collision of door with fuselage

The crew took off from Paris-Orly at about 18:30 and, during the climb, completed a first level flight at FL110.

The findings made during the investigation of the door hinge assemblies of the aircraft's left main landing gear determined that the nut on the door's rear hinge assembly had gradually become loose in service until it fell off, causing the landing gear door to become slightly misaligned with the fuselage. This misalignment resulted in excess drag on the aircraft. This abnormal position of the door also placed additional stress on the other hinge assembly points on the landing gear door, resulting in their successive failure in flight.

At the beginning of the descent to FL180, the door knocked against the fuselage, causing a thud that was heard by people on board, and then separated from the rest of the plane, causing the other damage found on the aircraft:

- damage to wing root fairings;
- scratches to cabin window and surrounding skin;
- tear on lower surface skin of left flap;
- scratches on lower surface skin of left wing;
- small dents on vertical stabilizer.

Not understanding what had just happened, but seeing that the flight parameters were normal, the crew decided to continue the descent and landed at Aurillac as normal. It was only on the apron that the damage to the aircraft was observed.

The investigation was unable to identify the exact cause of the loss of the nut on the rear hinge assembly of the main landing gear door, leading to the loss of the door. However, the investigation did highlight the possibility that the nut in question and the torque applied did not comply with the configuration specified by ATR during the initial design of the fastener.

The investigation also showed that lack of information in the manufacturer's generic maintenance documentation and difficulties in identifying the relevant information can lead, through a combination of organisational and human factors, to the installation of screw/nut combinations that do not reflect the state of the art. The consequences of these deviations from best practice on the performance of the screwed joint could not be precisely determined during the investigation, but may lead to the malfunction of the fastener.

Consequently, the BEA has issued ATR with two safety recommendations. These relate to a review of the manufacturer's generic maintenance documentation on fasteners and particularly, on the notions of the tightening torque to be applied, interchangeability of parts and reuse of self-locking nuts.

ORGANISATION OF THE INVESTIGATION

In the evening of 25 March 2018, the BEA was notified by the CRNA/SO On-duty Operational Manager of the occurrence and launched a safety investigation.

On 27 March 2018, a team of three BEA investigators travelled to Aurillac Airport to conduct the initial inspections of the aircraft. The preliminary information gathered led the BEA to classify this occurrence as a serious incident.

In accordance with the Standards and Recommended Practices in Annex 13 to the Convention on International Civil Aviation and Regulation (EU) No. 996/2010 on the investigation and prevention of accidents and incidents in civil aviation, the BEA involved in the safety investigation:

- The following BEA technical advisers:
  - ATR in its capacity as the aircraft manufacturer;
  - the company HOP! in its capacity as the operator and maintenance operator of the aircraft;
  - EASA in its capacity as the certification authority.
- The BFU, the German Federal Bureau of Aircraft Accident Investigation, in its capacity as the accredited representative of the maintenance operator Rheinland Air Service. The latter appointed a technical adviser to the BFU for the safety investigation.

1 - GENERAL INFORMATION

1.1 History of the flight

On 25 March 2018, the ATR 42-500 registered F-GPYF, operated by HOP!, was on a scheduled commercial passenger flight (flight A5 235) from Paris Orly airport (Val-de-Marne) to Aurillac airport (Cantal) . Forty-eight passengers and three crew members were on board, including one cabin crew. The flight crew consisted of the Captain, who was PM on this leg, and a First Officer in the right-hand seat, who was the PF.

The crew took off at about 18:30 and performed an initial level flight at FL110. During this level flight phase, the CRUISE SPEED LOW[(2)] alert was triggered once for a duration of 60 seconds.

[(2)] This alarm is activated by the APM when the aerodynamic performance of the aircraft is partially degraded, see paragraph 1.6.4.

About two minutes after the start of cruising at FL190, the CRUISE SPEED LOW alert was activated a second time and remained activated throughout the cruise. The crew followed the Operations Manual procedure and checked the airspeed. The indicated airspeed was 212 kt instead of the 224 kt given by the QRH for the occurrence flight conditions.

The flight continued without incident until the beginning of the descent, when people on board heard a thud and felt a jolt at about FL180. There was no significant deviation in the aircraft's autopilot trajectory. The crew checked that there were no abnormal flight parameters and then continued their descent towards Aurillac under nominal conditions.

After landing, the crew noted damage to the aircraft, particularly on the left wing fairing, and that the left main landing gear door was missing.

1.2 Fatalities and injuries

No one was injured in the event.

1.3 Damage to aircraft

The damage to the aircraft was as follows:

- ❒ all the component parts of the left main landing gear door were missing;
- ❒ damage to wing root fairings;
- ❒ scratches to cabin window and surrounding skin;
- ❒ tear on lower surface skin of left flap;
- ❒ scratches on lower surface skin of left wing;
- ❒ small dents on vertical stabilizer.

Source: BEA

Figure 1: Wing fairing damage and missing L MLG door

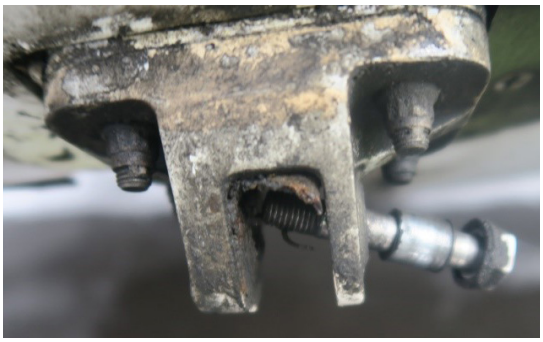
Source: BEA

Figure 2: Damage to the flap

The following two photographs show what was remaining of the fasteners of the front and rear hinge assemblies on the L MLG door, as seen after disassembly of the fairings protecting them[(3)].

- At the rear, the screw had come out of its housing and the nut and washer used to hold it in place were missing.
- At the front, the screw was found in place; a section of the male hinge was broken and locking wire was also present on the screw.

[(3)] Refer to paragraph 1.6.2 for details of the hinge assembly system and its components.



Source: BEA

Figure 3: Remaining part of rear hinge assembly

Source: BEA

Figure 4: Remaining part of front hinge assembly

1.4 Other damage

Not applicable.

1.5 Crew information

Data as at 25 March 2018	Captain	First Officer
Date started working for the operator	16 December 2002	18 October 2017
Type rating and validity	ATR 42/72 Validity 31 January 2019	ATR 42/72 Validity 31 December 2018
Medical class and validity	Class 1 Validity 30 November 2018	Class 1 Validity 08 September 2018
Total experience	7,294 flight hours	414 flight hours
Total experience on type	6,700 flight hours	132 flight hours
Recent experience (last 3 months)	151 flight hours	132 flight hours

Table 1: Flight crew information

1.6 Aircraft information

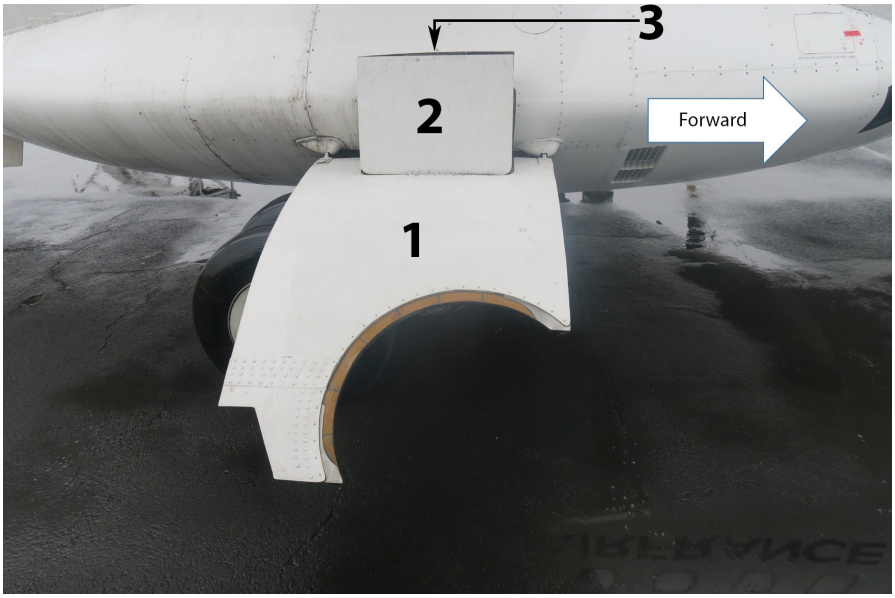
1.6.1 Airframe

Manufacturer	ATR
Type	ATR 42-500
Serial number	495
Registration number	F-GPYF
Introduction	1996
Use as at 25/03/2018	35,123 flight hours and 34,805 cycles

Table 2: Aircraft information

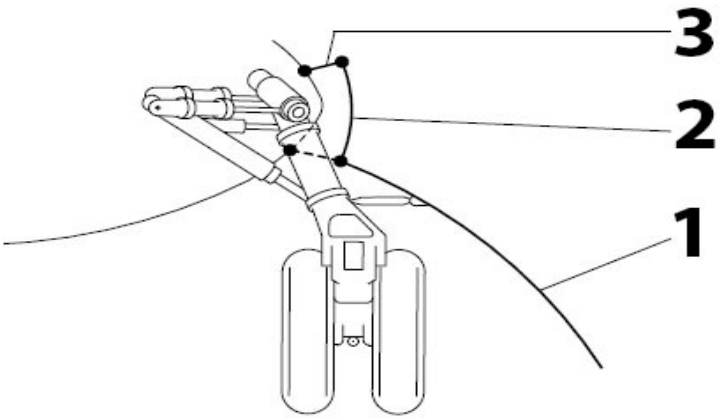
1.6.2 Landing gear door hinge assembly system

1.6.2.1 General



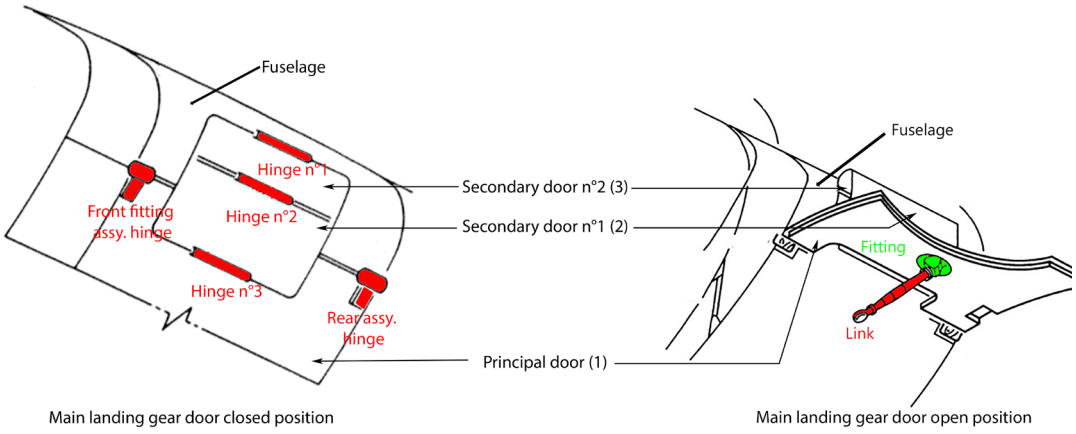
Source: BEA

Figure 5: F-GPYF's R MLG door



Source: ATR FCOM and BEA

Figure 6: Main landing gear doors



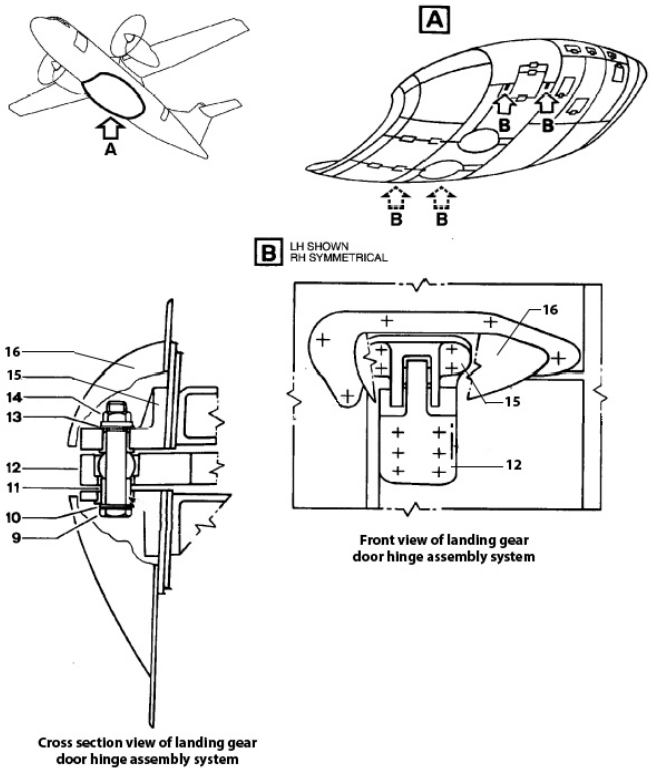
Source: ATR FCOM and BEA

Figure 7: Hinge assemblies and hinges on L MLG door

On the ATR 42, the main landing gear door system (see Figure 5) consists of three doors as shown on Figure 6: principal door (1), concertina door 1 (2) and concertina door 2 (3). The principal door is connected to the landing gear leg by a link, which allows it to be manoeuvred. The male hinges on the principal door are connected (pivot point) to the fuselage (female hinges) using two fasteners (front and rear), each of which is protected by a fairing. The doors are connected to each other and to the fuselage by hinges (see Figure 7).

The main landing gear door system weighs approximately 15 kg.

1.6.2.2 Main landing gear door hinge assembly



Source: JIC 52-81-00 RAI 10000 ATR and BEA

Figure 8: Door hinge assembly system

The fasteners of the front and rear hinge assemblies are constructed in the same way, i.e. each of them comprises (see Figure 8):

- an all-metal self-locking nut (14);
- two washers (13 and 10);
- a male hinge attached on the principal door side (12);
- a female hinge attached on the fuselage side (15);
- a bushing (11);
- a screw with its head pointing towards the rear of the aircraft (9).

The whole system is protected by a fairing (16). Both assemblies are lubricated with synthetic grease.

There are, however, differences between the front and rear hinge assemblies, particularly in respect of the dimensions of the various parts, materials and protections used.

The assemblies in question are not considered to be critical[(4)] by the manufacturer and the certifier.

[(4)] In the certification process, a critical part is a part whose failure could lead to a hazardous or catastrophic event for the aircraft.

1.6.3 Reference documents

All documents cited in this section are those that were applicable at the time of the incident. The documents and their dates of publication are summarised below:

Reference	Publisher	Title	Last date of the revision applicable on the date of the incident
AMM 20-21-12	ATR	TIGHTENING TORQUES OF STANDARD THREADED FASTENERS	The pages have various revision dates (Feb 01/02, Aug 01/08, Mar 01,11, Apr 01/00, Oct 01/16)
JIC 52-81-00	ATR	MAIN L/G DOORS REMOVAL AND INSTALLATION	1 January 2018
SPET	ATR	Standard Parts Equivalence Table	Version 10 dated December 2012
SRM 51-25-02	ATR	INSTALLATION AND FIT CONDITIONS OF BOLTS (TORQUE), NUTS, RIVETS	1 June 2017
SRM 51-40-03	ATR	ALPHANUMERIC NUTS CROSS-REFERENCE-INDEX	1 June 2018
SRM 51-40-30	ATR	NUTS AND ALTERNATIVES	1 October 2018
NAS1291	AIA	NUT, SELF-LOCKING, HEXAGON, LOW HEIGHT, LIGHT WEIGHT	Revision 14 dated 31 March 2014
NASM21043	AIA	NUT, SELF-LOCKING, 800 DEGREES F, REDUCED HEXAGON, REDUCED HEIGHT, RING BASE, CRES	Edition 3 dated 31 January 2013
NASM25027	AIA	NUT, SELF-LOCKING, 250°F, 450°F AND 800°F	Revision 1 dated 21 December 2012
NSA5050	EADS AIRBUS[5]	NUT – SELF LOCKING, CAPTIVE WASHER	Revision P dated January 2001
NTA11155	Aeritalia[6]	BOLT, 12 POINT HEAD, 200KSI MIN TENSILE, A286 CRES (NOMINAL AND OVERSIDE)	Revision 8 dated 26 May 1994
NTA11159	Aeritalia	BOLT HEX HEAD 95 KSI SHEAR SHORT THREAD A286	Edition C dated June 1984

Table 3: List of documents used in this report applicable at the time of the incident

[5] Now Airbus Commercial Aircraft.

[6] Now Leonardo.

The Aircraft Maintenance Manual (AMM) is the document that describes how maintenance tasks on an aircraft are to be performed. This includes information such as functional checks and aircraft maintenance, but excludes repairs and structural modifications, which are listed in the Structural Repair Manual (SRM).

A Job Instruction Card (JIC) is a document that describes a specific maintenance operation. It is attached to the AMM.

The alternatives and interchangeability of parts are accessible via two documents: the Standard Parts Equivalence Table (SPET) or the SRM. ATR specifies that the SRM is the reference document.

1.6.3.1 General

The most recent maintenance work on the landing gear doors of F-GPYF is summarised in Table 4 below. There are no specific remarks on the job cards for these operations relating to the main landing gear doors.

Maintenance operations	Maintenance dates/ times scheduled by the manufacturer	Date of completion of the operation on F-GPYF
General visual inspection[7]	Weekly check	19 March 2018
Lubrication	3 months or 600 landings	23 January 2018
General visual inspection	A Check	December 2017
General visual inspection	C Check	July 2016
Standard replacement of landing gear	Every 9 years or 20,000 landings	June 2015

Table 4: List of maintenance operations affecting the landing gear doors and the dates on which they were last performed before the incident

[7] There is no requirement to check the play on the landing gear door during this operation.

At the time of the incident and as part of preventive maintenance, only the standard replacement of the landing gear requires the removal/reinstallation of the main landing gear doors. It is therefore necessary to remove/reinstall the fairings as well as the fasteners. Only by removing the fairing is it possible to visually check the presence and/or position of the nuts.

Job card JIC 52-81-00 (available in appendix 1) specifies the tasks that must be performed to complete the removal/reinstallation of a main landing gear door. This job card was last applied to F-GPYF in June 2015 in Germany at Rheinland Air Service (RAS), an approved maintenance workshop.

1.6.3.2 Removing/reinstalling the main landing gear doors

1.6.3.2.1 Job card JIC 52-81-00

The JIC 52-81-00 entitled "*Main Landing gear doors removal and installation*" includes instructions for reinstalling the front and rear fasteners on the door: "*place the MLG doors male hinges (12) in the female hinges (8) and install bushings (11), bolts (9) with washers (10) (13), nuts (14) and tighten them.*"[8]

[8] The numbers in brackets correspond to those in Figure 8.

ATR distinguishes in its documentation between the specific tightening torques that are directly specified on the job cards and the non-specific (or basic) tightening torques that are defined in generic documents such as the AMM or SRM.

The JIC 52-81-00 does not mention specific tightening torques to be applied to the nuts, so the basic tightening torques are used.

In order to obtain the basic tightening torques from the generic documentation, it is necessary to have at least the P/N of the screw and the nut. In some cases, the initial state of lubrication of the screw and/or the presence or absence of specific lubrication of the assembly must also be taken into account.

1.6.3.2.2 Determining the P/N of the parts

In the remainder of the report, the following terms will be used:

IPC P/N	P/N listed in the IPC
IPC OPT P/N	Optional P/N listed in the IPC
ALT P/N	Alternative P/Ns listed in the SRM or SPET. *The origin of the P/N may be specified by adding the suffix SRM or SPET* *e.g.: ALT P/N SRM: Alternative P/Ns listed in the SRM*

Table 5: Terms used for the P/N

IPC 52-81-50 (attached in appendix 2) specifies the P/Ns and descriptions of all of the components of the front and rear fasteners. Table 6 specifies this information for the screws and nuts. Although not specified in the JIC and IPC, the MS21043 standard corresponds to a self-locking nut.

Position	**Nut**		**Screw**	
	Type	**P/N**	**Type**	**P/N**
Front	IPC P/N	MS21043-6	IPC P/N IPC OPT P/N	NTA11155-6H26 BACB30LE6H26
Rear	IPC P/N	MS21043-5	IPC P/N IPC OPT P/N	NTA11159-5SU22 BACB30LJ5SU22

Table 6: P/N of screws and nuts listed in the IPC

Thus, according to the IPC, the front and rear screws each have an optional P/N listed in the IPC, but the nuts do not.

However, ATR has authorised alternative P/Ns (ALT P/N) for the IPC P/N of the nut via two documents:

- the SRM, chapter 51-40-30 entitled ''*Nuts and alternatives*'';
- the SPET. The SPET indicates that its content is based on the DOA-approved documents, of which the SRM is one. The SRM is therefore the reference document.

As regards the IPC P/N for nuts, there is no P/N marking required (even a partial one) on the nut unlike for the IPC P/N and IPC OPT P/N for screws. According to the standard, only the nut manufacturer's symbol is required.

1.6.3.2.3 Possible alternatives for the nut with the MS21043 standard P/N

For simple parts commonly used in the aeronautics sector, such as nuts and screws, there are often multiple technical specifications, which are referred to as standards, which can meet the functional requirements sought by manufacturers. These standards may be developed by private companies, national standardisation bodies or associations.

Traditionally, although used, these standards are not available in the maintenance documentation and the maintenance operators do not usually consult these documents. Only information relating to the P/N codes is transcribed in the ATR documentation.

As the standards are published by different bodies, the P/N coding may be different. A P/N is usually the concatenation of the name of the standard followed by characters that serve to define the characteristics of the part in a unique way, such as a diameter, type of protection, material, etc. Parts are supplied based on the P/N of the standard[(9)].

1.6.3.2.3.1 Alternatives based on the Structural Repair Manual (SRM)

Chapter 51-40-30 of the SRM ''*Nuts and alternatives*'' primarily comprises three tables (an example of how to read these tables is available in appendix 3):

- the first table defines the authorised alternative standards;
- the second one describes how the P/Ns are coded (in particular the location of the codes for the material and the protection in the P/N) based on the standard indicated in the first table;
- the third one gives the codes for the materials and protections that are used in the P/N coding.

There are also important indications prior to these three tables. In particular, it is stated that the diameter, grip length and protection must be the same as the IPC P/N. The fastener code in the following chapters are limited to the type of fasteners. Cross-references and alternatives do not include diameter, grip length and sometimes also surface finish. These parameters have to be the same as original ones when the alternative fastener is chosen.

During the investigation and, although it is not stated in the maintenance documentation, ATR specified that, in accordance with the state of the art, the material must also be identical when choosing the alternative.

To define an ALT P/N, it is therefore necessary to know certain characteristics of the IPC P/N, such as the material and the protection. In the SRM, based on the input data of the MS21043 standard (standard of the IPC P/N of the front and rear nut), a reading of the three tables serves to determine that the nut exists only in one possible material/protection combination: material in corrosion resistant steel (CRES[(10)] or stainless steel) with a silver protection. This information is compatible with the MS21043 standard.

[(9)] For nuts with P/N MS21043-5 or MS21043-6, the corresponding standard is NASM21043 rather than MS21043. This is because the MS21043 standard initially published by the United States Department of Defence (Military Standard) is now published by the Aerospace Industries Association of America, which has led to a name change. To make for easier reading, in this report the MS21043 standard denotes the NASM21043 standard listed in Table 3.

[(10)] Corrosion Resistant Steel according to the ATR documentation.

As regards the IPC P/N of the nut of rear hinge MS21043-5 (or MS21043-6 for the front hinge), four standards are offered as alternatives. In contrast to the MS21043 standard, which is only available in one possible material/protection combination, at least 3 of the 4 alternative standards for the MS21043 are available in several combinations. By complying with the criterion of identical protection (i.e. silver) to the protection in the IPC P/N, the SRM allows only one combination for each standard:

- ALT P/N NAS1291***[11] made out of stainless steel with a silver protection;
- ALT P/N NTA11354-5 (or NTA11354-6) made out of steel with a silver protection;
- ALT P/N NSA5050-5C (or NSA5050-6C) made out of stainless steel with a silver protection.

The fourth standard BACN10JC is not listed in Tables 2 and 3 of SRM 51-40-30. Nevertheless, the SRM indicates that the BACN10JC and NTA11354 standards are cross-references[12]. Thus, the parts that follow these standards are assumed to be identical.

1.6.3.2.3.2 Alternative based on the Standard Part Equivalence Table (SPET)

The SPET also specifies alternatives. Unlike in the SRM, only one table is available. If we take the example of MS21043-5 (and MS21043-6), the table in part A provides a brief description of the part, material, protection and the reference number of the alternative nuts.

In this case, five alternatives are permitted. Preferably (P/N leader) NAS1291C5 (or NAS1291C6), and ''*optional without restriction*''[13] H41-5, PLH55, RH30C5 and 180001-5 (and H41-6, PLH56, RH30C6 and 180001-6).

ATR indicates that these different references correspond to different suppliers, but that all these references correspond to the NASM21043 standard and therefore to P/N MS21043-5 (and 21043-6).

AR	STANDARD PARTS					OPTIONAL PARTS	
	Basic P/N	Designation	Form	Material	Protection	Alternative Leader P/N	Optional without restriction
	MS21043-5	NUT-SELF-LOCKING	Hexagonal Reduced	CRS	Silver Plated	NAS1291C5	H41-5 PLH55 RH30C5 180001-5
	MS21043-6	NUT-SELF-LOCKING	Hexagonal Reduced	CRS	Silver Plated	NAS1291C6	H41-6 PLH56 180001-6 RH30C6

Source: ATR

Figure 9: Excerpt from the SPET Issue 10 dated December 2012

1.6.3.2.3.3 Errors in the transcription of the standards in the documentation

Note: during the investigation, only the standards relating to the nut with IPC P/N MS21043 and its alternatives were analysed.

- SRM chapter 51-40-30 ''*Nuts and alternatives*''

As mentioned above, various standards from different organisations have been used to define the alternative nuts using different coding. Tables 2 and 3 of the SRM serve to describe in a similar way the different ways of coding standards (an example of how these tables can be read is available in appendix 3). However, the transcription of the information from the standards into these tables contains errors that can lead to the wrong coding of the ALT P/N.

[11] The NAS1291 standard is not available in Table 2 of the SRM. Thus, it is not possible to deduce the complete P/N codings for the 2 possible combinations on the basis of the SRM alone. The symbol *** denotes here that the P/N coding is incomplete.

[12] Cf. SRM: Cross-references are different codes for the same attachment. The code is different because it is not the same specification (ASN-A or NTA ...) but the fastener is strictly identical (material, dimension, form, function) because every specification refers to the same manufacturer codes.

[13] The column ''*optional without restriction*'' refers to supplier references.

Determining an alternative nut to the IPC P/N of the rear hinge assembly for standard NTA11354 according to the SRM equates to choosing a P/N NTA11354-5 nut because the protection is silver (steel material). Also according to the SRM, this P/N also corresponds to the steel/cadmium combination. In reality, according to the standard NTA111354, a nut with P/N NTA11354-5 is made of steel with a cadmium protection and the steel/silver combination does not exist. The only material/protection combination identical to the IPC P/N (stainless steel/silver) has the code NTA11354-5C.

There is also no description of the P/N coding for the NAS1291 standard in Table 2 of the SRM, which could lead to the selection of the wrong combination.

❒ Chapter 20-21-12 of the AMM ''*Tightening torque of standard threaded fasteners*'': The basic tightening torques to be applied are defined in chapter 20 of the AMM (see 1.6.3.2.4). This chapter does not allow for alternative P/Ns to be determined, but it gives some information, such as the material and protection of the nuts.

Unlike with the SRM, the codes are directly included in the name of the standard. Not all possible combinations for each standard are described there. Thus, for the standard MS21043 and those possible alternatives according to table 1 of SRM 51-40-30:

- ❒ MS21043 is made of stainless steel with a passivated protection;
- ❒ NTA11354 is made of steel with a cadmium protection;
- ❒ NSA5050 is made of steel with a cadmium protection;
- ❒ NSA5050C is made of stainless steel with a silver protection;
- ❒ and NAS1291C is made of steel with a cadmium protection.

This document therefore also contains transcription errors. For example, the combination (stainless steel/passivated protection) does not exist for MS21043 and the C code for standard NAS1291C does not provide a unique definition of the material/protection. Indeed, a nut with P/N NAS1291C5 will be made out of stainless steel with a silver protection while a nut with P/N NAS1291C5M will be made of stainless steel without any specific protection.

1.6.3.2.4 Determining the tightening torque

Reminder: As the JIC does not mention any specific tightening torques to be applied, these are therefore basic tightening torques (see 1.6.3.2.1).

The basic tightening torque to be applied (which depends on the P/Ns of the screw and nut, and sometimes on the state of lubrication) can be found in two documents:

- ❒ chapter 51-25-02 of the SRM entitled "*Installation and fit conditions of bolts (torque), nuts and rivets*";
- ❒ chapter 20-21-12 of the AMM entitled "*Tightening torques of standard threaded fasteners*".

On the date of the incident, neither document contained a tightening table or information on the torque corresponding to the combination of screw/nut P/Ns mentioned in the IPC (MS21043-6/NTA11155-6H26 and MS21043-5/NTA11159-5SU22). The same applies to most of the optional or alternative P/Ns. In total, information on the basic tightening torque to be applied is only available for two screw/nut P/N combinations:

- NTA11354-6/NTA11155-6H26 (95 – 360 in.lbs);
- NTA11354-5/NTA11159-5SU22: This combination has two different tightening torque ranges: 60-35[14] in.lbs and 90-125 in.lbs depending on the table chosen (see details in appendix 5).

[14] The presence of a second number lower than the first number in the interval is probably due to a typographical error.

Several other inconsistencies or errors were found in these two documents during the investigation and when searching for the torque values for the IPC P/Ns. These inconsistencies are described in appendix 5.

1.6.3.2.5 Practice of replacing self-locking nuts during a maintenance operation

The manufacturer mentions the rule for reusing nuts in chapter 512511-02-001-A01 of the SRM - *Installation of tension bolt with application of tightening torque* and in chapter 20-21-13 of the AMM. Only visual inspections are required. There is no requirement to verify that the nuts still have their self-locking capability before reassembly.

(4) Reuse of Screws and Nuts
It is prohibited to reuse aluminium alloy nuts.
For screws or nuts in other materials, fastener elements can be reused if authorisation is given from inspection in the following conditions:
The protection on the elements (or the surface condition if there is no protection) is not damaged (particularly the threads of the screw and nut on the nut bearing surfaces and the wrench engagement surfaces, the shank and recess of the screw).
The lubrication is restored as follows:

- Initial lubrication:
  Restoring the lubrication.
- The screw and nut have standard lubrication:
  Redo the standard lubrication of the screw or nut.
- Only one of the 2 elements (screw or nut) has standard lubrication:
  Redo the standard lubrication of the element initially lubricated.
- The initial installation was performed with a specific lubrication (e.g. anti-corrosion sealant or grease):
  Upon installation, apply the specific lubricant initially used.

Source: ATR SRM

Figure 10: Criteria for reusing nuts

REJECTION CRITERIA

1. General

During maintenance operations, bolts and nuts evidencing the following damage shall be rejected :
- cracks, fractures, folds,
- protective finish deterioration and corrosion,
- distortion (stretching and brinelling),
- stripped threads,
- worn threads.

NOTE : Damage resulting from overtorquing and thread wear is readily detected by means of a thread form-gage.

Source: ATR

Figure 11: Excerpt from chapter 20-21-13 of the AMM

1.6.3.2.6 Summary of the removal/reinstallation of the main landing gear doors

To summarise chapter 1.6.3.2 Removing/reinstalling the main landing gear doors, an analysis of the maintenance documents relating to the removal/reinstallation of the main landing gear doors, as well as of the manufacturer's generic documents, shows that:

- The tightening torque to be applied to the nuts on the fasteners of the front and rear main landing gear door hinge assemblies is not specified on the corresponding job card. This ''basic'' tightening torque must therefore be found by the mechanic in the manufacturer's generic documentation.
- The basic tightening torque of the IPC P/N nut is not specified in this generic documentation.
- The generic documentation contains errors, inaccuracies and inconsistencies, both in respect of the selection of nuts as ALT P/N and the corresponding tightening torques. In addition, this information can sometimes be contradictory across the different documents.
- There is no requirement to check the self-locking capability of the nuts in the event that they are reused.

1.6.4 CRUISE SPEED LOW Alert

Aircraft Performance Monitoring (APM) is a system that monitors aircraft performance during flight. The system was initially designed and installed to detect aircraft additional drag in icing conditions. Thanks to its design principle, the system compares the speed and drag differences in respect of the theoretical values in the aircraft's flight conditions and the real-time values, regardless of the cause (wing icing, airframe damage, vertical movements of the atmosphere, etc.).

Depending on the discrepancy between the theoretical and real-time values, the system can issue different alert levels, the first (lowest) level of which is ''*CRUISE SPEED LOW*''.

By design, a CRUISE SPEED LOW alert is triggered when the aircraft is in cruise[15] (usually with autopilot in altitude-hold mode), in icing conditions or if icing conditions have been detected once before during the flight and:

- the drag calculated by the aircraft is greater than the drag expected on a 30-second rolling average;
- the air speed of the aircraft is 10 kt lower than the theoretical air speed under flight conditions.

A blue light lights up on the panel, but there is no audio warning. The FCOM procedure corresponding to this alert, which is the same as the one in the HOP! Operations Manual, requires monitoring of airspeed and icing conditions to anticipate a possible deterioration in aircraft performance.

[15] With an inhibition during the first 120 seconds of this phase to allow the aircraft to reach cruising speed.

1.7 Meteorological conditions

The data provided by Météo France indicated, for the time and location of the incident:

- an isolated line of cumulus and towering cumulus clouds between Bellac and St Flour, the top of which did not exceed FL150, and the bases of which were located between 3,000 ft and 4,000 ft QNH;
- 7/8 of the sky covered by alto cumulus at FL140;
- moderate icing between FL50 and FL150;
- showers below the cumulus line and TCU;
- low turbulence, locally moderate in the vicinity of the TCU;
- a variable, north-north-east wind at FL180, about 15 kt;

- a temperature of -24°C at FL180;
- a QNH of 1011 hPa.

1.8 Navigation aids

Not applicable.

1.9 Telecommunications

Not applicable.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The aircraft was fitted with two standard flight recorders. The recorders were read at the BEA's premises on 28 March 2018. The occurrence flight was recorded in the data on the flight data recorder and on the sound tracks of the cockpit voice recorder.

The data on the flight data recorder and the sound tracks of the cockpit voice recorder were synchronised.

The analysis of the data from the flight data recorder is described in paragraph 1.16.

1.12 Wreckage and impact information

All the components on the front and rear hinge assemblies on the left side of F-GPYF and their fairings were removed for analysis at the BEA. These analyses are described in paragraph 1.16.3.

The right landing gear doors were also visually inspected on site by removing/reinstalling the fairing protecting the assembly. With the exception of the presence of locking wire on the front hinge assembly screw, nothing specific was noted.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 Study of the data from the flight data recorder

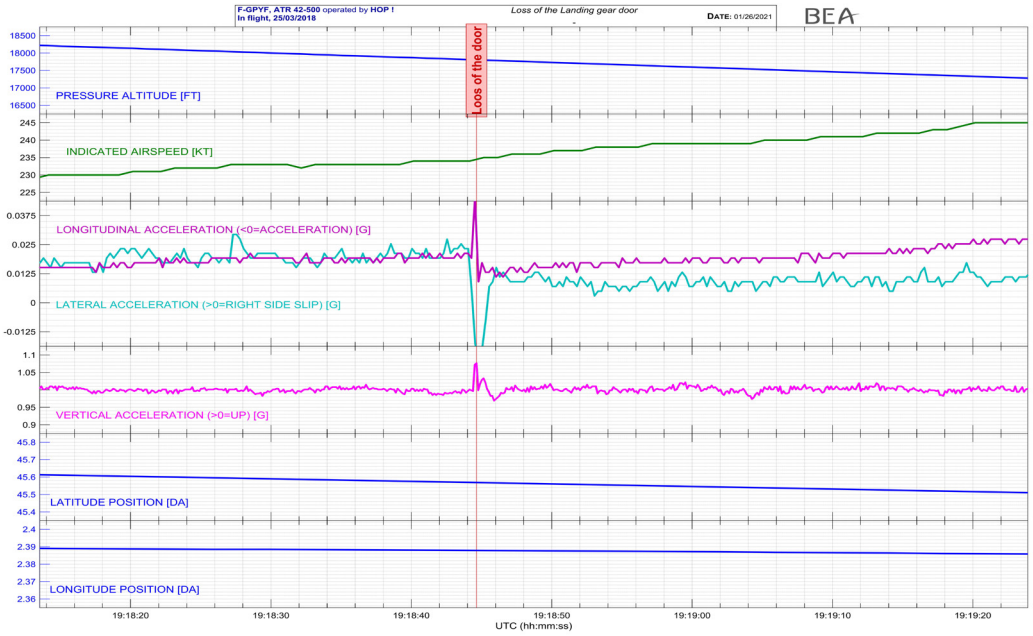
1.16.1.1 Dating and positioning of the event

During the aircraft's descent, the recorded values of the three accelerations (longitudinal, vertical, and lateral) were consistent. Shortly afterwards, at 19:18:44, these three acceleration values showed an extremum (see Figure 12).

These observations are consistent with the loss of the landing gear door at 19:18:44 and the corresponding aerodynamic modifications. The dating of this event by the FDR data is consistent with the sounds identified on the CVR.

The plane was on its descent and was powered. The coordinates of the position thus located were as follows:

- 45.568371° N - 2.387853 E;
- altitude of 17,800 ft (5,425 m).



Source: BEA

Figure 12: Locating the door loss using the flight parameters

1.16.1.2 Cruise speed low alerts

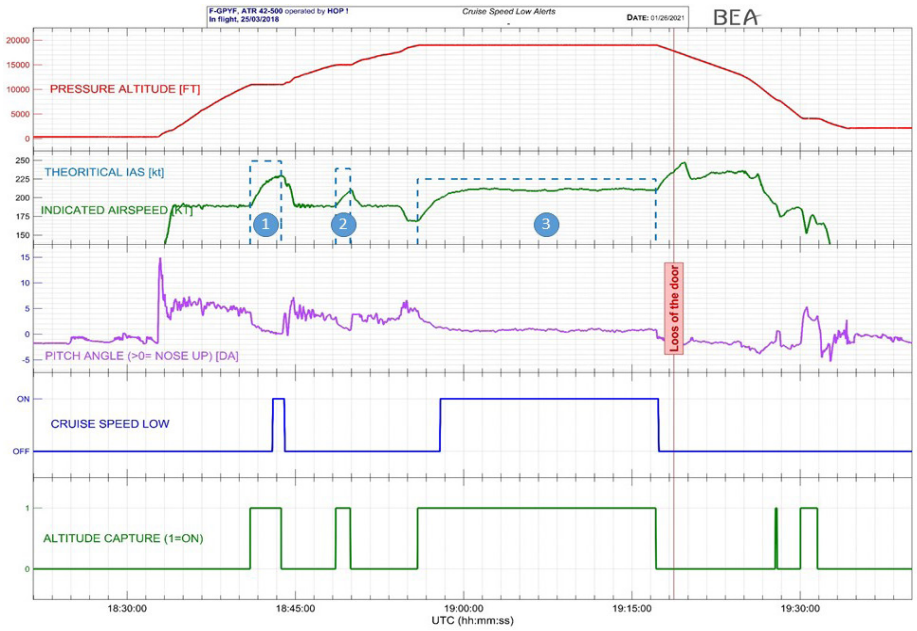
On the occurrence flight, the aircraft climbed twice before cruising.

During the first level flight phase (see point ❶ Figure 13), the Cruise Speed Low alert was triggered two minutes after levelling off. By design, this alert stopped when the aircraft resumed its climb.

The second level flight phase (see point ❷ Figure 13) lasted only 78 seconds, which was not enough time for the alert to be triggered, even if the other conditions had been met.

The Cruise Speed Low alert was triggered a second time 122 seconds after arrival at cruising altitude and remained active throughout the cruise phase (see point ❸ Figure 13). By design, it stopped when the aircraft began its descent.

The first level flight phase and the cruise (❶ and ❸ on Figure 13) show the same trend: the indicated airspeed increases up to a limit that is lower than the theoretical speed.

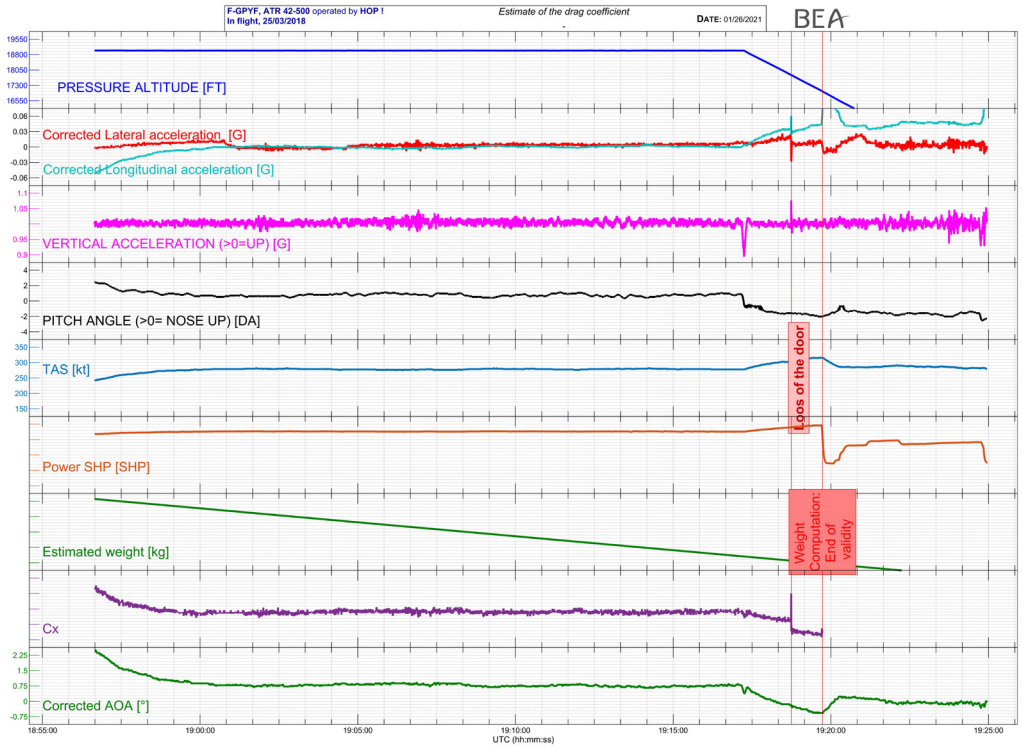


Source: BEA

Figure 13: Cruise Speed Low alerts

1.16.1.3 Study of drag

The drag coefficient (Cx) of the aircraft[(16)] is a function of the angle of attack (AOA). During cruising (see Figure 14), the angle of attack stabilised at an average value of 0.8°. During the 15 minutes of cruise, the CRUISE SPEED LOW alert was active and the aircraft's drag coefficient did not vary significantly (values close to the mean ± 5 %, with a standard deviation of 1 %).



Source: BEA

Figure 14: Drag study

(16) The drag coefficient (Cx) calculations performed by the BEA are based on approximate values with uncertainties that cannot be estimated and compared for two different flights or disjointed flight phases. However, these inaccuracies correspond to fixed value offsets. They do not affect the trends and changes in the parameters. The analysis will be based on these changes and not on the calculated values. When the flight crew rapidly reduces engine power for descent, the calculations are no longer feasible: the reduction in power implies a change in fuel consumption, which is not precisely known (no recording of fuel flow).

At the time the door became separated from the aircraft, there was an identifiable shift in the aircraft's drag coefficient values.

After the separation, the drag coefficient changed in line with the changes in the angle of attack, with a proportionately lower drag than during cruising.

Throughout the cruise, the landing gear door was in a position (or had freedom of movement) that generated additional drag, with no noticeable variation during this flight phase. This additional drag disappeared when the door was lost.

A review of the previous 19 flights did not reveal any activation of the CRUISE SPEED LOW alert.

1.16.1.4 Conclusion

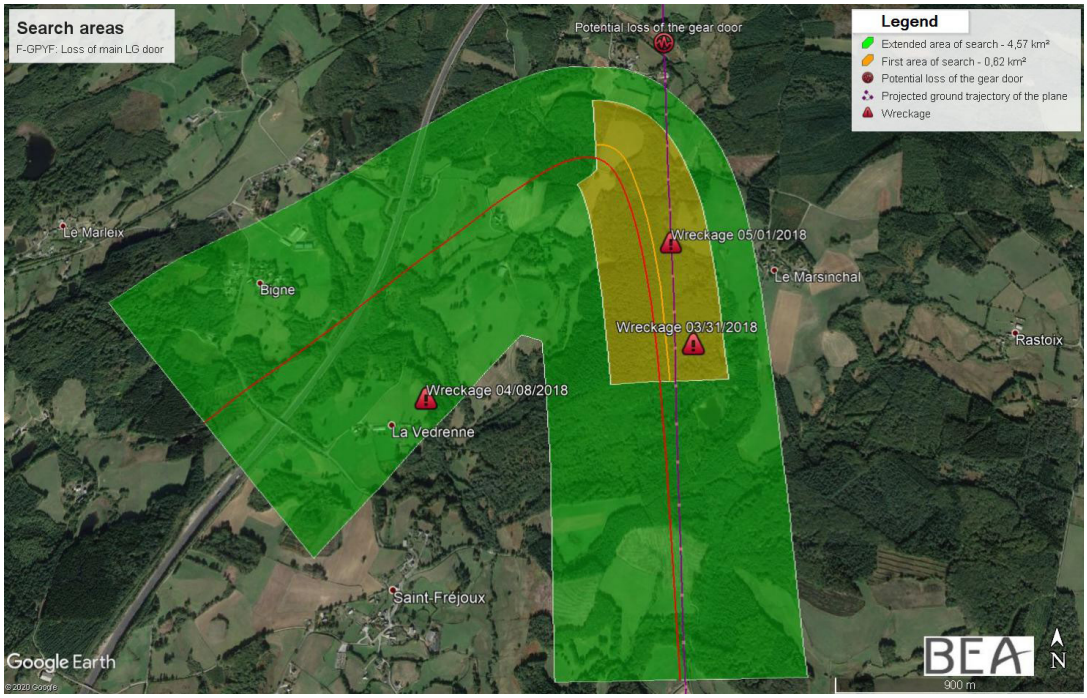
The FDR data show consistent aerodynamic behaviour of the aircraft from the first level flight phase at FL110 until separation of the landing gear door from the aircraft, with additional drag. It is most likely that this additional drag was generated by the landing gear door being in an unclosed position or by a degree of freedom of movement of the landing gear door.

However, it is not possible, with FDR data alone, to determine whether the landing gear door closed improperly during landing gear retraction or whether it opened progressively during the initial climb to FL110.

1.16.2 Search for and recovery of landing gear door components

Using the dating and positioning of the occurrence, a search area based on ballistic computation, taking into account the wind column and assumptions about the aerodynamic characteristics of the part, was established in an attempt to locate the missing components of the landing gear door.

Three components of the L MLG door were found respectively on 31 March 2018, 8 April 2018 and 1 May 2018, within a radius of approximately 2 km around the estimated point of loss of the door (see Figure 15).



Source: BEA and Google Earth base map

Figure 15: Location of debris found and search area

The door components were transported to the BEA for laboratory examination.

The door was thus almost completely reconstructed (see Figure 16) and contained both the front and rear male hinge assemblies.

Source: BEA

Figure 16: Recovered door components

1.16.3 Technical inspection of the parts of the hinge assemblies on the left main landing gear door

Examinations were carried out on the door components that had been recovered and on the components removed from the aircraft immediately after the incident. By way of a reminder, the description of the door can be found in paragraph 1.6.2.

1.16.3.1 Visual inspection of the recovered door components

A visual inspection of the landing gear door components was carried out. In addition to the fact that the landing gear door had broken into several pieces, the observations included the following:

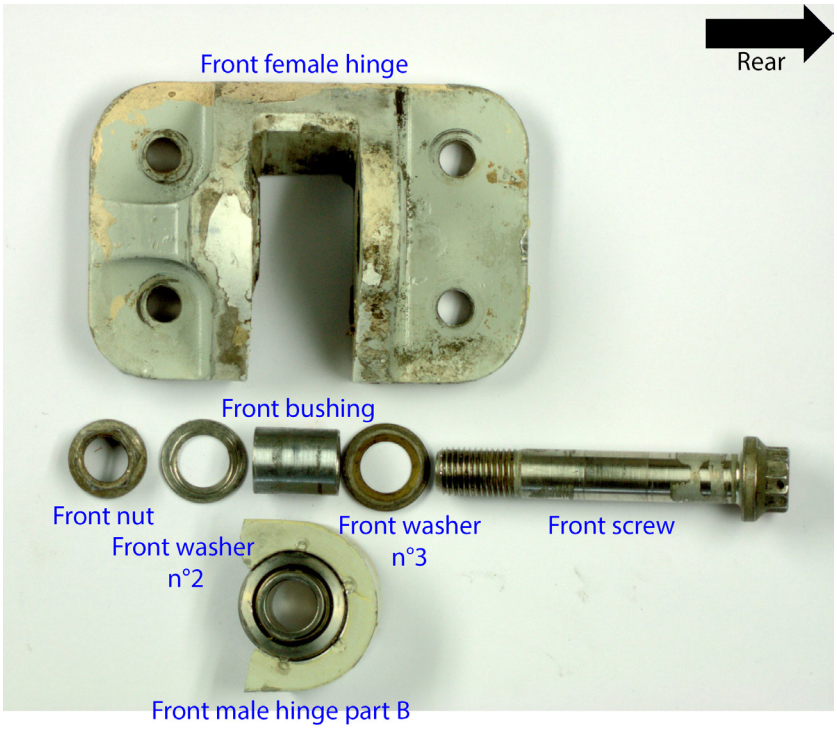
- ❒ fracture to hinge 1 (connection with the fuselage);
- ❒ fracture to the link at the junction between the landing gear door and the leg where it connects to the landing gear door;
- ❒ fracture of the front male hinge.

The front and rear male hinges and the fitting (and its piece of link) were removed for further inspection.

1.16.3.2 Left-side hinge assemblies

1.16.3.2.1 Front hinge assembly

The front hinge assembly components are shown in Figure 17. The male part of the hinge assembly was broken. A fractographic examination revealed the characteristics of a sudden fracture running from the front to the rear of the aircraft. The screw contained markings that were consistent with the IPC P/N.



Source: BEA

Figure 17: Front hinge assembly components

An EDS analysis showed that the material and the protection of the nut did not correspond to the nut specified by the IPC (see paragraph 1.6.2.2). Indeed, the protection of the nut analysed was composed mainly of cadmium and the measured content of chromium and the material of the nut did not display the characteristics of a stainless steel nut.

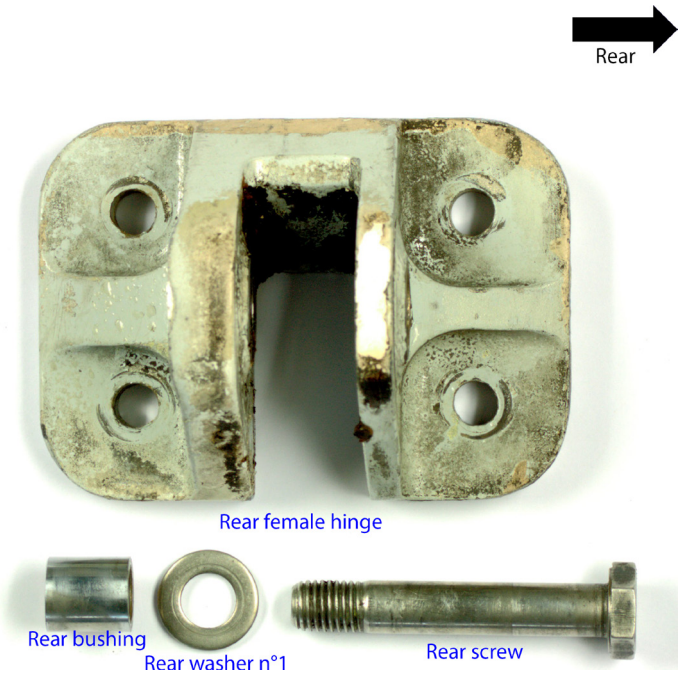
Lastly, the nut is magnetic while the stainless steel that makes up a P/N MS21043-6 nut is non-magnetic. An R marking was observed on both wrenching faces of the nut. This R may correspond to the marking of the nut manufacturer.

When the nut was removed, the tightening torque was measured using the torque marking method[17]. The resulting torque was 14 N.m (124 in.lbs)[18].

1.16.3.2.2 Rear hinge assembly

As indicated in paragraph 1.3 (see Figure 3), a washer and a nut on the rear assembly were missing. The disassembled parts of the female rear hinge are shown in Figure 18.

The female and male parts of the rear hinge assembly and the screw did not display any significant damage. The screw had a marking that was consistent with the IPC P/N.



Source: BEA

Figure 18: Rear hinge assembly components

The inside face of the rear fairing displayed traces corresponding to markings left by the screw head (see Figure 19). They bear witness to the significant displacement of the screw observed on the aircraft after the incident (see Figure 3) compared to its normal position.

[17] A mark was drawn on the screw and the nut and then the nut was unscrewed. It was then screwed back on using a torque wrench until the two parts of the mark were realigned with each other.

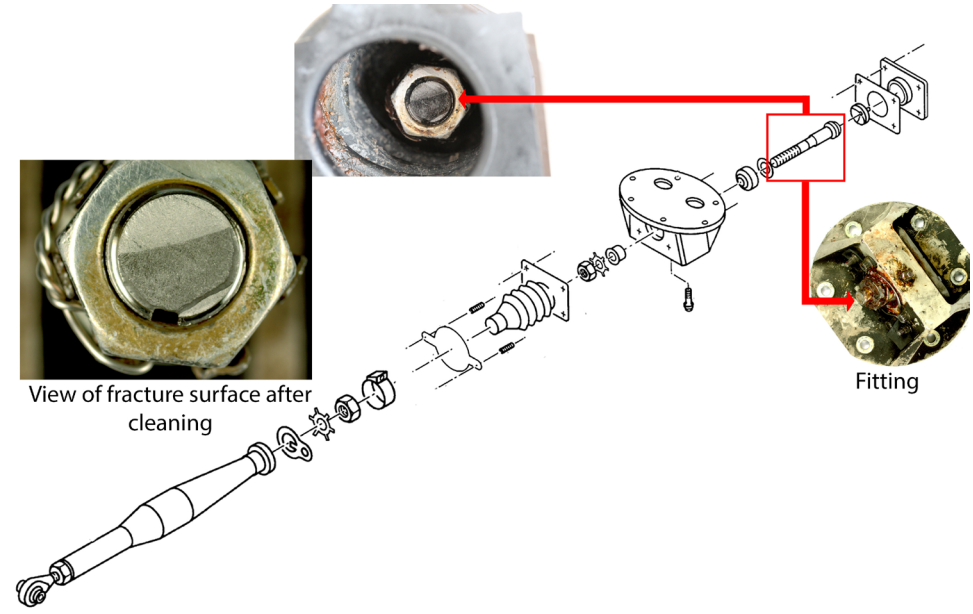
[18] This torque is given for information purposes only. Generally speaking, the torque using the marking method is lower than the tightening torque.

Source: BEA

Figure 19: Rear fairing - inside face

1.16.3.2.3 Link

The link was found detached from its connection to the landing gear door in the place where a screw is fastened to the door fitting (see Figure 20).



Source: ATR and BEA

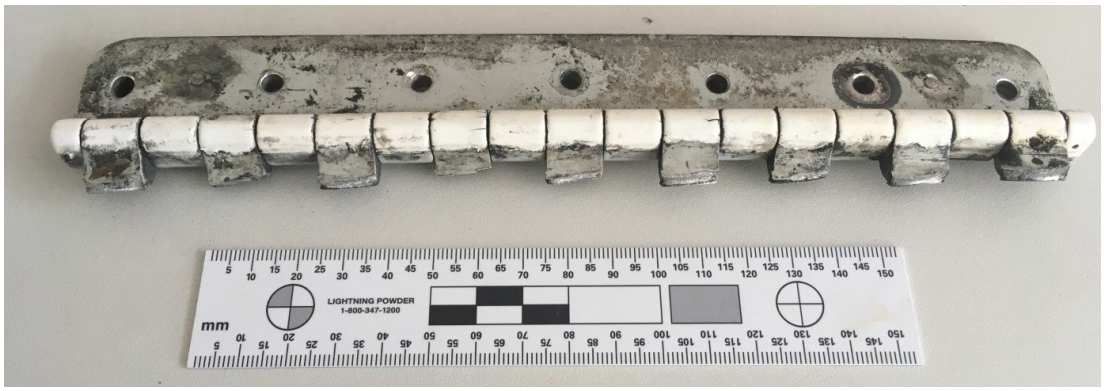
Figure 20: Examination of the link

A fractographic examination of the screw fracture using an SEM revealed an area of fatigue cracking in the form of fatigue striations with multiple surface initiations and an area displaying dimples, which are characteristic of a ductile sudden fracture.

The additional examinations carried out (hardness, metallography) showed that the metallurgical characteristics of the screw material were consistent with the manufacturer's specifications.

1.16.3.2.4 Hinge 1

All the moving parts of the hinges were broken. The fractographic examination revealed the characteristics of a sudden fracture caused by overload. A microscopic examination of the paint on the hinge fracture faces served to determine the direction of fracture propagation through small crack visualisation. It was thus determined that the fracture of the moving parts of the hinges was caused by overload from the front to the rear of the aircraft.



Source: BEA

Figure 21: Examination of hinge 1

1.16.4 Aircraft test

A test was carried out by the manufacturer on ATR 42 MSN002, which is now used as a ground training aircraft at Saint-Exupéry high school in Blagnac. On this aircraft, the front and rear hinge assemblies as well as the link are different from those on F-GPYF MSN495, but the geometry of the door is similar.

The door became detached from its hinge assemblies and its link. It was projected against the aircraft fuselage. The door was at that juncture retained only by hinge 1.

The damage observed on F-GPYF after the incident, particularly on the cabin window and under the wing root, was consistent with a landing gear door position as per Figure 22 followed by a backward and slightly upward movement.

Source: ATR

Figure 22: ATR test on MSN002

1.16.5 Checks and verifications on the ATR 42-500 fleet of the operator HOP!

As part of the internal safety investigation following the incident, HOP! conducted an inspection campaign of the main landing gear door hinge assemblies on the ATR 42-500 fleet to detect possible anomalies. HOP! also requested that the screws and nuts on the front and rear hinge assemblies be replaced during the next A checks on each aircraft. Some of the screws and nuts removed during the A checks were sent to the BEA laboratory.

1.16.5.1 Initial inspection by HOP!

The initial inspection requested by HOP! entailed checking the following points:

- ❒ removing the fairings;
- ❒ taking photos of the assemblies;
- ❒ checking that the screw was fitted in the right direction;
- ❒ checking that the P/N of the screw was correct;
- ❒ checking that there was no locking wire[19];
- ❒ checking that the nut was tightened within the following torque ranges (information provided by ATR to HOP! on 27/03/2018):
  - ■ Front: 150 - 250 in.lbf
  - ■ Rear: 90 - 125 in.lbf

[19] Installation of locking wire is not required by the IPC and the JIC.

In respect of the 38 assemblies that were inspected on 19 main landing gear doors on 10 aircraft, the following main points were reported:

- 1 loose rear nut (out of its nominal position), 2 excessively high tightening torques (those on the right side of F-GPYF)[20], the other 35 measured torque values being within the range of values indicated by ATR ;
- locking wires fitted on 3 front screws;
- 6 screws fitted in the opposite direction to that indicated in the JIC (with the screw head facing the front of the aircraft);
- 1 nut not complying with the IPC (by way of a reminder, verification of the P/N of the nut was not requested during this immediate inspection, which started the day after the occurrence)[21].

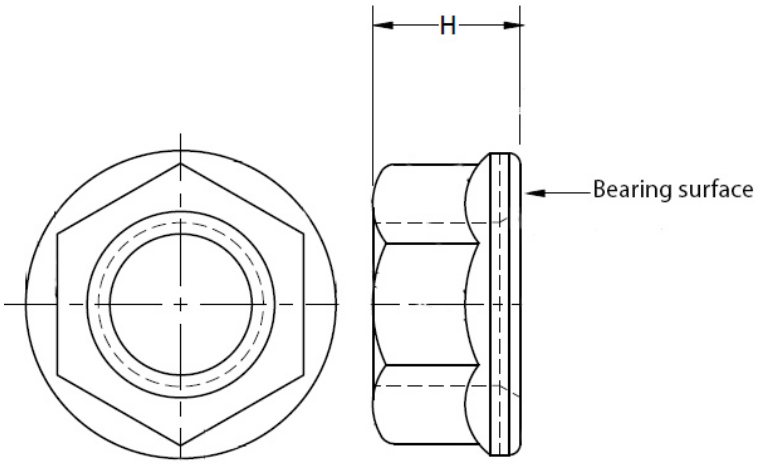
1.16.5.2 Examination by the BEA of the parts recovered after the A checks

A new nut with P/N MS21043-6 was sent to the BEA by ATR to make a comparison of the protection and material of the nuts. The L MLG front nut was very similar in shape and size to the one supplied by ATR. Non-visual examinations were therefore required to determine with certainty the protection and material of the nuts.

A stainless steel nut with IPC P/N MS21043-5 or P/N MS21043-6 is non-magnetic. Of the 18 nuts supplied by HOP! to the BEA, 9 were magnetic. An EDS analysis was performed on these 9 nuts, revealing a cadmium protection that does not correspond to the protection of the IPC P/N (silver)[22]. Of these 9 nuts, two were from the front and rear fasteners on F-GPYF's R MLG door.

The 9 nuts are made from a different material (steel) and protection (cadmium) compared to the IPC P/N (stainless steel and silver protection).

In an attempt to determine the P/N of the magnetic nuts that were recovered, the bearing surface was observed and the height H measured (see Figure 23). All 9 nuts have a circular bearing surface and a reduced height[23] (like the IPC P/N).



Source: BEA

Figure 23: Definition of the bearing surface and the height H of a nut

[20] The torque values were not measured and recorded; the initial inspection only verified whether the minimum torque was reached and/or the maximum torque was exceeded.

[21] Please note that the P/N is not marked directly on the nuts: only a C marking accompanied by the nut manufacturer's logo may be indicated on the nut.

[22] By way of a reminder (see paragraph 1.6.3.2.3.1), the ALT P/N or OPT P/N must have the same protection as the IPC P/N, i.e. silver.

[23] This is referred to as "*reduced height*" compared to nuts of a standard height. In this configuration, we can refer to a reduced height when H < 6.76 mm for the rear nuts and H < 7.16 mm for the front nuts.

As an alternative standard to IPC P/N, cadmium-plated magnetic nuts (steel material) with a reduced height and a circular bearing surface recovered during the A checks can be used as an alternative to P/N NAS1291-5 for the rear nuts (or P/N NAS1291-6 for the front nuts). It should be noted that, according to the NAS1291 standard, the P/N is inactive and for new designs, reference must be made to the MS21042 standard. Thus, the rear (or front) nuts can also correspond to the following P/N: MS21042L5 or MS21042-5 (or MS21042L6 or MS21042-6).

The three remaining nuts on F-GPYF are therefore not made of stainless steel with a silver protection (as with the IPC P/N) and have the following characteristics: magnetic, cadmium protection, reduced height and circular bearing surface.

1.16.5.3 Location of the last maintenance operations

HOP! provided the location of the last maintenance operations requiring the removal of the landing gear doors on the 6 aircraft (including F-GPYF), where non-conformities with respect to the initial inspection were detected. It appears that the operations took place in different maintenance workshops: HOP! in Morlaix, HOP! in Clermont-Ferrand, Rheinland Air Service in Mönchengladbach, Latécoère Aeroservices in Montpellier.

Thus, the various defects found on the assemblies are not related to the work performed by a particular workshop.

1.16.6 Presence of nuts on the ATR42-500

Nuts with IPC P/N MS21043 are found in several places on the ATR42-500, including in the following ATA:

- ❒ 21 AIR CONDITIONING
- ❒ 24 ELECTRICAL POWER
- ❒ 27 FLIGHT CONTROLS
- ❒ 29 HYDRAULIC POWER
- ❒ 30 ICE & RAIN PROTECTION
- ❒ 31 INDICATING/RECORDING SYSTEMS
- ❒ 32 LANDING GEAR
- ❒ 33 LIGHTS
- ❒ 34 NAVIGATION
- ❒ 36 PNEUMATIC
- ❒ 52 DOORS
- ❒ 53 FUSELAGE
- ❒ 54 NACELLES/PYLONS
- ❒ 55 STABILIZERS
- ❒ 56 WINDOWS
- ❒ 61 PROPELLERS
- ❒ 76 ENGINE CONTROLS

Nuts with ALT P/N NAS1291, NTA11354, NSA5050 are also found in many other locations on the aircraft.

1.17 Organisational and management information

1.17.1 HOP!

The company HOP! is the result of the merger of the three HOP! companies in 2016, Brit Air, HOP! Régional and HOP! Airlinair. The ATRs operated by HOP! come from HOP! Airlinair.

HOP! held the following certifications and approvals on the date of the occurrence:

- Air Carrier Certificate;
- Part-M and Part-145 approvals;
- Part-21 approval.

For the maintenance of its fleet, which comprises ATR, Bombardier and Embraer aircraft, HOP! uses the maintenance workshops of its Part-145 approval in Clermont-Ferrand, Morlaix, Lyon and Lille. Some maintenance tasks are subcontracted to other Part-145 approved workshops, such as Rheinland Air Service in Germany.

The maintenance documentation used by HOP! and provided to its subcontractors is based on the manufacturer's documentation.

1.17.1.1 Determination and application of tightening torque within the company

Interviews were conducted with several HOP! mechanics. During these interviews, it became apparent that, in the absence of information relating to nut tightening torque on the job card, several methods are used by the mechanics to determine the torque to be applied:

- If there is no tightening torque indicated in the JIC:
  - For some of the mechanics, this means that it is not essential, so they apply a so-called ''*standard*'' tightening torque by bringing the nut and its counterpart into contact and then tightening to 45°, checking that the threads of the screw protrude;
  - For other mechanics, they try to obtain information from the available documentation (AMM chapter 20 or SRM).
- If the tightening torque is indicated on the job card, then it is applied.

Note: the only standard maintenance process to apply a tightening torque in accordance with Part 145 is to follow the maintenance instructions from the manufacturer.

The torque tightening operation performed on the nuts on the main landing gear door hinge assemblies is considered non-critical by the mechanics that were interviewed.

When asked to determine the tightening torque based on the applicable documentation at the time of the occurrence, none of them found the appropriate tightening torque or noted that it was unavailable.

1.17.1.2 Possible alternatives to nuts with IPC P/N MS21043

Based on the interviews with the HOP! mechanics, the nuts are selected as follows:

- If there is no request in the JIC to change the nut when the part is removed/reinstalled, then the mechanics use the same nut unless damage is detected on the nut;
- If the need for a nut replacement is identified, then an IPC P/N part is requested from the parts store and used if available. Otherwise, the storeman searches in the inventory management software for possible alternatives and then selects the desired part from the store, where the different parts are stored by P/N and by batch.

At Airlinair, the AMASIS (Aircraft Maintenance And Spares Information System) software was used, along with other software, to oversee the maintenance programme, inventory management and limited-life equipment.

Since the merger of the three air operators, the AMOS (Airline Maintenance & Operational Systems) software has been used by the operator (in common for Part-M and Part-145) for these same purposes.

This software allows for the listing of alternatives to the IPC P/N, if necessary, after internal approval.

Both software packages have been tested by the BEA:

- In the AMASIS software, no alternatives to the nuts with IPC P/N MS21043-5 and MS21043-6 were listed.
- In the AMOS software, no alternative to the nut with IPC P/N MS21043-5 was listed. An alternative was listed for IPC P/N MS21043-6. This alternative was taken from the Embraer documentation and has never been called up by the system since its introduction in 2006.

According to the software data, there has not been a need for an alternative to IPC P/N MS21043 at HOP! or at its predecessors since 2006.

1.17.1.3 Re-use of self-locking nuts

Some HOP! mechanics were asked about the reuse of self-locking nuts. Several methods were mentioned:

- single use of a self-locking nut and replacement with a new one;
- checking that there are no friction points when re-tightening the nut;
- visual inspection of the nut ;
- no particular checks.

1.17.2 Rheinland Air Service

RAS is a company based in Germany that has been specialising in aircraft maintenance for over 40 years. The company's website states: "*For commercial airlines, RAS offers a full range of EASA & FAA-certified maintenance. RAS was the first ATR maintenance network partner in Europe and also offers ATR part-out services*"[(24)]. RAS was one of HOP!'s main subcontractors for the maintenance of its ATRs.

[(24)] https://www.ras.de/ras-e-ras-main.html

In June 2015, the standard part replacement of F-GPYF's main landing gear took place at the company's premises in Mönchengladbach. This was the last time that the doors of the main landing gear were removed/reinstalled. The job card was communicated to the BEA.

The BEA did not identify anything specific on the job card relating to this operation. The nuts on the landing gear door hinge assemblies were not replaced during this operation.

RAS's parts management software was also tested; no alternatives to nuts with IPC P/N MS21043-5 and MS21043-6 were listed in the system. In addition, the software had not recorded any new nuts with IPC P/N MS21043-5 and MS21043-6 leaving the parts store since the beginning of 2015.

Interviews with company mechanics were also conducted and produced similar results to those mentioned in paragraph 1.17.1.

On the basis of the SRM, some mechanics identified several tightening torques to be applied for the IPC P/N screw/nut combination.

1.18 Additional information

1.18.1 Good practices relating to screwed joint dimensioning

The mechanical performance of a screwed joint depends on many parameters defined during the initial dimensioning (coefficient of friction of the various parts, thickness of the clamped parts, tightening torque applied, type of materials and protections, type of tightening method, etc.). The modification of one of these parameters may call into question the dimensioning and, for example, render the initially defined tightening torque ineffective.

It should be noted that the precise mechanical phenomena occurring in fasteners that are not fitted in line with best practice are not fully known and that understanding the behaviour of the assembly usually requires testing.

1.18.1.1 Choice of materials: screw-nut combination

The French standard NF E 25-030-A[25] defines rules for dimensioning and tightening a pre-stressed[26] mechanical fastener and establishes a number of recommendations. In particular, in the chapter on screw-nut combinations, it is stated that for an all-metal self-locking nut, the quality class of the nut must be equal to that of the screw (and not higher) in order to avoid any risk of deformation of the screw thread.

The classification scale[27] for fasteners is different for steel nuts and stainless steel nuts. For fasteners, there is no provision for mixing materials (e.g. stainless steel screw with steel nut).

1.18.1.2 Defining a tightening torque

Tightening is an important factor in the mechanical performance of a screwed joint. It must be sufficient to guarantee that the fastener is properly held in place to withstand the stresses applied to the system (i.e. no breakaway torque or no slipping of the assembled parts in service) without, however, exceeding the mechanical characteristics of one of its component parts (cold working, stripping of the threading on the screw or nut, etc.).

[25] As at 23 August 2014.

[26] The pre-stressing corresponds to the stress introduced by the initial tightening of the fastener.

[27] The quality class for carbon steels or alloy steels is denoted (NF EN ISO 898-1) by a decimal number (e.g.: 10.9) whereas, for stainless steels, it is denoted (NF EN ISO 3506-1) by letters and numbers (e.g.: A2-70).

1.18.1.3 Use of all-metal self-locking nuts

Self-locking parts

Supply standard NASM25027 listed in standard MS21043 for IPC P/N nuts introduces the notions of maximum self-locking torque exerted by the nut[28] and minimum self-locking torque during unscrewing[29], which are 90 in.lbf and 9.5 in.lbf for the front nut and 60 in.lbf and 6.5 in.lbf for the rear nut.

Re-use of nuts

According to standard NF EN ISO 2320[30], a self-locking all-metal nut is a nut comprising one or more metal parts, and whose self-locking properties result from a deformation of the thread of the nut and/or of the nut itself, and/or of the metal insert(s). This standard further stipulates that self-locking torque performance diminishes as the number of reuses increases: the customer must take into consideration the consequences of the diminished level of performance before reusing the nut.

MS21043 nuts are nuts whose self-locking property depends on the deformation of the thread of the nut. According to the technical supply specification[31] referenced in the MS21043 standard, the nuts are tested for 15 screwing/unscrewing cycles in order to guarantee a given minimum self-locking torque value.

In addition, it was observed in the course of the investigation that other aircraft manufacturers request:

- Either not to reuse self-locking nuts;
- Or, in case of reuse, to take a measurement of the self-locking torque before final assembly in order to check that it is in a functional state of repair. This practice is applicable regardless of the criticality of the assembly.

1.18.2 Certification rules for fasteners

When certification was requested for the ATR 42-500 in 1993, the basis for certification was JAR 25 Amendment 13.

Several general initial certification rules are applicable to fasteners. The two main requirements for the dimensioning of fasteners can be summarised as follows:

- the suitability of each part must be established by tests (JAR 25.601);
- the parts must be able to support limit and ultimate loads (JAR 25.305).

Specific certification rules for fasteners are included in JAR 25.607 '*Fasteners*':

(a) Each removable bolt, screw, nut, pin or other removable fastener (see ACJ 25.607 (a)) must incorporate two separate locking devices if

(1) Its loss could preclude continued flight and landing within the design limitations of the aeroplane using normal pilot skill and strength; or

(2) Its loss could result in reduction in pitch, roll or yaw control capability or response below that required by Subpart B of this JAR-25.

(b) The fasteners specified in sub-paragraph (a) of this paragraph and their locking devices may not be adversely affected by the environmental conditions associated with the particular installation.

(c) No self-locking nut may be used on any bolt subject to rotation in operation unless a non-friction locking device is used in addition to the self-locking device.

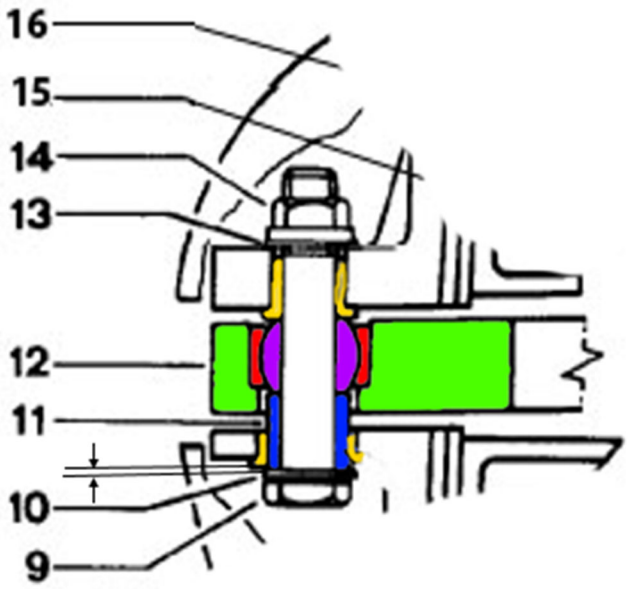
[28] The torque required to rotate the nut around the corresponding external threaded part without axial load during assembly or disassembly.

[29] The torque required to rotate the nut during the 360° rotation occurring immediately after the tension in the external threaded part is released during disassembly.

[30] As of 10 March 2016. standard listed for information purposes only. This standard is not referred to in the ATR documentation.

[31] NASM25027 revision 1 dated 21 December 2012.

During initial certification of the ATR 42, it was considered that the fastener was not subject to rotation because it is the ball joint (in red in Figure 24) mounted in the bore of the male hinge that rotates around the part in purple in Figure 24 encircling the screw. Thus, with proper lubrication, there is no torque force transmitted to the screw when opening and closing the landing gear door.



Source: ATR and BEA

Figure 24: Rotation of the assembly

Appendix H to JAR 25 ''*Instructions for Continued Airworthiness*'' also requires maintenance instructions, in particular to specify the torque to be applied: either via general tables (based on industry standards, for example); or via explicit specifications in the documentation.

1.18.3 Continuing Airworthiness Review Item (CARI) 20-01 of 30/08/2018

A CARI (see appendix 6) on "*Continued airworthiness of MS21042, NASM21042 and NAS1291 standard fasteners (nuts) used in critical installations*" was published on 30 August 2018 by EASA. This CARI (post-occurrence and unrelated to the occurrence) was issued by EASA following several nut failures supplied in accordance with standards NASM21042, MS21042 and NAS1291.

EASA has found that these standards may show an unacceptable failure rate (complete loss of the hinge assembly's fastening function, loss of self-locking capability) and therefore requests type certificate holders to report to EASA any failures of these parts and to explain how they control the risk associated with these potentially defective standard nuts used on critical installations. Particular mention is made of the risk of failure caused by maintenance errors, such as incorrect installation, application of the wrong tightening torque or incorrect reuse of the nut.

ATR responded to this CARI (see appendix 7) by saying that it had not had any reported failures related to the listed standards and that its generic maintenance procedures (AMM and SRM) ensured that the nuts were correctly installed with the correct tightening torque.

1.18.4 Flight crew statements

The pilot who inspected the outside of the aircraft on departure from Orly indicated that he did not detect anything specific on the aircraft or in the Technical Log Book (TLB).

The pilots reported encountering light icing conditions during the climb to level 100 and then when exiting the layer to climb to cruise level 190, where the atmosphere was calm with clear skies. The crew kept the anti-icing AOA on throughout the flight. Shortly after levelling off into cruise, both pilots saw the blue CRUISE SPEED LOW light come on and remain on throughout the cruise. They consulted the QRH and realized that the aircraft was flying slower than expected: 210 kt IAS compared to 224 kt calculated at QRH under the prevailing conditions that day. They thus applied the Operations Manual procedure and monitored the speed and any other alerts.

Shortly after starting the descent and when approaching level 180, the crew heard a thud and felt a jolt on board the aircraft. A call from the cabin crew indicated that the shock had also been felt in the cabin.

The captain then contacted the control unit to advise of the impact and ask if there were any military drones in operation. The air traffic controller replied in the negative. The crew wondered what had caused the impact for the rest of the flight, but, as they did not detect any problems with the aircraft or its systems, they continued the flight to their destination without issuing a PAN PAN or MAYDAY.

It was only when they were on the ground that the crew noticed the damage after being informed of it by the ground attendant.

1.18.5 Statement by the member of the cabin crew

The member of the cabin crew indicated that the start of the flight was smooth and that she had been able to complete her service during the cruise and stow the service cart away. While she was in the rear of the aircraft and was about to begin preparing the cabin for landing, she heard a bang and felt a jolt like going over a speed bump. She inspected the cabin and lavatories to ensure that everything was in order before contacting the flight crew. She continued to prepare the cabin for landing. There were no further incidents during the rest of the flight.

She indicated that, during the cruise, the flight was very smooth.

1.18.6 Similar events

As part of the safety investigation, ATR provided the BEA with information concerning a similar incident in 2013 on an ATR 42-500. This incident had not been investigated pursuant to ICAO Annex 13 by the state of occurrence.

The circumstances were as follows: about 35 seconds after the start of the descent from cruise level to FL140 and at a speed of 225 kt, the crew heard a thud and felt a jolt. The flight crew reduced its speed to 180 kt. An in-flight inspection was carried out and revealed damage to the right wing. Nevertheless, the landing continued to destination without further incident.

After post-flight inspection and examination of the parts, the following was observed:

- the fuselage was damaged at the junction with the right wing;
- the right internal flap was damaged;
- the vertical stabilizer was impacted;
- the right landing gear door was missing;
- the nut on the rear R MLG door hinge assembly was missing;
- the screw belonging to the rear hinge assembly was found inside the fairing and separated from its bolt;
- the link connecting the door to the landing gear had suffered fatigue failure;
- the male front hinge had failed due to overload;
- the two nuts on the left side were loose.

The safety analysis conducted by ATR, the operator and the maintenance organisation revealed that maintenance operation had been performed on the landing gear doors shortly before the occurrence and that the job card had only been partially applied because of a shift change while the task was being performed. This could have resulted in some of the nuts on the landing gear door hinge assemblies not being tightened.

Apart from this occurrence, no other occurrences of losses of landing gear doors in the landing gear up configuration were identified during the investigation of the ATR 42.

On the ATR 72, the landing gear door hinge assembly system differs from that of the ATR 42. The system design has been modified several times as a result of the loss of landing gear doors in the landing gear down configuration. No occurrences were reported in the landing gear up configuration.

1.18.7 Safety actions taken since the incident

1.18.7.1 Measures taken by the operator HOP!

Following the incident, the operator initiated an inspection of its fleet of ATR 42 aircraft, then replaced and analysed the assemblies during the A checks in the wake of the incident.

The results of these measures are described in paragraph 1.16.5.

1.18.7.2 Measures taken by the manufacturer ATR

On 19 April 2018, ATR issued an AOM (All Operators Message - Ref. AOM: 42/2018/03 issue 01) to all operators recommending that, within a deadline of one week:

- *they check the presence of the nut Item 10/20 of figure 1 from IPC 52-81-50-01 on both MLG doors at forward and aft hinge fittings*;
- *if a nut is missing, a new bolt, washers and nut shall be reinstalled before next flight, as per the instructions of the AMM JIC 52-81-00 RAI 10000*.

On 10/12/2018, ATR amended the AOM (Ref. AOM: 42/2018/03 issue 02) indicating that:

- Inspection of a number of aircraft of the same type had revealed a number of deviations and/or non-conformities in respect of the installation recommended by the documentation that was applicable at the time of the accident,
- In response to the above findings, the manufacturer ATR amended the job card (AMM JIC 52-81-00 RAI 100000) and Figure 01 of IPC 52-81-50 to clarify:
  - The tightening torque to be applied to the fasteners on the main landing gear door hinge assemblies, with a tightening torque range of 90-105 in.lbf for the front fastener and 60-65 in.lbf for the rear fastener[32];
  - How to install the fastener on the main landing gear door hinge assemblies with the screw head facing towards the rear of the aircraft.

The manufacturer also recalled:

- The presence of two tasks in the MPD relating to inspections/checks of the main landing gear door hinge assemblies that were incorporated or amended as a result of the incident:
  - 528100-GVI-10000-1: general visual inspection every 600 cycles to check for condition of the systems for hinging the main landing gear doors to the fuselage;
  - 321100-CHK-10010-1: checking for the presence of play on the main landing gear doors, to be measured at intervals of 600 cycles.
- The fact that locking wire does not have to be installed on any main landing gear door hinge (front or rear) in accordance with the approved maintenance documentation;
- Only nut P/N MS21043-5/-6 or approved interchangeable part has to be installed for front and rear MLG door hinges.

Note: ATR has launched EDORA and BIBLO projects in recent years to develop the aircraft documentation in line with in-service experience and new media technologies, through the upgrade of all ATR Technical Documentation to the S1000D publication standard[33].

[32] Please note that the tightening torque range is not indicated in the body of the text of the JIC, as can be seen on other ATR JIC, but instead in the illustrations.

[33] S1000D requires information to be created as individual data items, called Data Modules (DM), which are structured with XML elements and metadata. Each DM is self-contained and may be used wherever that piece of information is needed.

1.19 Useful or effective investigative techniques

Not applicable.

2 - ANALYSIS

2.1 Scenario

The crew took off at around 18:30 from Paris-Orly and during the climb, initially levelled off at FL110.

During the investigation, the observations made concerning the attachment points of the aeroplane's left main landing gear door made it possible to establish that the nut of the door's rear hinge assembly had unscrewed in service before coming off. The screw then moved backwards which allowed the male hinge to come out of the female hinge resulting in the landing gear door being slightly misaligned with the fuselage.

This misalignment increased the aeroplane's drag. When the conditions for the activation of the CRUISE SPEED LOW alert were all present (the first time at FL110 and then in cruise at FL190), the associated light came on in the cockpit. The crew carried out the associated procedure and continued the flight. The analysis of the FDR data found that the increased drag and thus the misalignment of the door was present at least from the first level flight at FL110 and that it probably did not exist on the previous flights.

This abnormal position of the door also resulted in additional loads on the other landing gear door attachment points, in particular the link which failed under fatigue at the start of the descent.

The loss of the link and rear hinge assembly attachment points then introduced substantial loads on the remaining main attachment point, the front hinge assembly, until failure under overload of the male hinge.

Once the three main attachment points were no longer effective (link, front hinge assembly and rear hinge assembly), the door swung upwards around hinge No. 1 and struck the fuselage and window. This situation generated the noise heard and jolt felt by people on the plane followed by the failure under overload of this same hinge.

The door then separated from the aeroplane, causing the other damage observed on the aircraft:

- damage to wing root fairings;
- scratches to cabin window and surrounding skin;
- tear on lower surface skin of left flap;
- scratches on lower surface skin of left wing;
- small dents on vertical stabilizer.

Not understanding what had just happened but seeing that the flight parameters were normal, the crew decided to continue the descent and then landed at Aurillac in a nominal manner. It was only on the tarmac that the damage to the aircraft could be seen.

An occurrence in 2013 reported by ATR (see paragraph 1.18.6) showed significant similarities with the observations made during the examination of the F-GPYF parts (absence of the nut and washer from the rear hinge assembly, failure under fatigue of the link, marks at the bottom of the fairing, damage in various places on the airframe including the wing root, the flaps and the vertical stabilizer). In this occurrence, it was surmised that the lost nut might not have been tightened during a maintenance operation carried out shortly before the occurrence flight.

Although the hinge assemblies of the main landing gear doors are not considered as critical parts, these two occurrences show that the simple loss of the nut from the rear hinge assembly can result in the loss of a main landing gear door weighing around 15 kg leading to risks for the aeroplane and also constituting a danger for people and infrastructures on the ground which cannot be ignored.

2.2 Factors which can lead to the loss of a nut

As the lost nut was not found, the investigation was unable to establish the exact reason for its loss. However, given the analysis of the manufacturer's maintenance documentation, the results of the inspection of the operator's fleet and the examination of the three other F-GPYF nuts which were recovered (nut from the front hinge assembly of the left main landing gear door and nuts from both the front and rear hinge assemblies of the right main landing gear door), the investigation brought to light several factors which, individually or together, might have potentially contributed to the unscrewing of the nut.

The mechanical performance of a screwed joint depends on multiple parameters defined during the initial design (see paragraph 1.18.1). The modification of one of these parameters may compromise the design. However, the actual impact of these modifications on the mechanical performance of the fasteners could not be quantified during the investigation (no test plan).

2.2.1 Choice of nut

The examination of the fasteners of the HOP! ATR 42 fleet found that around 50% of the nuts (and in particular the three nuts from the hinge assemblies of the left and right main landing gear doors of F-GPYF which were recovered) did not correspond to the material specified by ATR during the initial design of the assembly.

During the investigation, it emerged that there were differences between the configuration specified by ATR during the initial design of the hinge assemblies of the main landing gear doors and the alternatives authorized by the maintenance documentation. In fact, errors in transcribing standards and/or the omission of information in various documents (SRM, AMM, SPET), meant that it was possible to choose unsuitable alternative P/Ns (see paragraph 1.6.3.2.3.3).

The missing nut behind the separation of the door was lost during the occurrence and the investigation was not able to determine the operation (at least before 2015, see paragraph 1.17.1.2) which led to this nut first being installed or its characteristics. The hypothesis of an unsuitable nut cannot, however, be excluded given the number of unsuitable nuts on the rest of the HOP! ATR 42 fleet and the characteristics of the three remaining nuts on F-GPYF.

2.2.2 Application of tightening torque

Tightening torque is an important factor in the mechanical performance of a screwed joint. It must be sufficient to guarantee that the fastener is correctly secured with respect to the loads applied to the system without, however, exceeding the mechanical characteristics of one of the assembly components.

At the date of the occurrence, the tightening torque was not available in the job card which describes the maintenance operations for the installation of the gear doors (see MAIN L/G DOORS REMOVAL AND INSTALLATION). It was thus necessary to search for this information in the manufacturer's generic documentation (in particular in the AMM and SRM).

Information to determine the tightening torque to be applied based on this generic documentation was missing. In addition, there were errors in the documentation in question (see paragraph 1.6.3.2.4).

Interviews carried out with the mechanics in the Part-145 HOP! and RAS maintenance organisations revealed that these assemblies were not identified as being critical. In addition, given that the tightening torque was not indicated in the job card, few agents had looked for the tightening torque to be applied in the ATR documentation. In practice, they generally tightened the nuts by 45° (see paragraph 1.17.1.1).

The tightening torque information that ATR supplied to the operator for the inspection of the HOP! fleet, compared to the values indicated in the job card updated after the occurrence (see paragraph 1.18.7.2), also showed inconsistencies in the tightening torques to be applied to these assemblies.

Tightening torque range	ATR information given to HOP! during initial fleet inspection	Job card updated by ATR after occurrence
Front hinge assembly (in.lbf)	150-250	90-105
Rear hinge assembly (in.lbf)	90-125	60-65

Table 7: Tightening torque ranges

It should be noted that the minimum tightening torque values required by ATR following the modification of the job card are the same as the nut's maximum self-locking torque authorized by the procurement specification NASM25027 (90 in.lbf for the front hinge assembly and 60 in.lbf for the rear hinge assembly).

Thus, given the complexity of the documentation, the perception of the assemblies as having a low criticality level, and the discrepancy between the possible tightening torque ranges, it is probable that an unsuitable tightening torque was applied to the nut of the left rear hinge assembly on F-GPYF.

2.2.3 Defective nut

A defective nut (initially or after use) can also make a screwed joint ineffective.

2.2.3.1 Nut with initial defects

As indicated by EASA in its document CARI 20-01, certain batches of procured nuts complying with the standards NASM21042, MS21042 and NAS1291 can have defects which can lead to their failure.

As identified in paragraph 1.6.3.2.3, standard NAS1291 may be used for the nuts of the hinge assemblies of the main landing gear doors as alternative P/Ns.

As indicated in paragraph 1.16.5.2, it cannot be excluded that the three remaining nuts of the hinge assemblies of the main landing gear doors on F-GPYF corresponded to standards NAS1291 or MS21042.

2.2.3.2 Reuse impairing nut performance

The front and rear hinge assemblies of the landing gear doors have all metal self-locking nuts. The purpose of the self-locking function, a mechanical safety device chosen by ATR for these fasteners, is to impede the nut from unscrewing under transverse loads to the screw's axis and/or vibrations. Each time this type of nut is used, the self-locking torque decreases with the number of tightening/untightening operations.

At the time of the occurrence, the ATR documentation did not include any specific indication about checking the self-locking capability before reusing this type of nut. It could be reused if it met the visual inspection criteria (see paragraph 1.6.3.2.5) applicable to all nuts, but a failure of the self-locking function cannot generally be detected by this type of inspection.

2.3 Hinge assembly inspection actions

2.3.1 Detection of an unsuitable nut

The investigation found that the fairings protecting the hinge assemblies of the landing gear doors had to be removed in order to be able to check the nuts. However, even when the fairings are removed, it is still difficult to determine if the nut in place is the one wanted, due, in particular, to the absence of any marking on the nut.

Thus, once an unsuitable nut is installed on the plane, it becomes very difficult to detect the error during later operations.

2.3.2 Detection of unscrewing

Partial loosening or unscrewing of the nut does not result in the immediate loss of the hinge assembly's functionality (pivot link to open and close the door), this can in fact occur several years later as the incident to F-GPYF shows. Conversely, once the nut has been lost, the door may separate from the aeroplane in the relatively short time of a few flights.

At the time of the occurrence, only the removal of the fairings during maintenance operations would allow an agent to see whether the hinge fastener was loose. The frequency of these operations (in particular, every nine years or 20,000 landings for the removal of the landing gear) and the perception of their criticality meant that the possible progressive loosening of the nut on F-GPYF was not detected.

3 - CONCLUSIONS

3.1 Findings

- The aeroplane registered F-GPYF lost its left main landing gear door weighing around 15 kg at the start of the descent to Aurillac, damaging, in particular, the left wing root and a flap.
- The nut of the rear hinge assembly of the left main landing gear door of F-GPYF was missing and was not found.
- The loss of the nut of the rear hinge assembly of the left main landing gear door was behind the loss of the left main landing gear door which caused damage to the aeroplane.
- The exact reason for the loss of the nut was not established by the investigation.
- The nut of the front hinge assembly of the left main landing gear door of F-GPYF did not comply with the configuration specified during the initial design (material and protection different to the Illustrated Part Catalogue - IPC).
- The nuts of the front and rear hinge assemblies of the right main landing gear door of F-GPYF did not comply with the configuration specified during the initial design (material and protection different to the IPC).
- The P/Ns of the three F-GPYF nuts examined could not be determined with precision.
- Alternatives to the nut IPC P/Ns for the main landing gear door hinge assemblies are authorized by ATR through its generic documentation.
- There were errors in the generic documentation concerning possible nut alternatives (in particular with respect to the material and protection) which could result in nuts with a P/N which does not comply with the IPC being installed.
- The Job Instruction Card (JIC) at the date of the event and the generic documentation did not indicate the tightening torques to be applied to the IPC P/Ns of the landing gear door hinge fasteners.
- There were errors in the generic documentation concerning the tightening torques to be applied to possible alternatives to the IPC P/N nuts.
- The last operation on the rear hinge assembly of the left main landing gear door of F-GPYF was in June 2015 when the main landing gear was removed and reinstalled. The nuts were not replaced during this operation.
- The investigation was not able to determine what operations led to these nuts first being installed on F-GPYF.
- No specific check of these hinge assemblies existed in the maintenance programme at the date of the occurrence.
- ATR's generic maintenance documentation allows nuts to be reused without checking their self-locking capability.
- The examination, subsequent to the incident, of the fasteners of the HOP! ATR 42 fleet found that around 50% of the nuts did not comply with the IPC.
- The various deviations observed on the assemblies of the HOP! ATR 42 fleet are not a priori connected to work carried out by a particular maintenance workshop.
- The nuts used for the door hinge assemblies are also present elsewhere on the aeroplane.
- The errors in the generic maintenance documentation may also affect other fasteners on the aeroplane.

3.2 Contributing factors

The loss of the nut from the rear hinge assembly of the left main landing gear door was behind the door's separation from the aircraft. It was not possible to establish the exact reason for the loss of the nut.

The examination of the main landing gear door hinge assemblies on F-GPYF and the ATR42 HOP! fleet has, however, highlighted non conformities with these assemblies.

The investigation brought to light errors in the generic maintenance documentation that could lead to the installation of screw/nut combinations outside of state-of-the-art criteria. The consequences of these deviations from good practices, with respect to the mechanical performance of the screwed joint were not precisely determined during the investigation but could result in the fastener no longer fulfilling its function.

Thus, the following combinations of organisational factors and human factors may have contributed to the nut of the rear hinge assembly of the left main landing gear door becoming loose and then unscrewing:

- The ATR maintenance documentation concerning the choice of nuts to be used as an alternative to the IPC P/Ns was complex and contained errors which could lead to the choice of a nut with an unsuitable P/N.
- The tightening torque to be applied to this fastener and to the associated alternatives was missing from the ATR documentation.
- The ATR generic maintenance documentation allowed nuts to be reused without checking their self-locking capability. The landing gear door removal/installation job card did not specify that it was a self-locking nut and did not require a check for its self-locking capability or its replacement with a new nut.

4 - SAFETY RECOMMENDATIONS

Note: in accordance with the provisions of Article 17.3 of Regulation No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation in no case creates a presumption of fault or liability in an accident, serious incident or incident. The recipients of safety recommendations report to the issuing authority in charge of safety investigations, on the measures taken or being studied for their implementation, as provided for in Article 18 of the aforementioned regulation.

4.1 Fasteners: choice of P/Ns including alternatives and tightening torque

The investigation into the serious incident to F-GPYF brought to light that if the tightening torque of a fastener is not explicitly mentioned in the job card, determining this tightening torque using the manufacturer's generic maintenance documentation is difficult. What is more, the documentation included errors and inconsistencies which could result in the maintenance operator applying an unsuitable tightening torque.

Likewise, determining the alternative P/Ns of fasteners using the manufacturer's generic maintenance documentation is also complex and includes errors and inconsistencies which could result in the maintenance operator choosing unsuitable parts. In addition, 50% of the nuts used on fasteners on the ATR42s of the HOP! fleet were found to be unsuitable.

The tightening torque and the P/N (which determines, in particular, the material and protection) of the elements of the fasteners form part of the characteristics ensuring the mechanical performance of a screwed joint, thus preventing it from become loose and then unscrewing. As the serious incident to F-GPYF illustrates, the unscrewing of a fastener can lead to a hazard for the aeroplane as well as for people on the ground.

The investigation concentrated on the fasteners of the main landing gear doors. However, there are fasteners in numerous other places on the ATR and the problems raised by the investigation also apply to them.

Consequently, the BEA recommends:

- **that ATR ensure, with respect to standard parts with nuts, that there is no ambiguity in the documents about the choice of P/N and its alternatives, along with the tightening torque to be applied.**
  [Recommendation FRAN 2021-001]

4.2 Policy of reusing self-locking nuts

The F-GPYF investigation brought to light that ATR authorizes, in general, the reuse of self-locking nuts without checking the self-locking capability of these nuts.

The self-locking capability of a nut is a safety barrier to impede it from unscrewing. However, the state-of-the-art in this area indicates that each time this type of nut is used, its self-locking capability decreases with the number of screwing on/unscrewing operations.

As these self-locking nuts are present in numerous places on the ATR, the BEA recommends as a consequence:

- **that ATR define a policy for reusing self-locking nuts and ensure that the information about the presence of self-locking nuts can be easily found by the maintenance operator.**
  [Recommendation FRAN 2021-002]

APPENDIX

Appendix 1
JIC 52-81-00 RAI 10000: MAIN L/G DOORS REMOVAL AND INSTALLATION in force at the date of the occurrence

Appendix 2
IPC 52 81 50

Appendix 3
Example: determining the P/N of a nut as per NSA5050 with a silver coating as an alternative to P/N MS21043 as per SRM 51-40-30 "Nuts and alternatives"

Appendix 4
Excerpts from SRM 51-40-30 entitled "Nuts and alternatives" dated October 2018

Appendix 5
Details of inconsistencies for determining basic tightening torques

Appendix 6
Continued airworthiness review item of MS21042, NASM21042 and NAS 1291 standard fasteners (nuts) used in critical installations

Appendix 7
ATR's reply to CARI 20-01 dated 30 August 2018

Appendix 1

JIC 52-81-00 RAI 10000: MAIN L/G DOORS REMOVAL AND INSTALLATION in force at the date of the occurrence

MAIN L/G DOORS REMOVAL AND INSTALLATION

*** ON A/C ALL***

MINOR INFORMATION ADDITION

TECHNICAL DATA

ZONING DATA

ZONE : 193
194

PREPARATION

WORK	SKILL	MEN	MAN-HOURS
ELAPSES TIME			
BULK MATERIAL :	SYNTHETIC GREASE	04-004	

PUBLICATIONS
JIC : 32-31-55-RAI-10000
JIC : 32-31-00-FUT-10000
JIC : 12-22-32-LUB-10000
JIC : 52-81-00-ADJ-10000

TASK DESCRIPTION

001 WARNING

1. BEFORE UNDERTAKING MAINTENANCE WORK ON A/C
   DISPLAY WARNING NOTICES IN FLT COMPARTMENT
   ON PANEL 404VU(VM) PROHIBITING THE OPERATION
   OF EITHER HYDRAULIC SYSTEM OR LANDING GEAR
   AND/OR ASSOCIATED CONTROLS.
2. WHEN PERFORMING OPERATIONAL TESTS MAKE
   CERTAIN THAT THE FOLLOWING SAFETY RULES
   ARE OBSERVED:
   A. SAFETY PINS ARE IN POSITION AND THEIR RED

MARKER FLAGS VISIBLE.
B. A SAFETY BARRIER IS PLACED TO RESTRICT AREAS SO AS UNAUTHORIZED PEOPLE CANNOT ACCIDENTALLY OBSTRUCT ROTARY OR ANGULAR MOVEMENT OF LANDING GEARS CAUSING PERSONNEL INJURY.
C. BEFORE PERFORMING ANY TYPE OF MANEUVERS WARN SURROUNDING PERSONNEL OF YOUR INTENTIONS.
D. NEVER MAKE AN ADJUSTMENT WITHOUT FIRST ISOLATING HYDRAULIC POWER AND POSITIONING SAFETY PINS.

002 REMOVAL OF MLG DOOR LINK, DOOR PIVOT POINT

SEE JOB INSTRUCTION CARD
JIC : 323155-RAI-10000

003 L/G NORMAL RETRACTION

SEE JOB INSTRUCTION CARD
JIC : 323100-FUT-10000

004 REMOVAL OF MAIN L/G DOORS

NOTE: THE FOLLOWING PROCEDURE IS IDENTICAL FOR BOTH SIDES (LH OR RH).
REF. FIG. :528100-RAI-00106
1. UNSCREW NUTS (1), WASHERS (2) AND DISCONNECT BONDING LEADS (3) FROM MLG DOORS.
REF. FIG. :528100-RAI-00102
NOTE: RECOVER WITH CARE SHIM(S) (4) BECAUSE THEY ARE VERY IMPORTANT IN ADJUSTMENT OF THE FOLDING DOORS.
2. UNSCREW NUTS (3), WITHDRAW SCREWS (1) WITH RELEVANT WASHERS (2), RECOVER SHIMS (4) AND

DISCONNECT HINGES (8).

REF. FIG. :528100-RAI-00100

3. UNSCREW SCREWS (1), REMOVE FAIRINGS (2) AND RECOVER SHIMS (3) IF PRESENT.

CAUTION: HOLD THE MLG DOORS BY HANDS IN ITS POSITION WHEN REMOVE BOLTS (9), THEN WITHDRAW IT FROM FEMALE HINGES (8) WITH CARE.

4. UNSCREW NUTS (14), WITHDRAW WASHERS (13), BOLTS (9) WITH WASHERS (10) AND BUSHINGS (11).

5. REMOVE MLG DOORS AND PLACE IT ON SOMETHING SOFT.

005 INSTALLATION OF MAIN L/G DOORS

REF. FIG. :528100-RAI-00100

NOTE: THE FOLLOWING PROCEDURE IS IDENTICAL FOR BOTH SIDES (LH OR RH).
TAKING CARE NOT TO DAMAGE THE DOOR ASSY.
THOROUGHLY COAT SHAFT OF BOLTS (9) AND INTERNAL DIAMETER OF BUSHINGS (11) WITH SYNTETHIC GREASE MAT 04-004 PRIOR TO FINAL ASSEMBLY.

1. PLACE THE MLG DOORS MALE HINGES (12) IN THE FEMALE HINGES (8) AND INSTALL BUSHINGS (11), BOLTS (9) WITH WASHERS (10) (13), NUTS (14) AND TIGHTEN THEM.

REF. FIG. :528100-RAI-00104

2. LOOSEN THE NUTS OF FWD AND REAR STOPS (1) AND RETRACT THEM AS FAR AS POSSIBLE AND TIGHTEN THEM.

3. DRIVE THE MLG DOORS BY HANDS IN CLOSED POSITION AND MAKE SURE THAT IT IS FLUSH WITH AIRCRAFT PROFILE.

4. LOOSEN THE NUTS OF FWD AND REAR STOPS (1)

AND BRING THE STOPS IN CONTACT WITH MLG DOORS WITHOUT STRESS.

REF. FIG. :528100-RAI-00102

5. CONNECT HINGES (8), PLACE SHIMS (4) AND BONDING LEADS (7).
6. INSTALL SCREWS (1), WASHERS (2), NUTS (3) AND TIGHTEN THEM.
7. VERIFY THAT HINGE PINS (5) ARE WELL INSTALLED IN THE HOUSING AND BLOCKED BY SLOTTED PINS (6).

REF. FIG. :528100-RAI-00106

8. CONNECT BONDING LEADS (3) IN SAME POSITION, INSTALL WASHERS (2), NUTS (1) AND TIGHTEN THEM.

REF. FIG. :528100-RAI-00100

9. INSTALL FAIRINGS (2), SHIMS (3) IF PREVIOUSLY REMOVED, SCREWS (1) AND TIGHTEN THEM.

006 MLG AND MLG DOORS LUBRICATION

SEE JOB INSTRUCTION CARD
JIC : 122232-LUB-10000

007 L/G NORMAL EXTENSION

SEE JOB INSTRUCTION CARD
JIC : 323100-FUT-10000

008 INSTALLATION OF MLG DOOR LINK, DOOR PIVOT POINT

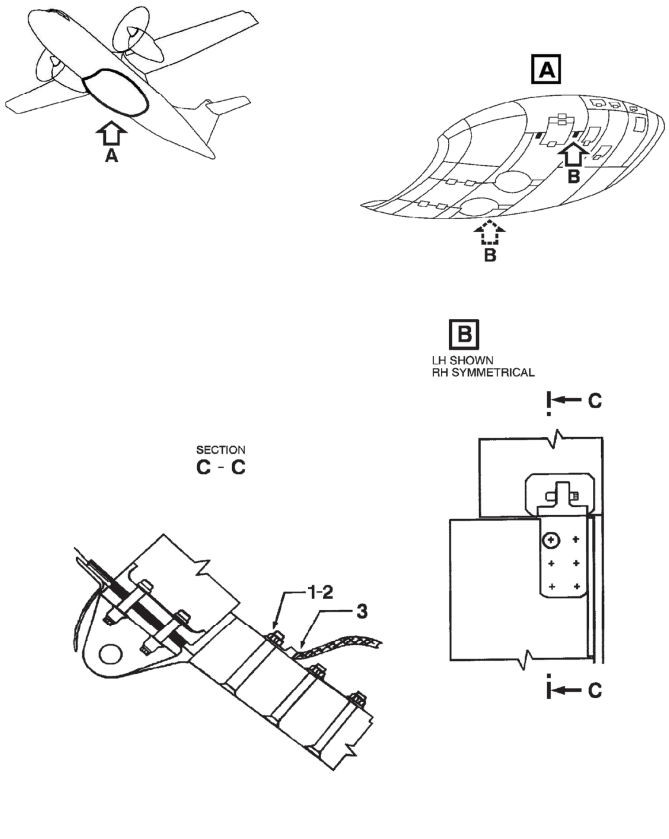
SEE JOB INSTRUCTION CARD
JIC : 323155-RAI-10000

009 MLG DOOR ADJUSTMENT

SEE JOB INSTRUCTION CARD
JIC : 528100-ADJ-10000

010 NORMAL EXTENSION AND RETRACTION FUNCTIONAL TEST

SEE JOB INSTRUCTION CARD
JIC : 323100-FUT-10000
(Ref Fig. 52-81-00 MLG DOORS REMOVAL AND INSTALLATION)
(Ref Fig. 52-81-00 MLG DOORS REMOVAL AND INSTALLATION)
(Ref Fig. 52-81-00 MLG DOORS REMOVAL AND INSTALLATION)
(Ref Fig. 52-81-00 MLG DOORS REMOVAL AND INSTALLATION)
52-81-00
52-81-00
52-81-00
52-81-00



SJ5_528100_RAI_00106_002_C_AB

Figure 52-81-00-RAI-00106-002 - MLG DOORS REMOVAL AND INSTALLATION
**** ON A/C ALL**

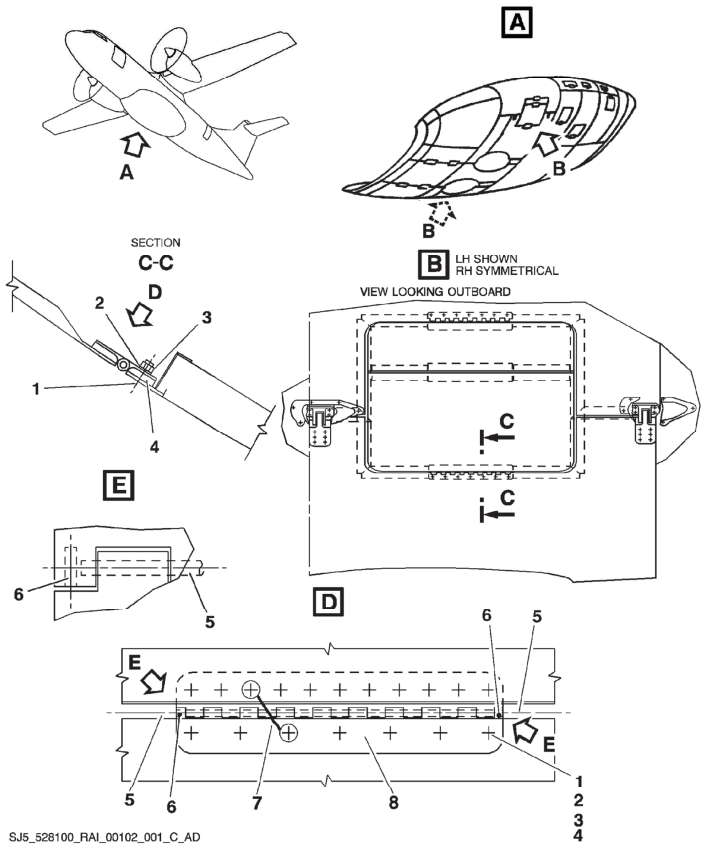

A
A
B
B
B
LH SHOWN
RH SYMMETRICAL
VIEW LOOKING OUTBOARD
SECTION
C-C
D
1
2
3
4
C
C
E
5
6
D
E
5
6
7
8
E
1
2
3
4
5
6
SJ5_528100_RAI_00102_001_C_AD

Figure 52-81-00-RAI-00102-001 - MLG DOORS REMOVAL AND INSTALLATION
**** ON A/C ALL**

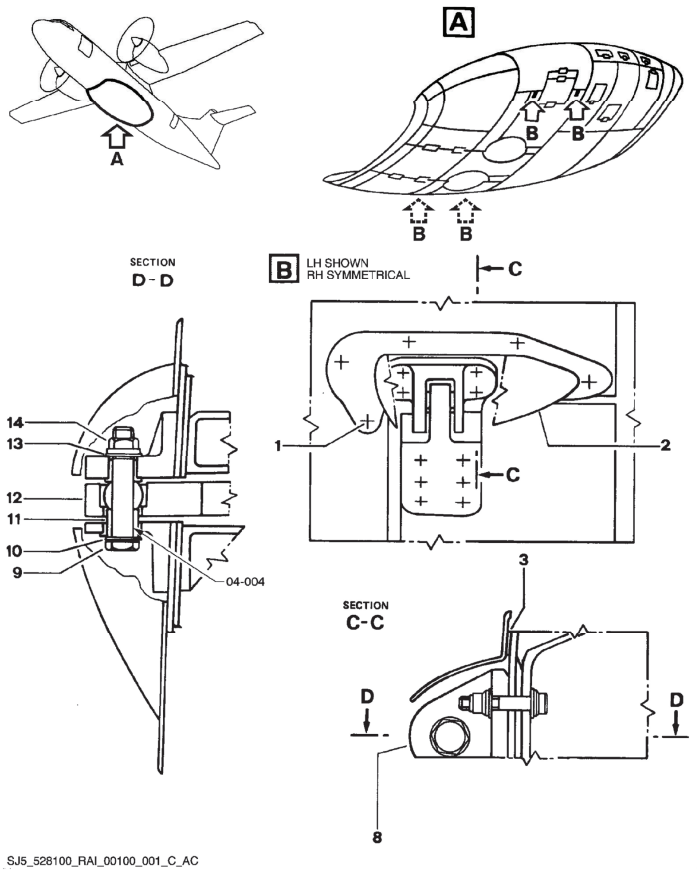
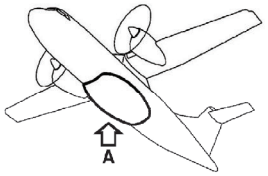
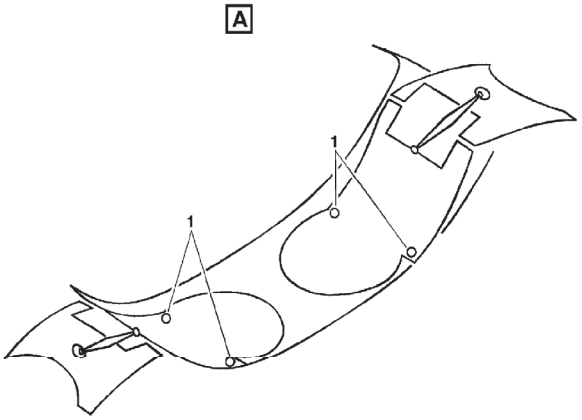

A
A
B
B
B
B
SECTION
D - D
B LH SHOWN
RH SYMMETRICAL
C
14
13
12
11
10
9
04-004
1
2
C
3
SECTION
C-C
D
D
8
SJ5_528100_RAI_00100_001_C_AC

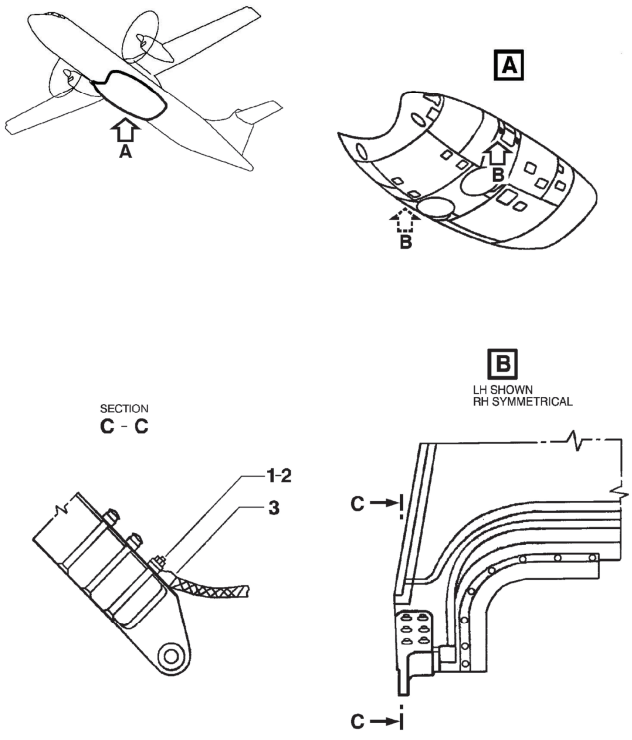
Figure 52-81-00-RAI-00100-001 - MLG DOORS REMOVAL AND INSTALLATION
**** ON A/C ALL**





SJ5_52B100_RAI_00104_001_C_AB

Figure 52-81-00-RAI-00104-001 - MLG DOORS REMOVAL AND INSTALLATION
**** ON A/C ALL**



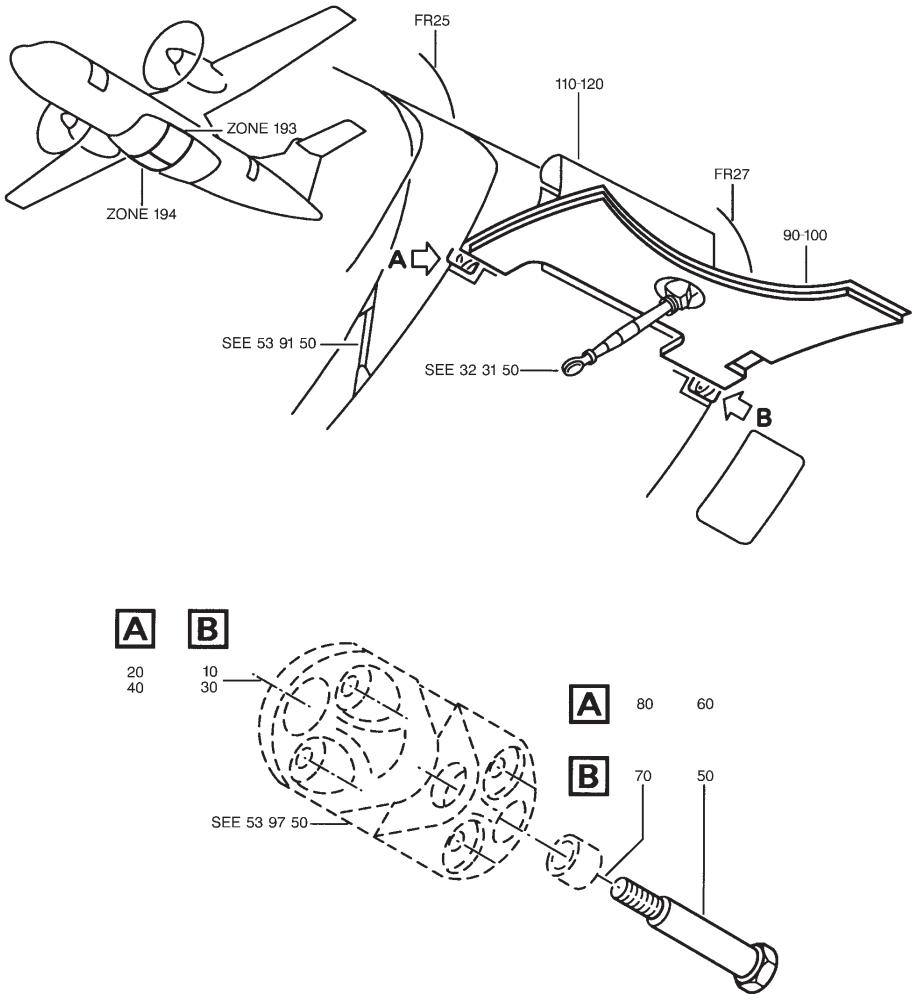
SJ5_528100_RAI_00108_003_C_AB

Figure 52-81-00-RAI-00108-003 - MLG DOORS REMOVAL AND INSTALLATION
**** ON A/C ALL**

Appendix 2

IPC 52 81 50

ILLUSTRATED PARTS CATALOG



SP5 52 81 50 01 -A

DOOR INSTL-FR25-FR27,Z193

FIGURE 1

52-81-50

PAGE 1-0
JAN.01/17

Printed in France

FIG-ITEM	PART NUMBER	1234567 NOMENCLATURE	USAGE FROM TO	UNIT PER ASSY
1 - 1J	S5397005015060	DOOR INSTL-FR25-FR27, Z193 (LH) (NP)		RF
- 2J	S5397005015063	DOOR INSTL-FR25-FR27, Z194 (RH) (NP)		RF
10	MS21043-5	.NUT		1
20	MS21043-6	.NUT		1
30	ASNA2397C516L	.WASHER VT0000 OPT TO AN960C516L		1
40	ASNA2397C616L	.WASHER VT0000 OPT TO AN960C616L		1
50	NTA11159-5SU22	.BOLT OPT TO BACB30LJ5SU22 (V81205)		1
60	NTA11155-6H26	.BOLT OPT TO BACB30LE6H26		1
70	NTA11551-5ACU	.WASHER		1
80	NTA11551-7ACU	.WASHER OPT TO BACW10BP7ACU (V81205)		1
90G	S5287130402850	.DOOR ASSY-MLG (LH) SEE 52-81-50-06E FOR DET RPLS S5287130401850		1
90H	S5287130402850	.DOOR ASSY-MLG (LH) SEE 52-81-50-06E FOR DET RPLS S5287130401850		1
100G	S5287130402950	.DOOR ASSY-MLG (RH) SEE 52-81-50-06E FOR DET RPLS S5287130401950		1
100H	S5287130402950	.DOOR ASSY-MLG (RH) SEE 52-81-50-06E FOR DET RPLS S5287130401950		1
110C	S5287130502060	.DOOR INSTL-CONCERTINA (LH) (NP) SEE 52-81-50-10C FOR DET		1
120C	S5287130502160	.DOOR INSTL-CONCERTINA (RH) (NP) SEE 52-81-50-10C FOR DET		1

-ITEM NOT ILLUSTRATED

MISSING ITEMS AND VARIANTS ARE NOT APPLICABLE

Printed in France

Appendix 3

Example: determining the P/N of a nut as per NSA5050 with a silver coating as an alternative to P/N MS21043 as per SRM 51-40-30 "Nuts and alternatives"

1. Table 1 indicates that the materials and protection are described in table 3.

STANDARD/ SPECIFICATION	DESCRIPTION	MATERIAL	FINISH	ALTERNATIVE	
				TWO WAY	ONE WAY
NSA5050  NSA5050	SELF LOCKING NUT SHAKEPROOF WASHER	Table 3	Table 3	ABS0050 MS21043 NAS1726	HW17

Source: ATR

Figure 25: Excerpt from table 1 of SRM514030-00-001-A01 page 14

2. Table 3 indicates that there are two material/protection combinations possible for a nut as per NSA5050.
    1. Combination No 1: steel (code: -) / protection: cadmium (code: none)
    2. Combination No 2: stainless steel (code: C) / protection: silver (code: none)

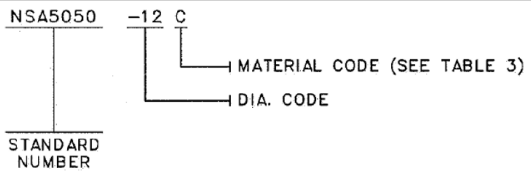
STANDARD /SPEC.	COMPONENT										
	NUT						WASHER			SHELL	CLIP
	CODE	MAT.	CODE	PROT.	CODE	LUBRI-CATION	MAT.	PROT.	LUBRI-CATION		
NSA5050	-	STEEL ALLOY	NONE	Cd.	NONE	CETHYL ALCOHOL	CARBON STEEL	Cd.	CETHYL ALCOHOL	NONE	NONE
	C	CRES		SILVER PLATE			CRES	PASS-IVATE			

Source: ATR

Figure 26: Excerpt from table 3 of SRM514030-00-001-A01 page 41[34]

[34] Standard NSA5050 can also be used to define nuts.

3. Lastly, table 2 explains the codification of the P/N. Thus, for combination No 2 with a silver protection, the P/N is NSA5050 -5C.

STANDARD/ SPECIFICATION	CODIFICATION
NSA5050	

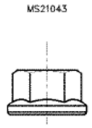
Source: ATR

Figure 27: Excerpt from table 2 of SRM514030-00-001-A01 page 29

Appendix 4

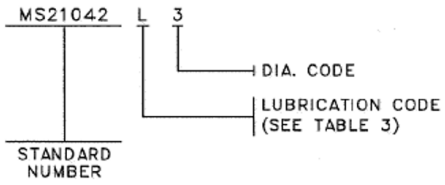
Excerpts from SRM 51-40-30 entitled “Nuts and alternatives” dated October 2018

❒ MS21043:

STANDARD/ SPECIFICATION	DESCRIPTION	MATERIAL	FINISH	ALTERNATIVE	
				TWO WAY	ONE WAY
MS21043  MS21043	HEXAGON NUT SELF LOCKING LIGHT HEIGHT (THIN)	Table 3	Table 3	NAS1291 NTA11354 BACN10JC NSA5050	-

Source: ATR

Figure 28: Excerpt from table 1 of SRM514030-00-001-A01 page 6

STANDARD/ SPECIFICATION	CODIFICATION
MS21042 MS21043 MS21051	

Source: ATR

Figure 29: Excerpt from table 2 of SRM514030-00-001-A01 page 26

STANDARD /SPEC.	COMPONENT										
	NUT						WASHER			SHELL	CLIP
	CODE	MAT.	CODE	PROT.	CODE	LUBRI-CATION	MAT.	PROT.	LUBRI-CATION		
MS21043 MS21087	NONE	CRES	NONE	SILVER PLATE	NONE	YES	NONE			NONE	

Source: ATR

Figure 30: Excerpt from table 3 of SRM514030-00-001-A01 page 38

❒ NSA5050:

STANDARD/ SPECIFICATION	DESCRIPTION	MATERIAL	FINISH	ALTERNATIVE	
				TWO WAY	ONE WAY
NSA5050  NSA5050	SELF LOCKING NUT SHAKEPROOF WASHER	Table 3	Table 3	ABS0050 MS21043 NAS1726	HW17

Source: ATR

Figure 31: Excerpt from table 1 of SRM514030-00-001-A01 page 14

STANDARD/ SPECIFICATION	CODIFICATION
NSA5050	NSA5050 −12 C STANDARD NUMBER DIA. CODE MATERIAL CODE (SEE TABLE 3)

Source: ATR

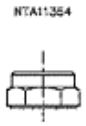
Figure 32: Excerpt from table 2 of SRM514030-00-001-A01 page 29

STANDARD /SPEC.	COMPONENT										
	NUT						WASHER			SHELL	CLIP
	CODE	MAT.	CODE	PROT.	CODE	LUBRI-CATION	MAT.	PROT.	LUBRI-CATION		
NSA5050	-	STEEL ALLOY	NONE	Cd.	NONE	CETHYL ALCOHOL	CARBON STEEL	Cd.	CETHYL ALCOHOL	NONE	NONE
	C	CRES		SILVER PLATE			CRES	PASS-IVATE			

Source: ATR

Figure 33: Excerpt from table 3 of SRM514030-00-001-A01 page 41

❒ NTA11354:

STANDARD/ SPECIFICATION	DESCRIPTION	MATERIAL	FINISH	ALTERNATIVE	
				TWO WAY	ONE WAY
 NTA11354	SELF LOCKING NUT	Table 3	Table 3	MS21042 MS21043	-

Source: ATR

Figure 34: Excerpt from table 1 of SRM514030-00-001-A01 page 18

STANDARD/ SPECIFICATION	CODIFICATION
NTA11354	NTA11354 CH 3 STANDARD NUMBER DASH NUMBER MATERIAL CODE AND PROTECTION CODE (SEE TABLE 3)

Source: ATR

Figure 35: Excerpt from table 2 of SRM514030-00-001-A01 page 34

STANDARD /SPEC.	COMPONENT										
	NUT						WASHER			SHELL	CLIP
	CODE	MAT.	CODE	PROT.	CODE	LUBRI-CATION	MAT.	PROT.	LUBRI-CATION		
NTA11354 NTA11452 NTA11453 NTA11454 NTA11457	NONE	STEEL ALLOY	NONE	Cd.	NONE	YES	NONE			NONE	NONE
			NONE	SILVER PLATE							
	C	CRES	M	PASS-IVATE							
			D	Cd.							

Source: ATR

Figure 36: Excerpt from table 3 of SRM514030-00-001-A01 page 43

STANDARD/ SPECIFICATION	DESCRIPTION	MATERIAL	FINISH	ALTERNATIVE	
				TWO WAY	ONE WAY
 NAS1291	HEXAGON NUT SELF LOCKING	Table 3	Table 3	NTA11303 NAS679 MS21042 MS21043 HL42	-

Source: ATR

Figure 37: Excerpt from table 1 of SRM514030-00-001-A01 page 13

STANDARD /SPEC.	COMPONENT										
	NUT						WASHER			SHELL	CLIP
	CODE	MAT.	CODE	PROT.	CODE	LUBRI-CATION	MAT.	PROT.	LUBRI-CATION		
NAS1291	NONE C	STEEL CRES	NONE	Cd. SILVER PLATE	NONE	NONE	NONE			NONE	

Source: ATR

Figure 38: Excerpt from table 3 of SRM514030-00-001-A01 page 40

Appendix 5

Details of inconsistencies for determining basic tightening torques

❒ AMM 20-21-22: Tightening torques for NTA11354-5/NTA11155-5SU22 combination

Two tables (both referenced in table 5) give two different tightening torque ranges for the NTA11354-5/NTA11155-5US22 combination.

- Page 28: 60-35 in.lbs. This seems to be a typing error as the first value of the tightening torque range (which is supposed to be the minimum value) is greater than the second value of the range (supposed to be the maximum value).

NUT TIGHTENING TORQUE			
SCREW		ALL	
NUT		NTA11353 NTA11354	
DIAMETER	THREAD SIZE mm (in.)	DRY OR LUBRICATED SCREW	
		mdaN min – max	in.lbs min – max
5/16–24	7.94 (0.3125)	0.68 – 0.40	60 – 35
3/8–24	9.53 (0.3750)	1.07 – 4.07	95 – 360

Source: ATR

Figure 39: Excerpt from AMM 20-21-12 Page 28 - Aug 01/08[35]

- Page 27: 90 – 125 in.lbs as the screw is lubricated. The lubricated condition of the screw is indicated in SRM 51-40-21 table 3.

NUT TIGHTENING TORQUE					
SCREW		AN3 THRU AN20 NAS606 NAS623 NAS1100 NAS1102 NAS1131		NAS1138 NAS1151 THRU NAS1158 NAS1801 NAS1802 NTA11156 THRU NTA11165 NTA11167	
NUT		MS21042 NTA11353 NTA11354			
DIAMETER	THREAD SIZE mm (in.)	DRY SCREW		LUBRICATED SCREW	
		mdaN min – max	in.lbs min – max	mdaN min – max	in.lbs min – max
5/16–24	7.94 (0.3125)	1.13 – 1.69	100 – 150	1.02 – 1.41	90 – 125
3/8–24	9.53 (0.3750)	1.81 – 2.71	160 – 240	1.69 – 2.26	150 – 200

Source: ATR

Figure 40: Excerpt from AMM 20-21-12 Page 29 - Aug 01/08

[35] Note: screw = all, means that all the screws listed in table 1 of AMM 20-21-12 can be used. The screw standards NTA11155 and NTA11159 are indicated.

❒ SRM 51-25-02: Determining basic tightening torques

In a similar way to chapter 20 of the AMM, chapter 51-25-02 of the SRM also presents tables with multiple entries. It is, however, indicated in the preamble (see Figure 41) that table 38 must be used to apply the tightening torques for all door fittings (hinge assemblies), although table 38 is entitled "*Oversize Bores Close-Tolerance Bolts (NSA 5026 to NSA 5029)*" and contains no tightening torque.

F. Basic Torque Values

The basic values are defined in Table 55 to Table 66 and Table 48 to Table 54.

NOTE : Use Table 38 to apply the torque in the following areas:

- MLG fitting attachment (truss, struts and side brace fittings on the fuselage);
- Wing-to-fuselage fitting (fuselage side) on frames 25 and 27;
- Fin-to-fuselage fitting
- All fittings concerning doors, fuselage and empennages.

Source: ATR

Figure 41: Excerpt from SRM 51-25-02 page 10

Appendix 6

Continued airworthiness review item of MS21042, NASM21042 and NAS 1291 standard fasteners (nuts) used in critical installations

EASA European Aviation Safety Agency		
	CARI :	20-01
	ISSUE :	1
CONTINUING AIRWORTHINESS	DATE :	30 August 2018
REVIEW ITEM	PAGE No.:	1 of 4
	STATUS:	Open
	NEXT ACTION :	TC Holder(s)

SUBJECT:	**Continued airworthiness of MS21042, NASM21042 and NAS 1291 standard fasteners (nuts) used in critical installations**
REQUIREMENT(S):	Part 21.A.307
APPLICABILITY:	Rotorcraft and Large Aeroplanes
PRIMARY PANEL:	3 (Structures)
SECONDARY PANELS:	4 (Hydro-mechanical Systems), 7 (Powerplant), 13 (Transmission)

IDENTIFICATION OF ISSUE:

Standard fasteners (nuts and bolts) are widely used on products, parts and appliances certified by the Agency. Deviations from the standard, or installation issues may result in unexpected failure of the fastener with consequences at the aircraft level. Within the last few years an accumulation of certain failed standard fastener nuts in aviation has been observed. These failures may have severe consequences at the aircraft level when used in critical installations.

The Agency has identified that the standard fasteners listed in Table 1 have exhibited higher failure rates than other standard parts. These failures are potentially due to the specific standards being particularly sensitive to one or more of the following:

1) Manufacturing process and quality issues;
2) Installation issues.

Each TCH may have a different approach to the use of these fasteners in design and expectations for production and quality by POA holders and MOA holders for installation. The intent of this CARI is to ensure that TCH's assess the risk of continued use of the nuts listed in Table 1.

In cases where service history does not support continued use of these standard fasteners in specific

applications, the TCH's should provide an action plan to mitigate the risk associated with continued use of the fasteners.

EASA POSITION (ISSUE 1, DATED 28.08.2018):

Failures of standard fasteners may have severe consequences at the aircraft level when used in critical installations. This Continued Airworthiness Review Item (CARI) is therefore addressed to TCHs of rotorcraft and large aeroplanes. The TCH's are expected to confirm that their existing designs are not exposed to potential unsafe conditions from continued use of these nuts and to take corrective action where this is not the case. The extent to which products are affected will be dependent on the level of risk, taking into account service experience and the level of safety expected at the aircraft level. This CARI provides these TCHs with guidance on performing a continued airworthiness review and requests specific actions consistent with the unsafe conditions. The TCHs are expected to provide the Agency with a report detailing existing and proposed actions.

Continued Airworthiness Review

The Agency has identified through service experience that the standard fasteners listed in Table 1 have been failing at an unacceptable rate since earlier initiatives such as SIBs, resulting in several Airworthiness Directives being issued relating to the same standard fasteners. The root causes of these failures have not yet been identified, however, inappropriate installations and poor quality are among the contributing factors leading to higher than expected failure rates.

Table 1

Standard	Description	Specific points of concern for all of these nuts
NASM21042	Nut	Thin walled; not designed as a tension nut. Several cases of hydrogen embrittlement or physical defects leading to common cause failures including complete loss of bolt retention function. Loss of locking capability. Failure to adhere to the installation requirements of NASM33588.
MS21042	Nut	
NAS 1291	Nut	

In order to reduce the risk of critical installations failing through the continued use of these standard nuts, the Agency requests that all TCHs of rotorcraft and large aeroplanes complete the following actions and provide the Agency with a report highlighting the results:

1. If any of the standard parts listed in Table 1 are used in critical installations provide the following information:

   1.1 Any reported failures.
   1.2 Any corrective actions taken to mitigate the risks.
   1.3 If no actions are taken, please explain the rationale supporting the decision to continue to use the parts.

2. In cases where any of the fasteners in Table 1. are used in critical installations, explain how the Instructions for Continued Airworthiness are adequate to ensure that the airworthiness condition of the aircraft and its parts are maintained, particularly if failures are associated with maintenance errors such as incorrect installation, torque or re-use. This should include ensuring that type design fasteners are only replaced by equivalent type design fasteners (i.e. a standard fastener is not an eligible replacement part).

3. Explain company continued airworthiness procedures and how it protects the fleet, in case of failures of fasteners, including standard parts.

4. Provide a report to the Agency with a response to this CARI within 6 months.

The Agency may take further actions concerning the standard fasteners listed in Table 1 and provide further guidance based on the TCH responses to this CARI.

DESIGN APPROVAL HOLDER'S POSITION (ISSUE 1, DATED DD MMM YYYY):

APPENDIX I – definitions and glossary

Definitions:

Terms	Definitions
Standard Fasteners (which are standard parts)	Fasteners (nuts and bolts) being produced according to a certain standard which is not directly approved by the agency. They fall within the category of standard parts as defined in Commission Regulation (EU) No 748/2012 21.A.303(c)
Type Design Fastener	A fastener for which the type design defines the specification, tolerance, critical characteristic, manufacturing process, quality inspection and/or control of their source, by methods defined by the DAH, is a type design fastener. Any required additional specification or verification of compliance imposed on a standard part fastener results in a type design fastener.
Critical installations	Mechanical and structural assemblies, including fasteners, the failure of which (single or multiple due to common cause) could result in an unsafe condition.

Glossary:

Abbreviation	Meaning
CARI	Continued Airworthiness Review Item
CAW	Continued Airworthiness
DAH	Design Approval Holder
EASA	European Aviation Safety Agency
ICA	Instruction and Information for Continued Airworthiness
MOA	Maintenance Organisation Approval
POA	Production Organisation Approval
SIB	Safety Information Bulletin
TCH	Type Certificate Holder

Appendix 7

ATR's reply to CARI 20-01 dated 30 August 2018

Blagnac, 02 July 2019

To:
Ludovic ARON - Head of Large Aeroplanes Department Certification Directorate
Javier GARCIA NEVADO - Large Aeroplanes Project Certification Manager

Copy:
Christian GUNITZBERGER - EASA ATR Project Certification Manager

Subject: CARI 20-01 - Continued Airworthiness of MS21042, NASM21042 and NAS 1291 standard fasteners (nuts) used in critical installations.

Dear Sirs,

ATR has analysed the CARI 20-01, please find here below the ATR answers related to the 3 Items raised by the CARI.

Item 1: If any of the standard parts listed above are used in critical installations, provide the following information:
- Any reported failure,
- Any corrective actions taken to mitigate the risks,
- If no actions are taken, please explain the rationale supporting the decision to continue to use the parts

ATR answer:
Up today, no failure related to the certified design regarding the fasteners identified by the CARI 20-01 has been reported to ATR.

Item 2: In case where any of the fasteners above are used in critical installations, explain how the instructions for continued airworthiness are adequate to ensure that the airworthiness condition of the aircraft and its parts are maintained, particularly if failures are associated with maintenance errors such as incorrect installation, torque or re-use. This should include ensuring that type design fasteners are only replaced by equivalent type design fasteners (i.e. a standard fasteners is not an eligible replacement part

ATR answer:
ATR Instructions for Continued Airworthiness (ICA) enable to guarantee through our Aircraft Maintenance Manual (AMM) and Structural repair Manual (SRM) that fasteners are adequately installed with adequate torque. The ICA provide the possible interchangeability and provide the re-use rules that have to be followed.

- Installation: Bolts installation instructions are available into ATR SRM chapter 51-25-04. Similar rules are also proposed into the AMM chapter 20.
- Torque: Unless a specific, torque is provided into the AMM Job Instruction Card, all the applicable torque values are available into the SRM chapter 51-25-02 and in the AMM chapter 20.
- Re-use: Nut and screw re-use rules are provided into the SRM chapter 51-25-11.
- Interchangeability: The SRM provides a dedicated chapter 51-40-30 for the nuts and alternatives, which presents global rules and specific tables providing interchangeabilities.

Item 3: Explain Company continued airworthiness procedures and how it protects the fleet, in case of failures of fasteners, including standard parts.

ATR answer:
Current continued airworthiness process (CG-0044) enables to collect / analyze / address all reports, which have a potential airworthiness impact. This procedure enables to meet the requirement of the continued airworthiness regulation described in the PART21, EU 376/2014 and EU 1018/2015.
If an event is reported to ATR on these kind of fasteners, this will initiate the continued airworthiness process. Then, as per process, the event will be collected, dedicated analysis will be done and specific corrective actions could be put in place if necessary.

We hope that these answers fully address the CARI 20-01, please receive our best regards.

BEA

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