RECOMMENDATIONS

16. Policy.

a. I agree that an operational safety review of the fuel system is required. This is under way and is the means by which any changes that are appropriate to the maintenance policy will be determined. I agree that the existing limitation on the use of cross-feed and SCP should remain in place until the aircraft goes out of service. An operational safety review of remaining elements of the hot air system will be considered with this in mind.

b. Action is already in hand to add aircraft systems to ageing aircraft audits.

c. Action is in hand to scope a review of the Nimrod Safety Case. I agree that, should this work be undertaken, then it should include full participation by experienced air and ground crews.

17. Fuel System.

a. Evidence presented to the BOI by MOD materials specialists showed that we have insufficient information about seal degradation with age to indicate that regular replacement of seals would ensure with any certainty that leaks would be prevented.

b. The original design certification for the seals did not include a finite installed life. Additionally, no engineering evidence is cited nor benefits quantified to justify a finite installed life, nor is any explanation offered for how this could ensure with certainty that leakages would thereby be eradicated. It is generally accepted that the rate of degradation (and hence installed performance) is dependent on many variables, the combination of which is often unique to each particular application or even location in an aircraft. However, the Nimrod Integrated Project Team has already tasked QinetiQ with undertaking a detailed independent investigation into seal degradation characteristics for Nimrod. A wider review has also been initiated through MOD specialists covering elastomeric seals fitted to all fleets.

c. I agree that, as a precautionary measure, pending the completion of the fuel system safety analysis, inspections of the integrity of fuel systems and ignition sources between port and starboard Rib 3 should be undertaken. Regular visual zonal inspections between port and starboard Rib 3 with the fuel system pressurised are already underway.

d. Given the importance of the installed environment on installed seal life, I do not accept that Eaton Aerospace (the manufacturers of the seals) are the appropriate source of expert advice on this matter. Further investigations have been put in hand
with QinetiQ materials experts and the aircraft Design Authority (BAE SYSTEMS) to determine whether further changes to the seal inspection regime are appropriate.

e. The hazard analysis element of the fuel system operational safety review supports the reinstatement of No 7 fuel tanks, provided that the use of the SCP and engine cross-feed remains suspended.

f. Formal action has been taken to introduce instructions for the correct fitting of the fuel couplings.

18. **Hot Air System.** I support the Station Commander's view that the existing limitation on the use of engine cross-feed and SCP should remain in place until the aircraft goes out of service.

(Original Signed)

Sir BARRY THORNTON  
Air Marshal  
Air Member for Materiel  

Date: 8 October 2007
INTRODUCTION

1. I agree with the comments made by the Station Commander and the Air Member for Materiel (AMM): the Board of Inquiry has made a commendable effort to identify the cause of this tragic accident and has produced a comprehensive and convincing report. However, I acknowledge that given the nature of the accident, the location of the crash site and the inability to recover the wreckage for specialist analysis, the likelihood of the Board identifying a definitive cause of the accident was low. I accept, therefore, that while the Inquiry has been thorough and logical, and has involved a large amount of detailed investigation, the cause of the accident cannot be established with absolute certainty.

2. Although a precise cause of the accident cannot be determined, it is important that the most likely cause or causes, together with all possible alternatives, are correctly identified and considered in full. I am content that the Board has succeeded in meeting this remit and that it has, therefore, met its Terms of Reference.

COMMENT ON FINDINGS

3. I am content that the evidence presented by the Board leads to the conclusion that the starboard No 7 Tank Dry Bay was the most likely location of the fire which led to the loss of the aircraft. I am also content that the Board has identified and considered all the potential sources of fuel and ignition that could have led to the fire. I consider the overall logic and supporting evidence leading to the Board’s findings to be persuasive and convincing, and I therefore agree with the majority of its conclusions, Observations and Recommendations. I have made it clear below where I disagree and where I have made no comment, it can be assumed that I concur with the Board.
CAUSES

4. The Board identified the two most likely sources of fuel in the No 7 Tank Dry bay; either a leak from a fuel coupling or pipe, or the overflow of fuel from No 1 Tank during AAR. The Board was unable to determine which of the two was more likely, and the AMM has suggested that the evidence points to overflow during AAR as being the most likely source. While it is tempting to try to determine the priority of these two sources of fuel, I do not believe there is sufficient evidence available to make a considered judgement possible. We can never be certain and must, therefore, take mitigating action that is equally effective against both potential sources of fuel. I am content that this has been done.

5. Having accepted that the starboard No 7 Tank Dry Bay was the most probable seat of the fire, there would appear to be little doubt that the source of ignition was the pipes of the engine cross-feed/SCP system. I am content that the appropriate action has already been taken to prevent these elements of the hot air system providing an ignition source in the future.

CONTRIBUTORY FACTORS

6. Age of Non-Structural System Components. While the Board identified age as a possible contributory factor in the accident, relating this specifically to fuel seals and hot air duct insulation, the Stn Cdr has challenged this, suggesting that it is the 'condition' of these components not their age that is the issue. The AMM has indicated he can find no direct evidence to support the linkage between aircraft integrity and the age or condition of non-structural components but equally, he has been unable to discount either as a possible contributory factor. I believe both age and condition are inter-related as possible contributory factors: the performance of a component is influenced by its 'condition' and one of the ways in which this condition is affected is age. However, because a relatively new component could be in poor condition and an old component could be in a good condition,
I believe that condition rather than age would have been a more accurate term to describe this aspect of the Board’s findings.

7. **Maintenance Policy – Fuel and Hot Air Systems.** While the Board and the Stn Cdr have indicated that they believe the Nimrod MR2 Maintenance Policy to have been a possible contributory factor in the accident, the AMM has indicated that he does not believe this to be the case for the fuel system. It is clear that there were deficiencies in the maintenance of the hot air duct insulation and this is not disputed. The contribution, or otherwise, of the fuel system maintenance policy is more difficult to determine using the evidence available. Importantly, however, regardless of the part played by the maintenance policy in place at the time of the accident, steps have now been taken, in the form of an enhanced inspection regime, with the aim of providing the maximum possible assurance of safety of the Nimrod MR2 fleet’s fuel system. I am content that this is the appropriate way forward until more detailed information on the long term maintenance policy of the system is available, following the outcome of the number of studies that are now underway.

8. **Nimrod Safety Case/Hazard Analysis, Fire Detection and Suppression System, and Incorporation of AAR Capability.** The Board has identified correctly the individual contribution of these three seemingly separate aspects of their Inquiry to the accident, but it is only when addressing the combined effect of the issues that their true impact is recognised. I agree with the Stn Cdr that it was the compound effect of successive modifications and equipment installations to the aircraft, including the AAR modifications, which set the conditions for this accident. In turn, while the Nimrod Safety Case and Hazard Analysis considered the potential fire hazards in Zone 614 (which includes No 7 Tank Dry Bay), the subsequent risk mitigation work assessed the risks as ‘improbable’. I agree with the Board that this failure to categorise correctly the potential risk to the aircraft caused by the collocation of fuel and hot air system components in the No 7 Tank Dry bay was a contributory factor in the accident. Furthermore, within this analysis, the aircraft fire detection and suppression system was cited as a Control for the risks in Zone 614.
However, there is no such system in the No 7 Tank Dry Bay, and while I accept that the effect of such a system, had it been fitted, cannot be determined, I am content that on the balance of evidence available, the lack of a fire detection and suppression system in No 7 Tank Dry Bay was a contributory factor in the accident.

**OBSERVATIONS**

9. **RAF Kinloss Engineering Management Structure.** The engineering management structure at RAF Kinloss was changed as a result of a Service-wide initiative to modernise Station structures. RAF Kinloss was a pilot station for the new structures and these changes have since been reviewed. While there is no evidence to suggest that a lack of engineering supervision had a bearing on this accident, the SO1 engineer post at RAF Kinloss has since been reinstated.

10. **Dilution of Engineering Skills.** While there is no evidence to suggest that tradesmen’s abilities or practices had any bearing on the accident, it is acknowledged that a greater than normal outflow of experienced engineering personnel has been experienced by RAF Kinloss over the past year. However, this has been managed closely and I am content that engineering standards have been maintained at the levels required to ensure the safe and effective operation of the Nimrod Force.

11. **Fuel Seals and Other Aircraft Types.** It is acknowledged that similar fuel couplings and seals to those used on Nimrod MR2 are fitted to a number of other RAF aircraft. The lessons identified in the course of the further work being undertaken on fuel seal integrity on the Nimrod MR2 must be shared with other engineering authorities and action taken as appropriate.

**RECOMMENDATIONS**

12. **Policy.**
a. I agree that all four recommendations of the Board with regard to Policy should be actioned.

b. I am pleased to note, as a result of discussions held while the Inquiry was in progress, that aircraft systems have been added to ageing aircraft audits and that an operational safety review of the fuel system is underway.

c. I agree that it is important when reviewing the Nimrod Safety Case, to include wide consultation with experienced air and ground crews, and I support the Stn Cdr's view that this should be extended to all aircraft fleets. It is clear that the assumptions used when the Safety Case was constructed have been undermined by changes to the way in which the aircraft is operated and the environment it is operated in.


a. The available expert advice on fuel seals and their installed life is contradictory, and this is clearly an area where authoritative advice should be sought and acted upon as a matter of urgency. I therefore welcome both the independent investigation into seal degradation characteristics for Nimrod, which is being undertaken by QinetiQ, and the investigations by QinetiQ and the Design Authority into whether further changes to the seal inspection regime are required.

b. I agree that until fuel system safety analysis is complete, regular inspections between port and starboard Rib 3 should continue. I note that regular inspections with fuel systems pressurised are already underway.

c. I also note that formal action has already been taken to issue detailed instructions for the correct assembly of fuel couplings and seals.
14. **Hot Air System.** I agree that existing limitations on the use of SCP and cross feed should remain in place for remainder of the in-service life of the aircraft.

15. **AAR Procedures.** I support a formal review of AAR procedures. However, I would need to be convinced of the practicality and value of a detailed study into pressure surges during AAR and their effect on aircraft fuel systems before agreeing to such an initiative. Similarly, while I accept that changes to simulator refuel rates are highly desirable, the practicality and cost effectiveness of such changes would need to be understood before such modifications were agreed.

16. **Operational.**

   a. In view of the new procedures adopted to prevent No 1 Tank overflow and the removal of ignition sources in No 7 Tank Dry Bay, I am content to lift the limitations prohibiting the use of No 7 fuel tanks.

   b. I agree with the Stn Cdr in that I do not believe the fitting of a parachute escape system to the Nimrod MR2 to be a practical proposition.

   c. I am content for Nimrod STANEVAL to consider the lessons identified at Annex P and their potential impact on crew emergency procedures.

17. **Aircraft Modification.** In view of the planned out of service date for the Nimrod MR2 fleet, and the risk reduction that has taken place through the changes made to operating procedures for AAR and the use of the cross-feed/SCP pipes, together with the planned review of AAR procedures, I cannot support the aircraft modification recommendations made by the Board at sub paras f (1-4). Similarly, I would need to understand the cost benefit analysis and modification timeline before supporting the recommendation to fit
a crash protected means of recording aircraft position and intercom voice to the Nimrod.

ADDITIONAL RECOMMENDATIONS

18. In his comments, the Stn Cdr makes a recommendation regarding an update to Service Deviation (SD) 132. While there are obvious linkages between the findings of this Board and SD 132, the two are independent, and SD 132 is already subject to regular review.

(Original Signed)

A D PULFORD
Air-Vice Marshal
Air Officer Commanding No 2 Group

Date: 24 October 2007
BOARD OF INQUIRY INTO THE LOSS OF NIMROD MR2 AIRCRAFT XV230 ON 2 SEP 06 – COMMANDER-IN-CHIEF AIR COMMAND’S COMMENTS

1. I commend the members of the Board for their work, which has been conducted with great diligence and determination under the most difficult circumstances, and I accept their Report, along with the amplifications and qualifications provided in sequence by the Station Commander, the Air Member for Materiel (AMM) and the Air Officer Commanding (AOC) No 2 Group. The resulting body of evidence and analysis (including those amplifying remarks) provides a cogent and convincing description of the potential causes of the crash, of the factors that played a part, and of their relative levels of probability. The Report also outlines the appropriate remedial actions required to ensure that the chance of a further loss of a Nimrod, from a similar cause, is reduced to a level which is as low as practicable.

2. I conclude that the loss of XV230 and, far more importantly, of the 14 Service personnel who were aboard, resulted from shortcomings in the application of the processes for assuring airworthiness and safe operation of the Nimrod. Most critically, this accident indicates that the Nimrod Safety Case (NSC) was wrong in its assessment that the overall identified zonal hazard probability for No 7 Tank Dry Bay (which contained Zone 614 – in all likelihood the origin of the fire) was 'improbable'. That assessment was based on incorrect assumptions regarding fuel leaks (also assessed as 'improbable' in the NSC) coupled with a flawed estimate regarding potential ignition sources (notably the Supplementary Conditioning Pack/Cross-Feed ducting). And, although we cannot know whether the presence of a fire detection/suppression system in No 7 Tank Dry Bay would have obviated this accident, here too I accept the assessment of AOC No 2 Gp; the lack of such a system was, on balance, a contributory factor. This flawed NSC assessment was further compounded both by the failure to take action in the 1980s to remedy the predicted No 1 fuel tank overflow phenomenon (identified during development trial work) and also by the failure to recognise and take alerting action when this phenomenon was observed during AAR missions (some shortly before this tragic accident). As regards the Nimrod's broader fuel system and increases in fuel system leaks, I acknowledge the AMM's assertion that it is not possible to eradicate leaks entirely and that removing any potential ignition source is the most effective means of ensuring safety. That said, I accept the compelling evidence that there has been an increase in fuel leaks over the years and I remain determined to reduce such instances to the lowest possible level; I will keep under review the work that has already been initiated in this regard.

3. Whilst I note and am reassured by the fact that the work recommended in this Report provides a path towards restoring the appropriate levels of assurance for full operation of the Nimrod fleet, I am clear that further activity must be undertaken for our other aircraft types to check whether there is any read-across of

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1 That is, where there is a difference of view, I agree with the later remarks in the sequence.
2 That is a probability per flight hour of between $1 \times 10^{-6}$ to $1 \times 10^{-7}$, which is a remote likelihood of occurrence during the operational life of a particular fleet.
3 Annex A to Part 2A – Fuel System Leaks per 1000 Flying Hours.
the lessons we have learned from this accident at such enormous (and immensely sad) cost. This should not be taken as implying that flaws exist throughout our entire airworthiness efforts; they clearly do not, or our safety record in relation to airworthiness would not be as good as it is. But, perhaps particularly for those aircraft where (for entirely practical reasons) no aircraft escape mechanism exists, I need to know that we have done (and are doing) all reasonable and practicable to assure ourselves of the safety of our aircraft, of our crews, and of other personnel who fly in those aircraft. That activity, already commenced, will include a high level Safety Case review, in order to determine exactly what is required and where effort should be prioritised. I am also quite clear that, although led by staff, this work must involve appropriate air and ground crews in order to ensure that current practices are fully understood; those personnel, after all, both know most about how our aircraft are operated and flown, and also have the greatest personal interest in having levels of safety with which all involved are comfortable.

4. In concluding my remarks, I wish to thank all those who have been involved in the aftermath of this loss. I commend, in particular, the members of the Canadian, United States and UK armed forces (especially No 34 Squadron RAF Regiment), who took part in the immediate post-crash activity. Also, my thanks go to the many agencies, both MOD and external, who have given assistance and vital evidence to the Board. Finally – and overriding all others – I pay tribute to Crew 3 of No 120 Squadron (as well as the two additional Servicemen on XV230) who lost their lives; they clearly maintained the very highest levels of professionalism right to the end. And so we owe it to them, as well as to their families, friends and colleagues, to work to remedy – to the maximum extent that this is possible and practical in the inherently risky environment of military aviation – any failures within our systems and processes that could result in a future loss of this kind.

Sir Clive Loader
Air Chief Marshal
Commander-in-Chief
Air Command

2 November 2007