INCIDENT

Aircraft Type and Registration:	Leonardo AW189, G-MCGT	
No & Type of Engines:	2 General Electric Co CT7-2E1 turboshaft engines	
Year of Manufacture:	2014 (Serial no: 92006)	
Date & Time (UTC):	30 July 2021 at 1530 hrs	
Location:	Near Heads of Ayr, South Ayrshire	
Type of Flight:	Training	
Persons on Board:	Crew - 4	Passengers - None
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	5,276 hours (of which 1,228 were on type) Last 90 days – 78 hours Last 28 days – 14 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a pre-fight brief for a SAR training flight, the co-pilot highlighted an event on a previous flight which had resulted in unexpected pitch oscillations following the selection of the Transition Down mode of the Automatic Flight Control System (AFCS). On the conclusion of the other training priorities for the flight, the crew replicated the circumstances that had triggered the pitch oscillations previously; this resulted in similar unexpected flight path oscillations in the pitch axis. The crew reported this second event to the operator.

The event was caused by a shortcoming in the design of the Phase 5 version of the AFCS software SAR upper modes which also resulted in incorrect AFCS mode indications to the flight crew. To address this issue pending the correction of the AFCS software in the Phase 9 release, the helicopter manufacturer issued a Technical Information Letter detailing actions to be taken in the event of a re-occurrence and updated the FMS Pilot's Guide for Phase 5, Phase 6 and Phase 8 software. The manufacturer has corrected the design shortcoming in the Phase 9 release of the AFCS software.

Safety action has been implemented by the operator regarding automation management and incident reporting.

History of the flight

On 30 July 2021, during the briefing for a regularly conducted SAR training flight, the co-pilot commented that, on a previous flight on 5 July 2021 when he was acting as co-pilot in the PF role, he had experienced unexpected flight path oscillations in pitch following the selection of Transition Down (TD) mode during a Flight Management System (FMS) directed Sector Search using Autonomous Groundspeed (NGSPD). The co-pilot explained that the crew had been unsure if this behaviour had resulted from incorrect set up of the parameters and switch selection and requested that they fly the helicopter in the same profile and configuration during the training flight.

The crew discussed the autopilot configuration and switch selection that had seemingly caused the behaviour and ascertained that there was nothing published advising against the configuration. Owing to concern of the hazard that this flight path behaviour may present in a degraded visual environment, the crew decided to fly the same profile and configuration in day VMC to see if the unexpected flight path oscillations re-occurred. The weather at the time of the incident gave a scattered cloud covering at 2,500 ft amsl with more than 10 km visibility and a north-westerly wind of around 10 kt.

After completing the other planned training, the crew set up the helicopter for an FMS-directed Sector Search pattern and re-briefed the switch selection that may have caused the unexpected flight path oscillations. The rear crew were advised to fasten their seatbelts as a precaution. The aircraft was above 1,000 ft agl over the water with Altitude hold (ALT) captured and Sector Search configured with NGSPD captured. As soon as the PM selected TD mode, the aircraft began to oscillate in pitch. The crew reported this felt “uncomfortable” with a sensation of lower ‘g’ force but were not able to determine the extent of the pitch variation, nor which modes were annunciated on the Primary Flight Display (PFD) as they were looking outside at the time of the event. However, they estimated that it was 20° nose-up followed by a nose-down pitch change of 40° based on their visual perceptions. On recognising the unusual flight path behaviour of the aircraft, the PF deselected the autopilot modes and returned the aircraft to normal stabilised flight.

After the flight, the commander raised an Air Safety Report (ASR) to highlight the potential issue of selecting TD with NGSPD mode captured during a Sector Search.

Previous flight – 5 July 2021

During the flight on 5 July 2021, on completion of some training conducted over land, the crew headed west towards open water. The PM set up the aircraft for a FMS directed Sector Search pattern with the groundspeed set at 60 kt in the FMS. The PM selected lateral navigation (NAV) mode and the Automatic Flight Control System (AFCS) subsequently captured NGSPD while at cruise speed when the Sector Search pattern activated; the aircraft then began to decelerate. Once over the water the PM then selected TD, at which point the aircraft began to oscillate in pitch. Although the PM could not be certain, he thought that he saw Winch Trim (WTR) SAR upper mode annunciated momentarily on the PFD in the pitch channel, before reverting to NGSPD. The PM described the aircraft behaving in a “nodding dog cycle” which, although not aggressive, was sufficient for the PF

to de-select all the upper modes completely after observing the behaviour for a number of cycles; the PF then re-selected the desired modes for each channel. The PF described the oscillations as “not violent but uncomfortable.”

The weather at the time of the incident gave a scattered cloud covering at 1,000 ft amsl with more than 10 km visibility and a south-westerly wind of around 10 kt.

During the debrief for the flight, the crew discussed the event but were unsure whether it was the result of incorrect switch selections or entry parameters, or it was a behaviour of the AFCS. The crew did not consider the 5 July event merited an ASR, but they did brief the oncoming crew of the event.

Event reporting

The degree of pitch oscillation during the event of 5 July 2021 did not trigger an alert in the operator’s helicopter flight data monitoring (HFDM) programme, and the operator’s safety department only became aware of this AFCS issue following reporting of the second event on 30 July 2021. In response, the operator raised a fault report with the helicopter manufacturer. Subsequently, following assessment of the data from the second event, the manufacturer and the operator each separately informed the AAIB several days later.

Aircraft examination

The AAIB did not examine the aircraft owing to the time that had elapsed between the event and the reporting of it to the AAIB. As part of a separate unrelated investigation, the AAIB was present during on-ground testing of G-MCGT’s AFCS on 27 July 2021 and no issues were found.

The pre-flight test is carried out daily; the AFCS performs a power-up test each time it is powered up and it also performs continuous testing in-flight. No faults were found, and no anomalies were reported by any of the AFCS tests in the intervening period.

Aircraft information

General description

The SAR AW189 helicopter is a derivative of the commercial air transport version with specialist role equipment and an enhanced AFCS. EASA issued the type certification in February 2014 for VFR and IFR operation by two pilots carrying up to 19 passengers.

AFCS

The AFCS is a four-axis dual-duplex redundant, predominantly electromechanical system, that provides varying levels of automatic control of flight. The helicopter software installation, that includes AFCS software, was at Phase 5 for both events. At the time of publishing this report, the majority of the civil AW189 fleet uses Phase 5 or 6 software. Phase 7 was never released for operational use. At the time of the event, the latest operational software certified was Phase 8 and was in use on military helicopters and was soon to be used on civil helicopters.

This investigation concerns SAR modes which are only enabled on helicopters configured for SAR operations. SAR modes can only be enabled by the helicopter manufacturer by means of a dedicated configuration file specific to the helicopter's serial number.

AFCS controls

The Autopilot Control Panel (APCP) provides the controls for mode arming and selection, and mode status display for the AFCS. It is also used for pre-flight testing. The APCP is in the centre of the inter-seat console between the pilots. It has 16 push buttons and two rotary/push knobs each annotated with its function (Figure 1). The APCP mode buttons illuminate green when a particular mode has been selected.

Figure 1
Autopilot Control Panel

The cyclic and collective grips have several controls for the AFCS.

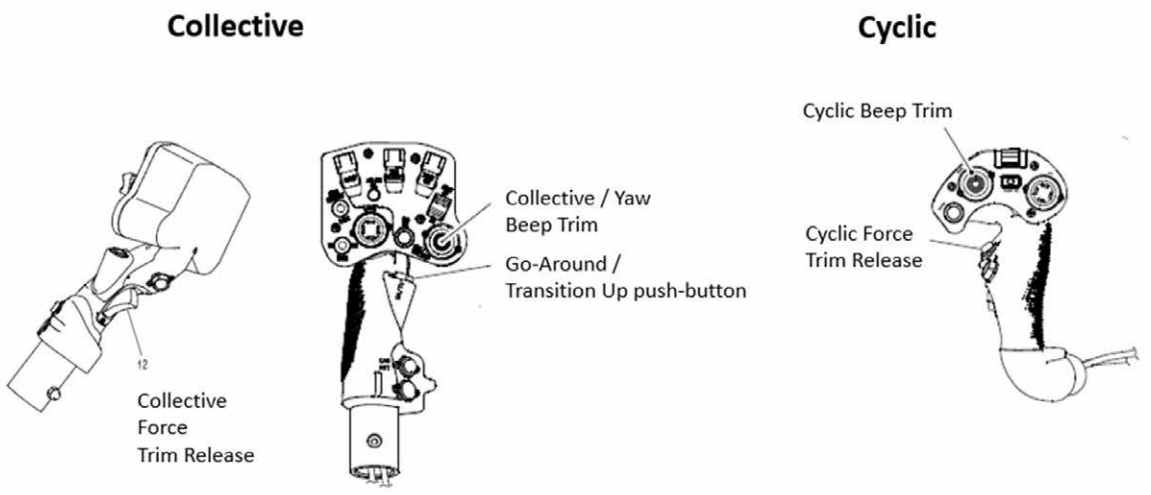


Figure 2
Collective and Cyclic AFCS Controls

Most modes are selected and deselected using the APCP. Some specific modes can be selected using the pilot controls on the cyclic or collective. The cyclic Force Trim Release (FTR) deselects all selected upper modes, while the collective FTR button temporarily deselects the collective trim while it is depressed. When a mode is captured on that axis, such as Radar Height Hold (RHT), the act of depressing and releasing of the collective FTR button resets the associated datum to the current value.

AFCS mode status display

The PFD Annunciator, located at the top of the PFD (Figure 3), provides a visual display to the pilots of which modes are armed or captured in each of the axes, collective, pitch and roll/yaw (from left to right). Captured modes are illuminated green, outlined by a box which blinks for a few seconds when first captured, while armed modes are white, next to the captured modes. Any degraded mode is illuminated in yellow. In addition, all mode changes are annunciated aurally with a single tone chime.

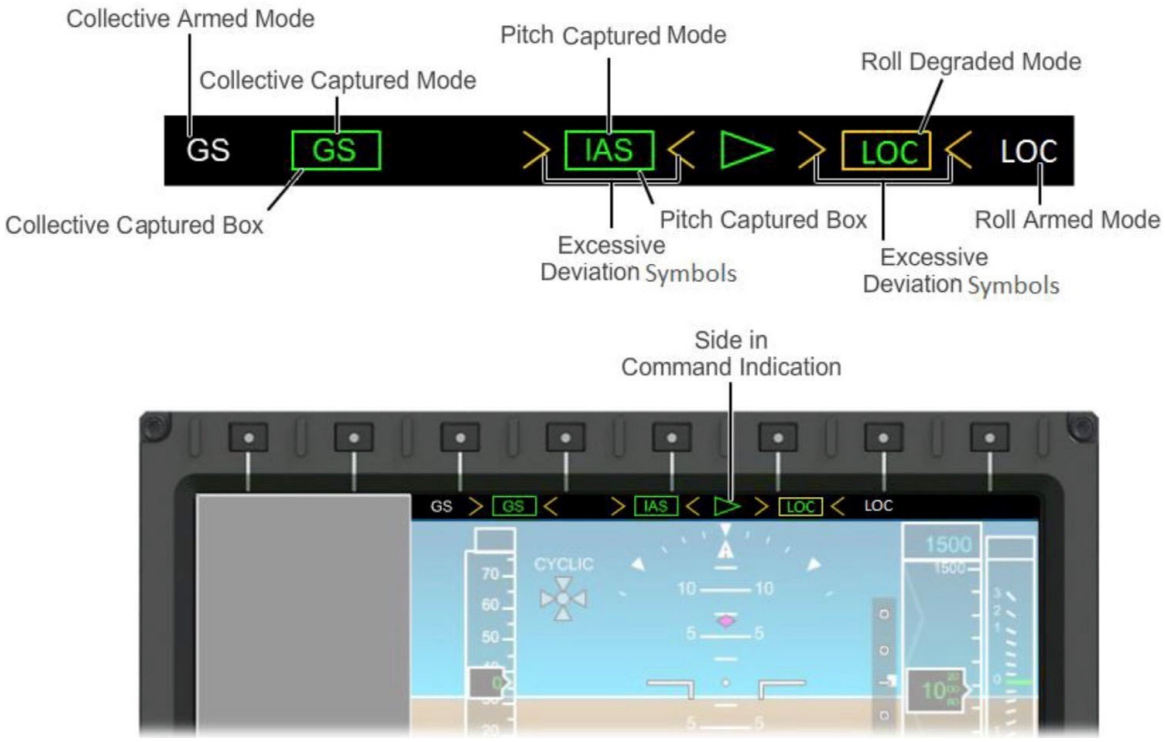


Figure 3

PFD Annunciator

AFCS modes

The AFCS upper modes, which consist of Primary, Flight Director (FD) and SAR upper modes, control the helicopter in four axes – (longitudinally in pitch, laterally in both roll and yaw, and vertically in the collective axis). Primary upper modes provide control of aircraft parameters and performance such as altitude, rate of climb or descent and speed (both air and ground), while FD upper modes control the flight path of the helicopter, both for NAV and approach modes, by coupling the AFCS to the FMS. Aircraft configured for SAR

operations, of which this was one, have additional AFCS SAR modes which provide SAR-specific capability.

The Phase 5 operational software introduced a number of design modifications and new functionality which included the introduction of primary upper Ground Speed Mode (GSPD) and the SAR upper mode, NGSPD.

AFCS modes relevant to the investigation

The AFCS functions and modes that are relevant to the investigation are as follows:

Attitude Hold (ATT) is the default mode of the system when the pilot is flying manually and provides the capability to acquire and hold an attitude reference in each of the axes independently.

The AFCS Primary upper modes relevant to the incident include:

- RHT mode captures a radio altimeter height through the collective axis.
- ALT mode captures a selected barometric altitude through either the collective or pitch axis. The collective axis is used if another mode is controlling the pitch axis.
- Airspeed Hold (IAS) mode captures a pilot selectable reference airspeed through the pitch axis.
- GSPD mode captures a pilot selectable reference groundspeed through the pitch axis.

The relevant FD mode is NAV

- NAV mode provides AFCS coupling to roll steering provided by the FMS. This operates through the roll axis with roll coordination achieved through the yaw axis.

The relevant SAR modes are:

- TD mode provides an automatic descent profile. The AFCS uses the collective axis to control vertical speed to reduce the radio altimeter height to 200 ft agl. Once it achieves this the collective axis switches to RHT mode which holds the radio height datum reference. TD mode also uses the pitch axis to reduce the airspeed to 80 kt, capturing IAS mode once achieved to hold the airspeed datum reference.
- For flying Sector Search patterns, the crew can define the search pattern using the FMS and then use NAV mode to allow the FMS to steer the aircraft. The crew can set the desired groundspeed (GS) for the Sector Search in one of two ways:

- by selecting GSPD mode on the APCP and then adjusting the GS datum on the cyclic beep trim,

or

- by setting the desired GS in the FMS when configuring the Sector Search[1] pattern.

- WTR mode can only be selected and captured when Hover (HOV) mode is captured, and it enables the winch operator to adjust the position of the helicopter using dedicated controls at his station. It operates through the pitch and roll axes.

Low height collective safety function

The Low Height safety functions prevent inadvertent descent below certain thresholds in forward flight or the hover when a collective mode is captured. If these thresholds are inadvertently exceeded the system will automatically increase collective as necessary to take the helicopter back to the threshold values. The Low Height protection function relevant to the incident is as follows:

- 75 ft agl if RHT or TD is captured while in the cruise condition.

The system also provides protection in the following circumstance:

- 17 ft agl when TD/H (and certain other SAR modes) are captured while in the hover condition.

When the Low Height protection function activates, a LOW HT caption will appear below the PFD Annunciator and the single tone chime will sound.

AFCS test functions

The AFCS has an in-built facility for self-test that allows the monitoring of system performance. The AFCS test functions are:

- Power up Built-in Test (PBIT) is automatically carried out when power is first applied to the AFCS.
- Continuous BIT (CBIT) runs continuously while the AFCS is in operation.
- Pre-flight Test (PFT) tests functions and components whose failures cannot be detected at CBIT and to detect failures prior to departure of the helicopter.

Footnote

[1] In this case, NGSPD will automatically be captured on the pitch axis at the point that the Sector Search mode is initiated, whenever NAV mode is captured.

Recorded information

The aircraft was fitted with a combined flight data, cockpit voice and airborne image recorder. The incidents were reported too late to recover audio or cockpit image recordings as they had been overwritten, but the parametric flight data included the incident on the 30 July 2021. Flight Data Monitoring (FDM) data from the 5 July 2021 event was made available and is shown in Figure 4.

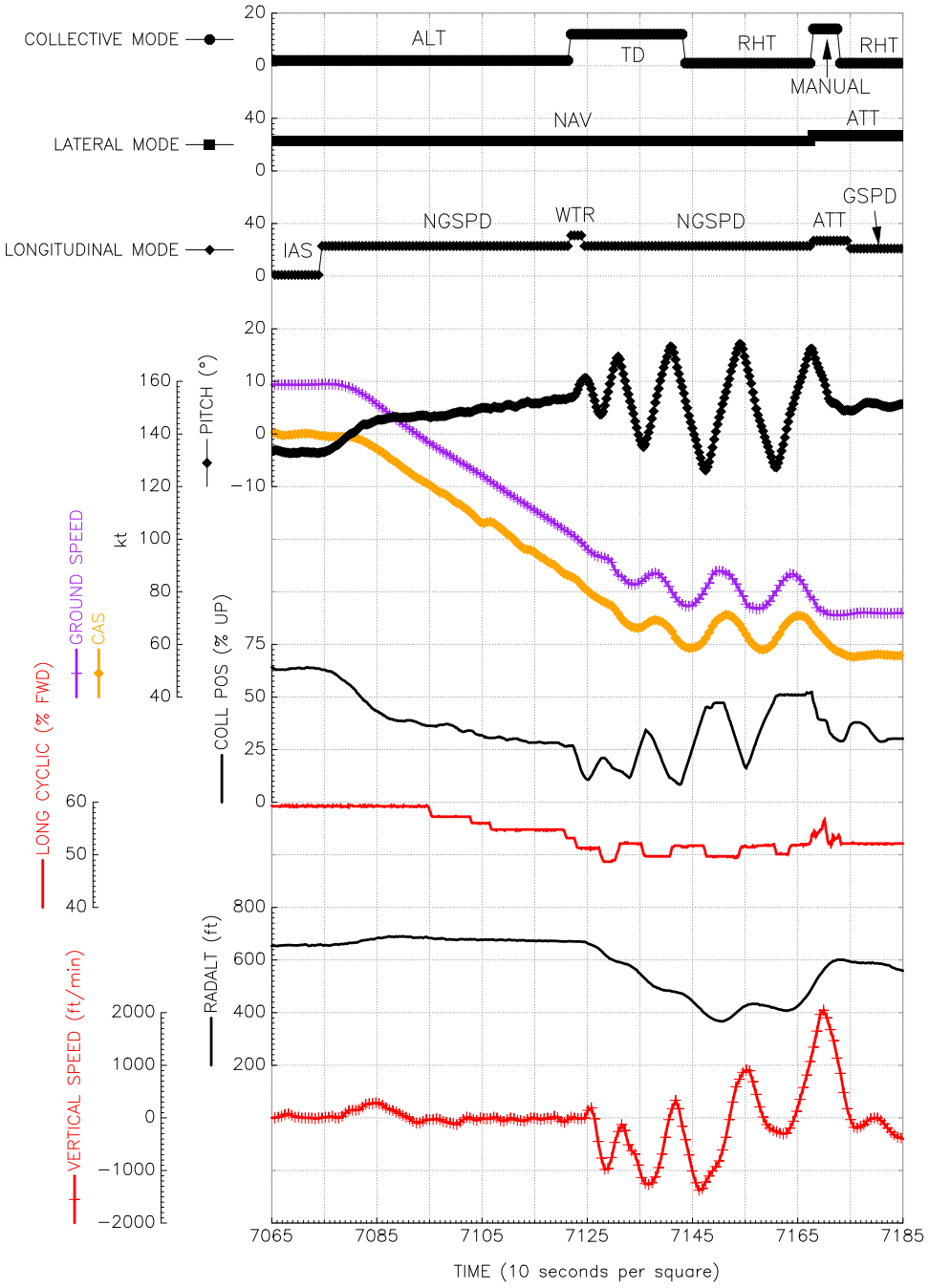


Figure 4

Pertinent extracts of FDM data from the 5 July 2021 incident

One aspect of the investigation centred on the AFCS modes displayed to the crew. The recorded AFCS modes are stored as numbers that are then referenced to a table that identifies the relevant mode. These are the same numbers that are sent to the displays that control the PFD mode annunciations. Figure 4 is annotated with what is displayed when the recorded numbers are sent to the displays. As discussed later in the report, the investigation identified that this does not accurately reflect the actual AFCS active modes under certain circumstances.

Description of 5 July 2021 data

The sequence shown in Figure 4 started with AFCS collective mode ALT captured, maintaining a selected altitude, lateral NAV mode captured, following an FMS path, and longitudinal IAS, holding approximately 140 KCAS. The longitudinal mode switched to NGSPD indicating that a search pattern had been activated. The helicopter pitched up slowly to decelerate to a target groundspeed associated with the search pattern.

The collective mode switched from ALT to TD to descend the helicopter from its radio height of about 670 ft to an updated radio height datum of 200 ft. Under these conditions, TD is associated with the IAS longitudinal mode to target 80 KCAS. The longitudinal mode recording showed a change to WTR mode, which was shortly followed by the helicopter pitching up. The criteria for capture of WTR were not met and information from the manufacturer (discussed later in this report) shows that it was not in fact captured and that the WTR indication was erroneous. The recorded longitudinal mode then switched back to NGSPD. The helicopter entered a cycle of pitching up and down manoeuvres, with the biggest transition being from 6.9° nose down to 17.1° nose up about 6.5 seconds later.

The collective mode was recorded to switch to RHT as the helicopter descended through a radio height of 470 ft with an increasing descent rate. This would have been triggered by pressing the collective FTR. At this point the helicopter pitch was approximately 8° nose up but with a nose-down pitch rate of 4.1°/s. The radio height datum updated to helicopter height as the RHT mode captured. During the following oscillation, the height reduced to 367 ft before recovering, and further radio height datum adjustments were made. This deviation was after more than two complete cycles of pitch oscillations.

The pitch oscillations continued for more than 40 seconds before the upper AFCS modes were deselected, and the crew took manual control of the helicopter using the primary ATT modes.

Description of 30 July 2021 data

The data recorded on 30 July 2021 is shown in Figure 5.

This event started with the helicopter flying at approximately 1,100 ft agl and 100 KCAS, with the AFCS collective ALT mode captured, along with the NAV and IAS modes. The longitudinal mode switched to NGPSD indicating the activation of an FMS directed search pattern. The helicopter started pitching up to reduce speed. The collective TD mode was selected to initiate a descent, and the recorded longitudinal mode switched to WTR. This

was the same behaviour as observed on the 5 July 2021 incident and resulted in the same erroneous indication that WTR was captured. The switch to TD resulted in an increased rate of pitching up. The helicopter reached a peak of approximately 12° nose up and then started pitching down. As the pitch reached approximately 3° nose down, the AFCS upper modes were deselected, and the crew took manual control.

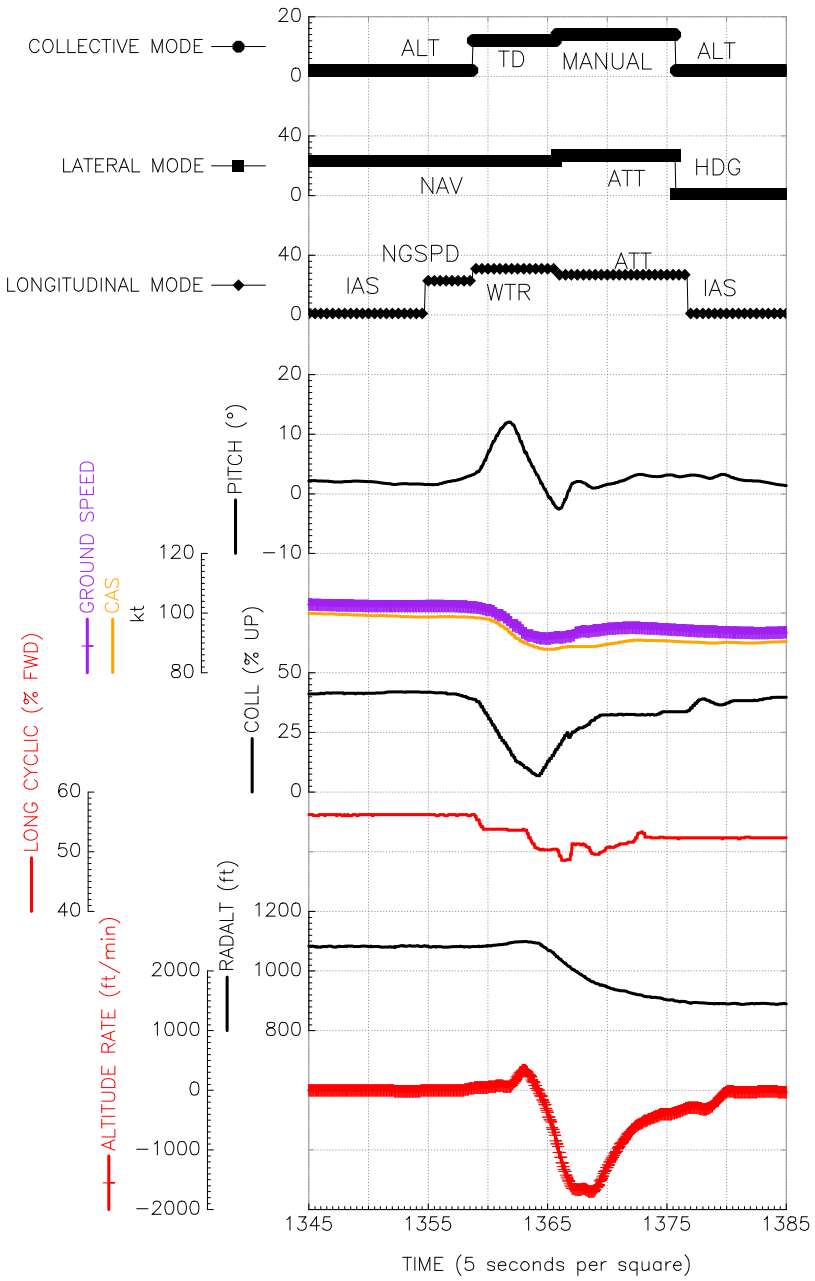


Figure 5

Pertinent extracts of flight recorder data from the 30 July 2021 incident

The helicopter manufacturer's assessment and response

The helicopter manufacturer was asked to review the data from the 5 and 30 July events and both were subsequently reproduced in their engineering flight simulator.

Software priority conflict

The manufacturer identified a software design shortcoming that had been introduced in Phase 5 of the software with the addition of NGSPD as an AFCS FD mode. The NGSPD mode, which uses the longitudinal axis to target a groundspeed, conflicts with the TD and IAS modes, which use the longitudinal axis to target an airspeed, when the TD mode is engaged with a RADALT higher than 150ft and an IAS greater than 80kts. Pitch attitude is used to control speed and so the conflicting speed requirements resulted in pitch oscillations. The manufacturer report concluded:

> *'The investigation identified the following:*
>
> > *2) …the … performance degradation is the result of a conflict in the priority allocated to the Groundspeed and Airspeed control algorithms in case and only if the TD mode is requested to engage when the NGSPD mode is engaged during a SAR pattern and all the following conditions are verified:*
> >
> > *a) Radar Height greater than 150 ft*
> >
> > *b) airspeed greater than 80 kts*
> >
> > *In the above flight conditions, Transition Down engagement request result in "TD" mode engagement…..'*

In addition, the manufacturer's report stated that:

> *'No degradation of control performance has been identified in case the Transition Down engagement request, while the NGSPD mode is engaged during a SAR pattern execution, results in "TDH" mode engagement (that is if none of the flight conditions 2a, 2b is verified).'*

Height loss

The manufacturer assessed the maximum flight path profile deviation during the 5 July 2021 as about 100 ft, contributed to by the delay in pilot intervention after the onset of conditions detectable by the crew. It was also noted that high initial airspeed drives the least favourable initial conditions because of the large difference between target air and ground speeds. This drives the largest pitch oscillations which create altitude rate oscillations creating vertical profile deviations.

Erroneous WTR mode annunciation

The recorded data indicated that the AFCS longitudinal WTR mode was captured during the incident. An actual WTR engagement would have been of concern as the speed was too

high for this mode and would have meant that the winch trim controls were active. However, the helicopter manufacturer confirmed that this was an incorrect annunciation of the mode which resulted from two modes being simultaneously captured on the same longitudinal axis. The mode to be displayed to the crew is encoded in a binary word and sent to the display and recording systems. The binary encoding for the modes of relevance is shown in Table 1.

Mode	Binary representation
TD	01100
NGPSD	10111
IAS	00001
WTR (Winch Trim)	11111

Table 1

AFCS coding of the pertinent longitudinal modes for display and recording

Two AFCS modes active on the same axis at the same time results in the binary coding of the modes being combined. This is done in a bitwise OR operation which means that each bit of the combined code is set to 1 if either of the corresponding bits for the clashing modes is a 1. Thus, when NGSPD (10111) and TD (01100) modes are active, the combination results in all 1s which equates to the WTR mode (11111). WTR is then displayed to the crew in the mode annunciators and the value of 11111 is captured by the recording systems. When NGPSD (10111) and IAS (00001) are both active, the combined code remains as 10111 and so NGPSD is annunciated and 10111 is recorded. Erroneous mode indications can be misleading for the flight crew as they do not reflect how the AFCS is controlling the helicopter.

Implications for flight

The manufacturer identified that the most critical phase of flight for the erroneous mode indications would be *'Hands-off IFR Flight…'* where it would require the pilot to '*to recognise deviation from flight path and initiate recovery action, resulting in significant reduction in safety margins and increase in pilot work-load.'*

However, the manufacturer, following a risk assessment performed in accordance with the applicable EASA Part-21 procedures, concluded that:

> *'…. there are no contributions to Catastrophic and/or Hazardous functional failures. The event frequency is still deemed acceptable for a MAJOR severity*

in terms of risk assessment. In case a non-compliance would exists [sic] this has been shown not to result in an unsafe condition.

Hence, the event occurred on AW189 s/n 92006 is classified as "NOT UNSAFE" and no short term mandatory action (AD) is necessary on the fleet.'

The European (EASA) and UK (CAA) Regulators have agreed with this assessment.

The manufacturer also advised that:

'Moreover in line with LHD products continuous improvement policy, the weakness identified within the AW189 AFCS SW has been traced… LHD has evaluated appropriate design improvement to solve [the weakness]. *This improvement is introduced within the scope of the next AW189 AFCS Software certification phases.'*

As a precautionary measure to alert flight crews to the software anomaly, the manufacturer issued Technical Information Letter (TIL), T-189-22-001 REV A, 'AFCS behaviour with Avionic Software Phase 5 or 6', applicable to the AW189 fleet, on 17 March 2022. The TIL states:

'With the present letter, Leonardo Helicopters (LH) wishes to provide advanced information on the Flight Management System (FMS) Pilot's Guide next revision that is going to be released to introduce the applicable information related to a specific Automatic Flight Control System (AFCS) helicopter behaviour.

Following an event reported by a SAR Operator, dedicated evaluation was conducted by LH and AFCS performance degradation was observed in specific flight conditions, for helicopters equipped with Avionic Software Phase 5 or 6. In details, in case that the Transition Down (TD) mode is selected when flying in a SAR pattern with FMS Autonomous Ground Speed Control (NGSPD) mode already engaged, an undesired pitch oscillation behaviour could be observed.

At the same time, temporary activation of the WTR caption on the PFD could occur. The activation does not result in the engagement of the related mode.

As precautionary measure LH will review all the applicable AW189 FMS Pilot's Guides, section "SAR Steering in Groundspeed" pertaining to the SAR Patterns, to introduce appropriate notes aiming to inform that if a TD procedure is desired when flying in NGSPD mode, the NGSPD mode shall first be replaced by Ground Speed (GSPD) mode before engaging the TD mode (by pressing TD pushbutton on Autopilot Control Panel).

In addition, LH is currently working to modify the AW189 AFCS accordingly at the next favourable AW189 Avionic Software Phase and to avoid any undesired pitch oscillation behaviour.'

The manufacturer also presented on the issue at the Helicopter Association International (HAI) Heli-Expo 2022 in Dallas and advised that AFCS performance degradation had been observed in specific flight conditions during an event reported by a SAR operator. In particular, it stated that '*undesired pitch oscillation'* could be observed *'when activating the TD… upper modes while NGSPD is active.'* This had been observed in helicopters '*equipped with Avionic Software Phase 5 or 6'* and the issue had been reproduced at its manufacturing facilities. The UK CAA has indicated that it will work with the operators of UK AW189 helicopters who use the AFCS SAR upper modes at software Phase 5 or 6 to ensure they are appropriately managed.

The manufacturer reviewed the AW189 FMS Pilot's Guide, for helicopters equipped with Phases 5, 6 or 8 of the avionics suite, and added the following note in the section on '*SAR STEERING IN GROUNDSPEED*' in the chapter on '*SAR PATTERNS*':

> *'When flying Search pattern with GSPD control (NGSPD mode active) if a TD procedure is desired the NGSPD mode must always be replaced by GSPD mode before press TD pushbutton on APCP and engage TD mode.'*

The manufacturer incorporated the software correction, along with other software changes, into the Phase 9 version of the avionics software, which was certified on 29 July 2022. It has also advised that it intends to issue an optional Service Bulletin to allow customers to install this version. The UK CAA has advised that it will monitor the uptake of the Phase 9 software by UK operators of AW189 helicopters used for SAR.

Operator incident reporting

On safety reporting, the operator's SMS manual states:

> *'Reporting is an essential element of the SMS and all employees are encouraged to …….. report incidents, accidents, and areas for improvement.'*

It defines an incident as:

> *'An occurrence, other than an accident, that affects or could affect the safety of the operation.'*

The operator stated to the AAIB that it expects flight crews to raise observations on system performance using an Air Safety Report (ASR) as the formal reporting mechanism.

The flight crew of the 5 July occurrence did not consider that the event merited the submission of an ASR.

Interviews with the crew of the event on 5 July 2021 highlighted among the crew a perception of insignificance to the event, confusion about exactly what had led to the pitch oscillations resulting in the existence of significant doubt among the crew whether it was the result of incorrect automation selection or a fault with the AFCS.

Various crew expressed confidence to report events and the operator provided evidence of a strong reporting culture. However, some crew also expressed the need to be able to repeat an event to ascertain the facts relating to an AFCS behaviour clearly before feeling confident to report a system performance issue through an ASR.

Following the submission of an ASR by the flight crew of the second event on 30 July, the operator's safety team categorised both events as a loss of autopilot stability at a critical phase of flight. A Safety Action Group (SAG) meeting was held where the events were assessed according to the operator's risk register, and it classified the events as high risk but with a remote probability.

Through the reporting of other incidents by crews, the operator's SMS had captured a number of previous AFCS performance behaviours on the AW189 which were associated with the introduction of functionality and software phase updates. Flight crews reported to the AAIB that they had, at times, encountered instances where the AFCS operated contrary to their expectation or understanding. The operator had sought to address this through the issuing of Flight Safety Instructions (FSIs) and amendments to procedures and sought rectification of these issues in the longer term through engagement with the helicopter manufacturer.

Following the July 2021 events, the operator reminded flight crews, through briefings, of the importance of reporting all incidents to highlight issues. It also emphasised the importance of accuracy and completeness when submitting an ASR.

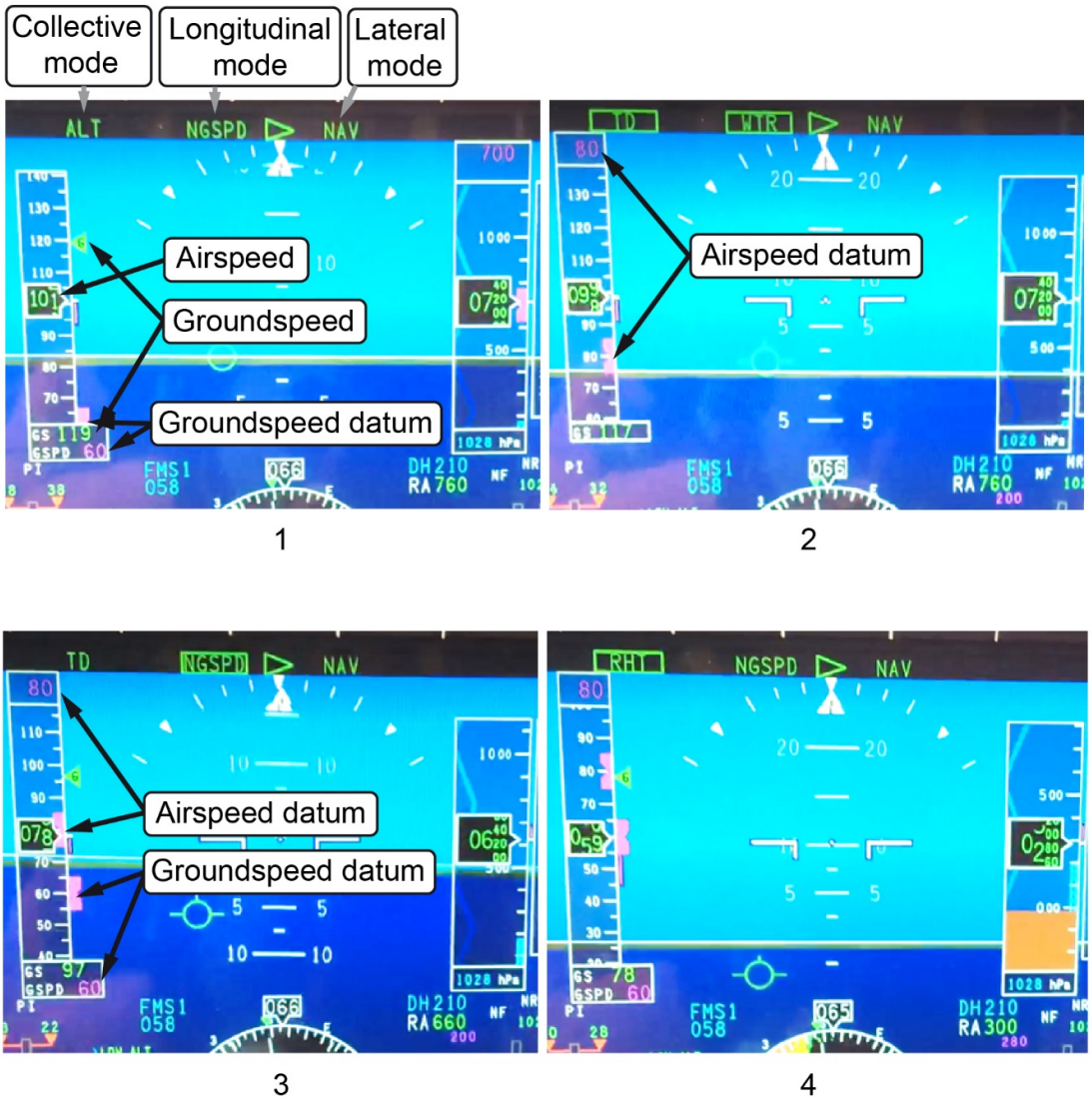
The operator was also concerned that a flight crew had sought to replicate the event that had led to a potentially undesired state. While the operator recognised that the intentions of the flight crew arose from lack of certainty if their automation selections had been the cause, it emphasised that *'putting the aircraft in a potentially dangerous configuration, for the purpose of investigation is not acceptable'.*

Tests and research

Operator test flights

In September 2021, the operator conducted a number of test flights in the simulator and on differing airframes. Although the pitch oscillations could not be replicated in the simulator, the operator's Test Pilot was able to replicate the AFCS behaviour on the airframe in which the original events occurred. Subsequently, he was able to replicate the pitch oscillations behaviour during test flights on other airframes.

A video recording of the PFD was made on the test flights conducted by the operator. Heights and speeds were not reproduced but the behaviour associated with the incorrect annunciations and the simultaneous groundspeed and IAS target speeds were recorded. Figure 6 shows a similar sequence to that which occurred during the 5 July event.



1 NGSPD active.

2 TD activated, longitudinal mode WTR annunciated, pitch oscillations start.

3 Slowed through 80 KIAS, longitudinal mode of TD switch to IAS, annunciation change to NGSPD, both groundspeed and airspeed datums.

4 FTR triggered height datum change, collective mode change to RHT, two speed datums persist, pitch oscillations persist until NGSPD deselected.

Figure 6

PFD mode annunciations and speed targets during reproduced sequence

The operator's Test Pilot made the following observations:

- The trigger to the behaviour was the selection of TD mode before the search speed datum had been achieved, ie during the deceleration phase to capture the demanded GS.

- The oscillation typically ranged between a pitch attitude of 17° nose up and 8° nose down. However, the oscillation would remain within those limits and not become divergent.
- The behaviour could be replicated irrespective of whether there was a tailwind or a headwind. However, the oscillations were greater when flying into wind with either a rate of climb of 2,250 fpm or a rate of descent of 1,950 fpm.
- WTR was annunciated on the PFD Annunciator. However, the corresponding button on the APCP did not illuminate, indicating WTR was not captured. This was confirmed by a crewman monitoring his station in the rear of the aircraft.

The behaviour would stop temporarily while cyclic FTR was depressed, and completely on selection of GSPD on the APCP, or on the deselection of the upper modes. It was noted that the behaviour could not be replicated when RHT was captured prior to the selection of TD.

The test pilot observed that *'the rate of flight path change could be alarming especially within a* [degraded visual environment] *DVE.'*

In October 2021, following the conclusion of the above tests, the operator issued an FSI to crews restricting the use of NGSPD in conjunction with TD. The operator also included information on this issue in the ground school training as part of its Operator Proficiency Check programme which all of its SAR AW189 crews have received.

Analysis

The events occurred during the day in VMC whilst conducting training flights. These are usually conducted on a regular basis and provide the opportunity by which crews maintain currencies and practise skills, competencies, and procedures, including the use of automation.

5 July 2021 event

For the event of 5 July 2021, the crew initiated the descent from 670 ft agl once they were over water. Although the crew recognised the amount of pitch change that occurred and the subsequent oscillations as unusual, they considered this only as an example of the AFCS operational performance being contrary to expectation. Other important indications occurred momentarily at the point of entry to the manoeuvre; notably, WTR mode was only briefly displayed on the PFD Annunciator. The PM stated he could not be certain that he had seen this annunciation, probably because he was surprised at the unexpected onset of the pitch oscillations and such an annunciation would also have been contrary to expectations. The crew also doubted whether they had set up the automation correctly for the intended search mode, as this required several inputs. Consequently, although the crew recognised the pitch oscillations were unusual, it is understandable why they perceived this as an operational performance issue rather than a safety event. It could also explain why they did

not have confidence, as stated to the AAIB, to raise an ASR to report the event since they did not understand exactly what had happened, how the event was triggered, or what they had seen and experienced.

30 July 2021 event

The replication of the event by the crew on 30 July 2021 also occurred during a training flight. As such, the intent among the crew to replicate the same use of automation as on 5 July would not necessarily have seemed inappropriate. The uncertainty surrounding the cause of the AFCS behaviour, together with the perception that it was less a safety issue but more one of operational system performance, may have contributed to the desire to establish the facts of the event through repetition and replication before reporting it. A number of other crews expressed this desire to confirm unusual AFCS behaviours before reporting them.

With that perspective, although the crew had not sought the guidance of the operator's Test Pilot prior to the flight, the decision to replicate the event to establish exactly what happened is understandable. Following the July 2021 events, the operator reminded flight crews, through briefings, that such events are to be reported and managed by the operator's SMS. This is to ensure that the investigation of reported events is conducted by appropriately qualified crews and reducing the risk of line crews putting a helicopter into a potentially hazardous configuration.

During both of the above flights, the unexpected AFCS behaviour stopped when the PF deselected the upper modes; it is likely that the collective Low Height safety protection would also have acted as an additional safety barrier against controlled flight into terrain. All these factors mitigated the potential hazard arising from the AFCS behaviour which resulted in an undesired aircraft state. The impact upon safety may have been greater if this had occurred to a crew on a task at a lower height, with a higher workload and in degraded visual conditions or at night, where disorientation is a real threat.

Incident reporting

The evidence indicates that the operator's reporting culture was strong, and crews did report AFCS system performance issues that had a potential impact on safety, enabling the operator to address these both through its SMS and discussion with the manufacturer. Nonetheless, the crew of the event of 5 July did not feel that the event was significant enough to merit reporting. The fact that this event was not detected through the HFDM programme highlights that there can be events where the safety of the aircraft can be potentially put at risk, without other elements of the SMS detecting it. This reinforces the importance of crew reporting of unusual events, even if they are not perceived to affect the safety of the aircraft.

The AFCS system on the AW189 has undergone a programme of development since certification. The development was driven both by the manufacturer's continual improvement policy as well as customer feedback, resulting in both design modifications and added functionality with each iteration. AFCS operational software development can present its

own challenges as a result of this continuous development. The exposure of crews to perceived unexpected AFCS behaviour at times may have contributed to increasing the threshold at which they may consider an event as being safety related and reportable.

Prompt resolution of any issue by the manufacturer through its airworthiness processes, and appropriate management by the operator through its SMS, can only be achieved with the reporting of all events by crews, even if crews may find it difficult to provide meaningful or complete information. Following these events, the operator has reinforced the need for flight crews to report events regardless of the perceived severity or completeness of the detail.

AFCS performance behaviour

During Phase 5 software development, while improving the AFCS FD behaviour for SAR operational capability, the manufacturer did not identify a design shortcoming which resulted in a priority conflict between different inputs of the TD / TDH modes. When using the AFCS to control the horizontal position and groundspeed of the helicopter as directed by the FMS to conduct a search pattern, under certain circumstances, selecting the AFCS mode to transition the helicopter down to a search radio height creates a conflict whereby the system is trying to acquire both a groundspeed and a separate airspeed datum. Pitch is used to control speed and the different speed targets result in pitch oscillations.

The maximum flight path deviation during the flight on 5 July 2021 was assessed to have been approximately 100 ft. This was more than 20 seconds after the onset of the condition, after more than two complete pitch oscillation cycles. The crews stated that, as they were engaged on training sorties, they allowed the situation to develop for longer than they would have done under other circumstances. The AFCS software issue is not triggered below 150 ft agl and, as the collective protection afforded by the Low Height function is unaffected, it would have been expected to act as an additional safety barrier if the loss of height from a similar event had occurred at a lower level.

The software issue also results in the mode annunciator displaying incorrect mode information to the crew. With TD and NGSPD captured, the WTR longitudinal mode is displayed, and when both IAS and NGSPD are using the longitudinal axis to target separate air and ground speeds, NGSPD is displayed. This is misleading because it does not reflect the datums being targeted by the AFCS when controlling the helicopter.

The manufacturer reproduced the AFCS software behaviour and carried out a risk assessment in accordance with the applicable EASA Part-21 procedures which determined the behaviour of the AFCS was a non-compliance and was “NOT UNSAFE”. The European (EASA) and UK (CAA) Regulators concur with this assessment.

The manufacturer has incorporated the software fix into the Phase 9 software (which was certified on 29 July 2022) and has advised that it intends to issue an optional Service Bulletin to allow its customers to install this version. The UK CAA has advised that it will monitor the uptake of the Phase 9 software by UK operators of AW189 helicopters used for SAR.

Conclusion

Investigation of the pitch oscillations behaviour by the manufacturer determined that it was the result of a design shortcoming in the Phase 5 version of the AFCS software. This resulted in a conflict between airspeed and groundspeed priority on selection of the Transition Down autopilot mode during a sector search pattern using Autonomous Groundspeed. While analysis of the FDR data identified the annunciation of the Winch Trim SAR autopilot mode on the primary flight display following the selection of the Transition Down mode, it was confirmed that this was displayed in error. The manufacturer and Regulators have assessed this AFCS behaviour to be "NOT UNSAFE", in accordance with the applicable EASA Part-21 procedures.

Safety action taken

The helicopter manufacturer has issued a Technical Information Letter advising operators of this behaviour and the actions that should be taken in the event of its occurrence. It also briefed the helicopter community on the issue during HAI Heli-Expo 2022 and has updated the FMS Pilot's Guide for Phase 5, Phase 6 and Phase 8.

The design shortcoming in the AFCS software has been corrected in the Phase 9 release.

The helicopter operator has restricted the use of NGSPD in conjunction with TD by its flight crews and has reinforced the importance of reporting incidents to ensure that issues that could affect safety are dealt with appropriately.

The operator also included information on this AFCS issue in the ground school training as part of its Operator Proficiency Check programme which all of its SAR AW189 crews have received.

Published: 29 September 2022.