Landing gear failure during landing run at Oulu Airport on 3 October 2016

Investigation number: L2016-02

SYNOPSIS

Based on section 2 of the Safety Investigation Act (525/2011), the Safety Investigation Authority, Finland (SIAF) decided to investigate an accident that occurred to a Reims F406 Caravan II aircraft, registered OH-OTL, at Oulu Airport on 3 October 2016. The right main landing gear of the aircraft collapsed during landing run. Major (ret.) Pekka Alaraudanjoki was appointed as team leader for the investigation group, and B. Eng Jan Nordlund as an expert member of the group. Chief Investigator Ismo Aaltonen acted as investigator-in-charge.

The accident was reported to the European Aviation Safety Agency (EASA), to The Bureau of Investigation and Analysis for Civil Aviation Safety (BEA) of France and to the National Transportation Safety Board (NTSB) of the United States. BEA and NTSB designated an accredited representative to the investigation.

The investigation report describes the events before the accident and after it. It also reviews the rescue operations and analyses the factors contributing to the accident. Finally, safety recommendations are issued to prevent similar accidents in the future or to mitigate their consequences.

The purpose of a safety investigation is to enhance safety in general, to prevent accidents and incidents, and to counteract any damage caused by accidents. The investigation does not address any questions of responsibility or liability for damages. Use of the investigation report for reasons other than improvement of safety should be avoided.

The investigation was initiated at Oulu Airport by photographing the damage to the aircraft and the marks on the runway. A SIAF investigator was present when the collapsed landing gear was removed from the aircraft in Oulu and re-installed temporarily for moving the aircraft. Since the cause of the accident was revealed during landing gear removal, the technical staff of Lapin Tilauslento Oy were permitted to examine other damage caused to the aircraft in the accident in more detail. They later gave a report on the damage to the investigators. The investigation group visited Lapin Tilauslento Oy's repair station at Rovaniemi Airport to review the company operations and to check their instructions and arrangements related to maintenance. Finavia was requested to provide an account of the actions taken by air traffic control and rescue services at Oulu Airport in consequence to the incident.

An opportunity was reserved for those involved in the accident and to the authorities responsible for supervision in the field of the accident to comment on the draft investigation report. The comments were taken into account when finishing the report. A summary of the comments received is available on the last pages of this report. However, no comments given by private individuals have been published.

The investigation report was translated into English by Leila Iikkanen. The report, including its summary and appendices, has been published on the SIAF website at *www.sia.fi*.

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Investigation report 6/2017
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Cover photo: Finavia, Oulu Airport

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1 FACTUAL INFORMATION

1.1 History of the flight

A Reims F406 Caravan II aircraft (OH-OTL), operated by the Finnish company Lapin Tilauslento Oy, departed for a routine cargo flight from Rovaniemi Airport to Oulu on 3 October 2016. The aircraft had a two-pilot crew and carried 347 kg of mail. There were no other persons on board besides the crew.

Flight preparation, aircraft loading and taxiing from the stand to take-off position were uneventful. Taxiing distance was about 800 m. The aircraft took off on runway 03 at 19:30 – all times in this report are Finnish local time. The weather was good and it was starting to become dark at that time in the evening. When the landing gear was retracted, the GEAR UNLOCKED warning light and the HYD PRESS ON indicator for the hydraulic system remained on. At the pilot-in-command's request, the co-pilot selected gear back down, and the three green lights indicating that the gear was down and locked illuminated normally. The HYD PRESS ON indicator and GEAR UNLOCKED warning were also extinguished as usual.

The pilot-in-command continued flying towards Oulu, and the co-pilot searched the emergency checklists for suitable procedures for the situation. Any procedures directly applicable to this malfunction were not found, but the pilots decided to follow the procedure for cases where the HYD PRESS ON light remained on continuously. The procedure assisted in isolating the fault to the landing gear system, but the exact nature of the malfunction was not clear. The pilots took the actions as instructed, except that the point "landing gear switch - rapidly recycle" was omitted, since the gear was already extended and the indicator lights showed that it was down and locked.

The pilot-in-command decided to continue to Oulu with the gear down, as the procedure did not call for landing as soon as possible and the weather was good. Approach and landing at Oulu were performed in darkness at 20:05. The aircraft touched down at the beginning of the runway, and the landing run was normal at first. When the plane had decelerated to a speed of about 60 kt[1], the pilot-in-command started braking, at which time the right main landing gear collapsed and the aircraft tilted to the right. The pilot-in-command stated that he had managed to keep the plane on the runway using nose wheel steering, braking hard on the left side and applying reverse thrust in the left engine. The aircraft stopped quickly after the landing gear had collapsed, within a distance of about 80 m.

The aircraft came to a stop on the right edge of runway 30, remaining well on the paved surface. The engines were running until the plane stopped and were then shut down. The pilot-in-command asked the co-pilot to report the incident to the ATC and request a tow vehicle. After sending the report, electrical power was switched off. ATC alerted the rescue services, and the pilots exited the plane uninjured.

Rescue services moved the aircraft off the runway using pneumatic lifting pads and a transport platform.

The runway was closed for about three hours, until 23:00. A NOTAM[2] was issued at 20:42 to notify other aircraft of this. One airliner turned back to its departure airport, Helsinki, and at

[1] Knots (kt) = 1.852 km/h, 60 knots equals about 111 km/h
[2] NOtices To AirMen, an information notice to aviators

least two scheduled flights were waiting in Helsinki for the runway to be opened again. No other effects on air traffic have been reported.

1.2 Damage to aircraft

The aircraft was significantly damaged in the area between the right propeller and the inner wing flap on the right-hand side.

As the front attachment of the right main landing gear failed, the landing gear leg was pivoted down and back, held only by the aft attachment. The dislocated gear damaged the inner wing flap and the landing gear door. The wheel was clamped between the runway and the wing flap, and its tyre was abraded through. The engine nacelle, wing skin plates, fairings and their brackets were also cracked and deformed in various places.

The right propeller and engine sustained impact damage. All propeller blades were bent, and abraded from the tips so that they were about 70 mm shorter. The blades were twisted into an abnormal position with their leading edges facing backward.

The landing gear end that rubbed against the pavement during landing run had become so hot that it melted a hole in the asphalt where the plane stopped. About one litre of oil leaked to the runway from the right engine propeller hub. There was no fire.

1.3 Personnel information

1.3.1 Pilots

The pilots had valid class and type ratings as well as medical certificates as required for the duty.

The pilot-in-command had a total flying experience of about 12675 hours on all aeroplane types and about 2010 hours on the type. The co-pilot's total flying experience was about 2426 hours on all aeroplane types and about 2205 hours on the type.

1.3.2 Technical personnel

The first aircraft maintenance licence for the mechanic who had installed the right landing gear was issued in 1979.

At the time of the accident, the mechanic held an EASA[3] Part 66 aircraft maintenance licence including an individual type rating for Piper PA-31 piston-engine aeroplanes and group ratings for small single-engine piston aeroplanes, and the equivalent national rating. The licence was valid until 8 February 2017 and contained category B1 and B2 ratings for the above-mentioned types.

The mechanic had a limited certifying staff authorisation issued by Lapin Tilauslento Oy's EASA Part 145 maintenance organisation, which was valid for the aircraft type in question. The authorisation had been issued for the first time on 2 June 2015. Other required types of training were also current, including human factors training, which had been provided on 30 September 2015.

The mechanic was fairly experienced, but was carrying out this particular maintenance action for the first time. According to his own report he was alert, and the maintenance environment and the tools used were appropriate and suitable for the task. He did not feel as being under a time pressure.

[3] European Aviation Safety Agency

1.4 Aircraft information

Reims F406 is a low-wing aircraft with full metal construction, equipped with two Pratt & Whitney Canada PT6A-112 turboprop engines. It has been developed from Cessna 404 Titan piston-engine aircraft, and the first F406 flew its maiden flight in 1983. The aircraft was manufactured by Reims Aviation, which also held the type certificate until year 2013, when the company ceased operations. Today the aircraft type certificate holder is the French company ASI Aviation.

The aircraft is intended for the carriage of passengers and freight. It is flown with a crew of 1–2 pilots, and the maximum number of passengers is 9.

The accident aircraft was registered OH-OTL and manufactured in 1986 with the serial number 0015. It had been flown for a total of 11644 hours and 15640 flights. The maximum certificated take-off mass is 4246 kg. The aircraft is owned by Oulun Tilauslento Oy and operated by Lapin Tilauslento Oy.

The aircraft certificates and documents as required for flight operations were valid. The aircraft had been maintained in accordance with a current maintenance programme, and it had been released to service after maintenance just before the accident flight.

The aircraft mass and balance were in the permissible range.

1.4.1 Description of the landing gear system

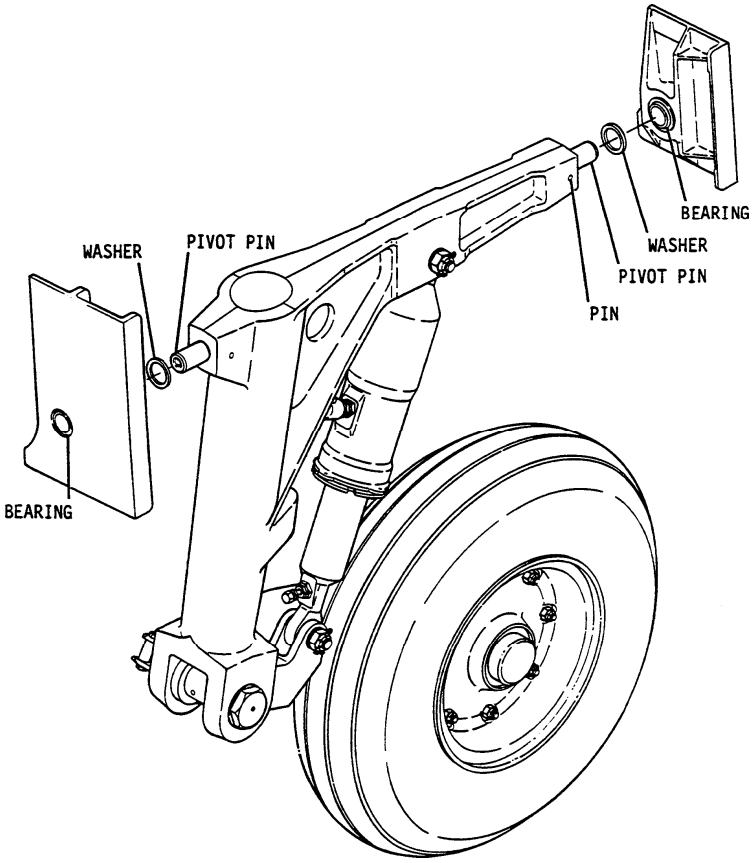
The landing gear system is conventional and consists of hydraulically retractable nose and main landing gear. This investigation focuses on the main landing gear, which is of an articulated, trailing link type as shown in the picture. It is retracted and extended by a hydraulic actuator, and is attached by pivot pins mounted on bearings to the front and aft wing spars.

When the pilot selects the landing gear up, the hydraulic valve in the landing gear system opens and admits pressure to the actuator, opening the internal downlock first. The actuator then pulls the gear up. When the gear reaches the up position, the roller on the side of the gear hits the wheel well uplock, which grips the roller and locks the gear up. The hydraulic valve closes when the gear is fully up and locked.

When either the landing gear or a wing flap has been selected to a new position, but has not yet reached the selected position, the HYD PRESS ON indicator light is illuminated.

Each landing gear has its own green indicator light, which is lit when the individual gear is down and locked. In addition, there is one common GEAR UNLOCKED warning light for all gears, which is illuminated in red if any of the gears is not secured in its uplock or downlock. When all gears are in their uplocks, all indicator lights are out.

In this context it must be noted that the downlock and its status indicator switch are mounted on the relevant actuator. As long as the actuator is in the locked position, the system indicates that the individual landing gear is down and locked. This is a rather typical feature.



Kuva 1. Main landing gear. Picture: ASI Aviation

1.5 Meteorological information

Weather in the Rovaniemi - Oulu area was good. The plane took off in the evening dusk, and night prevailed when it landed at Oulu. Visibility was good all the time.

Weather at Rovaniemi at 18:20: wind 330° 8 kt, CAVOK[4], temperature 5°C, dewpoint –2°C, barometric pressure QNH[5] 1030 hectopascal (hPa)

Weather at Oulu at 19:50: wind 350° 7 kt, CAVOK, temperature 7°C, dewpoint 0°C, QNH 1032 hPa.

1.6 Aerodrome information

The accident occurred at Oulu Airport, on the first section of runway 30.

1.7 Investigation of the accident site and aircraft

The investigation team leader arrived at the accident site on the following day, when the aircraft had been moved from the runway to the stand and raised on jacks. Airport maintenance staff had checked the runway condition on the previous evening after the accident.

The accident site was inspected again to record the marks left by the accident aircraft and to detect any loose parts on the runway. No loose parts were found, except for a few rivet heads. The aircraft wheel had left a black streak and the landing gear trailing link a slight metallic

4 "Ceiling and visibility OK". The code word CAVOK can be used to replace the groups for visibility, prevailing weather and clouds in a weather report when there are no operationally significant clouds or other meteorological phenomena. In practice, this means a ceiling of more than 1500 m and visibility over 10 km.

5 Altimeter sub-scale setting on which the meter indicates altitude above mean sea level

mark on the runway. Right engine propeller blades had hit the runway in the same area where the black mark left by the tyre began. The propeller had been rotating during the entire landing run, leaving a mark every time it struck the runway. The damage to the aircraft was photographed, and the damaged landing gear was removed from the aircraft while the investigator was present. At this stage the reason for landing gear failure was clearly revealed.

1.8 Medical information

The pilots were subjected to a breathalyzer test after the accident. The test result was zero blood alcohol level. No other medical tests were made.

1.9 Rescue action and survival aspects

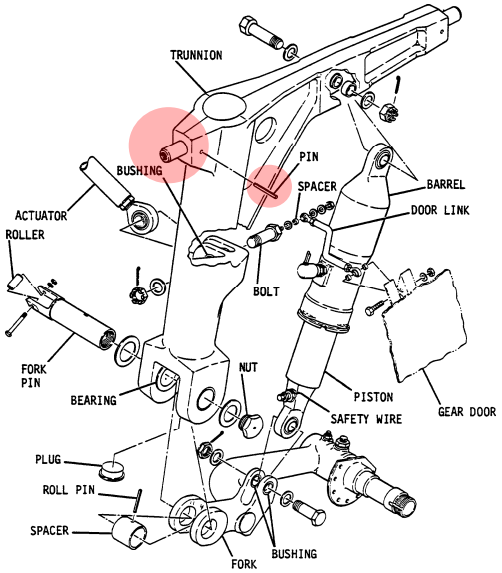
The pilot-in-command reported the landing gear failure to ATC immediately after the plane came to a stop. ATC alerted the rescue services of an aircraft accident at 20:05. The rescue units secured the plane and the surrounding area against fire. The pilots were not injured. The aircraft was lifted up using pneumatic lifting pads and moved away from the runway on a transport platform.

The runway was closed for about three hours, until 23:00.

1.10 Detailed investigations

1.10.1 Description of main landing gear attachment, installation, and instructions

The main landing gear is attached to the wing mainly with two pivot pins located front and aft in its upper part. The landing gear is removed by pulling the pins off using a special tool, and the gear then separates from the wing. Before this, other parts of the gear and the securing pins that lock the pivot pins in place must be removed (Figure 2).



Kuva 2. Main landing gear, with the separated pivot pin and the securing pin used to lock it in place marked with a circle. The actuator rod attached to the landing gear is shown under the pivot pin. Picture: ASI Aviation

The forward pivot pin is removed by pulling it forward inside the wing. To access the pin, an access panel in the wheel well must be opened and the bleed air tube inside the wing disconnected to create more working space. The access panel forms a part of the load-bearing structure and attached with several screws (Figure 3).

Kuva 3. Forward attachment point of the right main landing gear in place. The location of the pivot pin is shown by a red rectangle. The pivot pin is removed and fitted through an open access panel. Picture: Lapin Tilauslento Oy

When installing the landing gear, it is raised to the correct position up in the wheel well, and supported there so that the pivot pin holes in the trunnion are in line with the articulated bearings on the wing. The pivot pins are then fitted by pushing them through the bearings and further to their holes in the trunnion. Operating clearance between the bearing and the trunnion is adjusted by using a suitable number of shim washers, through which the pivot pin also passes.

The pivot pin normally slides easily through the bearing, and if the landing gear is properly supported, also to its hole in the trunnion. If the landing gear is not supported, more force is needed to move the pin.

When the gear is in place, the pivot pins are positioned more accurately so that the securing pin hole on the pivot pins is lined with the corresponding hole in the trunnion, and the securing pin can be fitted in place through both holes. The securing pin is a roll pin, which is further secured in place using safety wire. In this way the pivot pin is mechanically secured to prevent axial movement.

The pivot pins thus go through the articulated bearings attached to the wing structure. When the pins are correctly in place, the tip of the forward pin remains slightly visible in front of the bearing.

The mounting depth of the aft pivot pin is limited by the depth of the hole in the landing gear trunnion. The forward pivot pin hole, in contrast, extends until the vertical hole in the trunnion, so that the fitting position is not mechanically restricted. For this reason, especially the forward pin must be positioned carefully to make sure that the securing pin goes to its hole in the pivot pin, and not behind the whole pin as when the pivot pin is placed too far forward. The center of the securing pin hole in the pivot pin is located about 16 mm from the aft end of the pin.

When fitted, the front end of the forward pivot pin can be seen with a mirror through the wheel well access panel, and the aft end with a mirror or suitable borescope through the vertical hole in the landing gear trunnion. After the securing pin is fitted, it can be seen from the vertical hole if the securing pin has been left behind the pivot pin. Proper securing can also be checked by trying to pull the pivot pin with the puller tool while the landing gear is being supported.

There are no separate instructions for these checks, as the maintenance instructions rely on the use of good maintenance practices.

The maintenance instructions for landing gear installation are from year 1985. The investigation revealed shortcomings in them, and the order of actions was partly impractical. For example, the installation phase for the aft pivot pin was missing entirely, and during installation of the forward pivot pin, it is instructed that the fitting tool be removed from the pivot pin after the securing holes are aligned, but before the securing pin is fitted. The landing gear functional test was not instructed to be made after installation, but the plane should only be let down from the jacks onto its wheels after the last installations.

1.10.2 History of maintenance actions

Immediately before the accident flight, the aircraft had been subjected to phase 20 and phase 21 inspections of both main landing gears, for which the gear must be removed. Apart from the need for removal, the maintenance actions taken had no impact on the accident.

Both landing gears were removed normally, and the required inspections for cracks were made by a subcontractor. The tasks for gear removal and installation were shared so that one mechanic was in charge of the right landing gear and the other of the left. The mechanics worked independently during installation without co-operating to a significant extent. The mechanics' accounts of how the work progressed and of any informal review of each other's work were slightly different. However, the accounts were consistent in that such a review was not carried out on landing gear attachments.

When the right landing gear was installed, the forward pivot pin was left too far forward so that the securing pin supposed to go through it was eventually behind the whole pivot pin. As a result of the incorrect installation, nothing prevented the pivot pin from moving forward and out of the gear trunnion. The securing pin was put in place and a safety wire was installed through it. According to the mechanic that made the installation, he used a punch tool to make sure that the securing hole for the pivot pin was in the right place. When positioning the pivot pin, he first noticed that the punch did not go through the pivot pin, and repositioned the pin by supporting the trunnion with the other hand and moving the pivot pin with a puller tool at the same time. The punch then went through the hole in the trunnion, from which the mechanic assumed that the hole was correctly positioned and fitted the securing pin. When removing the puller tool from the pivot pin, he did not support the gear trunnion, and because of greater friction it seemed that the pivot pin was locked in place.

After the accident, the mechanic had a very clear impression on how the mistake had come about and that he had accidentally pulled the pivot pin too far forward when changing its position.

During installation, however, the mechanic was left with the impression that the installation was successful, and no further inspections were made.

The installation of both landing gears had been identified as a critical task in maintenance planning, and a double check[6] as required by aviation regulations was carried out. Based on the interviews, the attachments themselves had not been inspected, but only a general visual inspection was made.

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6 For critical maintenance tasks, aviation regulations require a double inspection of the target, where the mechanic checks his own work as usual but then another inspection is made, usually by another mechanic. The double check reduces the risk of errors in maintenance work, but does not necessarily eliminate it in all cases.

In principle, landing gear installation is a simple procedure as long as good maintenance practice is followed. The approved maintenance instruction[7] is fairly short. It contains one caution and two notes, neither of which draws attention to the possibility of error in the fitting of securing pins. As regards pivot pins and securings, the instruction reads as follows:

> (2) Position trunnion in place and insert forward pivot pin ensuring washers noted in step A are in place and holes in pivot pin and trunnion are aligned.
>
> NOTE: For minimum tire clearance maximum washer stack-up at fore and aft end of trunnion shall not exceed 0.350 inch.
>
> (3) Remove AN8 Bolt and flat washer [*pivot pin puller tool*] from pivot pin. Install pin in trunnion and pivot pin. Safety wire pin around trunnion.

The installation actions were completed and the access panel in the wing was closed.

The maintenance instructions do not require a landing gear functional test to be performed after gear installation. However, the test was carried out at the mechanics' own discretion by cycling the gear up and down several times without problems.

The aircraft was issued with a certificate of release to service as usual and checked out as airworthy.

1.10.3 Post-accident technical inspection of the aircraft

In the aircraft inspection after the accident, it was found that the pivot pin in the forward attachment point of the right main landing gear had partly slid off its place. The landing gear was pivoted back during the landing run, held only by the aft attachment and actuator.

The pivot pin in the forward attachment point was not attached to the gear trunnion, but instead to the wing bearing, from which it was removed after the accident. There were superficial marks at the back of the pivot pin, at a distance of about 10 mm (Figure 4). Otherwise the pivot pin was intact.

The securing pin hole in the pivot pin was covered with clean assembly grease. On the trunnion side, the securing pin was intact and still in its place, secured with safety wire (Figure 5).

Other damage and anomalies found had resulted from the collapse of the landing gear.

[7] MM 32-10-00 Page Block 400, revision Jul 1/85, point 3.B.

Kuva 4. The aft end of the right main landing gear forward pivot pin, photographed after the accident. This end is attached to the landing gear trunnion. Photo: Lapin Tilauslento Oy

Kuva 5. The securing pin of the right main landing gear forward pivot pin in place after the accident. Photo: Lapin Tilauslento Oy

1.11 Organisational and management information

Lapin Tilauslento Oy is an airline company and aircraft repair station, established in 2003. It operates one Reims F406 Caravan II turboprop aircraft and one Cessna 180 piston-engine aircraft. The planes are used for charter flights, and the F406 also for ambulance flights and for transporting mail.

The company holds an Air Operator Certificate[8] issued by the Finnish civil aviation authority for commercial air operations, a continuing airworthiness management organisation approv-

[8] EASA-OPS AOC

al[9] and an approval for line and base maintenance[10] of the aircraft it operates and other similar aircraft. The maintenance organisation approval was granted in autumn 2015.

Under the AOC of Lapin Tilauslento Oy operates the company Oulun Tilauslento Oy, which is a commercial air operator established in 1992 and based in Oulu. The latter company owns the accident aircraft, Reims F406. The maintenance organisation and hangars of Lapin Tilauslento Oy are located at Rovaniemi Airport.

The company maintenance organisation has three full-time employees – the accountable manager, quality manager and nominated postholder for maintenance. All three are nominated postholders also for the company's air operations and in the continuing airworthiness management organisation, and the quality manager is the company managing director as well. The nominated postholder for maintenance also acts as an aircraft type mechanic. In addition, the maintenance organisation employs three part-time mechanics.

The investigation examined the maintenance organisation's internal procedures, using both internal quality control findings and audit observations made by the civil aviation authority.

The investigation did not reveal any factors in the company operations that would have contributed to the accident.

Maintenance organisation management was not investigated due to its limited size.

There was no need to investigate the other organisations, as they did not have any effect on the sequence of events.

1.12 Other information

The investigators searched the databases of flight safety authorities and sent an enquiry to the aircraft type certificate holder. The aim was to find out whether similar maintenance errors have been previously reported for the F406 Caravan II aircraft type, or for Cessna 404 Titan that has a similar type of landing gear.

Based on the information obtained, some cases of pivot pin breaking loose due to maintenance errors have been reported at least for Cessna 404, resulting in main landing gear failure.

[9] EASA Part M Subpart G&I
[10] EASA Part 145

2 ANALYSIS

The accident analysis used the Accimap Approach[11]. The structure of the analysis text is based on the AcciMap graph prepared by the investigation group, which is attached separately as Appendix 1.

2.1 Accident analysis

2.1.1 Problem in landing gear retraction

After take-off, the right landing gear did not engage into its uplock, and the warning lights for gear uplock and hydraulic system remained on.

As the uplock indicator light is common for all landing gear, it does not show which of the three gears is not locked up. Uplock failure may typically be caused by an adjustment error, mechanical jamming of the uplock, insufficient lubrication, or contaminants such as icing. In this case, the failure of the right main landing gear to engage into its uplock position indicates that the gear geometry had already changed, even though the forward pivot pin may still have been partly attached to the landing gear trunnion.

The pilots selected the landing gear back down. The warning lights then extinguished and the three green lights for the landing gear illuminated, indicating that the gear was down and locked. The HYD PRESS ON warning also went off, and it seemed that the landing gear would be normally extended.

The landing gear system is designed so that the main landing gear downlock is fitted to the hydraulic actuator that drives the gear. For this reason, the downlock indicator light actually only shows the status of the actuator. The fact that the downlock indicator light came on indicates that the landing gear hydraulic and electrical systems were still intact.

2.1.2 Actions and trouble-shooting in flight

According to the information available to the pilots, the landing gear was safely down. Gear retraction had failed, but judging from the indications, it had settled into the downlocks without problems. No unusual noises were heard, so it could be assumed that the fault was in the landing gear hydraulics, or possibly there was a mechanical fault or an indication error in one of the three uplocks.

Although the situation was abnormal, nothing suggested an actual emergency. The weather was good and it was a short flight from Rovaniemi to Oulu, so the pilots decided to continue flying towards Oulu with the gear extended. However, the pivot pin in the landing gear front

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[11] The AcciMap Approach is used in analysing contributing factors, finding the most important conclusions as well as for preparing effective safety recommendations and targeting them to the right entities.

The accident is depicted as a chain of events at the bottom of the AcciMap graph. Identified decision-makers and other levels that guide action are marked on the left side. The different elements of the chain of events are shown as a bottom-to-top sequence. The lower part of the graph portrays an assessment of the individual accident which is being studied, from which the process leads to wider perspectives and implications, for example, at the national or international level.

The analysis text follows the AcciMap graph and provides more detailed background for individual text boxes and their interconnections. The analysis of actions taken by authorities, as required by the Safety Investigation Act, is done separately as necessary.

Source for the Accimap procedure: J.Rasmussen and I.Svedung, 2000, Proactive Risk Management in a Dynamic Society, Swedish Rescue Services Agency, Karlstad, Sweden.

attachment was loose or about to break loose from the gear trunnion. When fully separated, the pin falls down inside the wing.

2.1.3 Landing gear failure

When the landing gear was installed during maintenance before the flight, the pivot pin was left too far forward. The securing pin that was intended to secure the pivot pin had been fitted, but entirely behind the pivot pin. The securing pin should pass through the hole in the pivot pin, so that the pin is mechanically locked in place. Because of incorrect installation, the pivot pin was free to move forward and out of its place. Even at most, the pivot pin was only about 10 mm inside the gear trunnion.

During taxiing from the stand to take-off, the pivot pin was subjected to vibration, which reduced friction and also created forces that made the pin move forward out of its place. The pivot pin separated fully from the landing gear trunnion at the latest when the pilot started braking upon landing.

After the pivot pin came loose from the trunnion it remained attached to the wing bearing, from which it was removed after the accident. The pivot pin was intact apart from some superficial marks.

When maintenance work before the flight was started, the mechanic removed the right main landing gear. At the end of the work he reinstalled the same gear. The mechanic had no previous experience of the task in question, but he had approved maintenance instructions, proper tools and suitable working conditions at his disposal.

The work documents showed that the installation of both landing gears had been identified as a critical task in maintenance planning, and a double check had been carried out as required. However, the double check did not specifically focus on the fitting of the pivot pin.

The maintenance instructions are from year 1985, and in many parts, only based on good maintenance practice. For example, the instructions provide no warning of the possibility of incorrect securing pin installation, or advise that the securing should be checked after the pin is fitted, although such a check would be important and easy to perform.

In addition, the order of actions recommended in the instructions is impractical, as they advise to remove the puller tool used for positioning immediately after the securing holes are aligned, before the securing pin is fitted. Unscrewing of the puller tool increases the risk of the pivot pin moving to an incorrect position. Therefore the securing pin should be fitted as soon as the holes are verified to be aligned.

Essential procedures are also missing from the instructions, such as the fitting of the aft pivot pin in general, and the landing gear functional test after installation.

Nevertheless, the maintenance organisation had understood that functional test of the landing gear would be appropriate after such maintenance. This shows that the organisation had the ability to independently identify risks and to strive to work in a correct manner. It was observed that the organisation uses the risk assessment process in an active and documented way to supplement maintenance instructions when they are found inadequate.

The landing gear functional test was carried out by cycling the gear up and down several times without problems. Nothing suggested a latent error, so the aircraft was issued with a certificate of release to service as usual and checked out as airworthy after maintenance.

2.1.4 Rescue action

After the plane came to a stop, the crew reported the incident to ATC and asked for a tow vehicle. The crew was not injured.

The air traffic controller made a report of an air traffic accident and alerted rescue services. Emergency response was sufficient. No actual rescue action was needed, but Oulu Airport was closed to other traffic for three hours because of clearance work.

3 CONCLUSIONS

3.1 Findings

1. The aircraft was airworthy in accordance with applicable airworthiness requirements when departing for the flight.
2. The pilots and mechanics were appropriately trained, and their licences and qualifications were valid.
3. When the pilots selected gear up after take-off, the GEAR UNLOCKED warning light and the HYD PRESS ON indicator light for the hydraulic system remained on.
4. The gear lever was selected back down, and all three green indicator lights for the landing gear were illuminated.
5. Procedures directly applicable to this particular fault situation were not found in the emergency checklists.
6. The pilots used the procedure intended for situations where the HYD PRESS ON light remained on continuously. This helped to locate the problem in the landing gear system, but the nature of the fault was not revealed.
7. As the situation did not require turning back for landing as soon as possible, the pilot-in-command decided to continue the flight to Oulu with the gear extended and to examine the precise cause of the malfunction there.
8. The crew did not notice any additional or abnormal noises before the landing gear collapsed.
9. After a normal landing in Oulu, the aircraft started to tilt to the right as soon as the pilot started braking.
10. After the landing gear failed, the pilot-in-command managed to keep the plane on the runway by braking hard with the left wheel brake. The plane came to a halt at the runway edge after about 80 m.
11. Night prevailed at the airport, and the air traffic controller did not see that the landing was abnormal.
12. The pilot-in-command reported the incident to ATC and asked for a tow vehicle.
13. The runway was closed for three hours due to clearance work.
14. Immediately before this flight, the aircraft had undergone scheduled landing gear maintenance in which the main landing gear had been removed. The mechanic who installed the right main landing gear had not carried out this maintenance procedure before.
15. The technical investigation revealed that the pivot pin in the forward attachment point for the main landing gear had slid out of its place. The securing pin and safety wire intended to secure the pivot pin were in place and undamaged.
16. The securing pin fitting hole in the pivot pin was filled with grease. The securing pin had not been in its correct place inside the pivot pin, but had been installed behind it.

17. When installing the securing pin, the mechanic had to support the landing gear with his hands to move the pivot pin and align the securing pin hole with the gear trunnion. Without the mechanic noticing, the pivot pin had slid too far forward.
18. The mechanic fitted the securing pin without making sure that the pivot pin was correctly installed.
19. Installation instructions for the pivot pin and securing pin provide no warning of the possibility of incorrect installation.
20. The landing gear installation instructions do not cover all necessary phases of work, and the order of phases is impractical in some places.

3.2 Probable causes

The accident was caused by an installation error in the right main landing gear. Checks made during installation were inadequate, and even the final inspection of the work did not cover the correct fitting or securing of the pivot pin.

The pivot pin installation procedure is not complex, and the principle is easy to understand. Working conditions were good and the mechanic who fitted the pin was fairly experienced, so a clear and explicit cause for the error could not be determined. Even though this phase of installation was important structurally and for flight safety, one significant possibility may be that the mechanic's concentration was not focused on the seemingly simple task.

A contributing factor to the error was that the maintenance instructions did not adequately support the correct performance and quality assurance of the work.

4 SAFETY RECOMMENDATIONS

4.1 Safety actions already implemented

Lapin Tilauslento Oy has, on 9 January 2017, made an analysis of the sequence of events leading to the accident, and prepared a list of actions to improve work planning, inspection procedures and the company's internal instructions. The company has also provided Human Factors refresher training to its staff due to the incident. In addition, it is planning to make more extensive changes to its maintenance organisation exposition, with a focus on quality assurance and critical maintenance tasks.

4.2 Safety recommendations

4.2.1 Review of maintenance instructions for Reims F406 Caravan II aircraft

ASI Aviation is the current type certificate holder for the aircraft, and according to the information on its website, is planning to restart its production. To ensure that both existing aircraft and any new aircraft to be manufactured can be safely maintained, it is necessary to at least correct the errors detected and review the maintenance manuals for any other similar inaccuracies.

The Safety Investigation Authority, Finland recommends that

The European Aviation Safety Agency (EASA) require the aircraft type certificate holder to review and update the maintenance instructions for Reims F406 aircraft, so that any deficiencies in main landing gear installation instructions are rectified. The landing gear installation instructions do not cover all necessary phases of work, and the order of phases is impractical in some places. The instructions provide no warning of the possibility of incorrect pivot pin installation. [2017-S26]

Incorrect or insufficient instructions do not adequately support the performance of the work. The risk of maintenance errors increases and flight safety is compromised.

4.2.2 Review of maintenance instructions for other Cessna models

The Reims F406 aircraft type is based on Cessna 404. Both aircraft have the same landing gear construction, and maintenance instructions may also be partly the same. The same landing gear model may have been used in other aircraft types manufactured by Cessna.

The Safety Investigation Authority, Finland recommends that

The Federal Aviation Administration (FAA) of the United States require the aircraft type certificate holder to review and, where necessary, update the maintenance instructions for Cessna 404 and any other aircraft types with a trailing link landing gear, so that any deficiencies found in main landing gear installation instructions are rectified. The landing gear installation instructions may not cover all necessary phases of work, and the order of phases may be impractical in some places. [2017-S27]

Helsinki, 10.5.2017

Ismo Aaltonen Pekka Alaraudanjoki Jan Nordlund

REFERENCE MATERIAL

The following reference documents are archived at the Safety Investigation Authority, Finland.

1. Decision to initiate an investigation
2. Flight safety report filed by the pilots of OH-OTL
3. Flight safety report filed by the air traffic controller
4. Police investigation report
5. Material provided by Finavia Oyj
6. Emergency and accident description
7. Reims F406 maintenance manual and illustrated parts catalog
8. Material provided by the Finnish Transport Safety Agency
9. Documents from Lapin Tilauslento Oy
10. NTSB investigation reports
11. Photographs from the accident site and investigations
12. Recordings of interviews
13. E-mail correspondence

SUMMARY OF THE COMMENTS RECEIVED ON THE DRAFT INVESTIGATION REPORT

Comments on the draft investigation report were requested from the Finnish Transport Safety Agency, Finavia Corporation, Lapin Tilauslento Oy and ASI Aviation, as well as from the European Aviation Safety Agency (EASA), The Bureau of Investigation and Analysis for Civil Aviation Safety (BEA) of France, the Federal Aviation Administration (FAA) of the United States and the National Transportation Safety Board (NTSB) of the United States.

Lapin Tilauslento Oy did not wish to add anything to the draft report, but clarified some points about the actions that will be taken at the company due to the incident.

The Bureau of Investigation and Analysis for Civil Aviation Safety (BEA), praised the draft report as a whole and agreed with both recommendations, stating that they were appropriately directed. BEA's request for further information has been taken into account in the final investigation report.

The European Aviation Safety Agency (EASA) had no comments on the draft report.

The Finnish Transport Safety Agency had no comments on the draft report.

The Federal Aviation Administration (FAA) did not submit official comments, but stated that it would wait for the final report before taking any further action.

The other organisations did not respond to the request for comments within the time limit.