ACCIDENT

Aircraft Type and Registration:	Dassault Falcon 20D, G-FRAK
No & Type of Engines:	2 x General Electric CO CF700-2D-2
Year of Manufacture:	1969
Date & Time (UTC):	25 April 2015 at 1650 hrs
Location:	English Channel, approximately 20 nm south of Portland Bill
Type of Flight:	Special operations, target towing
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Wing leading edge torn and dented, winch carrier damaged, target lost at sea
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	64
Commander's Flying Experience:	12,700 hours (of which 9,000 were on type) Last 90 day - 121 hours Last 28 days - 32 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was undertaking target towing operations for a military exercise and was recovering the target whilst flying in an assigned danger area over the English Channel. With the target approximately 40 m from the aircraft, the target winch accelerated rapidly and the target struck the leading edge of the wing before detaching and travelling over the wing. Although, the launcher and the droop leading edge on the wing were damaged, the aircraft landed safely. The target winch is powered by a turbine, and the speed of the turbine is controlled by vent doors. The target winch had oversped due to a fault with the closed limit switch on the vent doors which prevented the doors from closing. The operator and manufacturer have carried out several safety actions as a result of the investigations and one Safety Recommendation is made.

History of the flight

The aircraft departed Bournemouth Airport at 1518 hrs, following a detailed crew briefing, to tow a target over the English Channel for a military exercise in a designated danger area. The target, 2.9 m long and weighing 53 kg, was attached to a winch housed on the pylon under the left wing, at around mid-span. A launcher for the target was attached to the outboard side of the winch (Figure 1).

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Figure 1

Image of an aircraft similar to G-FRAK with a RM30/ASL winch on its left wing and a target attached to the launcher on the outboard side of the winch

There were three crew members on board at the time of the accident: the commander who was pilot flying (PF), the co-pilot, and the Target Tow Officer (TTO), who occupied a rear-facing seat at the front, left-side of the cabin. The TTO had his own winch control panel located on the TTO console (Figure 2) which included various controls and monitors associated with the target-towing operation.

Figure 2

TTO winch control panel

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The target was being towed 4,145 m (13,600 ft) behind and about 1,000 ft below the aircraft, whilst at around 4,250 ft. The target had not been fired at during the exercise and recovery of the target commenced at 1640 hrs, with the aircraft climbing to 4,800 ft, to avoid cloud, while it was turned onto a steady north-easterly heading for the last stages of the recovery. The intention was to depart the Danger Area once the target was recovered and then return to Bournemouth. The minimum total air temperature (TAT) recorded during the recovery was 10.75ºC, whilst the airspeed ranged from 222 to 238 KIAS.

Initially, the target was reeled in at a nominal winch speed of 10 metres per second (m/s), until the last 340 m of cable was reached. At this point, the winch speed automatically reduced to 3 m/s. The TTO monitored this on a digital display (Figure 2) of cable length remaining and by looking out at the vent doors on the front of the winch as they moved from fully open to approximately two thirds open. The slowing of the counter display, along with observed vent door movement and lessening of the airframe vibration caused by the winch, indicated that the wind-in speed had slowed. The TTO switched on a video recorder that received inputs from two underwing cameras and from the aircraft's intercom and radio system. Only the image from the camera selected by the TTO was recorded.

The commander recalled that the wind-in checklist had been completed and that the aircraft was straight and level at 230 KIAS. The TTO verified these parameters using his own monitors and over the intercom he counted down the indicated, remaining cable length at 200 m, 100 m and 60 m. At 60 m the TTO was aware that the winch vibration reduced and he watched the vent doors close further. He checked that the rate of the change of the cable length readout was reducing to approximately 1 m/s. This assured him that, with the winch control switch, set to AUTO, it was now reeling in at its slowest rate (0.76 m/s). In accordance with standard procedures, the TTO selected the control switch to SLOW, as a backup to the automatic mode, and announced this on the intercom. The commander observed that the TTO's cadence was normal and he told the crew that he expected the target to be recovered in one minute and 20 seconds time.

The TTO recalled looking at his monitor of the image from the camera that was directed inboard from the underside of the left wingtip. He saw the winch and approximately 10 m of the cable behind it and he checked that the cable appeared to be stable. He called out "50 TO GO" and "40" as these were shown on the cable length indicator and was about to switch his monitor to the camera beneath the starboard wingtip, which would give him first sight of the target as it approached 35 m to go. The commander prepared to hand over control of the aircraft to the co-pilot, thus allowing the commander to look out on the left side and monitor the final stage of target recovery to the launcher. Before he could do this the TTO declared "STOPPING, STOPPING" and immediately after this all three crew members felt something impact the aircraft.

The TTO noticed that the numbers on the cable length display were reducing quickly and he sensed that the speed the cable was winding in had increased. As he said "STOPPING" his hand moved towards the STOP switch but, before he could move it, the target appeared on the camera monitor, closing rapidly towards the aircraft. He saw and felt it strike the launcher before it disappeared from the camera's view. The co-pilot recalled that the

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autopilot remained engaged and that the aircraft rocked. The TTO informed the pilots that "IT JUST CAME AT US" and that the target detached after hitting the wing. The aircraft's position was noted and the TTO told the commander that he could see damage to the leading edge of the wing.

The aircraft was receiving a Traffic Service from Plymouth Military ATC and the commander informed the controller about the incident. He passed the last known position of the target, which was within the notified danger area, and over the sea in an area that was clear of shipping. After discussion with ATC, the commander declared a PAN and the transponder was set to 7700.

The damage to the leading edge of the left wing appeared to be confined to a portion of the leading edge which drooped when the flaps were moved. The commander elected to continue the flight without extending the flaps as, based on his previous flight test experience of the Falcon 20, he felt this might provide greater stability given the damage.

A low speed handling check was conducted, with the co-pilot reading out the required checklist from the operations manual. The aircraft weighed a little less than 24,000 lb and the reference cards indicated that the V_{REF} for this weight was 142 KIAS. The commander assessed the aircraft's handling qualities at this speed, in a 1,000 ft/min descent, while the TTO observed airbrake deployment and used the underwing cameras to check for normal operation of the landing gear.

The aircraft's handling characteristics appeared normal and all systems indicated correctly. A radar-vectored ILS approach was flown to Runway 26 at Bournemouth, followed by a flapless landing. The aircraft was brought to a halt on the runway at 1708 hrs and the RFFS conducted an external inspection. After establishing that no further signs of damage could be seen, the crew taxied the aircraft to the operator's parking area.

Aircraft information

The Falcon 20 is a business jet with a fin-mounted tail, aft-mounted engines and swept wings. The aircraft had been modified with the installation of pylons for targets to be towed behind the aircraft for military exercises. The winch system was originally designed in the 1980s and is fitted to several different aircraft types, including the Falcon 20. G-FRAK's modifications were originally approved through an FAA Supplementary Type Certificate, which were validated by the UK CAA through an Additional Airworthiness Note (AAN). The system was modified in 1992 to the current standard by FRA modification FD304 and recorded as an addendum to the AAN. These approvals were subsequently passed to the EASA.

When installed, the target winches are mounted on out-board pylons and are hence located away from the engines and tail-plane.

The aircraft has droop leading edges (ie there is no slot formed when the leading edges are drooped) and trailing edge flaps; the control for these devices is such that they deploy together. Under both wing tips there is a video camera facing inboard which capture images of the winch and the area behind and below.

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Target winch information

The aircraft was fitted with a Meggitt RM30/ASL target winch, sometimes referred to as a reeling machine, which was mounted on a pylon under the left wing, at around mid-semi-span, Figure 3. There is a carrier, sometimes called a launcher, attached to the outboard side of the winch by a series of struts, under which the target is stowed.

Figure 3

Images of winch, target, launcher and pylon

At the front of the winch is a turbine and air vent system. The turbine rotates in both directions to provide mechanical power for reeling-in and can dissipate power during reel-out. The air vent system consists of seven radial, servo-activated doors; the greater the opening of the doors the greater the torque delivered to the winch. There are two limit switches: one for doors closed and one for doors fully open. The maintenance for these switches is on-condition.

A tachometer is mounted next to the vent system as part of the system that controls the speed of the turbine by varying the size of the opening of the vent door and hence the speed of the spool.

The centre body contains the spool which can accommodate cable lengths of up to 8,000 m. The torque from the turbine is transmitted to the spool by a series of chains and sprockets.

The afterbody contains a series of pulleys, the brakes system, the shock absorption system and the logic control module. There are several sensors that input the control system. Of note is that if an overspeed is detected by either the tachometer or by a Hall effect sensor, then the winch stops. The overspeed threshold is based on spool rpm, hence when the target is near to the aircraft the spool is full and the overspeed threshold is around 15 m/s..

Inside the body of the launcher is a line cutter; the cable can be cut from either the cockpit or the TTO's control panel.

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Target towing

The CAA issued the operator with a valid certificate of Exemption from Articles 128(1) and 128(4)[1] of the Air Navigation Order 2009. This Exemption permits the operator to carry out deployment and retrieval of target equipment in furtherance of Ministry of Defence contracts, in accord with a CAA-approved Flight Manual Supplement.

This Supplement includes the operation of Falcon 20 aircraft with external pylons and provides details of acceptable stores such as the winch and target carried on the accident flight. Crews for target-tow missions have to be suitably qualified and undergo a structured ground training syllabus followed by a series of target-tow missions under supervision before they fly on routine target-tow sorties.

The commander and TTO on G-FRAK were both experienced in this role. The co-pilot was recently qualified, but this was taken into account when the crew was constituted and during the pre-flight briefing.

The CAA Exemption allows the operator to tow targets up to 10,000 m behind the Falcon 20 but, in UK airspace, the target can only be streamed when inside a notified danger area. The operation can take place in IFR provided the aircraft is in receipt of a Traffic Service, with a proviso that target recovery is not allowed in cloud thick enough to prevent the wingtip cameras from being used to assess target stability within 30 m of the aircraft. The Supplement requires towing operations to be conducted only when the TAT is 5ºC or greater.

The operator presented a safety case to the CAA during the renewal process for target towing exemptions in November 2014. The safety case listed 21 incidents that occurred during target towing operations between 1 January 2012 and 4 November 2014. These incidents included several lightning strikes, occasions where the cable had failed and four events when the target was lost during recovery. In one of the recovery events, the cable was deliberately cut by the crew because of observed target instability. On two other occasions the circuit breaker supplying power to the winch tripped and the cable was then cut. The affected circuit breaker was subsequently upgraded. There were no recorded events during this period when the winch unexpectedly accelerated.

Procedures

A towing aircraft can climb into clear air during the initial phase of target recovery and it may turn with an angle of bank of up to 30º, observing a speed restriction of 200 to 250 KIAS. Once the cable reaches 300 m, the TTO must check that the leader marker lamp is illuminated and that the winch speed slows to around 3 m/s. The video recorder is turned on at this stage.

The TTO counts down the length of cable that remains from his digital display and the PF verifies that the aircraft is straight and level and is being flown between 230 and 250 KIAS.

Footnote

[1] Article 128(1) relates to the towing of articles other than gliders by aircraft and 128(4) stipulates a 150 m maximum tow length for any article that is towed by an aircraft.

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During target streaming, the TTO notes the precise range at which he loses sight of the target, using the furthest camera, so that during recovery he knows what the optimum cable distance is to look through this camera to see the target. Prior to this he uses the nearside camera to monitor the cable for stability. The target can then be wound all the way onto its cradle without stopping but, if there are any signs of instability, the TTO suspends the recovery. If the target cannot be stabilised the cable is cut.

The procedures in place when the accident occurred were for the TTO to watch the vents on the winch when the cable remaining was 60 m and to check that they moved to an almost closed position. At the same time he would sense decreasing vibration level from the winch and he would check the speed of wind-in using the cable length display to ensure that digits then reduced at a rate of approximately 1 m/s. Once this happened, he changed the control switch from AUTO to SLOW. From then on he used the cameras to monitor first the cable and then the target, while he also kept watch on the digits showing cable length remaining. For the final stages of the recovery the pilots changed control if necessary, so that the Pilot Monitoring could look out and watch the target once it came into his line of sight under the wing.

Damage to the aircraft

There was damage to the droop leading edge on the left wing and the struts between the target winch and the launcher. There was also deformation to the pylon where it attached to the wing spar, Figure 4.

Figure 4

Image showing damage to leading edge

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On-board video

There was a recording from the TTO's monitor, which included information from one or other of the two underwing, tip-mounted cameras (as selected by the TTO), plus the crew's dialogue. Using the recording the following timeline of events was generated:

Time on recording (min:sec)	Event
8:25	*"60"* (metres to go) called by TTO
8:39	TTO switches to camera under the left wing
8:40	"*onboard in 1 minute 20 seconds*" call
8:42	*"50 metres to go"* call
8:43	Video evidence that the vent doors start to partially open
8:46 to 8:47	Slight indication of the cable angle, and hence speed, changing faster than normal
8:49	Target comes into view of camera
8:50	The target strikes the wing leading edge, and is propelled over the wing leading edge, and detaches

The target was visible on the camera for only about 1 second. Simple estimates of the speed of the target range from 6 m/s (50 m in 8 seconds) to around 13 m/s (approximately 40 m in 3 seconds), and these are below the overspeed detection speed of around 15 m/s.

Engineering investigation

The video evidence clearly showed a significant increase in cable speed with approximately 40 m of cable left to recover, and the vent doors could be seen approximately half-open.

Functional and wiring continuity checks were made on the target winch system and nothing significant was found.

The limit switches for the vent doors OPEN and doors CLOSED were tested. The CLOSED switch was found to have a variable, high impedance and failed open circuit once during testing. An open circuit prevents the servo motor from operating in the closed direction. If the servo motor was not at the closed limit then an open circuit on the CLOSED switch would have prevented the vent doors from closing and the spool would speed up.

The change of winch speed to slow, at 60 m, would have required the vent doors to be commanded to closed, and shortly afterwards the vent doors would have been opened and closed to control the winch speed to 0.76 m/s. Analysis of the video suggested that the vent doors closed once, opened, but then failed to close.

It was also determined that the limit switches carried a current of up to 4A, and not merely a signal. Whilst the current was approximately that of the specification of the limit switch, it was unclear if this was a factor in the failure of the CLOSED limit switch.

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It was also found that disconnecting the tachometer, simulating an open circuit, would cause the vent doors to open fully and cause an overspeed condition. The manufacturer confirmed that this would occur, but advised that this would cause an overspeed condition and the winch would stop shortly afterwards.

Analysis

The target accelerated during the latter stages of its recovery, causing it to strike the aircraft. The acceleration was probably due to an overspeed of the target winch as a result of the failure of the vent door CLOSED limit switch preventing the vent doors from closing when commanded. The turbine would then have spooled up, increasing the torque and resulting in the winch accelerating.

All the operator's standard procedures appear to have been adhered to prior to the event. The TTO had already ascertained that the winch speed reduced to the minimum and his attention was prioritised towards the camera monitor. He was about to switch to a different view to look for the target and assess its stability but he could not do this at the same time as looking out at the vent doors, the movement of which was difficult to discern on the monitor. He managed to pick up an increased rate of change on the cable remaining indicator while simultaneously dealing with the camera monitor, but the target was already approaching the aircraft quickly. From the video evidence the target was visible on the TTO's monitor for about one second, and therefore it is unreasonable to expect him to have detected this and either to have moved the STOP switch or to have initiated the cable cutter.

Safety action

As a result of this accident the manufacturer of the target system and the operator have carried out several safety actions.

Because the vent door limit switches are on condition items, the winch manufacturer issued a Service Bulletin 094 on 13 May 2015 recommending:

- Replacing the cable harness (which includes the two vent door limit switches) every 10 years.
- Performing a ground test on the winch doors every 20 missions.
- The TTO should check, during recovery, the length display for the 'tens' changing from once per second to the 'units' changing to about once per second, after transition to SLOW.

The operator has carried out the following since the accident:

- Painted markings on the vent doors to enhance visual cues for movement.
- Changed its recovery procedure so that the Pilot Monitoring is seated on the same side as the active winch. His task from 1,000 m of cable remaining, is to observe the vent doors for correct movement.

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- Changed its recovery procedure so that the TTO selects slow with 130 m of cable remaining to be reeled in, rather than at 60 m. This gives the crew more time to detect an erroneous speed condition, and the system more time to detect an overspeed condition.
- Tested the vent door limit switches and introduced recurrent testing every 4 hours of winch running.
- Commenced a door limit switch replacement programme.

During the investigation several possible actions that could prevent reoccurrence were discussed including:

- Introducing an audible indication for target recover speed.
- Introducing limit switches with higher current ratings.
- Changing the distance at which the automatic speed reduces from 3 m/s to 0.75 m/s. Currently this is at 60 m; increasing this to 130 m would be in line with their revised recovery procedure.
- Lowering the overspeed threshold at lower speeds. The overspeed threshold is based on spool rpm, hence when the target is near to the aircraft the spool is full and the overspeed threshold is around 15 m/s. An overspeed threshold of around 10 m/s is more appropriate when the target is close to the aircraft.
- Improving the video imagery available to the TTO either by improving the camera or the monitors, or both.

The target towing system and associated winches are operated on a variety of aircraft throughout the world, and whilst the safety actions taken by the manufacturer and operator have reduced the risk of reoccurrence, there remains a possibility of reoccurrence on aircraft fitted with the RM30 and similar target winches. Therefore the following Safety Recommendation is made:

Safety Recommendation 2015-037

It is recommended that the European Aviation Safety Agency, require that Meggitt Defense Systems Inc review the design, maintenance and operation of the RM30 and similar winches to reduce the possibility of an uncommanded target acceleration during recovery.

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