MARITIME ACTIVITIES AT THE AUSTRALIAN WEAPONS SYSTEMS RESEARCH LABORATORY

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ABSTRACT

WSRL is a tri-service laboratory whose main aims are to maintain or develop Australia's Defence technology base, provide defence policy advice, solve problems for the Australian Defence Forces, contribute to new equipment development, and transfer technology to Australian Industry. Over 30% of the resources of WSRL are devoted to tasks sponsored by the Royal Australian Navy and this article describes some of the research and project support work which is carried out.

Introduction

The Weapons Systems Research Laboratory (WSRL) is one of five major R&D Laboratories within the Defence Science and Technology Organisation (DSTO) in Australia. While DSTO's resources are spread across the Eastern half of Australia (see FIG. 1), the bulk of them, including WSRL, are concentrated in a 16 sq km site near Adelaide, South Australia. This was the home of the Weapons Research Establishment (WRE), which was well known to UK MOD staff in the days of the Joint Project.

WSRL has a total staff of about 650, including 200 professional scientists and engineers and an annual budget of about $32M.

The activities of the Weapons Systems Research Laboratory should be viewed in the context of Australia's physical and strategic environment.

Over two-thirds of Australia is desert, about one third is in the tropics, and its 17 million population is largely confined to the east coast and south-eastern and south-western corners of the continent. The north is tropical and sparsely populated. Australia's position at the foot of Asia, in a hemisphere which is mostly ocean, leaves it largely outside the main stream of world activities. However, Australia has some unique environments for the evaluation of new materials and materiel: for example, the low acoustic noise characteristics of the Fiji ocean basin can be exploited in assessments of sonar systems and for long-range acoustic propagation experiments. Very high solar radiation, particularly in the UV region, is another feature of our environment. High humidity can strongly influence the propagation of electro-magnetic radiation through the atmosphere. Severe mycological and biological factors are associated with both marine and land tropical environments.

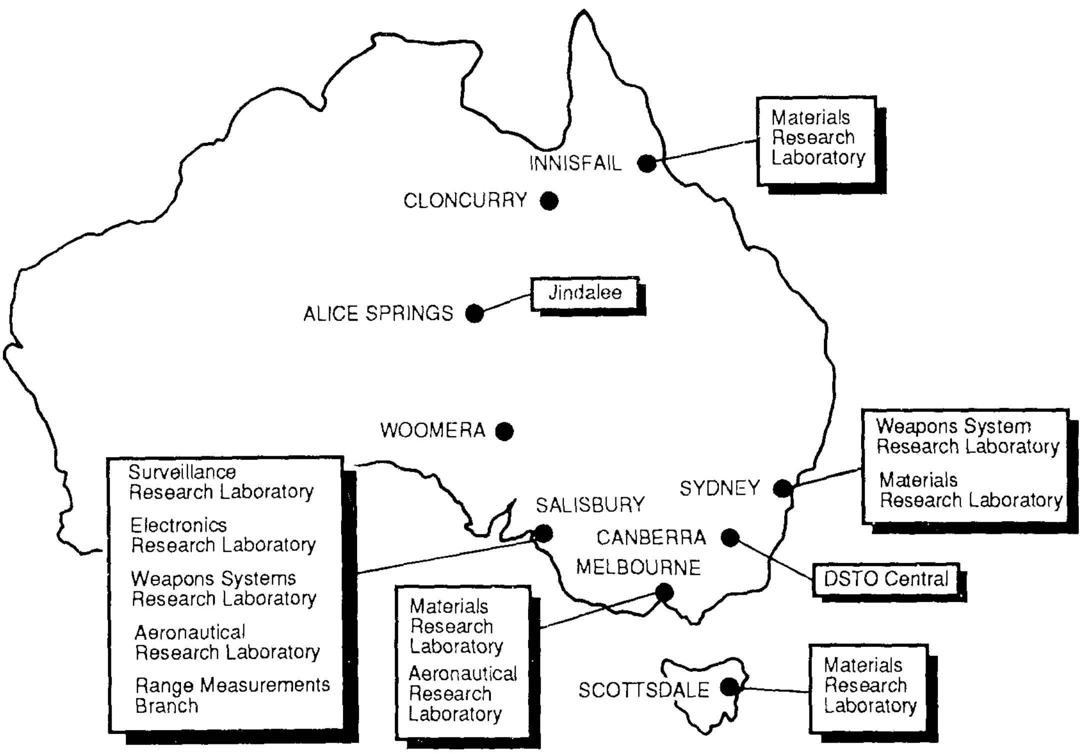

FIG. 1—DSTO R & D LOCATIONS IN AUSTRALIA

The threat scenarios facing Australia are different to those facing Northern Hemisphere nations. Given Australia's position as a Western nation in South East Asia, a variety of low to medium level contingencies may be postulated although potential aggressors would have to overcome the logistic problems associated with ocean transits in a tropical environment. Potential military threats in Australia's area of interest include equipments and weapons of western and non-western origin. For example, the submarine threat, although low, is somewhat different to the NATO threat: Australia faces a wide range of platforms, including modern diesel-electric submarines and their associated weapon systems.

Thus, as an island continent with a very long coastline and—particularly when islands and territories are included—a huge Exclusive Economic Zone, Australia must place special emphasis on maritime activities. Co-operation with other nations, such as the UK, USA, Canada, France, Germany and Sweden for example, in defence science and technology can provide mutual benefits through enlargement of the technology base, improving awareness of unique sites, facilities, and environments, exchange of staff and equipment, and improving inter-operability of complex systems.

WSRL Mission

The mission of WSRL is to enhance Australian defence capability through research and development in weapons, tactical combat systems, and underwater detection and surveillance. The four R&D Divisions of WSRL are:

- Maritime Systems Division
- Combat Systems Division
- Guided Weapons Division
- Ordnance Systems Division

The Director and the four Chiefs of Division are pictured in FIG. 2.

FIG. 2—THE WEAPONS SYSTEMS RESEARCH LABORATORY SENIOR STAFF
(CENTRE) THE DIRECTOR, COLIN EVANS (EX DEPUTY DIRECTOR OF RARDE IN UK, ON SECONDMENT TO THE AUSTRALIAN DEPARTMENT OF DEFENCE
(LEFT TO RIGHT) THE FOUR CHIEFS OF DIVISION: JOHN WILSON, ROGER LOUGH, DENIS BROWN, BRIAN JAMES

The Royal Australian Navy (RAN) sponsors tasks in all four Divisions, and the Divisions also conduct longer range research and development which is expected to be relevant to naval operations in the future. These longer range tasks, which are aimed at maintaining DSTO's technology base, are also important in ensuring that the RAN is a smart buyer and user of new equipment. Adaptation of overseas equipments to Australia's unique environment, e.g. hot, humid tropics and shallow acoustic surface ducts, is another important function of the Laboratory.

Since World War II, WSRL has been involved in many successful projects such as Malkara anti-tank missile, Ikara torpedo-carrying guided missile, Karinga cluster bomb, Barra sonobuoy and Mulloka ship's sonar. More recently, Kariwara towed array, Ebarra sonobuoy, Nulka ship-launched missile decoy, and the Precision Gliding Munition (PGM) project have become the current major projects in WSRL.

Maritime Systems Division

Maritime Systems Division (MSD) covers matters connected with undersea warfare in the fields of acoustic surveillance and detection, classification, and localization of targets by acoustic means. To achieve this it is necessary to understand the physics of the ocean, the methods by which sound is generated under water (including transmission across the air-sea interface), the mechanisms by which sound is propagated, diffracted, and scattered underwater, and the sources of background noise in the sea. This area of research and development also includes investigations into the means by which underwater acoustic signals are processed and interpreted by those parts of the Australian Defence Forces (ADF) concerned with maritime warfare. Research and development is carried out, and advice provided to the ADF, in the fields of underwater acoustics, oceanography and ocean engineering, active and passive sonar, acoustic classification, and acoustic warfare.

Towed Array Research and Development

Maritime Systems Division is the focus for R&D aimed at providing the RAN with the capability to carry out large area, passive, acoustic intelligence gathering from the ocean. Development of a unique slim-line hydrophone array will enable the RAN's New Construction (Collins Class) submarine and surface ships to be fitted with long, reelable arrays, significantly contributing to the ASW protection of Australia's focal areas and maritime approaches.

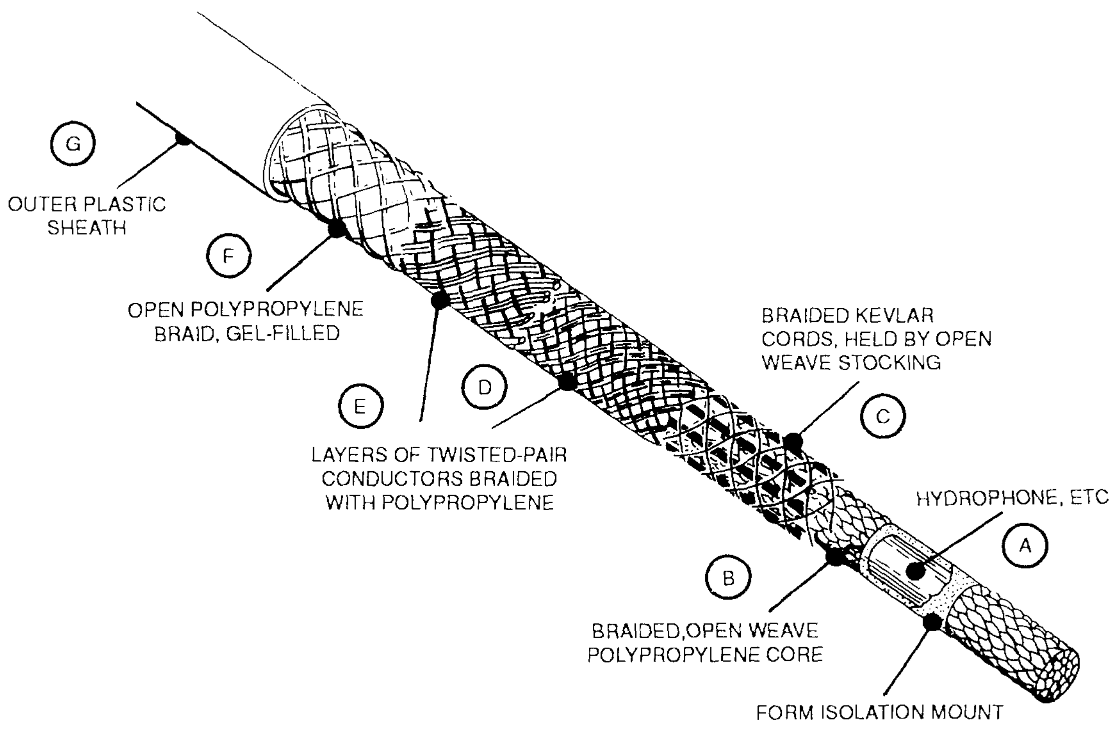

Fig. 3—Mk. II buoyant fibre array cable configuration. The cable is gel-filled and wrapped before extrusion of the outer sheath. Diameters in mm: A, 8; B, 15; C, 20; D, 23; E, 26; F, 28; G, 30

Towed array development in MSD began with Project Boolee (1975–1980), which utilized an American three inch diameter, liquid-filled array deployed from an Australian ship. From 1980 to 1985, MSD devoted significant resources to development of slim-line (about 40 mm or 1½ inches diameter), buoyant fibre arrays. FIG. 3 is a diagram of a typical buoyant fibre cable configuration.

In 1985, a full length streamer was built for deployment from Australia's OBERON Class submarines. The so-called Self-Streaming Towed Array System (SESTAS) has now completed four years in service very successfully.

SESTAS has been integrated with a WSRL upgraded British sonar, the Type 2007. The system provides an advanced signal processor for both towed and hull-mounted arrays. The system's sensors present the results of searching to the operator on board the vessel in the form of easily understood colour-coded signals on a display screen. Another advantage of the new system is that it includes self-noise reduction algorithms.

A Project Definition Study was conducted between 1985 and 1988 to determine the prime item development specification for an array for the New Construction Submarine. MSD examined areas of high risk, and gathered engineering data to ensure that an array could be built to specification. At the same time, manufacturing techniques were developed in industry . The reasons for Australian development of a towed array system, under Project Kariwara were:

(*a*) the requirement to deploy and recover an array from a relatively small submarine, dictating the need for a small diameter, winchable streamer;

(*b*) the need for low acoustic self-noise at the reduced diameter;

(*c*) the need for a long array with particular hydrophone spacings;

(*d*) the fact that none were available overseas.

Australian industry has been contracted to provide, *inter alia*, two full-length arrays based on the SESTAS technology by November 1991. A contract has also been let for the full-scale engineering development of a buoyant slim-line array, to meet the RAN's stringent engineering and acoustic requirements for the New Construction Submarine, with delivery of a prototype from the production facility in January 1993.

Three companies have signed agreements with the Department of Defence to carry out five-month, parallel project definition studies towards development by the Navy of an Australian Surface Ship Towed Array Surveillance System (ASSTASS), for which Kariwara has provided the technology base. To investigate performance of ASSTASS, MSD is undertaking Project Undara, a program of R&D involving advanced acoustic signal processing and data management techniques adapted to operational environments (warm ocean waters, etc) of significance to Australia. Project Undara will implement MSD's most advanced signal processing technology in forms considered most suited to the requirements of ASSTASS. Contracts have been let to Australian industry in the areas of:

(*a*) automatic detection and tracking;

(*b*) towed array shape estimation;

(*c*) towship noise cancellation;

(*d*) target motion analysis;

(*e*) contact management.

Project Undara, which is due to finish in 1992/93, will provide the Navy with fully-defined algorithms for inclusion in the ship-based signal processing equipment. The system is to use a minimum number of operators, hence the emphasis on automation of functions. It is expected that a further but smaller scale task will be to assist the Navy in developing operational and tactical doctrine, and in refining ASSTASS sub-system operating procedures. Background research will continue in expert systems for passive signal classification, array shape estimation, and long range tracking.

Sonobuoy Research and Development

Australia's interest in air deployed sensor systems began in the early 1960s, with investigation of the use of shaped arrays for low frequency submarine detection. This work led to Project Nangana, a study to establish the feasibility of developing a multi-element array sonobuoy. This, in turn, gave rise to the Barra sonobuoy which was conceived, born and nurtured to the project definition stage in WSRL. The Barra system consists of the sonobuoy (SSQ-801), the AQS-901 airborne receiver-processor unit developed in the United Kingdom, and an ASW ground support facility developed independently in Australia for the RAAF's long range maritime patrol P3C 'Orion' aircraft.

The Barra sonobuoy is an expendable, passive underwater sonar device designed to detect, localize and track submarines and surface ships. It can operate at selectable depths and consists of a surface buoy with a suspended submerged array assembly. FIG. 4 is a diagram of a Barra sonobuoy. The sonobuoy is currently in service with the RAF and RAAF.

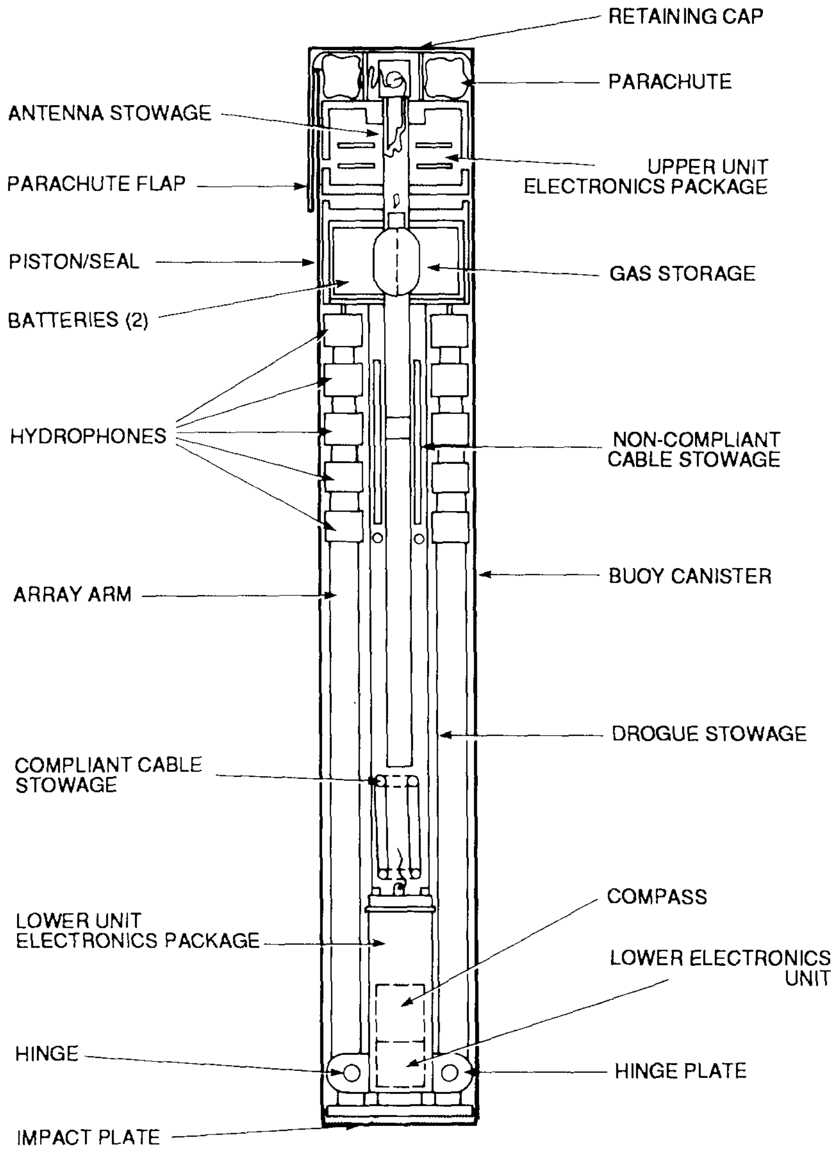

FIG. 4—A BARRA SONOBUOY FOLDED FOR PACKAGING IN A CONTAINER

The advantages of the Barra sonobuoy stem from the accurately known positions of the 25 hydrophones on the array. Data from each hydrophone is time-division multiplexed within the sonobuoy onto a single digital data stream which modulates an RF carrier for transmission to an overhead aircraft. Within the aircraft, data from the sonobuoy are fed, after reception, into the ASQ-901 processor. A signal processing technique known as beam forming takes the output signals from each of the 25 hydrophones and combines them in a way that enhances signals incident upon the sonobuoy from a selected direction, whilst at the same time cancelling signals from other directions. The direction of enhancement can be varied. The beam forming capability enables the sonobuoy rapidly to determine the directions of multiple targets and to detect weaker targets than would be possible with a single hydrophone.

To date, the complexity of the airborne electronics required to receive and process data from the Barra sonobuoy has restricted the use of Barra to the RAAF and RAF. Sonics processors fitted to aircraft of other countries are not powerful enough or properly configured to process Barra.

Enhanced Barra, or Ebarra, is a further development of the Barra sonobuoy which has been designed to overcome this limitation by carrying out much of the processing in the sonobuoy. To achieve this, a number of signal processing techniques were devised and tested. Studies indicated that these techniques could be implemented within the sonobuoy by using special VLSI chips. The first chips are being developed independently by two Australian firms. After fabrication, these chips will be extensively tested by MSD before being incorporated into a sonobuoy.

As a result of the in-buoy signal processing, a simpler signal can be transmitted to the aircraft. By careful design, this signal can be received and processed by almost all existing sonics processors fitted to aircraft in service in the Western world. To take advantage of this unique export opportunity, Sonobuoys Australia, manufacturers of the current Barra sonobuoy, have been licensed by the Commonwealth of Australia to develop, manufacture and market the new Ebarra sonobuoy.

MSD has also embarked on a programme to investigate the development of an advanced (post-Barra) sonobuoy with potential for introduction into service in the mid 1990s. MSD is the Research and Development Authority for the so-called New Generation Buoy (NGB) programme, undertaking the initial research effort, defining sonobuoy configurations, and specifying areas of technology needed to implement those configurations.

The NGB is designed to be packaged in an 'A' size container, with rapid activation on deployment and a single channel RF bandwidth. Major problem areas in the proposed development are seen to be:

(*a*) packaging of large arrays;
(*b*) deployment of large arrays;
(*c*) maintenance of deployed array shape;
(*d*) RF transmission of increased data within a reduced transmission bandwidth (for which in-buoy processing was seen to provide the only viable solution);
(*e*) development of miniaturized components such as hydrophones and heading sensors.

Contracts have been let to industry in several technology areas. These include miniature hydrophone transducers, miniature heading sensors, special purpose (neutrally buoyant, high strength) data cables, and VLSI implementation of several sonobuoy electronic functions (in addition to the in-buoy processing). In all areas addressed, significant progress has been made, and many of these initiatives will be implemented in the ongoing programme of improvement of production Barra sonobuoys.

Platform Counter-Detection Evaluation System

DSTO has had a long association with many UK laboratories, particularly in areas of mutual interest to the RN and RAN. Continuing this association, an officer from the Admiralty Research Establishment at Portland, UK, has developed a Platform Counter-Detection Evaluation System (PCDES) whilst on an exchange visit to DSTO Sydney.

PCDES is a software tool designed to evaluate the vulnerability of a naval platform to acoustic counter-detection by a threat equipped with a low-frequency passive sonar. Input parameters include platform and local shipping radiated noise, environmental ambient noise, and threat sonar performance. Probability of counter-detection is shown on a plan-position display in colour, raster graphics format.

Underwater Acoustics

For many years, WSRL has devoted resources to studies of the various parameters in both the active and passive sonar equations. Generally speaking, oceans and seas of interest to Australia are warmer and support less shipping traffic than waters of prime interest to NATO countries. In order to make the RAN a smart procurer and user of sonar systems, WSRL has built up a substantial base of knowledge of parameters such as volume reverberation, propagation loss and its influences such as pressure, temperature, and the presence of micro-bubbles, currents and eddies, ambient noise and shipping traffic noise, and the characteristics of the sea floor in important locations.

Biological noise can have a significant impact on sonar performance. Biological noise levels are frequently high in Australian tropical waters; at certain times a chorus may be the dominant noise component of an environment. Samples of ambient noise at a number of positions in tropical waters north of Australia have been measured in the frequency band 50 Hz to 4 kHz near sunset and sunrise to determine the presence of choruses. Long-term monitoring of choruses at 18°S within the Great Barrier Reef continues, concurrently with a study to identify the sources. Chorus distributions and temporal behaviour can then be predicted from known distributions and behaviour of source species. Biological transients are also being investigated.

Combat Systems Division

Combat Systems Division (CSD) is responsible for R&D on the integration of weapon and sensor systems on military platforms into complete combat systems. Research and development is carried out in: computing techniques and associated digital and display systems; software engineering and other software development methods and processes; information technologies, including human factors and artificial intelligence; the analysis of military requirements, operations and exercises; and the associated computer simulation techniques needed to estimate overall system effectiveness.

Command, Control, and Integration (C^2I)

In the maritime arena, CSD views combat data systems from a C^2I perspective—at the platform level, at the battle group level, and at higher levels of force deployment. Interoperability within the force and integration of sensors and weapons for optimum performance are key issues. How the human operator contributes to the total task is studied, and aspects such as tactical decision aids and training are researched. Much of this work, entailing the instrumentation and analysis of maritime exercises, requires an intimate partnership with the RAN. Significant enhancements to the operational software in such vessels as the OBERON Class submarine have resulted from this intensive attention to the integrated performance of the total combat data system in the operational environment.

Stress in Submariners

CSD has a contract on the University of Western Australia which addresses the human factor aspects of submarine operations. The particular problems being addressed are firstly the determination of the optimum length of the tour of duty with due consideration given to the physical limits of the submarine, the tactical requirements, and the performance of the submariners. The second problem is the duration of the individual watches and its effect on the performance of the operators.

As many readers will know, the effectiveness of submarines is highly dependent on the operators and their level of stress caused by the time they are away from home, the number of hours on duty, and the level of alert. The stress level of submariners, while at sea, is likely to be higher than for many other military operations. Thus further, unnecessary, introduction to yet more stress due to abnormally long tours of duty or inefficient use of watch periods should be avoided.

However, the optimum use of the submarine as a key element of Australia's deterrent force is also to be taken into consideration and, therefore, there must be a careful balance between the machine and its operators to obtain the most effective military tool.

Support for Complex Defence Equipment Acquisitions and Upgrades

Both cost advantages and performance advantages can be irretrievably won or lost in large measure during the equipment acquisition and upgrade process. Skills in the discipline of project engineering are critical to successful outcomes. After an identification of a capability deficiency by the military, the process begins with a requirements definition. As an example, requirements definition for the difficult man-machine interface is expedited by rapid prototyping to help the customer clarify his real needs. Then, at various times throughout an equipment acquisition cycle, performance analyses are required—during the preparation of military requirements and technical specifications, during tender evaluation, and during design reviews. Later during the development phase of a major project, an inability to control the quality and cost of software often surfaces. Because of this, CSD has an active research program to investigate the application of software engineering practices, including, for example, guidance in the tailoring of standards such as DOD-STD-2167A. Finally, the test and acceptance phase frequently requires a commitment of scientific and technical support. Examples of projects where CSD has made such contributions include the Nulka active ASM decoy, the Sea King helicopter, the DDG upgrade, the ANZAC frigates, and to a lesser extent, the COLLINS Class submarine.

Systems integration support was provided to the RAN Destroyer Utility Helicopter project, and contributions were made to both the Minehunter Weapon System Development and to the Minehunter Warfare Systems Centre integration.

Operations Analysis

For analysis purposes, wars are both infrequent and well beyond the control of the experimenter. Consequently, the tools available for assessing and optimizing the integrated effectiveness of a combat force are exercises and modelling. Modelling and simulation activities provide for the assessment of ways in which airfields and ships might be vulnerable to air attack and how they might more capably be protected. For example, they are used also in pro- and anti-submarine work, a topic of major importance in CSD's

Operations Research Group centred in Sydney; and major proposals like the FFG upgrade require the development of complex models of dissimilar integrated subsystems in order to home in on weaknesses and highlight the options which ought to yield maximum Defence capability. All of this modelling work in the maritime arena is integrated into a programme of measurement and model validation from operational exercises.

Guided Weapons Division

Guided Weapons Division (GWD) covers a co-ordinated programme of research and development in tactical weapons which have, to varying degrees, the capability to change direction, or react, during flight in order to increase the probability of hit. It covers most categories of precision guided munitions such as missiles, projectiles, bombs, submunitions, etc., and includes gun systems with dedicated fire control systems which provide feedback correction whilst the projectile is in flight. However, it does not cover underwater guided weapons, e.g. torpedoes; or space-based systems.

Precision Gliding Munition

The Australian Precision Gliding Munition (PGM), otherwise known as the Glide Bomb, is a viable complement in the anti-shipping role to more expensive missiles such as Harpoon and Exocet. It is also suitable for attacks on land targets.

The PGM concept has been developed by adding folding planar wings and tail mounted control surfaces to a basic Mk.82 bomb shape. The mid-course guidance system comprises a fully digital autopilot coupled to a low cost inertial attitude and heading reference system. Stringent requirements on

FIG. 5—PRECISION GLIDING MUNITION. DEPLOYMENT OF A PROTOTYPE DURING FLIGHT TRIALS

glide angle accuracy are met by the use of a novel low cost guidance system known as Dynamic Pressure Control. This in turn allows a low cost attitude and heading reference system to be used, thus making possible a truly low cost guidance system. The novel concept of dynamic pressure control of glide angle and climb/pitch manoeuvre, together with a low cost method of maintaining roll attitude, allows very cheap gyros to be employed, giving the PGM a cost advantage over existing systems. FIG. 5 shows the deployment of a prototype PGM during flight trials.

In the terminal phase, the PGM would employ an IR seeker in the anti-shipping role, and a semi-active laser seeker when operated against other targets. Further, a terminally unguided version, based on a low cost hybrid GPS-aided inertial mid-course guidance system, could prove effective against land targets such as airfields.

The PGM concept is not restricted to the 250 kg (Mk.82) class, but could just as easily be adapted to 500 kg (Mk.83) or 1000 kg (Mk.84) bombs. However, the advantages of a Mk.82 class glide bomb are that it can be adapted at minimum expense from a well-established Australian production capability in Mk.82 bombs, and secondly, it can be delivered from an F111 aircraft, for example, in sufficient numbers to saturate an enemy's defences. A Mk.82 PGM would have approximately the same explosive power as Harpoon.

Ordnance Systems Division

Ordnance Systems Division (OSD) covers ballistic unguided weapon systems based on guns and rockets, together with rocket motors and propellant-based gas generators, but excluding terminal effects (which are the province of Materials Research Laboratory in Melbourne). Emphasis is placed on ordnance system effectiveness and operability to meet the needs of the Australian Defence Forces (ADF).

The Division carries out research and development in the fields of gun systems and rocket motor technologies, ballistics, fire control, ordnance systems design, propelling charge design, propellants and materials, ignition and combustion, propulsion, service/safe life and serviceability, operational analysis and system modelling to support ADF operations and to enhance ADF self-reliance by providing specialist assistance and advice. Support is also provided to the Australian munitions industry through work on propellant manufacturing technology, ballistics and ordnance effectiveness. Included is the design and manufacture of technology demonstrators to assist the ADF in the assessment, selection, modification and through-life support of ordnance systems, and studies of weapon signatures, whether from plume or blast, gas generators or propellant activated devices.

Rocket Propulsion

The RAN uses rocket-propelled devices of various types for missiles, targets and flares. A high proportion are of overseas design and manufacture but some are manufactured in Australia under licence agreements and a few have been locally designed, developed and manufactured. It should be noted that until 1988 all munitions manufacture in Australia was carried out in Government-owned and Government-operated factories. These factories relied heavily on OSD for rocket propulsion R&D support (see note on p. 69).

Rocket propulsion activities for the Navy started in OSD in the early 1960s with the development of the rocket motor for the Ikara missile. Ikara utilizes a guided missile to deliver a light weight anti-submarine homing torpedo to a target submarine. The missile is launched from a surface ship and guided to the optimum torpedo-dropping position to maximize kill potential. After release from the Ikara vehicle the torpedo, usually the Mk.44 or Mk.46,