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DEPARTMENT OF
NATIONAL DEFENCE

DEFENCE RESEARCH BOARD OF CANADA

REVIEW 1970

OTTAWA, CANADA

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FOREWORD

This Review deals with activities during 1970 at the Defence Research Board's headquarters in Ottawa and its seven research establishments across Canada. The Review does not attempt to provide a full survey of the Board's operations and scientific projects, but instead concentrates on certain programs selected to provide a conspectus of the kinds of research with which the Board concerns itself. The annual reports of the Board's establishments should be consulted for further information on scientific programs and publications.

Slick-Licker in action removing oil and oil-soaked seaweed. Inhabitants Basin off Chedabucto Bay – April 1970.

THE DEFENCE RESEARCH BOARD

The Defence Research Board was established in 1947 by an amendment to the National Defence Act. Generally, the Board is concerned with providing scientific advice to the Minister of National Defence, meeting the research requirements of the Canadian Forces, contributing to the collective defence research efforts of our allies, and supporting basic research of defence interest in Canadian universities and applied research of defence interest in Canadian industry.

The Defence Research Board consists of a chairman and vice-chairman, a number of members appointed by the Governor-in-Council for three-year terms, and ex officio members representing the Canadian Forces, the Deputy Minister of National Defence, and the National Research Council. A list of present members of the Board is given on page 45. The Chairman of the Board is its chief executive officer, and the headquarters of the Board is one of the three entities (the others are Canadian Forces Headquarters and the Deputy Minister's Branch) that constitute National Defence Headquarters in Ottawa. The work of the Board is carried on at its Headquarters in Ottawa, at its research establishments in Nova Scotia, Quebec, Ontario, Alberta and British Columbia, and at its liaison offices in Washington, London and Paris.

In 1970, the Board held three meetings during which the Members were given special briefings on Northern research and on the current structure and status of the Canadian Forces. They also extended their knowledge of Maritime Command activities by means of on-the-spot observations while at sea on a Canadian destroyer off the coast of Nova Scotia.

In a detailed presentation at the March Board meeting in Ottawa, Mr. G.D. Watson, Chief of Plans, highlighted DRB's many contributions to Northern research and linked together in his wide-ranging review a variety of specific achievements.

Following the meeting in June held at Defence Research Establishment Atlantic, Members personally observed advanced Canadian anti-submarine warfare techniques while at sea aboard HMCS Terra Nova. The warship coordinated its efforts with Maritime Command aircraft in seeking and "destroying" a Canadian submarine that played the role of the enemy.

At the October meeting, held in Ottawa, Lieutenant General M.R. Dare, Vice-Chief of the Defence Staff, brought Board Members up to date on the Canadian Forces organization and on related defence activities.

Shortly after the sinking of the oil tanker "Arrow", off the Cape Breton Island coast, and the development of an expanding oil spill that threatened beaches and shore and sea life, the government established a Task Force charged with organizing and directing cleanup operations. Dr. Harry Sheffer, Vice-Chairman of the Board, was named Deputy Head of the Task Force appointed to plan, coordinate and supervise "Operation Oil", a crash cleanup project completed successfully several months later. A number of DREA and DREP scientists and engineers played prominent roles in this operation, as reported by these establishments.

The Board welcomed two new members in 1970. Lieutenant General D.A.G. Waldock, Chief of Technical Services, joined the Board as a member ex officio, and Mr. W.J. Cheesman, President Canadian Westinghouse Limited, joined as a member by appointment.

In late 1969 and early 1970, the Chairman, with the advice of the Board, reviewed and revised DRB's policies in the light of statutory obligations and current Government policy. The main policy changes involve increased emphasis being given to the defence of sovereignty, to internal security and to support for national development.

The objective of the Defence Research Board is to assist the Minister of National Defence and Defence Council in arriving at sound defence decisions and also to assist the Canadian Forces in achieving maximum efficiency and cost-effectiveness in the utilization of their resources, by being in a position to give them the most up-to-date and reliable scientific and technical advice and support. In the most general sense, this means ensuring that scientific knowledge is applied to the strengthening of present and future security. In meeting this objective, there is, on the one hand, a short-term role in which advice and assistance to the Minister and the Canadian Forces is applied to current policies and activities. In this role, DRB attempts to maintain access to all scientific knowledge that might be of benefit to the Department and to assist in applying it to current objectives and activities of DND. On the other hand, there is the long-term responsibility of DRB to conduct a research program that will, (a) maintain a cadre of expert defence scientists, (b) strengthen future security by contributing to allied defence science and (c) gain knowledge of defence science from allies in exchange for the Canadian contribution. This part of the program must be selected to allow for a range of possible future defence policies and programs and therefore cannot be too rigidly aligned to current defence policies, roles and functions. The output of research started now is most likely to bear applied fruit under policies that will be in effect more than ten years from now. Furthermore, since the Canadian Forces have primary responsibility for development, and have engineers concerned with the solution of short-term problems, a major objective of the DRB program must be the ensuring of the availability of scientific knowledge in the longer term, while at the same time contributing a significant portion of effort to the solution of current problems.

During the past year, planning studies on Policies for Defence Research; Research Relating to Northern Military Operations; Surveillance Research; Weapons Research and Maritime Research have been completed, and studies on Space Research; Electronics and Communications; Behavioral and Biosciences have been started. The Maritime Study has now been extended to allow more complete examination of the program in Sonar Research.

The recent and current trends in the DRB program might be summarized as follows:

(a) *Research related to northern military operations was an important part of the Board's program in the early fifties, but National Defence priorities declined. The Board maintained this work at minimum viable level, however, and under the new policies this part of the program has been strengthened.*

(b) *The work in infrared, optical, laser and radar fields related to surveillance technology has been strengthened and expanded.*

(c) *As a result of decisions taken in 1967-68, nuclear, biological and chemical defence work is at a markedly lower level than it was in the middle sixties.*

(d) *The emphasis on marine science has shifted from deep ocean to coastal shallow-water systems and towards problems in northern waters and under ice.*

(e) *Research in the behavioral and biosciences has developed a strong emphasis on operator adaptation and efficiency and on underwater physiology.*

(f) *Weapons research will consist of the minimum viable effort designed to retain essential expertise for present and future requirements.*

(g) *Communications and Electronic Systems continue to be of great importance to national security, and research related to anticipated future defence needs will continue.*

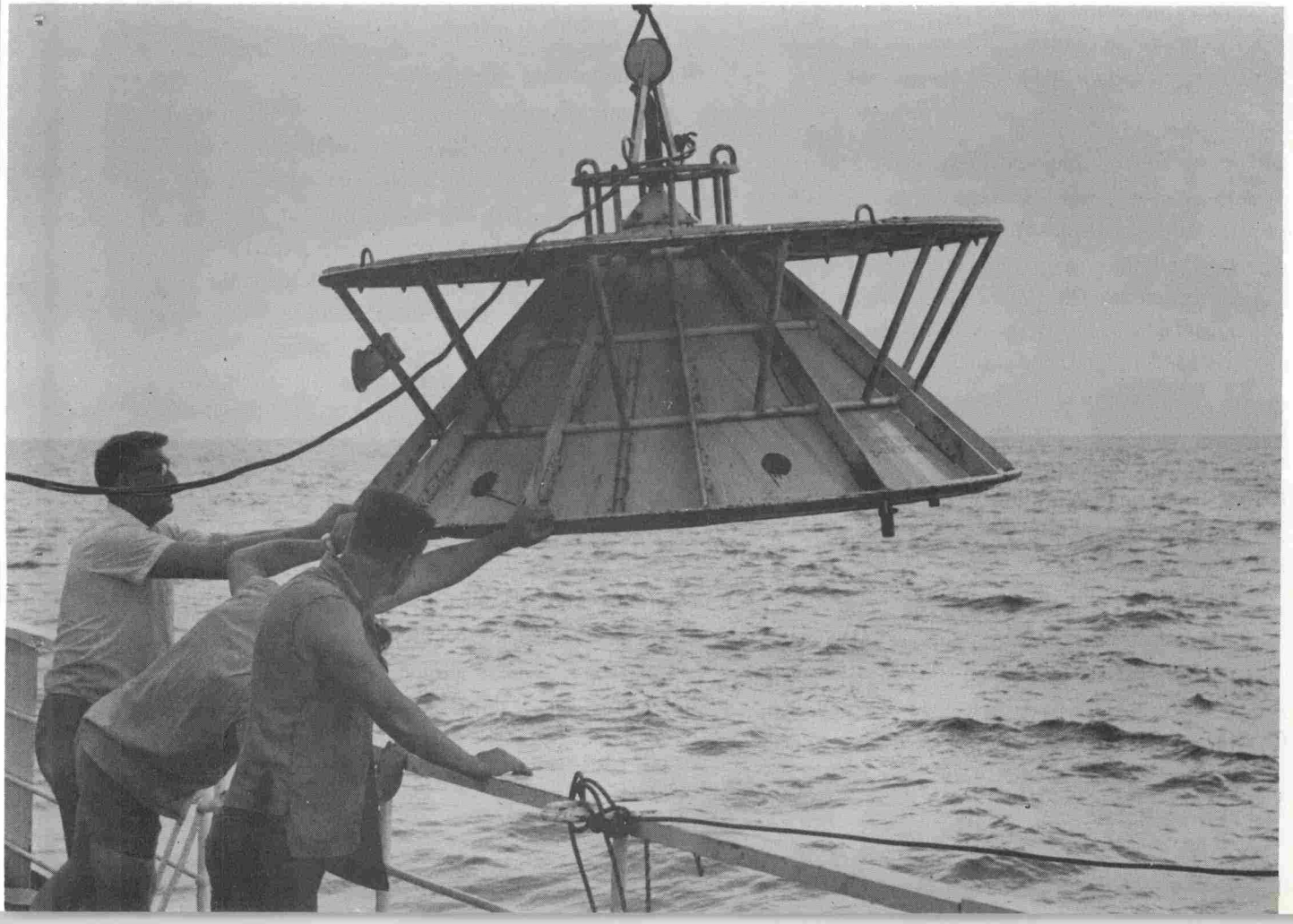
DEFENCE RESEARCH ESTABLISHMENT ATLANTIC

DARTMOUTH, N.S.

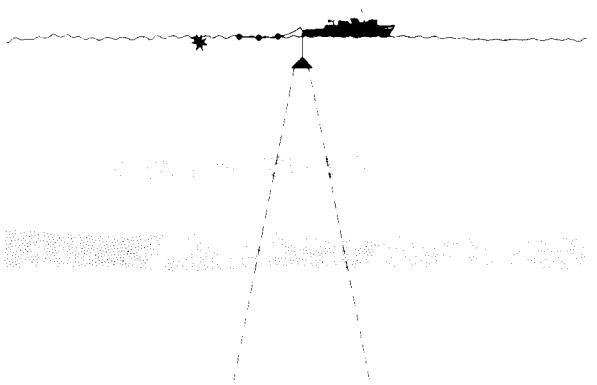
The sea has been to man both a road and a barrier. Research at the Defence Research Establishment Atlantic (DREA) is aimed at exploiting the road and reducing the effects of the barrier on military systems. In more prosaic terms, the purpose is to carry out a program of research to assist in meeting both present and future requirements of the Canadian Forces Maritime Command and related activities. In 1970, this research dealt largely with underwater acoustics and hydrodynamics, and about one third of the establishment's effort was applied in direct assistance to the Canadian Forces in a variety of ways.

Underwater Acoustics Research

In line with continuing emphasis on the use of sound in the detection of submarines, in 1970 research in underwater acoustics was carried out on the manner in which low-frequency sound travels in the sea, on the effects of the ocean on sound pulses transmitted through it leading to improved processing of sonar signals, and on the variation in reflections from scattering layers found deep in the ocean.



DREA cone, an underwater sound receiver, being lowered from CSS *Hudson.*



Experimental arrangement for measuring reverberations from the deep scattering layers by the use of explosives and a conical receiver.

Experiments in low-frequency acoustics were carried out in 1970 to investigate the performance of vertical and horizontal hydrophone arrays and to make fundamental measurements of wavefront coherence and of the directional properties of ambient noise. Investigation is continuing on propagation loss and the effects of environmental factors on acoustic parameters, particularly for conditions not previously encountered.

In association with laboratories of the United States Navy, studies were made at Cape North, N.S. on ambient noise and sound propagation in shallow water, both with and without ice cover and, in Hudson Bay, on reverberation and sound attenuation.

The emphasis of the signal processing effort at DREA has been shifting toward the implementation of automated detection and tracking procedures for active sonar. The theoretical framework for machine detection and tracking is reasonably well developed and has had most application to date in passive sonar. Experimental research has also been carried out for active sonar. Results appear to promise significant improvements in overall fleet performance of active sonars in the future if computer-aided detection and tracking is adopted. Measurements are being made at DREA on submarine echoes and reverberation to provide the information necessary for implementing such a system.

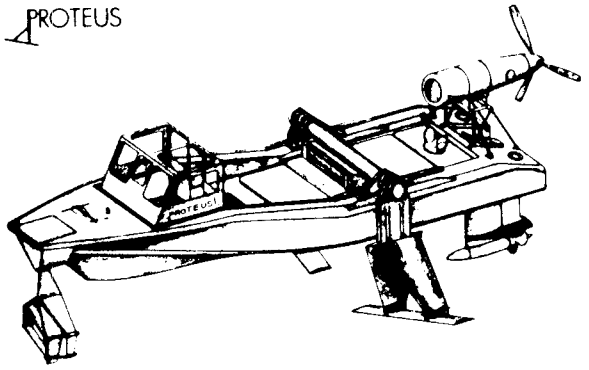
For the past decade, investigations have been made of volume reverberation that interferes with sonar performance. This backscattered sound has been found to come from layers of fish deep in the ocean. Recently, measurements were made over a wide band of frequencies by use of explosive charges and a downward-looking cone receiver. With this wide-band feature it has been possible not only to find the variation of sonar interference with frequency, time and geographic location, but also to estimate scatterer size by picking out resonant frequencies of the dominant scatterers in the layers. This has shown that for fish of a given size, population densities may vary greatly in different water masses. Also, considerable variation in size of fish in different areas has been recorded. To obtain further information on these scattering layers in northern waters, in 1970 DREA's new research ship CNAV *Quest* carried out measurements in the Labrador Sea up to 62° N. This was the first extended cruise in which DREA female scientists were embarked. Other such measurements were made by DREA personnel in the Eastern Pacific in 1970 as part of the "*Hudson 70*" cruise under the auspices of the Bedford Institute.

Fluid Dynamics Research

In hydrodynamics, a wide gap exists between research conducted under laboratory conditions in towing tanks, cavitation tunnels, etc. and actual service experience at sea. This can best be filled by developing rational design techniques through experiments on large-scale models run under realistic conditions in open water. The proximity of Bedford Basin to DREA and to the approaches to Halifax Harbor makes available a full spectrum of realistic conditions for tests of hydrofoil craft, propellers, towed bodies and faired cable.

To extend its existing facilities to permit a wider range of hydrodynamic experiments to be conducted under realistic conditions, DREA is constructing a versatile test craft known as *Proteus*. This 33-foot, 5-ton craft will be capable of operating at slow speeds as a displacement boat, at moderate speeds in a planing mode, and at high speeds on hydrofoils. Its configuration will make possible experiments on pro-

pellers, other propulsion and steering devices, testing hydrodynamic bodies mounted over the bow in undisturbed water, and the analysis of motions of a craft in a seaway. Independent air propulsion is provided for increased versatility to allow such experiments as varying the loading on underwater propellers while maintaining speed. Launching is planned for the spring of 1971.



Artist's concept of ***Proteus,*** a multi-purpose research craft, under construction for DREA.

Direct Assistance to Canadian Forces

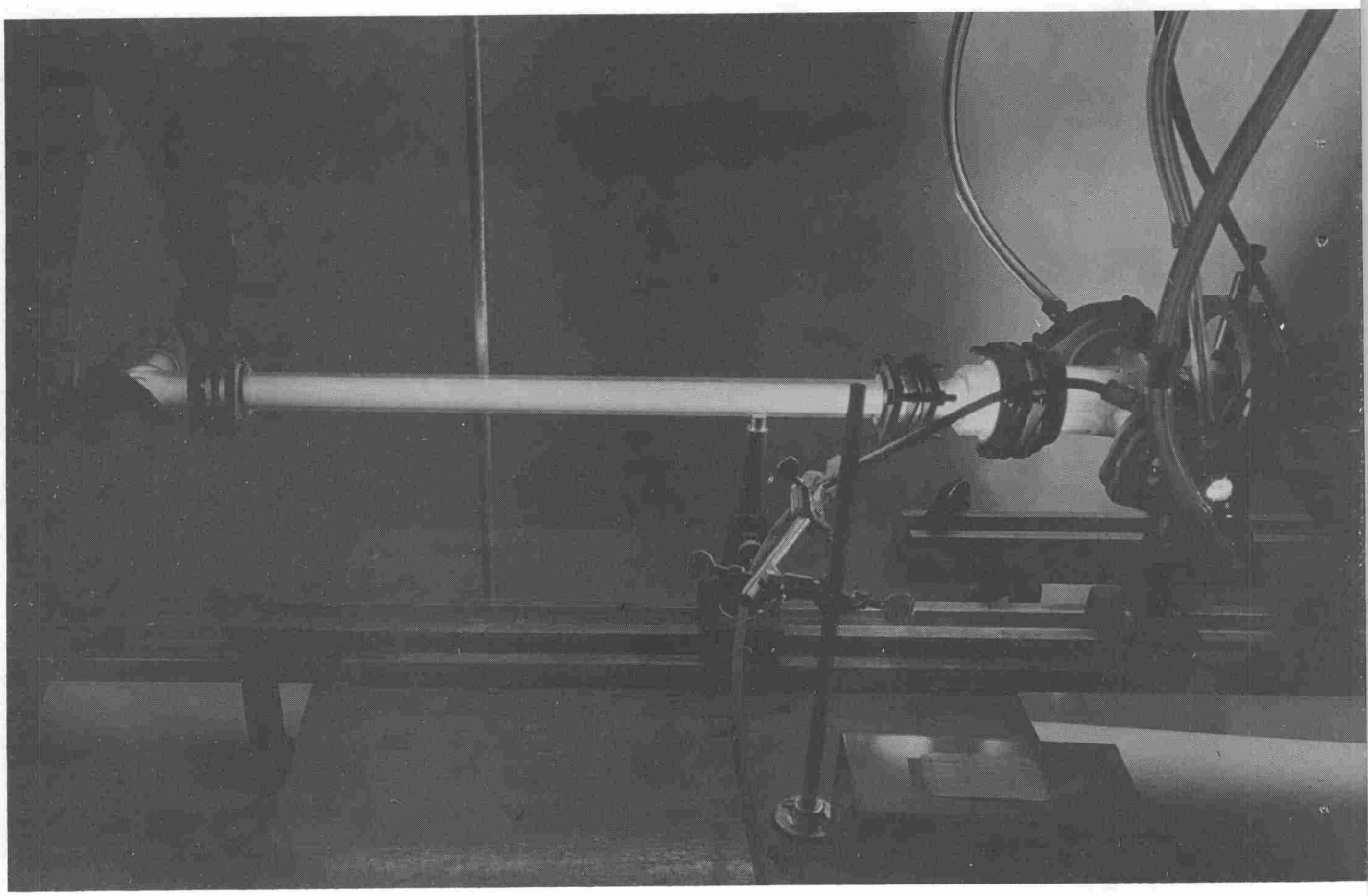
DREA provides direct scientific support to the Canadian Forces through its Dockyard Laboratory and the Anti-Submarine Warfare Service Projects Unit (ASW/SPU). The former carries out chemical and engineering analysis and testing as required by the Maritime Command. The ASW/SPU handles mechanical and electrical problems that plague the Service operator, such as those stemming from improperly functioning equipment or modifications suggested by Canadian Forces officers or men. By direct contact with Service personnel at all levels and with industry and other laboratories of the Defence Research Board, the ASW/SPU brings scientific expertise to these problems and avoids much red tape in getting results. The achievements and willing response of this small team of three scientists and two Canadian Forces officers, which frequently handles a dozen tasks concurrently, have won the respect of the Canadian Forces. These two groups have available the assistance of the entire establishment, all parts of which are readily accessible to the Forces.

Operation Oil

DREA's efforts during the initial crisis following the wreck of the tanker *Arrow* in Chedabucto Bay, Nova Scotia, on 4 February 1970 and in the long haul since then warrant a place in this review.

As soon as the magnitude of the disaster became evident, OPERATION OIL was organized by the Canadian Government, with immediate involvement of DRB and DREA staff and facilities. Dr. Frank A. Payne was commandeered to be scientific liaison officer to the Task Force and served on the spot in that capacity for many weeks, ultimately being replaced by Mr. J. Ray Brown. In just a few days DREA mechanical engineers and machine shop manufactured to order a large water-intake filter for a threatened fish-packing plant. DREA technicians were preempted to range over the shores of Chedabucto Bay to collect pollutant samples for analysis in DREA's Dockyard Laboratory. Oil pollutant samples collected from as far away as Sable Island were ultimately analyzed there also. The Dockyard Laboratory's Carvel W. Reyno came up with the live-steam-injection idea that contributed much to the speed of recovery of oil directly from the wreck. Staff members J.B. Allen and W.A. Gibson contributed to the concept of the Fishnet Laundromat, and Mr. Gibson carried the concept through design and fabrication in industry to a successful facility. Later DREA staff, particularly K.N. Barnard and J.R. Brown cooperated with LCdr D. Hope of the Fleet Diving Unit to produce simple underwater differential pressure-gauges to measure the depth of oil remaining in the tanks of the sunken *Arrow*, and more recently in the oil barge *Irving Whale* off Prince Edward Island.

CW Chemical Laser – CS_2/O_2 System.



DEFENCE RESEARCH ESTABLISHMENT VALCARTIER

VALCARTIER, P.Q.

The Defence Research Establishment Valcartier is the largest Federal Government research center in the Province of Quebec. This year is the 25th anniversary of its initial formation as the Canadian Armament Research and Development Establishment. More than three-quarters of its personnel numbering about 800 are bilingual, and its working language is French. The establishment provides technical assistance and advice to the Canadian Forces on current problems, and carries out long-term research in areas of science selected for their relevance to defence needs of the future. The current program stresses work on lasers, armament, surveillance, explosives, aerospace problems and weapons system analysis.

Optical and Infrared Surveillance

This extensive program at DREV includes activities in direct support of current Canadian Forces requirements (which are mostly outside the scope of this review) and activities initiated within DREV to meet anticipated Canadian military requirements including studies of the propagation and emission of infrared and optical radiation in the atmosphere.

A number of the foregoing investigations are carried out with DREV's well equipped mobile van, which contains optical and infrared imaging equipment (low-light-level vidicon, standard and near infrared vidicons, and thermal imaging devices for the atmospheric windows 3 – 5μm and 8 – 13μm) as well as optical and infrared radiometric equipment. Examples of these tasks are:

(i) radiometric and video tape records of the illumination from American and Swedish flares thrown from aircraft during a Canadian Forces exercise at Cold Lake, Alberta,

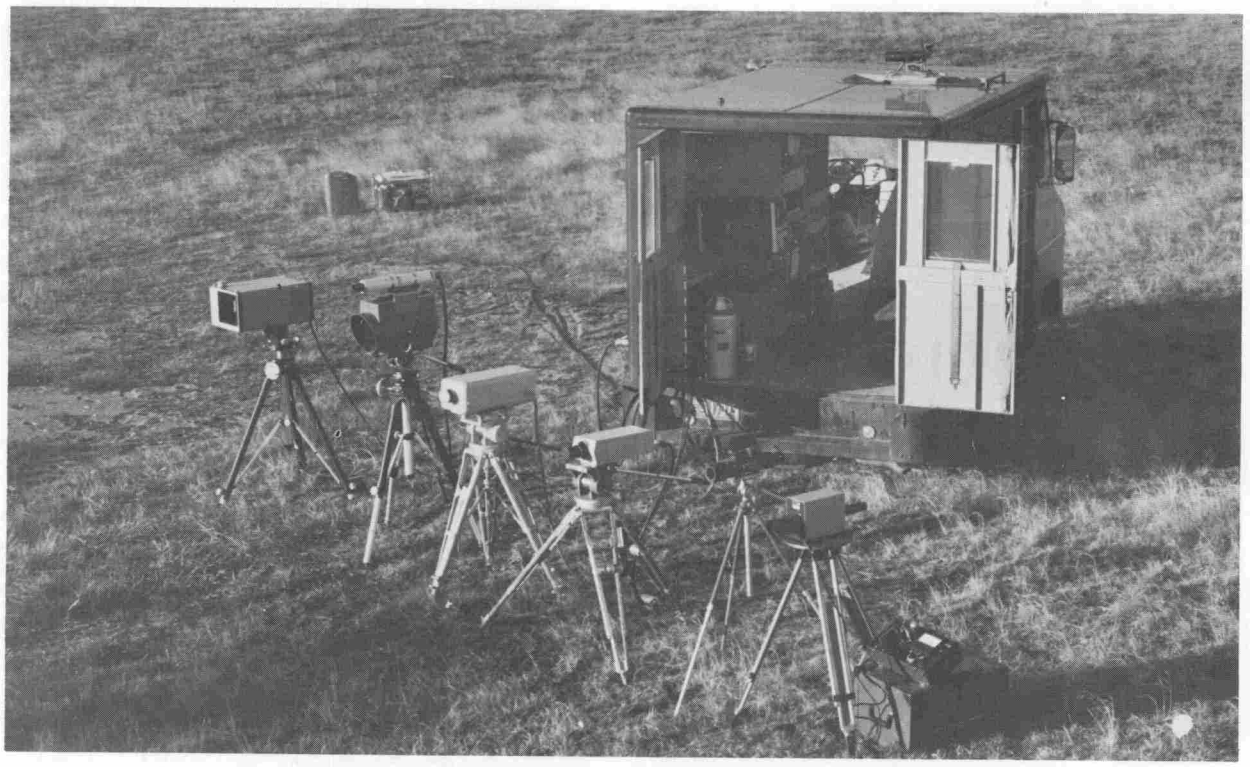
(ii) measurements of the infrared signatures of ships,

(iii) evaluation of the effectiveness of camouflage at various wavelengths,

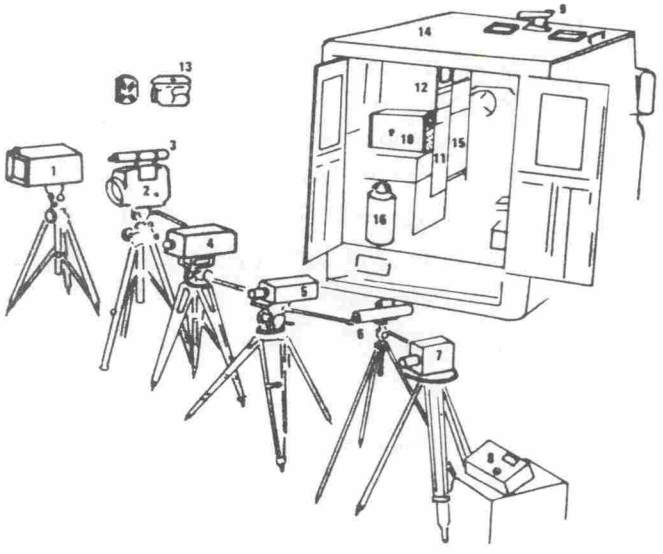
(iv) measurements of contrast transmission at various wavelengths.

Following upon the extensive joint program of ground-based measurements with the United States and the United Kingdom, measurements of the amount of radiation at various wavelengths in the visible and infrared spectral regions have recently been

completed aboard a high-altitude aircraft. These unique measurements, unperturbed by cloud and other tropospheric weather disturbances, indicate that for spectral regions free of auroral emission there is little variation, with latitude or season, in the amount of illumination available for surveillance purposes on moonless nights.



VARIOUS PIECES OF OPTICAL SURVEILLANCE EQUIPMENT AVAILABLE AT DREV



1 – Bofors Infrared Camera
2 – AGA Infrared Camera
3 – COHU 2000 TV Camera
4 – Westinghouse SEC TV Camera
5 – COHU 6000 High Resolution TV Camera
6 – Starlight Scope
7 – Gamma Photometer
8 – Gamma Photometer Control Unit
9 – Micro Candela Footcandle Meter
10 – Bofors Display Unit
11 – AGA Display Unit
12 – TV Monitor
13 – Portable Generator
14 – Step Van Vehicle
15 – Video Tape Recorder
16 – Liquid Nitrogen Flask

Chemical Lasers

The energy liberated during chemical reactions, if appropriately distributed and efficiently utilized, could provide an attractive source of laser energy. Chemical lasers would share many of the advantages that have led to the present wide use of combustion power sources. In particular, the compact, high-density storage of potential energy and chemical, as opposed to electrical, conversion processes offer promise of substantial weight and cost savings. The multitude of chemical reactions available makes operation at a great variety of frequencies possible. The unlocking of the energy of the chemical bonds makes very high efficiencies realizable and, with the elimination of the power source required for electrical excitation, portability becomes immediately more feasible. Such lasers could be used, of course, in many of the applications wherein CO_2 or other lasers are used, such as communications or tracking.

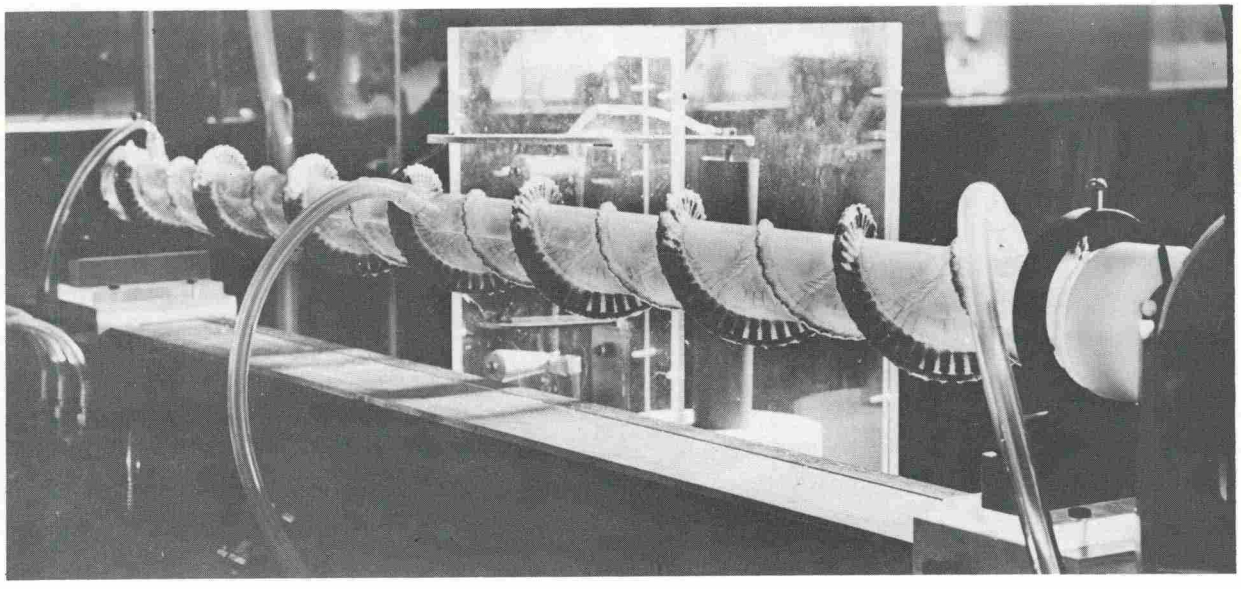
Since work began at DREV in 1969, several significant advances have been made both in pulsed and continuously operating (CW) chemical lasers. Laser action in the pulsed mode operation was achieved by the use of a number of new chemical systems in which lasing had not previously been observed. Recently, several chemical systems were found to operate at atmospheric pressure, extending the simplicity of operation of the TEA type CO_2 laser developed previously at DREV to new wavelengths. These lasers utilize simple inexpensive materials e.g. freon and propane. Further development of this pulsing technique may lead to the conversion of large amounts of chemical energy into electromagnetic, thus providing operating efficiencies greatly in excess of those obtained by conventional means.

The world's first continuously operating chemically-driven laser was developed in 1969 at Cornell University. In 1970, concurrently at DREV and at a U.S. laboratory, CW operation of a chemical laser was achieved by means of a second chemical system (the CS_2/O_2 combustion laser). In this device, oxygen atoms react with carbon disulphide molecules in a high speed gas flow, eventually producing excited carbon monoxide, which is the lasing medium.

TEA Lasers

The announced invention of the Transverse Excited Atmospheric (TEA) laser, at the beginning of the year, has given rise to much interest not only from the scientific community but also from potential users in the military and industry. These lasers, which use electrically-excited CO_2 gas for producing infrared

The helicoidal geometry is very suitable for the fundamental mode excitation of TEA lasers. Their short-pulse characteristic offers the possibility of measuring distances with a CO_2 ladar to a few centimeters.

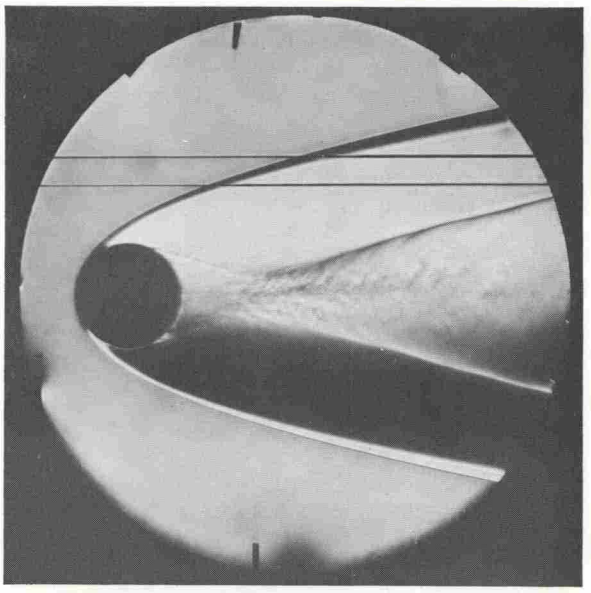


radiation, operate at atmospheric pressure. They can produce high peak powers (of the order of 100 megawatts so far) and have an inherent simplicity both in construction and operation. As a result, both the production and the operation costs are greatly reduced compared to other lasers of similar performance. Over sixty industrial firms have requested detailed information about the performance of these lasers. Fourteen Canadian companies made a formal application to be licensed to produce the TEA lasers, and two wholly Canadian companies (GEN-TEC in Quebec City and Lumonix in Ottawa) have been granted the license.

While most of the research effort has been aimed at improving laser design and reliability, a new laser laboratory to house more powerful lasers has been constructed and should be operational early in 1971. However, lasers now available are quite suitable for a number of military applications in the field of ladar (laser radar). The small beam divergence of lasers gives them a much higher angular resolution than radars without need of large antennas, and pulsed TEA lasers give a good range accuracy (± 10 meters). Furthermore, it has been found possible to "mode-lock" the TEA lasers to produce pulses two orders of magnitude shorter than the usual short laser pulse so that range accuracies of a few centimeters can be achieved. Such accuracies are sufficient for considering target imaging and identification. A preliminary study of the feasibility of ladar applications has produced very encouraging results. Transmission measurements of the laser beam have indicated that, for the long infrared wavelength of the CO_2 lasers, the obscuration of targets by smoke is negligible compared to that for visible wavelengths.

Acoustic Surveillance

In the field of acoustic surveillance, work on the intrusion alarm was continued by carrying out exercises with combat troops. Some fundamental work was also initiated in an attempt to use modern signal-handling and display techniques in air acoustics. The subjects under investigation include the identification of targets of interest, the propagation of sound in different environments, signal-handling techniques and display systems with a view to applying new techniques to military problems.



Schlieren photograph of a 2.7-inch diameter sphere traveling at 14,000 ft/sec at a simulated altitude of 60,000 ft (DREV Hypersonic Range No. 5).

Re-entry Physics

Investigation into re-entry physics problems employing light-gas guns to launch models at hypersonic velocities in ballistic ranges began in 1959 and has continued for over 10 years. The current project, now being brought to a highly successful conclusion, began in 1964-65. Its objective was to measure the various fluid dynamic and thermochemical variables such as velocity, mass density, temperature, and electron density, which characterize the behavior of the turbulent wakes behind hypersonic spheres and cones. Such experimental data were essential for the development of theoretical models of turbulent wakes, which could be used to predict the scattering of microwave energy from the trails of re-entry bodies. The scatter from a turbulent trail is considerably enhanced over that of the laminar case, and the information contained in a radar return may be useful for discrimination.

The obtaining of spatially and time-resolved measurements of physical quantities in ranges presents considerable difficulty. Velocity has been measured in wakes at DREV by means of three independent techniques: sequences of sparks, axial arrays of electrostatic probes and cooled-film anemometry.

Mass density and temperature distribution have been obtained with the electron beam fluorescence probe and with anemometry techniques. Electron densities have been measured by Langmuir probes and microwave interferometric techniques, and firings have also been observed in a 6-channel microwave scattering experiment. The statistics of electron density and temperature fluctuations are also derivable from the Langmuir probe and anemometry measurements.

Progress during the past year has included the first reliable anemometer temperature and velocity measurements and the first Langmuir probe absolute electron density measurements. With these most recent achievements, all of the stated goals of the turbulent hypersonic wake project in re-entry physics research have now been attained. The data generated by this research program have been of considerable value in U.S. circles. Over 50 DREV reports and open literature papers have already been published.

Atmospheric Radiative Processes

The DREV program is focused on the photochemistry of the ozonosphere, the region wherein the bulk of the solar energy driving the atmosphere is deposited. Much of the work forms part of CRAM (Centre de recherches sur les atomes et les molécules), which groups together a considerable number of DREV scientists with staff members of the Departments of Physics, Chemistry and Electrical Engineering, Université Laval. Research is under way in the following areas.

(i) Aircraft-borne experiments are used for those studies of infrared airglow and stratospheric composition where obstacles to viewing, such as clouds, haze and absorbers, must be avoided and where wide geographical coverage is desirable. A joint ARPA, USAF, DRB(DREV) program, under which stratospheric abundance of minor gases, emission intensity of $O_2(^1\Delta_g)$ and OH, and OH rotational temperatures over a wide range of latitudes have been measured, was completed by the end of the year. A program on the measurement of airglow in the visible and near infrared from Arctic latitudes is planned for 1971. Emissions from excited oxygen, OH, and aurorae will be examined to determine ambient illumination levels near the surface, and to deduce upper stratospheric and mesospheric photochemistry.

(ii) Laboratory investigations under way or scheduled for 1971 include:

(a) Singlet molecular oxygen formation by photolysis of ozone.

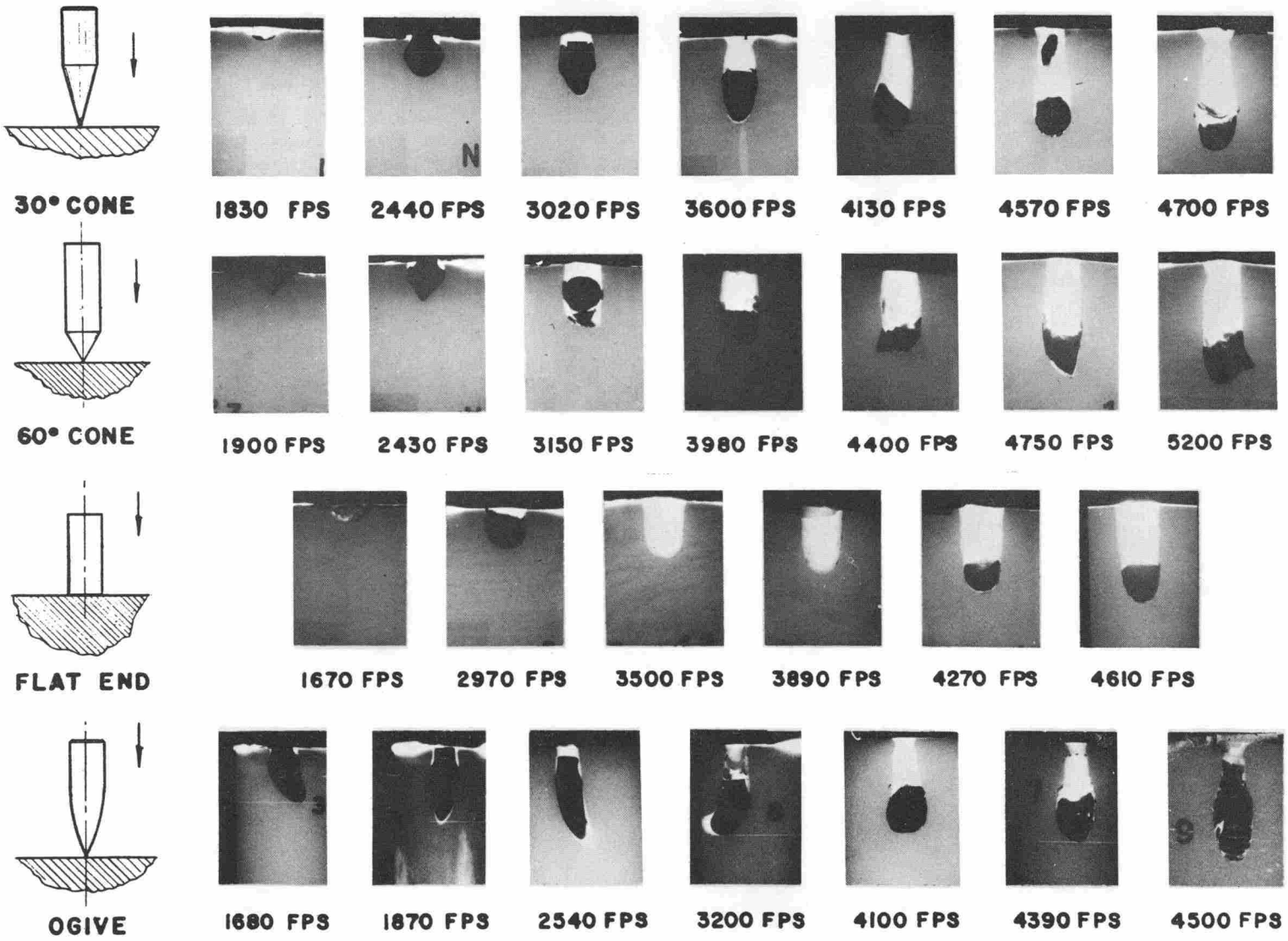
(b) Atmospheric OH rotational temperatures as a true measure of mesopause temperature.

(c) Atmospheric composition derived from solar and lunar absorption spectra of high spectral resolution obtained by a ground-based interferometer coupled to an optical tracker.

(iii) The best available kinetic reaction rates, atmospheric composition, temperatures and circulation are used to derive models of atmospheric radiation processes. Photochemistry of the stratospheric and mesospheric regions, 10 -- 100 km, is stressed. Model predictions of constituent distribution are compared to observed data to verify the modeling technique and highlight critical unknowns.

Pyrotechnics

Work in pyrotechnics at DREV was prompted by requirements from the Canadian Forces for an orange spotting-charge for practice bombing over winter terrain and two orange smoke signals, one of 3 minutes and the other of 12 minutes duration. The first item, a 0.85-inch diameter by 7.75-inch long aluminum tube containing a mixture of $VOCl_3$ and $TiCl_4$, both liquids, is now in production in Canadian Industry and designated as the MK 402 by CFHQ. The tube is ruptured when the bomb containing it strikes the ground. The chemicals then react with atmospheric moisture to yield a bright orange cloud, which remains readily visible to airborne observers for up to 20 seconds.



Evaluation of tungsten alloy penetrators of different shapes. Delayed hydrodynamic deformation of the ogival shape contrasts strongly with the behavior of other penetrator geometries.

The statement requirement for the two smoke signals, which are needed in search and rescue operations as markers and/or wind indicators, carried with it a firm (and almost unique) "no fire hazard" restriction because the signals will often be deployed where there is a danger of starting brush or forest fires. Thus their design is such that no flame or sparks are produced externally, and the temperature of both the smoke and the container are kept below the kindling point of dry grass, hay etc. The pyrotechnic candles in both signals contain the orange dye 1-aminoanthraquinone combined with potassium chlorate as oxidizer and lactose as the principal combustible ingredient. A settling chamber with or without baffles just below the exit port prevents sparks from being carried out in the smoke stream. Development of the shorter burning signal, now designated as the MK 70, was completed this year. The 12-minute signal is scheduled for completion in 1971.

Recently, the Pyrotechnics Group undertook to provide a suitable tracer for the improved 0.50-inch caliber armor-piercing ammunition (AP/T C44); difficulties in observing this trace over snow-covered ground and during periods of bright sunshine were resolved by May 1970. As an outgrowth of this project, improved trace compositions will be investigated by means of a laboratory test apparatus capable of spinning typical small arms projectiles at rates in excess of 100,000 rpm. Other new pyrotechnic work revolves about interest CFHQ has expressed in a colored-flame arctic marker; preliminary investigations towards this and a related marker for high-sea-state conditions have already commenced. Finally, sufficient progress has now been made in the development of a technique for casting smoke compositions, rather than pressing them in the conventional manner, that improved cheaper versions of the MK 70 and 12-minute smoke signals seem feasible in the near future.

Ballistic Evaluation of Materials for Armor Penetrators

One of the most frequently asked questions in terminal ballistics is: "What is the relationship between the static physical properties of a penetrator material and its subsequent ballistic performance?" The reason that no satisfactory answer has been given to this question is probably related to two factors, a) the wide variety of ballistic configurations for which correlations are required, and b) the possibility that a significant static property has either not yet been measured or does not exist.

One method of simplifying the problem of finding correlations (on the assumption that this is possible) is to control the ballistic configuration so that one mode of deformation predominates. This is most easily accomplished if the material of interest can be used as a target. One can arrange the impact geometry to obtain a pure shear, petaling, spalling or pure radial plastic flow. At the present time interest is centered on new materials that are available only in small quantities and whose usefulness depends on their ability to penetrate armor. A worth-while testing procedure must therefore provide loading geometries that are found during penetration but here again, for the ease of making correlations with static laboratory properties, it is desirable to control the impact geometry so that the same mode of deformation will be found in all cases. A simple test of this type has been found to be the impact of a smooth ogival penetrator on a semi-infinite ductile target at normal incidence.

This particular configuration was chosen because of an anomaly observed during an associated study on penetrator shape. A series of penetrators, made of a dense tungsten alloy, were fired into semi-infinite targets over a range of velocities up to 5000 ft/sec.

Radiographs for four different shapes are shown in the accompanying figure, together with the impact velocities. In each case, the projectile mass was held constant. It is immediately apparent that the behavior of the ogival projectile is completely different to that of the flat-ended cylinder or either of the two cones for velocities up to about 3200 fps. Whereas the cones and cylinder show steadily increasing deformation with impact velocity, the ogive does not. In fact, as the velocity increases, the amount of plastic deformation of the core decreases. When a velocity in excess of 3200 fps is reached, the point of the ogive deforms on impact. This increases the resistance to penetration causing a rapid build-up in projectile stresses. The process is unstable, and deformation

proceeds rapidly resulting in penetrations that are similar to the flat-ended cylinder. It is only the narrow entry hole of the ogive's crater that is indicative of the time required to destroy the point and initiate jet-like behavior. The same process is observed in the case of the 30° cone, but to a much lesser extent. If we consider penetration depth as an inverse measure of projectile deformation, we observe progressively more deformation as we go from the ogive through the 30° cone and 60° cone to the flat-ended cylinder. However, beyond an impact velocity of 3200 ft/sec, there is little difference between any of the four shapes.

The anomalous behavior of the ogival penetrator at relatively low velocities immediately suggested a method of comparing the resistance of different metals to deformation during the penetration of a thick target. Clearly the most effective material would be one that showed the largest initial gradient of penetration with respect to energy and the highest critical impact energy for the onset of unstable deformation of the ogive.

This technique has been found to be extremely useful in reducing the quantity of ballistic testing normally required during the development of new alloys for penetrators.

Simulation of Weapon Systems

Simulation is one of the most powerful techniques available for the evaluation of weapons and weapon systems. It is useful in situations where mathematical analysis becomes excessively complex, where tactics have to be evaluated, or where a human operator forms part of the system. It is most frequently performed on a digital computer, but analog or hybrid computers are also used, particularly when a human operator must intervene to perform physical actions.

An extensive digital computer simulation was performed recently at DREV in the context of the FHE-400 hydrofoil study. A detailed simulation model was set-up to compare the performance of the hydrofoil to that of destroyers and helicopters in the datum search operation of anti-submarine warfare (ASW). In searching for a submarine whose position is known with an error of at most a few miles, the ASW vehicles comb the area with their sensors according to a pre-set search pattern. The simulation model determines the probability of detecting the submarine in this search as a function of datum error, submarine speed, and initial distance between ASW vehicles and datum. It takes into account the capabilities of the vehicle sensors, the maneuverability of the vehicles, the submarine evasion rules, and the particular search pattern chosen. All these variables are provided as input data to the model, so that the simulation can be repeated at very short notice for any new variables or search patterns that it may be desired to investigate. This datum simulation model is permanently available at DREV.

Simulations using analog or hybrid computers can also be performed at DREV. A gun-aiming system was recently studied in this fashion. The problem consisted in determining the potential value of a computer-assisted sighting system without actually building it. The computer and servo-mechanism sections of the system were simulated by the analog machine, which was linked to a real gun, a real sight, a real gunner, and to a mechanical device simulating target motion. This was a very economical way of evaluating an idea for which mathematical analysis was impossible because of the presence of a human operator who could not be reduced to an equation.

The economy that can be achieved through the use of computer simulation will perhaps be better illustrated with a third example. In the fall of 1969, the Canadian Forces carried out trials at Canadian Forces Base Cold Lake to evaluate a new flight procedure designed to reduce helicopter flight times between two hover points, under Instrument Flight Rules. The trials were positive but very limited in extent because of restrictions on trial equipment and personnel. DREV undertook to analyze the results and succeeded in measuring helicopter speeds, accelerations, and turn rates as they occurred in the trials. These quantities were then used in a digital computer simulation model that had previously been prepared to study the performance of the helicopter in the datum search problem mentioned above. It thus became possible to complete the Cold Lake trials on the computer and to evaluate the new flight procedure under all the desired conditions, the trial results having been used to validate the simulation model.

The three examples given above were chosen to illustrate the wide variety of simulation problems that can now be performed with the computers available at DREV. They also illustrate the economical nature of simulation as compared to full scale evaluation.

DEFENCE RESEARCH ANALYSIS ESTABLISHMENT

OTTAWA, ONT.

The Defence Research Analysis Establishment program is almost exclusively related to the current problems of the Canadian Forces, particularly those concerned with the management of men and resources, future planning and operations. It is staffed by civilian scientists and military officers in the proportion of about 3 to 1. The establishment in Ottawa consists of two divisions: the Operational Research Division, which carries out studies of military operations and requirements, and the General Analysis Division, which is particularly concerned with strategy and planning in the broad sense and the management of men and materiel. DRAE also provides scientists for a number of small operational research sections working in military commands outside of Ottawa.

Assistance to Defence Planning

Assistance to defence planning takes place at many levels, from examining the strategic framework within which planning must take place down to the evaluation of specific alternative deployments for the performance of given tasks. In between these are a number of important problems such as the operation of the interface between planners and management, and the expression of general objectives in terms of the military capabilities required to achieve them. Although ideal planning techniques are unlikely to be achieved, the work is rewarding in that analysis does indicate where scientific methods can be employed; in particular it has been found possible to use simulation and war games to evaluate alternatives. These simulations, once developed, have proved of continuing usefulness for planning purposes.

Canada's Contribution to NATO Land Forces

The decision to reduce the strength of Canada's forces in Central Europe has been followed by a period of intense examination of the most suitable type of land force to leave there in the post-1973 period. A major concern has been to examine, by means of war games, the usefulness of relatively lightly armed, air mobile forces as a possible alternative to more conventional mechanized forces.

Canadian Forces Headquarters staff provided details of structure and equipment for the options to be considered and guidance on enemy force capabilities and tactics. The setting of the game and methods of play were worked out by DRAE with the assistance of CFHQ staff officers. A special effort was required to develop new rules for operations at night or in conditions of limited visibility.

Although war gaming is normally a slow process, these games were all played on a quick response basis in order to obtain timely answers. Methods of speeding up play by computer assistance were studied in parallel with the games themselves and were applied to a limited extent. These studies are continuing.

Effectiveness of Torpedo Decoys

A good example of how computer simulation can be applied to some particular aspect of a combat situation is provided by a study of the effectiveness of torpedo decoys. Such studies may answer a specific question, but they can also be used in developing rules and evaluation methods for war games. In this simulation, a number of types of torpedo have been considered in action against two types of Canadian ships, operating at various speeds. Torpedoes may be fired over a range of practical dispersion angles, and their behavior may be correlated with the firing errors to determine the probability of different outcomes of an engagement.

Arctic Surveillance

Early in 1970, operational research studies of maritime Arctic surveillance and defence were initiated. Two major activities in this program have been a cost-effectiveness comparison of different types of aircraft for Arctic surveillance, and a detection experiment in the Arctic environment.

The cost-effectiveness analysis was carried out by a study team made up of DRAE and CFHQ staff, led by the Director of Maritime Operational Research. A "unit surveillance task" was defined, taking into account the specific tracks to be flown to cover the area of interest and making allowance for off-track diversions for detailed search of particular localities or investigation of contacts. Aircraft performance characteristics and operational procedures were used to determine the number of aircraft of the different types considered that were necessary to perform the unit task with a stated frequency. Each type of aircraft was equipped and manned suitably for the task. The various options were costed on the basis of lifetime cost, including capital cost and operating, maintenance and personnel costs.

The aim of the detection experiment, carried out in conjunction with the NEW VIKING exercises, was to obtain data on the detection from the air of small military groups operating in the Arctic in the summer. The plan of the experiment was to conduct visual detection operations from Argus aircraft against ground troops at each of four advanced deployment bases: Sachs Harbour, Mould Bay, Eureka, and Isachsen. Successful experiments, carried out at two of these bases, gave useful data concerning visual detection ranges. The failures were also useful in indicating some of the special difficulties attending this kind of operation.

Maintenance and Equipment Replacement

One area of operational research in which methodology has been developing rapidly in recent years is logistics. The Directorate of Logistics Analysis in DRAE has found many opportunities for useful work in this field, because a considerable accumulation of statistical data collected by the Forces has not yet been fully analyzed and applied to logistics management.

A problem now being examined is the familiar vehicle replacement problem: deciding when to replace an existing vehicle by a new one if overall operating costs are to be kept to a minimum. This problem has a considerable economic impact in the Canadian Forces whose fleets of vehicles in some cases run into thousands. In the study, the work involves design and validation of models, rigorous analysis, and ultimately, the development of simple algorithms for practical use in future management. There are four variations on the basic problem: the economic replacement of the fleet by identical but new vehicles; replacement of the fleet by new and different vehicles; the economic condemnation of an individual vehicle considered as a separate event; and the economic condemnation of an individual vehicle subject to a constraint on the rate of replacement within the fleet. Enough has been accomplished to date to indicate that the use of these methods will yield substantial economies as well as more effective management. Preliminary estimates indicate savings of the order of $250,000 for one type of vehicle alone.

An activity less demanding scientifically, but of considerable practical value, was to organize data collected on the reliability of operation of major equipment on certain vessels of the Canadian Forces. The object was to organize a convenient reporting system for those collecting the data, and a useful method of presentation for the managers. The success of a study of this kind can only be judged by the practical results attained. Some practical results, which appear satisfactory to the user, include the early identification of equipment with unusually high failure rates, assessment of the load placed on the dockyard for repair of equipment, and the provision of cost data for making decisions on parts replacement.

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

SHIRLEY BAY, ONT.

The principal aim of DREO is to provide the Canadian Forces with the technical advice and support needed in the various areas of expertise that the establishment maintains. This support extends to development of prototype equipment. To ensure that this aim will continue to be discharged satisfactorily, a large portion of the establishment effort is devoted to projects that anticipate long-term military requirements, although much of the effort is directly oriented towards specific end-items.

The areas of defence science covered by DREO include the defensive aspects of biological, chemical and nuclear warfare, environmental protection, power-source items such as batteries, fuel cells, and thermionic and thermoelectric devices, and earth sciences, with particular emphasis on the Arctic environment, remote sensing and vehicle mobility. A telecommunications liaison office manages the DND telecommunications projects conducted at the Communications Research Centre (CRC) of the Department of Communications, conducts research on defence electronics, and monitors various extramural defence electronics projects conducted within the Defence Industrial Research program. There is also an extensive extramural university grants program in areas related to the interests of the establishment.

Examples of DREO's activities discussed here are: Study of Sea Ice by Infrared Scanner, Spectacles for the Combat Soldier, Light-Aircraft Transponder, and Liquid-Activated Battery Systems.

Study of Sea Ice by Infrared Scanner

DREO collaborated with the Ministry of Transport in an experiment in 1970 to assess the capabilities of airborne infrared line scanners for ice reconnaissance during the late-summer melt season. It had already been established that under winter conditions the surface temperature of the ice, as measured by the scanners, is a good indicator of ice thickness, and hence of age. The purpose of the new experiment was to test the usefulness of the technique after the summer sun had brought surface temperatures above melting.

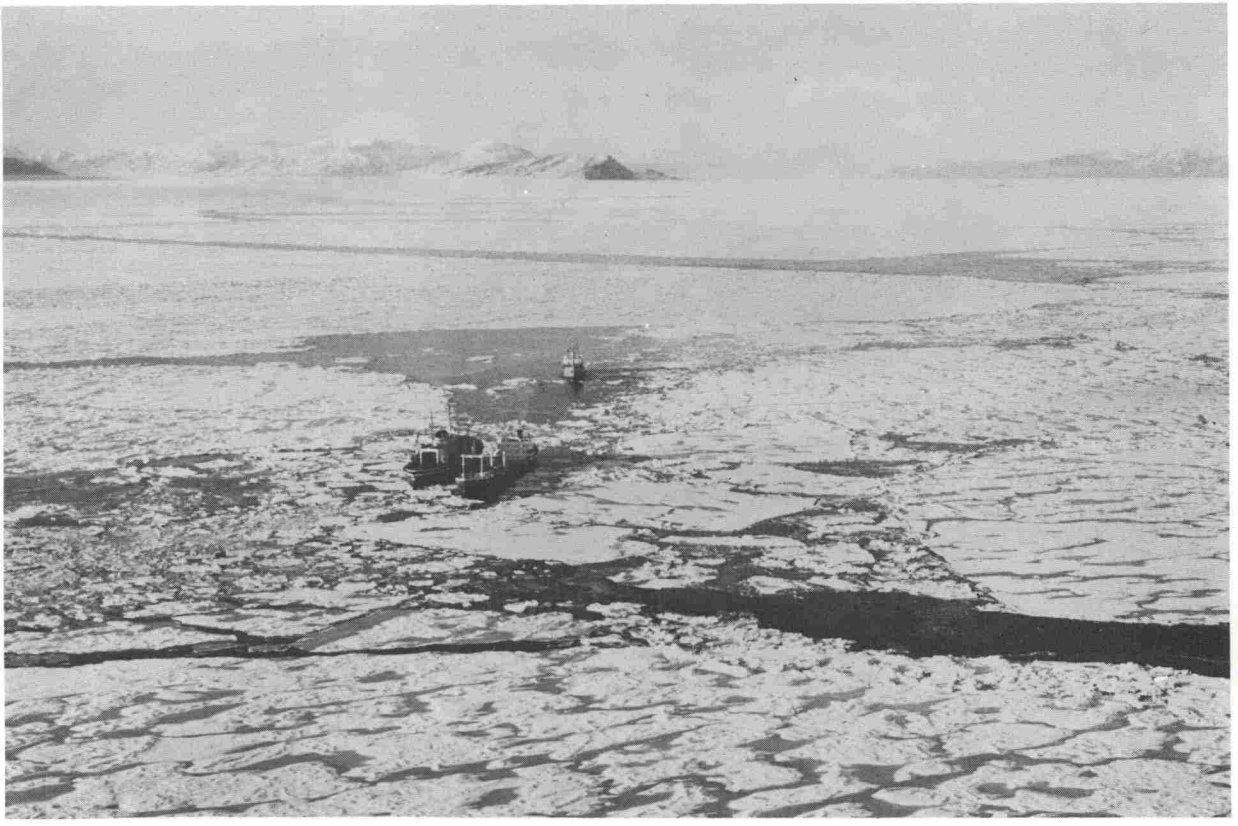
An ice party of three from DREO joined the Canadian Coast Guard icebreaker *John A. Macdonald* at Resolute for the annual supply trip to Eureka and Tanquary Bay. Throughout the voyage the *Macdonald* escorted a tanker and a small dry-cargo ship.

In contrast to the Western Arctic, the North Eastern Arctic experienced the coldest summer in 17 years, producing difficult ice conditions that slowed the convoy for long periods to a speed of advance of less than two knots. Despite this all cargo was delivered to all sites, including over five thousand gallons of fuel and a tractor to the DRB Camp at the head of Tanquary Fiord.

During the return trip through Norwegian Bay, the ice observer from the icebreaker searched ahead by helicopter for ice of different ages. On 4 September the convoy stopped for 24 hours while the ice party, with the help of five students from the Royal Military College and the ship's crew, laid out targets and markers along the selected flight line. The targets included a sheet of plastic with aluminized strips for measuring the resolution of the scanners, a gas lantern as a hot target, and several small oil spills. To guide aircraft to the area, a radio beacon was installed on the ice, and the ends of the flight line were marked by columns of steel barrels during the day and by flares at night.

Two sequences of flights by MOT aircraft carrying the sensors were scheduled for local noon and local midnight to study the effect of sunlight on the imagery, which was taken through both the middle and far infrared atmospheric windows. During the overflights the ice party measured radiation temperatures and collected meteorological data. The ice, which was about five feet thick, was cored during the interval between the flight sequences, and temperature and salinity profiles were measured. A preliminary study of the results of the experiment indicates that the thermal contrast between floes of different ages is not sufficient in late summer for discrimination by the infrared line scanners.

C.C. icebreaker ***John A. Macdonald*** refueling tanker with dry-cargo ship astern.



Spectacles for the Combat Soldier

Because an appreciable number of military personnel wear eyeglasses, DREO recognized that spectacles of special design should be developed to be worn with the protective mask without increasing the incidence of mask leakage. Other countries use optical inserts positioned inside the mask, with ordinary spectacles being worn at other times. A review of the mask-donning procedure indicated that retention of ordinary spectacles in the system would complicate and slow the masking drill, and that there would be a high probability of their being broken or lost. A need therefore existed for spectacles that could be worn at all times and would stay firmly in place during the rough-and-tumble activities characteristic of military operations. Such spectacles would have to be reduced in frontal width to avoid interference with the mask, the shanks would have to be very thin and lie on the cheekbone and not in the temple hollow, and a complete loop around the ear would have to be used to anchor the spectacles firmly on the face.

Combat spectacles

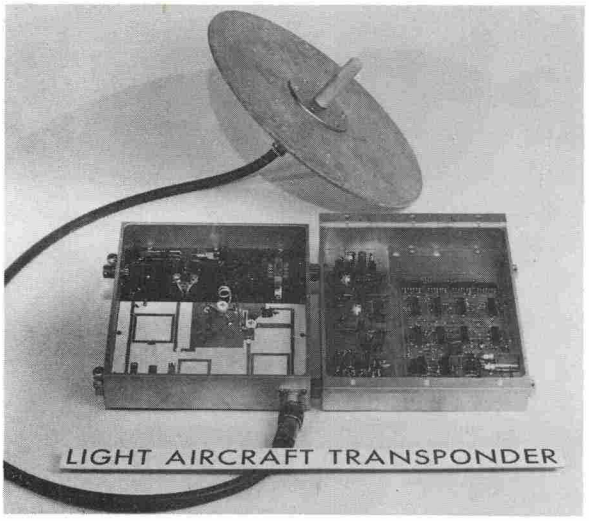
Starting from these rough design considerations, a model that showed surprising utility for a wide range of uses was developed. Parachutists at CFB Rivers, Manitoba, found the spectacles highly effective during free fall, static line and tower jumping, and also for jumping into water or swimming under water. Boiler-room workers, even when they were sweating profusely, found that the spectacles did not slip. Mechanics found the spectacles stayed in place no matter how their heads were turned, and the close fit to the head reduced interference in confined spaces. Scuba divers and other sports enthusiasts found the spectacles ideal. A check of the complete gamut of military uses is now being undertaken.

The spectacles are arousing considerable interest in the armies of other countries. The Australian Forces, for example, require spectacles that will stay in position during operations in dense jungle brush.

Combat spectacles firmly in place on man scrambling over wall

Light-Aircraft Transponder

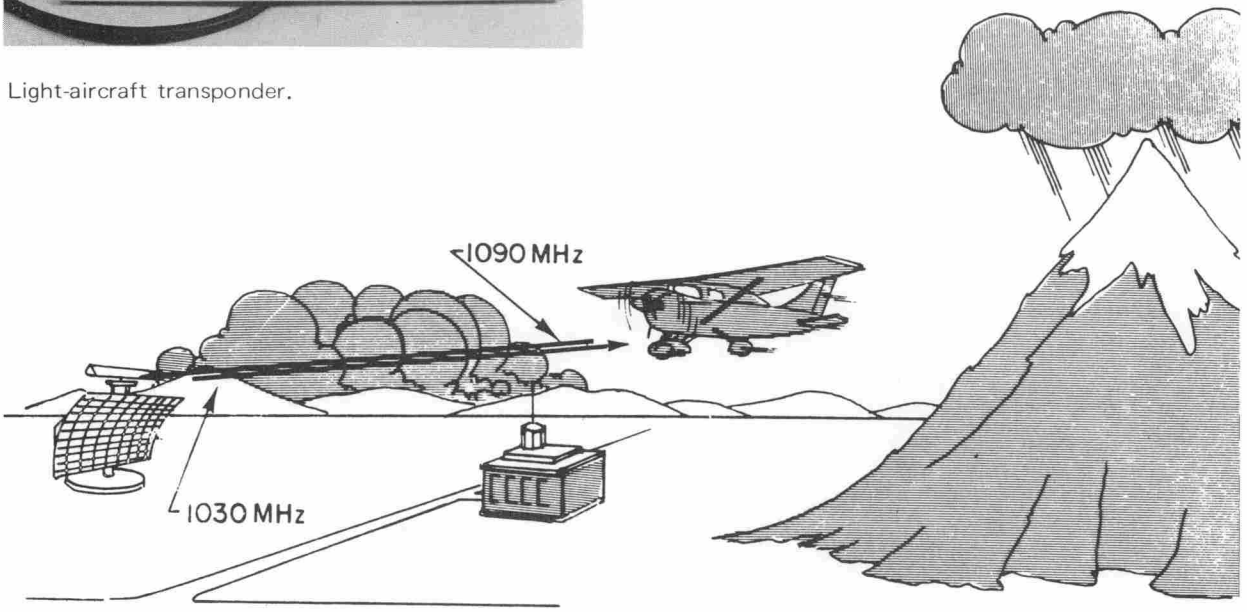
A serious flight hazard exists for military and commercial air traffic in the vicinity of metropolitan air terminals because of the presence in rapidly increasing numbers of light, non-military aircraft. These machines, which frequently are not seen above local ground clutter on the air-traffic-controller's display, have been intimately connected with a large number of mishaps or near-mishaps involving passenger-carrying airliners. The risk of collision is equally as serious for Air Transport Command as for commercial carriers, and accordingly DREO supported work at CRC to find a solution.



Light-aircraft transponder.

The CRC proposal is that all light aircraft operating in high-traffic areas be required by law to carry a small, inexpensive transponder that would give a reliable signature on the internationally standard Secondary Search Radar system used at all military and civil air terminals. Operational trials of an experimental transponder developed at CRC are being carried out in cooperation with the MOT, who have assumed responsibility for obtaining international acceptance of the equipment. The device meets all international specifications for SSR transponders except range, which in the CRC design is limited to 50 nautical miles. Thus, it deals effectively with the small-aircraft problem while minimizing any extra loading on air-traffic-control systems. The short range also facilitates cheap all-solid-state construction, ensuring high reliability with minimal maintenance. Arrangements are now being made to transfer expertise on the system to industry.

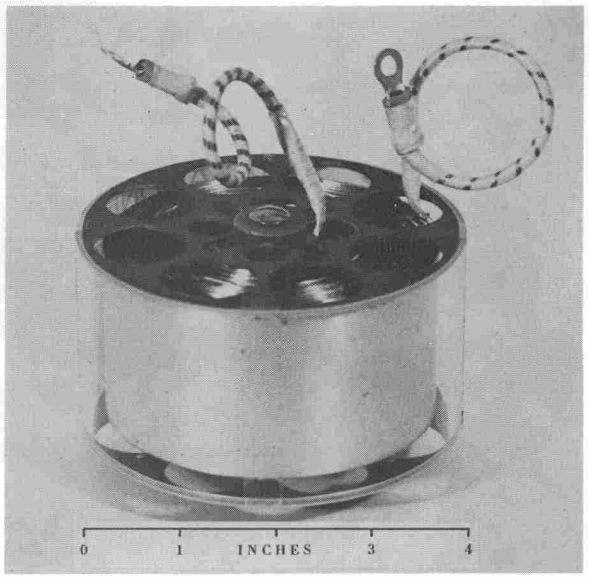
Operational use of transponder.

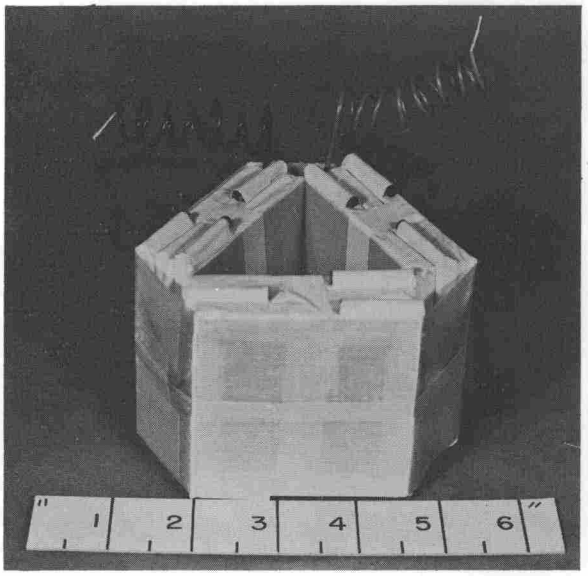


Liquid-Activated Battery Systems

Liquid-activated batteries are of considerable military and civil interest because they offer important characteristics such as protracted shelf life if stored dry, minimum maintenance, and high performance reliability on activation. The batteries are assembled in the dry charged state and are activated prior to use by the addition of electrolyte, which may be an acid or a base, water, seawater or other salt solutions. The electrolyte may be housed close to but separate from the battery (reserve type) or it may be the actual environment in which the battery operates (seawater type). The concept of activation only when required also permits the utilization of very active electrochemical systems, which could not normally be stored in the wet-charged condition because of their highly reactive nature.

Typical examples of liquid-(seawater) activated battery systems developed by DREO are the zinc/silver oxide reserve primary, and magnesium/silver chloride torpedo propulsion batteries. In addition to its high rate capability, the magnesium silver chloride system was found to have particularly good low-temperature (–40°) performance, a characteristic used to advantage in the reserve type URT 503 Survival Beacon Battery. One hundred of these battery units are currently being produced at DREO for Canadian Forces evaluation.





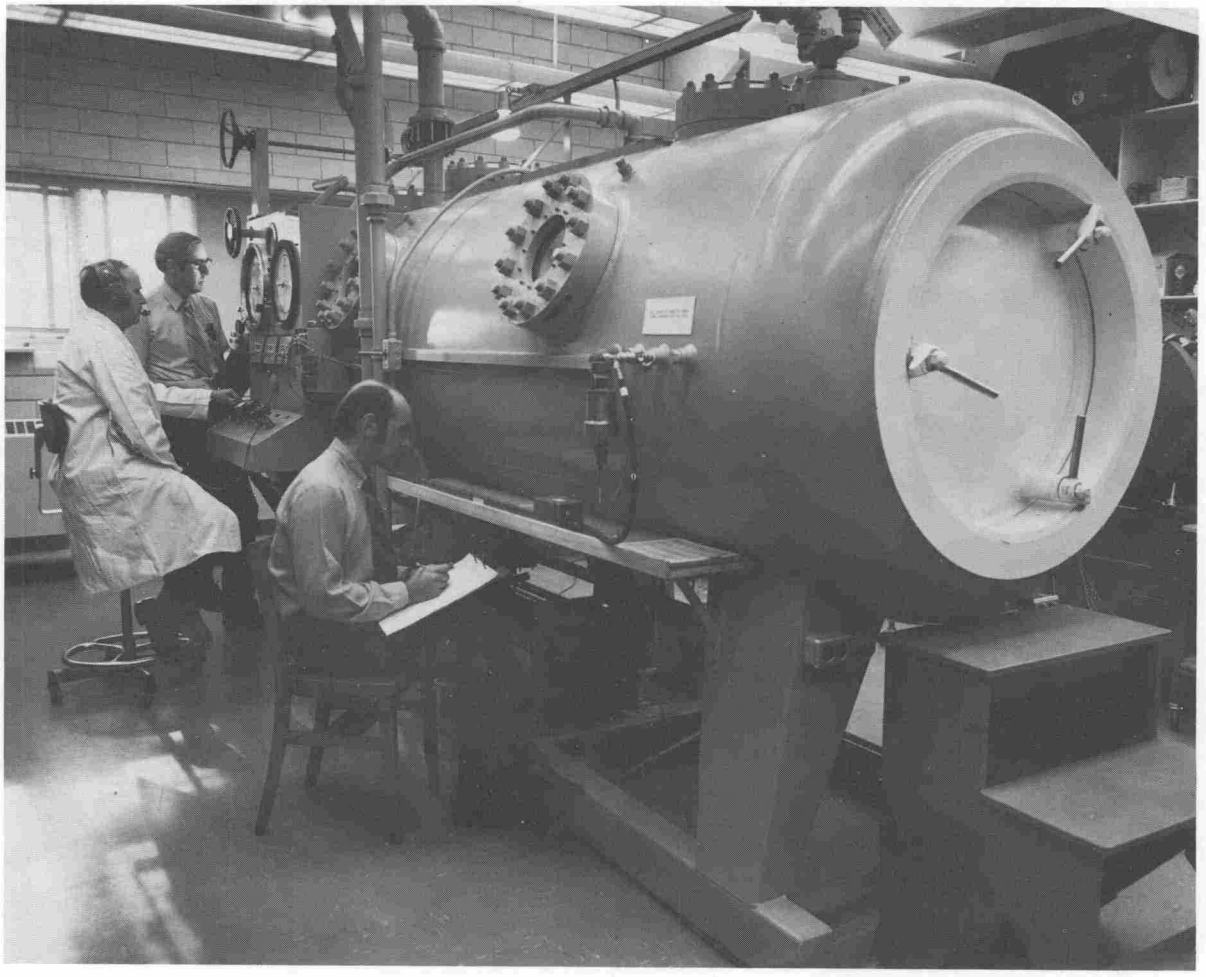
Low-rate telemetry/compass battery.

Two special batteries were developed for a new DRB sonobuoy system: (a) a compact spirally wound high-rate (300 watt, 3 min) battery to power the drive motor of the sonobuoy array, and (b) a low-rate (6 watt, 6 h) battery, patterned after the URT 503 Beacon Battery, for operation of the telemetry/-compass systems. Forty of each type have been produced commercially, and an additional eighty of the high-rate type are being procured for further sonobuoy trials.

A significant reduction in cost was achieved by the successful substitution of a DREO-developed lead chloride plate for the expensive silver chloride cathode. Research is now directed towards new anode materials and alloys (aluminum-tin, and magnesium-lead) to increase power output and low-temperature performance.

Spirally wound, high-rate, motor drive battery.

Research capability has been extended to pressures simulating depths of 1000 feet in the sea, with the recent installation of this high-pressure vessel at DRET. An air lock provides access to the pressurized interior during experiments.



DEFENCE RESEARCH ESTABLISHMENT TORONTO

DOWNSVIEW, ONT.

Human capabilities and limitations remain a critical factor governing the effectiveness of modern techniques of detection and defence. The Defence Research Establishment Toronto, as the major DRB center for human behavioral and bio-sciences research, is committed to the investigation of man's capabilities and limitations in the military context, and of the environmental factors that restrict or impose limits upon him. This broad scientific field includes physiology, biochemistry, physics, psychology and closely related disciplines and skills, mathematics and computer science. The program includes both basic research and applied studies, from which direct assistance is given to the Canadian Forces in the development of new or improved techniques and equipment.

In addition to its own research activities, the Establishment administers an extramural program in the fields of human resources, medicine, and physiology.

During 1970 the decision was taken to combine in a single institute the present Defence Research Establishment Toronto and the Canadian Forces Institute of Environmental Medicine. The complementary technical interests of these two agencies over a period of years has led to a number of collaborative activities, and their consolidation in a single institute concerned broadly with human behavioral and bio-science is expected to take place as facilities at the Downsview site are expanded.

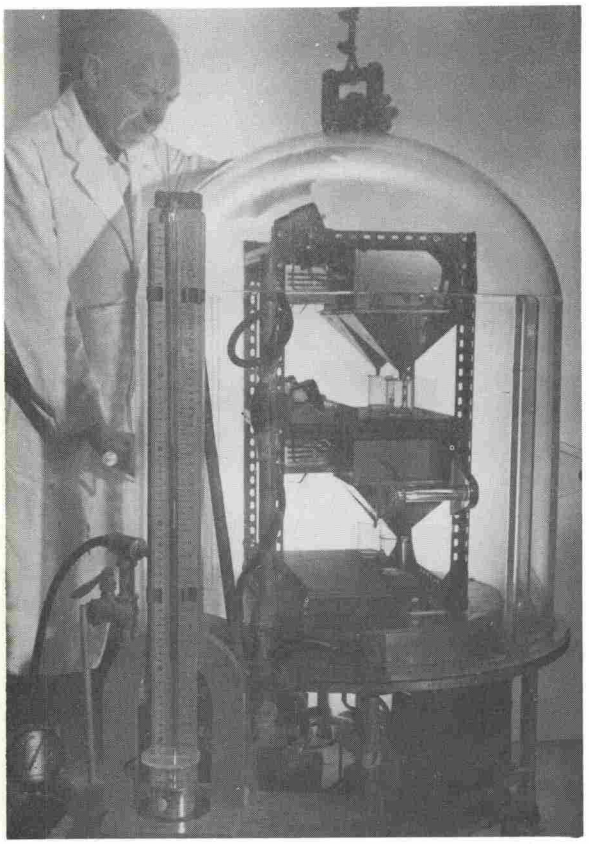
Physiological Response to Environmental Stress

The general objectives of the DRET research program on environmental stress are:

(a) the definition of the basic biological processes involved in man's responses to stressful conditions,

(b) means of alleviating and preventing the adverse effects of environmental stresses,

(c) the development of means of accelerating natural acclimatization and techniques for inducing rapid artificial adaptation to climatic stress.



The high-altitude environment can be simulated in the laboratory in chambers operating at reduced pressures and temperatures. The factors involved in acclimatization to altitude (hypoxia) and climatic adjustment are not well known, but impose limitations on man's operations in mountain terrain, in which both cold and hypoxic conditions are encountered.

DRET research projects in these areas are directed primarily towards potential advances offering the promise of new knowledge, new tools, and new concepts relevant to the above objectives, and in some cases a basis for applications where none existed before.

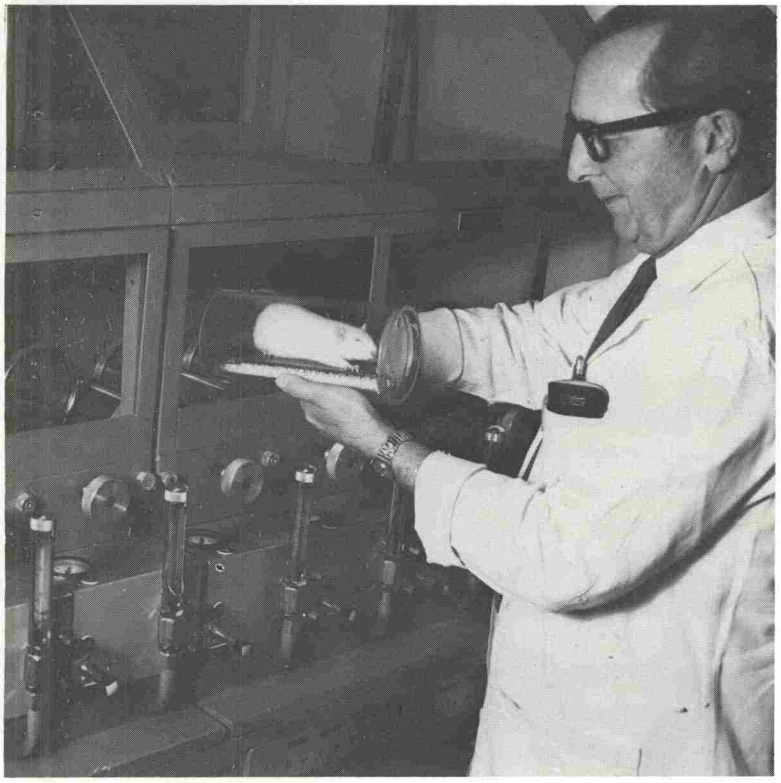
The central role of the vestibular apparatus in balance and orientation and its association with motion sickness have been well established by the work of this laboratory and many others. The Precision Angular Mover brought into service at DRET during 1969 allows the simulation of accelerations experienced in flight, and can rotate or oscillate a human subject about a vertical or horizontal axis with very precise and vibrationless control of acceleration, velocity, and position. Techniques have been acquired for recording eye movements and artificial horizon settings from man. Neurophysiological studies of activity in single primary units of the vestibular nerve in experimental animals have begun, following the successful development of difficult and complex techniques of electrode fabrication, dissection, electrode implantation, stimulation without losing the neuron, and data processing of the activity.

In response to the growing national interest in the Canadian Arctic, increased emphasis is being placed on man's response and adaptation to the cold environment, with major interest in immunological reactivity, metabolic response during adaptation, and endocrine function. The investigation of the effects of cold exposure on immunological reactivity in the body was prompted by the apparent increase in susceptibility to infections and allergens in a significant number of military personnel exposed to adverse climatic conditions. Studies in 1969 enumerated several consequences of cold adaptation on various immunological phenomena, but emphasized the need for a better defined (more homogenous) system for experimentation. The effort during 1970 was successfully directed toward the development of uniformly responsive and non-responsive strains of rabbits, the further characterization of the antibody response during cold exposure, and preliminary studies on the effects of cold on immune responsiveness in mice.

Life Support in Hyperbaric Environments

Among the more important fields of national, military, and civil interest is the exploration and development of undersea resources. However, the use of personnel in underwater operations is subject to limitations and hazards, such as the risk of oxygen-induced convulsions, inert-gas narcosis, and decompression sickness. The hyperbaric facilities established at DRET are unique in Canada, and permit the investigation of these hazards within the laboratory.

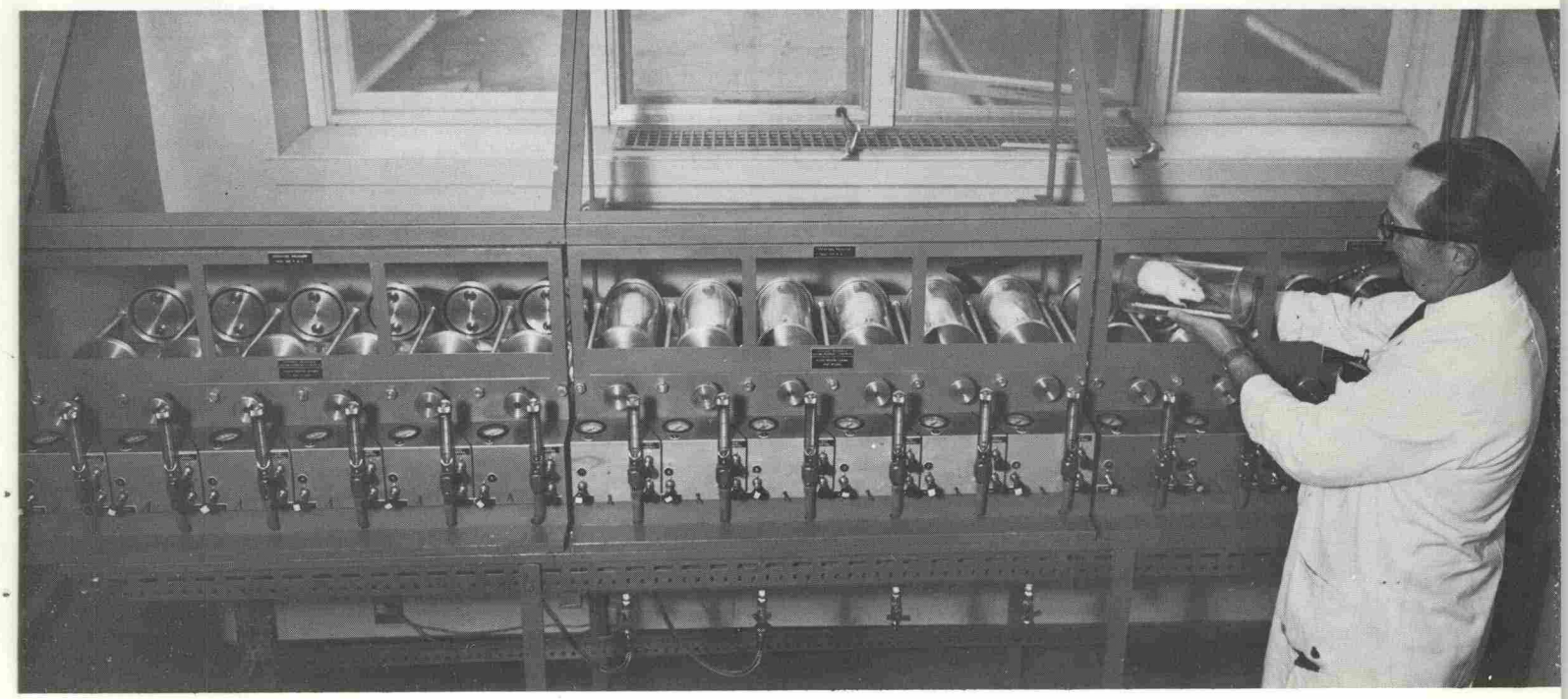
DRET research in decompression during 1970 has included the study of gas transfer in the body, the



The effects of oxygen at high pressure, and therapeutic agents to alleviate them, are studied in this assembly of small pressure chambers, which affords individual monitoring and control of environmental composition and pressure.

mechanics of gas-bubble formation and detection, the continued development of the pneumatic analog decompression-computer, and the investigation of the relation of the physical properties of blood to decompression phenomena. The construction of a prototype electronic decompression-computer has been completed, and a number of these computers are planned for use at field units for decompression training, diving-operation planning, and the treatment of decompression sickness. A gas-dynamic method of measuring and controlling the composition of gas mixture, a means of alleviating the problems of decompression and narcosis, has been based on previous DRET studies in this area, and patents have been applied for.

The use of oxygen at hyperbaric pressure in breathing mixtures has wide and well known usefulness in oxygen therapy, aerospace medicine, underwater diving, and decompression. The objectives of DRET research on oxygen toxicity have been to study the biochemical and physiological changes occurring in animals exposed to oxygen at high pressure (OHP), to relate these findings to the occurrence of OHP-induced convulsions and lung damage, and to find a means of protection against such disorders. Previous



studies showed that magnesium is an effective anticonvulsant and that manganese effectively reduces lung damage. In 1970, lithium has been shown to afford greater protection than any other cation tested to date against both OHP-induced convulsions and lung damage. The search for therapeutic agents useful against the toxic effects of oxygen will be accelerated owing to their obvious beneficial application in the field.

Human Perception and Performance

Human-factors research at DRET is concerned with sensory capacities and performance, with primary interest in the fields of vision, hearing and acoustics, perception and human-factors engineering, together with their application in the solutions of operational problems. Studies in visual perception, auditory perception, and human integration of information are largely basic in character, yet bear relevance to many situations of military importance in which the acquisition of displayed or transmitted information is crucial to decision making.

The effects of continuous and impulse noise on hearing sensitivity and acuity, with special emphasis on hearing conservation and hearing protection devices, are under continuing study. Recent work has exposed a number of significant gaps in the available knowledge of the effects of impulse noise on man and of the characteristics of the pressure waveforms produced by Canadian Forces weapons. A joint Defence Research Establishment Toronto/Defence Research Establishment Suffield program has been initiated to provide the necessary information.

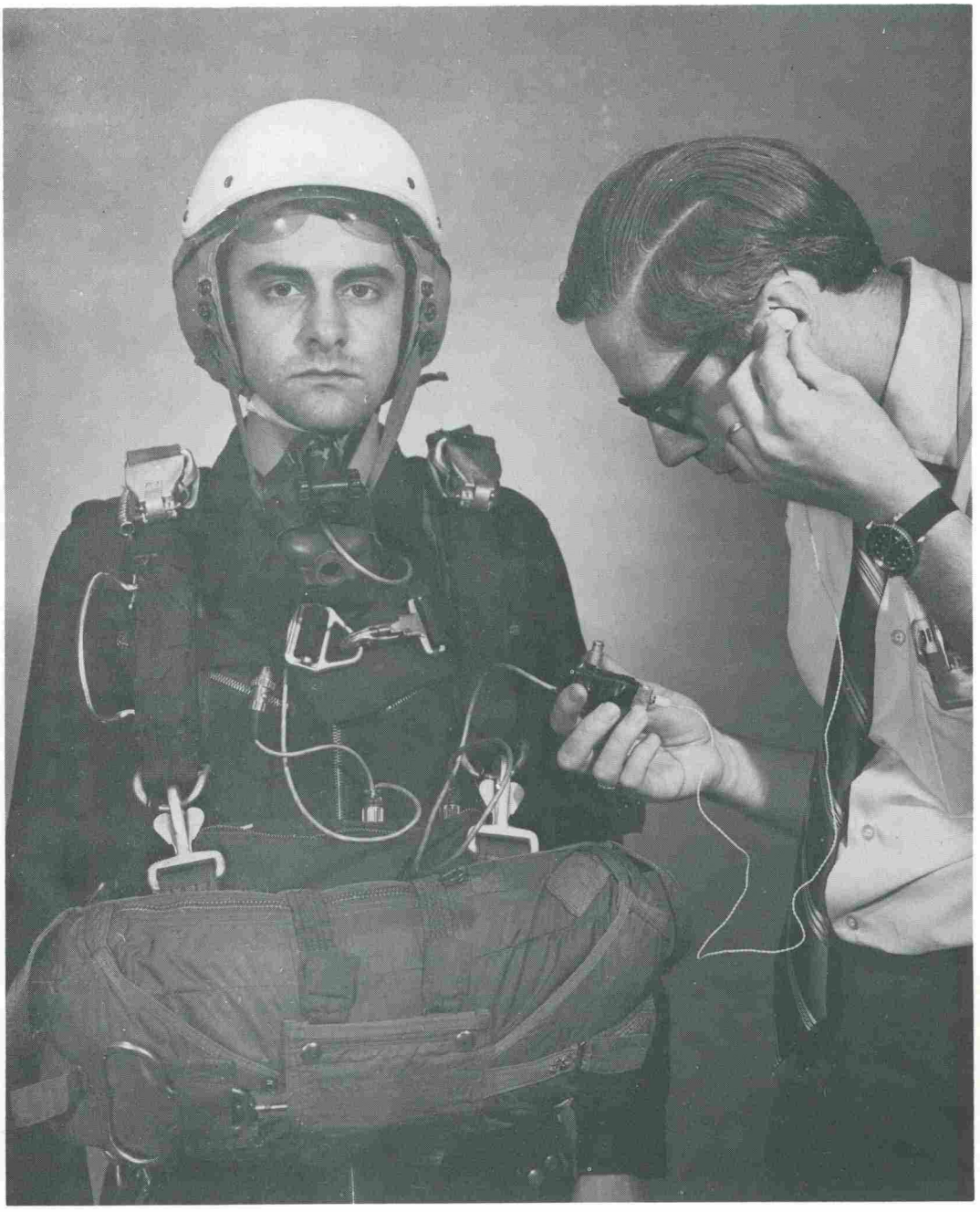
DRET studies on the perception of visual motion and the autokinetic illusion have demonstrated for the first time, under certain experimental conditions, a strong and reliable autokinetic illusion, which suggests that the strength and reliability of the illusion are related to the magnitude and consistency of the eye fixation and movement. Other studies are concerned with the characteristics of the eye in resolving spatial frequencies and the mechanisms by which the eye processes flickering light.

The theoretical and experimental study of human utilization of sensory information in the detection of signals is relevant to military operations such as auditory and visual sonar. The possible existence of potentially dangerous illusions or after-effects in situations of military significance, e.g. the presentation of information under overload conditions, underscores the importance of the studies of human integration of information carried on at DRET.

Human Factors Engineering

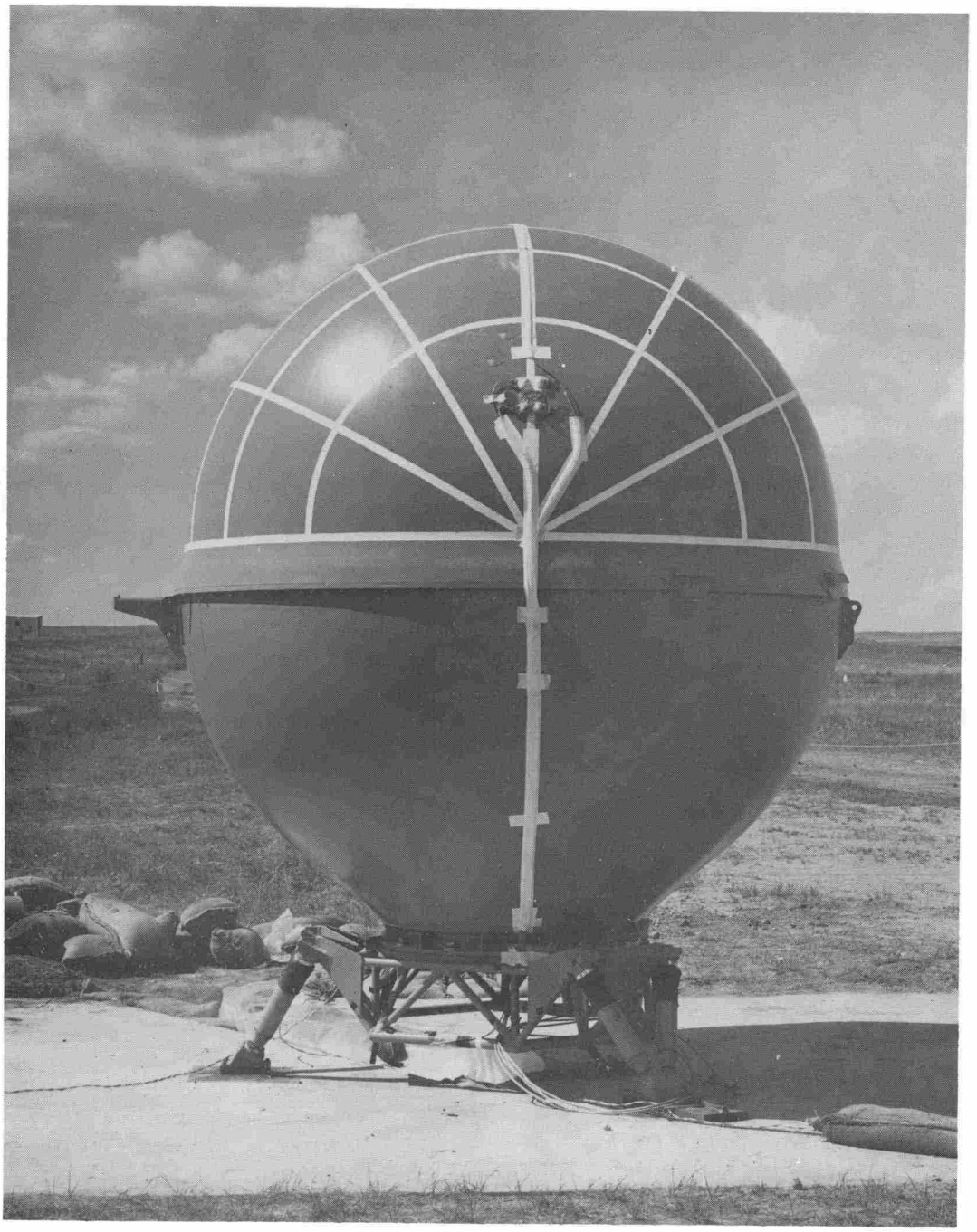
The human-factors engineering program of DRET is concerned with the solution of problems posed by the union of men and machines, i.e., man/machine systems. Problems studied in the past include the layout of various military work areas, navigation of aircraft at low altitudes, radar operation, and the general problem of designing information displays.

During 1970, human-factors-engineering studies have ranged from the evaluation of sighting devices for small arms, which will permit the soldier to fire with acceptable accuracy in the near dark as well as in daylight, to a collaborative study of the stress experienced by free-fall parachutists. Layout problems have included a new operations room for the Canadian Coast Guard, participation in the design of the rear (operating) compartment of the CHSS-2 helicopter, and a visual annunciator system for communication between artillery weapons and command post.



Instrumentation for the recording of heart rate and respiratory rate is modeled and adjusted prior to field trials with the First Canadian Airborne Regiment high-altitude, low-opening parachute team.

An M22 Radome, instrumented with strain and deflection gauges, and painted so that gross movement could be measured from high-speed film, was exposed for the Navy in the 500-ton DIAL PACK explosion carried out at DRES. Although there was some cracking and delamination of the honeycomb sandwich shell, the radome remained operational after exposure at the chosen overpressure.



DEFENCE RESEARCH ESTABLISHMENT SUFFIELD

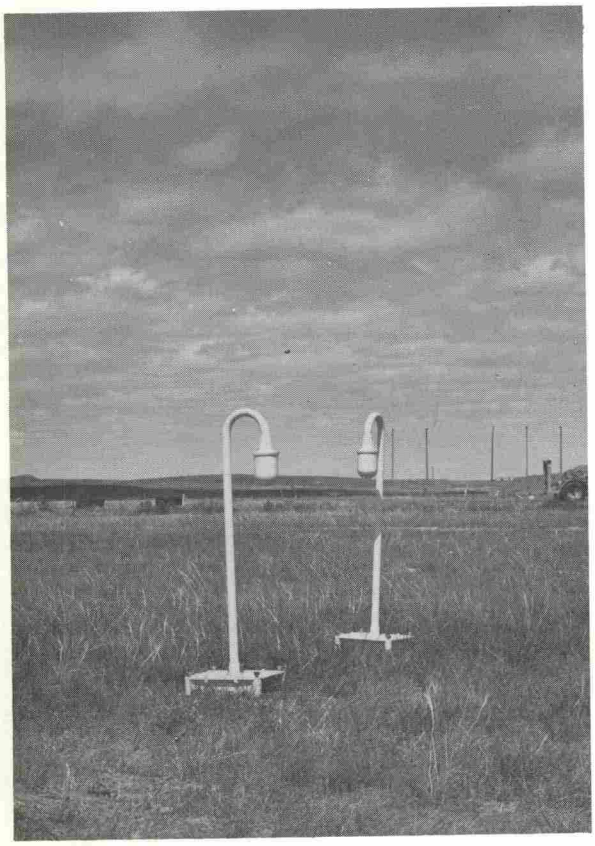
RALSTON, ALTA.

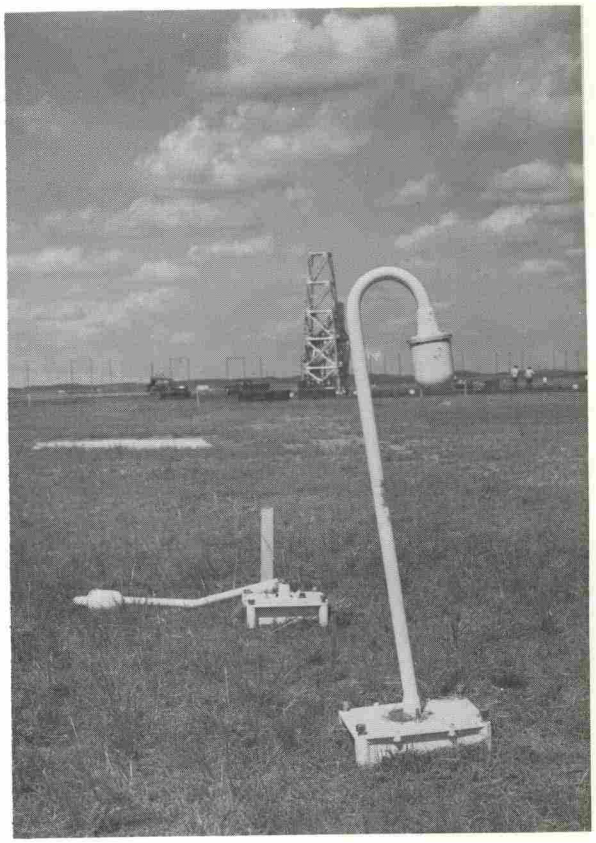
The basic responsibility of the Defence Research Establishment Suffield (DRES), located in southern Alberta, is to provide advice to the Department of National Defence on defence against chemical and biological agents and against shock and blast effects from conventional and nuclear weapons. However, studies are now in progress to determine how and to what extent the various disciplines among the technical staff, and the facilities available in the laboratories and on the Establishment's 1000 square-mile test area, can be directed towards other aspects of defence as defined in the new Defence Policy. In addition, professional staff is now involved in providing Canadian technical input to procedures for verification of U.N. agreements on production and use of C&B agents.

Research within the chemical and biological programs has been concerned with methods of detecting airborne microorganisms and of monitoring chemical ground-contamination. Studies have been made to improve procedures for biological and chemical defence and on training soldiers in their proper use.

A valuable tool for the assessment of the effectiveness of chemical-defence procedures can be provided by a total-intake simulant. In earlier experiments the absorption of quantities down to 50 mg of benzyl salicylate, resulting from pick-up on the skin or from ingestion from contamination on the face, could be demonstrated by the analysis of the exposed person's urine. By the use of a new compound diethyl-4-morphilino-phosphoramidate, quantities less than 1 mg absorbed by these routes can be demonstrated. The exhaustive acute and chronic toxicity determinations, which will be necessary before approval for the use of this chemical on humans can be obtained, are being planned.

Late in 1969, a small group was formed at DRES to develop, with the experience gained in Exercise VACUUM, improvements in methods for simulating chemical attacks in training troops to use protective equipment and procedures. A number of faults found in the methods used to simulate on-target attacks with air- and ground-released simulants in Exercise VACUUM have been eliminated, and the possibility





At the request of the Canadian Forces, pre-production prototypes of a radiation detector were exposed in Event DIAL PACK in the head- and side-on position. There was minor structural failure at the base and on the stem in the head-on position in a pair shown before and after exposure to an overpressure of 20 psi, which had been indicated as the damage threshold in tests in a shock simulator. Although the longer duration of the shock wave in the field, compared to that in the simulator, caused greater structural failure in the side-on position, the electrical system remained intact in both detectors. Minor design modifications only will be required to prevent the structural failures and provide blast hardness capability to this unusually high level.

of using such methods from a distance by radio control has been demonstrated by a commercial device designed for the control of model aircraft. A commercially available thermal fogger, which has many advantages over the vehicle exhaust generator used in VACUUM to provide aerosol clouds for simulation of exposure to agent downwind of an area under chemical attack, has been used successfully during troop concentrations at Wainwright, Alberta. Commercially, the availability of similar equipment, which is more silent and more mobile and can therefore be operated with less warning to soldiers under training, is being investigated.

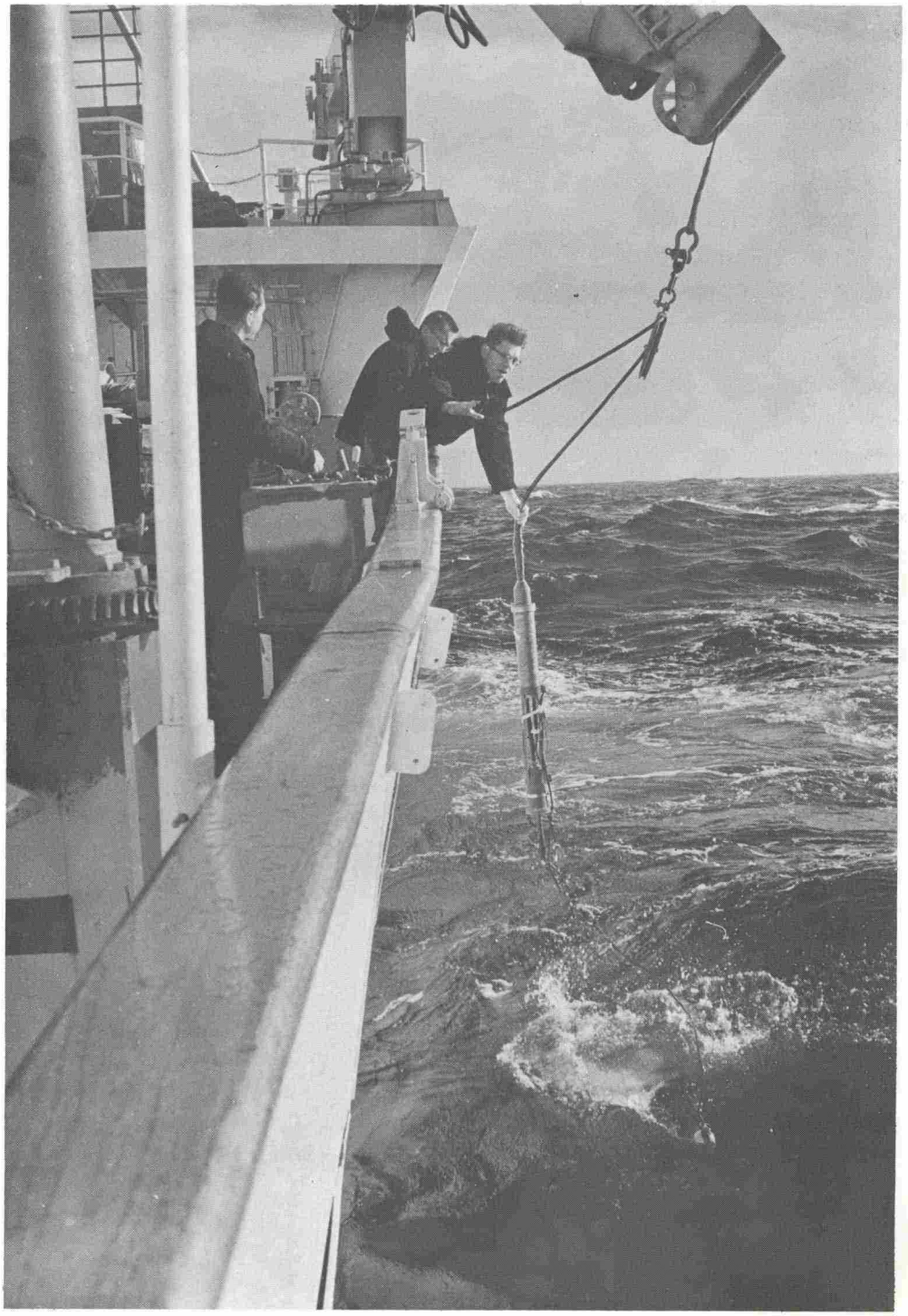
It has been shown in previous laboratory studies of possible biological detection processes that, by proper choice of media, a non-pathogenic test organism *Aerobacter aerogenes* can accumulate in a one-hour incubation period at optimum temperatures, sufficient radioactivity from added P^{32} orthophosphate, to give reliable counts from less than 10,000 cells. It has now been established that with the same media, similar numbers of organisms of *Escherichia coli* and *Serratia marcescens* will also give reliable radioactivity counts. There is evidence with *Serratia marcescens* that with four times the number of cells, reliable counts could be obtained after only 10 minutes incubation. These numbers of organisms are several hundred times the inhaled dose normally assumed to be infective for humans exposed to biological agents but compensation, by use of high-flow-rate samplers in a detection system, appears possible.

The major effort in shock and blast has been directed to the preparation for and carrying out of Event DIAL PACK, sponsored by The Technical Cooperation Program. This explosion of a 500-ton sphere of TNT, tangential to the ground surface and built from blocks supported in a styrofoam cradle, was one of the most successful of the several multi-ton explosions carried out at DRES. It provided data on the response to air blast and ground motions of many equipments exposed for the Canadian Forces and other organizations. These equipments included radomes, turbine ducting, and topmast and whip antenna for the DDH 280 destroyer, as well as communication antenna, radiation detectors and trench overhead covers (SKOP) for the land forces. A unique feature of this trial was the presence of a group of U.S. astronauts, whose interests in lunar experiments were chiefly in the mechanics of formation and the dimension of the crater.

One of the naval equipments exposed in DIAL PACK was the 8.5-foot-diameter M22 radome constructed from a fiberglas-reinforced plastic honeycomb sandwich. To allow a decision to be made on the overpressure exposure, which would give a meaningful result, a joint investigation based on analysis, acoustic excitation, and static and dynamic tests on the material was set up with the University of Calgary to predict the response. In addition, pressure distribution data were obtained on a model 4-foot-diameter sphere in a DRES shock tube. It was most gratifying to find that, following exposure, the radome showed sufficient damage to confirm the estimates and yet remain operational.

A number of items developed by the Canada Emergency Measures Organization, such as concrete shelter roof-slabs, fiberglas doors and a family blast shelter, were included in Event DIAL PACK. Pre-trial tests to determine suitable locations for two family shelters, made available for this event, were conducted by means of a surface-loading simulator under development at DRES since 1968. The simulator consists of 400 feet of explosive primacord placed on the ground in a weave pattern and surrounded with zonolite insulation within a 6-inch-deep frame covering a 16-foot square area, and is required to operate in the 50- to 150-psi range. The explosive is overburdened with a one-foot depth of water contained by a plastic sheet. The realism of the ground loading produced by the simulator, when detonated above a shelter buried to a depth of 3 feet, was confirmed in comparisons with accelerometer and soil-pressure records made during DIAL PACK and in the pre-trial simulations.

Hydrophone, preamp and explosive pod used for backscatter experiments being retrieved.



DEFENCE RESEARCH ESTABLISHMENT PACIFIC

ESQUIMALT, B.C.

Research conducted at the Defence Research Establishment Pacific is primarily concerned with maritime subjects related to equipment and operational factors of concern to maritime units of the Canadian Forces. Sound ranging and magnetic detection systems have long been the main tools for surveillance, detection, and tracking in undersea warfare. The attainment of improvements in effectiveness and reliability of these systems is dependent on a thorough knowledge of the ocean environment in which they operate, and the research conducted to gain that knowledge may lead to the discovery of other phenomena that may be exploited to increase our capability for underwater operations. The waters of the N.E. Pacific Ocean and the Canadian Archipelago are of prime interest at DREP.

Magnetics Research

For a number of years DREP has been studying the small, naturally-occurring fluctuations of the earth's magnetic field, which can interfere with and degrade the performance of highly sensitive airborne magnetic detectors of submarines. These fluctuations are due to two types of magnetic signals in the same frequency range as the submarine signal. The first type, called geomagnetic micropulsations, consists of electromagnetic signals originating for the most part in the ionosphere and thus constituting a world-wide phenomenon. The second type, called swell noise, comprises signals caused by the electrically conducting water in the waves of ocean swell, and can be detected by sensitive magnetometers flown at low altitude over the ocean.

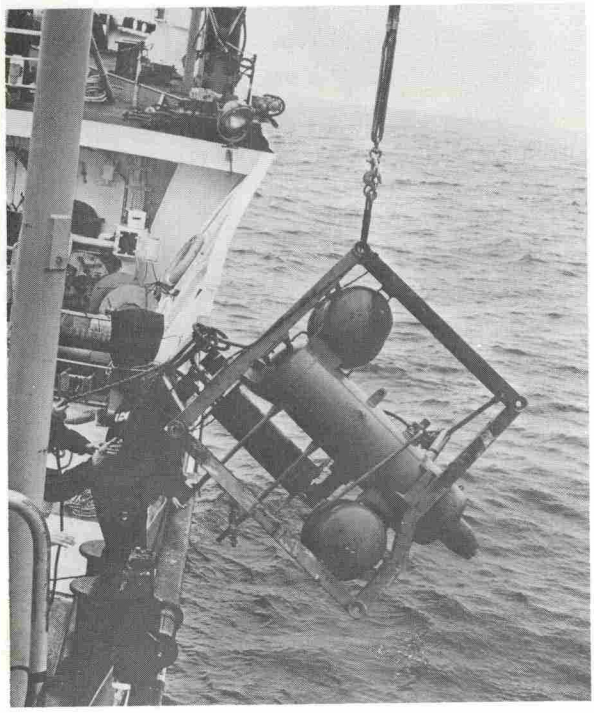
Swell noise is now fairly well understood and, from wave measurements made by DREP and others in recent years, the magnitude and occurrence of this type of noise and a means of combatting it have been determined. Micropulsations, however, are much more complicated phenomena, about which much has yet to be learned. For example, they increase very greatly during so-called magnetic storms, which in turn are caused by certain types of storms on the sun's surface. The magnetic group of DREP has been concentrating during the past year on acquiring accurate amplitude and frequency statistics of these micropulsations by the use of specially designed,

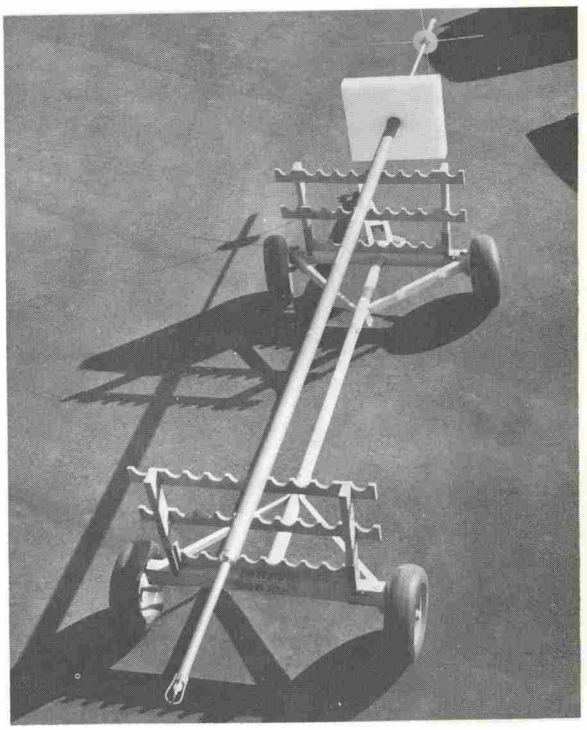
continuously recording, digital equipment set up on the DRES range at Ralston, Alberta. The geology of this area is such that the received signals resemble those measured over the ocean at approximately the same latitude. Because the equipment is continuously recording, all magnetic storms, whether short-lived or lasting for a day or two, are detected and the effect they would have on sensitive airborne magnetometers is recorded. Plans are now under way to extend this type of measurement to the Arctic, north of the auroral zone.

Close liaison is maintained by DREP with the National Aeronautical Establishment, which has a specially equipped four-engined aircraft, devoted to magnetic detection research for DND. Joint experiments are conducted from time to time by the two organizations, such as one during April and May of this year, when the output of the equipment at Ralston was compared with simultaneous airborne micropulsation recording over Southern Alberta.

In the past year also, DREP has broadened its magnetic studies to include all types of noise affecting airborne magnetic detection. Experiments made by others are not duplicated, but their results are used to determine the overall capability of new types of magnetic equipment in the whole noise environment.

Recovery of noise-measuring instrument package from Bowie Seamount after a year's operation.





Sonobuoy designed for ice-drift experiments showing hydrophone, float collar and antenna.

Acoustics

The work of the Ocean Acoustics Group is aimed at understanding how sound waves behave in the waters of the N.E. Pacific Ocean. Current interest centers on the nature of low-frequency sound propagation over ranges of up to several hundred miles, the characteristics of ambient acoustic noise, and the nature of the backscatter of sound from the volume of water surrounding a transmitter. During the past year, sound recording instrument packages placed on three seamounts, Bowie, Union and Cobb, were recovered, and approximately 12 months of recordings of the characteristics of noise in these locations were obtained. Further measurements were also made of the backscattering strength as a function of frequency, depth, geographical location and time, both seasonal and diurnal.

The main quest of the Arctic Acoustics Group is to determine the effectiveness of acoustics as a tool for detecting under-ice targets. During 1970 an experiment was conducted to test the effectiveness of ice-mounted sonobuoys. Specially designed and constructed sonobuoys were deployed, by means of a helicopter and hand-operated augers, in the western end of Parry Channel. These were then monitored at regular intervals, from overflights of a Canadian Forces Argus. On each overflight the position of each buoy was plotted and a ten-minute sample of under-ice noise, as detected by the sonobuoy, was recorded. Results show clearly that buoys installed in thick polar-ice floes survived much longer than those placed in annual ice, and the noise levels recorded correspond to previous measurements made under Arctic ice. For 1970 a sonobuoy field could have survived in polar ice essentially intact until mid-July. After that time rapid drifting took place as the ice cover disintegrated. The ice-drift speeds and directions depend on winds and the position of islands. Explanations of the measured drift will be attempted after recovery of recording barographs is made in April 1971. Investigation of the acoustic properties of northern waters will continue.

Materials Engineering

DREP has been involved to a considerable extent with research on several phases of hydrofoil environmental cracking problems. These include:

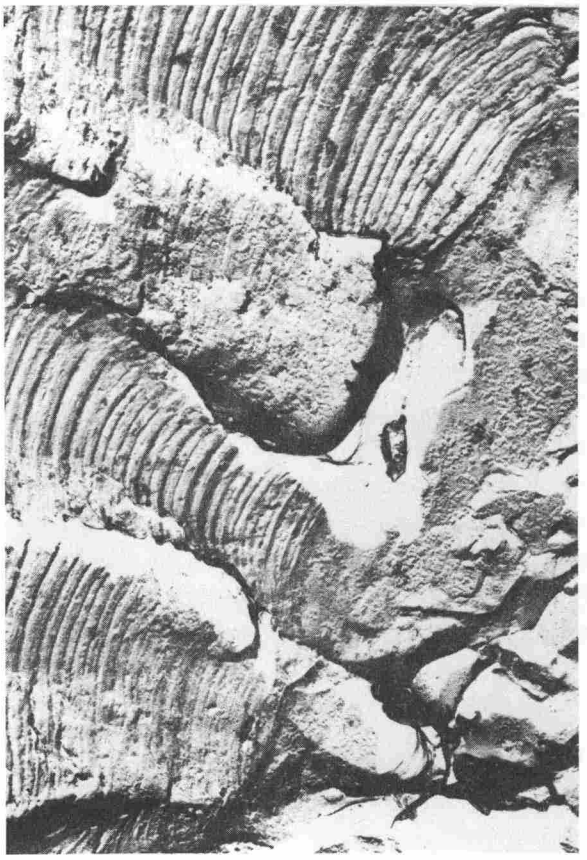
1. Evaluation of the role of residual stress in the cracking.

2. Determination of the time taken to propagate the cracks as shown by gradual de-bonding of the neoprene in the area of a crack.

3. Influence of coatings used internally in the foils on the tendency for cracking of stressed and wetted maraging steel.

4. Assessment of non-destructive-testing methods to permit detection and monitoring of cracking.

5. Development of various devices to warn of sea-water ingress into the foils.



Diagnosis of fatigue in CF101 skin depended on these fatigue markings shown by electron fractography.

The principal non-destructive effort has been in developments leading to an improved ultrasonic means of determining superheater and boiler-tube-wall thickness. Development has advanced from an isotope gauge requiring access from two surfaces to a small 20 MHz ultrasonic transducer requiring access from only one surface and having suitable sensitivity. This technique is being adopted with considerable savings in maintenance costs, availability of ships, and enhanced reliability.

This past year has seen the establishment of a strong capability in electron fractography for the understanding of metal fracture phenomena. This capability contributes markedly to difficult failure diagnoses.

Mr. R.B.H. Sewell of DREP developed a machine known as the Slick-Licker for cleaning up oil spills in Esquimalt Harbor. When the oil spill occurred as a result of the grounding of the *Arrow*, Mr. Sewell and Mr. S.P. Nelson put the machine into operation in Chedabucto Bay. The pickup of oil, oil-soaked seaweed and other floating material was so effective that modifications to the power and drive systems proved necessary. Three other machines were built locally incorporating the modifications, and four operational units consisting of Slick-Lickers mounted on suitable vessels including one on a catamaran were used to clean up several tens of thousands of gallons of floating oil and oil-soaked material. These units were used over a period of about four months in this operation, and the resulting recommendations of the TASK FORCE included the suggestion that one Slick-Licker be placed at each major port on the Canadian coast and that at least two others be held in a central contingency packet.

Methods developed by DREP for identifying the geographical source of crude and bunker oil proved helpful in identifying "*Arrow*" oil. The vanadium-nickel ratio, a characteristic feature, can be readily established by means of the X-ray fluorescence procedure developed here.

Spectrometric oil analysis has advanced to where the Forces-manned sea-going facility is providing diagnostic support for ships on extended cruises. Similar procedures, which promise to improve reliability in hydraulic systems, have been adapted to hydraulic fluids. These procedures involved the attainment of detection limits – particularly necessary for aircraft – at least ten times lower than necessary for lubricated systems.

Oily seaweed being collected by a Slick-Licker.

DEFENCE RESEARCH BOARD SYMPOSIUM

The Board's twenty-second annual Symposium was held in Ottawa from 17 to 19 November 1970.

The opening address on "Defence, Science, and Defence Science" was delivered in the Theatre of the National Arts Centre by Mr. Robert L. Sproull, President of the University of Rochester and former Chairman of the U.S. Defense Science Board (1968-1970), and Director of the Advanced Research Projects Agency of the U.S. Department of Defense (1963-1965).

Following Mr. Sproull's address four papers were presented covering different aspects of the Board's research program. One day was devoted to panel discussions continuing the format introduced last year, which is designed to encourage an exchange of views between personnel of the Canadian Forces and the Defence Research Board. The subjects covered in these seminars were: Human Factors in Aircraft Accidents; Radar and Signal Processing; Maritime Research; and Science and Automation in Military Management.

The final day of the Symposium was devoted entirely to papers covering the Board's Industrial Research Program. This was the first time that such a presentation had been made at the Symposium. Personnel from fourteen Canadian companies delivered papers, and seventeen companies participated in an exhibition of equipment and techniques arising from the Board's DIR program.

EXTRAMURAL GRANTS PROGRAM

During 1970 the Defence Research Board supported 462 projects in 37 universities and colleges through grants in aid of research. In addition, support was provided for university staff members who hold appointments in 12 teaching hospitals. This support of basic research in Canadian universities has three objectives: to acquire new scientific knowledge that may prove applicable to the solution of technical defence problems; to develop and support in the scientific community an interest in defence science, which may contribute to the long-term maintenance of a Canadian defence research capability; and to assist in recruiting young scientists for employment with the Board.

To meet these objectives, the Board invites members of all Canadian university staffs to submit research proposals. These are reviewed in the light of two criteria. The first is scientific quality; this is judged by Advisory Committees of experts in the appropriate scientific fields, drawn from the universities themselves, from industry, and from other government departments. The second is concerned with applicability to defence or, in more general terms, with the extent to which the proposed research will contribute to meeting the objectives outlined above; to judge this factor, all applications that have qualified on scientific grounds are reviewed by Defence Research Board scientists in collaboration with representatives of the Canadian Forces.

Funds available for extramural grants during 1970 totaled $3,076,130 of which $3,000,000 was voted by Parliament for the year's program. The remaining $76,130 represents unexpended funds carried forward as a credit for use in 1970. The total value of applications received by the Board increased from $7,438,566 in 1969 to $8,535,904 in 1970.

Table 1 shows the distribution of grants in 1970 among universities and other organizations; Table 2 shows distribution by scientific fields.

TABLE 1

GRANTS IN AID OF EXTRAMURAL RESEARCH – 1970

Distribution by Universities and Organizations

University or Organization	Number of Grants	Program Level $
Alberta	26	126,200
Arctic Institute of North America	1	7,500
Bishop's	1	5,300
British Columbia	31	248,000
Brock	1	5,000
Calgary	24	125,500
Carleton	11	69,150
Collège Militaire Royal	6	44,650
Dalhousie	7	50,050
Guelph	7	39,500
Laurentian	1	4,000
Laval	22	169,100
Loyola College	1	5,000
Manitoba	23	126,150
McGill	36	320,500
McMaster	24	133,900
Memorial	4	16,700
Moncton	1	4,500
Montréal	14	173,700
New Brunswick	6	37,300
Nova Scotia Technical College	1	6,000
Ottawa	15	81,700
Queen's	15	84,850
Royal Military College	25	232,250
Royal Roads Military College	2	3,250
St. Francis Xavier	1	4,000
Saskatchewan	16	93,680
Saskatchewan (Regina)	2	10,500
Sherbrooke	7	33,500
Simon Fraser	7	37,600
Toronto	48	320,900
Trent	2	13,000
Victoria	6	37,000
Waterloo	33	168,600
Western Ontario	16	109,650
Windsor	6	26,500
York	13	101,450
GRAND TOTAL	462	3,076,130

TABLE 2

GRANTS IN AID OF EXTRAMURAL RESEARCH – 1970

Distribution by Scientific Fields

FIELD			Number of Grants	Program Level $
Chemical Research			64	362,950
Power Sources Research			18	101,800
Environmental Protection Research			17	88,500
Clothing and General Equipment	4	25,500		
Entomology	13	63,000		
Defence Against Biological Agents Research			6	39,900
Human Resources Research			25	157,000
Medical Research			49	398,230
Plasma and Fluid Dynamics Research			30	185,750
Structures and Materials Research			39	247,700
Engineering (Civil and Mechanical) Research			35	223,650
Laser Research			7	61,000
Physics and Electrical Engineering Research			94	665,250
Geophysical Research			42	287,900
Applied Mathematics and Computer Science			29	210,500
Economics, Political Science and Operational Research			7	46,000
		TOTALS	462	3,076,130

DEFENCE INDUSTRIAL RESEARCH PROGRAM

The Defence Industrial Research Program was established in 1961 to stimulate an increase in the level of scientific and technological competence of Canadian defence industry. Under this program, the Defence Research Board normally pays half the cost of suitable applied research projects by means of a non-refundable grant. The initiative for submitting proposals lies with industry, the most promising proposals being selected for support on their merits.

The financial level of the program has remained unchanged from last year, the cash available for support in the fiscal year 1970-71 being $4,500,000. However, rising costs mean that the total volume of work being supported is tending to decline.

Since the inception of the program, 325 new proposals or extensions to existing proposals have been approved. This represents a total research effort of just under $70,000,000. On the assumption that all projects proceed to completion, the Crown contribution will amount to about $35,500,000. A total of 95 projects, spread among 45 companies, were active in 1970. During the year, 48 proposals and extensions were approved for a Crown obligation of $4,700,000.

During 1970, some changes in terms and conditions of grant were introduced. The ad hoc Cabinet Committee on Science Policy and Technology (from which evolved the Interdepartmental Committee on Innovation) recommended that "the Defence Industrial Research Program (DIR) should be modified to provide a higher than 50 per cent share of costs when appropriate to the risks and needs". This recommendation was subsequently confirmed by the Cabinet.

Pertinent to the above recommendation, DRB has set forth the exceptional circumstances that shall be considered "appropriate to the risks and needs" as follows:

(a) high defence interest;

(b) high technical risk, such as long-term research coupled with remote possibilities for an adequate return on investment within a reasonable period of time;

(c) financial stress on the company arising from causes beyond the control of the company;

(d) small firms attempting to branch out into the research field.

Further, in order to prevent the granting of off-normal sharing ratios becoming the rule rather than the exception, all exceptional circumstances are considered to be transitory. Accordingly, support exceeding the normal maximum 50 per cent shall be extended only for a one-year period. Unless recommended each year for continuing higher government support, the project shall automatically revert to the normal maximum 50 per cent Crown funding.

SCIENTIFIC AND TECHNICAL INFORMATION

The Defence Research Board's responsibility for collecting and disseminating Canadian and foreign scientific and technical documents of defence origin is discharged by the Defence Scientific Information Service (DSIS). This service is available to all who participate in Canadian defence research and development.

Selective acquisition and dissemination are the chosen means of reducing the impact of the information explosion. DSIS information scientists, whose knowledge and judgment control these means, are being progressively relieved of routine documentation work as a result of mechanization. A computer now handles not only all data inputted by DSIS staff, but also scans tapes from other documentation agencies, thus saving much of the work of re-processing documents here. A new selective dissemination service, entirely by computer, is now being added to the already mechanized announcement service.

Mechanization was introduced piecemeal as staff was not available to develop, build, and introduce a parallel system, and existing manual operation could not be stopped in favor of development. Much valuable consolidation has recently been achieved to integrate and streamline procedures, and to rationalize computer programs, thus reducing costs. Procedures and standards manuals are being prepared for publication, and a quality control system has been designed.

Development work on an on-line loan-control system has been started. So also has preliminary work on on-line retrieval, based on three years accumulation of bibliographic material already in machine-readable form.

PERSONNEL

The following table shows comparative authorized man-years and strength by category for 1969-70 and 1970-71.

	Authorized MY 1969-70	Strength 31 Oct. 1969	Authorized MY 1970-71	Strength 31 Oct. 1970
Executive, Scientific and Professional	496	493	506	496
Technical	740	727	720	701
Administrative and Foreign Service	70	67	80	72
Administrative Support	440	437	448	429
Operational	390	402	379	375
TOTAL	2136	2126	2133	2073
Seconded Personnel	34	28	34	28

The Board has a program under which scientific staff members may be granted scholarships in order to up-grade their academic qualifications. During 1970, seven scientific staff members were obtaining Doctorates under this arrangement, and nine were obtaining Master's degrees. In addition, two were granted educational leave with financial support, and three, leave without pay for advanced degrees. One scientific staff member was posted to a university in a combined liaison/training capacity, and another to a British research establishment as an exchange scientist under the auspices of TTCP.

On 19 November 1970, the Board and the Professional Institute of the Public Service of Canada signed the first Collective Agreement applicable to 375 employees in the Defence Scientific Service Officer bargaining unit of the Scientific and Professional Category. This Agreement will expire on 30 June 1971. An Agreement with the Institute was also negotiated in respect of a separate bargaining unit in the same Category embracing a small number of employees in the Engineer, Library Science and Nursing groups for the period 1 July 1967 to 30 June 1969. Negotiations for the renewal of this agreement were well advanced in late 1970.

A renewal of the Agreements between the Board and the Public Service Alliance of Canada, applicable to some 435 employees in the supervisory and non-supervisory bargaining units of the Operational Category and covering the period 1 October 1969 to 30 September 1971 was signed on 4 November 1970. Negotiations with the Alliance for renewal of the Agreements covering some 925 employees in the bargaining units of the Technical, Administrative and Foreign Service and Administrative Support categories began in November 1970. The initial Agreements pertaining to these bargaining units expired on 30 June 1970 in the case of the Technical Category, and on 30 September in respect of the other two.

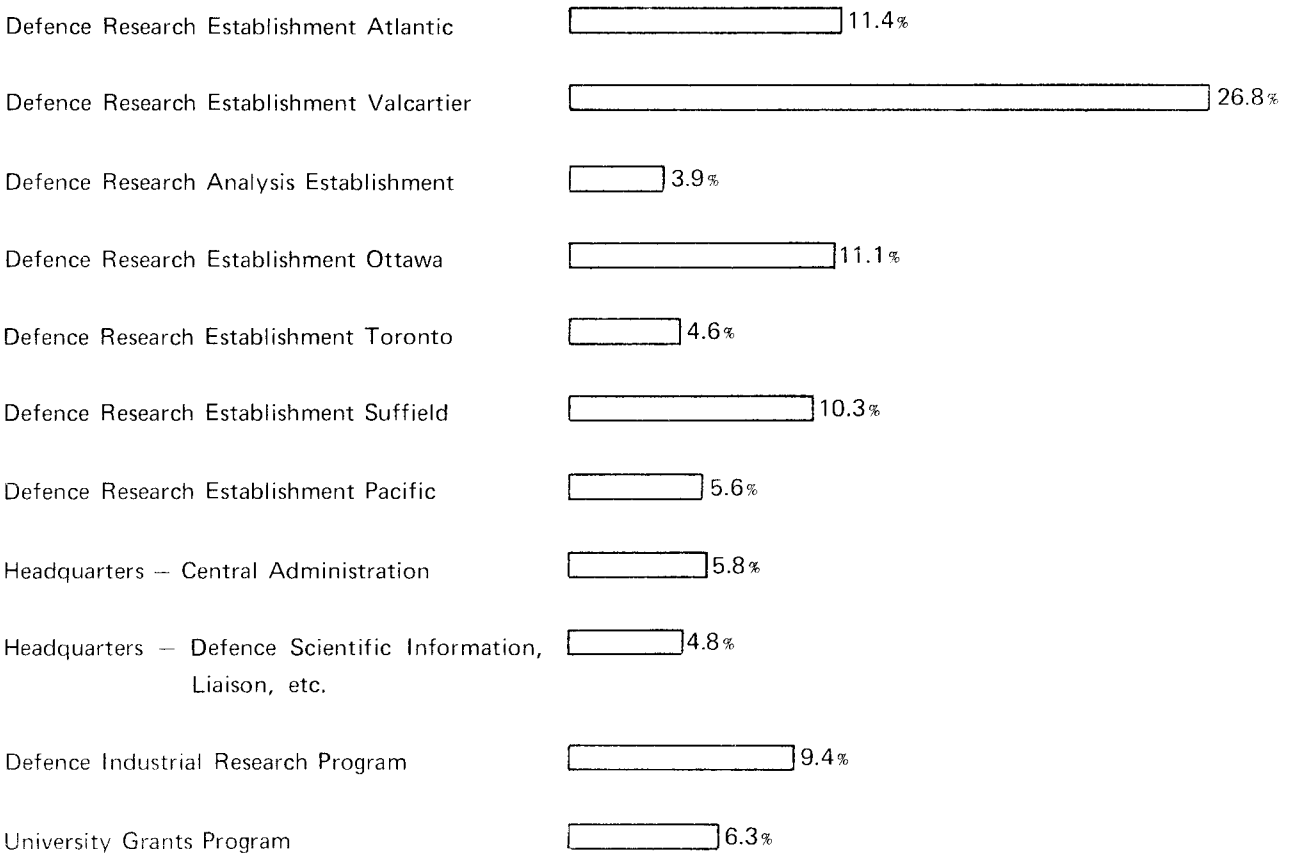
ADMINISTRATION AND FINANCE

It is the function of the Comptroller to control and coordinate efficient organization, provision and management of finance, materiel and services with a view to providing the best environment for research consistent with good business practice and the requirements of the public service and, generally, to relieve the scientific staff of unnecessary preoccupation with administrative problems. At the same time, it is the Board's policy to delegate administrative responsibility to Directors General of Establishments as far as is possible within the limits of government policies and procedures.

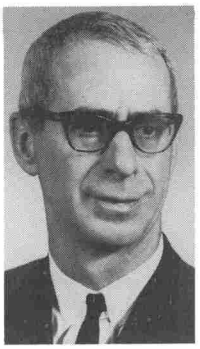
Of the total of $47,400,000 allocated to the Defence Research Board for the fiscal year 1969-70, the actual expenditure was $44,121,189. For the fiscal year 1970-71, a total of $47,650,000 has been allocated to the Board – a budgetary allotment of $47,400,000 plus an estimated revenue of $250,000. Diagram 1 shows the distribution of funds among the Board's activities and establishments during 1970-71.

DIAGRAM 1

PERCENTAGE DISTRIBUTION OF FUNDS – 1970-71



THE DEFENCE RESEARCH BOARD – 1970



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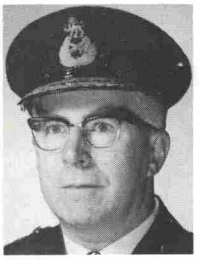

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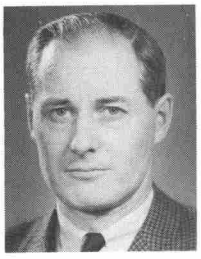

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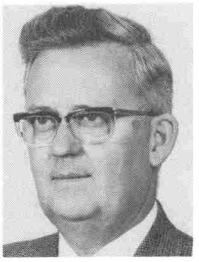

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