ACCIDENT

Aircraft Type and Registration:	DA 40 NG, G-CTSB	
No & Type of Engines:	1 Austro E4-A piston engine	
Year of Manufacture:	2015 (Serial no: 40.N283)	
Date & Time (UTC):	12 December 2020 at 0926 hrs	
Location:	Cranfield Airport, Bedfordshire	
Type of Flight:	Aerial Work	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Serious)	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	23 years	
Commander's Flying Experience:	1,229 hours (of which 779 were on type) Last 90 days - 70 hours Last 28 days - 33 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The pilot was seriously injured when the aircraft stalled and then struck the ground shortly after takeoff from a height of about 100-200 ft. It had been loaded with five containers of de-icing fluid, contrary to the approved training organisation's prohibition on the carriage of cargo and dangerous goods. One container, loaded in the front right footwell close to the flying controls, limited the control stick's available forward movement.

The aircraft was near its maximum permitted takeoff weight and aft centre of gravity limit when it departed. This, together with the limited control authority available, caused the accident.

The investigation found that aspects of the management of the Approved Training Organisation may have contributed to the accident. The de-icing fluid was probably incorrectly classified by the manufacturer as a non-dangerous good, with incorrect safety information supplied.

One Safety Recommendation is made regarding the use of recording facilities on digital flight instrument systems.

History of the flight

The pilot was an instructor with a large commercial Approved Training Organisation (ATO). The evening before the accident he had been contacted at home by the Head of Training Delivery asking whether he would complete two student flying progress checks the next day. The checks were due to be carried out at Bournemouth Airport, 90 nm from the pilot's home base at Cranfield Airport. The pilot agreed to do the checks and was given permission to fly from Cranfield to Bournemouth in one of the school's aircraft if the weather was suitable. If not, the plan was for him to drive to Bournemouth from his home, a journey of about three hours.

On the day of the accident the pilot left home at about 0700 hrs and drove to Cranfield Airport, a journey of about one and a half hours. During the journey he made calls on his mobile phone to assess the weather and check that it would be suitable to fly to Bournemouth. Deciding it was, he continued to Cranfield rather than changing direction towards Bournemouth. He was also contacted during the journey by the Head of Training Delivery, asking if he could bring some containers of de-icing fluid to Bournemouth in the aircraft as cargo. The pilot called staff at Cranfield, ahead of his arrival, to ask them to take some containers of fluid to the aircraft in time for him to load them prior to his departure.

Due to the injuries sustained in the accident, the pilot had little, if any, recollection of further events involving the flight. Other sources of information indicate that on his arrival at Cranfield Airport he spent time in the company operations room trying to determine with another instructor the weight of the containers he was planning to carry. He then went to the aircraft and, with the assistance of a member of the operations staff, loaded five 25 litre containers of de-icing fluid into it. One container was placed upright on the empty front right seat and one on each of the two rear seats. Another container was placed upright in the rear left seat footwell. The remaining container was placed upright in the front right footwell.

The operations staff member assisting with the loading reported that the pilot checked that the flight controls, including the rudder pedals, had full and free movement after loading the containers. He stated that the containers in the rear of the aircraft and in the front footwell were not restrained in any way, but could not recall whether the container on the front seat was restrained by the seatbelt.

The pilot was reported to have boarded the aircraft and the operations staff member returned to the hangar. The staff member did not see the pilot doing a daily check or walk-round of the aircraft, which was not visible from the operations room. The technical sheet on which the check should have been recorded has not been found.

At 0920 hrs the pilot was given taxi clearance and was asked by ATC whether he would be departing IFR or VFR. The pilot replied he would be departing IFR towards the Compton VOR, climbing to 4,000 ft, and requested a basic service. At 0925 hrs he was cleared for takeoff from Runway 21.

ATC cameras recorded the aircraft commencing its takeoff run and becoming airborne after about seven seconds. The aircraft's wings were then seen to rock slightly. About

five seconds after takeoff the right wing was seen to drop and be recovered, followed immediately by the left wing dropping. The aircraft was by then in a descent from a height of about 100 - 200 ft and continued in a left turn, hitting the ground to the side of the runway, about a third of the way along its length. The entire flight lasted approximately 12 seconds.

An aerodrome fire and rescue vehicle doing a wildlife patrol at the time witnessed the accident and initiated an emergency response before attending the scene. ATC also independently initiated an emergency response at 0927 hrs and an additional aerodrome fire and rescue vehicle was in attendance within one minute. Other off-airport emergency service assets arrived at the scene about 25 minutes later. The pilot was extricated from the aircraft and flown by air ambulance to hospital, having sustained serious injuries.

Recorded information

The aircraft was fitted with a Garmin G1000 fully integrated flight, engine, communication, navigation and surveillance instrumentation system. This had the facility to allow a significant range of flight and engine data parameters to be recorded onto an SD memory card, if one were installed in the unit. At the time of the accident the operator did not use this capability and there was no memory card inserted in the unit on the accident aircraft.

Aircraft information

The DA 40 NG is a four-seat, low-wing, single-engine aircraft with a fixed tricycle undercarriage. It is fitted with dual controls and a control column located in a cut-out in the base of each front seat (Figure 1). The rudder pedals have an adjustment mechanism fitted to allow them to slide backwards or forwards along a rail to accommodate different pilot leg lengths. Aircraft trim can be adjusted by either an electronic switch on the flying controls or a trim wheel situated on a console between the front seats.

Figure 1
Flight control stick DA 40 NG

Behind the rear seats, but within the cabin, is an area that can be used to carry bags and other similar items. It is provided with a net to secure them during flight.

G-CTSB had recently undergone a 1,000 hour service. This included a flight test the day before the accident, following which no outstanding problems were reported, and the aircraft had been released to service.

Aircraft examination

Initial examination of the aircraft was carried out by the operator. The AAIB carried out two further examinations of the aircraft to determine whether the de-icing fluid containers had potentially restricted the flying controls during the flight.

The aircraft was severely damaged in the impact, with the left wing and tail breaking off. There was also damage to the cockpit area with three of the de-icing containers having been ejected during the impact. Two containers remained in the aircraft, one in the front right footwell and another trapping the pilot's left arm against the side of the cabin.

Images of the aircraft taken after the accident show the de-icing fluid container positioned in the footwell of the front right seat (Figure 2). Once removed, this container was found to have been punctured on the lower part of its forward face (as found) and on the base adjacent to the forward face damage (Figure 3).

Figure 2

Container as found in wreckage (used with permission)

Figure 3

Lower forward face of container recovered from footwell of aircraft

These features indicate that the container had been positioned in the footwell in an upright position prior to the accident. The damage is consistent with the container moving forward during the accident, into the seat rudder pedal adjustment rail. This led initially to the forward face of the container being breached, followed by damage to the base of the container as it rode up over the rudder pedal adjustment rail. A scuff mark (Figure 4) was also identified on the top left surface of the container. This indicated that the container moved underneath the instrument panel during the impact sequence, providing additional confirmation that the container was upright during the accident, as the top surface would not have been scuffed if the container was laid either horizontally, or at an angle.

Figure 4

Scuff on upper front surface of container

Another container recovered from the accident site was found to have damage consistent with it being positioned on the front right seat. A crease along the front face of the container and damage to the right side of the instrument panel combing suggested that the container was forced against the combing during the impact sequence (Figures 5 and 6).

Figure 5
Crease in container

Figure 6
Damage to right instrument panel combing

The AAIB inspected another DA 40 aircraft with the same cockpit layout to determine whether, with a container in this position, there would have been any control restrictions. The elevators were placed in their neutral position and the distance from the left control stick to the edge of the instrument panel measured (approximately 188 mm). A further measurement was then made with the control stick moved fully forwards (approximately 126 mm). A surviving undamaged container was then positioned upright in the right footwell and the control stick moved as far forward as possible. This resulted in the base of the stick contacting the container with the stick being approximately 230 mm from the instrument panel. The position of the container was adjusted, placing it at an angle by moving the base into the footwell as far forward as possible until it contacted the rudder pedal adjustment rail. The stick was then moved as far forwards as possible and, again, it contacted the container. The distance between the stick and instrument panel was approximately 172 mm. The results are shown in Figure 7.

Container upright

Container at an angle

Figure 7

Control stick position measurements

This demonstrated that with the container in the upright position the control stick could not be moved forward of the control neutral point, and only slightly forward of the neutral point with the container lying at an angle with its base as far forward as possible (Figure 8).

Figure 8

De-icing fluid container positioned at an angle with its base in contact with the rudder pedal adjustment rail

The operator reported that in its initial inspection of the aircraft after the accident all cockpit switches were found to have been correctly selected for takeoff. The pilot's rudder pedal position adjusting lever was found to be out of its housing. The trim lever was also found in a slightly nose down position, away from the marked takeoff position. A subsequent examination by the operator of the rudder and elevator controls revealed no anomalies, other than those caused by the accident. It is possible that the position of both the rudder pedal adjusting lever and trim lever were the result of the impact and associated damage to the tail.

When sent by the operator for inspection the propeller governor was found to be fully serviceable. The operator also removed the Engine Control Unit (ECU) and sent it to the

engine manufacturer for inspection. It too was found to be serviceable. There were no engine faults recorded in the ECU memory and all recorded parameters appeared normal for the takeoff.

The ECU inspection report summary stated that the engine power lever was advanced to the 100% position and remained there for 20 seconds before being reduced to 17%. This coincided approximately with the right wing-drop. It then remained at 17% for 4 seconds before being advanced again to the 100% position. The report states that '*very shortly thereafter'* the ECU electrical connection was lost as the engine stopped.

Aircraft documents

The aircraft documents were recovered from the aircraft after the accident, including the technical log which had been damaged. The documents included the Certificate of Airworthiness and Airworthiness Review Certificate, both of which were valid.

There was a record of the 1,000 hour inspection completed on 9 December 2020. This recorded the aircraft hours as 2,986.9 flying hours at the time of the inspection, although the time recorded on the technical log before the inspection was 2,969.5 hours.

The technical log contained sheets titled *'Notes for Crew'*, which had the following wording at the top of each page:

> *'This document replaces the Blue Folder referred to in the Operations Manual. It does not replace the Technical Log pages, but supplements those pages. The main purpose is to provide an historical log of this particular aircraft's unserviceability's* [sic] *and technical observations. If the aircraft's commander determines that the aircraft is unserviceable, then the unserviceability is recorded on the appropriate Technical Log page and is also recorded in these pages. Whilst the demand for a double entry may seem onerous, it does provide pilots with a tool for trend analysis of faults over a period of time. These pages will be retained in the Technical Log. Additionally, observations that the commander considers do not warrant a declaration of unserviceability should be recorded in these pages; observations that may help towards a more complete analysis of a problem. Where an item is recorded as an unserviceability, reference must be made in the appropriate column to indicate the Technical Log page.'*

Three such sheets were recovered from the aircraft after the accident, all of which were full; the first entry being on 16 May 2018 and the last on 7 September 2020. There were several anomalies on the sheets, including items that hadn't been entered into the technical log but which referred to a technical log entry. When checked, these entries did not exist.

All the entries on the first two sheets were recorded as having been cleared. Whilst none of the eight entries on the most recent sheet were recorded as cleared, the relevant technical log pages were missing. Three entries did not include the name of the person entering the details. Some of the entries were of faults that should be entered into the technical log. One such entry recorded a missing screw which allowed the strut cowling to hang down.

The ATO stated that, as the result of an internal review, the technical log had been re-designed, removing the *'Notes for Crew'* pages. The new technical log was introduced on 1 October 2021.

Several of the Acceptable Deferred Defects Record (ADDR) entries in the technical log for G-CTSB between 5 September 2018 and the last on 31 July 2020 were incomplete.

The recording on 13 May 2019 of a fault with the ADF included several subsequent open entries which made the status of the defect unclear. An entry dated 20 November 2019 recorded the ADF as totally unserviceable and an entry dated 31 July 2020 deferred the fault to the next Scheduled Maintenance Inspection (SMI). The fault was not rectified during the aircraft's subsequent 100 hour inspection on 18 August 2020 and remained unrectified until the 1,000 hour inspection on 9 December 2020. The ADDR entry was closed on 12 December 2020, the day of the accident, but the entry in the *'Notes for Crew'* remained open.

A technical log entry for *'fuel leaking from the starboard wing with engine running'* was made on 9 December 2020, immediately after the 1,000 hour inspection. This was investigated but no fault was found and the entry was cleared on 10 December 2020. The aircraft subsequently completed 2.1 flying hours between the 1,000 hour inspection and the accident. No *'Notes for Crew'* log page was found which recorded this fault. It is possible that the sheet was either lost during the accident or not completed.

Survivability

The cockpit area was badly disrupted during the impact and the pilot hit his head, leading to serious injuries including memory loss. The aerodrome fire service attending the scene reported that the pilot's left arm had been trapped against the side of the aircraft by one of the de-icing fluid containers, which remained full. They reported another container was found in the front footwell in an upright position.

The aerodrome fire service reported they checked the labels on the containers and considered the contents did not present a safety risk based on the information provided. They stated that their response to dangerous goods relied upon identifying the United Nations (UN) number[1] which allowed them to source the relevant information on how to handle the material and any associated risks.

Weight and balance

Instructors and students were provided with laminated weight and balance charts and were required to complete weight and balance calculations prior to each flight. The pilot reported that several of them, including himself, used software to make these calculations. He stated that the use of such programmes was well known within the company and appeared to be accepted by senior managers; the ATO did not agree with that statement.

Footnote

[1] An internationally recognised numbering system assisting in the classification of dangerous goods. See section *Dangerous goods*.

The pilot stated that, due to his loss of memory, he could not recall calculating the weight and balance of the aircraft on the day of the accident. The weight and balance programme on his phone indicated it had been accessed on the day of the accident.

The pilot reported he had taken a flight bag and kneeboard with him. A 'land away kit' had already been stored in the baggage area within the aircraft, but it is not clear where the pilot's bag was placed. The company used a combined standard weight of 5 kg for the land away equipment carried in the baggage area and a pilot's bag. The pilot of G-CTSB would use a weight of 65 kg for himself on his weight and balance calculator. It is not clear what weight he would have used for the de-icing fluid containers had he made a calculation, but a full container weighed 29.1 kg.

The aircraft technical log and refuelling receipts indicate that the aircraft was refuelled the day before the accident, leaving it with full fuel tanks equivalent to 28 US gallons (89 kg). Taxi fuel used in calculations was 1 US gallon (3.04 kg).

Calculations using weights for the pilot of 65 kg, five full containers of de-icing fluid each weighing 29.1 kg, pilot's bag and land away kit of 5 kg, and fuel of 85.82 kg gave a takeoff weight of 1,249.46 kg. This was 60.54 kg under the maximum takeoff weight of 1,310.0 kg. The aircraft C of G arm using the same figures was 2.526 m aft of the datum (2.53 m limit), 0.004 m within limits (Figures 9 and 10).

	Weight (kg)	Arm (m)	Moment (kg.m)
Aircraft basic weight	948	2.474	2345
Pilot	65	2.3	149.5
Front passenger	58.2 (2 x 29.1 containers)	2.3	133.86
Rear seat x 2	87.3 (3 x 29.1 containers)	3.25	283.735
Takeoff fuel	85.96	2.63	226.075
Baggage (standard)	5	3.65	18.25
Total weight	1249.46		3156.420
Centre of gravity	2.526		

Figure 9

Aircraft centre of gravity calculation

Aircraft performance

Using information published by the manufacturer, the aircraft would require 582 m to achieve a screen height of 50 ft in the reported conditions at the time of the accident, at the maximum permissible aircraft takeoff weight of 1,310 kg, and with takeoff flap set. The ground roll at this weight was calculated at 388 m, or just under 22% of the available runway length.

The Aircraft Flight Manual (AFM) gave a rotation speed at the calculated takeoff weight of 67 KIAS. The pilot commented that the DA 40 had a tendency to become airborne when nearing Vr, requiring a forward control input to hold it on the ground and a feeling of 'wheelbarrowing'. On rotation the aircraft's initial climb speed should have been 72 KIAS with a stall speed between 60 - 62 KIAS (Figure 11).

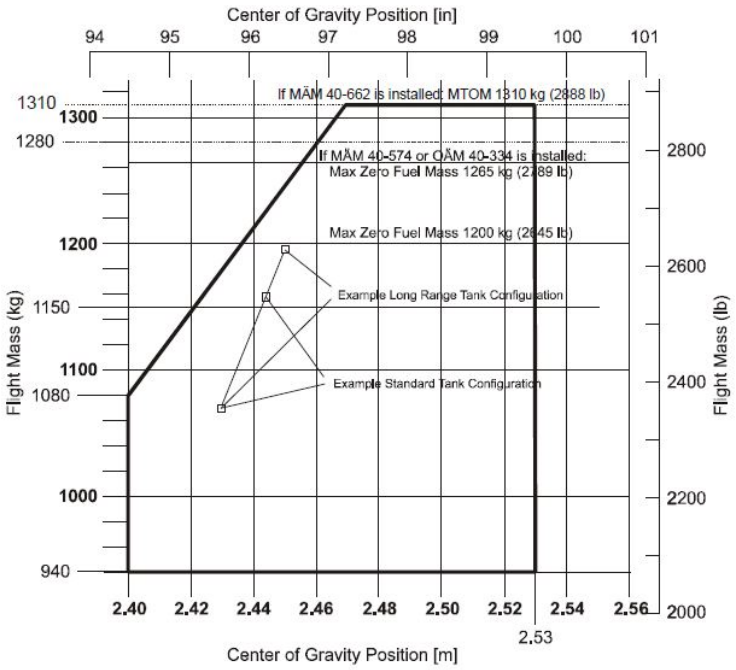

Figure 10

Permissible Centre of Gravity Range

1310 kg (2888 lb)	Bank Angle							
	0°		30°		45°		60°	
Flaps	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
UP	66	63	68	68	74	75	88	89
T/O	62	59	65	63	71	70	84	83
LDG	60	58	63	62	69	69	82	82

1200 kg (2646 lb)	Bank Angle							
	0°		30°		45°		60°	
Flaps	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
UP	64	61	67	66	73	73	86	87
T/O	60	57	64	62	69	68	82	81
LDG	59	56	62	61	68	67	81	80

Figure 11

DA 40 NG stall speeds

Meteorology

The route from Cranfield to Bournemouth at the time of the accident was affected by an occluded front, which was predicted to sit over Bournemouth at about 1200 hrs. The low-level forecast published at 0800 hrs predicted widespread broken or overcast cloud conditions during the morning, with a base at between 1,500 and 2,500 ft amsl. The forecast freezing level was between 3,000 and 5,000 ft amsl.

The METAR for Cranfield at the time of departure indicated that there was broken cloud at 700 ft agl in the area of the airfield and a visibility in excess of 10 km. Other METARs showed an improvement in the cloud base along the proposed route towards Bournemouth to above 2,500 ft.

The METAR for Bournemouth covering the planned arrival time indicated few cloud at 1,500 ft and a visibility in excess of 10 km.

The relevant TAFs predicted some temporary improvement in the weather for Cranfield later in the day and an increase in the cloud base at Bournemouth to 2,500 ft from the middle of the day.

The operator permitted the pilot to fly with a minimum cloud base of 600 ft and a minimum visibility of 1,800 m.

Aerodrome information

Cranfield Airport has a single runway, Runway 03/21. Runway 21 was active at the time of the accident and had a published TODA of 1,799 m.

In December 2018, temporary approval was granted to operate a remote ATC tower: the Cranfield Airport Digital Air Traffic Control Centre (DATCC)[2]. The DATCC was located in a building adjacent to the airport with full operating approval being issued in December 2020. Initially the DATCC was only used part-time but moved to full-time operations in March 2020, due to restrictions imposed by the COVID-19 pandemic. The DATCC provided more space than the conventional tower for the controllers to be separated from one another.

The DATCC used cameras located at the runway mid-point to cover a 360° view of the airfield, which was displayed to controllers on 14 large monitors within the control centre (Figure 12). The introduction of the DATCC had resulted in few operational changes for the controllers, and none concerning the initiation and management of an emergency response. The controllers reported that their view of the runway and taxiway surfaces was better due to the location of the cameras, but it was acknowledged that the image presented could suffer at range due to pixilation. Additionally, weather conditions could not be reliably assessed using the cameras, as there was a tendency for the visibility to look better than it was. Therefore, 'out-of-the-window' meteorological observations were still required.

Current CAA policy on Remote Aerodrome ATS is built on Annex I to EASA Decision 2019/004/R[3]. Chapter 5, paragraph 6 of this document states ICAO philosophy is to record and retain all data used to support the provision of ATS. For Remote Aerodrome ATS, this then extends the recording and retention of data to include elements specific to Remote Aerodrome ATS, including the visual presentation, the binocular functionality and other technical support systems such as aerodrome ambient sound reproduction.

Footnote

[2] In the UK such systems are referred to formally as Remote Aerodrome ATS, and sometimes called digital towers.

[3] Extant EU legislation not currently adopted into UK law.

Figure 12

DATCC Cranfield (used with permission)

ICAO specifies[4] that the image presented to the controller is to be recorded and retained to support accident and incident investigation. This includes the processed data presented to, and used by, controllers to support their decision-making, including both the view of the aerodrome and its vicinity. It also includes any overlaid data and information. In addition, the sensor data, ie the original data, may also be recorded to further support accident and incident investigation.

Current CAA policy for the approval of Remote Aerodrome ATS recommends the recording of visual display units (VDU) and aerodrome ambient sounds, but does not mandate it. However, it is mandated where VDUs use the overlay and/or integration of surveillance data.

The CAA commented that in moving towards the mandating of recording, a number of requirements need to be met. These include setting minimum technical standards for visual display systems, such as the quality of the picture, the screen update rate and the fidelity of recording required. The required length of time and storage arrangements for the data also needs to be established. This has yet to be agreed. The existing technical requirements have been established by Eurocae in ED-240A, *'Minimum Aviation System Performance Standards (MASPS) for Remote Tower Optical Systems'*. That ED only describes the technical requirements for optical systems (cameras) being used. Work is underway to produce ED-240B, which will include much of the data required to be able to establish many of the technical requirements, but it may be some time before this is available. The CAA stated that until this and the other technical requirements are published, it is unable to mandate the recording of non-surveillance visual display systems (VDS).

Footnote

[4] ICAO Annex 11, 6.4.1 and Note 1 to ICAO Doc 4444, 7.1.1.2.1.

Pilot information

Managers, instructors and other staff interviewed during the investigation all described the pilot as an intelligent and enthusiastic individual who was willing to do anything to help. They reported he had a 'can do' attitude and was easy to get on with. The pilot's career in aviation had started in January 2016 when he trained for an ATPL, completing an integrated course in June 2017. He then stopped flying for a year before, in June 2018, undertaking a flying instructor's course with the same school with which he had completed his ATPL training. This school had by then changed ownership and, on completion of the course in August 2018, the pilot began working as an instructor for a subsidiary of the company overseas.

The pilot completed an Instrument Rating Instructor qualification in July 2019 and, in November 2019, transferred to the company's training base at Cranfield Airport as an instructor, being promoted to Deputy Chief Flying Instructor (DCFI) for the base in February 2020. At the time he had approximately 1,000 total flying hours.

The pilot stated that officially he reported to the Chief Flying Instructor (CFI) at Bournemouth. However, he considered that as he generally had more contact with the Head of Training Delivery in managing the day-to-day flying programme, the Head of Training Delivery was effectively his line-manager.

The pilot's training records showed he had undertaken ground training, including stalling, on 24 August 2020. He had also completed a Class Rating Instructor's course in September 2020 for the DA 42. The course included stalling and the course assessment of competence recorded that the exercises were completed to a good standard.

The pilot stated he had received training in dangerous goods as part of his original ATPL qualification. He was aware of the basic markings that dangerous goods carried and, based on the markings on the containers of de-icing fluid, had not considered they constituted dangerous goods. The pilot said he was not aware of the Operations Manual prohibition on carrying dangerous goods or the restriction on carrying cargo. He also stated that had he considered the de-icing fluid may have constituted dangerous goods, he would have sought confirmation on whether he was permitted to transport it.

The pilot recalled on a previous occasion, in either January or February 2020, being given containers of de-icing fluid to transport from Bournemouth to Cranfield by air. He remembered several containers of fluid had already been loaded into the aircraft cabin when he boarded, and that the handles had been tied together with rope.

Organisational information

The ATO was operated by a company providing commercial pilot training through several bases in different countries. At the time of the accident the company operated two flight training bases in the UK, the main one at Bournemouth with an additional base at Cranfield.

The Cranfield base had started operations in July 2019, largely in response to a need to provide extra capacity for the training taking place at Bournemouth. It originally operated a mixed fleet of DA 42 twin-engine and DA 40 NG single-engine aircraft, but in February 2020 the DA 42s were relocated to Bournemouth.

There had been several changes of management posts within the company in the UK in the months preceding the accident.

Flying operations at Bournemouth were overseen by a CFI who had been promoted in early Spring 2020 from his position as DCFI of the DA 42 fleet. His position as DCFI had not been filled at the time of the accident and he was effectively still running the DA 42 training whilst overseeing the rest of the flying operation as CFI. There was also a DCFI at Bournemouth in charge of the DA 40 operation.

The company considered Cranfield was a satellite base to Bournemouth and so had not appointed a CFI, relying instead on a DCFI to run the operation there under the CFI at Bournemouth. In addition, there had been no DCFI in post at Cranfield until three months after the base had opened, the base being run in the interim by managers based at Bournemouth. The first DCFI at Cranfield left the company after two months in post, leaving it vacant again until the appointment in February 2020 of the pilot involved in the accident.

The company stated that the CFI's focus was largely on the bigger operation at Bournemouth Airport, where he was based, rather than operations at Cranfield. This had been influenced by travel restrictions imposed by the COVID-19 pandemic. The company reported an average of 94 students at Bournemouth around the time of the accident, compared with 18 at Cranfield.

The company structure at the time of the accident included a Global Head of Training and a Global CFI. These positions had responsibility for the flying operations being conducted by company bases in the UK, Portugal and New Zealand. Both lived in the UK, living closer to Cranfield than Bournemouth, and each spent time at the Cranfield base using the offices there and occasionally carrying out some training flights. The company considered this added a degree of oversight to the operation at Cranfield in the absence of a CFI based at the location.

The flying programme at both Bournemouth and Cranfield was overseen by the Head of Training Delivery, based at Bournemouth, who had been in post from July 2019. He had previous aviation experience and was familiar with areas of the Operations Manual on which he relied, such as flight time limitations. He was not aware of the prohibition on carrying cargo or dangerous goods and believed that on occasion items had been moved between Bournemouth and Cranfield by air, including aircraft spares and paper for office use.

At the time of the accident there were four members of staff covering ground operations at Cranfield, overseen by a manager based at Bournemouth. There was a basic written operations guide for each base, but these did not contain guidance on carrying cargo or dangerous goods. As operations staff were not required to read the operations manual, they might not have known of the prohibition on carrying cargo or dangerous goods.

After the accident the Global CFI was appointed to oversee the Cranfield base. This manager subsequently left the company and a management re-structure in November 2021 resulted in the Cranfield base once again being managed by a DCFI, the position being filled on an interim basis.

Other information

Stalling

The operator provided briefing information on identifying the stall and incipient stall, as well as the various recovery techniques required.

This information described the symptoms of the incipient stall as:

- High nose
- Low IAS
- Sloppy controls
- Stall warning horn
- Light buffet

It also described the standard stall recovery which, it highlighted, in the circuit was to be commenced at the first sign of a stall.

STANDARD STALL RECOVERY (SSR)

- Control column centrally forwards
- Full power – balance
- Symptoms/Warnings gone hold attitude
- Level wings
- Smoothly select the Vy climb attitude

It noted that there should be very little loss of height in conducting the recovery.

Dangerous goods

Dangerous goods are defined by ICAO as *'articles or substances which are capable of posing a risk to health, safety, property or the environment'*[5] and their carriage by air is subject to specific rules and restrictions.

The International Air Transport Association publishes its Dangerous Goods Regulations annually, classifying dangerous goods by name, UN number, class and packing instructions. The UN number is a four-digit number assigned to each hazardous material by the United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals. It is used to identify a hazardous article or substance, or a particular group of hazardous articles or substances.

Footnote

[5] Annex 18 - The Safe Transport of Dangerous Goods by Air 4th Edition, ICAO, 2011.

Dangerous goods must be properly packaged and clearly labelled with the UN number, classification and shipper's details[6]. Personnel working with dangerous goods must be trained to do so and operators can only transport dangerous goods with regulatory approval. Responsibility for the contents, packing and labelling lies with the shipper.

Operator documents and manuals

The ATO made documents including an Operations Manual available electronically, with pilots required each month to confirm they had read and understood the contents. Its documents policy stated: '*Effective document control is essential in order to maintain a consistent level of standards and practices across the ATO'*.

The Operations Manual contained information on the ATO operating bases in the UK, Portugal and New Zealand, but did not mention the Cranfield base. The company stated that relevant documents specific to Cranfield had been published separately. Some elements of the manual were out of date and the organisation commented that it was not user-friendly and was difficult to interpret.

Part B, Section 2.25 of the Operations Manual stated:

> *'2.25 Carriage of Dangerous Goods and/or Cargo*
>
> *Under no circumstances, may* [ATO] *aircraft carry dangerous goods as defined by the rules (Part CAT, NCO UK ANO, NZ CAR).*
>
> *Cargo carried is limited to aircraft equipment and to personal baggage such as a flight case or overnight bag. Any cargo carried is to be secured so that it cannot present a hazard to the safe conduct of the flight. Cargo carried is to be limited to a minimum practical amount and must be included in the mass and balance calculation.'*

After the accident the operator published Safety Notice 01/2021, dated 22 December 2020. This stressed the importance of being conversant with the contents of the Operations Manual. It also repeated the entry on the carriage of cargo and dangerous goods and stated that de-icing fluid was defined as dangerous goods.

A revision to Safety Notice 01/2021 was published later, stating that it superseded the original version. It contained new information regarding the carriage of cargo and dangerous goods to be added to the Operations Manual and information on the carriage of life rafts and ballast. The reference in the original safety notice to de-icing fluid being considered dangerous goods had been removed.

Although it was a revision, the safety notice had the same title and date of issue as the original version. The operator commented that the original notice had only recently been published and that there would be no confusion caused by the addition of information on the carriage of life rafts and ballast.

Footnote

[6] ICAO Annex 18 The Safe Transport of Dangerous Goods by Air, 4th Ed.

Pilot roster

The pilot usually worked from Monday to Friday, taking two days off over the weekend. On the week of the accident he had worked from Monday to Wednesday. This included, on the Wednesday, an instructional flight at Cranfield followed by a flight to Bournemouth to conduct two progress tests there, before then flying back to Cranfield.

The pilot had then taken two days leave on Thursday and Friday and was due to have two rostered days off over the weekend. On the Thursday he received a private aerobatics lesson but reported he had otherwise rested for the two days of leave. On the Friday evening he received the call asking whether he could undertake the flight tests at Bournemouth the following day.

When interviewed, the pilot stated he did not consider himself fatigued and, had he done so, would have declined the request to work on the Saturday.

Aircraft de-icing

Both the DA 40 NG and DA 42 could be de-iced on the ground using de-icing fluids specified in the relevant Aircraft Manual. This included two branded fluids and AL-5 / DTD406B fluid from any source. AL-5 / DTD406B fluid was also suitable to be used in the DA 42 in-flight de-icing system, being carried in a small tank on the aircraft for this purpose.

The operator used ground de-icing units at Bournemouth which allowed the fluid to be sprayed over an aircraft to remove any frost or ice which may have formed whilst parked.

Cranfield Airport prohibited the use of de-icing fluid for environmental reasons.

Early in 2020 several containers of de-icing fluid had been sent to Cranfield, where they were stored in the flying school's storeroom, inside the building housing the company office. This had been intended for use in the DA 42 aircraft based there. Once these aircraft had relocated from Cranfield the remaining containers were left in the storeroom, with six containers still there at the time of the accident.

During the week before the accident there had been a problem with the de-icing units at Bournemouth which had led to delays in the flying programme. The Head of Training Delivery, whilst not responsible for this aspect of the operation, had checked with the duty operations staff on the day of the accident whether the problem had been resolved. During the conversation, he had been informed that there were only sufficient stocks of de-icing fluid remaining at Bournemouth to allow about two days of further operations. He was also informed that there were still stocks of the fluid remaining at Cranfield, something he was not aware of. Accordingly, the Head of Training Delivery contacted the pilot of G-CTSB to ask him to bring some of the de-icing fluid with him that morning. As this had been at a weekend, the Head of Training Delivery was on a day off at home when he organised this.

De-icing fluid

DTD406b was one of many UK military standards belonging to the Directorate of Technical Development, giving rise to the prefix DTD. All DTD standards became officially obsolete in 1999 although DTD406b is still commonly used as a product standard and name in the aviation industry.

The operator had purchased twenty-four 25 litre containers of Marcon DTD406b de-icing fluid early in 2020, for use both for de-icing aircraft before flight and in the DA 42 in-flight de-icing system. The fluid was purchased direct from a company in Slovakia.

Each container (Figure 13) had a label affixed (Figure 14). The label stated the contents as DTD406b de-icing fluid consisting of 85% ethylene glycol (ethanediol), 5% ethanol or isopropanol, and 10% distilled water. It did not carry a UN number, but did carry markings and wording identifying that gas, mist and vapours should not be inhaled, nor the fluid ingested. It also provided a web address for safety data which, when tried, did not exist.

Figure 13
25 litre container as carried in G-CTSB

The operator held a safety data sheet (SDS) for the de-icing fluid, which referred to it as a combustible liquid and gave a packing number, but no UN number.

The AFM contained the following:

> *'WARNING*
>
> *The approved de-icing fluids are harmful. They are Glycol based with different additives. Refer to the Material Safety Data Sheets for proper handling which are available from the supplier of the de-icing fluid.'*

Figure 14

Label affixed to each container of de-icing fluid

In the original version of Safety Notice 01/2021, dated 22 December 2020 the de-icing fluid was considered dangerous goods. This statement did not appear in the revised version of the notice published shortly afterwards. The operator's report into the accident stated that the de-icing fluid being carried in the aircraft was not classified as dangerous goods.

The information available on the label and SDS was insufficient to enable the CAA to determine whether the de-icing fluid constituted dangerous goods. It considered the information to be incomplete in some areas but stated that the presence of isopropanol would normally classify it as dangerous.

Another established manufacturer of de-icing fluid, when shown the safety data sheet and container labels, commented that it would be unacceptable to list the contents as containing '*either ethanol or isopropanol*' as only actual constituents should be listed. It also commented that *'Plneno 12/2020'*, which appeared on the container labels, suggested the containers were filled in December 2020, although in fact they were purchased some months before.

The AAIB commissioned an independent evaluation of the Marcon DTD406b de-icing fluid, the labelling of the containers and the SDS provided.

The evaluation found the following inconsistencies in the hazard information and labelling.

- The SDS did not identify the de-icing fluid as a flammable liquid constituting dangerous goods for transport or storage. It found, by looking at SDS

documentation for three similar de-icing mixtures, all of which are designated as being flammable, that there were grounds to question the classification of Marcon DTD406b.

- The flashpoint of Marcon DTD406b was stated in the SDS as being in excess of 110°C. Flashpoint is used as a primary indicator in the classification of flammable liquids, with only those with flashpoints below 60°C considered flammable. Given the much lower flashpoints (ca 54°C) for similar de-icing formulations, the stated value appears inconsistent. It was also noted that as Marcon DTD406b formulation may contain either ethanol or propanol-2-ol, it would be expected that the flashpoint would vary between batches depending on which is used.
- Additional documentary evidence showed that dilute (2-5% by volume) solutions of propanol-2-ol in water give rise to flashpoints in the region of 50-65°C, further indicating that the Marcon DTD406b had been incorrectly classified.

The report pointed to Health and Safety Executive (HSE) publication HSG51 *'Storage of Flammable Liquids in Containers'* for guidance. The report also highlighted that even if the de-icing fluid was not considered flammable, it was combustible and, being in plastic containers, would serve to contribute to and spread a fire. As such it suggested the current storage arrangements described required improvement.

In conclusion the report found that, in line with similar de-icing products, Marcon DTD406b should be classified as a flammable liquid and thus be regarded as dangerous goods for the purposes of both transport and storage.

Attempts to contact the manufacturer in Slovakia revealed that Marcon International no longer existed.

ATO internal investigation

The ATO carried out its own investigation after the accident.

Regarding a test carried out with an identical container placed in the front footwell of another DA 40 NG aircraft, it stated:

> *'The investigator did a full and free check of the controls with the container as placed in the footwell. Although he could get full and free movement, it did come up against the lid of the container in the full forward stick position (down elevator). In the investigator's opinion it would not have prevented the pilot from applying enough forward stick to un-stall the aircraft.'*

The report concluded that the accident was probably due to the aft position of the centre of gravity, causing a marked nose-up pitch on takeoff which was then incorrectly handled by the pilot.

The report made several recommendations and stated that safety actions had already begun. These included a review of induction training for operations staff, the introduction of a human factors training programme for all operational staff, and the training and qualification of management personnel. It also included the analysis of an automated tool to calculate mass and balance, and considered additional resources to accelerate an update of the Operations Manual.

CAA inspection

The CAA first conducted an inspection of the operator's Cranfield base on 18 March 2019, prior to it becoming operational. The CAA conducted a further inspection on 18 June 2019, after it opened. Neither inspection raised any major issues.

As part of the AAIB's investigation, the CAA noted the addition of eight training organisations to the ATO over the two years before the accident and continuous management changes across the organisation. On 18 December 2019 the CAA placed the ATO under 'Special Attention' status due to delays in student training and to a lack of resources available for the number of students taken on. This was resolved by 21 July 2021.

An unannounced inspection on 10 March 2020 at Cranfield and a further unannounced inspection at Bournemouth on 7 August 2020 each resulted in three Level 2 findings[7]. These were resolved by 10 June 2020 and 12 October respectively.

The CAA carried out a review of information provided as a result of the accident involving G-CTSB and the initial investigation by the ATO. This resulted in three more Level 2 findings being made on 4 February 2021, related to the carriage of unrestrained dangerous cargo and the effectiveness of management.

For the latter three Level 2 findings the CAA set an initial rectification target date of 5 March 2021, later extended to 12 April 2021 and then to 12 May 2021. The three findings remained open awaiting revision of the Operations Manual. This was originally due on 31 August 2021 and was made available to the CAA until 18 November 2021.

The CAA reported it had continued to monitor the situation at the ATO and an unannounced visit was made to the Cranfield base on 25 November 2021. This was followed by a meeting between the CAA and the ATO on 9 December 2021. It was apparent that the COVID-19 pandemic had resulted in a significant reduction in the demand for training, leading to a further rationalisation of the organisational structure. At both the visit and the meeting the ATO satisfied the CAA that sufficient measures had been put in place to address the three findings of 4 February 2021. The CAA therefore closed these Level 2 findings on 15 December 2021.

Footnote

[7] A Level 2 finding is issued by the CAA when any non-compliance is detected with the applicable requirements of Regulation (EC) No 216/2008 and its Implementing Rules, with the organisation's procedures and manuals or with the terms of an approval or certificate which could lower safety or hazard flight safety.

Analysis

Direct cause

Neither the ATO nor AAIB investigations identified a technical fault with the aircraft that may have caused or contributed to the accident. The aircraft had recently emerged from maintenance and had completed a successful test flight on the day before the accident. Whilst a fuel leak had been identified, this is reported to have been resolved and, on its own, should not have resulted in the accident.

The takeoff run available was more than sufficient for the aircraft weight and prevailing conditions. The aircraft was within both its maximum takeoff weight and centre of gravity limits, although it was close to both. Whilst near these limits, the pilot should have had sufficient skill and experience to operate the aircraft under such conditions if it were capable of being operated normally. The position of the centre of gravity would, however, have exaggerated any nose-up tendency of the aircraft after takeoff.

The AAIB investigation found that during the accident flight the de-icing fluid container placed in an upright position in the front right footwell would have caused a significant restriction in the forward movement of the control stick at takeoff. It is possible that the absence of full and free movement was masked, as contact with the container was probably with the base, rather than the top, of the control stick. This might have given the impression that the stick had reached its natural full forward position, unrestricted by the container.

Whilst the speed of the aircraft at rotation was not determined, based on the pilot's comments it is possible that without adequate control input the aircraft would have become airborne at a speed below the correct rotation speed. The restricted forward movement of the control stick would have made a corrective nose-down pitch input difficult or impossible. This is consistent with the incipient stall indicated by the wing rocking seen on the ATC video.

Whilst the pilot had previously demonstrated his proficiency at stall recovery, the restriction caused by the container would have prevented him reducing the angle of attack to recover. It is possible that the reduction in power recorded on the ECU was a reaction to his inability to otherwise control the high nose-up pitch attitude. Although the wing drop was initially recovered, the wing appears to have remained sufficiently stalled to drop again at the point the pilot appears to have applied power instinctively in a further attempt to recover the situation immediately before impact.

Pre-flight preparation

The pilot used his car journey into Cranfield to check the weather was suitable, and it is not clear how much further pre-flight planning he had done on his arrival at the airport. He was familiar with the route to Bournemouth and had flown it only a few days before the accident. His announced intention to ATC to fly at 4,000 ft would have put the aircraft at an altitude where icing conditions were forecast.

The pilot was not seen to complete the required daily or walk-round checks; equally, the aircraft was not visible from the crew room in the hangar. It is therefore possible that the pilot completed the checks, unseen, in the time between the operations staff member leaving the aircraft and the aircraft being seen to taxi a few minutes later.

Both the Head of Training Delivery and the pilot stated that they had been unaware of the prohibition on carrying cargo and dangerous goods, although it was present in the Operations Manual. They were aware of, or had been involved in, the previous carriage of cargo in a manner that may have suggested to them it was an accepted practice within the company. The information available at the time was insufficient to enable both individuals to determine whether the de-icing fluid constituted dangerous goods. Had relevant information been included in the ground operations guides this might have assisted ground staff to consider whether it was appropriate for the containers to be carried.

It is not clear if or to what extent the pilot carried out a weight and balance check. Calculations made after the accident indicated it was possible to carry five containers in the positions described whilst remaining within the aircraft limits. However, as loaded, they were unsecured and could become a hazard in flight. The presence of the container in the right front footwell ultimately led to the accident.

ATO operations

The pilot had become the manager of the Cranfield base with little relevant experience and the CFI to whom he officially reported was able to provide only limited support. This was partly due to the restrictions presented by the COVID-19 pandemic, but the CFI himself was trying to fulfil a number of roles due to the lack of a replacement in his previous post.

The lack of a separate entry for the Cranfield base in the Operations Manual contrasted with the inclusion of other bases around the world that had no relevance to the UK operation. The ATO itself considered that the Operations Manual was hard to read and out of date. This reduced its value in fulfilling its intended purpose. The standard of the ground operations guides and management of the numbering of the re-published safety notice indicated a lack of rigour in the management of published documents within the ATO.

There was evidence of practices that varied from published procedures, such as the carrying of cargo and the use of privately created, unapproved, software for calculating aircraft weight and balance (it being noted that the operator told the AAIB it did not approve of this).

Technical log

The supplemental *'Notes for crew'* sheet introduced by the ATO within the aircraft documentation was additional to the normal technical log and ADDR requirements. Its stated purpose was to allow an aircraft's fault history to be monitored and to enter technical observations.

The difference between a technical observation and a fault may be subjective and could lead to the sheet being used to avoid grounding an aircraft, in place of an engineer rectifying or deferring a defect formally. Inspection of the technical log indicated incorrect recording or clearing of defects, including where a fault that potentially restricted control movement was entered as an '*acceptable deferred defect*'. In one case a fault deferred until the next SMI was not addressed during the subsequent inspection.

Whilst it is possible the tech sheet for the accident flight was lost because of the accident, it is also possible that it was not completed in the first place.

These circumstances indicate there was not appropriate discipline in the use of technical logs and technical oversight within the ATO.

Marcon DTD406b De-icing fluid

The AAIB investigation sought specialist advice to determine whether Marcon DTD406b should be considered a dangerous good and, whilst the result was not definitive, it is likely the fluid had been inappropriately labelled. This could present a hazard to those using, transporting or storing the fluid. It also presented a hazard to those coming into contact with it in emergency situations such as this accident.

The available information on Marcon DTD406b was such that the ATO had been similarly unsure about the status of the de-icing fluid. Initially it assessed that the fluid constituted dangerous goods, but then changed its view. This appears to be why the information contained in the original safety notice (stating that de-icing fluid should be considered a dangerous good) was removed in the subsequent revision.

As there was already a prohibition on the carriage of cargo, the mislabelling of the fluid should not in itself have led to it being carried. As the pilot stated, it is possible, had the container been clearly labelled as containing dangerous goods, that this might have caused him to seek further advice.

Whilst Marcon DTD406b may no longer be in production, it is important that the status of Marcon DTD406b de-icing fluid is properly established and that any appropriate action is taken. The HSE, in its role overseeing the UK registration, evaluation, authorisation and restriction of chemicals regulations, stated that as the manufacturer no longer existed, no action could be taken to ensure the appropriate labelling of any remaining stocks. It also considered it likely only small amounts, if any, of the product remained in existence. The CAA stated that it will publicise the information regarding Marcon DTD406b contained in this report, to improve awareness should stocks remain.

Data availability

The Garmin G1000 instrumentation system is widely used and its facility to easily record flight and engine data parameters is potentially beneficial. Since the accident the operator stated it has installed SD memory cards in all aircraft where this facility exists. The AAIB has experience of several other recent investigations where operators were either not

aware of this capability or did not use it. This has resulted in important data not being available. Such information may be equally of use to operators in normal circumstances. In order to ensure this capability is more widely known and understood, the following Safety Recommendation is made:

Safety Recommendation 2022-013

It is recommended that the Civil Aviation Authority promote the use of the recording facility on Garmin 1000 instrument systems and its potential benefits.

The fact the DATCC was operational at the time of the accident meant that the video cameras covering the runway were also operational. There was no regulatory requirement for the recordings to be retained, although in this case they were.

Since the accident, Cranfield Airport Air Navigation Service has issued supplementary instruction CIMS-CF-ATC-001-SI 02/21 regarding the impounding of recordings. This exceeds the current CAA regulatory requirement and will result in all video recorded by this digital tower being retained after an accident or serious incident, in addition to RTF and radar recordings.

There are other digital towers operating in the UK and this accident serves to reinforce the importance of ensuring such recordings are retained. It is important that both industry and regulators work together to set and implement the required standards to ensure future systems employ this important development in investigation capability.

Organisational issues

The AAIB investigation found that aspects of the ATO's management created the circumstances in which staff would find ways to address shortcomings in the operation, for example in the conduct and organisation of flights such as this one. This probably contributed to the circumstances of this accident.

A reduction in student numbers due to public health restrictions resulted in further change within the ATO and affected some of the remedial steps taken as a result of the accident.

The operator was granted three extensions to put in place the necessary measures to rectify issues related to the CAA findings resulting from the accident. The CAA closed all three findings seven months after the expiry of the last of these extensions. Closure was provisional on updates to the Operations Manual, and the CAA has stated that it is still not satisfied with the volume of the Operations Manual relevant the ATO's airline academy.

To the extent that safety shortcomings may not have been adequately addressed by previous regulatory inspections, this indicates that suitably resourced and continued regulatory oversight is necessary to ensure the required standards are being met.

Conclusion

The accident was caused by a control restriction preventing sufficient nose down pitch input to properly control the aircraft and avoid stalling. The restriction was caused by an unsecured de-icing fluid container placed in the front right footwell. Four other unsecured containers had been placed on seats and in the rear footwell, with the aircraft near its maximum permitted takeoff weight and aft centre of gravity position.

The de-icing fluid was incorrectly classified by the manufacturer and incorrect safety information was supplied.

Aspects of the approved training organisation's operational management appear to have influenced behaviour in the organisation, contributing to the circumstances of the accident.

Published: 21 July 2022.