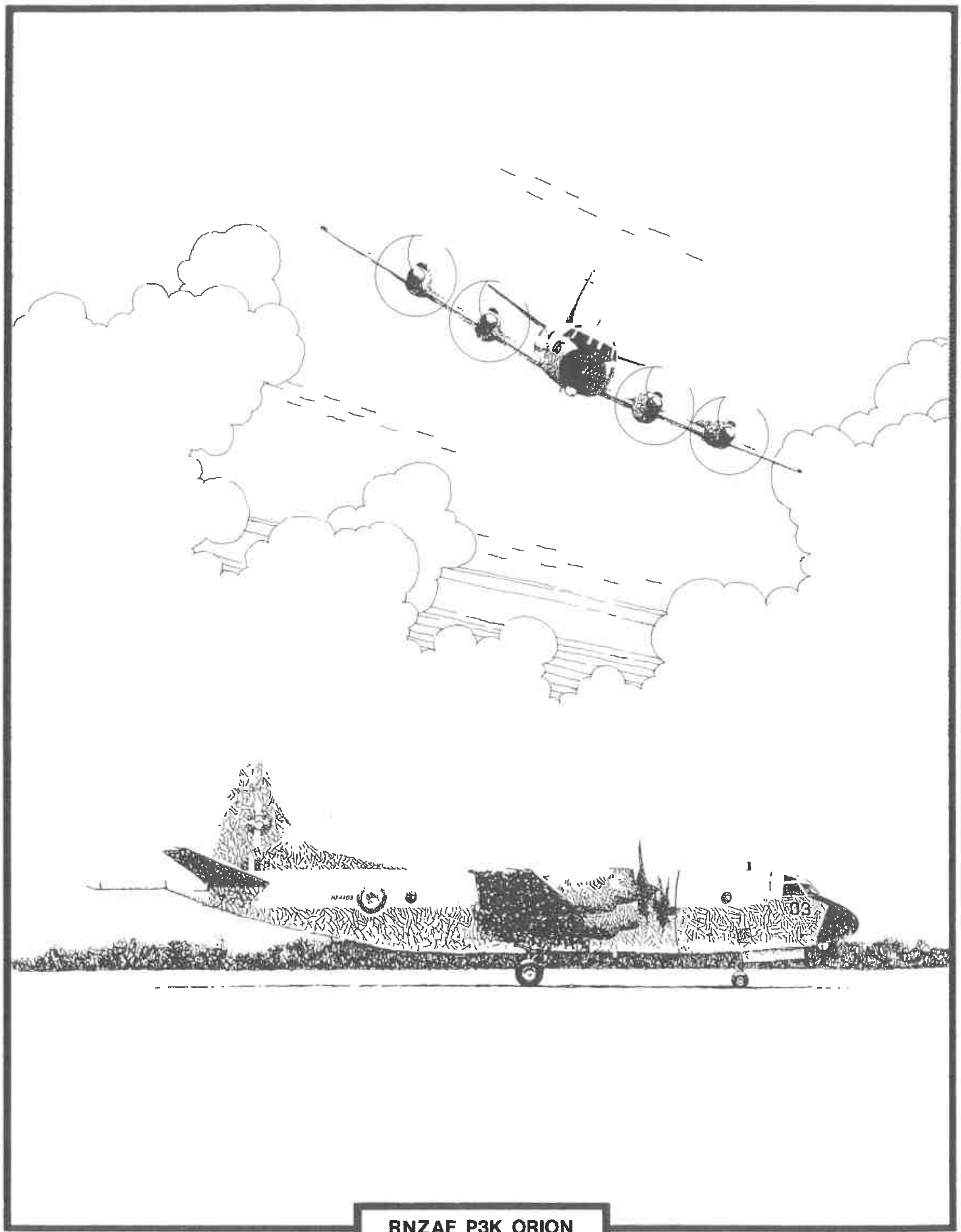
THE AUDIT OFFICE

THE QUALITY AND RELIABILITY OF DEFENCE EQUIPMENT: ROYAL NEW ZEALAND AIR FORCE

AUGUST 1992



RNZAF P3K ORION

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THE QUALITY AND RELIABILITY OF DEFENCE EQUIPMENT: ROYAL NEW ZEALAND AIR FORCE

This report is one of a series of reports published this year as a result of major value for money studies undertaken by the Audit Office.

Considerable public expenditure is involved with defence equipment, and the quality and reliability of that equipment is essential. In producing this report, we have focused on the Royal New Zealand Air Force and the attention it pays to the quality and reliability of its equipment. The audit reviewed equipment management, using, as an example, the P3K Orion long-range maritime patrol aircraft.

The Air Force's application of commercially-based management systems has enhanced their potential effectiveness and efficiency, and has demonstrated that these systems can be applied to a military organisation.

I would like to thank the Chief of Air Staff and his officers and personnel for their friendly co-operation afforded to my officers in the conduct of this audit.

It is also appropriate to acknowledge the work of the two officers from my Major Projects Group primarily responsible for the report, Alastair Donald and Pamela Fletcher.

I trust that the results of the audit, as set out in this report, will make a useful contribution to increasing the attention paid to the quality and reliability of equipment by the Air Force specifically and the New Zealand Defence Force in general.

J W Cameron
Deputy Controller and Auditor-General

18 September 1992

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INTRODUCTION

Mandate

101 This report describes the results of the third in a series of audits of New Zealand Defence Force (NZDF) equipment. This audit was of the quality and reliability of Royal New Zealand Air Force (Air Force) equipment. Previous audits were of the quality and reliability of Army equipment (1990) and Royal New Zealand Navy equipment (1991).

102 The authority for the audit is section 25(3) of the Public Finance Act 1977.

Defence Force Equipment and Roles

103 The NZDF has considerable capital invested in equipment. At the time of the audit, the net book value of all specialist military equipment was $1,494 million. Of that amount, Air Force aircraft had a net book value of $408 million, but a replacement value of $2,030 million.

104 Armed forces must have both equipment and personnel to enter a conflict. Given the reliance the armed forces place on their equipment, the quality and reliability of that equipment is critical.

105 High-quality, reliable equipment is capable of performing the tasks required of it and is available when needed. Increasing equipment reliability decreases repair costs and the need for replacement. By focusing on quality and reliability, the Audit Office sought to determine whether the NZDF applied appropriate equipment management policies and procedures.

106 The primary purpose of the NZDF is to provide the Government with a basis of military power when required. This may be to back up a diplomatic initiative, contribute to an allied or multinational force, or perform other military tasks required of it. To do this, the NZDF needs to ensure that it has the appropriate skills, equipment and facilities to meet the most likely demands. The NZDF also carries out peacetime functions such as patrolling the Exclusive Economic Zones of New Zealand and South Pacific Forum nations, search and rescue, and disaster relief.

107 The Air Force has aircraft squadrons contributing to four major defence roles:

- Air combat, which is performed by 21 A-4K Skyhawks;
- Long-range maritime defence, which is carried out by six P-3K Orion aircraft;
- Transport, which is performed by a combination of five C-130 Hercules, 10 Andover and two Boeing 727 aircraft, and 14 Iroquois helicopters; and

- Training, which is carried out by 15 BAC Strikemaster, six Aermacchi MB339C, three F-27 Friendship, 19 Airtrainer and four Airtourer aircraft, and four Sioux helicopters.

Audit Approach

Methodology

108 The range and complexity of defence equipment makes it impractical to examine in a single exercise the quality and reliability of all equipment. Further, each of the three armed services applies different equipment management practices. Consequently, the Audit Office has chosen to audit equipment management in each armed service separately, and to select certain items of equipment for each audit.

109 For the purpose of the audit, we used the New Zealand Standard 5604:1987 definitions of quality and reliability:

- *Quality*—the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.
- *Reliability*—the ability of an item to perform a required function under stated conditions for a stated period of time.

It is important to recognise that quality and reliability are inter-related. That is, the quality of an item of equipment affects its reliability, and the reliability of the equipment reflects its quality.

110 The audit team developed a series of performance expectations related to quality and reliability management. These expectations were developed under the broad headings of reliability, maintenance and availability.

111 Effective and efficient maintenance operations require a reliability-centred maintenance programme. Such a programme identifies what equipment is significant for safe operation and availability when required. By focusing the maintenance effort on that equipment, the programme avoids over-maintenance and consequently promotes the economic use of resources.

112 To develop and operate a reliability-centred maintenance programme, the reliability of the equipment must be measured. Reliability information can also identify equipment which is performing below expectation so that corrective action, such as redesign, can take place.

113 It is important for the Air Force to monitor individual aircraft and squadron availability so that it can compare that availability with the level of maintenance carried out and utilisation rates to determine:

- The number of aircraft needed to perform the missions required;
- Whether the aircraft are being maintained to the appropriate level of quality; and
- The consequences of changing maintenance practices for achieving the tasks required.

114 Technical terms used in the report are explained in Appendix 3 on pages 49–51.

Aircraft Selected for the Audit

115 Following discussion with the Air Force, we selected the Orion aircraft as the case study on equipment management. The aircraft was selected because:

- It has significant defensive and peacetime roles;
- It is financially significant; and
- There are not too many aircraft.

116 Defence forces of several other countries fly Orion aircraft, including the United States, Canada, Australia, the Netherlands, Norway and Japan. The Orion is a military derivative of the Lockheed Electra, a commercial passenger aircraft. It has four Allison turboprop engines, can fly at a maximum speed of 761 kilometres per hour, and has a range of 7100 kilometres.

117 The Orion can detect, identify and report surface and sub-surface vessels. The Air Force also uses it to patrol the Exclusive Economic Zones of New Zealand and South Pacific Forum nations, identifying fishing vessels and plotting their position. It is New Zealand's primary maritime search and rescue aircraft, performs emergency medical air transport and supports Skyhawk operations. F-27 Friendships and Andovers sometimes support the Orion in short-range maritime surveillance and search and rescue.

118 The Orion fleet had a net book value of $73.9 million in December 1991. This represented 18 percent of the Air Force's total aircraft net book value. The aircraft are flown by Number 5 Squadron, located at RNZAF Base Auckland, Whenuapai. In the 1991-1992 financial year, the Air Force spent around $80 million (including overheads of $51 million and depreciation of $17 million) operating Orion aircraft. We estimate that it costs $38,500 an hour to fly an Orion.

119 The Air Force has six Orion aircraft; five purchased new in 1966 and another bought second-hand in 1985. Each has a crew of 11, and can carry homing torpedoes and mines. All six had avionics equipment updated in the mid-1980s. This included the radar, infra-red detection system, computers and multi-function display units.

Equipment Selected for the Audit

120 The Orion aircraft as a whole is a robust design, with built-in redundancies, in both structural design and equipment carried. For example, although the aircraft has four engines, it can fly on two; and it has several communications systems. In addition, some equipment is not needed on all missions, and does not affect the safe flying characteristics of the aircraft. The sono equipment, for example, is used to detect, locate and identify submarine contacts and is used only for anti-submarine exercises or maritime surveillance. Consequently, an

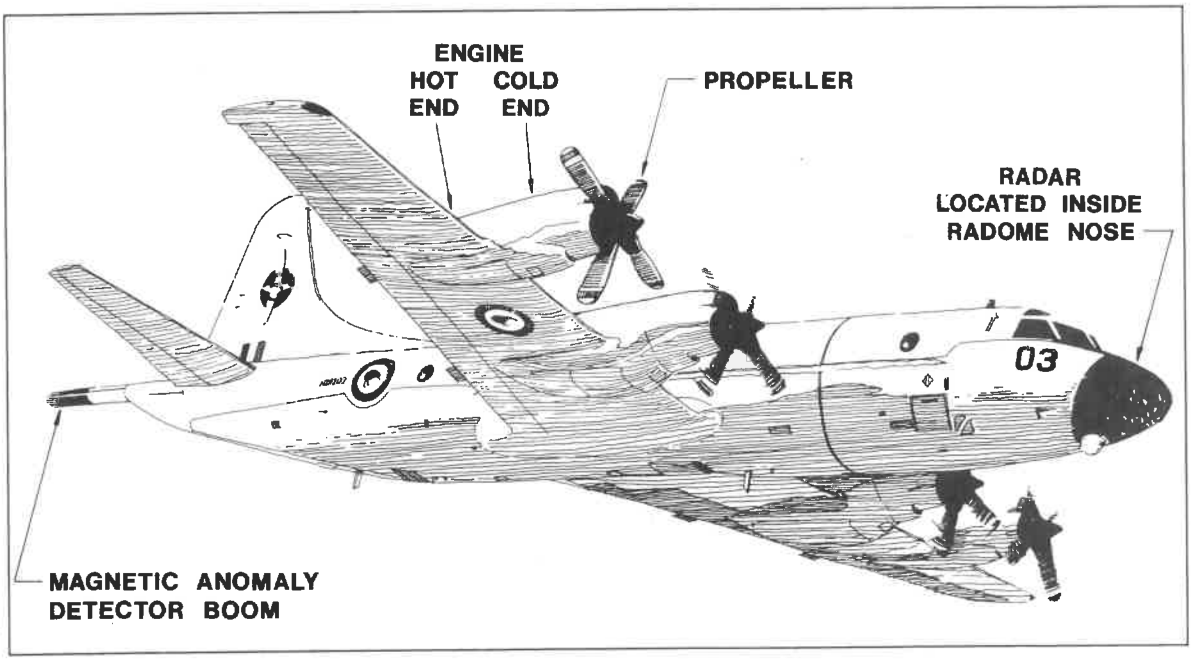
Orion can operate with several systems inoperable and still carry out specific missions.

121 We evaluated the Air Force's management of its reliability and maintenance programmes by selecting three significant pieces of equipment on the Orion aircraft. These were:

- The engines, consisting of:
  - ★ The cold end, incorporating a reduction gearbox and associated assemblies which convert the revolutions developed by the gas turbine to the propeller speed, and a compressor to assist combustion in the gas turbine;
  - ★ The hot end, consisting of a gas turbine, using combustion of aviation fuel to spin a shaft at high speed; and
  - ★ The propeller, a four-bladed variable pitch assembly using hydraulic pressure to alter the pitch of the blades, and connected to the gas turbine by the reduction gearbox;
- The AN/APS 134 surveillance radar, incorporating: a transmitter, antenna, receiver, power supply and data converter. This is fitted to the front of the aircraft and used to search for surface targets; and
- The sono equipment incorporating: passive and active sonar buoys, magnetic anomaly detector, high speed printer, retro-launcher, electro-mechanical tracer and transmitters. This is used to detect, locate and identify submarine contacts.

The location of the selected equipment is illustrated in Figure 1.

FIGURE 1
ORION P3K AIRCRAFT SHOWING LOCATION OF SELECTED EQUIPMENT



122 We chose this equipment for its critical nature in the Orion's missions. The aircraft's main missions are anti-submarine warfare training, maritime patrols and surveillance, supporting combat aircraft operations, pilot and crew training, and search and rescue. All of these missions require engines and the surveillance radar. The sono equipment is required for anti-submarine and maritime surveillance missions.

Structure of the Report

123 Chapter 2 describes the reliability-centred maintenance programme.

124 Chapters 3 and 4 assess the Air Force's approach to reliability-centred maintenance:

- Chapter 3 focuses on the reliability of selected Orion equipment, and how the Air Force measures this;
- Chapter 4 looks at maintenance management and how equipment reliability information is used to develop and modify maintenance practices.

125 Chapters 5, 6 and 7 focus on the consequences of maintenance in terms of aircraft availability, and how aircraft availability is managed:

- Chapter 5 is concerned with measuring the proportion of time that the aircraft are available to perform the tasks required of them;
- Chapter 6 assesses the management of aircraft availability and use; and
- Chapter 7 looks at the proportion of planned missions disrupted by equipment failure.

126 Chapter 8 outlines our general conclusions.

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RELIABILITY-CENTRED MAINTENANCE

201 Before 1977, the Air Force used maintenance programmes based on frequent examination of all structure and components, frequent system and component testing, and a long list of fixed-time reconditioning requirements.

202 In 1977, the Air Force introduced the Improved Maintenance Programme. The programme was developed from the maintenance programme produced by the Air Transport Association of America's Maintenance Steering Group. This group based its programme on a reliability-centred maintenance philosophy which has become accepted commercial airline practice.

203 The Improved Maintenance Programme is, at present, controlled through a manual recording system, which is soon to be replaced by a computerised system called the Air Force Logistics Information System.

204 The Air Force identifies significant equipment on the Orion aircraft by using processes outlined in the Air Transport Association of America's Maintenance Steering Group documents. These documents list a series of questions which identify the equipment to monitor for reliability analysis, and what is significant for safety, availability, capability and economical use of resources. This approach avoids the need to monitor all equipment—which would be neither effective nor efficient.

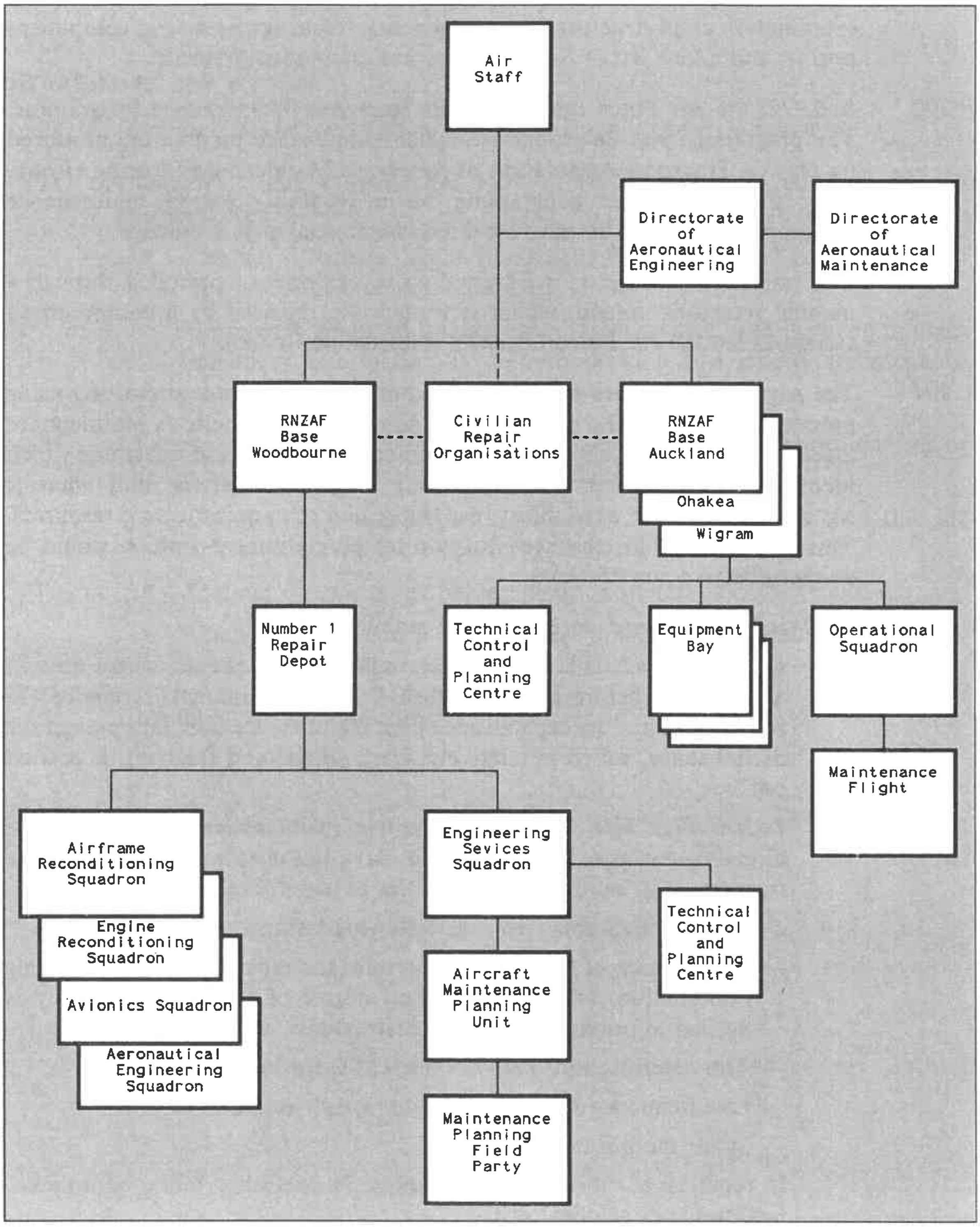
205 The Air Force operates three levels of maintenance:

- *Operating level.* This is the squadron-level maintenance, where aircraft are serviced before and after flights, faulty equipment is repaired or replaced within the capabilities of the maintenance unit, and preventive maintenance, which is relatively short, simple and frequent, is carried out.
- *Intermediate level.* This is preventive maintenance which takes the aircraft out of operation for several days, but does not require the same investment in equipment or facilities as depot level maintenance.
- *Depot level.* This comprises the following tasks:
  - — Examination of the aircraft structure (and repairs that arise from this examination) where a significant degree of aircraft disassembly is needed to provide access to the structure;
  - — Anti-deterioration measures such as corrosion prevention;
  - — Low-frequency servicing of systems and components; and
  - — Major modifications.

  It requires a substantial investment in specialist tools, equipment, facilities and technical skill.

206 The Air Force carries out maintenance activities, including planning and monitoring, in a variety of locations and units. See Figure 2.

FIGURE 2
AIR FORCE MAINTENANCE ORGANISATION CHART



207 The Air Force has carried out two Improved Maintenance Programme reviews of the Orion aircraft, in 1977 and in 1986. These reviews were carried out by Maintenance Planning Field Parties, which identified and then calculated the reliability of significant equipment systems. The results were used to assess the relevance of current maintenance actions. The Maintenance Planning Field Parties also produce a Master Maintenance Schedule from these reviews, outlining the preventive maintenance actions to be carried out at the operating, intermediate and depot maintenance levels.

FIGURE 3
ORION IN DEPOT-LEVEL MAINTENANCE AT RNZAF BASE WOODBOURNE

Official RNZAF photograph

3

RELIABILITY

Background

301 The importance of having reliable equipment cannot be stressed too strongly, particularly when aircraft are involved. The actual, and potential, costs of unreliable equipment are not merely financial, but also safety-related.

302 In the United States, experience has shown that an investment in reliability of around two percent of the cost of acquisition produces a return of 14 percent of the original purchase price. This net return of twelve percent could be realised in:

- Longer life;
- Better utilisation;
- Less money spent on acquisition; and
- Less maintenance and modification required.

303 An equipment item's reliability is defined as the ability of that item to perform a required function under stated conditions for a stated period of time.

304 A common measure of reliability is the probability that an item can perform as required, which is calculated from failure rates and the average time or distance between failures. Failure rates are the number of failures over a given time. The failure rate can indicate the reliability of equipment without calculating probability.

305 It is important, therefore, to monitor reliability to detect any deterioration. Such monitoring requires a standard of reliability stating:

- Function(s) required;
- Operating conditions; and
- A specified period.

306 To calculate the reliability of equipment, enough data has to be collected regularly. Equipment components or systems which significantly influence reliability, and which will be repaired after a failure, should be individually identified. Their effect on reliability should be analysed, using the types of failures occurring, the rate of failure, and the average time or distance between failures.

307 Collecting reliability information makes it possible to detect any deterioration in reliability. Any decrease in reliability, and, consequently, equipment availability, may affect the equipment's operating cost. Equipment that is unavailable through failure incurs two costs:

- Repairing the failure in the equipment; and
- The need for additional spares to replace failed equipment.

308 We expected that the Air Force would measure equipment reliability to operate a reliability-centred maintenance programme. This would entail identifying and monitoring the performance of significant equipment, and modifying maintenance actions based on that performance. We also expected that calculations would be made of the reliability of individual equipment in such a way as to be able to identify the reliability of the whole aircraft.

309 In carrying out the audit, we independently confirmed the reliability of the engines. The Air Force's own calculations were used for the sono equipment and radar.

Findings

310 To help identify equipment failure or loss of performance, the Air Force uses test procedures, including performance monitoring, on aircraft equipment systems. The procedures include the use of engine monitoring equipment, and built-in test equipment for electronic equipment. Condition monitoring (such as boroscopic inspections, spectrographic oil analysis, turbine inlet temperature analysis, strain measurement, vibration analysis, x-ray and ultrasonic inspection) is also used. The Master Maintenance Schedule specifies the test intervals for these checks.

311 Reports are made of failures and their causes so that corrective action is readily identified, and common failures are isolated for reliability analysis.

312 The frequency with which equipment is removed from the airframe is used as the basis for monitoring the reliability of significant equipment. Records of aircraft flying hours are normally used to calculate the length of time that individual equipment is in use on the aircraft. The Improved Maintenance Programme review carries out reliability analysis that identifies Mean Time Between Failure and plots the rate of failures over stated periods.

313 The Air Force does not routinely extend its reliability analysis to calculate the probability of failure of individual items of equipment. Consequently, it cannot combine reliability calculations in such a way as to calculate the Orion aircraft's ability to perform its varied missions.

314 However, it identifies where failure rates are constant, and predicts equipment performance, so that it can develop maintenance programmes that reflect that performance. The failure-rate calculations are kept at individual equipment level, such as the radar, sono equipment and engines.

315 We calculated the failure rates for the Orion engines':

- Cold ends;
- Hot ends; and
- Propellers,

to verify maintenance decisions for this equipment. The results showed that the conclusions reached by the Air Force on maintenance timings were correct, and that the current maintenance actions are appropriate, given the performance characteristics of the equipment.

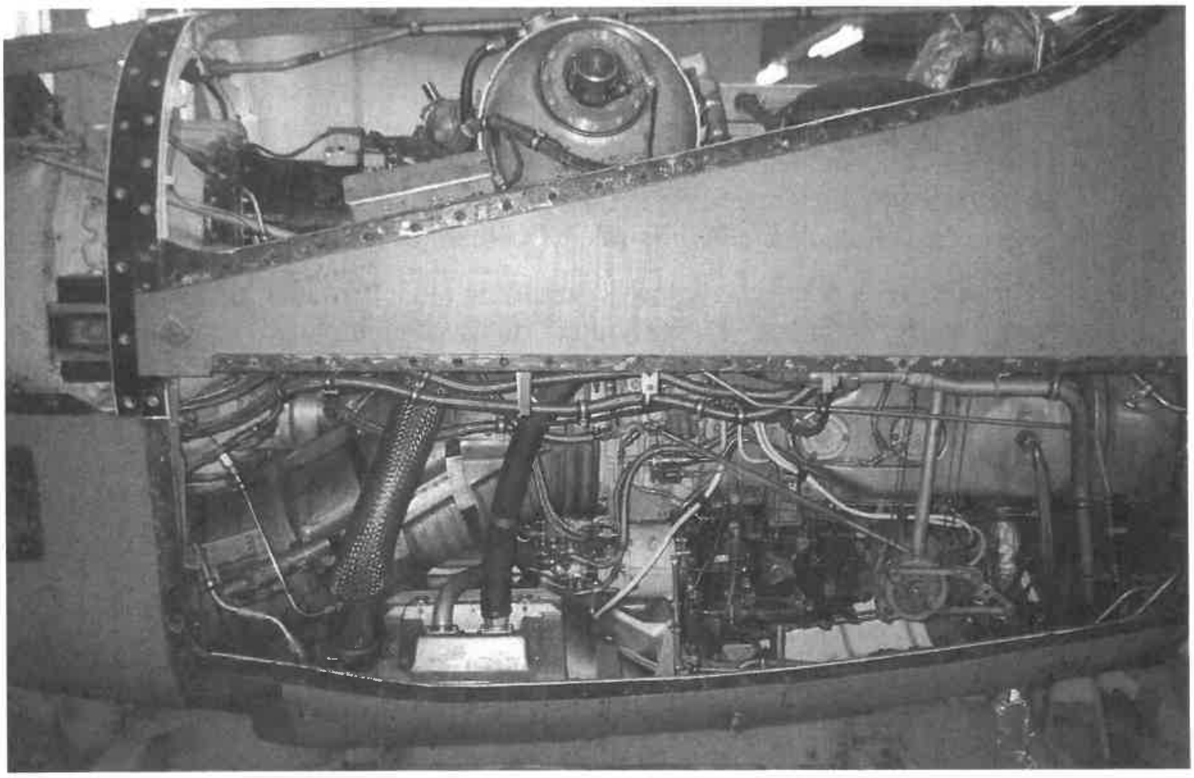
316 We identified Mean Time Between Failures for the engine components, using data held at the Technical Control and Planning Centre and Engine Bay, RNZAF Base Auckland. See Figure 4.

FIGURE 4
MEAN TIME BETWEEN FAILURES—ENGINE

Equipment	Period	Mean Time Between Failures (Hours)
Hot end	1966–1991	4377
Cold end	1966–1991	6334
Propeller	1966–1991	1797

317 The results in Figure 4 show the engines to be reliable pieces of equipment. The hot and cold ends, in particular, ran for thousands of hours without failure. The interior of an engine is illustrated in Figure 5.

FIGURE 5
ENGINE WITH COWLING REMOVED



318 The Air Force also calculates Mean Time Between Failure in between Improved Maintenance Programme reviews if staff are concerned about the reliability of particular equipment. Both the radar and the sono equipment were reviewed in 1991.

319 The Air Force does not verify that reliability calculations carried out between Improved Maintenance Programme reviews use the same method consistently or have access to the same data. Aircraft maintenance data is stored at several locations on an Air Force base, or among different bases. When a need arises to analyse equipment performance between Improved Maintenance Programme reviews, the unit that has the best access to the information carries out that analysis. For example, the Technical Control and Planning Centre carried out the sono equipment Mean Time Between Failure calculations, while the Avionics Equipment Bay carried out the radar Mean Time Between Failure calculations, even though both units were located at RNZAF Base Auckland.

320 We could not identify whether the units used the same methods or had access to all relevant data. This could affect the results of these calculations. When the computerised Air Force Logistics Information System is implemented this problem should disappear, as the computer's database, holding maintenance information, will be common to all units.

321 Information stored at different locations does not affect an Improved Maintenance Programme review, as a Maintenance Planning Field Party collects and combines all data held.

322 From the Air Force's summary of radar failures over flying hours, we have calculated the radar's performance, shown in Figure 6.

FIGURE 6
MEAN TIME BETWEEN FAILURES — RADAR

Equipment	Period	Mean Time Between Failures (Hours)
Power Supply	1990–1991	737
Synchroniser/Exciter	1990–1991	369
Transmitter	1990–1991	123
Receiver Pulse Compressor	1990–1991	368
Antenna	1990–1991	421
Signal Data Converter	1990–1991	983
Total System	1990–1991	50

323 The radar has not been as reliable as expected. At the time of purchase, it was expected to have a Mean Time Between Failure of 100 hours, but our calculations show that at present it is achieving a Mean Time Between Failure of only 50 hours (see Figure 6). The longest flight carried out by an Orion during the 1990–91 financial year lasted 11.6 hours. A Mean Time Between

Failure of 50 hours is therefore unlikely to influence individual missions. However, where several overseas missions are carried out in succession, such as on a Pacific Islands patrol, radar failure affecting the patrol becomes more likely.

324 As stated in paragraph 312, records of aircraft flying hours are normally used to calculate the length of time that equipment is in operation. This is appropriate for equipment which is used for most, or all, of a flight, such as the engines, but overstates the use of equipment that is only used intermittently. Consequently, some equipment appears to operate for longer than it does, affecting validity of Mean Time Between Failure calculations. To overcome this, Number 5 Squadron maintenance flight personnel and the Technical Control and Planning Centre analysed missions carried out over 1990-1991 and came to an estimate of the sono equipment's hours in use. By using these figures, the sono equipment's performance was calculated as shown in Figure 7.

FIGURE 7
MEAN TIME BETWEEN FAILURES—SONO EQUIPMENT

Equipment	Period	Mean Time Between Failures (Hours)
Active Sonar Processor	1990–1991	38
Sonobuoy Signal Processor	1990–1991	4.4
Tape Recorder 1	1990–1991	34
Tape Recorder 2	1990–1991	76
Sonobuoy Receiver	1990–1991	36
Electronic Surveillance Measures 1	1990–1991	34
Electronic Surveillance Measures 2	1990–1991	63
Magnetic Anomaly Detector	1990–1991	33

325 The sono equipment is unreliable because the sonobuoy signal processor, a critical component, lasts only 4.4 hours between failures. This is only about half the flight time of overseas surveillance missions, and 1.5 hours less than the length of the average mission requiring use of the sono equipment.

Conclusions

326 The Air Force identifies equipment failures, measures reliability and is using the results appropriately at individual equipment level.

327 The Air Force does not calculate the probability of failure, so cannot combine known equipment reliabilities to calculate the overall reliability of an individual Orion or the whole squadron. These are useful measures and would be an accurate way of expressing the Orion squadron's performance.

328 The Orion aircraft has items of equipment which are not reliable, in particular the sono equipment. The Air Force acknowledges the poor reliability of this equipment, stating that it is a function of its age (designed in the 1960s and no longer manufactured). During the 1980s, the Air Force planned to replace the sono equipment, but lack of funds and a review of airborne anti-submarine warfare capability prevented this. If this capability is required, the sono equipment should be replaced.

Recommendations

329 **We recommend that the Air Force:**

- **Calculates the failure probability for individual items of equipment; and**
- **Combines this data to calculate the probability of aircraft carrying out defined missions.**

4

MAINTENANCE MANAGEMENT

Background

401 An efficient organisation maintains its equipment to the minimum standard necessary to perform the tasks required of it. Maintenance management covers a range of activities. The audit focused on three aspects; operating a reliability-centred maintenance programme, monitoring repair times, and monitoring the effects of maintenance decisions on aircraft availability.

402 Maintenance is defined as the combination of all technical and corresponding administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function.

403 Most maintenance programmes are a combination of:

- *Preventive maintenance,* which services equipment:
  - ★ At pre-determined intervals; or
  - ★ Corresponding to prescribed criteria;

  to reduce the probability of failure or loss of performance.

  The Air Force has defined this as scheduled maintenance.
- *Corrective maintenance,* which services equipment after failure has occurred, and is intended to restore an item to a state in which it can perform its required function.

  The Air Force has defined this as unscheduled maintenance.

OPERATING A RELIABILITY-CENTRED MAINTENANCE PROGRAMME

404 Reliability-centred maintenance programmes require the user to monitor and modify maintenance actions based on collected performance data of significant equipment, rather than follow a series of rigidly-fixed manufacturers' schedules. These schedules may result in equipment over-maintenance, which incurs an extra cost and may actually reduce equipment reliability.

405 We expected the Air Force to evaluate the maintenance programme at regular intervals and modify it to reflect equipment performance.

Findings

406 The Air Force has established general reliability and maintenance objectives, but more specific objectives for individual systems on the Orion have been developed only for equipment added since 1979. The specific objectives are stated in Maintenance Policy Statements, developed and held by the Air Staff in Wellington. Earlier equipment does not have this information.

407 All maintenance actions leave an audit trail in the maintenance documentation, identifying what has been done, why, and when the action has been cleared. Our analysis of maintenance records identified errors in data entry, but nothing of material significance.

408 The Master Maintenance Schedule targets critical equipment and, where parallel equipment exists, places less emphasis on maintenance.

409 The 1986 Improved Maintenance Programme review of the Orion identified an engine cold end Mean Time Between Failure of 1,742 flying hours. Before 1986, engine cold ends were reconditioned after they had been operated for 4,000 flying hours. However, the Mean Time Between Failure calculation, while a good indicator of equipment performance, does not assist in estimating the best point to carry out a recondition or dispose of the equipment. The Air Force therefore carried out failure rate calculations which showed the predicted life of the engines. These calculations showed a failure rate well beyond the 4,000 hour figure. The Maintenance Planning Field Party recommended that reconditions should only be carried out:

- When a failure requiring reconditioning occurred;
- If an engine had been operating for more than 6,000 hours when it was removed from the wing; or
- When engine cold end condition or performance deteriorates.

410 Implementing this recommendation has resulted in some engine cold ends reaching over 10,000 operating hours without failure. We carried out rate of failure analyses on the engine hot and cold ends, and agree with the Air Force's decisions.

411 Figure 8 illustrates the increase in average time between reconditions which has resulted from the Maintenance Planning Field Party recommendation.

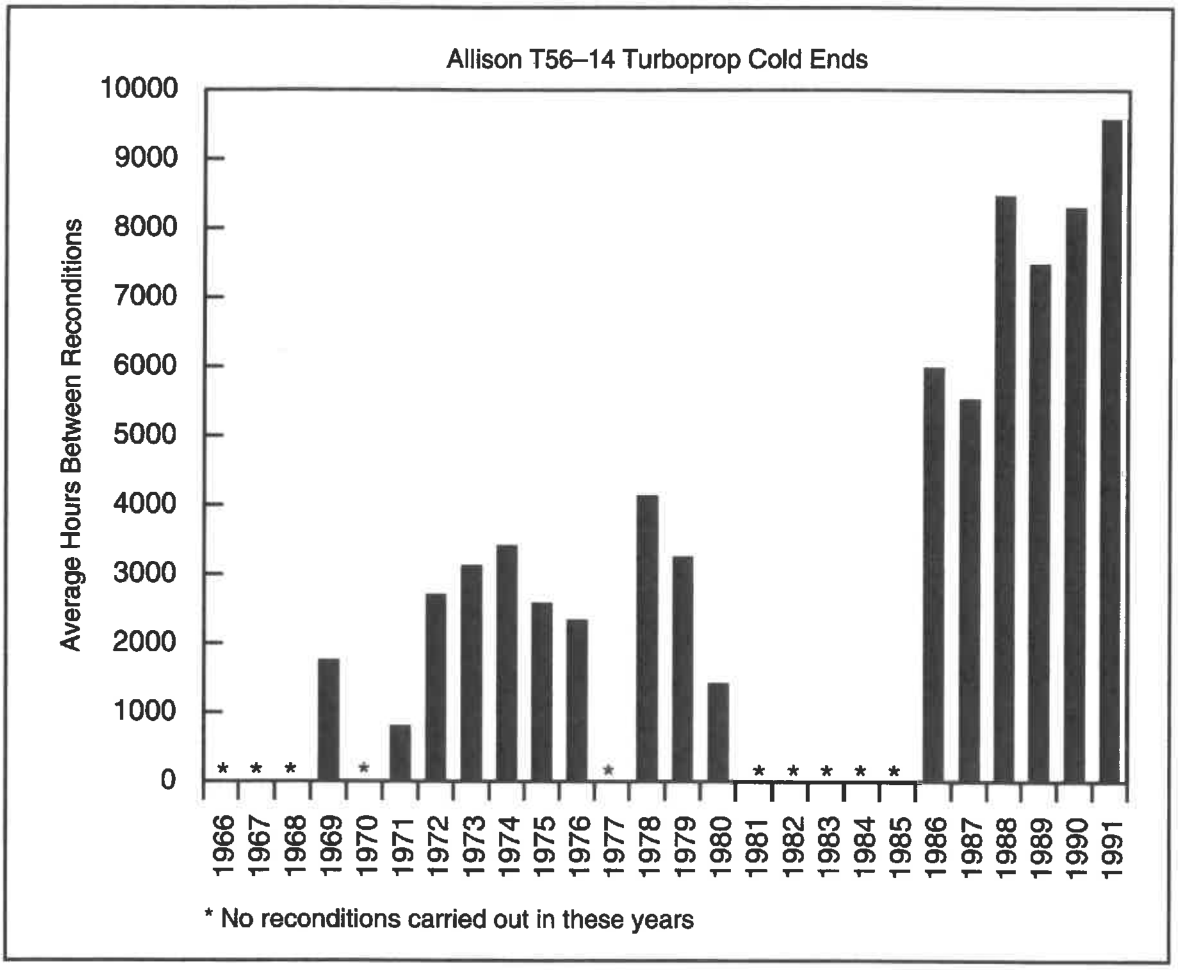
Conclusions

412 The Air Force has a reliability-centred Improved Maintenance Programme (see paragraphs 202-204). This is based on industry-standard techniques and methodology. The Audit Office commends the Air Force for setting in place processes that actively support the effective and efficient operation of its equipment.

413 The Air Force monitors the reliability of significant equipment, and uses the results to modify its Improved Maintenance Programme. The decisions made from this monitoring are sound, and reflect the equipment performance.

414 Not all significant equipment has Maintenance Policy Statements. There is therefore no standard against which to compare actual reliability. This hinders the ability to identify deviations in actual equipment performance from expectations.

FIGURE 8
RECONDITION RATES OF THE COLD END SECTION



Recommendations

415 **We recommend that the Air Force:**

- **Develops Maintenance Policy Statements for equipment purchased before 1979, so that reliability and maintenance expectations can be standardised for all significant equipment; and**
- **Continues to develop the necessary databases and utilise its reliability-centred maintenance programme.**

MONITORING REPAIR TIME

416 We expected the Air Force to monitor the time taken to repair and replace failed equipment. Down time affects aircraft and equipment availability, and directly affects cost, as more equipment may need to be purchased to replace unavailable equipment.

417 The Orion's design and construction enables the adoption of flexible maintenance practices. Apart from the airframe, most equipment is "rotable"; that is, it can be taken out in modular form for repair and replaced by spare modules. This lessens the time the aircraft is out of service to that needed for equipment to be replaced, rather than the time needed for it to be repaired.

Findings

418 When replacement equipment is unavailable through the Air Force's supply organisation, the maintenance units strip aircraft they do not plan to use, for spares. This suggests that there is not enough spare equipment available to fully supply aircraft needs under peacetime conditions. That could be because:

- Not enough spare equipment is held in store; and/or
- Repair organisations take too long to repair equipment.

Figure 9 illustrates spare engines in store.

FIGURE 9
SPARE ENGINES IN STORE

419 The Air Force calculates the Mean Time To Repair "rotable" equipment from the time it leaves the supply system for repair until it is returned to store. Figure 10 shows the Mean Time To Repair for selected components of the Orion between 1984 and 1991.

FIGURE 10
MEAN TIME TO REPAIR: FIGURES FOR SELECTED EQUIPMENT

Description	Quantity	Mean Time To Repair (Days)
Propeller Blade assembly P3	5	80
Propeller assembly, basic	47	125
Engine hot end assembly	30	210
Engine cold end compressor	33	210
Radar radome nose	5	450

420 However, the Air Force does not specify how long repairs should take; nor does it identify the repair phases that may unduly prolong a maintenance action, such as:

- Logistic delay—including awaiting spares, equipment, information or environmental conditions;
- Technical delay—including equipment cooling, interpretation and application of information, and interpretation of displays or printouts;
- Failure diagnosis—including running diagnostic tests and analysis;
- Failure correction—including repair and replacement of parts; and
- Checkout—including testing that the failure has been repaired.

421 If the Air Force does not monitor repair time in this level of detail, it is unlikely to identify and minimise delays.

422 In 1989, the Number 1 Repair Depot (at RNZAF Base Woodbourne) carried out a comprehensive review of its depot level maintenance actions, and targeted areas for change. By analysing maintenance actions based on occupational activity classes, the depot identified work that was unnecessary, or took too long to complete. For one Orion, this analysis showed that depot-level maintenance could be reduced from 22,989 to 18,111 work hours, a saving of 4,878 hours.

Conclusions

423 There are not enough spares available to supply Number 5 Squadron, and serviceable equipment has to be removed from other aircraft. This is costly in terms of:

- Labour;
- Increasing the risk of damage to serviceable equipment; and
- Decreasing aircraft availability.

424 There is not enough information to determine whether this spares shortage is due to the supply organisation holding insufficient spares, or repair organisations taking too long to repair equipment.

425 There is no monitoring of the potential delays in repair times, nor, until recently, was there specification of how long a repair should take. The Air Force therefore cannot identify if repairs are taking too long. The introduction of the Air Force Logistics Information System has the potential to monitor repair times in greater detail and thus identify potential delays.

426 Specification of acceptable repair times would enable actual repair times to be used to evaluate Air Force and contractor repair operations. This could lead to a decision to:

- Modify repair operations;
- Change the repair organisation, whether Air Force or contractor; or
- Accept a limited transfer of serviceable equipment between aircraft as a trade-off against the extra cost of investing in additional stores;

before purchasing extra equipment to cover shortfalls in equipment held in store. We note that the latest civilian repair contracts specify both working hours and calendar time for repairs, and that it is the intention to apply these specifications to all equipment repairs undertaken by Air Force personnel as well as contractors.

Recommendations

427 **We recommend that the Air Force:**

- **Identifies the relevant components of down time and monitors them;**
- **Specifies the time that equipment should take to repair; and**
- **Re-assesses the management of spares to avoid removing serviceable equipment from aircraft to repair other aircraft.**

EFFECT OF MAINTENANCE DECISIONS ON AVAILABILITY

428 An aircraft undergoing maintenance is unavailable to perform its designated functions. We expected the Air Force to monitor the effect of maintenance decisions on aircraft availability, as part of its evaluation of maintenance procedures.

Findings

429 Reducing depot-level maintenance frequency has increased Orion aircraft potential availability. At the 1986 Improved Maintenance Programme review, the Maintenance Planning Field Party recommended that the Orion undergo preventive depot-level maintenance every 50 calendar months, instead of the 40 months then prescribed. Adoption of the longer interval has significantly decreased down time due to depot-level maintenance. For example, an Orion on a 40-month cycle would have four depot-level maintenance actions between 1986 and 2000. However, an Orion on a 50-month cycle would have only three depot-level maintenance actions, reducing depot level maintenance costs by $1.2 million an aircraft. The squadron will save $7.2 million over that 14-year period. This saving would be offset to some extent by the Air Force's decision to introduce a ten-day Intermediate Structural Examination midway between depot level maintenance, and the extra operating-level maintenance required as a result of the greater aircraft availability.

430 In addition, Number 1 Repair Depot has carried out separate audits of its depot-level maintenance process, which has increased the depot's capacity and increased Orion availability. The increase was achieved by introducing two work shifts, which reduced the calendar days required to carry out depot-level maintenance from 183 days (including weekends and holidays) to 118, while still carrying out the same structural checks, repairs and painting. As a result, aircraft can be released to the squadron nine weeks earlier than had previously occurred. On current practice, this will reduce depot-level maintenance time on the Orion squadron by 18 months from now until the year 2000.

431 The Air Force has made substantial modifications to maintenance practices at depot, intermediate and operational level. However, it has not amalgamated data on the consequences of these changes for aircraft availability to identify the overall effect on Orion availability.

432 The Orion aircraft consists largely of "rotable" parts or equipment. Consequently, when carrying out corrective maintenance at the operating level, only the time taken to change a "rotable" item directly affects availability. However, the Air Force does not monitor the time taken to change a "rotable" item. In addition, it does not identify and monitor the time that different phases of repair actions take (see paragraph 420). It is therefore unlikely to identify actions that would shorten repair times, which in turn indirectly affect availability.

433 At the operational level, maintenance officers set priorities for corrective maintenance based on professional judgement. Highest priority is given to defects which affect flying ability, followed by defects which limit the role of the aircraft. A maintenance engineering officer may certify an aircraft as serviceable for flight with some defects unrepaired. If this is the case, the defects will be entered into either the aircraft's deferred defects log or its acceptable limitations log. The captain in charge of the mission has the final decision to accept or reject the aircraft with the particular defects and/or limitations.

434 This approach differs from that required of commercial airlines. They are governed by regulations which stipulate that each commercial aircraft type must have a minimum equipment list. This lists all the equipment that must be serviceable in order to achieve the design criteria for reliability and safety. An aircraft may not fly unless all equipment on the list is serviceable, although it may fly if non-essential equipment is defective.

Conclusions

435 Programme reviews have decreased the Orion aircraft's down time for preventive maintenance, increasing its potential availability.

436 Using professional judgement as a basis for determining maintenance priorities at the operational level works well. The pressure on maintenance staff to maintain aircraft to the highest standard is countered by a pressure to minimise maintenance costs by restricting staffing levels and overtime. This encourages them to set priorities for ordering maintenance and to spread the maintenance work load.

437 However, the Air Force does not specifically identify the minimum equipment necessary for different types of mission flown by the Orion. Consequently we cannot determine whether current practice results in the most efficient use of maintenance resources. Aircraft may be maintained to a higher standard than that required for planned missions.

Recommendation

438 **We recommend that the Air Force:**

- **Considers developing minimum equipment lists for different types of mission, similar to those used by commercial airlines. This would not remove the need for professional judgement, but would enhance it.**

5

CALCULATING AVAILABILITY

Background

501 Availability refers to the proportion of time that an aircraft is in a state to perform its designated tasks. Availability is a good measure of the combined effects of aircraft capability, reliability and maintenance operations. It is also important, in conjunction with utilisation rates, for determining the number of aircraft required. For these reasons, we expected the Air Force to set aircraft availability targets and measure actual availability.

502 Defence forces in other countries measure the proportion of time that equipment is in various states of availability. For example, the United States Navy has a comprehensive programme for monitoring maintenance operations. This includes setting availability targets based on the proportion of time the aircraft are expected to be available. The United States Navy also records the number of hours each day that aircraft are in different stages of "readiness".

503 In 1991, the United States Navy operated a fleet of 344 Orion aircraft. Twenty-eight percent of these were P-3Bs and the remainder were a later model, the P-3C.

504 We carried out our own analysis of aircraft availability, based on the United States Navy approach. We used maintenance data for three Orion aircraft for one year and identified the number of hours each aircraft was:

- *Fully-mission-capable*—able to perform all of its missions;
- *Partially-mission-capable*—able to perform at least one, but not all of its missions; and
- *Non-mission-capable*—not capable of performing any of its missions due to maintenance requirements.

Findings

505 The Air Force has general availability targets for its aircraft. For 1990–91, these were:

- To fly the Orion squadron for 2,600 hours during the year;
- To have sufficient aircraft and crew to be able to achieve the number of missions and level of training possible within the allocated 2,600 flying hours; and
- To have the aircraft and crew available at degrees of notice agreed with the Minister of Defence.

506 The Air Force does not set availability targets based on the proportion of time it expects aircraft to be available. However, it collects information on aircraft

availability. All operating squadrons complete daily "flying returns" which are aggregated into monthly "operational status" reports. These reports identify the number of aircraft at 8 a.m. each day which are either:

- Potentially available (i.e. not undergoing preventive maintenance);
- Available to fly and carry out any required mission; or
- Available to fly with limitations (i.e. having some equipment which is not fully functional and which may make them unsuitable for some missions).

507 The flying returns represent only the situation at 8 a.m. each day. Because they do not take account of how much of the day each aircraft is in each of the three availability states, they can overestimate or underestimate the time that aircraft are actually available. For example, an aircraft could be classified as not available at 8 a.m. because maintenance staff were working on it, but become available later in the day. Conversely, an aircraft could be classified as available with limitations at 8 a.m., but be unavailable later in the day because it is having those limitations corrected.

508 In addition to daily availability information, the Air Force calculates what effect major changes in maintenance practices will have on aircraft availability (see paragraphs 429–430).

FIGURE 11
AVAILABILITY OF ORION AIRCRAFT
(Average for each aircraft based on three aircraft for one year: 1/7/90-30/6/91)

AVAILABILITY STATE	DAYS	%
Non-mission-capable		
Depot or intermediate level preventive maintenance	108	30
Depot level corrective maintenance	19	5
Operating level maintenance (preventive and corrective)	88	24
Subtotal Non-mission-capable	*215*	*59*
Mission-capable		
Partially-mission-capable	37	10
Fully-mission-capable	113	31
Subtotal Mission-capable	*150*	*41*
TOTAL	365	100

509 Neither the routine returns nor the occasional calculations of availability carried out by the Air Force allow it to measure the proportion of time that aircraft are actually available to fulfil their roles.

510 Our analysis of aircraft availability showed that the three selected Orion aircraft were out of service for maintenance for more time than they were available to fly. See Figure 11.

511 For the 1990–91 financial year, the aircraft were:

- Fully-mission-capable 31 percent of the time;
- Partially-mission-capable 10 percent of the time; and
- Non-mission-capable 59 percent of the time.

512 The method of calculating aircraft availability used by the Air Force produced significantly higher rates of availability, particularly for partially-mission-capable. For the same time period, the Air Force reported an average of 2.3 aircraft available per day with no limitations, and a further 2 with limitations. This is equivalent to approximately 38 percent fully-mission-capable and 33 percent partially-mission-capable, leaving only 29 percent non-mission-capable. See Figure 12.

Conclusions

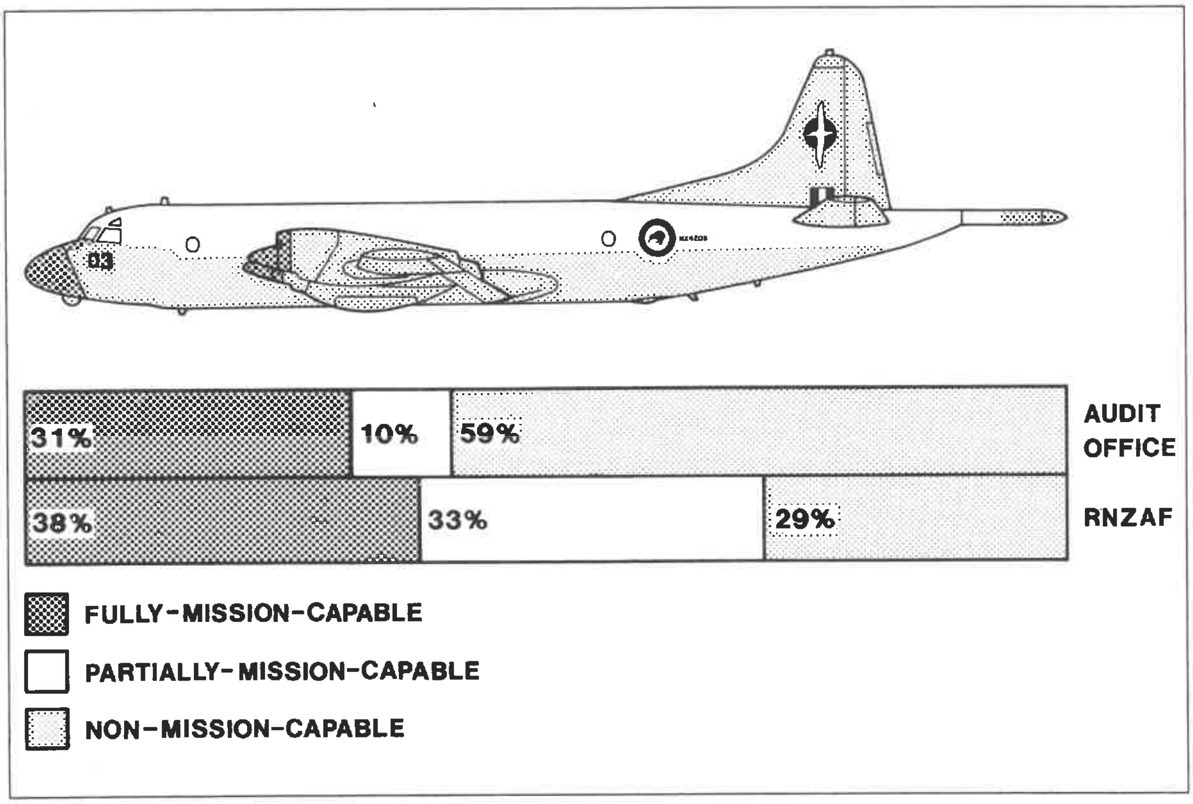
513 The Air Force's calculation of aircraft availability based on one observation per day is useful for identifying trends in non-mission-capability due to depot and intermediate level maintenance. It also gives an indication of the number of aircraft which could be flown on a particular day if they were required. However, it does overestimate aircraft availability—particularly partial-mission-capability.

514 This suggests that it could be common for the Air Force to record aircraft as available with limitations at the beginning of the day and then carry out maintenance on them later in the day if they are not required.

515 If the Air Force were to set availability targets related to planned utilisation, and calculated availability rates which reflect the proportion of time that aircraft are available, it would be able to compare actual availability with that required to meet operational requirements. It would also be able to monitor more accurately the effect of maintenance operations on availability. This would provide useful information to assist it in maximising maintenance efficiency and effectiveness. The Air Force recognises the need for a more precise measure of aircraft availability and intends using the Air Force Logistics Information System to develop this.

FIGURE 12

PROPORTION OF TIME AIRCRAFT AVAILABLE
AUDIT OFFICE AND RNZAF CALCULATIONS



Recommendations

516 **We recommend that the Air Force:**

- **Sets more precise availability targets; and**
- **Develops a more precise measure of aircraft availability. This can be used with utilisation rates to monitor squadron readiness as well as maintenance effectiveness and efficiency.**

6

MANAGING AVAILABILITY

Background

601 An efficient and effective organisation purchases the minimum amount of equipment, and maintains it to the minimum standard needed, to perform the tasks required of it. Under these conditions, equipment is available when needed and is used for most of the time it is available.

602 These efficiency principles apply to the NZDF's management of its equipment, but their application is less straightforward given the dual purposes of the NZDF:

- Being capable of providing the Government with a basis of military power when required; and
- Performing normal peacetime activities (including maintaining resources and skills for military contingencies).

603 The NZDF's primary purpose of providing a basis of military power means that equipment levels held are often greater than those required for normal peacetime activities. In the case of the Air Force, this excess capacity reduces the pressure to maximise aircraft availability and utilisation, and consequently imposes greater challenges to managers to maximise efficiency.

604 To manage aircraft availability under normal peacetime conditions, the Air Force first needs to identify the normal peacetime roles of the aircraft and set performance targets. It has done this.

605 For the Orion aircraft, the four main roles are:

- Maintaining a capability to conduct military operations;
- Military reconnaissance and surveillance in the Pacific region;
- Surveillance of New Zealand's Exclusive Economic Zone and those of the South Pacific Forum nations. These are usually carried out in conjunction with military reconnaissance and surveillance; and
- Search and rescue patrols.

606 The performance targets for 1990–91 included the availability targets listed in paragraph 505 (see page 28) and also:

- To remain within budget.

607 The Air Force largely met its performance targets for 1990–91, although the squadron was able to fly only 2,193 of the 2,600 hours allocated for the year. An increase in aviation fuel costs during the Gulf War meant that the squadron had to fly fewer hours in order to stay within budget.

608 We expected the Air Force, having established the aircraft's roles and performance targets, to differentiate between aircraft needed for normal

peacetime activities and those which are essentially held in reserve for military contingencies by:

- Identifying the minimum number of aircraft needed to meet peacetime requirements and the cost of maintaining them;
- Identifying the number of aircraft surplus to peacetime requirements which are held in readiness for contingencies, and the cost of maintaining them;
- Endeavouring to maximise the availability and utilisation of the minimum number of aircraft required for current activities;
- Maintaining additional equipment held in reserve, to the minimum level necessary for it to be made available at the required notice; and
- Specifying the amount of notice required to prepare equipment to meet a contingency.

FIGURE 13
ORIONS AVAILABLE FOR FLIGHT

Findings

609 The Air Force does not differentiate between aircraft needed to conduct normal peacetime activities and those which are essentially held in readiness to meet contingencies.

610 However, it does identify degrees of notice for aircraft and crew to be available for some situations, including preparedness for certain contingencies. The Air

Force also makes contingency plans in response to specific situations; for example, the 1990 Gulf War.

611 An armed force's size is dictated by the Government's requirement to meet contingency operations. This can lead to equipment numbers which are in excess of peacetime requirements. Furthermore, the total flying hours available to the squadron is limited by budget and staffing constraints. Our analysis of aircraft availability indicates that the Air Force does not need all six Orion aircraft to carry out normal peacetime activities. The three aircraft used to calculate availability rates flew an average of 411 hours each during the year. As they were fully-mission-capable for 2,712 hours (113 days, see Figure 11 on page 29), they were operational for only 15 percent of the time during which they were in that state.

612 The Orion squadron is also required to keep an aircraft on standby (ready to fly at two hours' notice) for search and rescue. This equates to an annual average of 1,460 hours on standby for each of the six aircraft. Adding this standby requirement to the 411 hours of actual flying time increases the average time for which the Air Force needs each aircraft to be available to a maximum of 1,871 hours a year. This is 69 percent of the time they are fully-mission-capable and 52 percent of the time they are either fully or partially-mission-capable.

613 The average of 1,871 hours a year per aircraft is the maximum time the aircraft would need to be available. If necessary, some repairs can be carried out within the two-hour notice period for search and rescue, and sometimes aircraft already flying can be diverted to undertake a search and rescue mission.

614 Over the last decade, the potential availability of Orion aircraft has been increased by both streamlining depot-level maintenance (see paragraphs 429–430) and the purchase in 1985 of the sixth Orion.

615 The purchase of the sixth Orion was prompted by:

- A 1983 Defence Review proposal to increase surveillance in the Pacific;
- Air Force concern about the impact of accidental loss of one of the existing five aircraft; and
- An NZDF proposal to provide surveillance for a naval force operating away from New Zealand.

616 At the time, the Orion squadron was required to fly around 3,000 hours a year. It was able to achieve that target with the five aircraft. Since then, there has been no increase in flying hours and the Air Force has implemented maintenance practices designed to reduce the time aircraft are unavailable.

617 Purchasing the sixth Orion cost an estimated $34.2 million ($58.94 million at 1991 prices). This includes the purchase price and upgrading of the aircraft to the same equipment configuration as the rest of the fleet. However, the Air Force has not needed six aircraft for normal peacetime requirements.

618 At the time of our audit, the Orion squadron had a full complement of six aircraft potentially available. That is, none were in depot or intermediate-level maintenance. Maintenance personnel in Number 5 Squadron responded to this situation of high potential availability by dividing the aircraft into two groups. They planned to maintain one group of aircraft to a level where those aircraft could achieve most of the allocated flying hours each month, while keeping the other group available for missions at short notice.

619 The latter group required minimum maintenance, but could also have any deferred maintenance carried out if there was spare maintenance capacity. Aircraft would be rotated between the two groups to even out flying hours and maintenance work across the six aircraft and throughout the year.

620 The system of managing the aircraft in this way is similar to one based on separating normal peacetime functions from a reserve for contingencies.

Conclusions

621 The Air Force does not identify the minimum number of aircraft required to undertake agreed annual peacetime activities. As a result, it cannot:

- Manage the squadron to maximise aircraft availability or utilisation.
- Know the proportion of aircraft which are essentially reserves for contingencies; or
- Identify the true cost of normal peacetime roles or of maintaining the additional aircraft for potential contingencies.

622 Distinguishing between normal peacetime requirements and reserves for contingencies, and developing maintenance policies which acknowledge the differences, may not significantly reduce maintenance costs. However, it would enhance the efficiency of equipment management and allow greater transparency of Air Force costs.

623 The low rate of aircraft availability that we identified (paragraph 511), and the even lower aircraft utilisation rates (paragraphs 611–612), demonstrate that the Air Force has more Orion aircraft than it needs to fulfil current peacetime roles. The purchase of the sixth Orion aircraft, and decreasing time spent in depot and intermediate-level preventive maintenance, have also increased capacity. This has resulted in the Air Force lacking an operational incentive to carry out operational-level maintenance in an efficient manner during normal peacetime activities.

624 Orion squadron maintenance personnel recognise that there is overcapacity for current requirements, and have developed innovative ways of managing aircraft maintenance and utilisation.

625 Dividing the aircraft into high-usage and low-usage groups was one such approach. However, without calculating aircraft availability and utilisation rates, and maintenance costs for the two groups, it is difficult to ascertain the extent of any efficiency gains.

626 Determining the optimum number in each group and the allocation of flying hours to the groups also becomes a matter of trial and error.

Recommendations

627 **We recommend that the Air Force:**

- **Identifies the minimum number of aircraft necessary to fulfil normal peacetime requirements;**
- **Identifies and evaluates the costs and potential benefits of equipment held in reserve for contingencies, and determines the minimum number required for this role; and**
- **Identifies and evaluates methods of:**
  - ★ **Managing minimum peacetime equipment levels to maximise availability and utilisation;**
  - ★ **Minimising maintenance costs of equipment rotating through the group held in reserve for contingencies.**

7

MISSION COMPLETION

Background

701 An important measure of the Air Force's management of equipment reliability and availability is the extent to which missions can be completed without failures in mission-critical equipment. We therefore expected the Air Force to:

- Set targets for successful mission completion rates;
- Monitor the effect of equipment failures on mission completion; and
- Identify reasons for partial completion or non-completion of missions.

702 We carried out our own analysis of aircraft ability to complete missions when required. We combined information available from in-flight and post-flight reports and flight authorization books for all six Orion aircraft, and maintenance data on three aircraft. From that information, we were able to identify missions which the Air Force completed successfully and those which did not go as planned (either because of an equipment failure or some other reason, such as poor weather).

703 For the purposes of assessing mission completion, we defined an equipment failure as occurring when the equipment was unable to perform all functions required for the successful completion of the mission. Figure 14 illustrates an Orion on mission.

Findings

704 The Air Force does not set mission completion rate targets or routinely analyse the effect of equipment failures on mission completion rates.

705 It has a comprehensive system for monitoring and reporting on equipment failures, particularly those relating to aircraft safety. However, this is essentially concerned with monitoring equipment reliability, rather than whether the failure affected the completion of particular missions.

706 Air crews produce flight reports for some missions which provide limited information on whether equipment failure affected a mission.

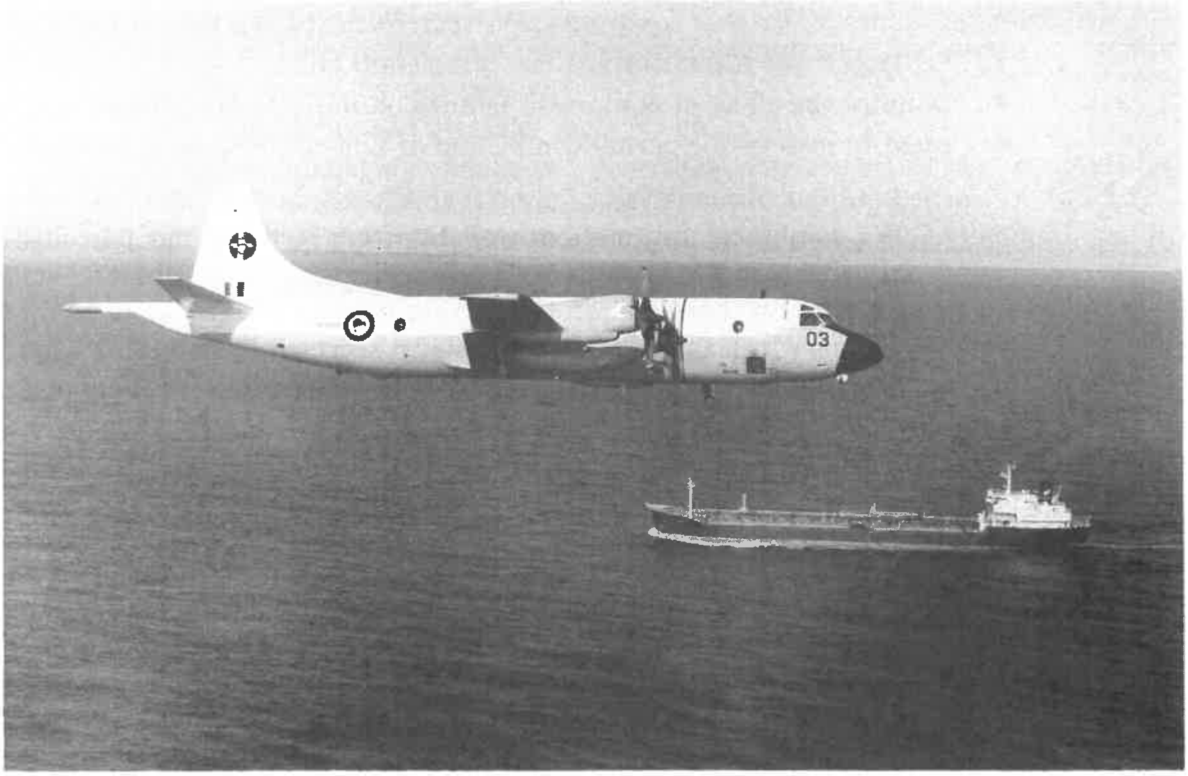
707 Maritime patrol crews transmit in-flight reports for both overseas and locally based fishing and surveillance patrols. Operation commanders write post-flight reports for both overseas patrols and overseas military exercises. However:

- The reports may or may not contain information on equipment "unserviceabilities" and whether they disrupted the mission.
- The system for ensuring compliance with reporting requirements is deficient. In the 12-month period studied, out of 20 reports due, two post-flight reports were not written and another two could not be located. Three of the unavailable reports related to maritime patrols

which had transmitted short in-flight reports, but the fourth related to an overseas military exercise for which there was no in-flight report.

- There are usually no reports for flights other than maritime patrols and military exercises.

FIGURE 14
ORION ON MISSION



Official RNZAF photograph

708 Squadrons also have flight authorisation books in which to record basic information on all flights. This includes the date, aircraft number, the nature of the mission, take-off and landing times, duration of flight, whether the mission was carried out and, if not, the reason. However, reasons for non-completion were not always recorded. There were also inaccuracies in the books. Wrong aircraft tail numbers were occasionally recorded against a flight. Air crew sometimes recorded flight take-off and landing times for overseas missions in a mixture of New Zealand standard time, local time or Universal Co-ordinated Time, without necessarily specifying which.

709 For the purposes of our audit, Air Force staff categorised Orion aircraft missions into 18 different types and identified the mission-specific equipment for each. See Appendix 1 (page 46).

710 From the post-flight and in-flight reports, we were able to identify missions which were cancelled prior to take-off, aborted during flight, delayed, or experienced failure in mission-specific equipment, but which continued. However, because of the limitations of the reports (noted in paragraph 707), we could not be sure that we identified all missions affected by equipment failure.

711 For those missions which did not have in-flight or post-flight reports, we were able to identify only missions which experienced major problems resulting in either cancellation or abortion.

712 Figure 15 summarises the information obtained for missions during the year ended 30 June 1991 with either an in-flight or post-flight report. Section A of Appendix 2 (see page 47) lists the equipment failures which affected these missions and the effect they had.

713 Out of a total of 213 planned missions, 187 were completed. Of those 187 missions, 145 were completed without incident, 38 were completed despite failure of equipment required for the mission, and 4 were completed with missions modified.

714 As would be expected, failure in safety-related equipment was more likely to result in mission cancellation or abortion, while failure in mission-specific equipment tended to reduce the effectiveness of the mission.

715 For example, missions were aborted or cancelled because of failures such as: propeller malfunction, inoperable radar, cracked windshield, or the illumination of engine oil contamination warning lights.

716 Propeller malfunction was the most common reason for cancelling a mission. Nine out of the 13 cancelled missions were because of propeller failure. A single propellor failure can affect more than one mission, particularly if the aircraft is on an overseas patrol or an exercise consisting of several missions. For example, single propeller failures occurring during three separate overseas exercises resulted in eight mission cancellations, because staff were unable to correct failures between flights. Five of these missions were part of maritime attack exercises, representing 45 percent of planned maritime attack missions for the year.

717 A pack of spare parts and maintenance equipment always accompanies aircraft on overseas missions, but weight considerations restrict the contents of the pack. Because of this, spare propellers may be too heavy to include in some packs.

718 A single failure in mission-specific equipment during an overseas patrol or exercise could also affect more than one mission. For example, the most common failure in mission-specific equipment was a faulty retro-launcher, which is used to discharge a marker to identify the location of a surface or subsurface object. Retro-launcher failures affected 19 completed missions. However, half of these missions were part of two Pacific Island surveys in which one faulty retro-launcher affected five missions and another affected four.

FIGURE 15
IMPACT OF EQUIPMENT FAILURE ON MISSION COMPLETION FOR MARITIME PATROLS AND OVERSEAS EXERCISES
(1 July 1990–30 June 1991)

Type of Mission	Mission Completed				Mission Not Completed			Mission Status Not Known	*Total Number*
	No Mission-Critical Equipment Failures	Equipment Failure		Mission Degradation Due to Weather[1]	Equipment Failure		Other Causes		
		Mission Continued	Mission Delayed		Mission Aborted	Mission Cancelled			
	%	%	%	%	%	%	%	%	
Anti-submarine and surface warfare exercise	65	14	2		5	7	2	5	*57*
Maritime attack exercise	55					45			*11*
Joint exercise with Navy	40	30[2]	10[3]				20[4]		*10*
Escorting fighter aircraft	86						14		*7*
Pacific Islands patrol	100								*8*
Pacific Islands survey	51	33	4[3]		4[5]	7			*45*
South East Asia patrol	50		50						*2*
Patrol around New Zealand	74	14		11					*35*
Transit to overseas missions	90		5		3	3			*38*
Total %	68	15	3	2	3	6	2	1	100
Total Number	*145*	*31*	*7*	*4*	*6*	*13*	*4*	*3*	*213*

Notes: 1 Mission modified; for example, because of deteriorating weather.
2 Includes one mission which was also a patrol.
3 Includes one mission which was delayed due to equipment failure and also had an equipment failure during flight but the mission continued.
4 Plus an unknown number of missions cancelled because the submarine was out of service.
5 Includes one mission delayed due to equipment failure and also aborted due to equipment failure.

Percentages may not add to 100 due to rounding.

719 Failure in communication equipment reduced effectiveness for eight missions. These missions could continue because the Orion has several methods of communication (ultra high frequency, very high frequency and high frequency transceivers), but communications were made more difficult or delayed as a result of the equipment failure.

720 Sometimes, more than one piece of equipment was faulty. For example, on four missions requiring sono equipment, both the retro-launcher and the magnetic anomaly detector (used to locate submerged objects) were inoperable.

721 Not all missions were cancelled because of equipment failure. Four were cancelled as a result of other factors. One mission was cancelled because of poor weather, another because of crew fatigue, and part of one exercise with Naval forces was cancelled because the participating submarine was unserviceable.

722 A post-flight report for an overseas exercise comprising three missions referred to some missions not being completed. As no more details were available, the status of the three missions concerned is not known.

723 Figure 16 summarises the information available on the 304 missions for which flight crew did not write reports. These missions were local flights concerned mainly with training. Reasons for non-completion of local flights are provided in Section B of Appendix 2 (see page 48).

724 The proportion of local missions completed was similar to that for overseas exercises and maritime patrols (90 percent compared to 88 percent). As with the overseas missions, the most common equipment failures resulting in mission cancellation or abortion were in equipment required for safety—particularly the engines.

Conclusions

725 Overall, in the year ended 30 June 1991, the Air Force planned 517 Orion missions and completed 462 of them. Some of the 462 missions classified as completed experienced failure in equipment required for the mission, but were still able to accomplish the main tasks required.

726 The Air Force does not collect adequate information on the extent to which equipment failure disrupts missions. It is therefore difficult for the Air Force to identify ways of improving its mission completion rate. Seven percent of missions were cancelled or aborted due to equipment failure. If there had been no equipment failures, the Orion fleet could have achieved a mission completion rate of 96 percent.

FIGURE 16
IMPACT OF EQUIPMENT FAILURE ON MISSION COMPLETION FOR LOCAL MISSIONS AND TRANSIT FLIGHTS
(1 July 1990–30 June 1991)

Type of Mission	Mission Completed	Mission Not Completed				*Total Number*
		Equipment Failure		Other Causes	Cause Not Known	
		Mission Aborted	Mission Cancelled			
	%	%	%	%	%	
Pilot training	89	3	3	4	1	*71*
Pilot/Engineer training	95		5			*21*
Crew anti-submarine training	84	1	7	4	4	*75*
Pilot night training	100					*5*
Navigator training	89		6		6	*18*
Crew conversion training	88	9		3		*32*
Training for overseas flights	100					*8*
Transit within New Zealand	100					*21*
Search and rescue	100					*18*
Test flight	94		6			*35*
Total %	91	2	4	2	2	100
Total Number	*275*	*6*	*11*	*7*	*5*	*304*

Note: Percentages may not add due to rounding

727 It is unrealistic to expect that equipment failure will never affect mission completion. Nevertheless, monitoring equipment failures which do affect missions would provide the Air Force with valuable information on the consequences of equipment reliability, maintenance practices, and equipment management decisions.

728 A single equipment failure during an overseas exercise can significantly reduce the training value of such exercises. If maintenance crew cannot readily correct the fault, the aircraft can miss several missions. Cancelling five maritime attack missions and at least four anti-submarine missions during the year represents significant lost opportunity to participate in joint international exercises.

Recommendations

729 **We recommend that the Air Force:**

- **Sets mission completion targets;**
- **Routinely monitors the effect of equipment failure on mission completion; and**
- **Regularly assesses what spare parts should accompany aircraft on overseas exercises.**

8

GENERAL CONCLUSIONS

801 We selected the Orion aircraft as the case study of the Air Force's equipment management. The Air Force applies the same management principles to all its aircraft. Consequently, while the findings in this report relate to the Orion aircraft, the conclusions drawn are applicable to Air Force equipment management in general.

802 The Air Force operates a reliability-centred maintenance programme which is based on industry-standard techniques and methodology. The Audit Office commends the Air Force for setting in place processes that actively support the effective and efficient operation of its equipment.

803 The primary purpose of the NZDF, and hence the Air Force, is to provide the Government with a basis of military power when required. Because of this, the Air Force has more equipment than it needs for normal peacetime activities.

804 It is important for the Air Force to monitor aircraft availability, utilisation rates and maintenance operations in order to determine:

- How many aircraft it needs to perform the tasks required;
- Whether it is over-maintaining or under-maintaining its aircraft; and
- The consequences of changing maintenance practices for meeting operational requirements.

805 The Air Force measures aircraft availability, but the method used tends to overestimate the proportion of time aircraft are actually available.

806 The Air Force has developed several processes to monitor the quality and reliability of its equipment and is using the results to modify maintenance practices. This has resulted in demonstrable increases in maintenance efficiency and potential availability.

807 However, the Air Force does not combine data on aircraft availability, utilisation and maintenance operations to either identify how many aircraft it needs for normal peacetime requirements, or monitor maintenance effectiveness and efficiency.

808 Instituting these measures would give the Air Force greater assurance that it is managing its equipment effectively and efficiently.

809 Of the three armed services subject to this quality and reliability audit, only the Air Force has implemented a comprehensive reliability-centred maintenance programme. In addition, the Air Force has reviewed its operations regularly and has instituted changes which have materially affected the availability and maintenance practices of its equipment.

810 At the time of the audits of equipment management by the Royal New Zealand Navy and the Army, both of those services had instituted only some of the management processes utilised by the Air Force. Given the potential savings and increased availability, the Air Force experience shows that an investment in the concepts of quality and reliability can directly benefit military equipment management.

APPENDIX 1
ORION AIRCRAFT: MAJOR EQUIPMENT SYSTEMS REQUIRED FOR DIFFERENT MISSION TYPES

MISSION TYPES	MAJOR EQUIPMENT SYSTEMS											
	SSP	ASP	TR	RETRO	BATHY	ESM	MAD	RADAR	IN	DHS	IRD	IFF
Anti-submarine and surface warfare	X	X	X	X	X	X	X	X	X	X	X	X
Maritime attack exercise				X		X	X	X	X	X	X	
Joint exercise with Navy				X		X		X	X	X	X	X
Escorting fighter aircraft								X	X	X		X
Pacific Islands patrol	X			X		X	X	X	X	X	X	X
Pacific Islands survey	X			X		X	X	X	X	X	X	X
South East Asia patrol	X		X		X	X		X	X	X	X	X
Patrol around New Zealand	X			X		X	X	X	X	X	X	
Transit to overseas missions								X	X	X		
Pilot training								X		X		
Pilot/Engineer training								X		X		
Crew anti-submarine training	X	X	X	X		X	X	X		X	X	
Pilot night training								X		X		
Navigator training								X	X	X	X	X
Crew conversion training								X		X		
Training for overseas flights	X	X	X	X		X	X	X	X	X	X	X
Search and rescue	X	X	X	X		X	X	X	X	X	X	X

KEY

SSP	Sonobuoy signal processor	BATHY	Bathythermograph	IN	Inertial navigation
ASP	Active sonar processor	ESM	Electronic support measures	DHS	Data handling system
TR	Tape recorder for sonar	MAD	Magnetic anomaly detector	IRD	Infra-red detector
RETRO	Retro-launcher	RADAR	Radar	IFF	Identify friend or foe

APPENDIX 2

EQUIPMENT FAILURES AND THEIR EFFECT ON MISSION COMPLETION
(1 July 1990–30 June 1991)

A Maritime Patrols and Overseas Exercises

Mission Completed—Partially-Mission-Capable Due to Failure in:	Frequency
Communication equipment	9
Sonar	4
Magnetic anomaly detector	6
Retro-launcher	18
Radar	4
Propeller	1
Pilot's display	1

Mission Delayed Due to Failure in:	Frequency
Air conditioning	1
Data handling	1
Engine	1
Radio	1
Retro-launcher	1
Sonar	1
Unspecified failure	2

Mission Aborted Due to Failure in:	Frequency
Engine	2
Engine-driven compressor	1
Radar	2
Windshield	1

Mission Cancelled Due to Failure in:	Frequency
Propeller	9
Radar	1
Windshields	2
Unspecified Failure	1

B Local Missions

Mission Aborted Due to Failure in:	Frequency
Engine	4
Radar	1
Unspecified	1

Mission Cancelled Due to Failure in:	Frequency
Engine	3
Propeller	1
Radar	1
Landing gear	1
Unspecified	5

APPENDIX 3

EXPLANATION OF TERMS

Acceptable deferred defects log: maintenance log for recording minor unrectified defects in an aircraft which do not affect its airworthiness. Each aircraft has its own acceptable deferred defects log.

Air Force Logistics Information System: a computerised database which includes information on individual aircraft equipment failures and maintenance actions.

Availability: the proportion of time that an aircraft is in a state to perform its designated tasks.

Capability: the aircraft's ability to perform its required functions.

Contingencies: operations carried out outside peacetime requirements, such as military action.

Corrective maintenance: services equipment after failure has occurred, and is intended to restore an item to a state in which it can perform its required function.

Depot-level maintenance: this comprises the following tasks: detailed examination of the aircraft structure; anti-deterioration measures, low frequency servicing and major modification. It requires a substantial investment in specialist tools, equipment, facilities and technical skill.

Down time: the time the aircraft is non-mission capable due to maintenance actions. It includes logistic delay, technical delay, failure diagnosis, failure correction and checkout.

Engine cold end: the part of the engine incorporating a reduction gearbox and associated assemblies which convert the revolutions developed by the gas turbine to the propeller speed, and a compressor to assist combustion in the gas turbine.

Engine hot end: the part of the engine consisting of a gas turbine, using combustion of aviation fuel to spin a shaft at high speed.

Failure rates: the number of failures over a given period.

Flight authorisation book: book held at squadron level for recording information about each flight, before the aircraft takes off and after it has landed.

Fully-mission-capable: aircraft is able to perform all its missions.

Improved Maintenance Programme: reliability-centred maintenance programme introduced by the Air Force in 1977.

Improved Maintenance Programme Review: periodic reviews of aircraft performance carried out by Maintenance Planning Field Parties as part of the Improved Maintenance Programme.

EXPLANATION OF TERMS

Infra-red detection system: uses an infra-red television camera to passively scan terrain along and around the aircraft's path and displays this as a television type image of the infra-red patterns of the terrain.

Intermediate level maintenance: routine maintenance which takes the aircraft out of operation for several days, but does not require the same investment in equipment or facilities as depot level maintenance.

Limitations log: maintenance log for recording modifications and defects in the aircraft which may affect its performance or role. Each aircraft has its own limitations log.

Maintenance: the combination of all technical and corresponding administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required functions.

Maintenance Planning Field Party: group of maintenance experts who work together for the duration of an Improved Maintenance Programme Review of a particular aircraft.

Maintenance Policy Statements: these statements include equipment descriptions, repair organisations, intended application, implementation timescales, recommended supply volumes and handling instructions.

Master Maintenance Schedule: reference manual which details preventive maintenance actions for significant equipment.

Mean Time Between Failure: for a stated period in the life of an item, the mean value of the length of time between consecutive failures, under stated conditions.

Mean Time To Repair: the time an item leaves the supply system for repair until it is returned to store.

Missions: for the Orion aircraft, include anti-submarine warfare training, maritime patrols and surveillance, supporting combat aircraft operations, pilot and crew training, search and rescue, and transit flights.

Mission-capable: aircraft is able to perform at least one of its missions.

Multi-function display unit: a television display capable of alternatively showing radar, infra-red television pictures and computer information.

Net book value: the value of depreciated fixed assets.

Non-mission-capable: aircraft is not capable of performing any of its missions due to maintenance requirements.

Operating squadron: squadrons with responsibility for operating military equipment.

Operational-level maintenance: squadron level, where aircraft are serviced before and after flight, faulty equipment is repaired or replaced within the capabilities of the unit and routine maintenance which is relatively short, simple and frequent is carried out.

Partially-mission-capable: aircraft is able to perform at least one, but not all, of its missions.

EXPLANATION OF TERMS

Potential availability: the aircraft is not undergoing depot or intermediate level maintenance, but it may be undergoing short term operational level maintenance.

Preventive maintenance: services equipment at predetermined intervals, or corresponding to prescribed criteria, to reduce the probability of failure or performance degradation.

Propeller: in the Orion a four-bladed, variable-pitch, assembly using hydraulic pressure to alter the pitch of the blades, and connected to the gas turbine by the reduction gearbox.

Quality: the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.

Reliability: the ability of an item to perform a required function under stated conditions for a stated period of time. A common measure of reliability is the probability of equipment performing its required function over a stated period of time. Probability of failure is calculated from failure rates and the average time or distance between failures.

Reliability-centred maintenance programme: significant equipment is identified, its performance is monitored and maintenance actions are modified on the basis of equipment performance.

"Rotable" equipment: equipment which can be taken out in modular form for repair and replaced by spare modules.

Significant equipment: equipment critical to the safety or operational effectiveness of the aircraft.

Sono equipment: incorporating passive and active sonar buoys, magnetic anomaly detector, high speed printer, retro-launcher, electro-mechanical tracer and transmitters. It is used to detect, locate and identify submarine contacts.

Surveillance radar: incorporating a transmitter, antenna, receiver, power supply, and data converter. It is fitted to the front of the aircraft and used to search for surface targets.

Utilisation rate: the proportion of time an aircraft is in use.

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