SERIOUS INCIDENT

Aircraft Type and Registration:	Bell 429 GlobalRanger, G-WLTS
No & Type of Engines:	2 Pratt and Whitney Canada PW207D1 turboshaft engines
Year of Manufacture:	2014 (Serial no: 57191)
Date & Time (UTC):	2 January 2019 at 1255 hrs
Location:	Melksham Airbase, Wiltshire
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - None
Injuries	Crew - None Passengers - N/A
Nature of Damage:	None reported
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	3,890 hours (of which 360 were on type) Last 90 days - 8 hours Last 28 days - 4 hours
Information Source:	AAIB Field Investigation

Synopsis

The report considers two events which occurred while the pilot was conducting a Power Assurance Check. In one, an un-commanded yaw pedal movement caused a rapid rotation of the helicopter through two and a half complete rotations; in the other, a trim runaway was contained by the pilot. The trim runaway was found to be an unknown feature of the Automatic Flight Control System logic.

Following these events, safety action was taken by the helicopter manufacturer and Transport Canada to help crews respond to a yaw trim runaway and to address the underlying causal factor. Also, the flight recorder manufacturer improved the way it reported the results of CVR recording inspections.

Two Safety Recommendations are made: one to Transport Canada in relation to conduct of the Power Assurance Check; and one to the European Union Aviation Safety Agency to ensure that the installation of new equipment on aircraft does not have a detrimental effect on existing equipment.

History of the flight

This report refers to two separate events with the same helicopter, one on 15 June 2018 and one on 2 January 2019.

15 June 2018

G-WLTS had returned to base from a Helicopter Emergency Medical Service (HEMS) task at Redlands, near Swindon. It had been an uneventful flight and a visual approach was flown to the Final Approach and Takeoff (FATO) path followed by a hover taxi to dispersal and landing on a westerly heading. This was the first landing at the base that day, so the pilot planned to conduct a Power Assurance Check (PAC). The Rotorcraft Flight Manual (RFM) refers to both manual and automatic PACs. The operator used the automated PAC, with pilots recording figures manually to help monitor the engine performance trend.

The two technical crew on board were informed about the intent to conduct the PAC, so they vacated the helicopter and entered the operator's building next to the dispersal. Shortly afterwards, one of the technical crew walked to the edge of dispersal and stood in front of the helicopter, helmet still on, to provide safety and fire cover in accordance with the operator's Standard Operating Procedures (SOPs).

In preparation for the PAC, the pilot recalled setting the N_R to 100%, though flight data showed that it remained at 104%. The No 1 generator and the 'Trakka' searchlight power were selected off. At this point the pilot recalled adopting "the standard posture" for doing the PAC: "feet off pedals, knees up to make writing easier and hands guarding the cyclic and collective [controls]". The pilot used a 'chinagraph' pencil to record fuel figures (710 lbs) and landing time (2012 hrs[1]) onto the left knee board of the flying suit and intended to record PAC details in the same way. The pilot selected the PAC screen on the relevant Display Unit (DU), rotated the No 2 throttle to idle and raised the collective lever for the PAC. The data showed that, when the collective lever reached approximately 23% of its range of movement, it stopped for about three seconds during which time the N_R was set to 100% and the autopilots (AP) were both selected off. Just before the APs were selected off, a yaw out-of-detent condition occurred[2]. The collective was then raised to approximately 30% for the PAC. The chinagraph pencil was still in the pilot's right hand ready to record the PAC figures.

Early in the power check, the pilot heard a loud "clunk" or "crunch" from the right side of the helicopter just behind their seat, felt a "lurch" downwards to the right, and thought that the landing gear was collapsing on the right side. The helicopter yawed rapidly to the left, which the pilot described as "lurching" laterally and longitudinally while also bouncing up and down. The pilot's instinct was not to move the flying controls for fear of inducing a rollover. However, feeling very disorientated and realising that action was needed to try and contain the situation, the pilot lowered the collective lever and then tried to move the

Footnote

[1] 1912 hrs UTC.

[2] See later section, *'Yaw trim actuator'*.

engine switches to CUT OFF. After some brief difficulties, both engines were shut down. The pilot applied the rotor brake and, after another approximately 180° of rotation, the helicopter came to rest. During the event the helicopter made two and a half rotations in approximately ten seconds.

2 January 2019

On 2 January 2019 the same pilot was preparing to conduct another PAC in the same helicopter. For this event, however, the pilot's feet remained on the pedals throughout. The pilot noticed unusual feedback forces in the pedals and endeavoured to record the event in as much detail as possible. The technical crew member in the left seat was able to make a short video. In this event, the pedals were trying to drive towards full scale deflection left and, although the pedal loads were significant, they were readily containable through foot pressure. The pilot depressed the FORCE TRIM release button[3] momentarily but this did not clear the out-of-detent condition which now existed or remove the feedback forces. A subsequent and longer press of the FORCE TRIM release button cleared the condition and removed the forces.

Recorded information

15 June 2018 event

Following the event on 15 June 2018, flight data from the combined recorder (ie a single flight recorder that combines the functions of the flight data recorder (FDR) and cockpit voice recorder (CVR)) was obtained by the operator, and a copy was subsequently given to the AAIB. The helicopter manufacturer analysed the data from the electronic data recorder (EDR) in the DUs which recorded the FDR data but at a lower sampling rate. The flight data for the event is plotted in Figure 1 and the key points are:

1. The collective was initially raised [A] with the AP engaged (in ATT mode).
2. The collective was held at about 23% of its range of movement for approximately 3 seconds [B].
3. Total torque (the No 2 engine was at idle, so all torque was from the No 1 engine) exceeds 30% [C].
4. During the three seconds the collective was held at about 23%, the pedals started to drift left [D], the pedal status changed to a yaw out-of-detent condition, the rotor speed reduced to 100% [E] (rpm switch on the collective), and the AP disengaged [F].
5. The yaw out-of-detent condition remained for approximately ten seconds during which time the pedals moved to the left by about 1.5% of their full range of movement.
6. The pedals then suddenly moved to left maximum deflection [G] in about one second.

Footnote

3 See later section, *'Automatic flight control system'* and *Figure 5.*

7. The yaw out-of-detent condition cleared, and the collective was lowered [H] within one to two seconds of the pedal movement.

8. The helicopter made two and a half rotations to the left in approximately ten seconds [I] during which time both engines were shut down.

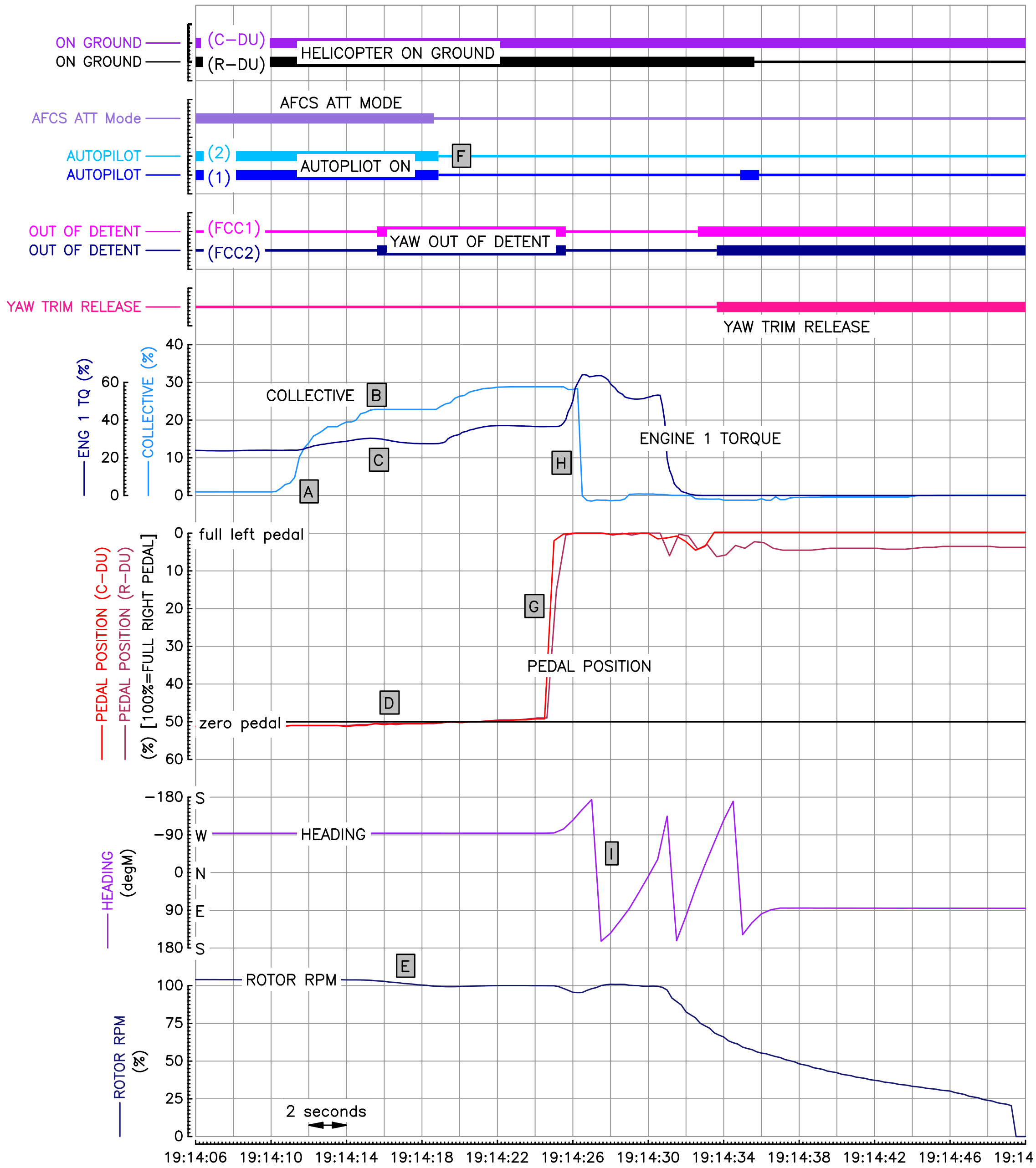

Figure 1

FDR data for 15 June 2018 event

2 January 2019 event

For the event on 2 January 2019, the combined recorder was removed from the helicopter and taken to the AAIB for download and analysis of the flight data and cockpit voice recordings.

The salient flight data for this event is plotted in Figure 2.

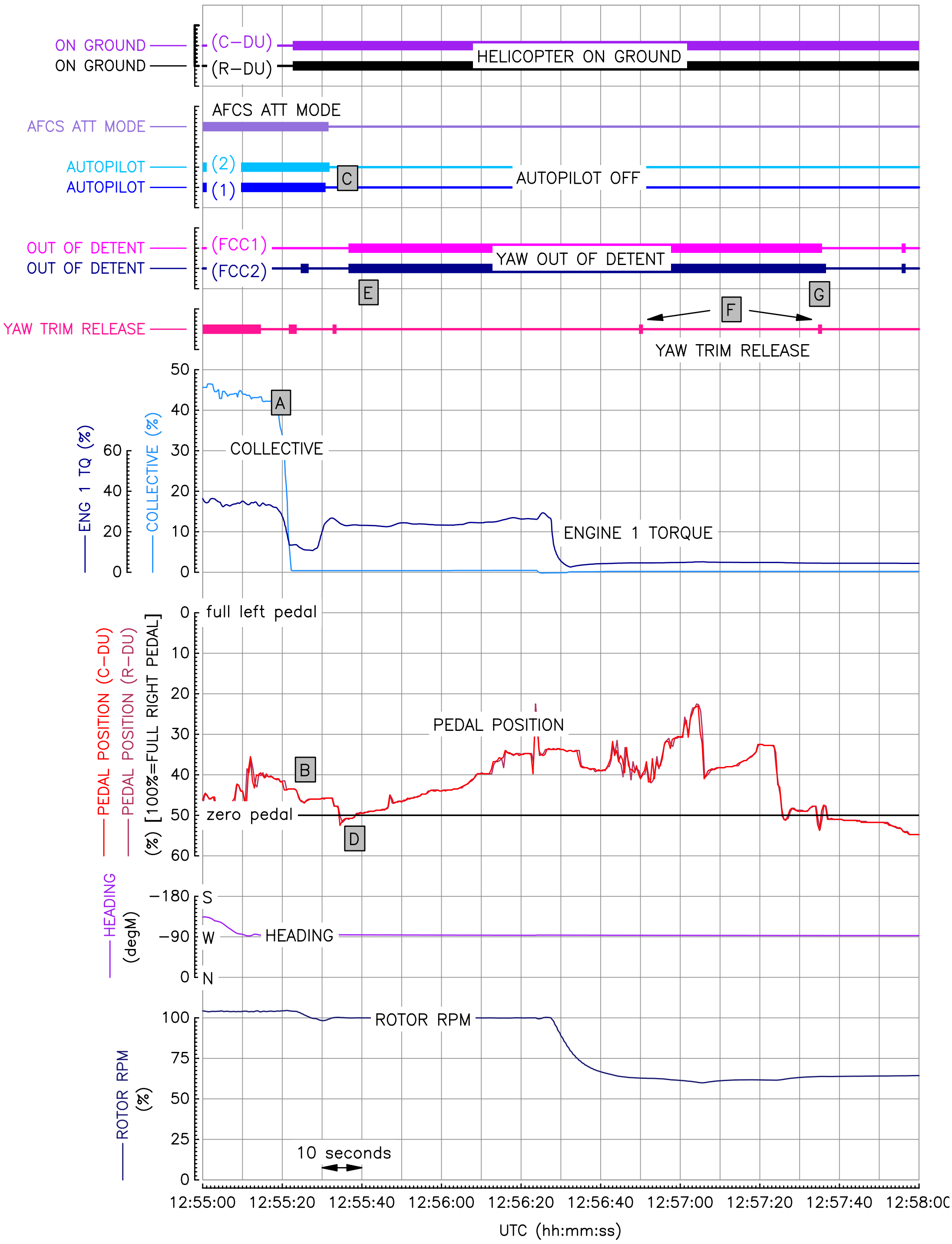

Figure 2

FDR data for 2 January 2019 event

The key points shown in Figure 2 are:

1. The collective was lowered on touchdown [A].
2. A little left pedal input was made and held [B] as the AP was disengaged [C] ten seconds after touchdown.
3. A very brief right pedal input was made [D] before the pedals moved left and a yaw out-of-detent condition was detected [E].
4. The yaw out-of-detent condition remained active for nearly two minutes during which the TRIM RELEASE button was pressed on at least two distinct occasions [F].

   Note: the sampling of the TRIM RELEASE is once every second so these button presses could have been anything from a single press of up to just under two seconds in duration, or multiple presses over the same period. Equally, unless the sampling occurs when the button is depressed, transient presses during any one second will not be recorded.
5. The yaw out-of-detent condition cleared after the second of the TRIM RELEASE button presses [G].

CVR recording issues

When listening to the CVR recordings for the January 2019 event, audio clipping was heard on both crew channels when the crew were speaking. Audio clipping is a form of waveform distortion where the amplitude of the signal waveform has been limited; for speech signals, this can affect the intelligibility[4]. No clipping during flight was evident on the cockpit area microphone (CAM) channel. Figure 3 shows the signal waveforms for the three channels for the two-hour duration of the CVR recording.

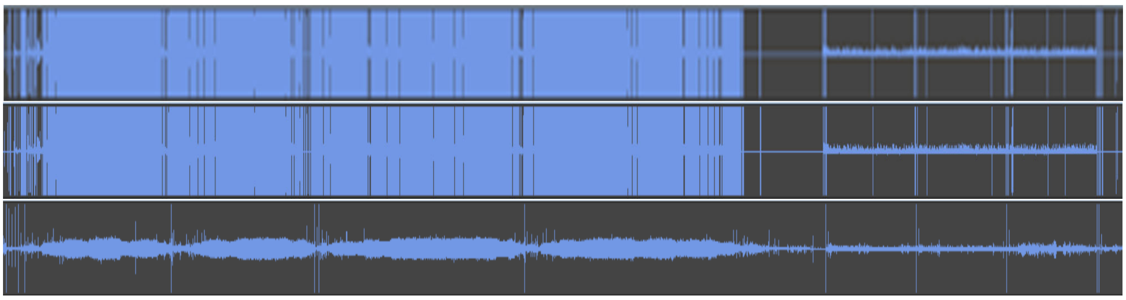

Figure 3

Signal waveforms for the three channels of CVR recording showing the two clipped crew channels (top and middle) and the CAM channel (bottom)

Footnote

4 Clipping caused by overloading an audio channel reduces the perception of the recorded quality. Provided the clipping is of speech without significant background noise the intelligibility of speech is hardly affected. If the clipping is severe and occurs after speech is mixed with significant noise, and the speech-to-noise ratio is low, the intelligibility can be severely reduced. Therefore, clipping should be minimised as far as possible to maintain good audio quality.

Inspection of flight recorder recordings

Annex IV (Part-CAT) to Commission Regulation (EU) No 965/2012 for the implementing rule CAT.GEN.MPA.195 on the preservation, production and use of flight recordings requires:

> *'(b) The operator shall conduct operational checks and evaluations of flight data recorder (FDR) recordings, cockpit voice recorder (CVR) recordings and data link recordings to ensure the continued serviceability of the recorders.'*

The corresponding Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Annex IV – Part-CAT (February 2016) states that for solid state flight recorders:

> *'…and the flight recorder system is fitted with continuous monitoring for proper operation, the time interval between two inspections of the recording may be up to two years.'*

This was reflected in the flight recorder manufacturer's periodic maintenance requirements for the flight recorder in that a maximum interval of 24 months was specified between inspections of the CVR and FDR recordings. For the inspection of the CVR recording, the action was to '*Replay and evaluate the quality of the in-flight recording*' and, for the FDR recording, to '*Check all mandatory parameters are active and are acceptable quality*'.

For G-WLTS, the operator was using the flight recorder manufacturer to perform these operational and maintenance tasks, which were carried out annually and resulted in a data analysis report being issued. For the CVR, the report was just a statement saying what had been done and found. For the FDR, a similar statement was issued together with a list of the parameters recorded and a plot of them for the 25-hour duration of the recording. The assessment of the CVR recordings was made by listening to extracts. No visual examination of the signal waveforms was made even though the manufacturer's software used to analyse the flight recorder recordings could facilitate this.

CVR recording inspection findings

From 2015, inspections were carried out on 27 August 2015, 24 August 2016, 3 July 2017, 17 July 2018, and 8 January 2019 following the 2 January 2019 event. For each of these five inspections (shared between three different engineers), the report stated that for the CVR recordings *'All channels were found to be clear and intelligible with no trace of distortion*'.

Bell 429 cockpit audio controller

The cockpit audio controller fitted to the Bell 429 has outputs connected directly to the CVR for the crew audio to be recorded. For the original audio controller fitted to the Bell 429 (as installed on first delivery of the helicopter), the signal levels being presented to the CVR would have been evaluated during testing to ensure they complied with the input requirements of the CVR.

Terrestrial Trunked Radio (TETRA)[5]

In May 2015, G-WLTS was fitted with a TETRA communications system that required the original audio controller to be replaced by a third-party system to enable integration with the TETRA 'tactical' radios being fitted. The EASA Part 21 Subpart J approved Supplemental Type Certificate (STC) holder for this work classed the change as minor[6] and made under the privileges of an EASA DOA (Design Organisation Approval).

The design change instruction sheet created by the STC holder, which described each of the tasks to be performed for the change, made no reference to the CVR system. For the system function checks it stated that they were to be done in accordance with a document entitled '*Instructions for Continued Airworthiness*' which itself did not list any checks. Tests were, however, made to verify that there were '*no negative impacts on the operation or performance of the existing and installed aircraft systems due to mutual electro-magnetic effects between systems*' (ie EMC/EMI[7] tests).

The *Instructions for Continued Airworthiness* referenced the installation and operation manual for the new audio controller being fitted, which stated that:

> '*The unit is shipped from the factory with all internal adjustments set to the normal test levels. Once installed in the aircraft, it may be desirable to change some of the settings to best suit the local operating environment. The internal adjustments* [trimpots] *are located on the sides of the unit …* [and] *are used to adjust the levels of the audio in the user's headphones.*'

On inspection after the January 2019 event, the trimpots were found at the factory-set levels.

Following the August 2015 flight recorder inspection, a copy of the report (stating that for the CVR '*All channels were found to be clear and intelligible with no trace of distortion*') was provided to the STC holder.

EASA guidance material for Minor Changes

EASA Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes (CS-25) and for Large Rotorcraft (CS-29) both state (in paragraphs CS 25.1353 and CS 29.1353 respectively) that for electrical equipment and installations:

> '*Electrical equipment and controls must be installed so that operation of any one unit or system of units will not adversely affect the simultaneous operation of any other electrical unit or system essential to the safe operation. Any*

Footnote

5 TETRA is a one-to-many communication radio system with centralised call control so that priority calls can be put through and other calls queued. Features like this make it ideal for use by emergency services.

6 A 'minor change' is one that has no appreciable effect on the mass, balance, structural strength, reliability, operational characteristics, noise, fuel venting, exhaust emission, operational suitability data or other characteristics affecting the airworthiness of the product.

7 EMC – Electromagnetic Compatibility. EMI – Electromagnetic Interference.

electrical interference likely to be present in the aeroplane must not result in hazardous effects upon the aeroplane or its systems except under extremely remote conditions. (See AMC 25.1353 (a).)'

However, AMC 25.1353 refers to '*possible sources of interference'* due to EMC/EMI rather than to equipment that share an interface across which, for example, information is shared. Also, equivalent paragraphs do not exist for Small Rotorcraft (CS-27)[8] applicable at the time when the TETRA was fitted[9].

For applicants who are not DOA holders the minor change (and repair) certification process is managed through EASA and a 'Minor Change/Repair Design Approval' that states in the conditions that:

'Prior to installation of this repair it must be determined that the interrelationship between this repair and any previously installed modification and/or repair will introduce no adverse effect upon the airworthiness of the product.'

Again, this does not specifically identify equipment that share an interface (and information), and it only refers to previously installed modifications and not original equipment.

EASA document *Minor Change Certificate Document*[10] provides guidance that is intended to assist applicants in '*having a more uniform methodology for Minor Changes*'. It is directed specifically to applicants making changes to GA aircraft (and especially those who are not DOA holders). Part 1 of this document covers the description of the change and states in Section 1.3 that:

'If the newly installed equipment is interfaced with other existing equipment on the A/C a description or list/schematic should be provided.'

Part 14 ('*Other possible impacted areas*') then goes on to say:

'Include here the description and reference to other areas where it is believed to have an impact (in line with the interfaces identified in Section 1.3).'

No such guidance exists for changes to CAT aircraft.

Footnote

8 G-WLTS was (predominately) certified to the requirements of Canadian Airworthiness Manual Chapter 527 so the equivalent EASA airworthiness code CS-27 would apply (see next section 'Helicopter information').

9 CS-27 amendment 4 (30 November 2016) has since introduced paragraphs CS 27.1316 (Electrical and electronic system lightning protection) and CS 27.1317 (High-intensity Radiated Fields (HIRF) protection).

10 https://www.easa.europa.eu/download/general-aviation/documents-guidance-and-examples/Minor%20 Change%20Certification%20Guidance%20Document%20-%2017.02.16%20-%20v1.docx. (accessed on 6 April 2020).

Helicopter information

The Bell 429 is an eight-seat, twin-engine, Category A, single pilot IFR certified helicopter. The type is predominantly certified to the requirements of Canadian Airworthiness Manual Chapter 527, which defines the specification requirements for Normal category rotorcraft with maximum weights of 7,000 lb (3,175 kg) and up to nine passenger seats. Where necessary for Category A operations, the helicopter was certified to the appropriate paragraphs of Airworthiness Manual Chapter 529, which defines the requirements for Transport category rotorcraft. The equivalent specifications in Europe are CS-27 and CS-29 respectively.

G-WLTS was manufactured in 2014 and is configured for HEMS operations.

Flying controls

The flying controls use conventional mechanical controls that are hydraulically boosted. The boosted controls are powered by four hydraulic servo actuators. Each servo actuator is pressurised by two independent hydraulic systems.

Automatic Flight Control System

The helicopter has an integrated avionics system, which includes DUs a dual digital Automatic Flight Control System (AFCS), and a 3-axis Stability and Control Augmentation System (SCAS).

Two APs reside as independent functions inside two identical, interchangeable Flight Control Computers (FCCs). The APs are engaged and disengaged by depressing their respective pushbuttons on the AP control panel (Figure 4).

Figure 4
Autopilot control panel

The APs can be engaged in two modes of operation using a pushbutton on the AP control panel:

1. Stability and Control Augmentation System (SCAS) mode uses high speed actuators (known as series or SCAS actuators) to improve flight characteristics by adding corrections into the control inputs. SCAS improves helicopter dynamic stability, including stability in windy conditions. SCAS is intended for use where extensive helicopter manoeuvring is required and the pilot wishes to be hands-on without attitude retention mode (see below). When the helicopter is on the ground, SCAS operation is suspended.

2. Attitude retention (ATT) mode maintains helicopter pitch and roll attitude to references that are stored at the time of engagement. If ATT is engaged, the helicopter will return to the previously set attitude after a disturbance with the pilot's hands off the controls. The references are reset to the current condition whenever the cyclic TRIM RELEASE button is pressed and released. In addition, the references can be adjusted using the cyclic trim beep switch. Heading hold and turn coordination are automatic functions that are active when ATT mode is engaged. At speeds less than 40 kt and until the helicopter exceeds 45 kt, current heading is held by the AP using pedal input. If the yaw trim beep switch is operated when ATT mode is engaged, the trim command 'beeps' the internal heading reference, which results in the AP manipulating the pedals to achieve and then hold the new heading reference. This, and the other, AP functions are inhibited when the AFCS is in the 'on-ground' state because when the helicopter is on the ground the airframe cannot move as it would in the air.

The AFCS will transition from 'on-ground' to 'in-flight' if the total torque (the sum of each individual engine torque) exceeds 30%. This transition will occur irrespective of the weight-on-ground switch status, and the AFCS will remain 'in-flight' until the total torque decreases through 25% and the weight-on-ground switches indicate 'on-ground'. This function is a safety feature of the AFCS and is not described in the manuals or taught to pilots. The use of torque to establish flight status is designed to mitigate an erroneous indication of weight-on-ground to the FCC. The threshold is set sufficiently above the minimum on-ground torque to ensure that the AP is disabled when it should be, but low enough to ensure that the AP remains active in low-torque conditions in flight. The on-ground hazard is mitigated by limiting the use of the AP during ground operation. The '*AFCS Limitations'* chapter in the RFM states that '*AFCS shall be disengaged or operated in SCAS mode during prolonged ground operation, except as required for AFCS check.*' The normal procedures chapter states that the AFCS should be selected to SCAS after landing.

Force trim

The force trim system uses spring force to hold the cockpit controls in a set (detent) position. The force is generated by torsional spring (artificial feel) mechanisms in the trim actuators. The detent can be moved anywhere in the control range by releasing the flight control from the spring mechanism and re-engaging it in a different position, or by driving it to a new position using the trim actuator (beep trimming). The flight control is released from the spring mechanism when the pilot presses (and holds) the TRIM RELEASE button on the cyclic stick top. The yaw trim beep switch is on the collective lever and the pitch and roll trim switch is on the cyclic stick top (Figure 5).

Force trim can be turned on and off by pressing a pushbutton on the AP control panel.

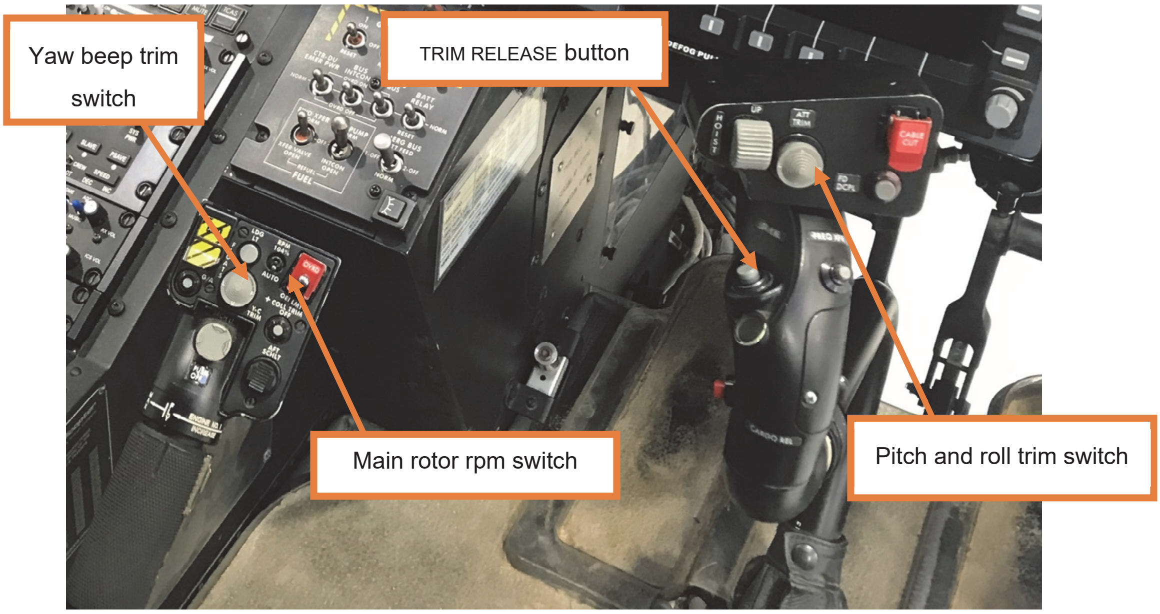

Figure 5

TRIM RELEASE, beep trim and rotor rpm switches

The AFCS and force trim system has a 'fly-through' AP capability. If the pilot makes overriding control inputs, the trim actuator is forced out of the detent position and the AP suspends operation of the associated actuator until the controls return to the detent position.

Directional control system

The tail rotor directional control system allows pitch adjustment of the tail rotor blades for yaw control. Pilot inputs are achieved using two sets of adjustable pedals that are mechanically linked through a torque tube assembly. A push-pull cable connects the torque tube output to the input of two SCAS actuators connected in series in the aft fuselage. The SCAS actuators have a limited range of movement and each actuator is controlled by one FCC. If the respective AP is turned off, the corresponding actuator behaves as a fixed length mechanical control rod. The output from the SCAS actuators is connected to the input of the hydraulic servo actuator that drives the tail rotor pitch change mechanism.

Yaw trim actuator

The yaw trim actuator is controlled by the AFCS and its output lever is connected to the pedal torque tube (Figure 6).

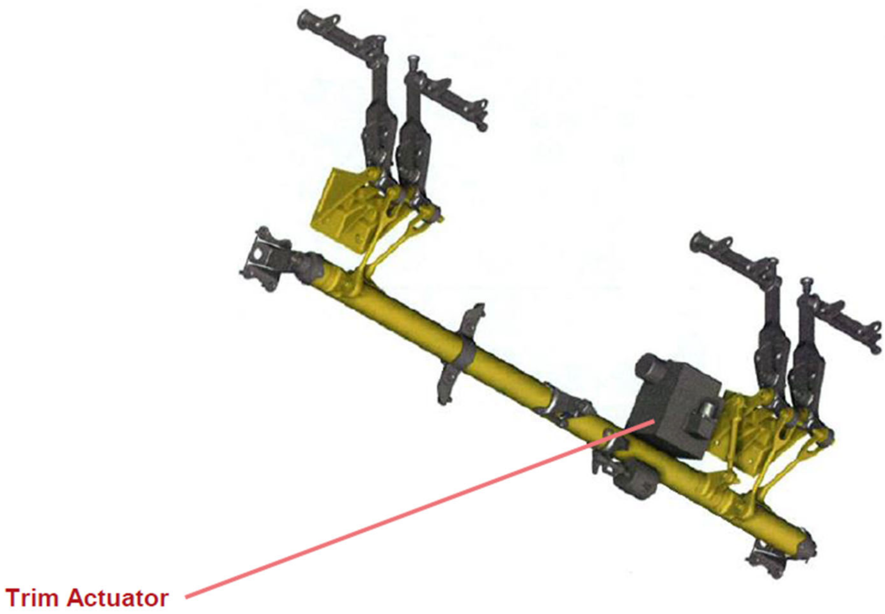

Figure 6
Trim actuator position with respect to the pedals

The actuator comprises an irreversible electric motor assembly that is connected to a preloaded torsion spring (artificial feel force unit) via a clutch and damper. The clutch is engaged when electrically energised and disengaged by pressing the TRIM RELEASE button, which releases the spring from the motor. The output from the spring is connected to the trim actuator output shaft. An electrical microswitch on the spring assembly changes state if the spring is deflected into an out-of-detent condition. This happens if the pedals are moved by the pilot, or if the pedals are prevented from moving when the trim actuator is operated. A Rotary Variable Differential Transformer (RVDT) measures the position of the actuator output lever, which is mechanically linked to the pedals. The FDR uses the output from the RVDT to record the pedal position.

Automatic pedal trim

Description

The yaw axis has an automatic pedal trim function that automatically adjusts yaw trim to match the pedal position during low speed flight. If the trim position matches the pedal position, the pedals are 'in detent'. The function allows the pilot to adjust the pedal trim without using the cyclic TRIM RELEASE or manual beep trim.

Automatic pedal trim is operational when the following conditions exist:

1. Force trim is ON.
2. Airspeed is below 40 to 45 KIAS (turn co-ordination speed).
3. Helicopter heading is stabilised (absolute yaw rate <4°/s second).
4. The pedals have been out of the trimmed (detent) position for >1 second and remain in an out-of-detent condition.

Automatic pedal trim is independent of the AP status and it remains operational on the ground if force trim is ON. This aspect was not mentioned in the RFM or the Integrated Avionics Manual (IAM) and, in July 2019, the helicopter manufacturer amended the latter to include a note about it.

Normal operation

If the pilot makes an input using the pedals, the spring in the trim actuator will deflect. The detent microswitch will change state and an out-of-detent condition will be detected. If the pedals are out-of-detent, a small yellow 'Y' is displayed in the trim status box in the upper right corner of the pilot's DU (Figure 7). Changes in the detent status indication are not accompanied by an audible tone or any other attention getting features, and the pilot's attention was not drawn to the indicator in either incident on G-WLTS.

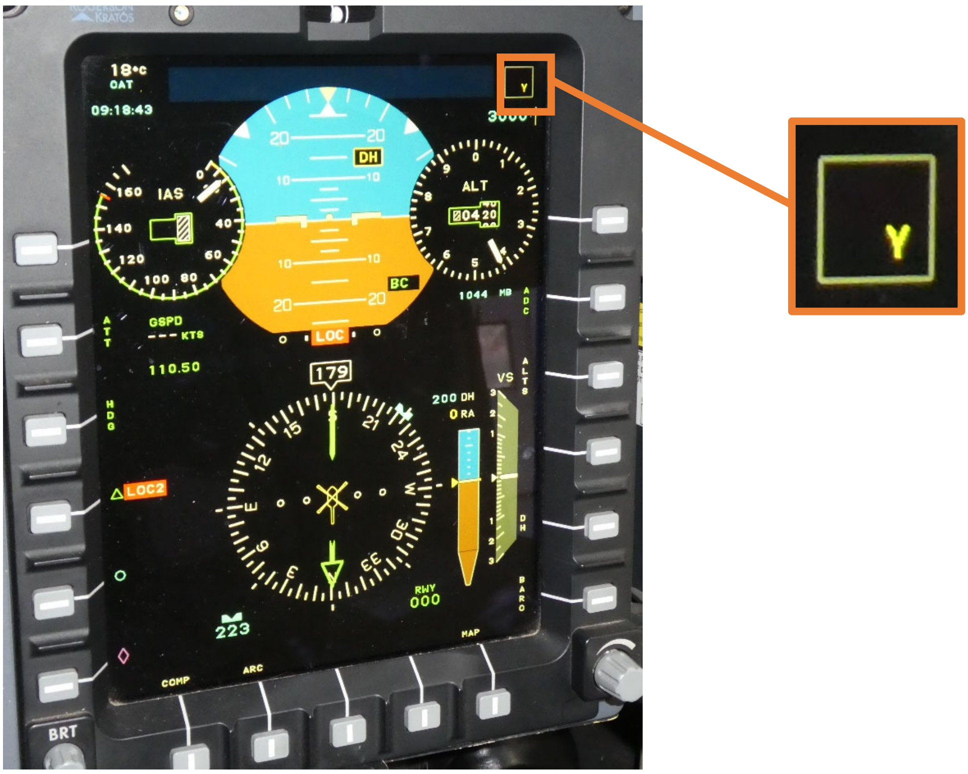

Figure 7

Yaw out-of-detent indication

The AFCS uses the trim actuator RVDT to establish the direction of pedal movement and attempts to restore the detent condition by driving the trim actuator accordingly. The AFCS drives the actuator until the microswitch indicates that the pedals are in detent or the system 'times out' after two minutes of operation. If this occurs, an amber AUTOTRIM warning illuminates in the cockpit.

Automatic pedal trim can be interrupted by:

1. Pressing the TRIM RELEASE button. This releases the spring mechanism and restores the detent condition in the current pedal position.
2. Operating the yaw beep trim. This stops the automatic pedal trim function on the assumption that the pilot will continue to beep-trim the pedals to the desired position.

Normal operation of the automatic pedal trim feature is depicted in Figure 8.

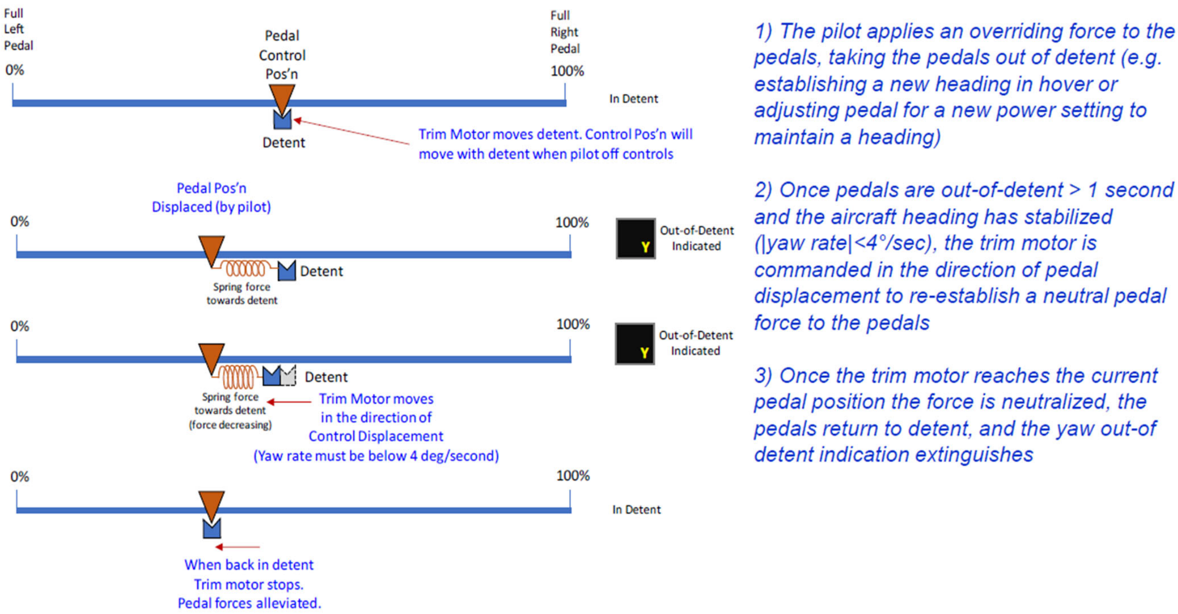

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Figure 8

Normal automatic pedal trim operation

Power Assurance Check

The PAC is referred to in both the RFM and the IAM, although neither document gives a complete explanation of, or defines, the PAC as part of normal procedures. The Category A Supplement to the RFM places the PAC before takeoff in the Normal Procedures.

The IAM describes that the PAC is part of the daily safety routine and verifies proper operation of the engines. The Performance chapter in the RFM briefly outlines two methods for undertaking the check depending on whether the helicopter is in the hover or on the ground. The manual does not contain a definitive procedure for either check and it does not define an AP or AFCS configuration. The Category A supplement to the RFM includes a requirement to carry out a PAC as part of the normal procedures prior to every flight.

If the check is performed in the hover, the pilot must record several parameters to manually derive engine performance using charts in the flight manual.

If the check is performed on the ground, an automated power assurance page on the DU can be used. Engine performance is derived automatically and the results of the last 100 checks are stored electronically. Irrespective of this, however, the flight manual still requires the pilot to record several parameters.

Section 7 of the Bell 429 Integrated Avionics Manual contains a description of the automated power assurance calculations, including a procedure for undertaking the PAC. The procedure is preceded by a warning note that:

> *'UNDER SOME CONDITIONS, IT IS POSSIBLE FOR THE HELICOPTER TO BECOME AIRBORNE WHILE PERFORMING A POWER ASSURANCE CHECK. CARE MUST BE TAKEN TO ANTICIPATE POSSIBLE HOVER FLIGHT CONDITIONS.'*

Helicopter examination

June 2018 – the first incident

The AAIB did not investigate the initial incident and the operator sought assistance from the helicopter manufacturer. Functional checks on the helicopter identified no anomalies.

The manufacturer reviewed information from the EDR in the DUs, which showed a rapid pedal movement immediately before the loss of control. The AP was not engaged when the pedal movement occurred, and the rate of movement exceeded the capability of the SCAS or trim actuators. The pilot's feet were reported to have been off the pedals, so the tail rotor hydraulic actuator was suspected to have 'runaway' to full deflection. The unit was removed for further investigation and hydraulic fluid samples were taken from the helicopter. No faults were found.

The manufacturer wrote to the operator to provide assurance that the design of the tail rotor hydraulic actuator was such that, if the pilot's feet were on the pedals, the pilot would be able to overcome the pedal forces generated by a failure in the main control valve. The manufacturer stated that if the AP was off, the force to stop pedal movement or to hold pedal position would be 20.5 lb and the force to reverse the direction of pedal movement would be 29.5 lb. The operator is understood to have issued guidance that its pilots should guard the pedals whilst carrying out a PAC. Flying operations of G-WLTS resumed after the helicopter had been checked by one of the manufacturer's test pilots.

January 2019 – the second incident

Initial tests

Functional checks of the yaw control system found no anomalies. The control friction and break-out forces were checked, and the left pedal friction was below the minimum allowable limit. This would not have accounted for, or contributed to, the events under investigation. The pedal friction was adjusted to bring it back into the allowable range.

Tests conducted by the AAIB found that the pedals took approximately nine seconds to travel from neutral to full deflection when they were trimmed using the yaw beep trim. The incident pilot assessed the force that was apparent at the pedals and stated that it was much less than the force experienced during the second incident.

Further tests

Additional tests were carried out after the recorded data from both incidents had been reviewed by the manufacturer and the AAIB. These tests identified a set of conditions where it was possible to induce a yaw trim runaway on G-WLTS. If the pedals were displaced away from the detent but reversed before the automatic trim had established a new detent, the AFCS would continue to drive the trim motor in the direction of the initial pedal movement. If the pedals were prevented from moving, the artificial feel spring 'wound up' and the force at the pedals increased. Testing found that when a maximum force of 40 to 60 lb occurred, the trim actuator clutch started to slip. The out-of-detent indication was displayed on the pilot's DU and the increased force at the pedals remained apparent until either of the following two events occurred:

1. The pedals were released. This allowed the spring to 'unwind' rapidly, driving the pedals to a new position. The out-of-detent indication cleared when the spring relaxed, and the pedals entered the detent position.
2. The TRIM RELEASE button on the cyclic stick top was pressed and held. This disengaged the trim actuator clutch, allowing the spring to 'unwind' without driving the pedals. The speed at which the spring unwound was limited by the friction damper in the trim actuator, and the TRIM RELEASE button had to be pressed and held until the force was no longer apparent.

The manufacturer recreated the runaway scenario on another Bell 429 helicopter and, after reviewing the design, concluded that it was a feature of the AFCS logic (Figure 9).

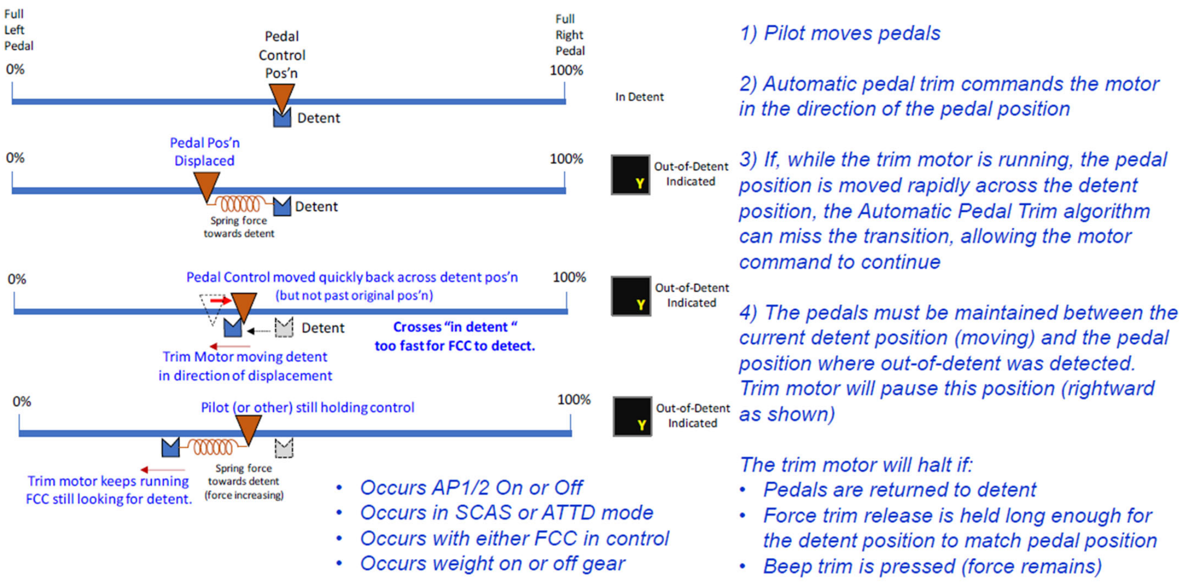

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Figure 9

Automatic pedal trim runaway scenario

Additional analysis of the system logic identified another scenario that could occur if the pedals changed direction within 80 ms of initially being displaced. This would result in the AFCS detecting an out-of-detent condition but capturing the wrong direction of pedal movement. If the pedals were subsequently held in a very narrow range, automatic trim would attempt to drive the pedals in the wrong direction and the force at the pilot's feet would increase. The manufacturer was able to induce this scenario on a test platform but was unable to recreate it on a helicopter (Figure 10).

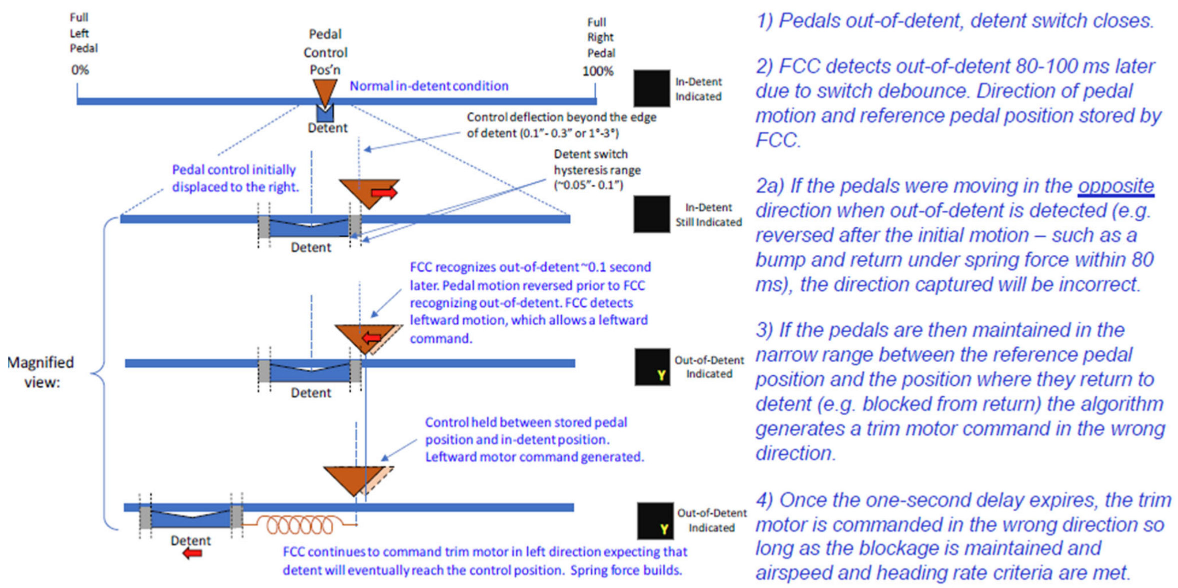

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Figure 10

Theoretical pedal trim runaway scenario

Trim actuator

The trim actuator was removed from the helicopter and returned to the manufacturer for testing and disassembly under the supervision of the AAIB and the helicopter manufacturer. The unit was disassembled and there was no evidence of foreign objects, excessive wear or a jam condition.

Automatic pedal trim runaway

Functional hazard assessment review

The manufacturer reviewed the Functional Hazard Assessment (FHA) that supported the original helicopter certification. There were two failure conditions with similar effects to the runaway scenario that was identified during the investigation:

1. A '*single axis slow over'* can result from a stuck beep trim switch. The failure condition was classified as minor because the '*crew will detect rotorcraft response, by monitoring flight instruments, and take control*'.

2. An '*auto trim runaway'* caused by a failure within the FCC. The failure will result in the trim actuator moving at its maximum rate of travel (normal commanded trim rates are limited to 75% of the full rate). This hazard was classified as minor because the '*crew will detect rotorcraft response and take control'*.

The assessment of both failure conditions was based on airborne IFR operations with the pilot's feet off the pedals because the manufacturer considered this was the most severe case for both conditions. The FHA did not consider the possibility of the failures occurring with an additional fault condition, such as a restriction of the controls during the runaway which is then released. The helicopter manufacturer stated that for ground operation at 100% rpm, they would '*expect the pilot to be on, or closely guarding the controls'*.

Rotorcraft flight manual amendment

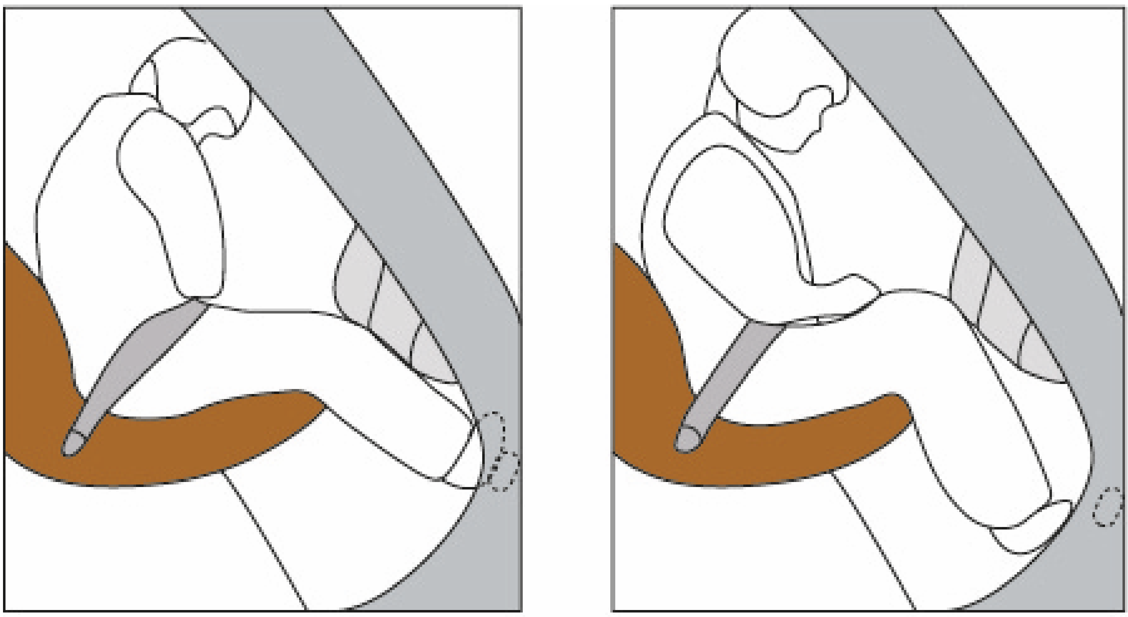
In April 2019, the helicopter manufacturer published a revision to the RFM to reduce the risk of a trim runaway and to provide procedures for responding to a runaway so that control of the helicopter would be maintained.

State of Design Authority assessment

Transport Canada reviewed the investigation findings and assessed the RFM amendment. They agreed that the changes would reduce the level of risk but indicated that the preferred long-term course of action would be to '*change the design of the AFCS to eliminate the potential for force trim (yaw) runaway*'. Emergency Airworthiness Directive CF-2019-16 was issued in May 2019, mandating the incorporation of the RFM amendment and that all flight crews be advised of the changes. The helicopter manufacturer recorded a problem report (PR) against their FCC software and indicated that they would develop enhancements to the automatic pedal trim function in a future revision of the software.

Pilot posture during the power assurance check in June 2018

The pilot of G-WLTS did not think the helicopter would become light on its skids or lift off during a PAC, and several of the operator's pilots stated it was common practice to do the PAC with their feet off the pedals. The pilot was right handed and used a chinagraph pencil to record the necessary figures onto the flying suit's left kneepad (to avoid the writing being rubbed off while flying). The pilot found it more comfortable to do this with feet off the pedals. Figure 11 is a diagram created by tracing the pilot's outline from photographs when performing this task with feet on and off the pedals of G-WLTS. It shows that having feet off the pedals resulted in a more aligned posture with less twist and tilt of the head. In either case, however, the pilot would have been looking down into the cockpit while writing meaning their head would have been tilted in relation to the axis of the yawing movement.



Feet on pedals
Note: awkward posture,
twist and tilt of head

Feet off pedals
Note: more comfortable posture,
head still tilted

Figure 11

Pilot body posture while writing with feet on and off the pedals

Prior to this incident, the pilot had not received training or discussed the possibility of any situation that would result in a rapid, un-demanded yaw on the ground. The pilot reported a sensation of rolling when the helicopter started to yaw on the ground and initially concluded that the helicopter landing gear had collapsed on the right side, having heard about another type of helicopter that was susceptible to landing gear collapse. The pilot reported that the forces experienced during the rotation affected the speed and accuracy with which the engine fuel could be cut off.

Organisational information

When the events occurred, the operator was operating under the provisions of a third-party Air Operator's Certificate (AOC). The operator emailed its flight crew with additional advice on the conduct of the PAC, but the email was not recorded as a formal event in its Safety Management System (SMS) and none of the operator's documents were changed to reflect the new advice.

The operator's intention was to operate to Category A Performance Standards, which requires the helicopter to be operated under the terms of the Category A Supplement to the RFM. The Supplement requires a PAC to be conducted prior to each take off. The operator preferred to conduct the PAC at the conclusion of the first flight back into its operating base each day because the emergency response nature of its operations meant that the helicopter did not fly every day.

The unit only had one paper copy of the RFM and that was carried in the helicopter. At the time of the event, none of the unit's crews had access to the Bell Technical Publications online portal.

Analysis

The event on 15 June 2018

During the first event the recorded data showed that when the pilot pulled up on the collective lever to start the PAC, the APs were ON, the AFCS was in ATT mode and the main rotor RPM switch was set at 104%. The collective was raised to approximately 23% of its range of movement and the total torque exceeded 30%. The AFCS transitioned to 'in-flight' and, with the APs ON and ATT engaged, it would have attempted to maintain the reference attitude (pitch and roll through the main rotor) and heading (using the yaw SCAS and trim actuators). The data showed that the pedals started a gradual movement to the left and the pedal status changed to out-of-detent indicating that the microswitch in the trim actuator changed state. This would happen if the trim actuator was operated whilst the pedals were restricted or if the pilot made an input using the pedals. The latter possibility was discounted because the pilot's feet were not on the pedals.

The out-of-detent condition would have been indicated by a yellow 'Y' in the trim status box on the DU (Figure 7). However, the focus of the pilot's attention was elsewhere, and the trim status box has no attention getting qualities, so the indication was not noticed (and was unlikely to have been).

The main rotor RPM was selected to AUTO (100%) and the collective remained at 23% for about three seconds whilst the pilot turned the APs OFF. This disengaged ATT but the AFCS remained 'in-flight' because the total torque was still above 25%.

The out-of-detent condition continued, and the collective was increased to about 30% of its range to continue the PAC. The data showed a gradual, almost linear, pedal movement of approximately 1.5% to the left over the next 10 seconds before the pedals 'snapped' to full deflection to restore the detent position. When the pedals travelled to full left deflection, the tail rotor pitch angle changed rapidly, generating increased thrust. This additional thrust overcame the frictional force at the skids and the helicopter started to rotate.

The pilot could have stopped the rotation using the pedals but, for several reasons, did not do so. The loud "clunk" and sudden unexpected motion would likely have been startling. The angle of the pilot's head while looking down may have led to disorientation caused by the Coriolis illusion[11]. A fast, un-demanded yaw on the ground had never been trained or discussed and the pilot concluded that the right landing gear must have collapsed. Despite being confused and disorientated, the pilot lowered the collective lever quickly and then shut down the engines and applied the rotor brake to stop the rotation.

Tests on G-WLTS found that it took approximately nine seconds to trim the pedals from neutral to full deflection using the beep trim. When the pedals were prevented from moving, the trim actuator continued to operate, winding up the artificial feel spring. The recorded data from the event indicated that the automatic yaw trim was trying to restore the detent condition but was unable to do so because of a restriction. When the restriction cleared, the spring, which was now under tension, drove the pedals to full deflection. The manufacturer pointed out that, ergonomically, with feet on the floor, it is possible for the right foot to contact the right pedal adjuster, thereby restricting forward movement of the left pedal. In the case of G-WLTS, the pilot did not believe this happened and so the cause of the restriction could not be determined.

The investigation identified two mechanisms where the auto-trim logic could cause a trim runaway. The first, a rapid pedal input reversal across the detent, could be discounted because the pilot's feet were not on the pedals. The second[12] could not be reproduced on a helicopter during testing, but the investigation could not exclude it as a possibility because the FDR sampling rate and limited parameters prevented a comprehensive analysis of the initial pedal movement and out-of-detent condition. Similarly, it is possible that the runaway was triggered by another mechanism that remains unknown. Overall, the investigation was unable to determine what triggered the runaway that occurred on 15 June 2018.

The event on 2 January 2019

The pilot was preparing to undertake a PAC and was holding the pedals in the neutral position using moderate pressure. The force at the pedals increased and the pilot detected an un-demanded pedal movement to the left that was successfully countered. A technical crew member in the left seat had their hands and feet clear of the controls, eliminating them as a possible cause.

The recorded data showed that the pedals were out-of-detent for almost two minutes whilst the pilot attempted to diagnose the cause. The automatic pedal trim tried to restore the detent condition, and the force to hold the pedals in the neutral position increased as the

Footnote

11 The Coriolis illusion is caused by tilting of the pilot's head out of the plane of rotation while the aircraft is turning. This results in the simultaneous stimulation of two semi-circular canals. It produces a disorienting sensation which may feel like the aircraft is rolling, pitching and yawing at the same time. https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/spatiald.pdf (accessed on 6 April 2020).

12 See *Helicopter examination – Further tests.*

trim actuator spring wound up. As in the earlier event, the out-of-detent condition would have been indicated in the trim status box on the DU but, as before, it was unlikely to have been noticed.

The pilot reported pressing TRIM RELEASE a couple of times, but the high pedal force remained. The recorded data showed two TRIM RELEASE events, but the parameter is only recorded once per second, so it is possible that other events were not recorded. The first operation was a momentary event that occurred approximately one minute after the out-of-detent condition started. The second operation was longer in duration and, within the limitations of the FDR sampling, commensurate with the pedals returning to the detent condition. Testing showed that if a trim runaway occurs, the TRIM RELEASE button should be pressed and held until the trim actuator spring has unwound through the damper mechanism and the out-of-detent indication in the DU has cleared.

The pilot's description of the event, combined with the recorded data, indicated that a yaw trim runaway occurred with the pilot's feet on the pedals. The limitations of the FDR sampling rate prevented a definitive assessment, but the most likely scenario was that the pilot inadvertently induced a trim runaway by reversing the pedals across the detent.

This event demonstrated that if a pedal trim runaway occurs, a pilot can overcome the pedal forces, which can be eliminated by pressing and holding TRIM RELEASE until the out-of-detent condition on the DU clears.

Power assurance check

The PAC is not mentioned in RFM Normal Procedures for normal operations (ie operations other than Category A operations). The description of the PAC is in the Performance section of the manual, where it states that the PAC should be completed daily. However, it does not define the required configuration for the APs and AFCS and does not specify whether the PAC should be carried out pre- or post-flight. The Integrated Avionics Manual contains information on the PAC, including a warning to '*anticipate possible flight conditions',* but this was not routinely available to the flight crew and, in any case, was probably not considered to be a quick-reference document for operational information. The operator's only copy of the RFM was required to be carried in the helicopter and was therefore not always readily accessible to pilots. These factors reduced access to information and might explain why the operator and its pilots did not expect the helicopter to become light on its skids or the AFCS to transition to 'in-flight' during a PAC. Prior to the first event, therefore, the operator did not foresee these possibilities as hazards to be controlled, perhaps by guarding the pedals during a PAC. Consequently, the operator and its pilots saw no reason not to record figures on their kneeboards during a PAC with their feet clear of the pedals, and the trim runaway on 15 June 2018 was unopposed, allowing the pedals to deflect to the full extent.

By the time of the January 2019 event, the pilots were more aware of the potential for un-commanded yaw on the ground and would guard the pedals during the PAC. With feet on the pedals, the pilot was able to quickly recognise the runaway and easily oppose the movement of the pedals.

The operator conducted the PAC out of sequence with the RFM Category A Supplement, where the intent is to carry it out as part of the pre-flight procedures for every flight. The main body of the RFM does not require the PAC to be conducted on the first start of a day, only that it should be achieved on a daily basis. The PAC is a normal procedure but is not reflected in the Normal Procedures section of the RFM. The inclusion of a defined procedure in Section 2 of the RFM, including starting parameters before the procedure such as AP status, would reduce ambiguity and allow flexibility in the timing of the procedure. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2020-010

It is recommended that Transport Canada require Bell Textron Canada Limited to amend Section 2 of the Bell 429 GlobalRanger Rotorcraft Flight Manual to include a Normal Procedure for the conduct of the daily Power Assurance Check.

CVR recording issue

The fitment of the TETRA communication system on the helicopter in May 2015 required changing the audio controller. This work was carried out as a Minor Change without any reference to the fact that the audio controller directly interfaced with the CVR, and that the signal levels coming from the audio controller needed to be adjusted to input levels that the CVR was expecting. Therefore, the levels remained at those set by the manufacturer which were higher than the input requirements of the CVR resulting in the recorded crew's speech being clipped.

The flight recorder manufacturer was tasked with evaluating the flight recorder recordings to ensure continued serviceability of the flight recorders. Five consecutive annual inspections of the flight recorder recordings, between three different engineers, failed to identify the clipping on the CVR. When listening to an audio recording, the effect of clipping can be subjective because it does not usually affect the intelligibility of speech greatly if the speech-to-noise ratio is high. Because the inspection process of the CVR recording relied on the engineer just listening to extracts from the CVR recording, the obvious indications of clipping present in the signal waveforms were missed.

The software used to analyse the flight recorder recordings had an option to plot the CVR signal waveforms just as it could plot the data of each parameter recorded on the FDR. However, these signal-waveform plots did not form part of the inspection report for the CVR. The parameter data plots formed part of the inspection report for the FDR so that any obvious anomalies or parameters not recorded could be easily identified. As a result of this investigation, the CVR inspection reports now also contain a plot of the CVR signal waveforms.

CVR recording inspections are required to verify that the audio quality of the CVR is acceptable and has not deteriorated due to undetected failures in the CVR system. They are also required when modifications are made to the CVR system or other aircraft systems that interface with the CVR. The inspection process itself is subjective and results in variability in the assessment of what is good quality, and what is of poor quality requiring immediate attention from the operator.

In 2018, the European Flight Recorder Partnership Group (EFRPG)[13], considered the issues of CVR recording inspections so that guidance material could be developed and made freely available to any organisation carrying out these inspections, and to try and remove some of the variability of the overall assessments. The aim of the document was to: promote best practice; show what tests should be carried out and what issues looked for during an assessment; and propose clearer definitions for the assessment rating of 'good', 'fair' or 'poor'. The guidance material, published in October 2018, can be found on the AAIB's website[14].

The STC holder that carried out the Minor Change made no reference in the work package to the fact that the audio controller interfaced directly with the CVR system. There was, perhaps, an indirect reference to the CVR system in the audio controller installation manual that said that the factory-set audio levels may need to be adjusted to '*best suit the local operating environment*'. There was, however, no evidence to suggest this had been done because the output levels of the audio controller had not been altered.

If the newly installed equipment interfaces (and shares information) with other existing equipment on an aircraft, tests must be conducted to ensure the installation has not had a detrimental effect on the existing equipment (these tests must be conducted in addition to any EMC/EMI/HIRF/IEL testing). EASA specifically reminds Minor Change applicants of this in guidance contained in their 'Minor Change Certificate Document'. The document is aimed at applicants making changes to GA aircraft, and especially those who are not DOA holders and who may have limited experience in the change process. There is, however, no equivalent guidance, or even reminder, to organisations qualified and practised in carrying out changes or repairs to CAT aircraft, leaving the potential for these tests to be overlooked and the continued airworthiness of the aircraft to be compromised. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2020-011

It is recommended that the European Union Aviation Safety Agency remind Minor Change applicants of the importance of verifying that new equipment does not have a detrimental effect on existing equipment with which it has a direct interface.

Footnote

[13] The European Flight Recorder Partnership Group is an independent voluntary group of European (and United States) flight recorder experts from industry, safety investigation authorities and national aviation authorities that was formed to provide advice and opinion on flight recorder issues and practices to EASA.

[14] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/850370/Guidance_on_CVR_recording_Inspections_.pdf (accessed 6 April 2020).

Conclusion

The first event on 15 June 2018 occurred during a PAC when the pilot's feet were clear of the pedals. The yaw trim actuator operated but the pedals could not move because of a restriction, and so the actuator wound up the artificial feel spring instead. When the restriction cleared, the pedals 'snapped' to full deflection as the spring unwound, increasing tail rotor thrust and causing the helicopter to rotate rapidly to the left through two and a half revolutions. The investigation did not determine the cause of the trim runaway or the pedal restriction.

A similar yaw trim runaway on 2 January 2019 was controlled because the pilot's feet were resting on the pedals. The manufacturer determined that the AFCS logic meant that it was possible for pilots to inadvertently induce a yaw trim runway and issued a revision to the RFM to reduce the risk of a recurrence. The manufacturer also undertook to address susceptibilities in the flight control system software identified during the investigation into these events.

The PAC is a normal procedure which was not reflected in the Normal Procedures section of the RFM. A Safety Recommendation has been issued to update the RFM with an appropriate procedure.

It was found that the CVR audio performance was poor after the installation of the TETRA communication system. A Safety Recommendation has been issued to EASA to remind Minor Change applicants of the importance of verifying that new equipment does not have a detrimental effect on existing equipment with which it has a direct interface.

Safety action

Following these events, the following Safety Action was taken:

> Bell Textron Canada Limited published a revision to the Rotorcraft Flight Manual to reduce the risk of a yaw trim runaway. This included procedures for responding to a runaway so that control of the helicopter would be maintained.
>
> Bell Textron Canada Limited amended the Integrated Avionics Manual to include a note that automatic pedal trim remains operational on the ground if force trim is engaged.
>
> Transport Canada issued Emergency Airworthiness Directive CF-2019-16, which mandated the incorporation of the Rotorcraft Flight Manual revision and required all flight crews to be advised of the changes.
>
> Bell Textron Canada Limited recorded a Problem Report against their flight control system software related to the susceptibilities identified. The susceptibilities would be addressed by future enhancements to the automatic pedal trim function of the software

The flight recorder manufacturer included a plot of CVR signal waveforms as part of its CVR recording inspection report to enable anomalies such as clipping to be easily identified.

Published: 30 April 2020.