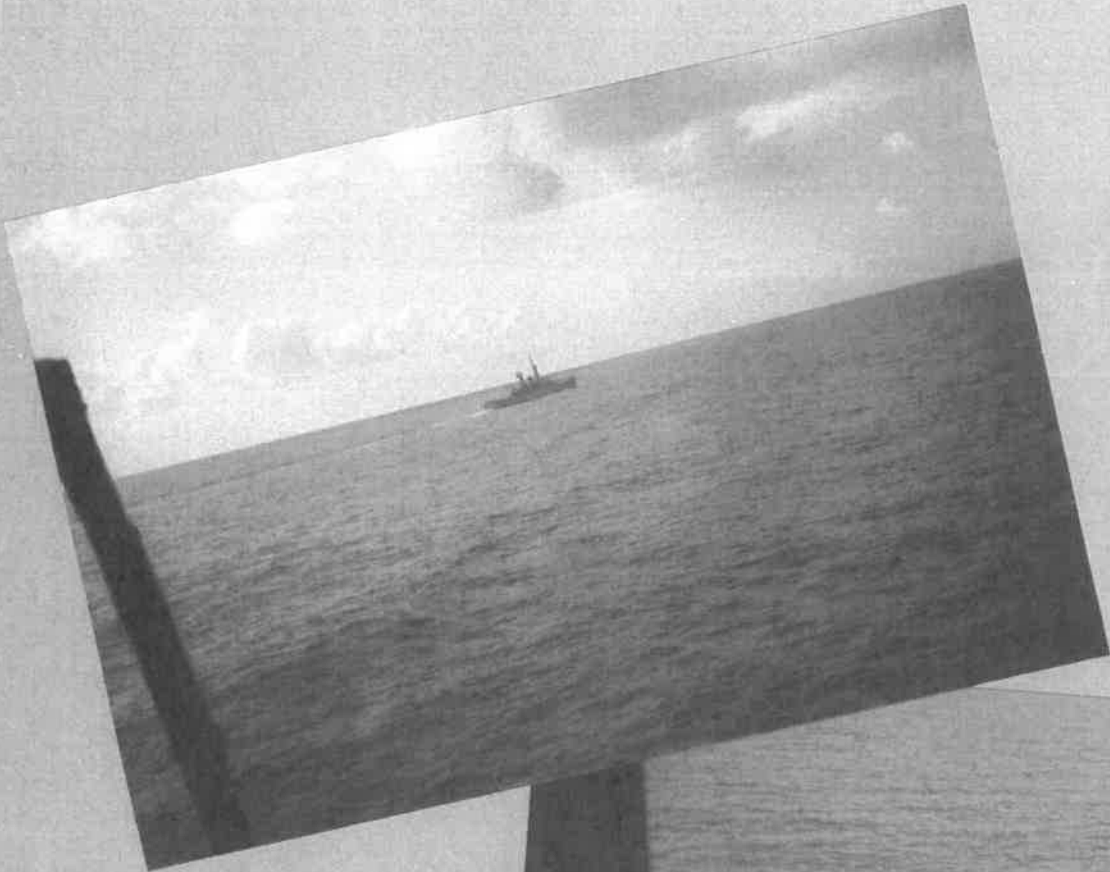
THE AUDIT OFFICE

# THE QUALITY AND RELIABILITY OF DEFENCE EQUIPMENT: ROYAL NEW ZEALAND NAVY

AUGUST 1991



ISBN 0 477 02822 5

# THE QUALITY AND RELIABILITY OF DEFENCE EQUIPMENT: ROYAL NEW ZEALAND NAVY

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 Navy and the attention it pays to the quality and reliability of its equipment. This audit reviewed the frigate HMNZS *Canterbury* and some of its major equipment, and makes other more general assessments.

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

It is appropriate to acknowledge the work of the three officers from my Major Projects Group primarily responsible for the report, Anne Gooch, John Lee and Alastair Donald.

I hope 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 in the Navy specifically, and in the New Zealand Defence Force in general.

J.W. Cameron
Deputy Controller and Auditor-General

2 August 1991

# CONTENTS

# EXECUTIVE SUMMARY

## Introduction

Equipment is critical to an effective defence force. The quality and reliability of equipment, therefore, impacts on the capability of a defence force to carry out its tasks. In addition, quality and reliability affects the amount of money spent on maintenance and modification of equipment. They are a measure of efficient and effective management practice.

The range and complexity of defence equipment precludes the Audit Office from examining the quality and reliability of each item. Further, each service applies different equipment management policies. Therefore, in order to gain an insight into the quality and reliability of defence equipment, the Audit Office has chosen to audit each armed service separately.

This report on the Royal New Zealand Navy is the second audit in the series, the first one having been carried out in the Army. For a sample item of equipment in the Navy, we chose HMNZS *Canterbury*, a Leander class frigate. HMNZS *Canterbury* is one of four frigates making up the combat force of the Navy. As a frigate is a large system, made up of a wide variety of equipment, we selected five particular items of equipment for detailed study. These were the:

- Steam power plant;
- 4.5 inch guns and turret;
- Seacat anti-aircraft missile system;
- Type 965 long-range air surveillance radar system; and
- LW08 long-range air surveillance radar system.

The audit team reviewed files, interviewed staff, both ashore and at sea on HMNZS *Canterbury*, and analysed available data to determine the attention the Navy pays to quality and reliability.

## Key Findings

### *Procurement*

We examined the procurement of the LW08 radar to assess the attention paid by the Navy to quality and reliability when buying new equipment. Generally, the Navy met the Audit Office's expectations, in that it:

- Identified the need for a new radar;
- Developed technical and operational requirements;
- Identified sufficient radars for evaluation to make the most suitable selection;
- Carried out an evaluation of the two most suitable contenders; and
- Finally bought a radar that met stated or implied needs. (Paragraphs 307–319).

However, the Navy did not identify the added costs associated with installing the LW08 radar on HMNZS *Canterbury* when evaluating it against its competitor. Consequently, the competing radar had a cheaper purchase price than the LW08. (Paragraph 320).

In addition, the Navy did not calculate the whole-of-life cost of the two evaluated radars. The Navy based its decision on purchase price and performance, and did not include an analysis of operation and support costs for the life of the radars. Therefore, the Audit Office cannot confirm that the LW08 radar was the best choice based on price. However, given the manufacturer's reported reliability of the LW08 radar, our own analysis of available data, held by the Navy, leads us to believe the LW08 was the better purchase. (Paragraphs 321–326).

***Reliability***

To manage the reliability of equipment, the Navy must record equipment performance.

The Navy does not adequately measure the reliability of its equipment. Equipment records do not provide sufficient information to calculate equipment reliability. In addition, the Navy has not developed performance standards for monitoring an individual equipment's reliability. (Paragraphs 410–413).

In analysing the selected equipment on HMNZS *Canterbury*, we noted that the steam plant and the 4.5 inch guns and turret were capable of sustaining several failures while remaining operational. This was because components were duplicated, or the effect of failure was degraded performance rather than total failure. Where that duplication is missing, such as in the components of the Seacat Missile System, we found that it was more susceptible to total failure. (Paragraphs 414–416).

The Navy has not identified the critical components of systems that impact on that system's reliability. Reliability information should be retained in the Navy's Equipment Management Policy Statements together with reliability standards and performance. (Paragraphs 417–419).

Where the Navy records equipment failure, it rarely records the cause of that failure. Consequently, it cannot target recurring causes of failure, and is therefore unlikely to lessen the probability of failure in the future. (Paragraphs 420–421).

***Maintenance***

An effective maintenance process allows the continuing performance of equipment so that it can fulfil its operational requirements. The Navy's management of its maintenance programme not only affects the operational ability of its ships, but also ensures that the equipment meets safety standards.

As the Navy does not keep reliability information, it cannot identify whether it is under- or over-maintaining its equipment, and consequently, does not know if its maintenance systems are appropriate. (Paragraph 533).

The Navy is unable to substantiate the fleet's operational reliability and number of failures occurring on ships, or to monitor the cost of downtime because of failure.

The Navy measures the availability of its ships by determining their "operational ability". This is calculated as the percentage of operational time over the total time elapsed. The Navy identifies one of its maintenance periods, the Assisted Maintenance Period, as operational time. We question how a ship in this maintenance period can be operational when equipment may be unavailable for up to 47 hours. We therefore assessed the operational ability of HMNZS *Canterbury* at 64 percent, 16.7 percent below the best operational ability target set for the combat force by the Navy. If HMNZS *Canterbury* was to meet the 80.7 percent goal over the next 15 years, it would spend an extra two and a half years in "operational ability" time. (Paragraphs 520–529).

In addition, the Navy refits the frigates HMNZS *Canterbury* and HMNZS *Wellington* on a three-year cycle, instead of the four-year cycle used for the frigates HMNZS *Waikato* and HMNZS *Southland*. This could cost the taxpayer one, or possibly two, extra refits at a cost of around $25–40 million. Given the:

- Cost of refits,
- Lack of information on the impact of these refits on the capability of the frigates, and
- The adverse impact on operational ability,

the Navy should re-assess the refit periods for HMNZS *Canterbury* and HMNZS *Wellington*. (Paragraphs 530–532).

The Navy uses a comprehensive maintenance system based on components being serviced at regular intervals. However, components are still failing during operational time, indicating under- or over-maintenance.

The Navy is about to implement a condition-based maintenance system for selected items of equipment in the fleet. This has the potential to reduce maintenance costs through extending the periods during which equipment remains in operational use. The Audit Office commends the Navy for this approach. (Paragraphs 542–545).

## Conclusion

The Navy needs to pay more attention to quality and reliability. While equipment procurement identifies quality and reliability information, the Navy does not monitor its reliability on a continuing basis. It therefore cannot determine equipment's availability, or modify maintenance processes, to reflect the operational performance of its equipment. In addition, the Navy cannot determine if it is under- or over-maintaining its equipment.

The greatest benefit for the Navy through increased quality and reliability will be in the availability of equipment, and therefore increased operational capability.

# CHAPTER ONE

# INTRODUCTION

## Mandate

*101* Our audit examined the quality and reliability of New Zealand Defence Force equipment. The authority for the audit is section 25(3) of the Public Finance Act 1977. We selected the Royal New Zealand Navy for our second audit, having completed a similar audit in the Army in August 1990.

*102* Armed forces must have both equipment and personnel to enter a conflict.

*103* In the 1990–91 year, around $200 million has been allocated to the purchase of capital equipment for the New Zealand Defence Force. The total value of existing equipment is estimated to exceed $3.5 billion. The heightened quality and reliability of equipment increases military capability, and thus decreases repair costs and the need for replacement.

*104* Given the reliance placed by the armed forces on their equipment, the quality and reliability of that equipment is critical.

*105* By focusing on quality and reliability, the Audit Office sought to determine whether the New Zealand Defence Force applies appropriate equipment management policies and procedures. The quality and reliability of equipment affects the periods when the equipment is in service or under repair, and, consequently, that equipment's availability to carry out its role. This, in turn, is a useful measure of that equipment's capability. In addition, it is important to recognise that quality and reliability are inter-related. For example, the quality of a piece of equipment affects its reliability, and the reliability of a piece of equipment reflects its quality (see paragraph 111).

## Audit Approach

*106* The Navy's fleet consists of a combat force of four frigates, and support vessels for supply, training and hydrographic survey.

*107* Three of the four frigates in the combat force are HMNZS *Canterbury*, HMNZS *Wellington* and HMNZS *Waikato*, which are general-purpose frigates of the Leander class, originally designed for the Royal Navy. These ships can be used for several roles, and are fitted with a wide variety of equipment (see paragraph 109). HMNZS *Southland*, the fourth frigate, while of the Leander class, is primarily fitted for an anti-submarine role.

*108* We selected HMNZS *Canterbury* as this frigate met the criteria which we had determined for review. That is, it was:

- Part of the combat force;
- Not too numerous; and
- Financially significant.

## INTRODUCTION

109 HMNZS *Canterbury* is a Batch III Leander class frigate whose design dates from the late 1950s. She was built in Britain for the Royal New Zealand Navy in 1971.

Displacing over 3000 tonnes when fully loaded, the Leander class is fitted with various weapons, surveillance and communication equipment. These include a turret containing two 4.5 inch (114 mm) guns, anti-submarine torpedo launchers, anti-aircraft missiles, a helicopter, and a long-range surveillance radar. The engines can propel the frigate at a maximum speed of about 28 knots.

110 As HMNZS *Canterbury* is a complex item of equipment, we selected, after discussion with Naval Staff, certain equipment to assess the quality and reliability of the frigate.

Our selection criteria targeted equipment systems which were militarily, physically and financially significant. Those selected were the:

- Steam power plant; the equipment, including boilers, pumps and condensers, that converts fuel energy into mechanical energy to drive the propellers and provide power generation to the whole ship. The audit team studied only the equipment used to raise and maintain steam pressure.
- Seacat anti-aircraft missile system; a surface-to-air missile fired from a launcher and controlled from a director, which uses radar to locate and track targets; and a visual, manually-operated, radio-guidance system to control the missile. It has a maximum range of approximately 5 kilometres. The audit team concentrated on the guidance and launching systems, and excluded the missile itself from evaluation.
- 4.5 inch guns and turret; a turret containing two 4.5 inch (114mm) guns, each firing a 25kg shell at about 20 rounds a minute in anti-aircraft, anti-shipping and gunfire support roles to a maximum range of about 19 kilometres. The audit team excluded the radar controlled guidance system and the ammunition from its audit.
- Type 965 radar system; a long-range air surveillance radar with a maximum range of 270 kilometres.
- LW08 radar system; a long-range air surveillance radar system providing air and surface target detection to a maximum range of 270 kilometres. This replaced the Type 965 radar in HMNZS *Canterbury*'s 1987–1990 refit.

111 The audit team applied the definitions of quality and reliability as stated in the internationally-adopted New Zealand Standard 5604:1987.

- **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.**

These definitions should be understood when quality and reliability are referred to in the report.

*112* Common to these definitions are pre-stated functions or needs which we sought to identify.

*113* We examined the processes for procuring new equipment, and for monitoring in-service performances of existing equipment.

*114* The report structure is as follows:

- Background (Chapter 2)
- Procurement (Chapter 3)
- Reliability (Chapter 4)
- Maintenance (Chapter 5).

*115* A final section (Chapter 6) outlines conclusions and issues which, in the opinion of the Audit Office, the Navy should consider.

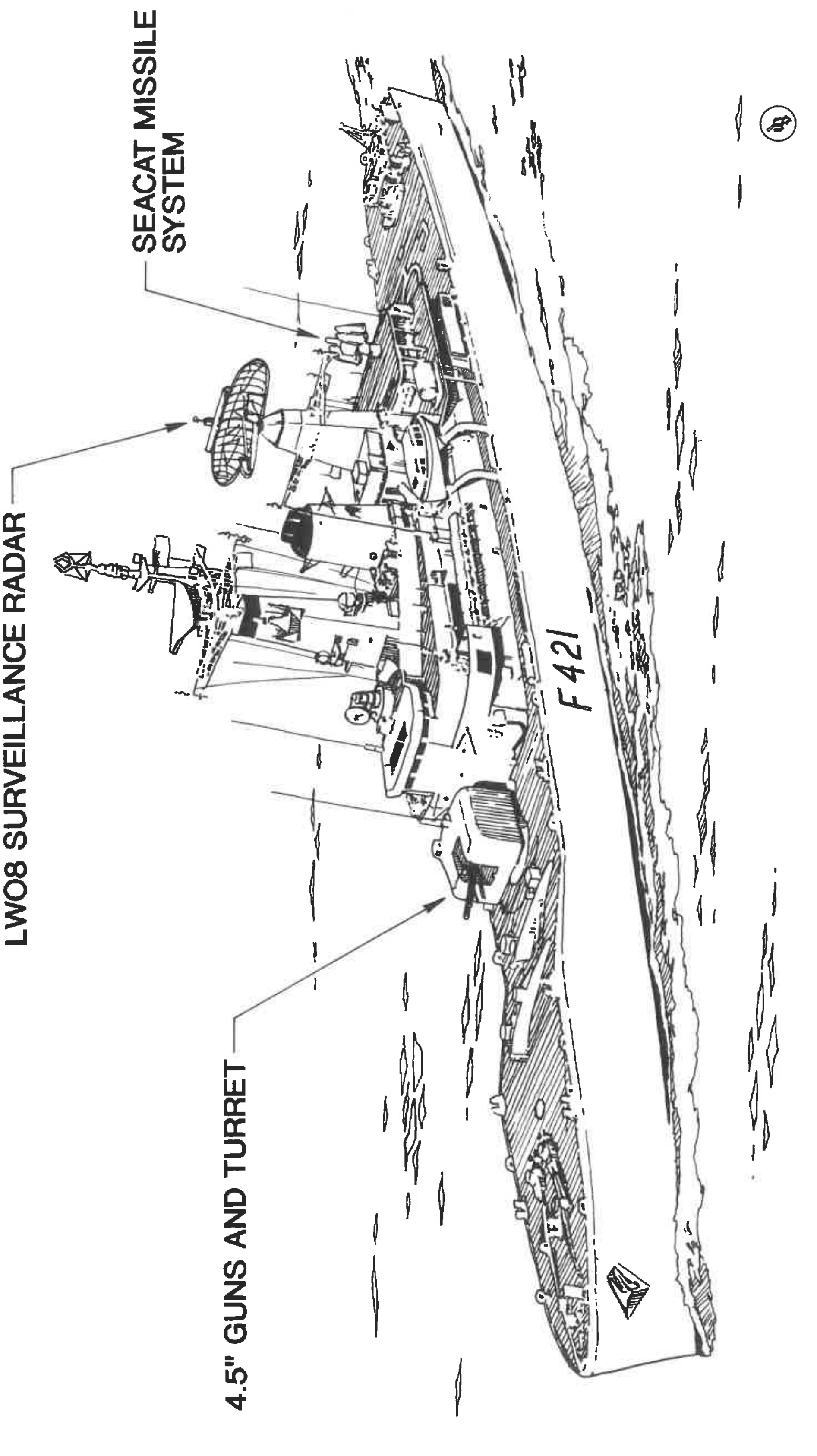



**Figure 1**
**HMNZS *Canterbury*, showing the position of the selected equipment**

# CHAPTER TWO

# BACKGROUND

*201* Two organisations hold primary responsibility for defence; the Ministry of Defence and the New Zealand Defence Force. The Ministry of Defence is responsible for policy advice and monitoring. The New Zealand Defence Force provides the necessary support and co-ordination of the three armed services: the Royal New Zealand Air Force, the Army and the Royal New Zealand Navy.

*202* Each armed service, although co-ordinated by Defence Force Headquarters, operates autonomously and has a different organisational structure.

*203* The Navy's primary function of maritime security requires both patrol and surveillance capabilities and, when required, combat capability.

*204* To support this function, there are several naval shore-based organisations, which include:

- HMNZS *Wakefield* in Wellington, where Naval Staff provide policy for the operations and maintenance of Navy ships;
- The Office of the Commodore, Auckland, the Operational Administrative Authority for the fleet;
- HMNZS *Philomel* in Auckland, which provides the fleet with administrative, supply and maintenance support;
- HMNZS *Tamaki* in Auckland, the centre for naval basic, specialist and officer training; and
- HMNZ Dockyard in Auckland, which undertakes work specified in the maintenance schedules and other dockyard work.

Maintenance is carried out at sea by the ships' staff and on-shore by HMNZS *Philomel* and HMNZ Dockyard.

# CHAPTER THREE

# PROCUREMENT

## Introduction

*301* We examined the attention the Navy paid to quality and reliability when procuring a new equipment system.

*302* The inherent quality and reliability of an item of equipment must be a design feature. The design specification must ensure that roles have been determined and that performance standards based on those roles are met.

## Audit Approach

*303* HMNZS *Canterbury*, when first delivered in 1971, carried a Type 965 surveillance radar. This was replaced in the 1987–1990 refit by the Hollandse Signaalapparaten LW08 surveillance radar.

*304* We selected the procurement of the LW08 radar as an example of the Navy's procurement processes. This was physically the largest and most expensive capital addition in HMNZS *Canterbury*'s last refit.

*305* To assess the procurement process, we expected the Navy to have demonstrated that:

- Each equipment system's role was clearly defined;
- Existing equipment needed replacement;
- Options were compared and evaluated;
- Manufacturing standards complied with the Navy's quality assurance standards; and
- Whole-of-life costs (defined in paragraph 322) were calculated.

*306* When procuring new equipment, the Navy should have established specifications, taking account of:

- Military capability;
- Technical capability;
- Risks; and
- Costs associated with those risks.

## Findings

*307* HMNZS *Canterbury* and HMNZS *Wellington* are expected to remain in service for another fifteen years to 2005, during which period the new ANZAC frigates will replace the current combat force.

*308* In July 1987, the Defence White Paper stated that surveillance and reconnaissance were essential contributions to defence objectives. The Navy identified a long-range surveillance radar as an important system with which to carry out those objectives.

*309* The original manufacturer was no longer producing spare parts or refurbishing components of the Type 965 surveillance radar, and the Navy could not identify another source. The Navy therefore established that there was no longer any operational, technical or supply support available to maintain the Type 965 for another 15 years. For example, in 1987 it identified a nine-month delay in manufacturing and supplying a failed Type 965 radar component.

*310* In October 1987, ministerial approval was given to the Navy to purchase two long-range air warning radars for HMNZS *Canterbury* and HMNZS *Wellington*, for an indicative cost of $15.11 million for both radars.

*311* The Navy developed specifications for technical and operating requirements for the radar.

*312* The Navy's specifications were consistent with our expectations (paragraph 306). These covered:

- Operational and technical performance;
- Ease of installation;
- Compatibility of new radar with existing and planned equipment;
- Reliability; and
- Ability to maintain equipment.

*313* The Navy also estimated costs associated with the purchase of a new radar, including purchase price, spares and support items, training, and manufacturer's installation.

*314* There were 14 initial registrations of interest from suppliers. After consideration of these against the Navy's specifications, seven were eliminated because five radars failed to meet the minimum long-range required and two were too heavy to be fitted on the ships.

*315* Two further radars were eliminated, as accurate information on performance and availability could not be obtained from the suppliers. The Audit Office agrees with the Navy's decision to eliminate them from the tender process at that stage.

*316* The five remaining radars were reduced to four when a manufacturer was unable to further reduce the weight of the aerial.

*317* The final four radars, which met the Navy's specifications, were evaluated on estimated purchase cost. The Navy then rejected the two most expensive.

*318* The Navy invited final tenders from the two selected companies, one of which was the LW08 radar manufactured by Hollandse Signaalapparaten. On receipt of these tenders, the Navy carried out a detailed evaluation, based on:

- Operational and technical merits;
- Installation details;

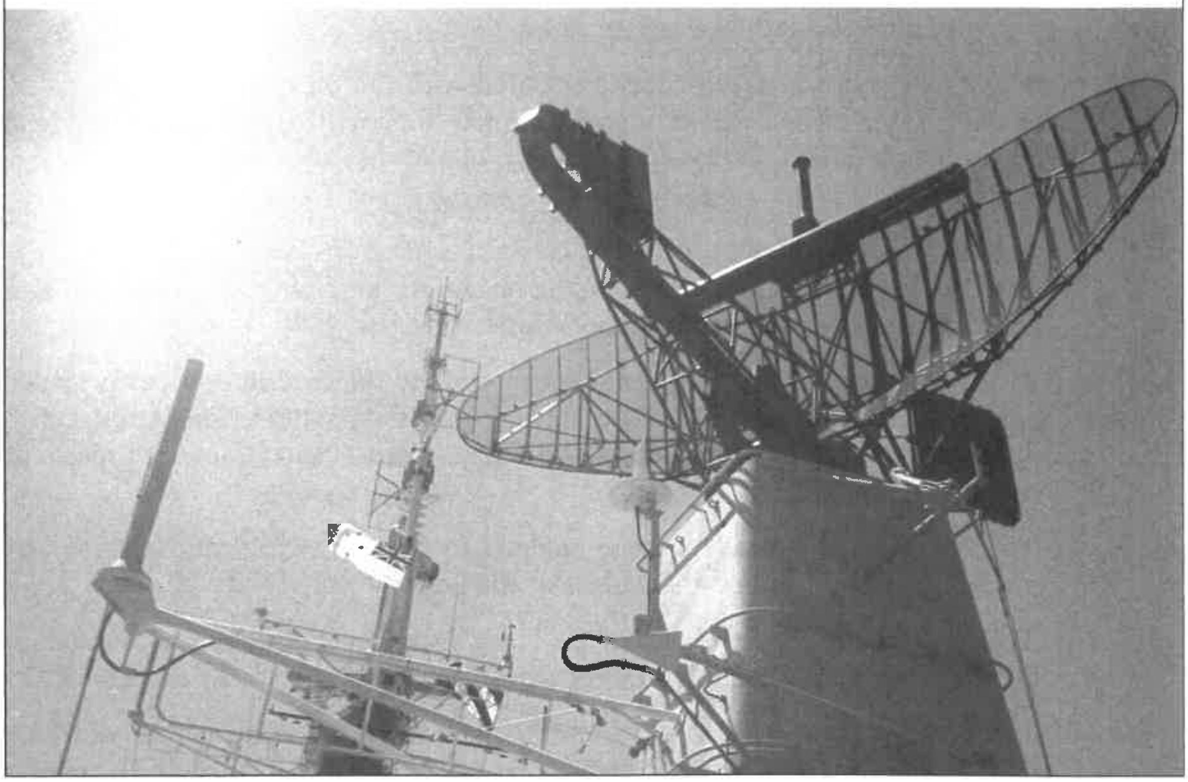
- Compatibility with existing and planned equipment on HMNZS *Canterbury* and HMNZS *Wellington*; and
- Cost.

*319* This showed that both radars exceeded the Navy's operational and technical requirements, and that the LW08 radar's performance was superior to that of its competitor.

*320* However, the LW08 radar required major changes to its aerial to operate on HMNZS *Canterbury* and HMNZS *Wellington*. As designed, the radar was half a tonne too heavy and would have caused stability problems for the ship. To overcome this, the tender from the LW08's builders identified changes to the radar itself, and to the mast on which the radar was to be mounted. The other radar, however, required only a small change to the mast.

Because the Navy did not separate out the maintenance costs to rectify known defects from the cost of rebuilding the mast on HMNZS *Canterbury*, it could not provide any comparative and accurate costs of installing the contending radars.

**Figure 2**
**LW08 Radar, installed on HMNZS *Canterbury***



*321* While evaluations of suitable radars were undertaken, we could not fully prove that the LW08 radar was the better choice because the Navy did not assess whole-of-life costs, including the costs of modification prior to installation.

322 Whole-of-life costs are those associated, not just with the initial purchase of the equipment system, but also with its operation and support over the intended life cycle of service with the Navy.

323 Operation and support costs include:

- Pay and allowances for staff using the equipment;
- Consumables such as energy and materials for operations and maintenance;
- Costs for maintaining or modifying the system;
- Sustaining investment with replenishment spares, software support, and replacing support equipment;
- Contractor support where appropriate;
- Updating publications, recurring engineering or technical services, and leasing or maintaining support equipment or materials; and
- Indirect costs such as base operating support, and personnel recruitment and training.

324 However, the final tenders only included prices for:

- A spare aerial;
- 90 days' onboard spares; and
- 3 years' depot spares.

The tender covering these items for the LW08 was $1.4 million, $2.6 million less than the other tender. The Navy did not consider costs of those other items listed in paragraph 323.

325 While both radars were assessed as capable of working with existing or planned equipment on the ship, the more recently designed LW08, unlike its competitor, did not require modification.

326 When both radars exceeded the Navy's operational and technical requirements, the whole-of-life cost should have become the main factor in the decision to purchase the radar. In the final tender evaluation, the Navy identified the purchase price of LW08 radars including equipment to link command and control systems, as being $19 million, nearly $4 million more than the approved indicative cost (see paragraph 310), and $1.07 million more than its competitor. However, the Navy purchased the LW08 radar. This decision was based on the superior performance of the LW08 as reported in the Navy's tender evaluation (see paragraphs 318 and 319). In the absence of whole-of-life costing and identification of the mast alteration costs, the Navy could not confirm that the LW08 will be the less expensive radar over its service life.

327 The approved contract included:

- Training to achieve and maintain quality;
- Training of both naval and civilian maintenance staff;
- Supplying information to enable further integration;
- A warranty section; and

- Delivery of most equipment to meet dockyard dates for installation and testing.

328 The manufacturer complied with North Atlantic Treaty Organisation quality assurance standards, meeting the Navy's requirement that the manufacturer be assessed independently. Naval staff visited the factory producing the equipment to check that the work was proceeding on time and to quality requirements. The Navy received reports of progress during the manufacturing phase.

329 The equipment arrived at HMNZ Dockyard in time for installation on HMNZS *Canterbury* while the ship was in refit.

330 The Navy tested the LW08 at sea on 18 September 1990 with the manufacturer's representatives in attendance. This sea trial showed that its performance exceeded the Navy's requirements. Both parties then signed a final and formal acceptance of the LW08 radar on 24 September 1990.

## Conclusions

331 The Navy satisfied the Audit Office that the LW08's performance met "stated or implied needs".

332 In our opinion the Navy had:

- Specified the operating and technical requirements of the radar;
- Developed performance standards; and
- Identified sufficient radars for evaluation to make the most suitable selection.

333 We were impressed with much of the radar system's evaluation process. However, the Navy did not consider whole-of-life costs, including costs for installing the new mast.

334 As a consequence, we are unable to confirm that the radar now fitted to HMNZS *Canterbury* was the best choice based on the whole-of-life cost. However, the manufacturer's information indicates the LW08 is capable of superior reliability and maintainability to that of its competitor. Our own analysis of available data collected by the Navy leads us to believe the LW08 radar was the better purchase.

# CHAPTER FOUR

# RELIABILITY

## Introduction

*401* The reliability of an item of equipment is defined as the ability of that item to perform a required function under stated conditions for a stated period of time.

The principal measure of reliability is the probability that an item can perform as required; this is calculated from failure rates and the average time or distance between failures.

*402* The importance of having reliable equipment cannot be stressed too strongly. The actual, and potential, costs of unreliable equipment are not merely monetary but also safety-related.

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

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

*404* To calculate the reliability of equipment, sufficient data has to be collected regularly. Equipment components or systems which critically influence reliability and which will be repaired after a failure should be individually identified and their effect on reliability analysed. For example, the performance of equipment can be identified by calculating the types of failures occurring and the rate of failure, expressed as down time caused by those failures, and the average time or distance between failures.

*405* This information makes it possible to detect any deterioration in reliability. Any decrease in reliability, and, consequently, the availability of the equipment system, may also have an impact on the cost of operating that equipment. Equipment unavailable through failure incurs two costs:

- Repairing the failure in the equipment; and
- Supplying additional equipment to take the failed equipment's place until it is repaired.

*406* In the United States, experience has shown that an investment in reliability of around 2 percent of the cost of acquisition has an investment return of 14 percent of the original purchase price. This leaves a net return on the investment in reliability of 12 percent. This return could be realised in:

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

However, the greatest impact on the Navy could be the improved capability of a ship to undertake its functions through increased equipment availability.

## Audit Approach

*407* For the selected equipment on HMNZS *Canterbury*, we reviewed all information which the Navy recorded on reliability to identify the reliability standard, the successful performance, and the average time or distance travelled between failures. We then compared this information against the Navy's requirements.

*408* We also identified, through analysis of recorded failures and interviews with Naval staff, critical components of the selected equipment:

- The 4.5 inch guns and turret;
- The Seacat missile system; and
- The steam power plant.

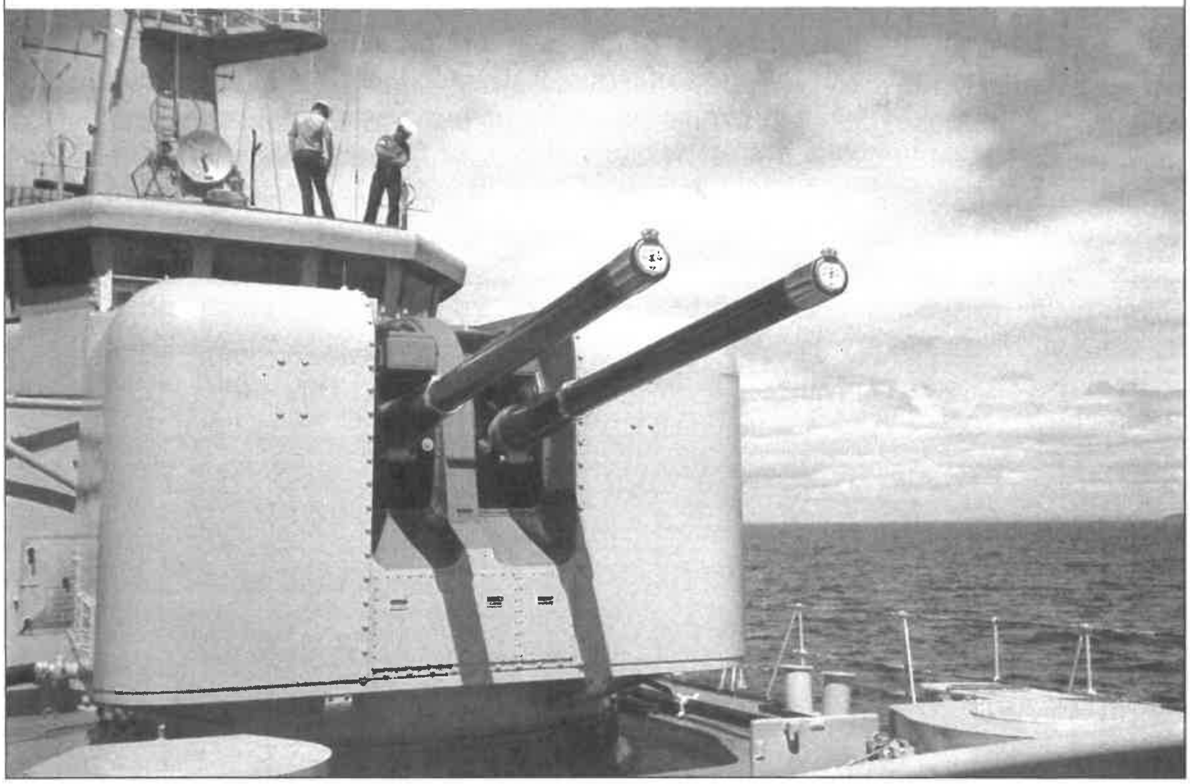
We used this information to identify the capability of the selected equipment to continue working after component failures.

## Findings

*409* When the Navy records failures, it does so in one or more ways:

- An operational defect (OPDEF); which affects the operational capability, or safety, of the ship. In the period between February 1982 and October 1987, HMNZS *Canterbury* reported 23 OPDEFs in the steam plant, eight OPDEFs in the Seacat missile system, and six OPDEFs in the 4.5 inch gun turret.
- A defect; which may be recorded on the ship's permanent datapacks, containing information on that piece of equipment from its introduction into service, or recorded in temporary logbooks, which are discarded when completed. In the period between October 1971 and August 1990, HMNZS *Canterbury* recorded, in its datapacks, 157 failures in the steam plant, 20 failures in the Seacat missile system, and 12 failures in the 4.5 inch gun turret.
- RNZN 2022 Report of Defective Material and Design form; which reports failures and shortcomings in equipment. In the period between February 1973 and February 1987, HMNZS *Canterbury* recorded, on 2022 forms, 37 failures in its steam plant, eight failures in the Seacat missile system, and nine failures in the 4.5 inch gun turret.

**Figure 3**
**The 4.5 inch Gun Turret**



410 The records did not contain:

- The total time during which the equipment was in use; and
- The time from the failure occurring to the failure being corrected.

411 While the Navy recorded failures in the selected equipment, it did not do so in such a way as to allow the failure probability of those systems to be calculated.

412 Without this ability to calculate the probability of failure, the Navy cannot measure the reliability of its equipment.

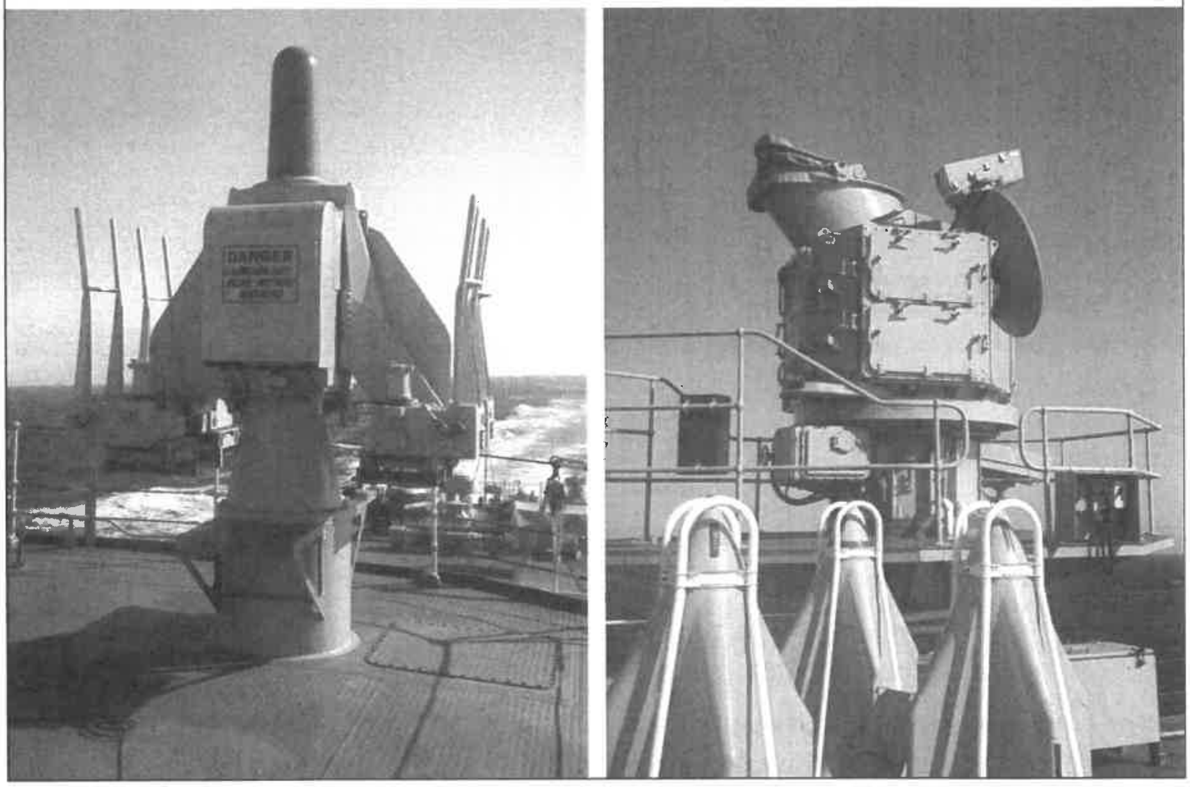
413 Ships' staff record failures when the failures are considered to be of importance to the operational capability or safety of the ship, or where the records are of use to staff in charge of that equipment. It is the responsibility of the ships' staff to signal an operational defect to the staff of the Commodore, Auckland. To calculate reliability throughout the fleet, the Navy must record information consistently. As the Navy relies on the judgement of staff on individual ships to decide on the critical nature of failures, it cannot ensure that consistency of information.

414 The Navy has not identified, through an analysis of actual or potential failures, critical components in equipment used on HMNZS *Canterbury*. The possible reliability of an equipment system can be evaluated by studying the effect of critical component failures on the ability of that system to carry out its role.

We examined the Seacat missile system, the 4.5 inch gun turret and the steam plant to assess their ability to work despite component failures.

415 We found the steam plant to have a design which allowed for continued performance despite several component failures. This is because components are duplicated, or the effect of failure is degraded performance rather than total failure. The 4.5 inch gun turret, while having fewer duplicated components, could still operate despite several component failures. Where that duplication is missing, as in the components of the Seacat missile system, we found it to be more susceptible to total failure.

**Figure 4**
**The Seacat Missile System**
**Seacat Launcher** **Seacat Director**



416 Therefore, while the steam plant experienced 23 OPDEFs between February 1982 and October 1987, none of those failures would have halted its operation. However, all eight reported OPDEFs for the Seacat missile system would have shut down the system.

417 While HMNZS *Canterbury* is a general-purpose frigate, capable of carrying out many roles, individual systems on the frigate carry out more specific roles. The Navy had not clearly identified the critical components of the systems based on these specific roles.

418 When the Navy adds a new piece of equipment to a ship, it produces an Equipment Management Policy Statement, which contains the Navy's policy requirements for managing that item. However, no Equipment Management Policy Statements apply to equipment selected for study by the audit team, as the 4.5 inch gun turret, Seacat missile system and steam plant were supplied with HMNZS *Canterbury* in 1971. Of all the Equipment Management Policy Statements produced by the Navy, 78 percent did not set quantifiable standards for usage, availability, reliability and maintainability. At the time of our audit, the Navy had not produced an Equipment Management Policy Statement for the LW08 radar. However, the tender evaluation for this radar gave the manufacturer's data on claimed reliability. We saw no evidence of any reliability process to monitor the achievement of either these claims, or the 22 percent of those Equipment Management Policy Statements which did identify reliability standards.

419 Older equipment, on HMNZS *Canterbury* when she was purchased, does not have Equipment Management Policy Statements. The Navy monitors the Seacat and 4.5 inch gun performances against pre-refit trials, and the steam power plant against the original steaming trials (carried out in 1971). However, this monitoring does not measure the long-term reliability of the equipment system to meet its performance requirements over a set period of operational time.

420 Our examination of the selected equipment data packs, operational defect reports and 2022s showed that the Navy rarely reports the actual cause of a failure. The reports on equipment failures usually identify only symptoms and not causes. This is demonstrated in Figure 5.

**Figure 5**
**Percentage of failure causes identified against total failure reports from HMNZS *Canterbury* between February 1982 and December 1990**

| | *Number of Reports* | *Causes Identified* | % |
|---|---|---|---|
| Steam Plant .. .. .. | 110 | 4 | 4 |
| Seacat Missile System .. | 21 | 1 | 5 |
| 4.5 inch Guns and Turret .. | 19 | 2 | 11 |
| TOTAL .. .. .. | 150 | 7 | 5 |

421 Consequently, the Navy is unlikely to target those causes. Accordingly, it is unlikely to lessen the probability of failure in the future, and therefore produce a more efficient and effective maintenance programme.

## Conclusions

422 Assuring and assessing quality and reliability requires greater effort from the Navy. While new equipment, such as the LW08, has been purchased with quality and reliability in mind, the Navy does not have the mechanisms in place to measure the quality and reliability of this equipment while it is in service. Older equipment does not have performance standards against which to measure reliability.

423 The Navy has not identified critical components or equipment which affect the capability of HMNZS *Canterbury* to undertake its various roles. In addition, while the Navy collects data on failures, it does not collect sufficient information to measure the reliability of its equipment or identify the causes of failure.

424 The Navy has not developed Equipment Management Policy Statements, stating reliability standards, for the equipment selected for the audit, or for the equipment originally supplied with HMNZS *Canterbury*.

425 If levels of performance and reliability standards were developed, the Navy could monitor both availability and reliability achieved by equipment and note reasons for variance. Where problems arose, the Navy could assess the cause, take remedial action, and measure the results of that action. In any event, the Navy should be able to report its operational capability, a key indicator of its management performance.

# CHAPTER FIVE

# MAINTENANCE

## Introduction

501 An effective maintenance process enables the ongoing performance of equipment so that it can fulfil its operational requirements.

502 These requirements place demands on the Navy's maintenance processes and on its ability to maintain equipment to a high standard. Not only does maintenance affect the Navy's operational ability, but it ensures that equipment safety standards are met.

503 There are two different methods of maintaining an item of equipment. These are:

- **Preventative maintenance**—where equipment is serviced:

  ★ At pre-determined intervals; or

  ★ Corresponding to prescribed criteria;

  to reduce the probability of failure or performance degradation.

- **Corrective maintenance**—where equipment is serviced after failure has occurred, and is intended to restore an item to a state in which it can perform its required function.

504 The Navy informed the Audit Office that it had spent approximately $52.5 million on vessel maintenance in 1989–90.

## Audit Approach

505 We reviewed the current maintenance system, including associated information used in the Navy, both onshore in Auckland and on HMNZS *Canterbury*. We examined the operational and administrative structures which the Navy has to record, analyse and report maintenance information.

506 We measured the effect of the maintenance system on HMNZS *Canterbury*'s downtime. This is illustrated diagramatically in Figure 7 on page 30.

507 We compared our analysis of critical components in equipment (paragraph 408) with the Navy's Technical Management System maintenance programme, to assess whether this programme targeted those critical components and whether the reliability of equipment affects the periods of maintenance.

508 We also reviewed a new maintenance system intended to assess continuously the performance and condition of equipment with rotating components.

## *PRESENT MAINTENANCE PROCESSES*

509 The Navy acquired its maintenance procedures, known as the "R2" system, from the Royal Navy. In June 1987, the Navy implemented a revised and modernised version of the R2 called the Technical Management System.

510 The Technical Management System follows Royal Navy maintenance procedures but incorporates changes based on Royal New Zealand Navy operating experience. This management system in part incorporates a planned preventative maintenance system, for which performance monitoring is an integral component. The planned preventative maintenance system is supported by a number of formatted reports, returns, historic data collection system, maintenance operation advice and instruction, together with several maintenance planning aids. Some components are:

- **Books of Reference**, which outline the Navy's maintenance policies and procedures for all Navy ships;
- **Planned Maintenance Schedules**, which specify what preventative maintenance is required, how often and by whom;
- **Job Information Cards**, detailing the instructions to undertake preventative maintenance;
- **Ships' Equipment Lists**, which show equipment fitted in the ship on which maintenance is necessary; and
- **Ships' Data Packs**, containing important facts about the ship's equipment performance.

511 The Planned Maintenance Schedules specify the intervals for inspections and overhauls. These required inspections range through daily operator checks and annual overhauls to maintenance work during refit periods every three or four years.

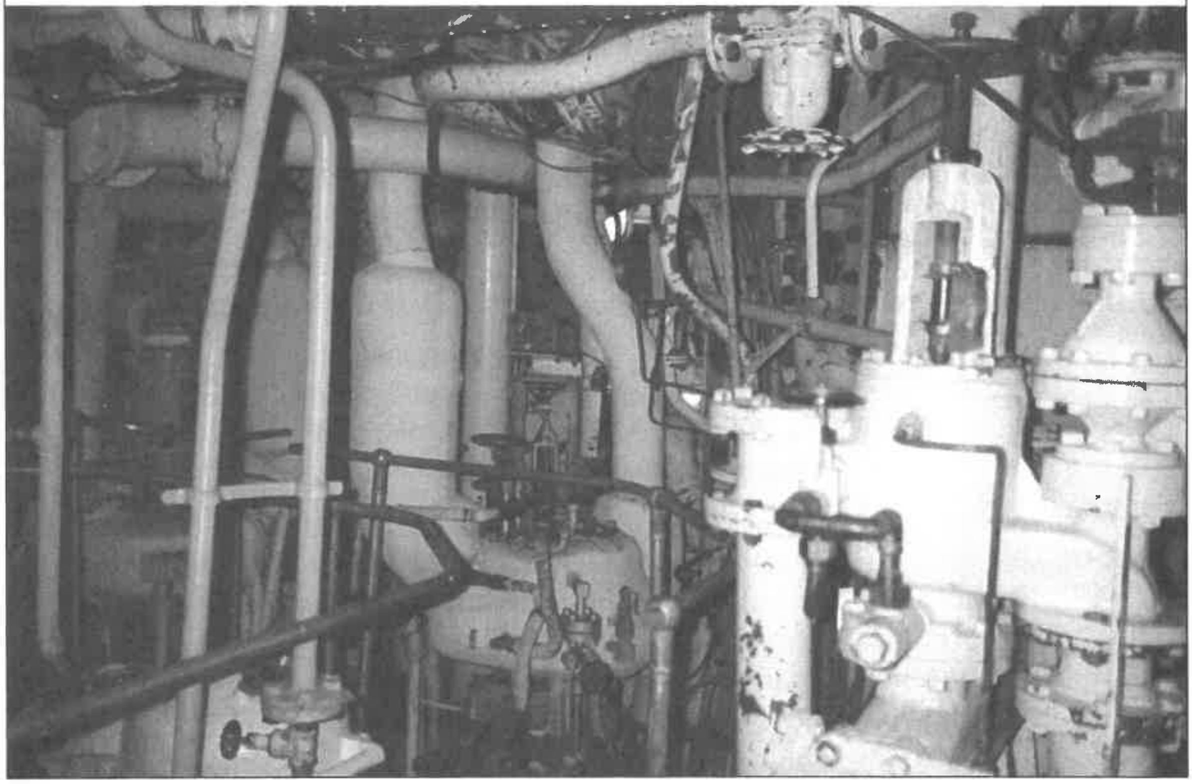
The Navy plans its maintenance periods on continuous cycles of 156 weeks for frigates on a three-year refit period and of 208 weeks for frigates on a four-year refit period. These cycles may include:

- **Self Maintenance Periods**, when the ship carries out its own maintenance with normal eight hours' notice for sea; that is, the time within which a ship can be readied for sea;
- **Assisted Maintenance Periods**, when the ship will be assisted by shore support and dockyard facilities, but at 47 hours' notice for sea;
- **Docking and Essential Defects**, when docking, with full maintenance support facilities, undertaken between refits to correct defects which impact on the operational capability of the ship; and
- **Refits**, intended to restore the ship to its full operational standard.

512 There are various levels of refit performed in the Navy. These include:

- **Normal refits**, which are undertaken by HMNZ Dockyard and include maintenance originating from defect reports. These refits are usually performed every three or four years;
- **Major refits**, based on defect reports, which also include additional maintenance work to bring the ship to full operational standards, and are carried out every third normal refit; and
- **Special refits**, which are specifically used for modernisation, conversion, or major repairs as directed by Naval Staff. This includes a special half-life refit.

**Figure 6**
**The Engine Room—HMNZS *Canterbury***



513 HMNZS *Canterbury* started her special half-life refit in November 1987. The refit was completed in June 1990 and, as a result, she is expected to be in service until 2005. The Navy estimates the cost of this refit as $73 million.

514 During the refit process, the Navy carries out pre- and post-refit trials on the weapons and electrical equipment and on the marine engineering plant. These trials, overseen by the Fleet Trials Analysis Unit, are normally carried out by ships' staff.

515 In addition to the preventative maintenance system, the Navy has a process to record defects, described in paragraph 409.

516 The Technical Support Group in Auckland provides technical assistance, beyond the capability of the ship's staff, to maintain the operational state of ships. Within this group, the Ship's Maintenance Co-ordinating Authority holds all master records for ships using the planned maintenance schedules and receives all RNZN 2022 forms and OPDEFs.

## Findings

517 The Navy does not base its planned maintenance schedules on any reliability analysis of its equipment. However, the Navy does modify these schedules in the light of past New Zealand and overseas engineering experience.

518 While the Navy does record failures, it is impossible to assess whether the maintenance periods are appropriate for different equipment.

519 However, some analysis of information recorded in the preventative maintenance system has enabled the Ship's Maintenance Co-ordinating Authority to make technical changes to the maintenance schedules and, in some cases, to extend maintenance intervals on certain equipment. The Ship's Maintenance Co-ordinating Authority only records and acts on reported failures, which may, or may not, be critical. (See paragraphs 420–421).

520 We were unable to calculate the down time in HMNZS *Canterbury*, or on specific equipment, because:

- Defect reporting does not record the time during which equipment is under repair; and
- Corrective maintenance of less than four hours is not recorded.

521 Naval staff responsible for maintenance seek approval before deferring work specified on maintenance schedules. Between June 1985 and June 1987, all but 13 percent of planned maintenance was completed for HMNZS *Canterbury*. However, the Navy's reporting format did not allow us to assess whether these uncompleted schedules had been granted approval for deferral by the commanding officer of HMNZS *Philomel*, Auckland.

522 The Technical Management System has extended the maintenance intervals in the R2 system from four months to six months and, dependent upon the frigate, refits from two and a half years to three or four years. This has increased the time during which ships are available for operational duties and, by implication, reduced the costs of maintenance. However, these extensions were not based on reliability information.

523 The Navy defines a ship's operational ability as its capability to perform duties when required. Refit cycles impact on a ship's operational ability. The Navy has two separate refit cycles for the combat force. HMNZS *Canterbury* and HMNZS *Wellington*, which are to remain in service until 2005, have a three-year refit cycle. The other two frigates, HMNZS *Waikato* and HMNZS *Southland*, are refitted in a four-year cycle.

524 The Navy calculates operational ability by adding operational time (when the ship is not in a maintenance period) and time spent in Assisted Maintenance Periods and Self Maintenance Periods, and dividing that total time period by the number of days in the maintenance cycle (refer paragraph 511).

$$\frac{\text{Operational Time} + \text{Assisted Maintenance Periods} + \text{Self Maintenance Periods}}{\text{Days in Maintenance Cycle}}$$

= Operational Ability

Furthermore, the Navy does not consider ships to be operational when they are in refit or undergoing Docking and Essential Defect periods (paragraph 511).

525 Naval Staff has determined an operational ability target of 74.4 percent of the days in the maintenance cycle for HMNZS *Canterbury* and HMNZS *Wellington*. It bases this target on the preventative maintenance schedules specified in the Technical Management System.

526 The audit team assessed HMNZS *Canterbury*'s operational ability from 1974 to 1990 as 70 percent, which is 4.4 percent below the target set in the Technical Management System.

527 However, we question how a ship in an Assisted Maintenance Period is operationally able when some equipment may be unavailable for up to 47 hours.

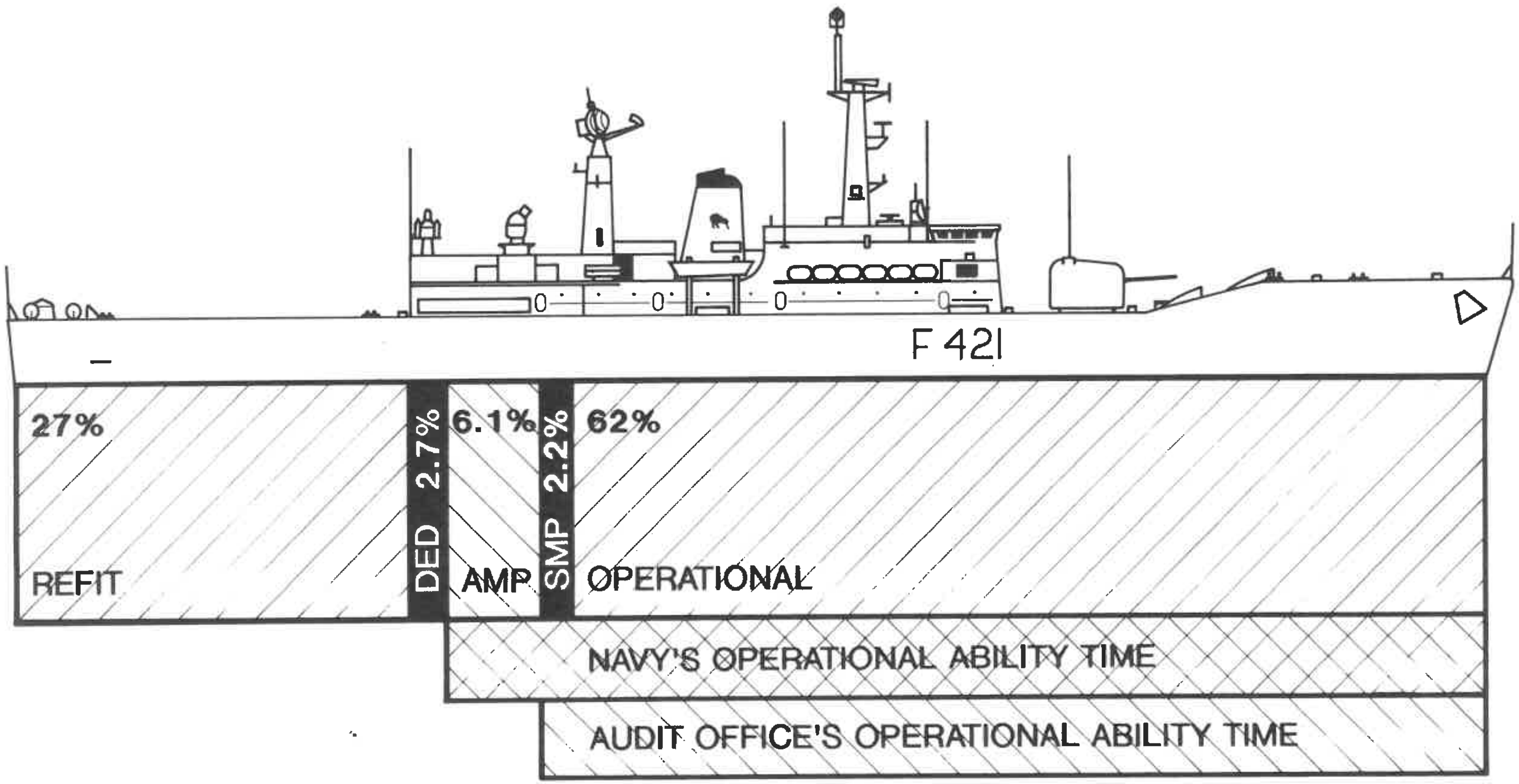
528 It takes approximately 8 hours for a Leander class frigate to raise sufficient steam to leave harbour. As a Self Maintenance Period (paragraph 511) would not delay a frigate longer than this, we accept that this maintenance period does not detrimentally affect the ship's operational ability.

529 Consequently, after removing Assisted Maintenance Periods from our first calculation, we assess HMNZS *Canterbury*'s operational ability, from 1974 to 1990, as only 64 percent.

530 HMNZS *Canterbury* has not met the best operational ability target set by the Navy for its combat force. The Navy calculates the operational ability (see paragraph 522) of a four-year refit cycle as 80.7 percent. HMNZS *Canterbury*'s actual operational ability is 16.7 percent below this, at 64 percent. If HMNZS *Canterbury*'s operational ability was to increase to 80.7 percent for the next fifteen years, this would increase her operational time from nine and a half years to 12 years in that period.

531 Figure 7 illustrates HMNZS *Canterbury*'s time spent in planned preventative maintenance while not at sea, between January 1974 and June 1990.

**Figure 7**
**HMNZS *Canterbury*—Maintenance History January 1974 to June 1990**



532 A consultant's report, prepared for the Navy in 1986, recommended that the Leander frigates should have a refit every three and a half years. By refitting in a three-year rather than a four-year cycle, the Navy reduces the time when HMNZS *Canterbury* and HMNZS *Wellington* are available for sea. In addition, this involves the Navy in carrying out another one, and possibly two, extra refits. This could cost, using figures from the 1987–1990 refit of HMNZS *Canterbury*, around an extra $25–40 million.

533 We have not seen any evidence to justify the decision that the first two frigates should be refitted more frequently than the others. The lack of reliability information held by the Navy does not allow it to measure the effect on the capabilities of the frigates in the three- or four-year refit cycles.

534 We analysed the Technical Management System (see paragraph 509) to identify whether that system was targeting critical components in our sampled systems. The Technical Management System is a comprehensive maintenance system based on components being serviced at regular intervals. However, components are still failing during operational time. Therefore, the Technical Management System programme is not eliminating these failures. These failures could be the result of under- or over-maintenance. As the Navy has not carried out an analysis of its equipment's reliability, we could not determine whether maintenance was targeted at reducing predictable failures. The Navy's information could not assure us that it was reducing this number of failures to a minimum, and therefore providing an effective and efficient maintenance system.

## Conclusions

535 The availability of the Navy's ships, especially its combat force of four frigates, is affected by its maintenance processes. Any decrease in the time spent on maintenance whether carried out at sea, in maintenance periods, in dock, or in refit, will increase the availability of the force.

536 The Navy does not know whether it is under- or over-maintaining its equipment, and, consequently, cannot assess whether its maintenance systems are appropriate.

537 The Navy had no requirement to record equipment failures for reliability analysis. However, it does have a reporting system and complex maintenance organisation in the Ship's Maintenance Co-ordinating Authority, which would make it possible to collect appropriate data to undertake reliability analysis.

538 We consider that, without relevant data, the Navy is unable to assess the fleet's operational state and number of failures occurring on its ships, or to monitor the costs of downtime.

539 The Navy considers that its ships are operational during an Assisted Maintenance Period. In our opinion, maintenance work that takes a ship out of operation must reduce its operational ability.

540 The Navy plans to refit two of its frigates every three years, and the other two frigates every four years. Given the:

- Cost of refits;
- Lack of information about the impact of these refits on the capability of the frigates; and
- The adverse impact on operational ability,

the Navy should re-assess the refit periods for HMNZS *Canterbury* and HMNZS *Wellington*.

## *FUTURE MAINTENANCE PROCESSES*

541 The Navy is developing a condition-based monitoring system on selected items in the fleet. Quality Assurance and Industrial Monitoring Development (Project QUASIMODO) will use four assessment techniques:

- **Vibration Analysis**, to measure noise vibrations on all rotating machinery;
- **Spectrographic Oil Analysis**, to monitor the contamination of oil;
- **Non-destructive Testing**, which includes using ultrasonics and dye penetrants to detect the condition of pipes, valves and turbine casings; and
- **Performance Monitoring**, where a software programme allows machine operators to monitor continuously trends in equipment performance.

## Findings

542 Project QUASIMODO is reviewing the maintenance processes so that defects can be detected earlier and, therefore, the time between failures extended.

543 The Navy has been using vibration analysis for several years but has met problems. The present equipment lacks noise sensitivity and testing cannot be conducted until the ship is in a planned maintenance period.

544 The current preventative maintenance schedules do not require the measurement of equipment performance, although QUASIMODO techniques should provide that information.

545 In a trial carried out for Project QUASIMODO, the Navy monitored selected equipment on HMNZS *Waikato*. The monitoring identified performance deterioration in an engine room pump. This alerted the Navy to carry out repairs before the pump failed, thereby preventing considerably more damage.

The cost of repairs was $23,000, compared to an estimate of $68,000 to repair a complete pump failure.

## Conclusions

*546* We commend the Navy for reviewing the appropriateness of its current maintenance procedures, and for implementing, on a trial basis, a condition-based monitoring system.

*547* Effective condition-based monitoring (paragraph 541) will allow equipment to be left in service until it requires maintenance. Additionally, it may extend the operational periods by reducing the number, or length, of periods spent in maintenance.

*548* With condition-based monitoring as a further tool, the Navy should be able to develop minimum levels of performance for each item of equipment, and minimise the resources required to maintain that equipment.

*549* Reliability information will help the Navy implement QUASIMODO effectively and efficiently.

# CHAPTER SIX

# PRINCIPAL CONCLUSIONS

*601* While our audit concentrated on HMNZS *Canterbury*, the maintenance processes used by the Navy are applicable for all equipment in the fleet. The conclusions drawn from HMNZS *Canterbury* can therefore be applied to the rest of the fleet.

*602* We have no reason to doubt that the repair and maintenance work undertaken by the Navy is of a high standard. Nor do we question the Navy's ability to detect and remedy minor and major defects as they occur.

*603* However, the Navy cannot show that its equipment management practices are targeted at sustaining its equipment at the best quality and reliability. We believe the Navy should invest more effort in assessing and assuring the quality and reliability of its equipment. The greatest benefit for the Navy through increased quality and reliability will be in the availability of equipment, and, therefore, increased operational capability.

# OTHER AUDIT OFFICE PUBLICATIONS

**Value for Money and Major Project Reports**

Electrical Supply Authorities: Local Hydro-Electric Power Schemes (1987)
Ministry of Transport: Road Transport Division (1987)
Ministry of Works and Development: Irrigation Schemes (1987)
Inland Revenue Department: Income Tax Compliance Control (1987)
Department of Justice: Administration of the Courts (1987)
Department of Education: Provision and Management of School Buildings (1988)
Territorial Local Authority Health Inspection Services (1988)
New Zealand Fire Service Commission: Effectiveness of Management of the Fire Service (1988)
The Planning of Roads (1989)
Management of Public Hospital Surgical Workloads (1989)
Effectiveness and Efficiency of the Access Training Scheme (1989)
Effectiveness and Efficiency of the New Zealand Lottery Board (1989)
Effectiveness and Efficiency of the Forecasting Service of the New Zealand Meteorological Service (1990)
The Quality and Reliability of Defence Equipment: The Army (1990)
The Customs Department: Effectiveness of Revenue Collection (1990)
Marine Fisheries Management (a joint report of the Controller and Auditor-General and the Parliamentary Commissioner for the Environment) (1990)
Audit of the Decision to Upgrade the Wellington City Council Abattoir (1991)
Housing Corporation of New Zealand: Maintenance of State Rental Properties (1991)
The Process for Disposal of Crown-funded Irrigation Schemes (1991)

**Special Reports**

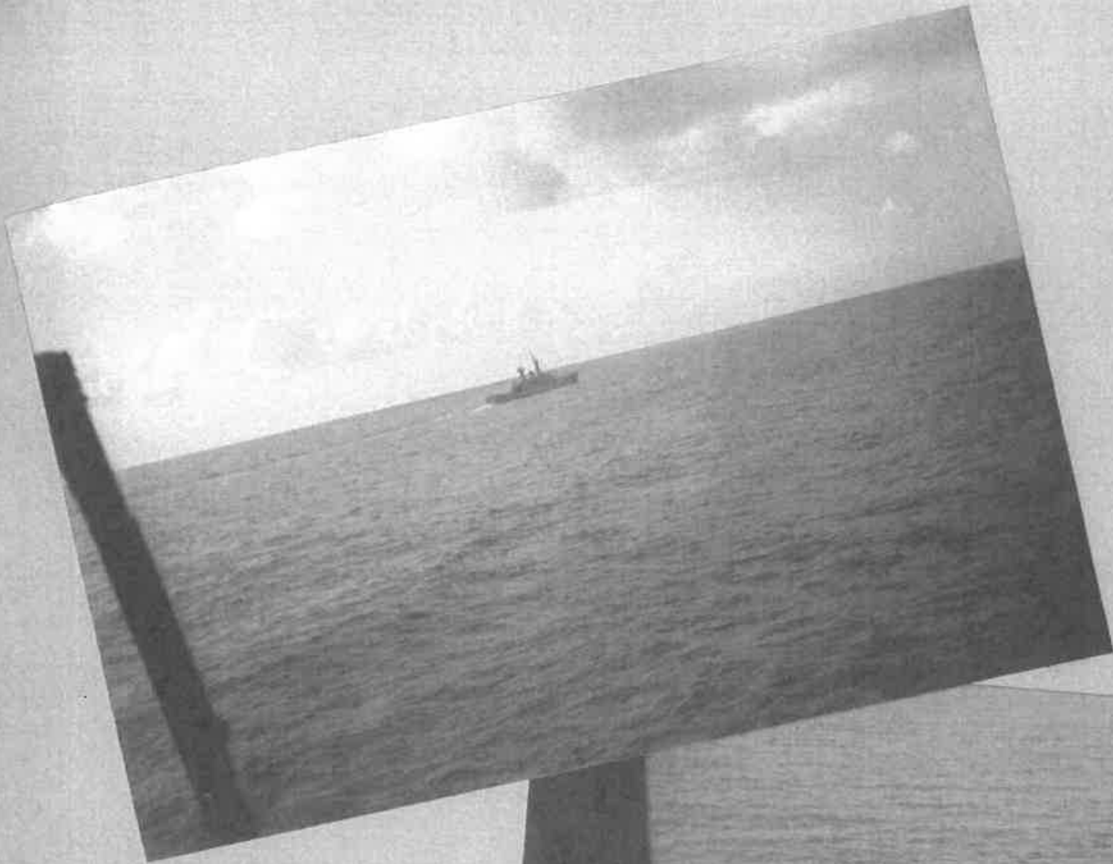
Report on an Investigation into Allegations of Mismanagement Against the Waitemata City Council (1989)
Suggested Guidelines for a Convention on Publicly-funded Government Advertising and Publicity (1989)
Report on the Parliamentary Postal Privilege (1990)
Report on an Investigation into the Aotea Centre Project of the Auckland City Council (1990)

**Other Publications**

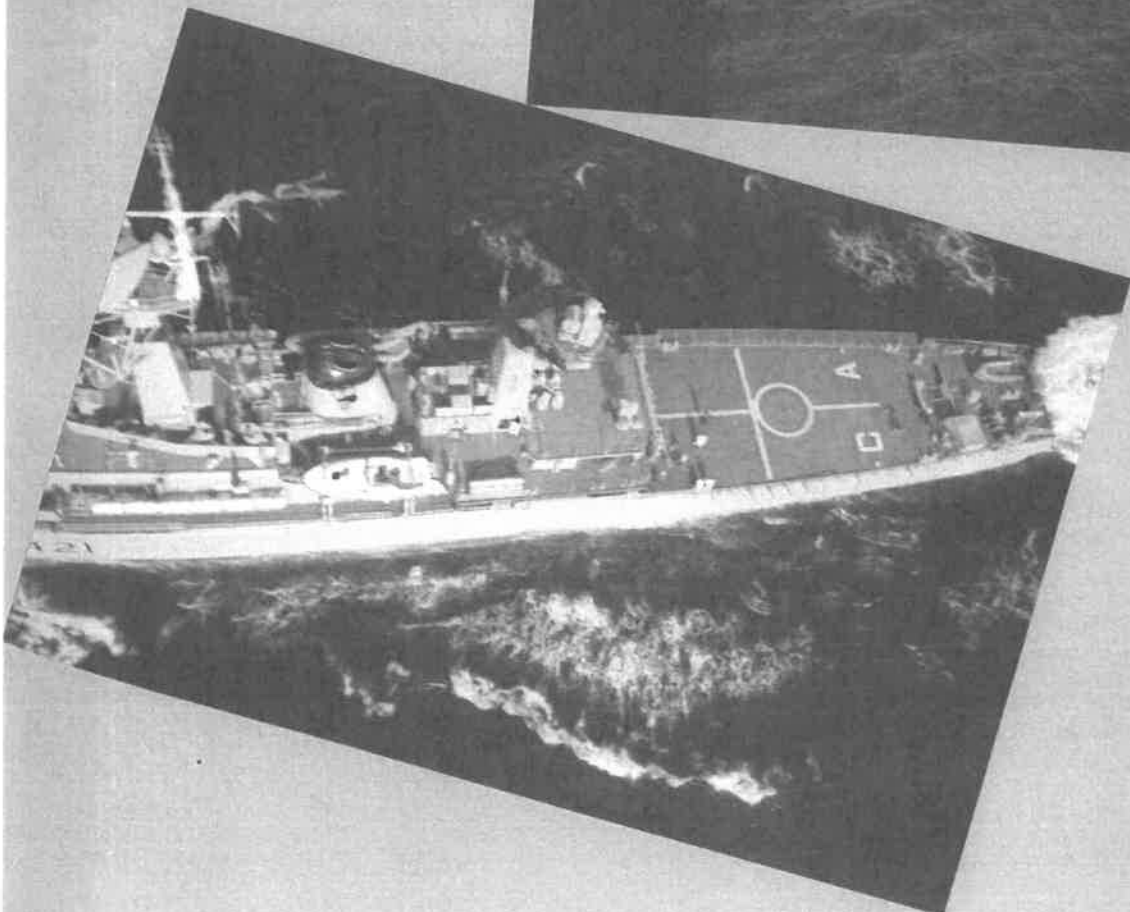
Suggested Criteria For Good Management Practice in New Zealand Territorial Local Government (1981)
Suggested Criteria for Good Management of Plant and Vehicles in New Zealand Local Government (1987)
Suggested Criteria For Good Practice in the Preparation and Use of Annual Estimates by Local Authorities (1988)
Public Sector Accounting Concepts—A Simple Guide to the New Reporting Standards (1988)
Public Sector Accounting Concepts—Guidelines to Assist in the Implementation of the New Reporting Standards (1988)
Guidelines on Costing and Charging for Public Sector Goods and Services (1989)
Guidelines for Improving Supply Management in Local Authorities (1989)
Internal Auditing in the Public Sector (1990)
Report of the Audit Office for the year ended 30 June 1990
Corporate Management Plan 1990–91

Copies of these publications may be ordered from:
Reports Group
The Audit Office
P.O. Box 3928
WELLINGTON
Ph. (04) 496–3099
Fax (04) 712–929

GP PRINT LTD 1991—27913A/91B




F 421


A
C