INCIDENT

Aircraft Type and Registration:	Avro 146-RJ100, G-CFAE
No & Type of Engines:	4 Lycoming LF507-1F turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	11 January 2006 at 0830 hrs
Location:	Edinburgh
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 98
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nil
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	7,300 hours (of which 65 were on type) Last 90 days - 65 hours Last 28 days - 30 hours
Information Source:	AAIB Field Investigation

Synopsis

Prior to starting the second engine on an aircraft with an unserviceable Auxiliary Power Unit (APU), the engine rpm was not increased on the operating engine, as required. Once the start was initiated, the increased load on the operating generator resulted in the operating engine going into a sub-idle condition. The engine was then over-fuelled and the result was a jet-pipe fire, which was reported to the flight crew by a ground handler. The operating generator also went off-line, leaving the battery as the sole source of electrical power for the aircraft. The cabin crew could not establish communications with the flight crew, who were completing the engine fire drill, and were unable to open the locked cockpit door. With visual indications of an engine fire, the cabin crew initiated an emergency evacuation of the passengers.

The incident was initiated when the procedure for engine start, with the APU not available, was not followed. The investigation revealed a lack of knowledge of the communications system under degraded electrical power. The locked cockpit door contributed to a lack of effective liaison between the flight and cabin crew. Shortly after the incident, the operating company reviewed the procedure for starting the engines stand whenever the APU or its generator was unserviceable. The company also conducted a review of the communications information within the company manuals and the information provided during training. The investigation also highlighted the importance of critically reviewing the effects of security requirements on aircraft safety.

Sequence of events

The crew, comprising two pilots and three cabin attendants, prepared the aircraft for a scheduled departure at 0800 hrs for a flight from Edinburgh Airport to London (City) Airport; the aircraft was parked on Stand 22. The commander had noted from the Technical Log that the APU was unserviceable and that there was a minor problem with one row of passenger seats; he briefed the purser accordingly.

With an external power unit connected, and communications established with the ground handler, the crew obtained clearance from ATC to start No 4 engine and then to pushback off stand. The subsequent start was uneventful and, after selecting No 4 generator 'ON', the ground handler was cleared to disconnect the external power unit. The push back was normal and the aircraft was stopped abeam Stand 23 on a heading of approximately 300º; the surface wind was 240º/17 kt. After the tug was disconnected and clear of the aircraft, the commander was cleared by the ground handler to start engines Nos 3, 2 &1 in turn. The commander initiated the start sequence for No 3 engine but, just after pushing the start button, he realised that he had not increased the rpm for the high-pressure compressor (N2), of the No 4 engine, to 65% as required. Almost immediately, the cockpit lights dimmed and the ground handler called that there was a fire on No 4 engine. Neither pilot could see the No 4 engine from the cockpit. The commander could not later recall if he had actually selected the No 3 fuel lever to 'ON' but was certain that it was now 'OFF' and he also switched the starter master switch to 'OFF'. With another more urgent call from the ground handler that No 4 engine was on fire, the commander selected the No 4 fuel selector to 'OFF' and reached for the No 4 fire handle. However, the first officer already had his hand on it and the commander instructed him to pull the handle and fire both extinguishers. The commander then transmitted a 'MAYDAY' call to ATC, which was immediately acknowledged. There had been no cockpit indications of an engine fire. About this time, the commander saw the 'DOOR' warning light illuminate and heard shouts from the cabin to the effect of "get out". He was aware that the aircraft was now only on battery power and he made no attempt to transmit on the Public Address (PA) system or to call the cabin staff on interphone. The commander manually unlocked the cockpit door, and shortly after the purser entered the flight deck to confirm that the pilots were alright and to tell the commander that all the passengers were now off the aircraft.

Within the cabin, the pre-flight checks had indicated that the 'PA' and interphone systems were fully serviceable. Whilst the engines were being started, the three cabin attendants (CA) had been positioned for the emergency equipment demonstration; the purser was at the front of the cabin, CA No 3 was abeam seat row 6 and CA No 2 was abeam seat row 12; all three were facing to the rear. The demonstration was based on an automatic pre-recording system with the cabin attendants demonstrating the use of the equipment. At about the time that the briefing was covering the donning of life jackets, the attendants were aware of the electrical power going off and the emergency lights illuminating. After about five seconds, the power came back but only for about one second before going off again. The purser attempted to contact the commander by using the interphone but the system seemed to have no power. He then tried to open the cockpit door but was unable to do so. As he then turned back towards the cabin, he saw CA No 3 approaching with some passengers behind, saying that there was a fire and that they had to evacuate.

CA No 3 had noticed a flashing light to his left shortly after the second power failure and was then aware of a

passenger to his left with a "horrified look" on his face. The attendant looked out of the right side of the aircraft and saw a flame stretching about 6 ft from the rear of an engine. The flame appeared to be constant and he watched it for about 1½ seconds before turning and moving towards the front of the cabin. As he did so, he was aware of the sounds of passengers releasing their seat belts. When he reached the purser, he reported that there was a fire on the right side of the aircraft and that they needed to evacuate.

The purser again tried to contact the commander by interphone but there was still no indication of power. He then tried to select 'PA' but, with no light indication on the panel or handset, did not attempt to speak on the system. He then decided to evacuate the aircraft and having checked that the exterior of the left front cabin door appeared clear, he opened that door. The slide operated normally and the purser moved to open the front right door but was reminded by CA No 3 that there was a fire on that side. Both cabin attendants stayed in position and commenced passenger evacuation by the front left slide only. As they were doing so, the purser attempted to contact the rear of the aircraft cabin, using the interphone, but again there was no indication of power. He also considered using one of the two loudhailers, located in the forward overhead lockers, to communicate with the rear of the cabin but concluded that this was unnecessary as the evacuation was proceeding in an efficient manner.

Towards the rear of the aircraft, CA No 2 had moved to her station at the rear to use the communication system as she became aware of passengers getting up and moving forward. She selected both interphone and PA system but could see no indication of any power. Turning back towards the front of the cabin, she then followed the passengers forward, checking as she did so that each row was clear. Initially, she thought that it was a 'Precautionary Rapid Disembarkation' (using the normal exits) but, as she approached the front she became aware that it was an 'Emergency Evacuation'.

Many of the passengers were also unaware that an emergency evacuation was in progress until they had reached the front of the cabin. Then, when they reached the ground, they moved away from the aircraft but were conscious that there was no-one to direct them where to go. By the time that the three cabin attendants had left the aircraft, which was immediately after the final passenger, the purser could see buses approaching and the passengers were directed towards them.

Within the cockpit, the commander confirmed that the AFRS was on its way and then he and the first officer confirmed that the aircraft was empty before leaving it. By the time they had reached the ground, the AFRS was in attendance.

Operational information

Flight crew procedures

Engine start procedures, with no APU available, were detailed in the company Operations Manual and required that all engines should be started on stand using an external AC power supply or that No 4 engine should be started on stand and then the other engines started after pushback. The latter method was the preferred option. If this method was used, the start master switch should be selected 'OFF' after No 4 engine start in order to allow the generator to be brought on line before reselecting start master to 'ON'. Prior to starting the other engines, the APU generator should be selected 'OFF' and No 4 engine N2 selected to 65% until the other engines have started.

Locked cockpit door policy

JAR-OPS 1.1255(c)(1) requires that the cockpit door of aircraft such as G-CFAE:

> *'shall be closed prior to engine start for take-off and will be locked when required by security procedures or the Commander until after engine shut down after landing, except for authorised persons to access or egress in compliance with National Aviation Security Programme.'*

The company Operations Manual required the flight crew to confirm that the flight deck door was secured in accordance with Department for Transport aviation security regulations.

Cabin crew procedures

The Cabin Crew SEP Operations Manual contained the following information relating to evacuation initiation:

> *'Any unusual or abnormal occurrence, either visual, e.g. refuelling truck fire, cabin fire, engine fire, smoke in the cabin, etc, or audible, e.g., noise, vibrations, etc, on any part of the aircraft, internal or external, must be reported to the Captain. However should a Crew Member become aware of a situation which is clearly catastrophic they should initiate an evacuation. He/She shall alert all Crew Members by verbal communication, passenger address, interphone or loud hailer and immediately proceed with an evacuation as soon as the aircraft has stopped.'*
>
> *'The good judgement of cabin crew is imperative in order to evaluate the situation before initiating an evacuation.'*
>
> ***'Unless there is immediate danger Cabin Crew should wait 15 seconds.*** *This period of time allows the Flight Crew to perform shut down checks and establish whether an evacuation is required. If no flight deck command is received after 15 seconds the SCCM (Purser) should investigate by either calling on the interphone or visiting the flight deck.'*
>
> *'Emergency conditions, which would require Cabin Crew to initiate evacuation, include:*
>
> 1. *A self-sustaining aircraft fire*
> 2. *Dense smoke in the cabin*
> 3. *An extreme and unusual aircraft attitude*
> 4. *Any time the passengers are in immediate danger*
> 5. *Unusual sounds prior to stopping (loud scraping or tearing of the aircraft structure)'*

At the time of the incident, there was no information in the Cabin Crew SEP Operations Manual relating to the aircraft internal communications system under degraded electrical conditions. Furthermore, many personnel, including the crew of G-CFAE and some of the company training personnel, were not fully aware of the capabilities of the communication system under these conditions.

Recorded information

Cockpit voice recorder

The solid state cockpit voice recorder (CVR) provided 30 minutes of high quality four-channel recording and two hours of mixed channel recording. On this aircraft, the CVR records when power is available on the aircraft and the avionic master switch is on. The high quality recording covered the five and a half minute period

between the activation of the avionic master switch and the incident. From the recordings, it was evident that before the incident there were good communication channels in the cockpit, between the cockpit and the ground engineer, between the aircraft and ground control and between the cockpit and the cabin.

Initially, ground power was supplied to the aircraft because the APU was inoperative. Permission was granted to start engine No 4 on the stand, push the aircraft back, and then start up the remaining engines using a 'cross start' from engine No 4. The crew followed the engine start checklist and the aircraft was then pushed back. When the pushback had been completed the crew discussed the appropriate N2 setting for an engine being used to start another engine; the value of 65% N2 was agreed. They had a further conversation regarding a takeoff performance calculation. The start of engine No 3 was initiated immediately afterwards; power to the CVR was then lost.

Flight data recorder

The flight data recorder (FDR) was successfully downloaded. The FDR recording of parameters on this type of aircraft is only enabled when the low-pressure compressor speed (N1) from any engine reaches 20%. The recording in this case started only once engine No 4 had started and lasted for just over three and a half minutes. The parameters of interest were engine related. Unfortunately, the useful parameters in this case were limited to N1 values and the Thrust Lever Angles (TLAs). Play in the mechanism used to measure the TLAs meant that the accuracy of these parameters was limited to ±6º.

The relevant recording started at 0807 hrs, with the N1 for engine No 4 reading 26%, the remaining N1s read between 1% and 2%, indicating no power. At this time, the TLA for engine No 4 was at 16° with the other TLAs reading 0º. During the next 40 seconds, the N1 for engine No 4 fluctuated between 24% and 27% and then settled to approximately 26% for a little under three minutes. The Operations Manual stated that, after engine start, the expected stable N1 and N2 values should be 25% and 50% respectively. Given the recorded N1 value, it is considered reasonable to assume that the N2 during this period was in the region of 50%.

Figure 1 shows the FDR recording just prior to the loss of power. The TLA for engine No 4 did not change until after the N1 for engine No 4 started dropping. The FDR recording stopped for less than a second and then restarted briefly, operating for approximately three further seconds before it stopped again.

Within the limitations of data being recorded only once every second, there is no indication that the N1 of engine No 4 was increased above the idle state. Therefore, it is reasonable to conclude that the N2 of engine No 4 was below the required value of 65% when the start of engine No 3 was attempted.

Throughout the recording, the engine control systems were active and not indicating any faults. No indications of fire or overheat were recorded.

ATC recording

A recording was available of Edinburgh Ground radio transmissions on frequency 121.725 MHz. This confirmed that the crew contacted Edinburgh Ground at 0806 hrs to request clearance for a push and start and for clearance to start one engine on stand. ATC approved this request and the next transmission was at 0812.40 hrs when the commander declared a 'MAYDAY' and reported that they had a fire on No 4 engine and that they were evacuating the aircraft.

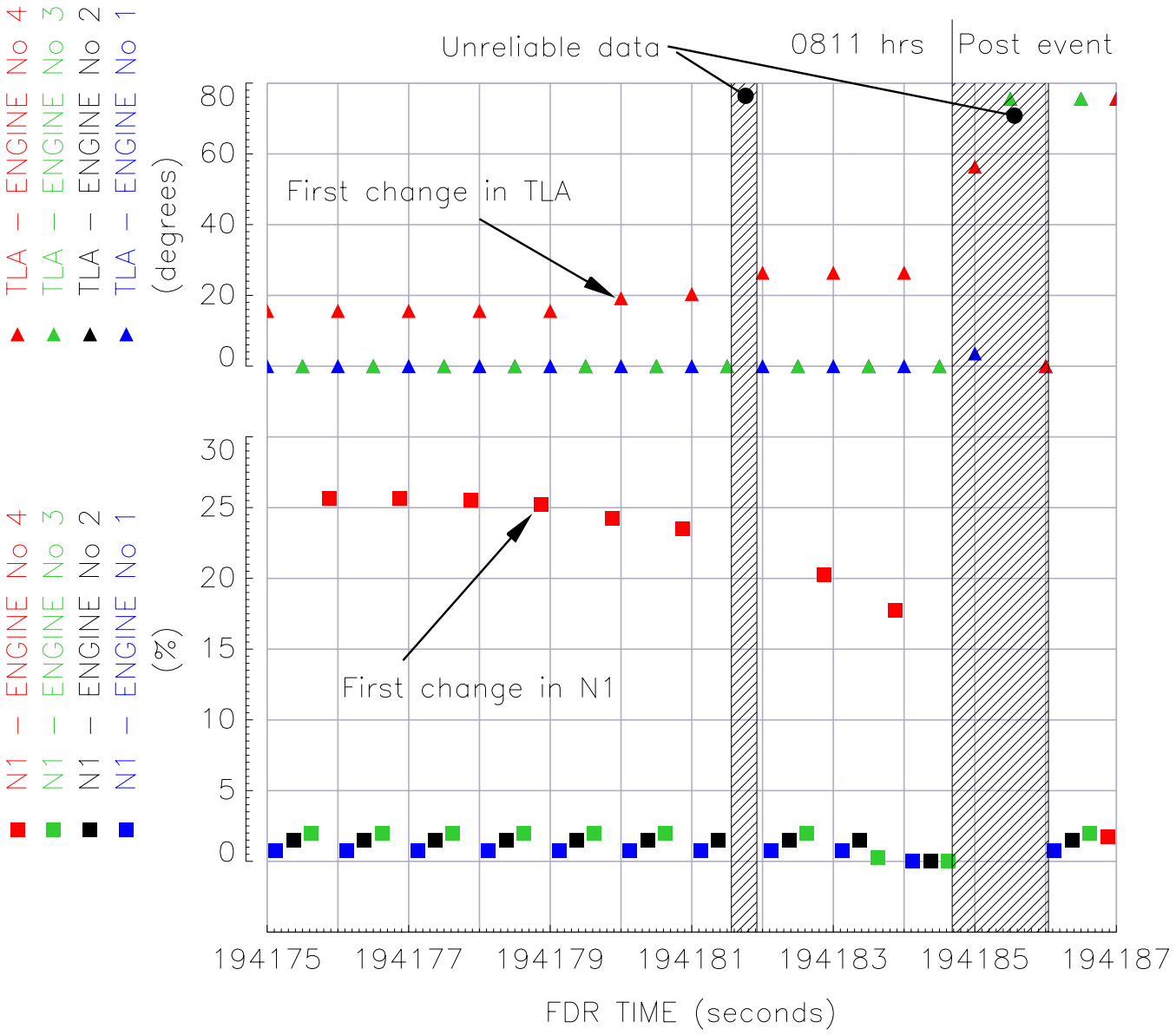

Figure 1

FDR recorded N1 and TLA parameters. Note that TLA No 2 is hidden behind TLA No 3

Then, at 0814.27 hrs, the commander made a further transmission asking ATC to confirm that the AFRS were on the way; this was confirmed by ATC. At 0816, the AFRS asked ATC to relay a request for the crew to contact them on frequency 121.6 MHz but there was no response as the crew had already left the cockpit.

Aircraft information

Electrical generation and engine starting

The aircraft was equipped with four Honeywell LF507-1F turbofan engines and a Sundstrand APU. All of the main engines are fitted with electric starter motors. The two outboard engines (Nos 1 & 4) and the APU are each equipped with an AC generator to supply the aircraft's electrical requirements.

In normal operations, the APU provides the electrical supply to start the main engines. In the event that the APU is inoperative, all of the main engines can be started from a ground electrical power supply, or an outboard engine can be started from the ground power supply and the remaining engines started using a 'cross start' from the operating engine. During a 'cross start' the operating engine provides all of the aircraft's AC electrical power requirements.

The procedure for carrying out a 'cross start' requires the engine providing the electrical supply to be accelerated from idle to 65% N2 speed prior to initiating the starting procedure. This prevents the operating engine being 'dragged' into a sub-idle condition as the load on the generator increases. In that condition, the air flow though the engine would be reduced, resulting in over-fuelling of the engine. Unburnt fuel could then pass out of the combustion chamber and ignite within the engine's turbine resulting in a plume of flame from the exhaust nozzle. At the same time, the increased load on the generator would result in the generator tripping off-line.

Engine examination

Analysis of the aircraft's engine health monitoring system confirmed that the No 4 engine started normally and reached a stabilised ground-idle condition. FDR data confirmed that the engine remained at this speed until the initiation of the No 3 engine start. Immediately after the initiation of the start procedure, the FDR data showed that the engine's N1 speed began to decrease below the normal ground idle level. The forward movement of the No 4 engine thrust lever recorded on the FDR as the N1 speed decreased would have increased the amount of fuel being supplied to the engine. This would have resulted in a corresponding increase in the size of the exhaust flame.

An inspection of the engine immediately after the event confirmed no signs of external fire or damage. Additionally, no fault codes were identified during the download of the engine Full Authority Digital Engine Control memory. After replacement of the fire bottles, a series of engine starts were carried out. No problems were observed during the start of the No 4 engine or the subsequent 'cross starts' of the remaining engines.

Internal communications

The aircraft was fitted with an interphone system that allowed communication between the forward and rear cabin crew stations and the flight deck. A PA facility was also integrated within the communications system to allow broadcasts to be made from any station to the aircraft cabin. Both the forward and rear cabin crew stations were equipped with a handset with an integral push button selector panel and a 'press to talk' button for use during PA broadcasts.

Normal operation

With AC electrical power available, when a cabin crew handset is lifted from its cradle, the integral push button selector panel is illuminated. Pressing a button selects the appropriate mode of operation, and allows the crew station to communicate with the other station and with the cockpit. Each cabin crew station can also operate the PA system by pressing the 'PA' button and then using the 'press to talk' switch when speaking. The flight crew can communicate with the cabin crew on interphone and can broadcast on PA. The system produces an audible chime to alert the cabin crew and flight deck when someone wishes to communicate with them.

Operation on battery power

When operating on battery power, the functions of the internal communication system are severely restricted. The push button selector panel in the cabin crew handsets are no longer illuminated and the push button functions are disabled. However, if the 'push to talk' button is depressed, a PA broadcast can still be made throughout the aircraft cabin. The flight crew also retain the ability to broadcast a PA message from the cockpit and can also speak to either the headset operative or the cabin crew using the interphone. However, the system does not produce an alert 'chime' to indicate that the flight crew wish to communicate, and in the event that a handset is picked up whilst the flight deck are attempting to contact the cabin crew, the limited functionality of the system means that the flight crew are unable to hear any response.

Tests were carried out on several aircraft, which confirmed that the function of G-CFAE's interphone and PA on battery power was 'normal' for a BAe RJ100. The system was compliant with the current EASA certification requirements, CS 25.1423.

Cockpit door

G-CFAE was fitted with a ballistically reinforced cockpit door. When locked, there was no means of opening the door from the passenger cabin. The door can be unlocked from the cockpit either by manually releasing it, which would normally involve a crew member leaving their seat, or through the use of a remote electrically operated release switch at the rear of the centre instrument pedestal. Power for the remote cockpit door release is provided by the aircraft's AC electrical power supply and the loss of AC power renders the remote door release system inoperative.

Neither the operators Minimum Equipment List nor the manufacturers Master Minimum Equipment List allow the aircraft to be dispatched with the remote door release switch inoperative.

Analysis

Flight crew actions

The initial start of No 4 engine was normal but the crew did not then follow the required procedure of increasing the engine N2 to 65% prior to starting the next engine. An engine start with no APU available is not an unusual event and both crew members had previously experienced this procedure. It may be relevant that the crew had become aware of the need to review their takeoff performance calculations just after the discussion about the starting procedure. Nevertheless, such a distraction is not an unusual occurrence on an aircraft and pilots should be aware of the vital importance of systematic checks prior to initiating an action such as an engine start.

The consequences of the incorrect procedure were a loss of normal electrical power and a flame from the exhaust nozzle of No 4 engine. The flight crew were aware of the electrical power degradation and were twice advised by the ground handler that there was a fire on No 4 engine. Although the crew could not see the affected engine and had no cockpit indications of a fire they acted in accordance with their procedures to complete the appropriate drill, relying upon the information provided by the ground handler. Having completed the appropriate actions they then advised ATC of the engine fire. Thereafter, they would normally have initiated liaison with the cabin attendants, but by then the evacuation was underway.

Following this incident, the operating company changed the starting procedures, with effect from 23 March 2006, to require that, with an unserviceable APU or APU

generator, all engines should be started on stand. This directive remained in place until the company had changed the flight deck copy of the working checklist to include the procedure for cross-bleed starts.

Cabin attendant actions

The purser was aware that the APU was unserviceable, but that this involved no safety-related implications. With the No 4 engine started on stand, the cabin attendants commenced the normal passenger briefing during the pushback. During engine starts, it was not unusual to experience electrical power interruptions and none of the attendants were alarmed by the initial loss of electrical power. However, the second and permanent loss of AC electrical power affected the actions of all three cabin attendants. CA No 3, positioned near the centre of the cabin was alerted to an apparent engine fire by the actions of a passenger. When he saw the extent of the flames, which he had never seen before during his flying career, he immediately moved towards the purser to report the situation. His view was that the situation was critical and that an evacuation was required. This view may have been reinforced by the sound of passengers undoing their seat belts and following him. Meanwhile, the purser had tried to contact the flight crew by interphone and then by opening the cockpit door. However, in the extant electrical condition of the aircraft the interphone was severely restricted and the cockpit door could only be opened manually from inside the cockpit. Once CA No 3 had reported the fire, and expressed his view that an evacuation was required, and with no apparent means of contacting the flight crew, the purser had to make the decision to evacuate or not. In a situation where the aircraft was off stand and reportedly on fire, the only practical solution was to commence an evacuation. After checking that the left side of the aircraft was clear of obstacles and with the fire on a right engine, it was sensible to utilise only the left emergency exit at the front of the aircraft. The evacuation appeared to the two attendants to be progressing effectively and the purser considered that the use of the loud hailer was unnecessary. This decision left some passengers and CA No 2, positioned at the rear of the cabin, unaware that an emergency evacuation was taking place. The use of the PA to announce the evacuation was possible but, with no power indication on the handsets, none of the cabin attendants thought that it was operable. Nevertheless, the evacuation proceeded effectively and the passenger cabin was checked to be clear before the cabin crew left the aircraft. Prior to the cabin crew leaving the aircraft, the purser had reported the passenger evacuation to the commander, since the cockpit door had now been opened by one of the pilots.

Following this incident, the operating company changed the procedures for cabin attendants, with effect from 7 March 2006, to require that the safety demonstration would not commence until after the aircraft moved under its own power. In addition, following representations from the company, the Department for Transport issued an aircraft type variation adjusting aviation security measures in respect of locking the flight deck door.

Post evacuation

Once outside the aircraft, there was some confusion amongst the passengers who were not sure what to do. The situation was resolved once the cabin crew had joined them and transportation arrived. While accepting the difficulties of planning for every eventuality, such as an evacuation from an aircraft on the ground whilst not on a stand, there should be some form of guidance. Complications include the facts that the prime responsibility of the cabin crew is to ensure that all the passengers leave the aircraft and that personnel first on the scene, such as the AFRS, normally have other

priorities. Nevertheless, following an incident to a Boeing 777, registration AP-BGL on 1 March 2005, the AAIB made a Safety Recommendation (2005-131) to the CAA to review the advice given in CAP 168 relating to the evacuation of passengers away from the scene of an incident. The CAA accepted this recommendation and amended CAP 168 in May 2006 to include the following wording to highlight the need for effective passenger handling immediately after evacuation.

> *'The Aerodrome Emergency Plan shall include procedures for leading passengers, evacuated from aircraft, to secure areas away from the scene of an incident, and shall ensure that the relevant Aerodrome Emergency Orders suitably address this topic'.*

The CAA has also confirmed that during their routine audits, the Aerodromes Standard Department will ensure that an airport's Emergency Plan addresses this issue.

Communications

While the incident was initiated by the flight crew not following the correct procedures for engine starting, the subsequent evacuation resulted from a lack of communication between the flight and cabin crew. A jet pipe fire can be very alarming, particularly to the occupants of the affected aircraft, and the resultant desire to leave the aircraft can be very strong. Therefore, the commander would need to take an early decision not to evacuate and to communicate this clearly to the cabin occupants. In this incident, the only indication to the flight crew of a serious problem was when they were advised by the ground handler that there was an engine fire. The first priority for the flight crew was then to complete the appropriate actions to contain the fire. However, during this time the purser was unable to establish communications with the commander or to enter the cockpit. While accepting that evacuation may still have been the best option, the lack of effective communications resulted in the flight and cabin crew operating in isolation from each other and, within the cabin there was a further breakdown in communication, effectively isolating the CA No 2 and a number of passengers at the rear of the aircraft. This lack of effective communication resulted from a combination of insufficient knowledge of how the internal communications worked on degraded electrical power and the locked cockpit door.

The current regulations required that the cockpit door be locked before engine start. While this was based on security considerations, there was a need to critically review the consequences of this policy to ensure that appropriate safety considerations were taken into account. Since there was no means of opening the door from the cabin, a full understanding of the capabilities of the communications system was essential. With the lack of information in the Operations Manual, it was not surprising that the cabin attendants were not fully prepared for the situation in which they found themselves. Early in this investigation the operating company was alerted to the correct operating conditions of the internal communications system and has now reviewed and expanded the information available to their flight and cabin crew and included these aspects in the initial and recurrent training of their crews.

Conclusion

The incident was initiated by the flight crew not following the correct procedure for engine start with the APU not available. However, the subsequent loss of normal electrical power resulted in no effective liaison between the flight and cabin crew. The investigation revealed a lack of knowledge regarding the communications system in degraded electrical conditions, which the company has taken action to rectify. The communication difficulties

were compounded by the cockpit door being locked, with no means of operating it from the cabin. The situation required the flight crew to unlock the door or for the cabin and flight crews to establish communications. With the flight crew dealing with the reported engine fire, unlocking of the door was not their first priority. With no communication between the flight and cabin crew, the purser made the correct decision to evacuate the aircraft.

The investigation has highlighted the essential need for any new procedure, such as locking the cockpit door, to be properly evaluated to ensure that security requirements do not have an unduly adverse effect on safety aspects.