INCIDENT

Aircraft Type and Registration:	Avro 146-RJ100, G-CFAF
No & Type of Engines:	4 Lycoming LF507-1F Turbofan Engines
Year of Manufacture:	2001
Date & Time (UTC):	1 October 2004 at 1355 hrs
Location:	Near Birmingham Airport, West Midlands
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 80
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	6,500 hours (of which 2,500 were on type) Last 90 days - 60 hours Last 28 days - 20 hours
Information Source:	AAIB Field Investigation

Synopsis

The crew had planned an instrument departure from Birmingham Airport using the aircraft's Flight Management System (FMS), although they believed the Honiley VOR to be out of service. Shortly after takeoff, the crew observed indications showing that the Honiley VOR was serviceable and whilst confirming its identity, inadvertently retracted the flaps instead of the landing gear. When the aircraft was at about 750 ft agl, the stick shaker activated. The commander immediately reduced the pitch attitude and allowed the aircraft to accelerate to a safe speed and the co-pilot raised the landing gear. The remainder of the flight was uneventful.

History of flight

The pilots reported for duty at 0515 hrs at their home base, Birmingham Airport, for a three sector day, at the end of which they were to position back to Birmingham as passengers. The commander was a training captain with the company although no training was planned for the flights that day.

The first return flight went without incident. At Birmingham the pilots returned to the crewroom for a scheduled break before their third and final sector of the day, which was to be flown in a different aircraft. This break was rostered as 2 hours 35 mins but, owing to a delay on the sector back into Birmingham, this was reduced to 2 hours. At about 1300 hrs the pilots boarded the aircraft to carry out the final sector to Stuttgart.

The before flight checks were completed and the crew briefed for a reduced thrust take off, with Flap 18 set, from Runway 15. The ATIS information used by the pilots for the before flight checks and briefing, valid at 1250 hrs, reported that the Honiley VOR was out of service. Just prior to pushback, at about 1440 hrs, clearance was received from ATC for a COWLY 1E departure. This departure required reference to the Honiley VOR, a fact noted by both pilots. However they considered that despite the VOR being out of service they would still be able to continue with the departure using the aircraft's flight management system (FMS), which they believed was certified for use during instrument departures. The aircraft was pushed back from the stand 10 minutes behind schedule although there was no ATC slot time to make for the departure and neither pilot reported feeling under any pressure.

The commander was the handling pilot for this final sector and after a normal engine start the aircraft was taxied and lined up on Runway 15. Once cleared for takeoff the commander advanced the thrust levers and engaged the autothrust. The take-off roll was completed as normal and once the aircraft was airborne both pilots commented to each other that the Honiley VOR appeared to be serviceable, as the beam bar on both their navigation displays had become active. The co-pilot called "positive climb" and the commander instructed him to raise the landing gear. The co-pilot believes that at about this point he pressed the VOR ident button on the communications selector to identify the Honiley beacon and confirm that it was indeed serviceable. As he was doing so he caught sight of the three green landing gear position indicator lights still illuminated which caused him to question the commander as to whether he wanted the gear up. The commander replied he thought he had already ordered it to be raised. Almost immediately the co-pilot advised the commander that he had in fact retracted the flaps by mistake and he reached forward and raised the gear lever.

The commander immediately decreased the pitch in order to accelerate the aircraft at which point the stick shaker briefly activated. The commander could not recall whether or not he increased the thrust to the Take Off and Go Around Maximum (TOGA Max) setting. The commander estimated the aircraft descended by about 100 ft during the acceleration to zero flap speed (V_{FTO}), at which point the commander resumed the climb. The aircraft had remained in visual meteorological conditions at all times and the crew could see the ground throughout; they considered that at no time was there a risk of impact. On resuming the climb the commander called for the autopilot to be engaged and continued on the cleared departure.

The rest of the flight went without incident and the aircraft landed safely at Stuttgart at 1515 hrs. The two pilots then positioned back to Birmingham as passengers on the same aircraft and on returning to the crewroom at about 1925 hrs the commander filed a company air safety report and immediately notified the base manager of the incident.

Stall warning and identification system

The aircraft was fitted with a stall warning and identification system which activates the stick shaker and stick pusher, respectively, in response to the instantaneous sensed angle of attack (AOA). The AOA required to trigger a response varies according to the flap setting and the aircraft's speed.

Throughout the sector of the climb during which the stick shaker was activated in this incident, the airspeed remained below 185 kt. With the flaps set at 18, as they were for this takeoff, the stick shaker would have

operated at 17° AOA and the stick pusher at 25° AOA. With the flaps retracted, however, the stick shaker would have operated at 16° AOA and the stick pusher at an AOA of 22.5° at speeds below 158 kt, reducing linearly to 19.5° at 185 kt.

There was no indication of AOA available to the pilots of this aircraft, therefore a safe margin from the aerodynamic stall was ensured by reference to airspeed. With the aircraft at the weight calculated for this takeoff, the stick shaker would have operated, in 1g flight, at 163 kt and the pusher at 153 kt.

RNAV[1]

The operator had two types of FMS fitted to its RJ100 fleet, the GNS-X and GNLU 910. The aircraft involved in this incident was fitted with the GNLU 910 and at the time the company Flight Operations Manual contained the following information:

> *2.2.1 Flight Management Systems*
>
> *The RJ100 Fleet is fitted with 2 different FMS; the GNS-X and the GNLU 910. Both systems contain Departure and Arrival information within their databases. The GNLU system is certified to P-RNAV standard and may be used for RNAV departures and arrivals without further restriction. The GNS-X system is only certified to B-RNAV standard and may not be used as the sole reference for RNAV departures and arrivals below MSA. If the crew is not able to verify the navigational performance of the GNS-X system using raw navigational information then alternative arrangements should be made. VNAV data is available from both systems but it can only be used as advisory information to help plan climbs and descents.*

Footnote
[1] Area Navigation (B-RNAV meaning Basic and P-RNAV meaning Precision (Area Navigation))

Flight data

Data was successfully downloaded from the aircraft's solid state flight data recorder and its enhanced ground proximity warning system (EGPWS) computer. The cockpit voice recorder had been overwritten.

The flight data for the event is given in Figure 1.

The key points taken from the data are as follows:

- Flap retraction started 5 to 6 seconds after takeoff (defined as weight off wheels from all three gear squat switches) with a Computed Air Speed (CAS) of 157 kt.
- Flap retraction took between 18 and 22 seconds to complete.
- Approximately 23.5 seconds after takeoff the gear status changed from locked down to not locked down.
- Approximately 24 seconds after takeoff, between 0.125 and 1.125 seconds after the landing gear was unlocked from the down position, the stick shake warning was initiated. At this point, the CAS was between 154.5 kt and 155 kt, the altitude was approximately 800 ft AAL, the height was 750 ft AGL, the Angle Of Attack (AOA) was between 15.8 and 16.4 degrees, the flaps were still moving but were at less than 1 degree, the pitch attitude was 16.6 degrees nose up and the wings were within 0.5 degrees of level.
- The stick shaker operated for between 1 and 2 seconds when the design alert criteria were exceeded.

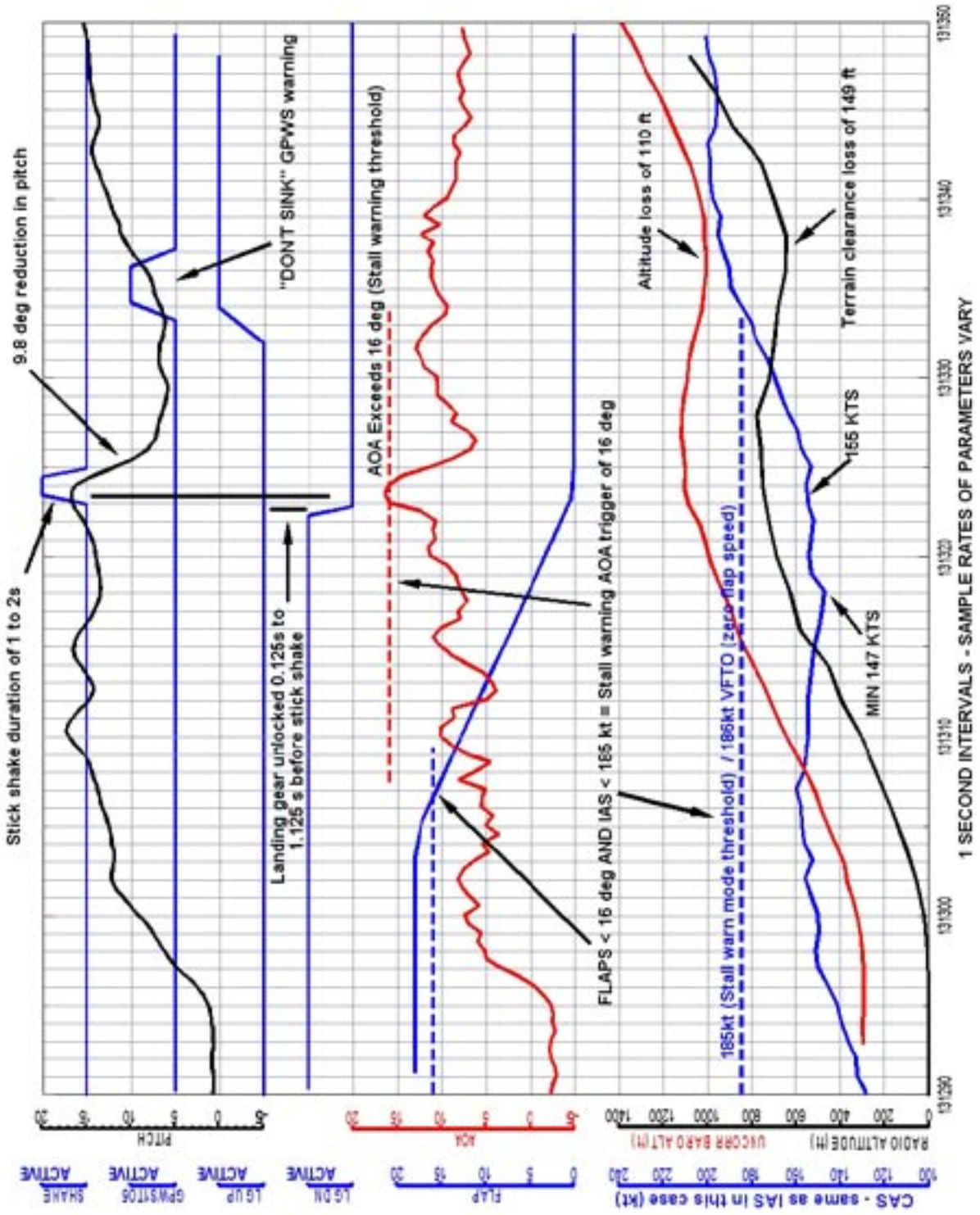

Figure 1

Key flight parameters
(Incident to G-CFAF on 1 October 2004 at Birmingham)

- After the stick shake, the pitch was reduced by 9.8 degrees over a period of approximately 6 seconds.
- Approximately 10 seconds after the onset of the stick shake warning, the aircraft reached the V_{FTO} of 186 kt and the Ground Proximity Warning System (GPWS) issued a mode 3 "Don't Sink" alert.
- The altitude loss during the event was 110 ft, with a reduction in terrain clearance to 624 ft.
- The thrust levers were not moved during the event.
- There were very slight fluctuations in N1% on all four engines during flap retraction.

Analysis

Investigation of this incident has focussed on trying to determine why the co-pilot mistakenly selected the flap lever when attempting to raise the gear. In doing so several significant areas were identified which may have been contributory.

a Fatigue

The co-pilot commented that he had had a particularly busy roster during the month leading up to the incident, flying 87 hours 50 minutes in the previous 28 days. The legal absolute maximum number of flying hours quoted in CAP 371 over the same period is 100 hours. In the same period he had been rostered nine days off, two of which were single days off. In all but one case these days off were preceded by duty periods finishing between 2035 hrs and 2110 hrs (local) and all were followed by duty periods starting between 0600 hrs and 0925 hrs (local). He stated that the week leading up to the incident had been particularly busy with six duty periods, half of which involved early starts.

Whilst his roster conformed to the required legal limitations the co-pilot believed that it had left him generally fatigued. This, in his opinion, was the major cause of the incident and he stated that he had failed to recognise in himself "a level of fatigue that would facilitate such an error".

Both pilots had also intended to eat at the company canteen during their break in the crewroom, however they had not gone straight to the canteen and by the time they did so it had closed. Despite there being opportunities to eat elsewhere within the airport both pilots chose to wait for their crew meal on the third sector. Thus both pilots had not eaten since their crew meals on the first sector of the day. The co-pilot believed that this had amplified the effects of his fatigue.

b Distraction

The ATIS valid at 1250 hrs, which was used by the pilots, stated that the Honiley VOR was out of service. Neither pilot stated that they checked the ATIS for updates prior to their pushback at 1340 hrs, nor did they question ATC about the status of the Honiley VOR when given their clearance. Birmingham Airport ATC have stated that their procedures preclude the issuing of a clearance without the necessary navigational aids being serviceable.

The crew believed that the Honiley VOR was out of service but that they could depart solely by reference to FMS. Both pilots were still sufficiently aware of the Honiley VOR to cause them to comment when the VOR appeared active shortly after rotation, the point at which the beacon is normally received when operating from that particular runway. The co-pilot also stated that he was keen to identify the beacon aurally to ensure that it was indeed serviceable. This involved him selecting the VOR button on his communications

selector box, situated on the right-hand side of the central console, just above the flap lever. It was whilst doing so that he noticed the three green landing gear lights still illuminated and became aware of his error.

The flap lever is situated next to the communications box and is similar in operation to the landing gear lever, ie pull either lever out and then either raise or lower it to raise or lower the flaps/gear. The toggles however are deliberately different in shape. It is possible that in focussing on his need to identify the VOR, when the co-pilot went to raise the landing gear lever he was already sub-consciously directing his hand towards the communications box, which resulted in his hand going to the flap lever instead. Once his hand was on the flap lever, using the same action as he was conditioned to use on the landing gear lever, in this case pulling out and raising the lever, he would have raised the flaps.

Information from the co-pilot and the FDR indicate that the VOR was identified during the initial climb between 100 and 700 ft agl. Whilst no specific reference could be found in the Operations Manual current at the time, this would seem to be an inappropriate point in the departure sequence to be carrying out such a task. Indeed, the Operations Manual stated that even in the event of an engine failure after takeoff, no actions should be taken below 500 ft above airfield level.

c Aircrew Actions

Having realised his mistake the co-pilot immediately informed the commander and raised the landing gear. At this point the flaps were almost fully retracted and the stick shaker operated for between 1-2 seconds. The commander immediately responded by reducing aircraft pitch attitude from 16.6° to 5.8° nose up in order to accelerate the aircraft towards its zero flap speed (V_{FTO}) of 186 kt.

When the stick shaker activated, the aircraft's speed was 155 kt CAS. The performance information in the aircraft Flight Manual states that at the aircraft's reported weight, with wings level and a mid centre of gravity, the stick push would operate at 153 kt IAS (equivalent in this case to CAS). The stick pusher operation, however, would have been triggered by the sensed AOA rather than the airspeed and, due to the effects of power and reduced 'g', the stall speed would have been lowered slightly. Notwithstanding this, it can be seen that the aircraft came within a few knots of a full stall, it's height at the time being only 769 ft agl.

The aircraft took approximately 10 seconds to accelerate to V_{FTO} during which time it lost 110 ft, descending to a terrain clearance of 624 ft. Study of the FDR shows that the thrust levers remained at their reduced thrust take off setting (N1 Flex) throughout the acceleration and that engine power remained constant. The memory items contained within the stall warning drill require power to be increased. Had power been increased from N1 Flex to N1 Ref it would have provided additional thrust approximately equivalent to 300 ft/min rate of climb. This enhanced performance capability could have been used to either reduce the height loss during recovery or to increase the acceleration rate to V_{FTO}.

The pilots were also asked if they had considered lowering the flaps again to their original position when they realised that they had been mistakenly raised. They believed that to do so might have caused the flaps to lock in position and so they had elected to leave them in the UP position. This belief stemmed from previous training received that should the flap lever position be reversed whilst the flaps were still travelling then a FLAP INOP would be annunciated and the flaps would stop moving.

Investigation has revealed that this would only happen should the flap lever remain out of the gate for two or more seconds. In this situation if the flaps have reached either the FLAP 0 or FLAP 33 position when the INOP light illuminates then a ground reset would be required to restore the system. Thus in this incident the crew could have safely reversed the flap selection should they have wished to do so. Whilst the operator stated this information was provided in training no reference could be found relating to it in the Operations Manual. After discussions with the aircraft manufacturer the operator has now included relevant information in the Operations Manual.

RNAV

The pilots believed that as the aircraft was equipped with the GNLU system they would be able to fly the COWLY 1E without the use of the Honiley VOR, referring only to the FMS as their sole means of navigation during the departure.

The operations manual did not make it sufficiently clear that the certification to P-RNAV standard related only to the equipment. At the time of the incident the company had not been given authorisation to operate any of its aircraft to a P-RNAV standard. To do so would require the company putting specific operational requirements into place to ensure that the safety of the operation matched that of the P-RNAV system, principally involving the production and audit of the database used. As such, all aircraft within the operator's fleet were being operated to a B-RNAV standard, under which the pilots must monitor the navigational accuracy of the aircraft's flight path during the departure procedure by reference to primary navigation aids, as stated in JAA Temporary Guidance Leaflet (TGL) No 10:

> *"during the pre-flight planning phase, the availability of the navigation infrastructure, required for the intended operation, including any non-RNAV contingencies, must be confirmed for the period of intended operation."*

If the Honiley VOR had been out of service the pilots would not have been able to monitor the flight path generated by the FMS and, therefore, they should not have accepted the clearance.

A further requirement for an aircraft to carry out a departure by sole reference to RNAV is stated in EASA Series Guidance Material AMC 20-5:

> *"When flying SIDs/STARs the procedure established by the State of the aerodrome has to be authorised/published by that state for the use of GPS. The state of operator/registry (as applicable) has to approve the operator for such operations."*

At the time of this incident only two airports in the UK had a procedure complying with this requirement. This did not include Birmingham Airport.

Comment

Since this incident the operator has published updated information to its crews in an attempt to clarify the restrictions applying to the use of RNAV equipment. This investigation has attempted to understand fully the current restrictions imposed by the CAA and other European States' aviation authorities. This related not only to restrictions imposed on equipment in use but also to restrictions imposed on the operation of such equipment to see how these may have related to this incident. The matter is complex and there were be numerous, and

sometimes conflicting, sources of reference information emerging from both regulators and operators.

The operator is this case is particularly concerned about this situation as countries to which it currently operates are now publishing procedures for use by B-RNAV equipped aircraft when flying above MSA. These rely on navigation by conventional aids when below MSA but then allowing the use of RNAV waypoints when above MSA. This must be seen in context with the current CAA view that B-RNAV is primarily designed for enroute navigation and that no such procedures therefore exist in the UK.

Another serious incident, also under investigation by the AAIB but involving a different operator, has demonstrated that where crews have available to them equipment that they feel capable of operating but are not authorised to do so, there remains a strong temptation for them to make use of such equipment when they feel it is warranted. The matter is made considerably worse where the guidance material is sufficiently vague that crews can apply their own interpretation to it. To cover all the eventualities that crews are likely to encounter on a route network covering numerous countries with different aircraft types and RNAV equipment standards, clear guidance is essential.

Conclusion

The co-pilot mistakenly selected the flap lever when attempting to raise the landing gear after takeoff. The reasons for this are likely to have been the result of a combination of fatigue, distraction and inappropriate task prioritisation.

The dangers of such actions have long been recognised and attempts have been made to alleviate the problem by design. To aid proper recognition of the lever being selected, the flap lever toggle has been designed to represent a flap and the gear lever toggle, a wheel. The levers are also positioned so that the flap lever is easily accessible by both pilots whilst a conscious effort has to be made to reach for the gear lever. Pilots are also trained to take due care when making any selection, especially at critical phases in flight. This message has been further reinforced by the operator in this incident by subsequently issuing instructions to crews on the matter in the Operations Manual.

Occurrences of inappropriate selection on the flight deck, however, remain a recurring problem. Research has revealed numerous similar cases, the most serious being when a fuel switch was mistakenly selected instead of landing flap resulting in an aircraft landing with the wrong flap setting with one of its two engines shut down.

Safety Recommendations

The operator in this incident has been extremely open and co-operative and, as a result, further incidents of inappropriate flap and landing gear lever selections have come to light. It is, however, the belief of the AAIB that this does not point to a particular problem with this operator or aircraft type, but rather an under-reporting of such events by others. This is likely to result from the fact that most mis-selections are quickly recognised and rectified before they lead to a more serious reportable incident. Certainly it is known that one recent serious incident involving the mis-selection of flight controls by another operator went un-reported to the AAIB.

Safety Recommendation 2006-002

It is recommended that the Civil Aviation Authority encourage operators to monitor possible mis-selections of gear and flap levers through established flight data monitoring programs in an attempt to identify the scale and severity of the problem.

Whilst not the prime focus of this investigation the AAIB has become aware of issues surrounding the use of FMS in combination with RNAV. This and other incidents raise concern that there is a lack of clear understanding at all levels within the airline industry about current advances and the permitted use of FMS navigation, especially in the departure and approach phases of flight. Clarity is required, especially on the flight deck, to provide a proper understanding and therefore use of these systems. Only in this way can maximum advantage be made of the technology whilst still operating within current navigational requirements.

Safety Recommendation 2006-003

It is recommended that the Civil Aviation Authority should provide up-to-date guidance to operators regarding the use of FMS for navigation purposes, keeping it under frequent review, and require operators to update their operations manuals in accordance with the latest guidance within a specified period.