TECHNICAL DESCRIPTION OF NO 1 FUEL TANK AND GROUND REFUELLING

1. **Construction.** No 1 tank (See Figure 1) is in the fuselage, outside of the pressure hull, within the wing centre section. The tank (capacity 16000 lb) is divided into 4 cells, each containing a robust, flexible bag tank. The cells are numbered 1 to 4, from front to rear.

![Diagramatic Arrangement of Tank Baffles and Clack Valves](image)

**Figure 1**

2. **Refuelling.** Fuel enters No 1 tank through 2 refuel valves in cell 3 and, when it reaches the level of 2 large clack valves approximately half way up the cell 3 walls, overflows into cells 2 and 4. The only means for fuel to enter cell 1 is through 2 much smaller holes at the bottom of the cell 1/2 dividing wall. Therefore, at high refuel rates, cell 1 will fill more slowly than cells 2, 3, and 4. Refuelling only stops automatically when high-level float switches in cell 1 and cell 4 are both operated - when those cells reach maximum capacity. At normal ground refuelling rates, all 4 cells fill evenly and the float switches cut-off flow when the tank reaches full capacity. However, with high refuel rates, the rear cells will fill, but the high-level float switch in No 1 cell will not be made and the refuel valves will stay open. Therefore, until the fuel reaches the cut off level in No 1 cell, fuel will continue to enter the already full cells 2, 3, and 4. This fuel will overflow into the vent system through a small diameter pipe in the upper rear corners of the No 4 cell. This can happen at the much higher air-to-air (AAR) rates, but can also happen on the ground if the browser pressure is not reduced towards the end of the refuel (see para 5).
3. **Overflow.** Once cells 2, 3 and 4 have filled, the incoming fuel will have only 3 potential exits: into the vent system, through the small diameter pipe in the upper rear corner of cell 4; into cell 1 via the small vent pipe between cells 1 and 2; or, as previously, through the 2 small holes at the bottom of the cell 1/2 dividing wall. The inability of cell 1 to accept fuel at the rate of the other cells, combined with the small diameter of the vent pipes, is likely eventually to cause an increase in pressure in the other cells. The No 1 tank structure is protected from excess pressure by a blow-off valve within No 3 cell. If the refuel valves are not closed by operation of the high-level float switches, the blow-off valve will release any excess pressure through an overflow pipe, which exits the fuselage under the starboard wing root. It appeared possible to the Board that, during AAR, fuel could enter the vent lines and that, subsequently, additional pressure generated in the No 1 tank would lead to the operation of the blow-off valve, resulting in discharge of fuel from the No 1 tank.

4. **Fuel Vent System.** The vent connections from the No 4 cell consist of moulded pipe extensions of the bag tank. These extensions are pulled through holes in the cell wall and are secured by jubilee clips to the outside of the external metal vent pipe. The fuselage fuel vent system is not subject to any pressure test to ensure that it is sealed. Any fuel leaking from either the small bore No 1 tank vent pipe or the aircraft main vent line to No 7 tank starboard, could escape from the vent pipe and flow down into the Rib 1 and No 7 tank dry bay areas.

5. **Ground Refuelling.** It is an established practice amongst Nimrod ground crew that, during the latter stages of refuelling, the delivery pressure is reduced, to prevent fuel entering and spilling from the vent system or tank blow-off valves. The maintenance procedure for refuelling stipulates that refuelling must be stopped on reaching 70,000 lbs and then recommenced at a reduced pressure of 20 psi. This reduced pressure allows the fuel to level out, such that all cells reach full together and thus, refuelling is stopped before overflow occurs. Also, ground refuelling takes place through 2 under-wing couplings which each have a restrictor fitted to limit flow to a maximum of 200 gall/min (730 kg/min). Therefore, the maximum ground refuelling rate is 400 gall/min (1460 kg/min). This is a significantly lower maximum flow rate than during Tristar AAR. A trial at RAF Kinloss revealed that when the delivery pressure is reduced to 20 psi, the delivery rate to No 1 and No 5 tanks together is 154 gall/min (560 kg/min) combined and about 143 gall/min (520 kg/min) to the No 1 tank on its own. A tanker’s booster pump rate can be as high as 302 gall/min (1100 kg/min). Therefore, reducing to tanker booster pumps may not prevent fuel overspill or blow off.

Exhibit 69
ANALYSIS OF THE AIR-TO-AIR REFUEL OF XV230

1. **Introduction.** Hydraulic Analysis Ltd (HAL) was contracted to produce a computer model of the Nimrod No 1 fuel tank, to investigate the reported blow-off and venting phenomena. The model, which reflects the behaviour of fuel within No 1 tank and its associated vent lines, was independently reviewed by QinetiQ (Exhibit 70) to confirm its validity. BAE Systems completed further independent analysis of the No 1 tank and estimated that the No 1 tank blow-off valve will open at flow rates above 1355 kg/min; furthermore BAE Systems confirmed that, as No 1 tank continues to fill the level of fuel in the aft vent line will rise (Exhibit 71). It was accepted that the model did not reflect the full characteristics of No 1 tank, but that the simplification had a minimal affect on the outcomes it was designed to demonstrate. The model’s prime purpose was to determine whether the reported phenomena could have occurred during XV230’s final sortie. Using previous experience of such operations and planning data it was possible to estimate the rates of refuel which would have been experienced by XV230 during the air-to-air (AAR) procedure on 2 Sep 06. This in turn allowed the Board to establish the probable individual tank contents at the end of the refuel sequence and the effect that fuel load might have.

2. **Starting Fuel Load On Ramp.** From the MOD Form 700, prior to its final sortie, XV230 had 81 200 lb of fuel, loaded as follows:

| No 4 Tanks | 19 000 lb |
| No 2 Tanks | 12 000 lb |
| No 3 Tanks | 20 600 lb |
| No 1 Tank  | 15 200 lb |
| No 5 and 6 Tanks | 10 600 lb |
| No 7 Tanks  | 3800 lb   |
| **Total**   | **81 200 lb** |

3. **Fuel Used In Transit To AAR Point.** Planning documents predict that, during the flight to the operational area, the aircraft would use approximately 21 000 lb of fuel and, indeed, this was the figure that the air engineer advised would be required during AAR. The Tristar air engineer reported actually transferring 22 000 lbs of fuel, but a 1000 lb difference between planned and actual fuel onload is not unusual.

4. **Distribution Of Fuel Prior To AAR Contact.** During the transit to the area, fuel would have been used from the No 1, 5, 6, and 7 tanks. This would probably have left the fuel in the aircraft tanks distributed as follows:
Table 2

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Fuel Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No 4 Tanks</td>
<td>19000 lb</td>
</tr>
<tr>
<td>No 2 Tanks</td>
<td>12000 lb</td>
</tr>
<tr>
<td>No 3 Tanks</td>
<td>20000 lb (small amount used in take off)</td>
</tr>
<tr>
<td>No 1 Tank</td>
<td>4000 lb</td>
</tr>
<tr>
<td>No 5 and 6 Tanks</td>
<td>3000 lb / 2000 lb</td>
</tr>
<tr>
<td>No 7 Tanks</td>
<td>Empty</td>
</tr>
<tr>
<td>Total</td>
<td>60000 lb</td>
</tr>
</tbody>
</table>

As can be seen from Table 2, it is considered likely that some fuel would have been left in the No 5 and 6 tanks. Although retention of fuel in this way is not a defined procedure, it has become standard practice during operational uplifts. The restrictor in the No 5 tank (implemented as part of Mod 715 – see Annex M) limits its refuel rate to about 320 lb/min (145 kg/min) and can result in a longitudinal imbalance between No 5 and 6 tanks if not managed correctly. Thus, in order to uplift as much fuel as possible and remain in balance, the air engineer usually manipulates his fuel load before an operational AAR serial, such that, during AAR, tanks 5 and 6 will reach full in unison with the other fuel tanks. Not doing so could result in all other tanks being full, while the No 5 tank continues to fill at approximately the same rate as the aircraft is burning fuel; thus the aircraft could never achieve a maximum uplift. The main caveat that would be applied by the air engineer is that the total of the extra fuel carried in the No 5 and 6 tanks, when added to the aircraft Zero Fuel Weight (ZFW), would not exceed the normal maximum ZFW for the Aircraft of 104000 lb. In this case, with XV230’s ZFW of 99000 lb, up to 5000 lb could be retained in the No 5 and 6 tanks.

5. Sequence Of Uplift. With the fuel distribution as in Table 2, the sequence of refuelling would probably have been as follows:

a. No 1, 2 and 3 tank booster pumps would be switched off – to prevent feeding from a tank being refuelled. All engines would be fed from the No 4 tanks, which are refuelled indirectly via the 4A tank and therefore kept “topped up”.

b. Refuel valves for No 1, 3, 5, 6 and 7 tanks would be opened in addition to the No 4 tank valves. The No 4 tanks valves would then be closed and re-opened as required to maintain their contents between 6000 lb and 6500 lb until the No 1 tank contents reached 8000 lb.

c. When the No 1 tank contents reached 8000 lb, the No 1, 2 and 3 tanks booster pumps would be switched on, thereby transferring fuel feed from No 1 tank to the engines. No 4 tanks’ refuel would be continued until their contents reached 6500 lb.

d. Refuel would then continue until each remaining tank indicated full or was selected off by the air engineer.
6. Final Tank Contents.

a. Assumptions. In order to provide a basis for modelling the refuel of the No 1 tank, the following information was used and assumptions made:

(1) Approximately 2000 lb of fuel would have been consumed by XV230 during the whole of the AAR event, from establishing contact to departing for echelon starboard. Thus, from the 22 000 lb (10 000 kg) total delivered by the tanker, about 20 000 lb (9100 kg) was added to the 60 000 lb carried by XV230 at the start of the refuel.

(2) The tanker did not start at the maximum fuel flow rate; however, pressure was increased quickly, by the initial use of booster pumps, which were then supplemented by first one Carter pump, then the other. The Tristar air engineer reported that fuel was delivered at 2000 kg/min for most of the event, with a relatively rapid reduction in flow rate at the end as first one Carter pump, then the second, was switched off, followed immediately by the booster pumps. An average refuel rate of 200 kg/min was assumed (from Nimrod trials and experience) for each tank refuel valve. Therefore, the total flow rate from the tanker was divided equally amongst all open refuel valves; this gives a progressive increase in flow rate to the No 1 tank as other tanks become full and their valves are closed.

(3) Following the accident to XV230, some further trials were carried out to validate a new refuel procedure that had been put in place (Exhibit 72). Although these trials were completed using only one Carter pump, the refuel rates achieved have been used as a basis for the modelling, with slight increases to the flow rates to account for the second Carter pump used during XV230’s AAR event. Also, since use of the No 7 tanks is not currently permitted, they were empty for the above trial and their refuel rate was estimated by reference to previous air engineer experience.

b. Based on the above assumptions, the following refuel rates were estimated for the No 1 fuel tank:

(1) For the first 2.5 min – 400 kg/min (a low rate as a total of 10 refuel valves were open).

(2) From 2.5 min to 4.5 min – 1200 kg/min (the wing tanks were full, and their refuel rates were added to the No 1 tank; No 6 and 7 tanks were still filling but little fuel was going into the No 5 tank).

(3) From 4.5 min to 5.5 min – No 1 tank increased quickly to either 1600, 1800 or 2000 kg/min (No 7 tanks were full by now, No 5 and 6 tanks were still filling with No 6 tank leading and may have reached longitudinal balance limit).

c. Modelling Results. The HAL model for the No 1 tank was run with the
above input parameters to establish when venting occurs and when the blow-off valve operates. DARU data was used to establish the range of pitch attitude and use this range as an input parameter to the model. The average pitch attitude during this period was 1.4 deg nose up but oscillated between slightly nose down and 3.3 deg nose up. Therefore the modelling process was carried out for each of 1600/1800/2000 kg/min for the final minute and for attitudes of 1, 2 and 3 degrees nose up. Baseline parameters were set at a vent pressure of 0.05 barg, initial contents of 4000 lb in No 1 tank and refuel rates to No 1 tank as noted in sub para 6b.

Table 3

<table>
<thead>
<tr>
<th>Attitude + final minute flow rate</th>
<th>Contents at vent</th>
<th>Time at vent min.sec</th>
<th>Contents at blow off</th>
<th>Time at blow off min.sec</th>
<th>Amount vented at time of blow off</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 deg nose up 1600kg/min</td>
<td>14 900 lb</td>
<td>5.35</td>
<td>15 400 lb</td>
<td>5.46</td>
<td>19 lb</td>
</tr>
<tr>
<td>1 deg nose up 1800kg/min</td>
<td>14 800 lb</td>
<td>5.25</td>
<td>15 400 lb</td>
<td>5.35</td>
<td>18 lb</td>
</tr>
<tr>
<td>1 deg nose up 2000kg/min</td>
<td>14 700 lb</td>
<td>5.16</td>
<td>15 300 lb</td>
<td>5.24</td>
<td>15 lb</td>
</tr>
<tr>
<td>2 deg nose up 1600kg/min</td>
<td>14 400 lb</td>
<td>5.30</td>
<td>15 400 lb</td>
<td>5.48</td>
<td>30 lb</td>
</tr>
<tr>
<td>2 deg nose up 1800kg/min</td>
<td>14 300 lb</td>
<td>5.18</td>
<td>15 300 lb</td>
<td>5.34</td>
<td>26 lb</td>
</tr>
<tr>
<td>2 deg nose up 2000kg/min</td>
<td>14 300 lb</td>
<td>5.12</td>
<td>15 300 lb</td>
<td>5.25</td>
<td>22 lb</td>
</tr>
<tr>
<td>3 deg nose up 1600kg/min</td>
<td>13 800 lb</td>
<td>5.22</td>
<td>15 200 lb</td>
<td>5.49</td>
<td>46 lb</td>
</tr>
<tr>
<td>3 deg nose up 1800kg/min</td>
<td>13 800 lb</td>
<td>5.22</td>
<td>15 200 lb</td>
<td>5.32</td>
<td>37 lb</td>
</tr>
<tr>
<td>3 deg nose up 2000kg/min</td>
<td>13 800 lb</td>
<td>5.03</td>
<td>15 200 lb</td>
<td>5.21</td>
<td>30 lb</td>
</tr>
</tbody>
</table>

d. **Interpretation of Results.** The following conclusions were drawn from the tabulated results:

(1) The model clearly establishes the phenomenon of differential filling of the cells in the No 1 tank leading to the attempted continued refuelling of cells which are already full.

(2) As the aircraft pitch attitude increases, fuel enters the No 4 cell vent line earlier and at a level which is always below 15 000 lb.

(3) For the flow rates and pitch attitudes modelled, venting occurs in a timescale which is consistent with the estimated length of XV230’s refuel
event from mission tape analysis.

(4) The quantity of fuel entering the vent system is considered sufficient, if it leaked out of the vent system, to cause the No 7 tank dry bay fire once ignited.

(5) Operation of the blow-off valve occurs before the tank is filled to capacity and, dependent on pitch attitude, is close to the 15 000 lb level the air engineer was assumed to be aiming for. The time scale for operation of the blow off valve is also consistent with the mission tape timeline.

(6) Operation of the blow-off valve occurs when the connecting vent pipe from No 2 cell to No 1 cell becomes blocked with fuel; this increases the pressure in the No 3 cell to the level at which the blow off valve operates. While QinetiQ has validated the mathematical accuracy of the model, it is recognised that it does not reflect the dynamic nature of fuel within the No 1 tank. Changes in pitch attitude will cause the fuel to move back and forth and the actual level at which the No 2 to No 1 cell vent becomes blocked will vary considerably. Therefore the point at which the blow off valve operates could be earlier than predicted by the static model. It certainly could have been earlier than the 15 000 lb level to which it is believed the air engineer was aiming to fill the No 1 tank.

e. **Final Tank Contents.** Assumed final wing tank contents based on 22 000 lb delivered; 2000 lb burnt in contact; and 20 000 lb uplifted are shown in table 4.

### Table 4

<table>
<thead>
<tr>
<th>Tank</th>
<th>Final contents</th>
<th>Uplift</th>
</tr>
</thead>
<tbody>
<tr>
<td>No 4 tank</td>
<td>19 500 lb</td>
<td>500 lb</td>
</tr>
<tr>
<td>No 2 tank</td>
<td>12 000 lb</td>
<td>0</td>
</tr>
<tr>
<td>No 3 tank</td>
<td>22 000 lb</td>
<td>2000 lb</td>
</tr>
<tr>
<td>Totals</td>
<td>53 500 lb</td>
<td>2500 lb</td>
</tr>
</tbody>
</table>

(1) Therefore 17 500 lb was shared between No 1, 5, 6, and 7 tanks.

(2) No 7 tanks receive 2000 lb each so No 1, 5, and 6 tanks shared 13 500 lb.

(3) No 1 tank started at 4000 lb and rose to 15 000 lb based on statement of advice to FS Davies from other air engineer that blow off could happen at 15 000 lb. Therefore No 1 tank uplifted 11 000 lb.

(4) No 5 and 6 tanks shared remaining 2500 lb. No 5 tank started at 3000 lb and probably uplifted only 200 lb; this is based on the Board’s best interpretation of intercom, which is incomplete at this point. Possible reasons for the No 5 tank not appearing to fill are a refuel valve which
failed to open, or a gauge error. It is considered unlikely that this lack of filling is due to a fuel leak, as such a fuel leak would have affected other tank contents as well as No 5 tank and there is no reference to such a fault on the intercom.

(5) No 6 tank started at about 2000 lb and ended at about 4000 lb; it probably stopped before full because longitudinal balance limit with No 5 tank reached.
FLYING CONTROL AND HYDRAULIC SYSTEMS

1. **General Description.** The Nimrod possesses 4 hydraulic systems, specifically designed to provide system redundancy. The 2 principal systems, powered by engine-driven pumps are known as the Blue and Green systems. A DC electrical pump supplies the Yellow system, while an AC electrical pump supplies the Red system. The 4 systems supply hydraulic pressure at 2000 to 2500 psi to activate flying controls, landing gear, nosewheel steering, air brakes, flaps, wheel brakes and bomb doors, as shown in Figure 1.

![Hydraulic System Services Diagram]

*Figure 1 – Hydraulic System Services*
2. **Flying Controls.** Each of the flying control surfaces is moved by a hydraulically powered servodyne. Two servodynes are attached to each surface but only one is selected at any one time. The primary servodyne is powered by the Blue hydraulic system and the secondary is powered by the Green system with a back up supply from the Yellow system. Both Blue and Green systems include backing accumulators which provide a reserve of pressure in the event of system failure to allow time for a smooth changeover to the alternate system. The No 7 tank dry bay houses a number of key hydraulic pipes running from the Rib 1 area through the right hand (RH) sealing panel in the rear spar. The pipes originate in the hydraulic equipment compartment and route along the starboard Rib1 area, into the dry bay, from where they take one of 3 routes: into the aileron bay, across the bomb bay towards the port side, or into the starboard wing. They are constructed of steel with aluminium alloy unions. The hydraulic pipes that run through the RH sealing panel include:

a. Blue system pressure.
b. Blue system return.
c. Green system pressure.
d. Green system return.

Therefore, a fire in the No 7 tank dry bay has the potential to cause the failure of both the Blue and Green hydraulic systems. Furthermore, a fire in the aileron bay or close to it could disrupt the Yellow system.

3. **Loss of Flying Controls.** The Board suspects that in the aircraft's final moments, it became uncontrollable as hydraulic power to the flying control servodynes was lost. Once a servodyne loses all hydraulic power it locks in its last selected position so the aircraft would continue to fly in its last trimmed attitude until upset by turbulence or a change in the centre of gravity. A possible explanation of events would be as follows.

a. Due to the co-location of the pressure pipes for the Blue and Green system in the RH sealing panel, it is probable that those 2 systems would fail at approximately the same time. The crew would get a warning that Blue pressure had been lost and attempt to change flying controls to the Green system. A further warning would alert them to the loss of the Green system. This would prompt a change of flying controls to the Yellow system.

b. It is unlikely that the Yellow system was serviceable at this stage; the wiring to the electric motor which drives the pump was probably compromised and the fire had probably caused leaks in the system's pipes.

c. As noted above, the Blue and Green systems have backing accumulators that provide a reserve of pressure to allow time for changing to an alternative system. The inlet from the Blue aileron and rudder backing accumulator to the primary servodyne is on the starboard side of the aileron bay. This is also likely to have been compromised by the fire. Pressure to the elevator from the Blue elevator backing accumulator could still have been available as this section of pipe work is away from
the fire area. The Board considers that, in view of the multiple emergencies, the crew would have had insufficient time to restore elevator control using the remaining pressure in the Blue backing accumulator. The non-return valve (NRV) for the green backing accumulator is also located in the aileron bay and a leak downstream of this would allow any reserve of Green backing pressure to leak away.

3. **Summary.** Each of the drills that select a change of flying control system would take a finite time to action. There was no mention of hydraulic failure on the mission tape before data was lost about 2 minutes before impact. Therefore, the crew had only a short time to action the basic drills as their situation rapidly deteriorated.
DESCRIPTION OF CREW ACTIONS DURING THE EMERGENCY

1. **Introduction.** Nimrod crews practise regularly the drills required of the crew of XV230 on 2 Sep. Pilots and air engineers rehearse a wide range of emergencies during sorties in the flight deck dynamic simulator. Additionally, rear crews are involved in the airborne practise of drills to deal with cabin fires and warnings caused by fire or hydraulic mist in the Nimrod’s underfloor bays. However, the events of 2 Sep imposed a series of concurrent emergencies on Crew 3, in a manner which would have tested any crew. There are lessons to be identified for all multi-engine aircrew from the difficulties they faced.

2. **Disposition of the Crew Prior to the Emergency.** During AAR, both beam lookout positions would normally be occupied, although the AEO\(^1\) can undertake the starboard lookout duties from his window. Analysis of the mission tape suggests that R1\(^2\) was in the port beam, with S2 either in the starboard beam, or at acoustics. All other crew members would have been at their stations and the 2 would have been close to an oxygen point, as briefed by the captain, but not necessarily seated.

3. **Actions When Warning Received.** Once the bomb bay fire and elevator bay warnings were received, the AEO would have moved to the galley to prepare to operate the fire extinguisher connected to the underfloor bays. The S2 probably made his way rearwards to assist the S1 secure the passengers; the wet team are normally allocated responsibility for conducting underfloor drills. He and the ESM\(^3\) operator would then probably have assisted S1 don the portable oxygen set in view of the smoke entering the cabin from the underfloor bays; as smoke was already entering the aircraft there would have been no need for S1 to physically check the aileron bay before donning the portable oxygen. It is unlikely that anyone would have had time to go to the rear door and collect the second portable oxygen set before the aircraft depressurised. Although the captain ordered the initial actions for the bomb bay fire drill, there is no evidence that these were carried out, probably because the crew focussed on the aileron bay smoke, which may have appeared the greater threat; however, it is possible that the record of these actions could lie on a section of damaged mission tape. The crew would have been aware that the natural airflow under the cabin floor is from the aileron bay rearwards to the elevator bay and deduced that the smoke rising from the latter bay had probably originated in the aileron bay. This was initially reported from ESM as “it’s in the rear bay there’s smoke coming from it”. The captain ordered the co-pilot onto oxygen once the smoke was reported and continued to fly the aircraft while the co-pilot donned his oxygen mask.

4. **Depressurisation.** Within a minute of the initial warnings the air engineer and pilot simultaneously reported the depressurisation of the cabin, probably marking the breach of the aileron bay wall. This complicated matters by restricting the movement of all crewmembers;

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\(^1\) Air Electronics Officer.
\(^2\) The mission crew operators are divided into 2 teams: the radar (dry) team (R1-R4) and the acoustic/sonar (wet) team (S1-S2)
\(^3\) Electronic Support Measures.
each had to remain in a seat using an available oxygen mask, with freedom of movement restricted by the length of their oxygen hose. This is probably another reason why no report is ever offered from the bomb bay periscope. Also, the R1, even if he had left his seat to go rearwards to assist, would now have to return to the port beam to the vacant oxygen mask in that position. Furthermore, the S2 would have had to return to acoustics to use his oxygen mask. A request is heard from the AEO asking the air engineer to deploy the passenger oxygen masks because of the depressurisation. This should have happened automatically as the cabin altitude rose through 12 000 ft but they can also be deployed individually by manually releasing a catch on the mask stowage. However, at this point the air engineer’s intercom failed, presumably in the transition from headset to mask and nothing is heard from him for the next one minute. It is unclear whether he had just lost the microphone facility and could hear but not speak or if he was totally out of contact. It is possible that he actioned items from the underfloor and depressurisation drills during this period and deploying the passenger masks would have been one of these actions. It is also possible that the crew may have moved the passengers forward into the tactical area to use vacant crew masks (AEO and S1) as this would have taken them away from the seat of the perceived threat in the aileron bay. At 1113:10 hrs the AEO states ‘everyone’s on oxygen down the back apart from 2 the passengers are getting theirs on now’. About 40 seconds after the depressurisation, everyone was on oxygen.

5. **Loss of the Air Engineer’s Intercom.** The air engineer’s role at this stage of an emergency is to take control of the drills by reading from the Flight Reference Cards (FRCs). In particular, he coordinates the underfloor drills with the AEO, to ensure the fire extinguisher is fired at the correct moment into the correct bay. He is also responsible for using his knowledge of the aircraft systems to analyse the situation and provide advice to the captain about the cause of the problem and any potential solutions. That process had begun when he tried to relate the overheated Supplementary Cooling Pack (SCP) with the bomb bay and elevator bay warnings. Given that he was off intercom for one minute, it is considered unlikely that his intercom problem was a simple switch or connection problem as these can be resolved quickly. The air engineer probably used hand signals to make the captain aware that his intercom had failed. Realising the gap in the normal process, the captain nominated the checklist reader to read the drills, but this did not happen. Therefore, loss of the air engineer’s intercom was a major disruption to the smooth flow of the drills and any analysis of the problem. However, on this occasion, the nature and location of the fire were such that no action the crew could have taken would have stopped the fire.

6. **The Pilots.** During this time, the pilots had been swapping flying control of the aircraft as they each donned their oxygen masks in turn, finishing with the captain taking control back and confirming that all his crew were on oxygen. The navigators were requested to confirm the destination selected on the navigation system and replied that Kandahar was selected. The captain would then have used this information to refine his descent point; he had continued the turn towards Kandahar which had been initiated after leaving the tanker. A MAYDAY was transmitted as the captain initiated a descent for Kandahar airfield. The pilots would now have focussed on correct positioning of the aircraft to arrive at Kandahar at the correct height and speed to ensure a landing as quickly as possible. As noted in the main report, a simulator reconstruction showed that this had been successful up to one minute before the crash.
7. No other reports were heard, or requested, of the external situation although the captain does begin to say ‘and just look at...’ at 1114:56 hrs. Bearing in mind that the rest of the crew were involved in fighting the immediate threat in the aileron bay, or were restricted to their crew stations by the need to remain on oxygen, this is understandable. No mention is made by the pilots of the starboard engines, although the captain asks for the ‘nearest suitable’; this is possibly a request for an airfield closer than Kandahar - but there were no other airfields available. The air engineer returned to intercom shortly after this, but makes no reference to the ; this may indicate he could neither hear nor speak when off intercom. The mission tape contains no further reference to the external fire, although it is possible that reference exists in one of the damaged or missing areas of tape; nonetheless, the crew continued to focus on the immediate threat from the fire in the underfloor bay.

8. **Summary.** Crew 3 were faced with an extremely difficult, rapidly developing and complex situation. As noted in the main report, nothing they could have done would have altered the outcome. However, in dealing with those emergencies they were aware of, the crew did all that could be expected. They acted in a coordinated and logical way, adhering to standard procedures and adapting them to overcome the additional difficulties of the depressurisation and the air engineer’s intercom failure. The main lessons identified are as follows.

a. It is vital that all available information is gleaned from all sources. It is possible that if the starboard lookout position had been occupied for longer, the crew would have been aware earlier that the source of the fire was external to the pressure hull. In other circumstances, early acquisition of such information might assist fault diagnosis. However, the Board considers that in the case of XV230 this not would have affected the outcome in any way.

b. Continuity of communication is crucial. The reliability of all intercom systems is essential; however, faults will occur and practice for this eventuality should be included in regular training. Nonetheless, the Board considers that the temporary loss of the air engineer’s intercom had no affect on the loss of XV230.

c. Dealing with an internal cabin fire, when the crew need to be on oxygen because of fumes, has long been recognised as a difficult situation; the 3 portable oxygen sets are the only means by which a crew member can remain mobile and take an extinguisher to a fire which is not adjacent to a crew station. A similar situation occurred on XV230 but the restriction in movement was caused by the depressurisation. The QinetiQ combustion study stated that the aileron bay wall was breached in a predictably short time scale. It is likely that an internal fire in an underfloor bay will have similar consequences. Therefore, it may be prudent to consider the provision of
additional portable oxygen sets. Also, their location should be given careful
consideration, as only one set is currently located centrally and in easy reach of crew.

d. The crew of XV230 looked after their passengers and ensured they were on
oxygen. However, a larger number of passengers would have imposed a higher
supervisory load on the crew as they attempted to deal with the aircraft fire; it is not
unusual to ferry larger numbers of ground crew between operational locations in the
aircraft. In particular no crew member has a long enough oxygen hose to supervise the
correct donning of the passengers’ masks in the ordnance area.
LIST OF EXHIBITS

<table>
<thead>
<tr>
<th>Exhibit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mission tape transcription Version 12 (23 Feb 06)</td>
</tr>
<tr>
<td>2</td>
<td>C2 agency transcript (SECRET US/UK EYES ONLY)</td>
</tr>
<tr>
<td>3</td>
<td>Statement of (CSAR Team) (13 Sep 06) provided to SIB Kandahar</td>
</tr>
<tr>
<td>4a</td>
<td>Statement of 34 Sqn RAF (15 Feb 07)</td>
</tr>
<tr>
<td>4b</td>
<td>Answers by to further questions from BOI</td>
</tr>
<tr>
<td>5</td>
<td>No 120 Sqn Crew 3 Combat Ready Status (1 Aug 06)</td>
</tr>
<tr>
<td>6</td>
<td>Flight Authorisation Sheet and Flying Times (02 Sep 06)</td>
</tr>
<tr>
<td>7</td>
<td>DARU transcription</td>
</tr>
<tr>
<td>8</td>
<td>Kandahar ATC Transcript (2 Sep 06)</td>
</tr>
<tr>
<td>9a</td>
<td>Statement of, The Royal Canadian Dragoons (2 Feb 07)</td>
</tr>
<tr>
<td>9b</td>
<td>Supplementary answers from, The Royal Canadian Dragoons</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Photographs (held in separate folder)</td>
</tr>
<tr>
<td>12a</td>
<td>AAIB Final Report into the Accident to a Nimrod MR2 XV230 (EW/D2006/09/1)</td>
</tr>
<tr>
<td>12b</td>
<td>Supplementary letter to AAIB Final Report</td>
</tr>
<tr>
<td>13</td>
<td>Notes taken during discussion with (Pilot of Predator) (7 Sep 06) (Member of initial deployment from Kandahar) (7 Sep 06 and 8 Sep 06)</td>
</tr>
<tr>
<td>14</td>
<td>Statements by</td>
</tr>
<tr>
<td>15</td>
<td>XV230 MOD Form 705 – Flight Servicing Certificate (Sheet 90)</td>
</tr>
<tr>
<td>16</td>
<td>Weather Forecast for South West Afghanistan (1 Sep 06 to 3 Sep 06)</td>
</tr>
<tr>
<td>17</td>
<td>Aviation Pathology Report - Number 10 of 2006 (2 Feb 07)</td>
</tr>
<tr>
<td>18</td>
<td>Confirmation of Aircraft Categorisation Signal (ABA HIL KQY K3H 061200Z/Dec06)</td>
</tr>
<tr>
<td>19</td>
<td>Book value of XV230 and Cost of Role Equipment Lost on XV230</td>
</tr>
<tr>
<td>20</td>
<td>Third Party Civilian Claims – Afghanistan (Civil secretariat HQ PRT Lashkargah letter LKG/J8 23 Feb 07)</td>
</tr>
<tr>
<td>21</td>
<td>Loss of Protectively Marked material, V&amp;A Equipment and Other Items aboard Nimrod XV230 (11 Dec 06)</td>
</tr>
<tr>
<td>22</td>
<td>Missing items of PM material presumed lost in crash of XV230 Nimrod (KIN/310/2/06/06/Sy (2 Oct 06 and 11 Oct 06)</td>
</tr>
<tr>
<td>23</td>
<td>Addendum 1 to BAE SYSTEMS Report (MBU-DEF-R-NIM-SC-0976 Issue 2, 2 Sep 04)</td>
</tr>
<tr>
<td>24</td>
<td>XV227 Hot Air Duct Failure – Requirement for Leak Detection System (IPT letter DLO/(strike)/wvt/512752/21/227 5 Jul 06)</td>
</tr>
<tr>
<td>25</td>
<td>Letter for IPT following meeting on 20 Feb (DLO/STRIKE/WYT/512752/21/230 15 Mar 07)</td>
</tr>
<tr>
<td>26</td>
<td>Nimrod R1 XV249 Report Post Fuel Leak Investigations May-Jul 99 (518/402/1/1/Eng 23 Jul 99)</td>
</tr>
<tr>
<td>27</td>
<td>Kandahar ATC Radar Tape Corruption (18 Feb 07)</td>
</tr>
<tr>
<td>Exhibit</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>28</td>
<td>RN Flight Safety and Accident Investigation Centre - Accident Report 3/06</td>
</tr>
<tr>
<td>29</td>
<td>Drawing of clam shell doors by (7 Sep 06)</td>
</tr>
<tr>
<td>30</td>
<td>QinetiQ Combustion Analysis of Nimrod MR2 XV230 Accident (QINETIQ/05/01833/26 Mar 07)</td>
</tr>
<tr>
<td>32</td>
<td>JAP 100A-01, Chap 5.13 [Ageing Aircraft Audit]</td>
</tr>
<tr>
<td>33</td>
<td>Further clarification of BOI questions – FRS Coupling Maintenance Policy (IPT Letter DLO/STRIKE/WYT/512752/21/230 10 Jan 07)</td>
</tr>
<tr>
<td>35</td>
<td>Nimrod XV249 Persistent Fuel Leaks (BAe letter PJ/P/AF/402 26 Jan 99)</td>
</tr>
<tr>
<td>36</td>
<td>NAEDIT Task Report 917/06 Provide Operating Temperatures of Hot Air Pipes and Temp Control Amplifiers (NAEDIT/1505/06/917TASK Dec 06 and 8 Jan 07)</td>
</tr>
<tr>
<td>37</td>
<td>Extracts from Nimrod Safety Case (print outs from Cassandra database 8 Feb 07)</td>
</tr>
<tr>
<td>38</td>
<td>Ground Incident Report KIN/142/00 XV229 (11 Dec 00)</td>
</tr>
<tr>
<td>39</td>
<td>Extracts from AP101B-0503-3A, Chap 41-20, Figures 7 and 8 [Showing unidentified couplings and seals]</td>
</tr>
<tr>
<td>40</td>
<td>Reconstruction of MOD Form 703 and 704 for XV230</td>
</tr>
<tr>
<td>41</td>
<td>IPT Response to BOI Query – AQ0971 Acoustic System (DLO(Strike)(Wyt)/5/8/5/2 Feb 07)</td>
</tr>
<tr>
<td>42</td>
<td>Ground Security at – 1/2 Sep 06 (Miss: Engagement Report) (7 Nov 06)</td>
</tr>
<tr>
<td>43</td>
<td>DSTL letter from Post Flight Report (extract)</td>
</tr>
<tr>
<td>44</td>
<td>Post Flight Report (extract)</td>
</tr>
<tr>
<td>45</td>
<td>Serious Fault Signal XV255 fuel pipe leak in Rib 1 (4 Sep 06)</td>
</tr>
<tr>
<td>46</td>
<td>Serious Fault Signal XV236 corroded pipe in Rib 1 (22 Nov 06)</td>
</tr>
<tr>
<td>47</td>
<td>Eaton Aerospace Investigation Report [Fuel Seal Analysis] (L1/06/044 12 Jan 07 and 19 Mar 07)</td>
</tr>
<tr>
<td>48</td>
<td>Fuel Pipe Pressure Test Report (AWN/NIM/1538, Issue 1 Mar 07)</td>
</tr>
<tr>
<td>49</td>
<td>Annex I to AP101B-0500 Topic 2(R)1, Leaflet 013 [Fuel Leaks]</td>
</tr>
<tr>
<td>50</td>
<td>Request for Information – Nimrod R1 AAR Fuel Leaks (51S/402/9/Eng 30 Jan 07)</td>
</tr>
<tr>
<td>51</td>
<td>Observed Pressure Surges Nimrod R1 (51S/4/2/Air 22 Feb 07)</td>
</tr>
<tr>
<td>52</td>
<td>Details of Nitrogen Purge Gauging System [Pressure Transducer and Gauge] (BAE SYSTEMS letter 07/0006/CL dated 31 Jan 07)</td>
</tr>
<tr>
<td>53</td>
<td>AP101B-0503-15A, Book 1, Part 2, Chap 11 [90% call] AL18</td>
</tr>
<tr>
<td>54b</td>
<td>BAE SYSTEMS advice on Definition of Assumed Fuel Pipe Pressures (07/0007/CL 5 Feb 07)</td>
</tr>
<tr>
<td>55</td>
<td>Extract from Tristar K Mk1 Release Trials 1986-1989, Nimrod Annex (TM1485 Nov 89)</td>
</tr>
<tr>
<td>56</td>
<td>Ground Incident Report KIN 59/06 XV252 (31 Oct 06)</td>
</tr>
<tr>
<td>57</td>
<td>Nimrod AEW Mk3 Operating Instructions for AAR (BAe Report HAS-MPP-</td>
</tr>
<tr>
<td>Exhibit</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>59</td>
<td>BAES Memo – Advice on Tank 1 and 5 BOV Dye Testing in Flight (07/0010/CL 20 Feb 07)</td>
</tr>
<tr>
<td>60</td>
<td>BAES airflow modelling diagrams</td>
</tr>
<tr>
<td>61</td>
<td>API101B-0503-15A, Book 3, Part 2, Chap 11 [AAR Refuelling]</td>
</tr>
<tr>
<td>62</td>
<td>Identification of Electrical Supplies in Rib 1 and No 7 Tank Dry Bay</td>
</tr>
<tr>
<td>63</td>
<td>Integral Thermal Insulating Scheme for High Temperature Stainless Steel Ducts (Specification DHA/567 13 Sep 67)</td>
</tr>
<tr>
<td>64</td>
<td>NiMS/NLS Dry Bay Water Test (KIN/900/30/Eng 16 Feb 07)</td>
</tr>
<tr>
<td>65</td>
<td>Decent Profile Study – Nimrod Dynamic Simulator (OC STANEVAL Report W:\STANEVAL\Boss\CORRESPONDANCE SIMULATOR TRIAL run 1 – JR Report.doc 26 Sep 06)</td>
</tr>
<tr>
<td>66</td>
<td>Nimrod AEW Mk3 Integrity of Tanks 1 and 5 Blow Off during AAR (BAe Report HAS-MPP-F-AEW-0063 15 Mar 85)</td>
</tr>
<tr>
<td>67</td>
<td>Nimrod AEW Mk3 AAR System (BAe Report HAS-MPP-F-AEW-0065 May 85)</td>
</tr>
<tr>
<td>68</td>
<td>Nimrod R1 – Airframe Strength [Structural Problems related to AAR] (BAe Letter 15 Jan 87)</td>
</tr>
<tr>
<td>69</td>
<td>Nimrod MR2 Refuel System Tests (2 Feb 07)</td>
</tr>
<tr>
<td>70</td>
<td>QinetIQ/HAL report on No 1 Tank Modelling</td>
</tr>
<tr>
<td>71</td>
<td>Nimrod No 1 Tank Back Pressure Analysis (BAE SYSTEMS letter MBSY/MA/050307/1 1 Mar 07)</td>
</tr>
<tr>
<td>72</td>
<td>STANEVAL Tristar Refuel Test (6 Feb 07)</td>
</tr>
<tr>
<td>73</td>
<td>Notes on telephone call with Royal Canadian Dragoons</td>
</tr>
<tr>
<td>74a</td>
<td>Photograph of the relative size of the Nimrod as seen by Harrier GR7 pilot</td>
</tr>
<tr>
<td>74b</td>
<td>Photography of the relative size and aspect of the Nimrod as seen by Royal Canadian Dragoons</td>
</tr>
<tr>
<td>75</td>
<td>Declaration of Design and Performance for FRS Couplings</td>
</tr>
<tr>
<td>76</td>
<td>Board’s record of the meeting with DLO, Eaton Aerospace and BAE Systems (29 Mar 07)</td>
</tr>
<tr>
<td>78</td>
<td>JAP 100A-01 Chap 5.4, Para 10 [Corrective Maintenance Data Gathering and Analysis]</td>
</tr>
<tr>
<td>79</td>
<td>QinetIQ Report on DARU and Mission Tape analysis (EPT ESR 01446 2 Apr 07)</td>
</tr>
<tr>
<td>80</td>
<td>BAE Systems Review of Nimrod Accident History (MBU-DEF-R-NIM-SC-0676 2 Sep 04)</td>
</tr>
<tr>
<td>81</td>
<td>Extract from Cassandra database quoting Nimrod IPT’s Final approval of baseline Hazard Log (DLO(Strike)(WYT)512725/27/1/Nimrod 1 Feb 05)</td>
</tr>
<tr>
<td>82a</td>
<td>Initial Statement by Harrier GR7 Pilot (3 Sep 06)</td>
</tr>
<tr>
<td>82b</td>
<td>Human Factors Report by HFI Ltd (9 Oct 06)</td>
</tr>
<tr>
<td>82c</td>
<td>Diagram concerning the last minutes of VIGIL 34</td>
</tr>
<tr>
<td>83a</td>
<td>Tristar Mission Report (2 Sep 06)</td>
</tr>
<tr>
<td>83b</td>
<td>Statement by Tristar Captain (7 Sep 06)</td>
</tr>
<tr>
<td>83c</td>
<td>Statement by Tristar Air Engineer (undated)</td>
</tr>
<tr>
<td>83d</td>
<td>Statement by Tristar Co-Pilot (undated)</td>
</tr>
<tr>
<td>Witness</td>
<td>Details</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Air Traffic Controller, Kandahar Air Base</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Duty Briefing Officer, DOB</td>
</tr>
<tr>
<td>7</td>
<td>Engineering Officer, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>8</td>
<td>Aircraft Ground Engineer, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>9</td>
<td>Propulsion Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>10</td>
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</tr>
<tr>
<td>11</td>
<td>Avionics Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>12</td>
<td>Armour Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>13</td>
<td>Radar Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>14</td>
<td>Airframe Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>15</td>
<td>Aircraft Ground Engineer, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>16</td>
<td>Propulsion Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>17</td>
<td>Airframe Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>18</td>
<td>Electrical Tradesman, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>19</td>
<td>DOB, 902 EAW, DOB</td>
</tr>
<tr>
<td>20</td>
<td>RAF Police (Special Investigator), DOB Security Officer, DOB</td>
</tr>
<tr>
<td>21</td>
<td>SNCO IC DOB Medical Centre, DOB</td>
</tr>
<tr>
<td>Witness</td>
<td>Details</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>22</td>
<td>Air Engineer, Crew, 120 Squadron, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>23</td>
<td>Captain, Crew, 120 Squadron, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>24</td>
<td>Pilot, Crew, Nimrod Detachment, DOB</td>
</tr>
<tr>
<td>25</td>
<td>Engineering Officer, 216 Squadron Detachment, DOB</td>
</tr>
<tr>
<td>26</td>
<td>Air Engineer, 216 Squadron Detachment, DOB</td>
</tr>
<tr>
<td>27</td>
<td>Pilot, IV(AC) Squadron, RAF Cottesmore</td>
</tr>
<tr>
<td>28</td>
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</tr>
<tr>
<td>29</td>
<td>Captain, 216 Squadron, RAF Brize Norton</td>
</tr>
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</tr>
<tr>
<td>31</td>
<td>Air Engineer, 216 Squadron, RAF Brize Norton</td>
</tr>
<tr>
<td>32</td>
<td>Operations Wing, RAF Kinloss</td>
</tr>
<tr>
<td>33</td>
<td>Nimrod Line Squadron, RAF Kinloss</td>
</tr>
<tr>
<td>34</td>
<td>Logistics Support Wing and Depth Support Manager, Nimrod IPT, RAF Kinloss</td>
</tr>
<tr>
<td>35</td>
<td>Propulsion Trade Specialist, Nimrod Line Squadron, RAF Kinloss</td>
</tr>
<tr>
<td>36</td>
<td>STANEVAL Air Engineer, RAF Kinloss</td>
</tr>
<tr>
<td>37</td>
<td>Sqn Cdr A Sqn, The Royal Canadian Dragoon, CFB Petawawa</td>
</tr>
<tr>
<td>38</td>
<td>Driver, The Royal Canadian Dragoons, CFB Petawawa</td>
</tr>
</tbody>
</table>
## GLOSSARY

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>Ageing aircraft audit</td>
</tr>
<tr>
<td>AAIB</td>
<td>Air Accident Investigation Branch</td>
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<td>AAR</td>
<td>Air-to-air refuelling</td>
</tr>
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<td>ac</td>
<td>Alternating current</td>
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<td>ACM</td>
<td>Aircrew manual</td>
</tr>
<tr>
<td>ADR</td>
<td>Accident data recorder</td>
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<tr>
<td>AEW3</td>
<td>Nimrod airborne early warning aircraft mark 3</td>
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<tr>
<td>agl</td>
<td>Above ground level (height)</td>
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<td>ALARP</td>
<td>As low as reasonably possible</td>
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<tr>
<td>AMM</td>
<td>Aircraft maintenance manual</td>
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<tr>
<td>amsl</td>
<td>Above mean sea level (height)</td>
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<td>APU</td>
<td>Auxiliary power unit</td>
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<td>ARC</td>
<td>Air refuelling and communications</td>
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<tr>
<td>ATC</td>
<td>Air traffic control</td>
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<tr>
<td>BAe</td>
<td>British Aerospace</td>
</tr>
<tr>
<td>barg</td>
<td>Bar gravity</td>
</tr>
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<td>BLEVE</td>
<td>Boiling liquid expanding vapour explosion</td>
</tr>
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<td>BTM</td>
<td>Bromotrifluoromethane</td>
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<td>C2</td>
<td>Command and control</td>
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<td>CAU</td>
<td>Cold air unit</td>
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<td>CO</td>
<td>Commanding Officer</td>
</tr>
<tr>
<td>CR</td>
<td>Combat ready</td>
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<tr>
<td>CR(A)</td>
<td>Combat ready (advanced)</td>
</tr>
<tr>
<td>DARU</td>
<td>Data acquisition and recording unit (ADR)</td>
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<td>DASC</td>
<td>Defence Aviation Safety Centre</td>
</tr>
<tr>
<td>dc</td>
<td>Direct current</td>
</tr>
<tr>
<td>Def Stan</td>
<td>Defence standard</td>
</tr>
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<td>deg</td>
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</tr>
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<td>DLO</td>
<td>Defence Logistics Organisation</td>
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<td>DPP</td>
<td>Declaration of Design and Performance</td>
</tr>
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<td>DOB</td>
<td>Deployed operating base</td>
</tr>
<tr>
<td>EAW</td>
<td>Expeditionary Air Wing</td>
</tr>
<tr>
<td>ESM</td>
<td>Electronic support measures</td>
</tr>
<tr>
<td>F700</td>
<td>MOD Form 700 – aircraft maintenance log</td>
</tr>
<tr>
<td>F703</td>
<td>MOD Form 703 – limitation log</td>
</tr>
<tr>
<td>F704</td>
<td>MOD Form 704 – acceptable deferred defects log</td>
</tr>
<tr>
<td>fg hrs</td>
<td>Flying hours</td>
</tr>
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<td>FI</td>
<td>Fatigue index</td>
</tr>
<tr>
<td>FL</td>
<td>Flight level (height in thousands of feet in ISA)</td>
</tr>
<tr>
<td>FIt Lt</td>
<td>Flight Lieutenant</td>
</tr>
</tbody>
</table>
**Abbreviation** | **Meaning**  
--- | ---  
FRC | Flight reference cards  
FS | Flight Sergeant  
gall | Gallon  
GPS | Global positioning system  
GR7 | Harrier ground attack and reconnaissance aircraft mark 7  
HAL | Hydraulic Analysis Ltd  
HP | High pressure  
IED | Improvised explosive device  
IPT | Integrated project team  
ISA | International standard atmosphere  
JAP | Joint air publication  
kg | Kilogramme  
lb | Pounds  
LCpl | Lance Corporal  
LH | Left hand  
LP | Low pressure  
min | Minute  
MLEP | Mini life extension programme  
MOD | Ministry of Defence  
Mod | Modification  
MR2 | Nimrod maritime reconnaissance aircraft mark 2  
MRA4 | Nimrod maritime reconnaissance and attack aircraft mark 4  
NM | Nautical mile  
NRV | Non return valve  
NSC | Nimrod safety case  
OC | Officer Commanding  
OSD | Out of service date  
PRSOV | Pressure reducing and shut-off valve  
psi | Pounds per square inch  
QNH | Airfield altimeter pressure setting  
R1 | Nimrod reconnaissance aircraft mark 1  
R1 | Crew position radar 1  
RAF Regt | Royal Air Force Regiment  
RCD | The Royal Canadian Dragoons  
RH | Right hand  
RN | Royal Navy  
RPM | Revolutions per minute  
SAM | Surface-to-air missile  
SAR | Search and rescue  
SCP | Secondary cooling pack  
sec | Seconds  
Sgt | Sergeant  
SOP | Standard operating procedure  
Sqn | Squadron  
Sqn Ldr | Squadron Leader  
UAV | Unmanned air vehicle  
UOR | Urgent operational requirement
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>USAF</td>
<td>United States Air Force</td>
</tr>
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<td>USN</td>
<td>United States Navy</td>
</tr>
<tr>
<td>ZFW</td>
<td>Zero fuel weight</td>
</tr>
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<td>ZULU</td>
<td>Greenwich mean time/universal time</td>
</tr>
</tbody>
</table>