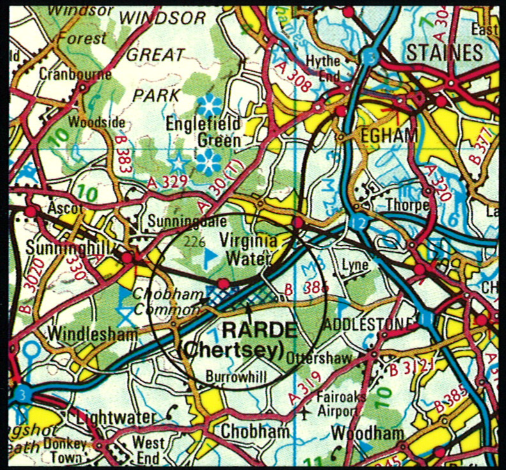
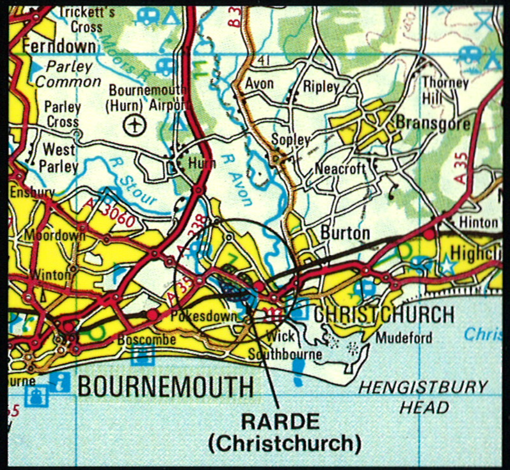
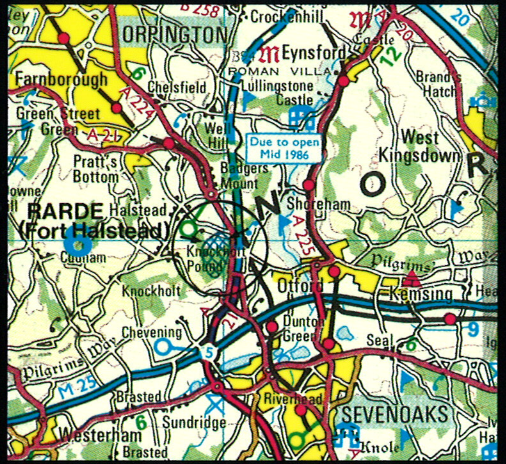
RARDE



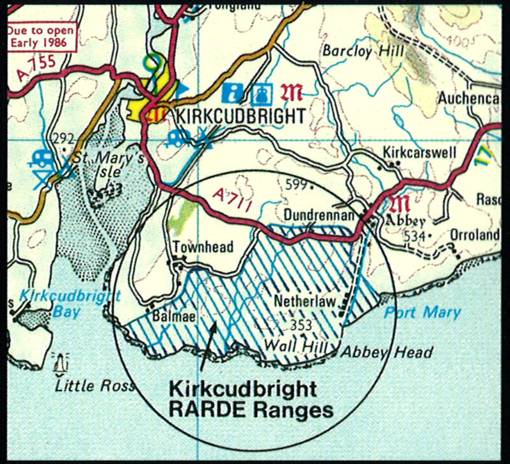
Chertsey



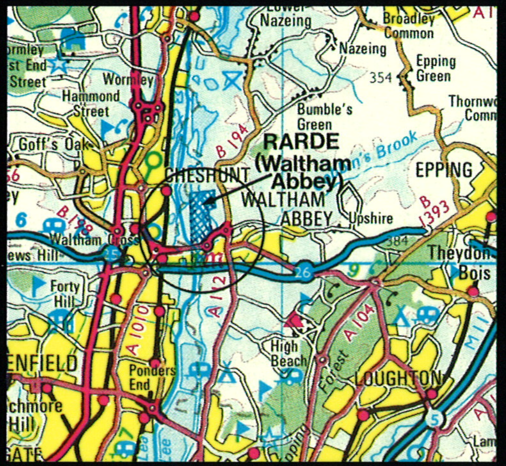
Christchurch



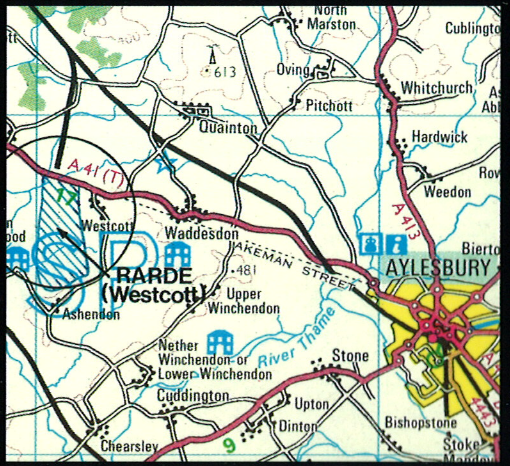
Fort Halstead



Kirkcudbright



Waltham Abbey



Westcott

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Shaping our defence future

RARDE

A Changing Threat

No defence system can afford to stand still. Weapon research goes on throughout the world all the time and thus our potential enemies have a continuously changing capability.

It is RARDE's task to keep in the vanguard of technical change and refinement so that our land forces are at all times properly equipped.

Recently there has been an integration of three separate land defence Establishments, each of which had evolved its own specialisations. Now, therefore, there exists a complete land defence organisation – and this has enabled RARDE to marshal its technical expertise to the best effect.

Now RARDE, with its Headquarters at Fort Halstead, comprises an organisation which takes in the gamut of land defence including tanks and military vehicles, artillery, ammunition, mines, rocket and guided missile warheads, explosives and battlefield information systems.

The Scientific Background

At RARDE the emphasis is now on research, and the nature of modern defence means that more research will be long term. The new, coherent organisation will be able to use that research more effectively and keep abreast of technology.

RARDE gets closely involved in all aspects of equipment, including the technical specification. We also take a leading part in the evaluation of equipment proposals, particularly those where there is international collaboration.

The definition of standards is part of our role, as is the improvement of existing equipment. And of course we are heavily concerned with new weapon systems and concepts.

Increasingly, battlefield intelligence is an essential defence ingredient and we provide the scientific background necessary to make the right assessments.

At RARDE we are confident and ready to face the changing threat.

This brochure aims to give a broad picture of the Establishment and its work.

International Collaborative
Multi-Rocket Launcher System

A Brief History

Weapons

RARDE's pedigree stretches back to the 14th century. It was then that an organisation was set up in the Tower of London to carry out gun trials on a field known as the Artillery Garden.

During the 17th century gun proof was moved to Woolwich, and a laboratory was set up for the manufacture of ammunition and pyrotechnics. George III later named the establishment the Royal Arsenal.

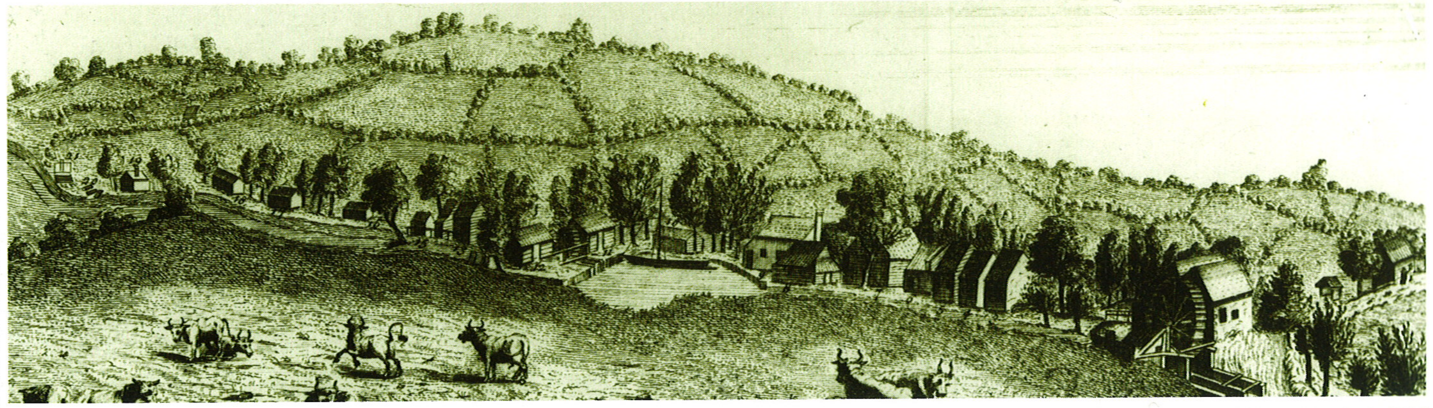
Serious deficiencies in our ammunition during the Boer War and the growing complexity of weapons led to the start of the Chemical Research Department at Woolwich in 1903, which subsequently became the Research Department. This was the first British organisation to be devoted wholly to armament research.

During the First World War the engineering design and development of weapons was concentrated progressively into a separate department known as the Design Department. The first association with Fort Halstead came in 1937 when the site was used by the Research Department for experimental rocket work. During the Second World War the Design Department then later the Research Department moved to Fort Halstead when a vast amount of work was done on weapon technology.

After the war, the establishment at Fort Halstead took on the biggest and most important project in its history, the development of Britain's first atomic bomb – later this work was transferred to Aldermaston.

In 1955 the two conventional armament departments were combined and in 1962 the present title was granted of Royal Armament Research and Development Establishment (RARDE).

The Royal Laboratory Woolwich in 1750



RARDE Waltham Abbey Gunpowder Mills on the site in 1735

Explosives and Guided Missiles

The private manufacture of explosives was taken over by the government in the 18th century. Known as the Royal Gunpowder Factory, the site at Waltham Abbey produced most of the explosives used in the early years of both world wars.

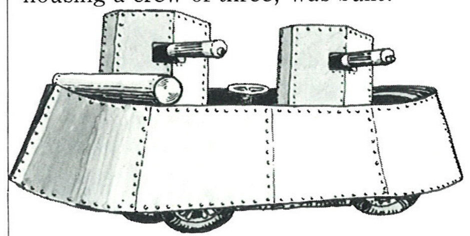
In 1945 it became primarily a research establishment, later titled the Explosives Research and Development Establishment (ERDE).

Immediately after the war there was another significant development, the formation of the Guided Projectile Establishment based at Westcott, which ultimately became responsible for all guided missile propulsion systems. This establishment was renamed the Rocket Propulsion Establishment (RPE).

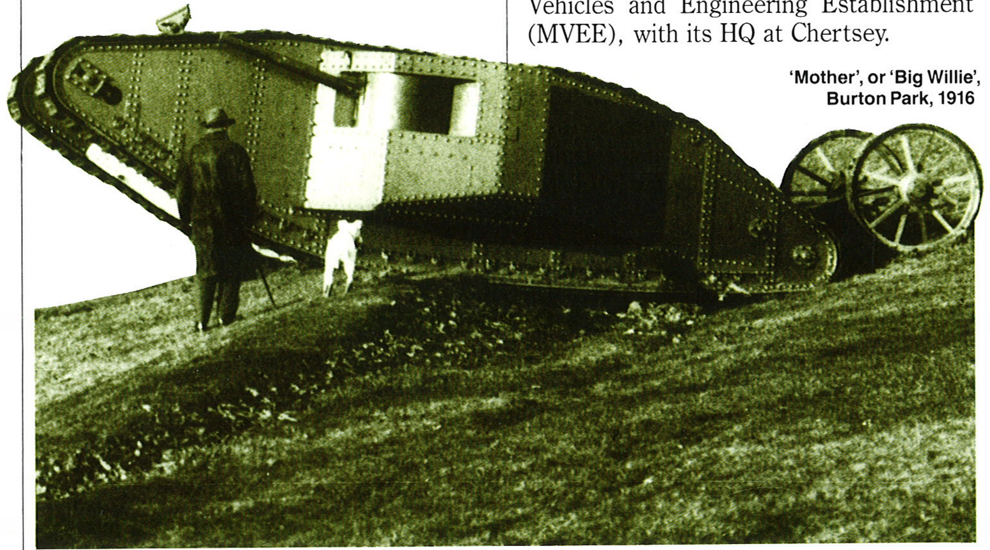
In 1973 RPE and ERDE were merged and retitled in 1977 as the Propellants, Explosives and Rocket Motor Establishment (PERME).

Tanks, Armoured Vehicles and Engineering Equipment

At the turn of this century, the growing use of automobiles led to experiments with armour protection and the first British armoured car, known as the Pennington, mounting two Maxim machine guns and housing a crew of three, was built.



The Pennington Armoured car 1900



'Mother', or 'Big Willie', Burton Park, 1916

It was not until 1915 that the first tank, known as Big Willie, was successfully demonstrated. This led to direct Ministry involvement in tank development through the Ministry of Munitions; and in 1920 a Mechanical Warfare Board was set up to control these developments.

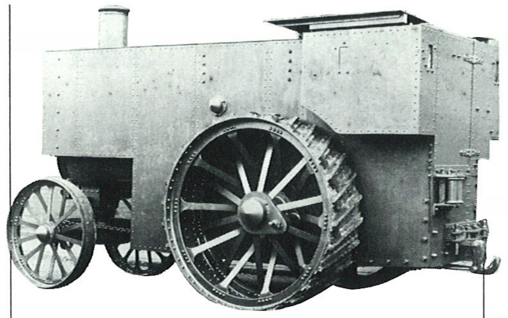
Between the wars the experimental establishment at Farnborough, research facilities at Woolwich and a variety of ranges combined to push tank and armoured vehicles' development rapidly ahead. So in the Second World War, existing tanks included the Churchill and the TOG.

During the war a tank design department was formed at Chobham which led to the now famous range of British post-war tanks.

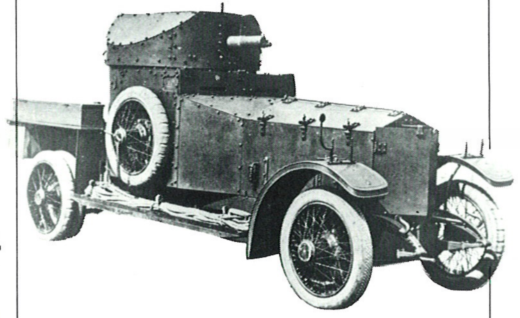
In 1970 all tank and military vehicle research and development, together with the Military Engineering Experimental Establishment (MEXE) at Christchurch, were combined to form the Military Vehicles and Engineering Establishment (MVEE), with its HQ at Chertsey.

MEXE brought to the new Establishment its technologies of field engineering, mainly for the Royal Engineers, and military bridging. The majority of military bridging equipment in Western Europe originated at Christchurch, including the Bailey bridge in World War II and more recently the medium girder bridge.

The Christchurch Establishment was unique in that on its 50th anniversary it received the Freedom of the Borough of Christchurch.



Fowler Armoured Locomotive for Boer War, 1900



Rolls Royce, 1914 pattern, R.N.A.S. London 1915

Amalgamation

In 1984, the three establishments (RARDE, MVEE and PERME) were amalgamated to form one land systems research establishment under the name Royal Armament Research and Development Establishment (RARDE), with its Headquarters at Fort Halstead.

The Establishment's role has become primarily research oriented, with design and development being devolved to industry, though we still maintain a very important project support role.

A22 Churchill (Mark IV leading Mark III) U.K. 1943

RARDE's Place in the Ministry of Defence

Within the MOD, the Procurement Executive (PE) has the responsibility for all aspects of defence research. Research is defined in the MOD as all work prior to the writing of the Staff Target – a staff target expresses in broad terms the function and desired performance of a new weapon or equipment.

The Controller R & D Establishments, Research and Nuclear has overall management of the research programme designed to meet the needs of the armed services.

All PE Establishments have a prime task, to develop and apply technologies for the advancement of the national defence capability. To do this there is an overall programme, the non-nuclear part of which is divided into fifteen major fields; the director of RARDE is the leader of three of these and participator in another.

The leader is responsible for the construction, co-ordination and overall management of activities within his field and sets guidelines for future research.

The major field leader is supported by his Research Area Leaders who develop the basic programme and monitor progress.

The research areas within RARDE are:

- Propellants – combustion and chemistry
- Pyrotechnics, explosives, initiatory devices and structural materials
- Guns, mortars, charges, ballistics and rocket systems
- Ammunition, warheads, barriers
- Optical systems and detection
- Command, control and land warfare studies
- Vehicles engineering and system integration
- Vehicle technology
- Protection, assessment and materials
- Trials and engineer equipment

In addition, the Research Area Leader for Air Launched Anti-tank guided weapons and intelligent munitions – in support of Deputy Director Royal Aircraft Establishment – is at RARDE.

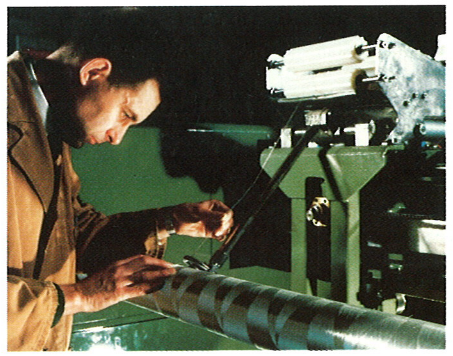
Annually the Research Area Leaders present their research programmes outlining their objectives, future aims and achievements for review, comment and agreement by interested parties including system controllers, military users and associated establishments.

These reviews then form the basis of annual recommendations to MOD.

The People

Committed to a galaxy of high technology projects, RARDE has to have a large staff of many disciplines.

Some 2,500 people work between the six sites at Fort Halstead, Kent; Chertsey, Surrey; Christchurch, Dorset; Waltham Abbey, Essex; Westcott, Bucks; Kirkcudbright, Scotland. These include professional, technical, administrative, clerical and industrial staff plus advisers from the armed services.


Experimental GRP Filament winding machine

Approximately 1,100 are professional scientists and engineers, mostly graduates. Engineers enter either from a student engineering scheme or directly as graduates. The latter are given a two-year postgraduate training, on the successful conclusion of which they are offered a permanent post. Scientists, unlike engineers, do not undergo formal postgraduate training.

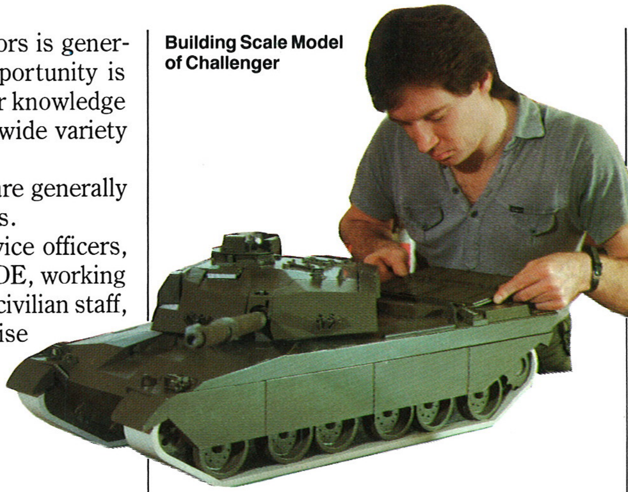
Specialist staff may be seconded to Industry, be sent on courses or attend seminars in order to increase their experience and keep abreast of current technology.

The recently introduced Scientist Sponsorship scheme enables undergraduates to get training within RARDE during their long vacations.

The training of administrators is generally 'on the job' but every opportunity is given for them to increase their knowledge and experience by ensuring a wide variety of duties within RARDE.

Senior management posts are generally filled by scientists or engineers.

There are a number of service officers, mostly from the Army, at RARDE, working in close collaboration with the civilian staff, for the officers' military expertise is a most valuable interface between this research establishment and the service user.


Building Scale Model of Challenger

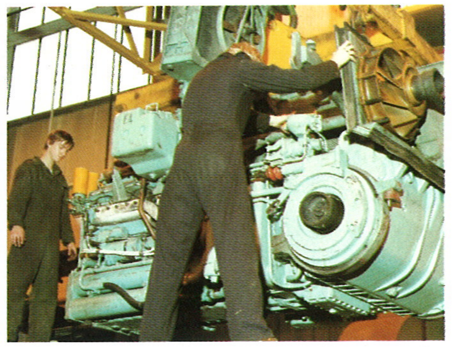
Working with Industry

A great deal of RARDE's work involves direct contact with industry, principally through extra-mural research contracts. In the coming years there will be ever greater co-operation to establish collaborative research projects employing multi-discipline teams.

A high priority is given to modern equipment; for example RARDE was one of the first establishments in the UK to have the fast, advanced CRAY super computer.


Instrumented Firing trials

Many of the professional staff at RARDE travel abroad on collaborative projects, to represent Britain on international committees or to present papers at conferences, thereby extending their own experience and gaining a wider range of contacts with overseas organisations.


Challenger power pack removal in workshops

The Future

With an increasing emphasis on research, the work at RARDE will have even broader horizons in the future. It will mean giving greater importance to the qualified professional though still rating highly the on-the-job experience gained within the Establishment.

Regular assessment of all staff ensures that everyone's career is thought through regularly, an essential means of maintaining and developing the potential and progress of people – the Establishment's most important asset.


Unmanned Vehicle Research Team

Research at RARDE

The need to maintain national capabilities for the study and assessment, technical evaluation and development of defence systems and equipment can be met only by the continuous advancement, through research, of national expertise and knowledge in these areas. Without such investment current capabilities will be eroded.

The national industrial capability to conduct applied research in the armaments field is substantial but is in general linked to specific product types, involves studies in aid of particular systems and is often short term. However, in the industrial framework there is a reluctance to conduct fundamental research without government aid.

RARDE has therefore to complement the industrial research capability, provide long term in-house continuity, comprehensive coverage and maintenance of special facilities and expertise.

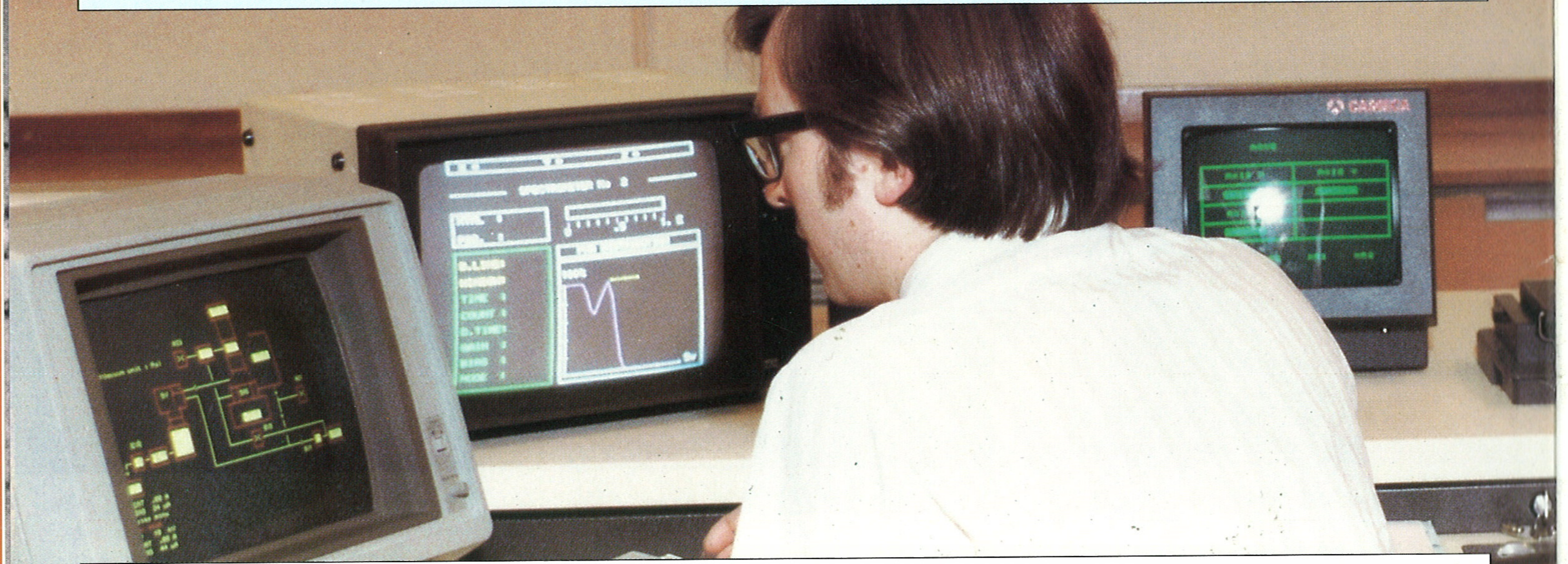
The research activities at RARDE cover a wide spectrum. At one end is the research of a short term nature aimed at solving a specific problem; for example, how does a new gun propellant behave at low temperatures?

Then there is the applied research and assessment work which is directly related to the current equipment procurement process, as in RARDE computer modelling support to the multi-launcher rocket system international project.

At the other end are the more speculative longer term research programmes such as the development of electro-magnetic guns; they are often thought of as programmes which provide answers to questions which have not yet been asked.

This Establishment already has a splendid record of research.

We aim to continue advancing the national technology base in our areas of conventional weapons and military vehicle responsibilities; keeping up-to-date our knowledge of the state-of-the-art in all relevant technology; generating concepts for new and improved weapons; stimulating and sponsoring work in industry and universities and providing improved facilities for test and evaluation. We give scientific and engineering support to MOD, industry and user agencies and maintain centres of expertise in areas where industry shows little interest or capability.



Collation of output from Electron Probe Microanalyser provides analysis of surface areas down to 1/1000 mm. diameter.

Vehicle and Army Engineer Equipment

The vast range of modern military vehicles provokes a large body of research, including some of the most demanding in RARDE. The tank, however, predominates in the work at Chertsey – which seeks to solve the diverse problems of today's tanks and to envisage the tank of the future.

Some current projects are briefly described in the following paragraphs.

Logistic Vehicles

Although the armed services rely heavily on the commercial motor industry for many of their load carrying and passenger carrying vehicles, the particular needs of the Services require special capabilities for certain types of vehicle.

One example of the new range of logistic vehicles – 14 tonne

They often need good cross-country mobility as well as high road speeds, a combination not normally provided by commercial vehicles. Furthermore the Services require these vehicles to be reliable, cost effective and serviceable anywhere in the world.

Our research programme therefore covers the assessment of novel automotive systems and components, improvement of our test procedures and studies of criteria which determine the mobility of wheeled vehicles off-road. We are also studying vehicle handling parameters and the effects of cold environments on vehicle performance.

In order to make our evaluation testing more representative of actual service use we are comparing the effects on three representative instrumented vehicles of running over various terrains, both on our own test courses and in service in BAOR.

Preliminary work has been carried out on an improved stretcher suspension for military ambulances. Trials are also planned on a medium sized vehicle which has had a steerable third axle fitted centrally, so providing an experimental test bed which can be driven by 2, 4 or 6 wheels, with various loads, over difficult terrain in order to study significant mobility parameters.

Direct hit on Saracen carrier, on trials

Crew Survivability

Two particular aspects of crew survivability in armoured fighting vehicles that are being investigated are those concerned with improving the environmental conditions in the crew compartment; and increasing the crew's chances of surviving the hazardous conditions of a fuel fire or explosion.

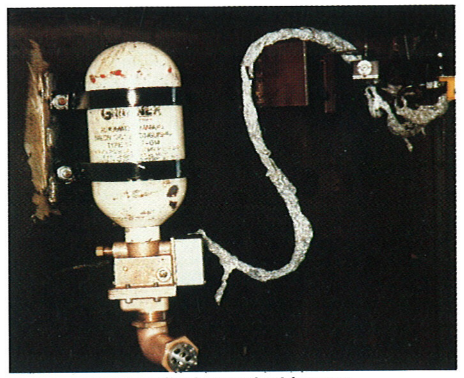
Looking at the first aspect, we want to provide the crewman with a temperature and humidity controlled environment and a supply of air for breathing which has been cleansed of dust and other battlefield contaminants. To this end we are conducting research into combined environmental and filtrations systems together with detectors capable of reliably identifying the low levels of certain battlefield contaminants occurring when filters are worn out.

Filtration systems that are different in concept to the traditional methods are being investigated to see whether they offer improved operational or logistic effectiveness.

The crew compartment of an armoured fighting vehicle can be very dangerous if a fuel fire or explosion occurs. If the crew are to stand any chance of surviving, a very fast acting suppression system is required.

Traditionally the suppression systems are activated by optical sensors but these are not always easily installed due to the need to cover all of the compartment with a limited number of detectors.

Alternative detection systems are being investigated which detect the attack before it has resulted in an incipient fire.



Fire suppression discharger inside crew compartment

The Weapon System Demonstrator testing the digital stabilized sight fire control system

Surveillance and Target Acquisition

The effectiveness of future Armoured Fighting Vehicles (AFV's) will partly be determined by their ability to detect and engage targets faster than the enemy. The crew thus needs assistance in target detection tracking and communications.

This will be provided by automatic aids based on sensors which operate in the visual, near infra-red and far infra-red (thermal) wavebands with signal processing to give the required output. This output must be coupled to the crewman in the optimum way to allow him to make best use of the information and to minimise his workload.

The research work involves bringing together the enabling technologies of, for example, optics, TV and thermal imaging to sense the target in its environment, of image processing to provide image enhancement, target classification and tracking, and lasers for rangefinding and target discrimination.

Applications of the latest advances in devices and techniques are involved in these areas.

A considerable study of human factors is also required in order to present and process the information in the most appropriate way so that man and machine work effectively together.

Experimental work includes laboratory simulation to allow adequate system modelling, the design and building of sensor systems and their evaluation, leading to full scale vehicle trials.

Vehicle Electrical/ Electronic System Integration

Modern military vehicles have to incorporate many complex electronic systems and we face demands for an increased range of functions, higher performance, greater sophistication, together with better survivability, availability and reliability. All this needs to be achieved in smaller volumes since vehicle size has to be minimised to reduce overall vulnerability.

Against this complexity we have to make vehicle and weapon systems easy to use without imposing undue stress or fatigue on the vehicle crew members.

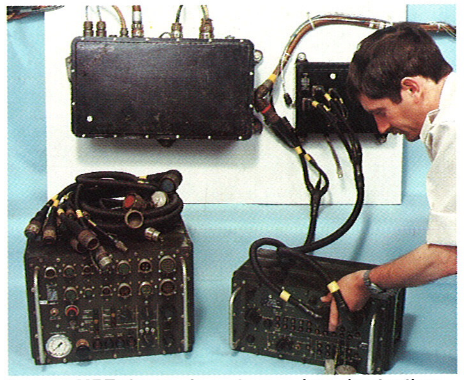
By using modern micro-processor systems operating under software control, Information Technology techniques, modern robust displays and controls, we are researching methods for automating many systems on the vehicle. In addition, by careful study of the operational role of the vehicle crew, we are able to achieve an integration of the crew with the interconnected vehicle control and information systems.

The techniques described also apply to the electrical power generation, storage and management system on a vehicle.

The research is carried out by means of computer based models of system configurations, backed up by the use of static and mobile test rigs in which the performance of both men and machines is assessed.

Extensive use of mini and main frame computers is made in the simulation work, particularly on the static rig where it is possible to control and monitor the operation of a vehicle electrical and electronic system in real time.

Systematic Approach to Vehicle Electronics (SAVE)



Present MBT electronic system undergoing testing with current test equipment.

New computerised electronic system under test incorporating SAVE.

Mr Marks with wide tracked, bellyless mobility research vehicle (left) with mobile test rig facility vehicle (right)

Unmanned Vehicles

Some progress has been made in the development of remotely controlled unmanned vehicles, but no one so far is close to producing a fully autonomous vehicle; that is a vehicle which can operate entirely on its own.

Mr. Adrian Marks, a Computer Scientist at RARDE, is part of a team of 25 people who are investigating the technological problems of such a vehicle.

At this stage, the systems that will allow autonomy are the key to progress in this field and not the particular vehicle on which they are to be mounted. Even so battlefield conditions are taken into consideration at all stages of research.

This formidable research task is divided into four main areas, namely; mobility, sensors, intelligence and effectors.

Mobility, as Mr. Marks describes it, is "coming to terms with the obstacles on the earth's surface – some that stop you moving and some that don't". The research has to identify those objects on different terrains that prevent movement and those that can be traversed. A novel tracked research vehicle has been developed to study this aspect.

Next these objects have to be recognized by sensors – the eyes and ears of the vehicle – and a variety of electronic devices are needed to sense the vehicle's environment. Among them may be TV cameras; rangefinders; sensors that measure speed, tilt or position as well as those that can detect colour, humidity or shape.

After this, the intelligence task is to plan the operation. If a vehicle is to move autonomously it must decide how and where to move. So computer planning is necessary to establish a sequence of activities, taking into account information from the sensors. Such planning ultimately controls the whole operation and must be continuously updated.

A small vehicle capable of navigation through a maze has been tested successfully.

Finally, having arrived at a given location, autonomous vehicles may need to perform a number of tasks. Devices, or 'effectors', are then needed to allow these to happen – for example, a vehicle might need to locate and load an ammunition pallet where some kind of lifting device will be necessary.

So far the team has mainly been concerned with picking up and putting down objects but this is very complex since it involves coping with items which may be square or circular, floppy or hard.

A number of extremely flexible 'grippers' have been developed from this work and they are able to pick up a variety of loads. Other tasks could be surveillance or weapon firing.

Whilst this project is ahead of any commercial experience, some contractors and universities are collaborating on selected research areas.

There is also considerable international co-operation; with NATO; a special collaborative agreement with Germany; and close links with the United States.

In this demanding work, it is difficult to make predictions but Mr. Marks believes that in the next 5-10 years we should be able to demonstrate vehicles that can perform limited tasks autonomously.

Weapon Aiming

The aiming of a gun barrel is achieved by traversing and elevating or depressing the barrel by using a servo control system.

The work is a challenging mix of control engineering and dynamic analysis.

The problems which arise can be resolved by mathematical modelling which, in the process, must seek precise control of position and speed of a very large structure.

Ultimately this control has to be obtained by a system which has variable coefficients and is driven by a mechanism which suffers from backlash.

Mathematical modelling techniques are now available which can allow for backlash problems and experimentally validated models can be used to determine which of the many factors involved may best be changed to improve performance of an unsatisfactory control system.

Validation is obtained through a Hull Motion Simulator which, through the use of a full scale representative gun and turret, is capable of replicating the full range of activity in aiming a gun.

Hull Motion Simulator replicates the full range of aiming a gun

'Challenger' on firing trials

Vehicle Mobility

Research into vehicle mobility covers all aspects of automotive research from the fuel tank, through the engine and transmission, to the ground. As such it includes suspension and track design amongst its activities.

We were responsible for the development of the highly successful hydrogas suspension unit fitted to the Challenger Main Battle Tank. This unit has many advantages, notably in wheel travel and spring characteristics, over conventional systems.

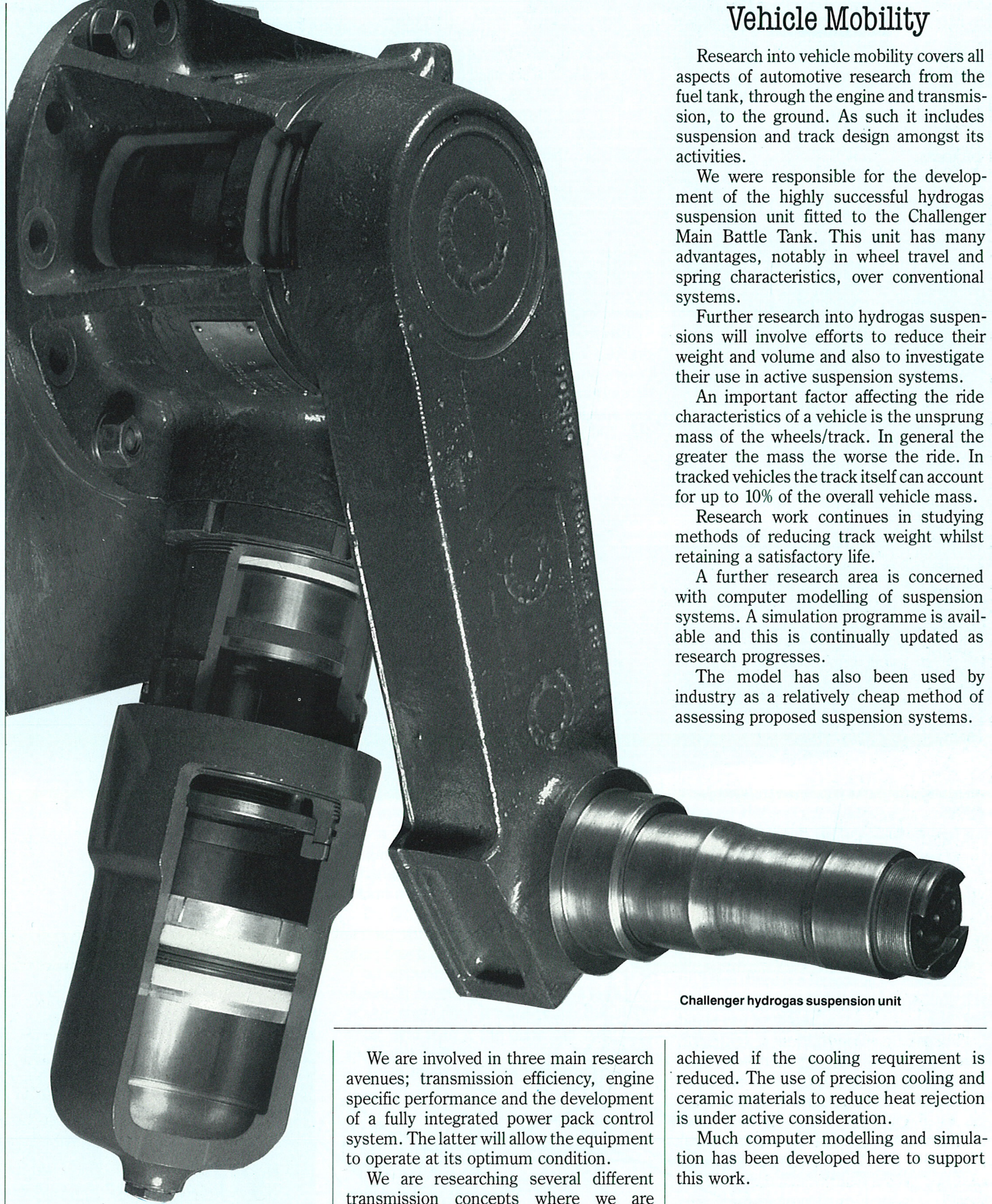
Further research into hydrogas suspensions will involve efforts to reduce their weight and volume and also to investigate their use in active suspension systems.

An important factor affecting the ride characteristics of a vehicle is the unsprung mass of the wheels/track. In general the greater the mass the worse the ride. In tracked vehicles the track itself can account for up to 10% of the overall vehicle mass.

Research work continues in studying methods of reducing track weight whilst retaining a satisfactory life.

A further research area is concerned with computer modelling of suspension systems. A simulation programme is available and this is continually updated as research progresses.

The model has also been used by industry as a relatively cheap method of assessing proposed suspension systems.



Challenger hydrogas suspension unit

High Performance Power Sources

There is an ever pressing demand for a reduction in size and weight of automotive components in armoured fighting vehicles.

Much of our work is aimed at achieving this with no loss of automotive performance or driveability.

We are involved in three main research avenues; transmission efficiency, engine specific performance and the development of a fully integrated power pack control system. The latter will allow the equipment to operate at its optimum condition.

We are researching several different transmission concepts where we are looking to achieve a marked increase in efficiency as well as a decrease in the volume of these systems.

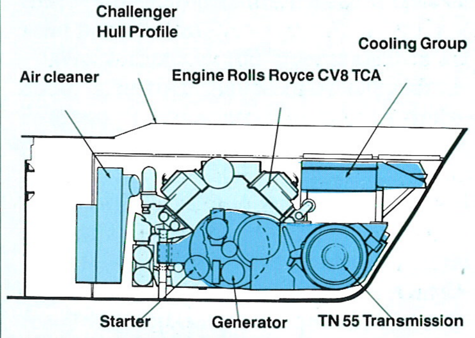
This research will also result in a reduced cooling requirement and enable engines of lower power to be used.

Work is also in hand to increase the power of engines for no increase in volume.

Methods under investigation include: variable geometry turbocharging, variable valve timing and variable injection timing.

A further saving in volume can be achieved if the cooling requirement is reduced. The use of precision cooling and ceramic materials to reduce heat rejection is under active consideration.

Much computer modelling and simulation has been developed here to support this work.



Challenger Engine

Munitions

The long history of munitions has evolved through research which is now at the centre of some of the most innovative technology.

Here are some examples of existing projects.

Large Calibre Guns

Research and technical advice on all types of gun systems above 30mm calibre is provided by RARDE.

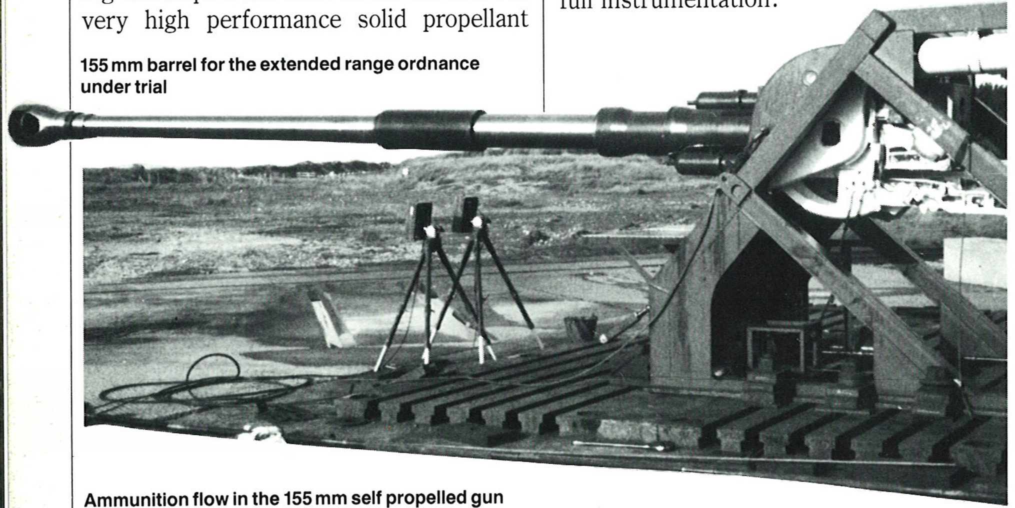
Increasingly we are looking at new concepts, system studies and the application of new technologies and materials to direct and indirect firing systems. Particular emphasis is being placed on novel methods of propulsion.

Sophisticated computer-aided engineering techniques are used in the research of very high performance solid propellant guns which includes mathematically modelling the gun dynamics as the shot moves along the bore and exits at the muzzle. Models are used for stressing and optimising designs, and simulators are used to test components under realistic conditions.

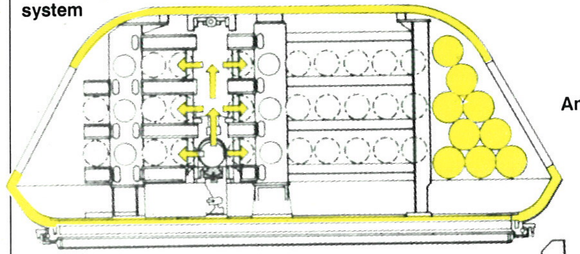
Specially instrumented trials (including firing trials) using about a quarter scale initially and later full scale equipments, are tested to verify calculations.

Work on artillery systems includes navigation, automatic gun laying, ballistic computation and other aspects that give an increased level of automation and autonomy to self-propelled gun systems.

Electro-magnetic guns continue to provoke a growing area of research which covers both rail guns and linear induction accelerators. Practical work is undertaken in a specially constructed facility attached to a 100 metre enclosed firing range with full instrumentation.

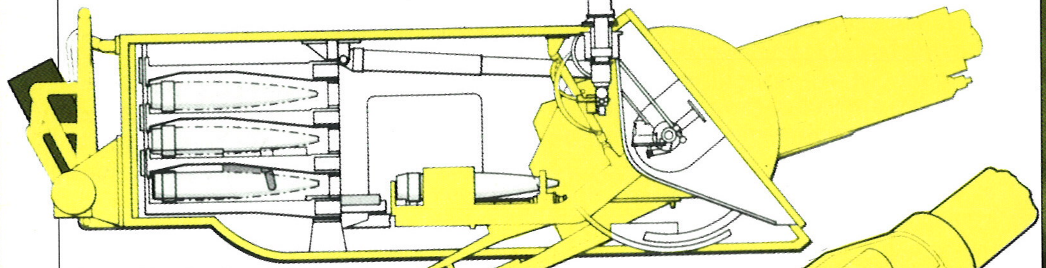


155 mm barrel for the extended range ordnance under trial

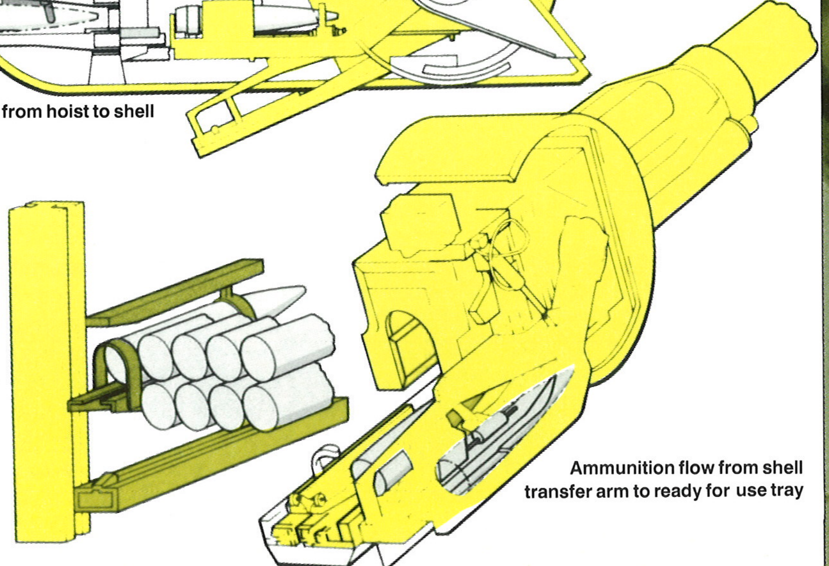


Ammunition flow in the 155 mm self propelled gun system

Ammunition flow to magazine storage



Ammunition flow from hoist to shell transfer arm



Ammunition flow from shell transfer arm to ready for use tray

Dr. George Cook and the 'Experimental Liquid Propellant Gun'

A New Concept in Gunnery

For around 700 years guns have used solid propellants to project their shot. Now RARDE is working on a programme that will change that situation and allow the use of liquid propellants instead.

Dr. Cook leads six scientists plus contractors in research and trials that will culminate in the production of a large calibre liquid propellant tank gun.

One of the main problems concerns the way in which the liquid is loaded into the gun. There are two basic ways, either by loading the liquid into the chamber in a conventional manner, or by injecting it into the combustion chamber continuously. Dr. Cook's project team have opted for an injection method using a regenerative process, i.e. a differential piston which amplifies combustion pressures and injects the liquid progressively – like a liquid propellant rocket motor.

So far a lot of the work has been concerned with computer modelling but the team now has a physical piece of equipment – an experimental liquid propellant test vessel. It doesn't look much like a tank gun at this stage, but it does much the same thing, and with it the team can compress and inject liquids.

Trials using the chamber in its various configurations will ultimately complete the data on the key areas of liquid compressibility, injection properties, combustion and liquid sealing.

Huge advantages

There are huge advantages in the successful completion of this project.

First there is a significant improvement in muzzle velocity.

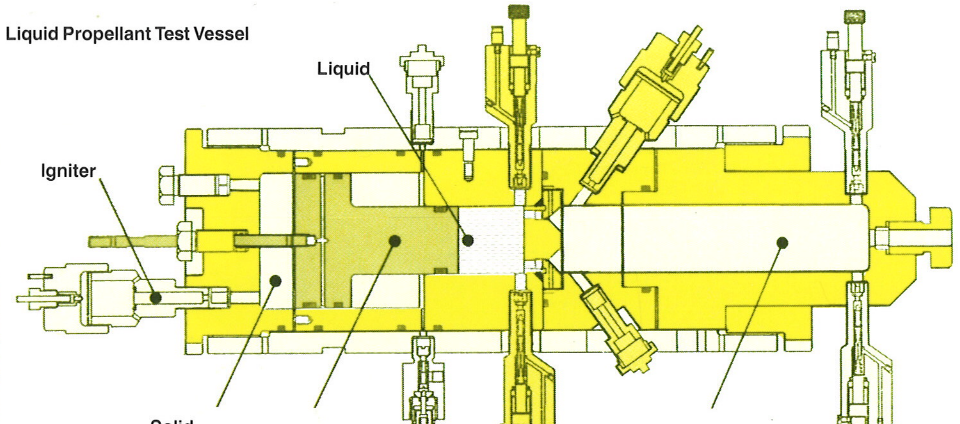
Then there is a reduction in vulnerability – because it is not handled mechanically the liquid can be stored in the safest place, and if the tank is hit most of the propellant will tend to be thrown out unburnt. And liquids can be easily supplied and carried around in optimum quantities whereas solid propellants involve special manufacture of different charges for different situations, and take up more space.

And by no means the least advantage is cost – liquid propellants cost only 10% of solid propellants.

Whilst there is still a great deal to be done, a testbed gun is reasonably close. Even so, it will eventually mean a fundamental redesign of large calibre tank guns 'from the ground up', and so the team is looking to the new system going into service very early next century.

This is about par for the course on major new weaponry. But after 700 years it is not really very long to wait.

Liquid Propellant Test Vessel



Understanding the Combustion Process

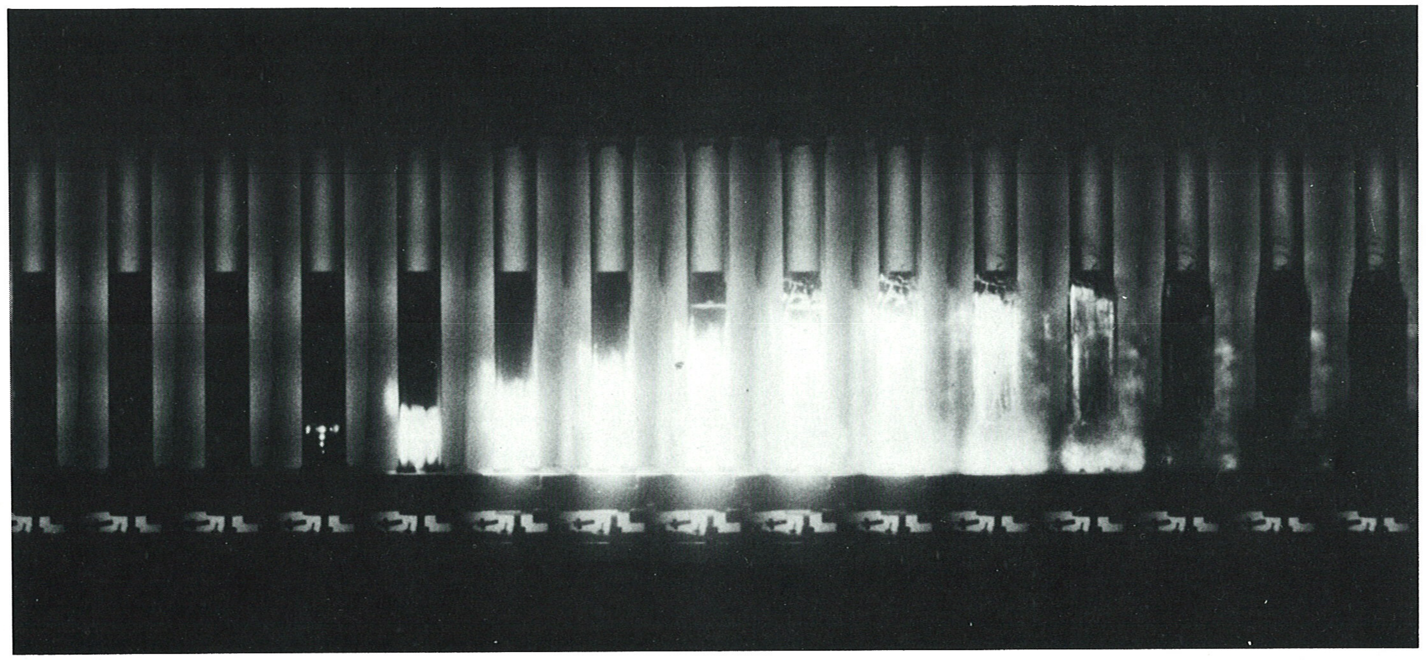
Internal ballistics of guns and mortars systems of 30 mm calibre and upwards is another sphere of RARDE responsibility.

Our work embraces fundamental and applied research to further the understanding of the internal combustion process and fluid dynamics in direct and indirect firing gun systems. A better comprehension of these aspects will lead to increased charge efficiency, to improved ignition, to increase reliability, to a reduction in gun bore and chamber wear with a view to increasing system life and accuracy, and to a reduction in pressure waves thereby increasing system safety and accuracy.

In addition we investigate novel methods of propulsion and charge design to enable radical improvements in gun system performance. This includes the use of a liquid, rather than the conventional solid propellant and the study of modular change systems and novel propellant shock shapes to help improve packing density.

The practical work is carried out in a variety of closed firing ranges that have comprehensive instrumentation for both internal and external ballistic measurements.

RARDE is the acknowledged centre of expertise on internal ballistics in the UK and gives technical advice throughout the country. It has also established numerous international contacts through the auspices of NATO etc.



High speed cine film of the initial stages of a mortar internal ballistic cycle

Gun Dynamics

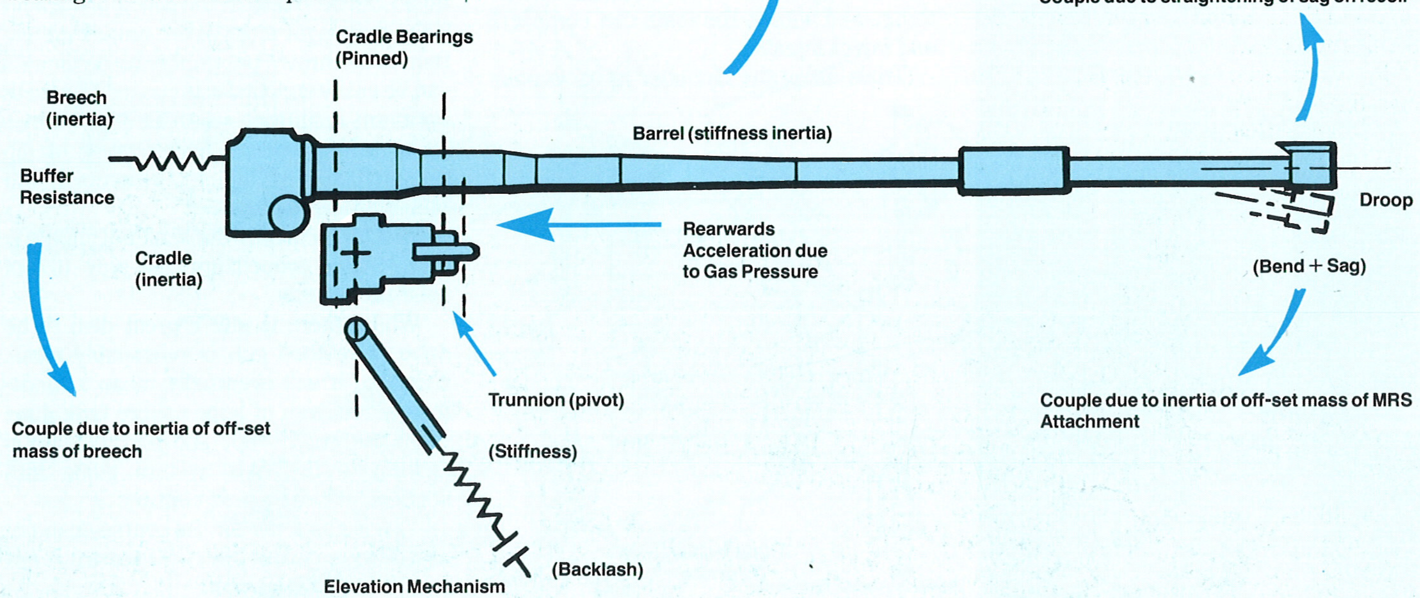
In current tank guns, an asymetric breech structure allows depression of the gun within a low turret silhouette and for the fitting of special sight mounts. During firing the rearward acceleration of the gun barrel acts on this structure and excites complex vibration modes in the gun barrel.

These vibrations are augmented by reaction from the various gun mounting bearings as well as the pressure waves travelling longitudinally along the barrel.

Vibrations can affect the accuracy and consistency of gunnery, and whilst such effects are widely appreciated they are not well researched. RARDE is thus in the process of developing computer models for the prediction of performance in these respects, and which will help improve design and investigate inaccuracies that can occur in service.

The models will be validated by extensive firing trials.

In addition to analysis, modelling and firing trials the work includes instrumentation and identification of design improvements – a comprehensive mix of mechanical engineering and dynamic analysis.



Ammunition

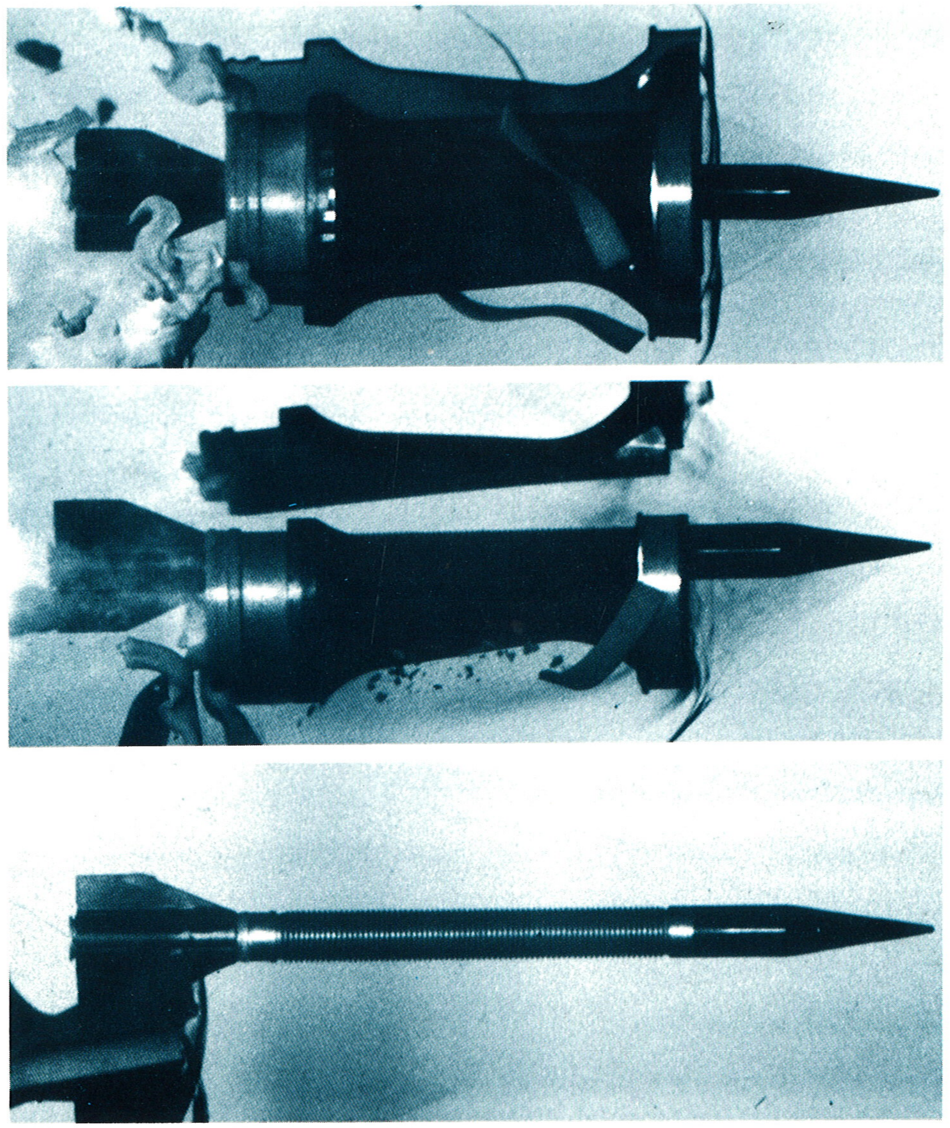
All guns require effective ammunition if they are to have the desired effect namely on destroying enemy equipment and personnel, and RARDE has the responsibility for research into improvements to all ammunition, except small arms, for the British Services.

Priority is given to improving ammunition for anti-tank weapons. Tanks are hard targets; they are thickly armoured, mobile and present relatively small silhouettes. The ammunition must therefore be extremely accurate and also capable of penetrating many centimetres of armour plate at a range of several kilometres.

Improvements are being explored into kinetic energy round long rod for the defeat of tank armour, and the firing of full scale (120 mm) rounds conducted to establish the performance in practical firing trials.

Also computer modelling techniques are being used to assist in the design detail as are representative model-scale firings at 40 mm calibre. And computer modelling is being used to predict performance by establishing theoretical equations for penetration into hard targets so that performance can be estimated in advance of test firings.

Research into indirect fire ammunition is concentrating on extending the range. The current limitation for the Army's 155 mm shell is 24 km and the research aim is to extend this to 30 km for carrier shells which could contain and dispense bomblets.



Sequence in the Firing of an Armour Piercing Fin Stabilised Discarding Sabot (APFSDS) long rod round

Warheads

RARDE undertakes research into warheads for conventional guided and unguided weapons whose role is to attack tanks protected by advanced armours, high performance aircraft, missiles, ships and submarines.

The warheads involved are of different capabilities including Blast, Fragmentation, Continuous Rod, Shaped Charge and Semi-Armour Piercing.

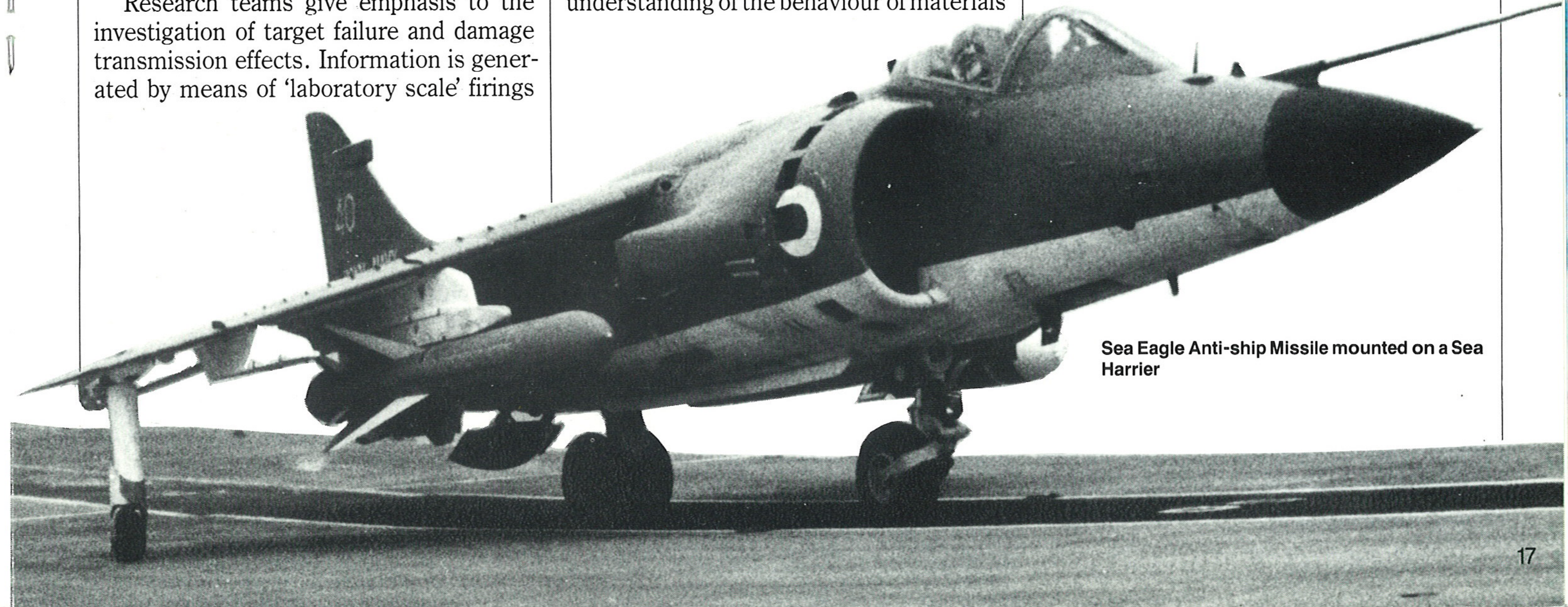
Research teams give emphasis to the investigation of target failure and damage transmission effects. Information is generated by means of 'laboratory scale' firings supported by a wide range of instrumentation techniques.

Firings are conducted at Fort Halstead and at external ranges, often involving full-scale warshot missile firings against representative targets.

Much effort is devoted to studies undertaken by computer of the simulation of the physical processes involved in warhead detonation and target penetration. An understanding of the behaviour of materials when subjected to extremely high pressures combined with large rates of strain is an essential prerequisite to the generation of physically realistic predictions.

Computer-based techniques are also applied to the problem of assessing the effect of specific weapons upon the operational capabilities of particular targets.

Close contact is fostered with the Defence Intelligence Staffs.



Sea Eagle Anti-ship Missile mounted on a Sea Harrier

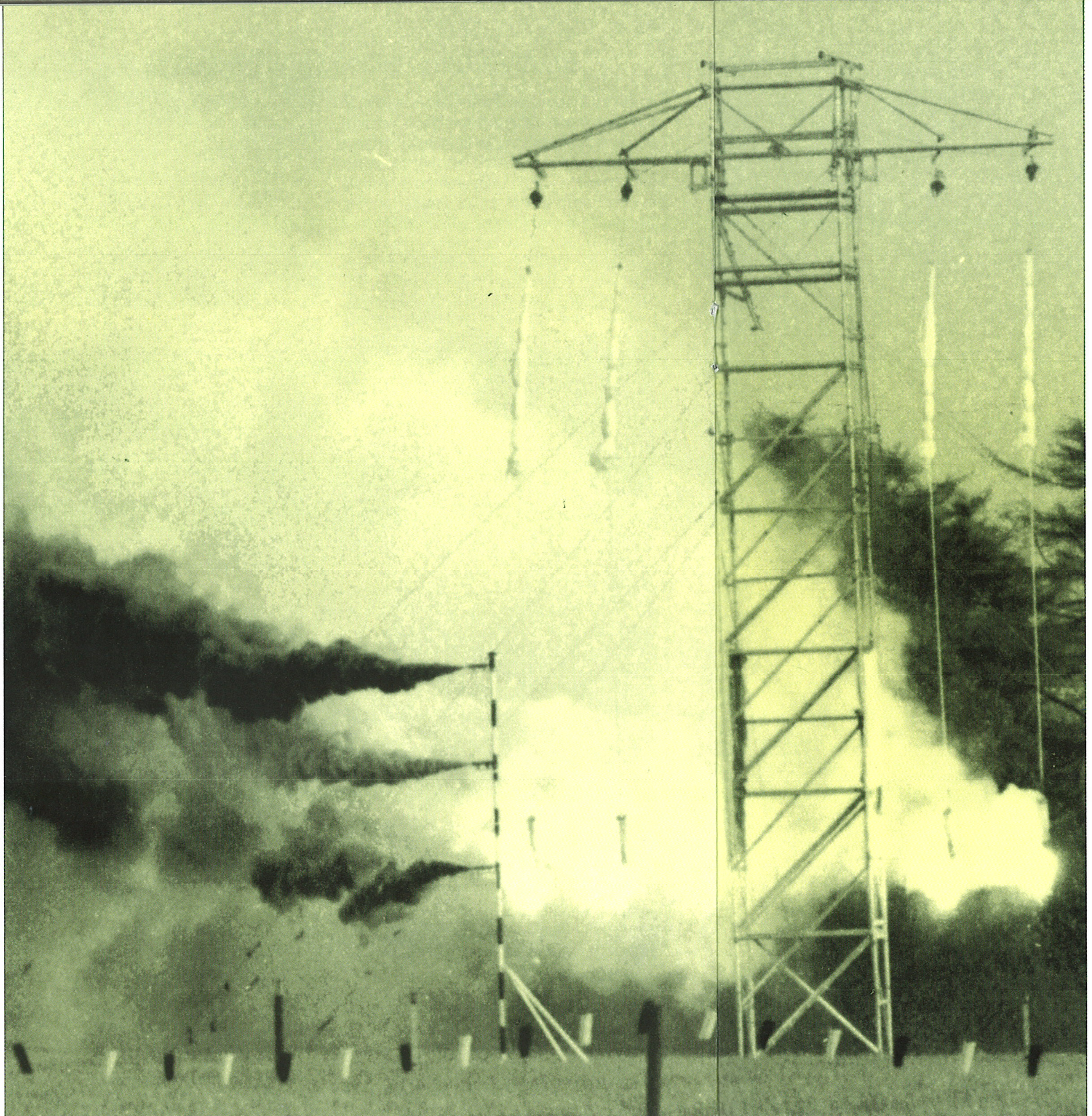
Mine Fuze Research

Anti-tank mines are no longer restricted to buried objects which, when actuated by the pressure of a wheel or track, damage the passing vehicle by blast.

New mines include concepts that contain small shape charge warheads and can be delivered by gun, rocket or aircraft, or alternatively can fire armour penetrating warheads from a distance into a passing target. These new concepts require new influence fuzes that exploit modern sensor and signal processing technologies including the use of programmable devices that allow the selection of special features.

The sensors may detect a variety of target influences or signatures including magnetic, seismic, acoustic, infra-red and microwave, and RARDE is involved in meeting the research challenge of measuring these signatures by trials and deriving suitable algorithms to activate the new mine concepts and maximise their effectiveness.

Measuring tank signature



Infra Red Decoy Research

For the all important requirement of battlefield survivability the pyrotechnic composition plays a major role in the protection of military vehicles and weapon systems against attack by radiation seeking missiles whether on land, at sea or in the air. With aircraft, for example, heat seeking missiles use the infra-red radiation given out by an aircraft, mainly from its engine, to identify its target.

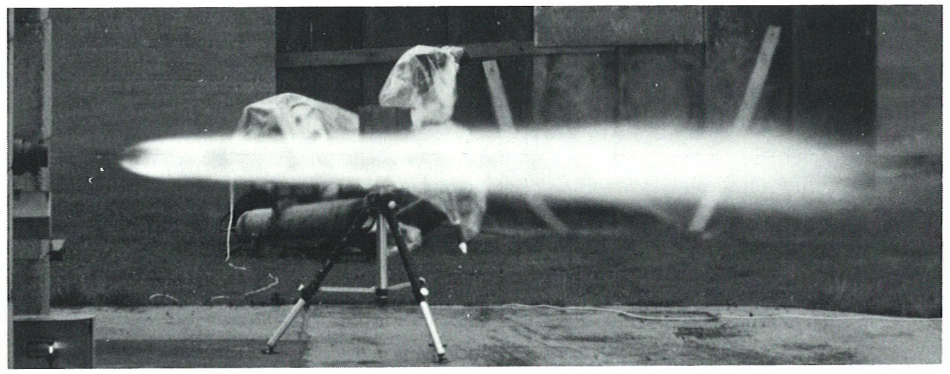
To defeat this type of missile threat infra-red decoys have been produced which are basically pyrotechnic flares. The composition of these flares burns to give a very high energy output and a strong infra-red emission which confuses the attacking missile.

Missile technology is continuously advancing and research has to be ongoing to improve the present decoys and defeat new threats.

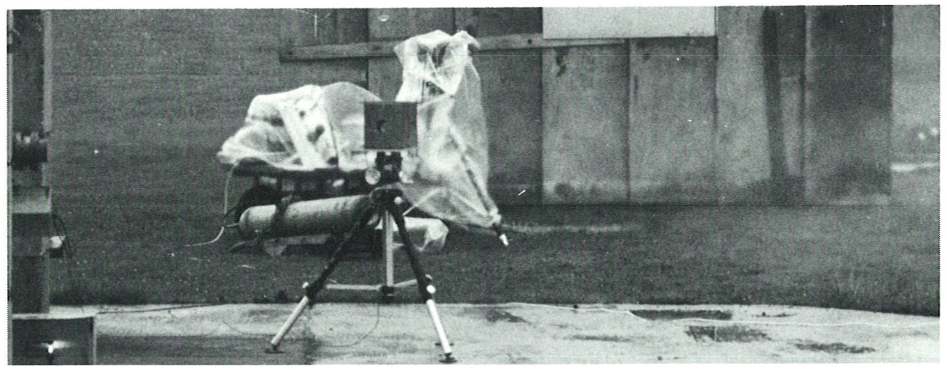
Using spectroscopic means, the infra-red signatures of vehicles can be determined and the aim of infra-red research is to formulate a composition which will match the signature as close as is possible.

Intramural and extramural research is undertaken into metals and alloys as fuels, new polymers for use as oxidants and the identification of additives which could modify the emission to resemble more closely the signature from the possible target. When a new material is identified it is incorporated into a new composition.

Evaluating the infra red emission from
a) above: pyrotechnic flares
b) below: pyrophoric liquids



A solid propellant rocket firing showing secondary combustion



A similar firing with suppression of secondary combustion

Plume Technology

The exhaust from a rocket motor, whilst having negligible effect on thrust once it has passed the nozzle, is important for a number of reasons. It gives an adversary a means of detection and of evasion; it will affect guidance signals; it may obscure the target from the tracking station; and it may cause significant damage to the launch vehicle.

The size and visibility of the plume will depend not only on the design of the motor but also on such factors as altitude and velocity. It is obviously important to be able to predict the nature of the exhaust at an early stage of motor design.

At Westcott, RARDE models the structure of the plume from factors such as propellant composition, nozzle geometry and external conditions. Improvements are continually made in calculating the complex interaction through turbulent mixing of the fuel rich exhaust and the surrounding air. The secondary combustion, which occurs as the result of this mixing, is the major cause of the plume's visibility.

The tasks are to test predictions by ground-level firings and the measurement of infra-red and visible radiation and attenuation of microwave signals. And to study by means of laboratory flames the nature of the chemical processes occurring within the exhaust.

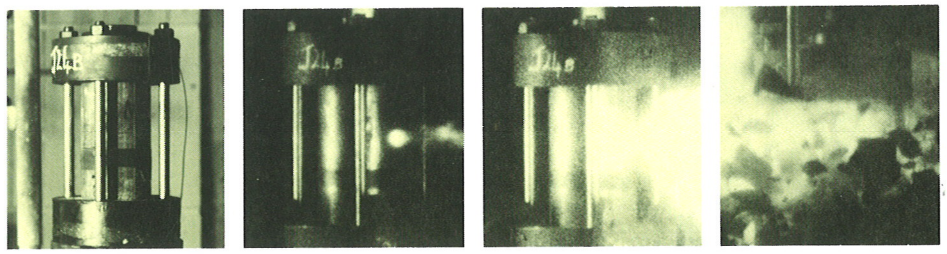
Of particular concern is the mechanism by which secondary combustion can be suppressed by the addition of potassium salts.

Rocket Motors - Fragment Attack

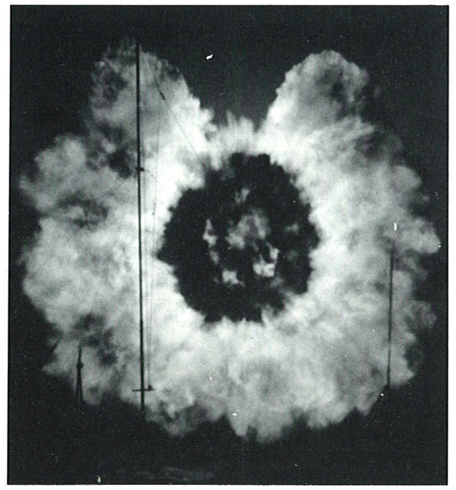
Rocket motors are subject to many hazards, not least of which is being attacked by high velocity fragments generated by explosions or bullets.

RARDE is responsible for evaluating the response of motors to these hazards. In this respect it is important to understand the relative importance of propellant characteristics, motor cases and methods of construction, and to do this a research programme has been developed. In this both small and model rocket motors are attacked by standard fragments fired from a gun and the results are examined physically and by high speed photography. As a result of this work it is now possible to predict the effects of fragment attack on given motors simply from a knowledge of the propellant energy and physical properties.

The research will continue with a study into methods of reducing fragment effects by using novel case construction techniques.



Before attack — Fragment striking — Explosive rupture — Case fragmentation



Fuel/Air Explosion

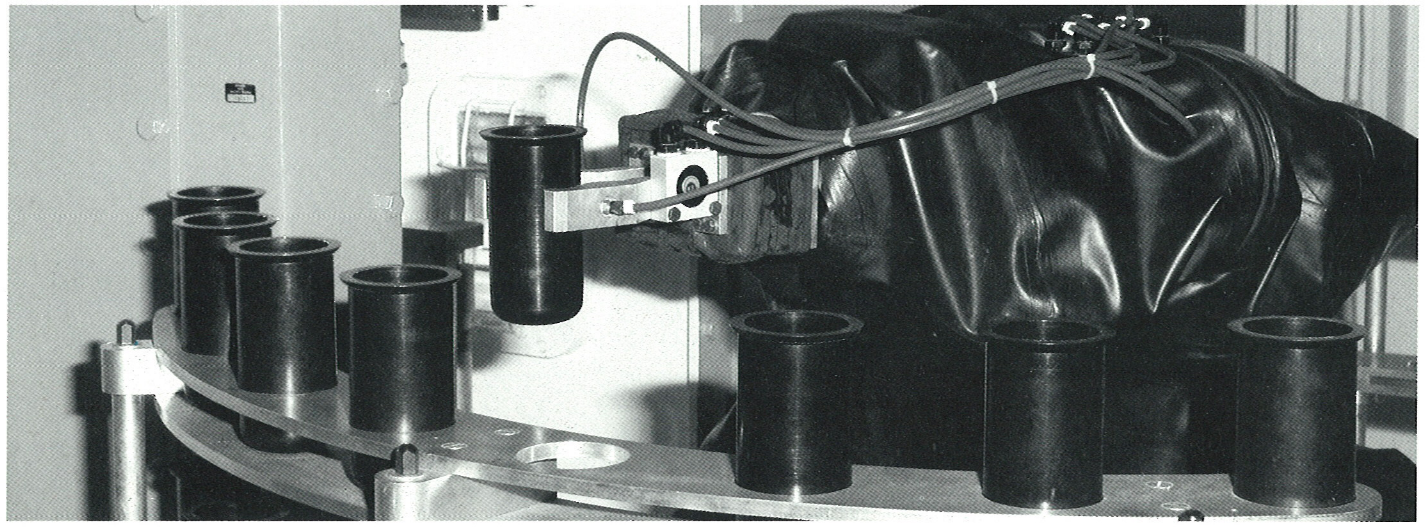
Pyrotechnics

RARDE is responsible for the research conducted into all aspects of military pyrotechnics. This family of explosive compositions find wide application in virtually all weapons ranging from the time-delay fuze in a hand-grenade to the most complex devices to protect weapon systems on the battlefield from attack by radiation-seeking missiles.

The research requires the characterisation of the performance of the pyrotechnic composition over a wide range of operating conditions using specialised techniques and equipment. These include the particle analysis of sub-micron powders, the measurement of flame propagation velocities, the use of thermal imagers and fast response radiometry.

The extensive pyrotechnics filling facilities at RARDE allow for the safe processing of precise quantities of very sensitive explosives that may be used in miniaturised initiators to the remote handling by robots of large quantities of high energy materials that are required for infra-red decoy deployment systems.

The harsh operating environments under which these explosives are required to function with high reliability are simulated within the comprehensive systems evaluation facility where the effects of temperature, pressure, windspeed and acceleration are accurately determined.

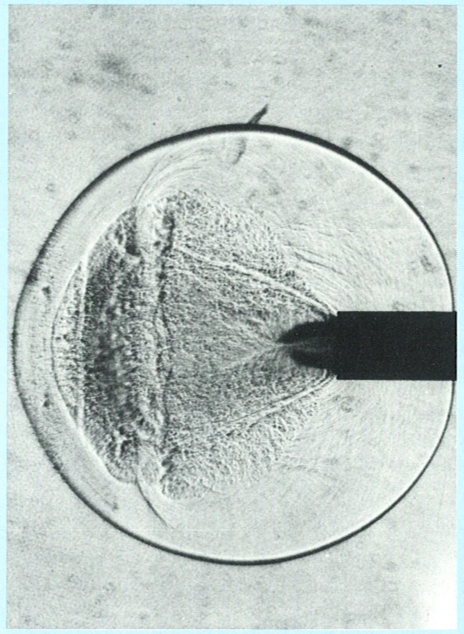


Robot handling high energy materials

Ballistics, Flight Dynamics and Rocket Systems

The firing by gun and rocket weapons produces noise and blast overpressure at high temperatures. Hot gases emerging from the launcher temporarily overtake the projectile and may disturb its flight.

Research conducted on muzzle flows is aimed at developing theoretical and experimental tools for the analysis of these unsteady situations and minimising unwanted effects. Work is undertaken in partnership with universities, and the study of flows by fluid dynamic computation is an important aspect.



High Enthalpy Blast Simulator Studies

Blast flows are produced experimentally using the High Enthalpy Blast Simulator to study muzzle brake designs, sabot separation and noise suppressors.

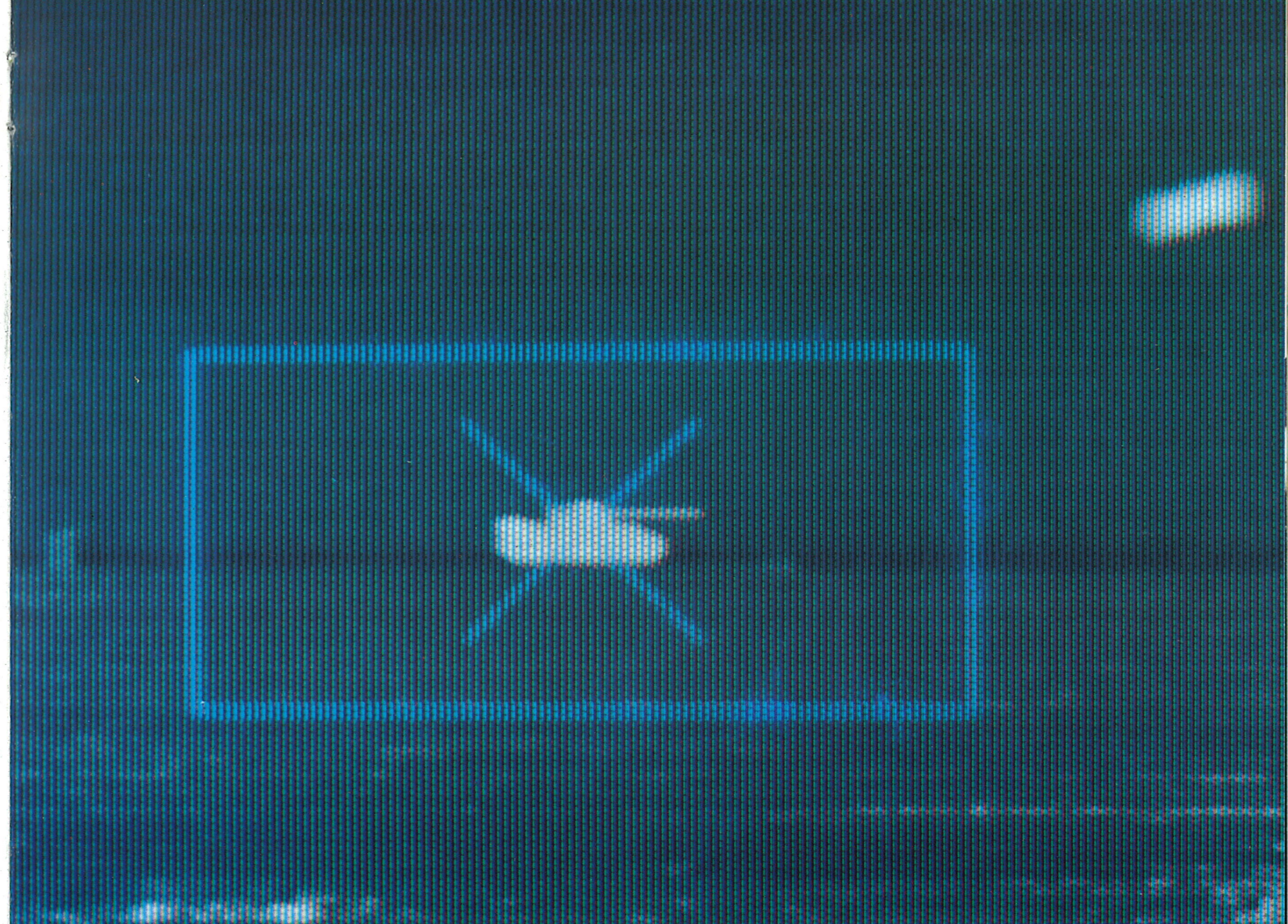
When clear of muzzle effects, the flight dynamics of projectiles fall into two regimes according to whether they use spin stabilisation, as in small arms and artillery guns, or fin stabilisation as in the anti-armour rounds fired from tank guns. Here again the aerodynamic design of these projectiles is studied in collaboration with universities and contractors and is aided by fluid dynamic computation using the CRAY computer, and by experiments in subsonic and supersonic wind tunnels.

Research is also carried out on component technology for lightweight anti-armour weapons.

A range of technologies is involved including electronics, aerodynamics, explosives, materials and propulsion engineering.

Demonstrator rounds are designed, tested and fired to assess system performance.

Prototype automatic target and missile tracker



Applied Physics and Mathematics

The recent rapid advancements in applied physics and computer based mathematical analysis are being fully exploited at RARDE in a number of advanced projects, some of which are described as follows.

Guided Weapons

RARDE explores new techniques and conducts studies into army anti-tank guided weapon (ATGW) systems leading to full-scale development. Similar responsibilities are also carried for indirect fire weapon systems which employ homing and guidance techniques.

Guided weapon technology draws on a wide range of disciplines – our interests include mathematics with particular emphasis towards computing, applied physics, electronics, aerodynamics and explosives.

One purpose of the present development programme is to improve the performance of ATGW under the conditions of poor visibility which can exist on the battlefield. All possible types of guidance and control techniques are being actively investigated, involving applications of lasers, infra-red imaging systems, electro-optical sensors, image processing and digital scene synthesis.

Swingfire missile fired from Striker

Field trials are conducted to evaluate new sub-system techniques and to assess the full performance of a complete weapon system. These trials are carried out under the widest possible range of environmental and battlefield conditions.

Even after weapon systems have been approved and released for service, we continue to monitor performance throughout the in-service life in order to improve operational effectiveness and reliability by exploiting advances in technology.

The design and development of ATGW systems is undertaken by firms in the aerospace and electronics industries, but RARDE is responsible for monitoring their progress and assessing the technical viability and effectiveness of their designs against the Army's operational needs. Development of guided weapons is very much a matter of team work and RARDE is committed to the development of the next generation of direct and indirect fire anti-tank guided weapon systems based on advanced and sophisticated technologies.

Optics and Lasers

RARDE deals with a diversity of electro-optical topics. These include the application of optics to surveillance devices and weapon systems in the visible, near infra-red and far infra-red (thermal) bands; electro-optical countermeasures; devices for surveillance, target acquisition and viewing in limited visibility; and the military application of inertial navigation systems and lasers.

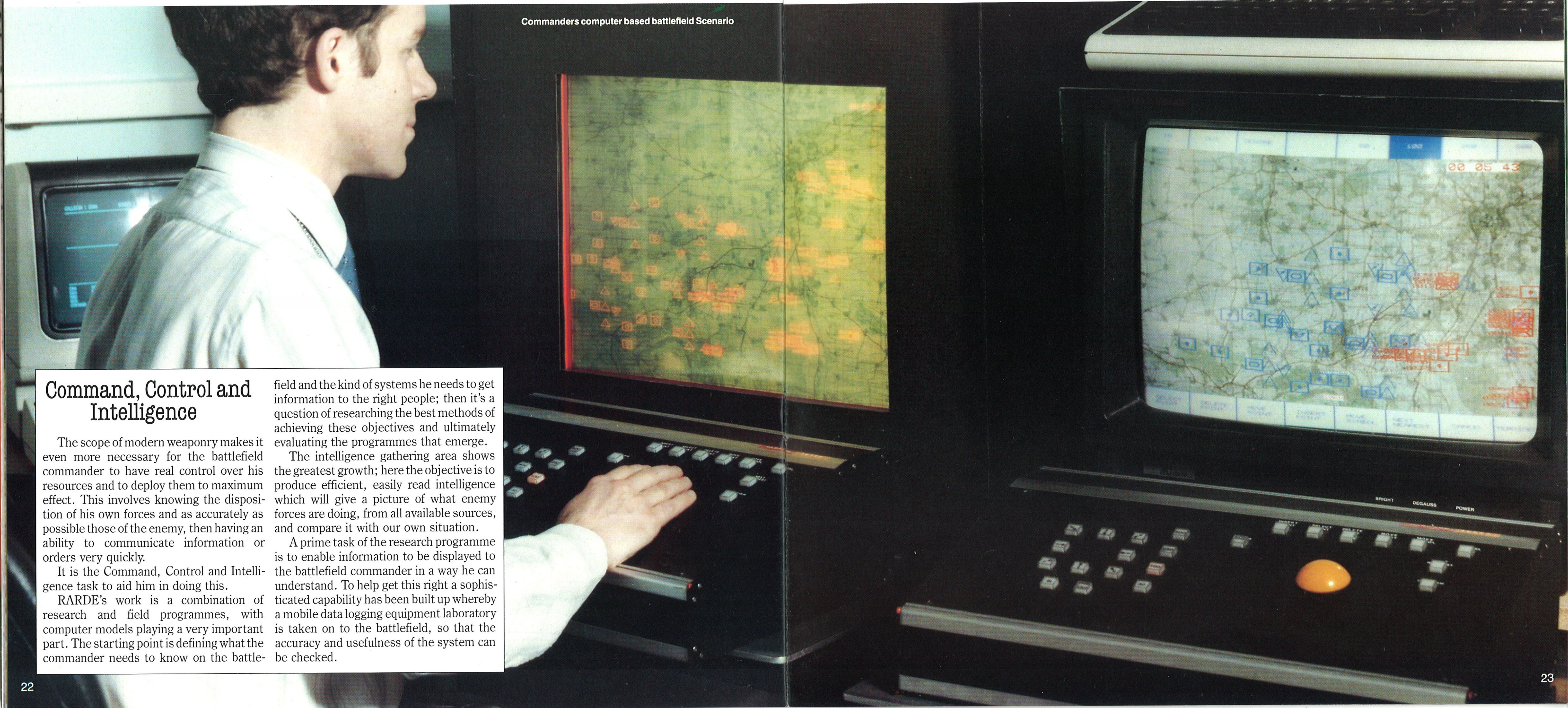
We also provide technical advice to a variety of clients including the Royal Navy, Royal Signals and Radar Establishment, and industry.

Our work has pioneered the use of computers in the design and assessment of optical systems. Research has led to the development of a computer-aided design facility, enabling the designer to optimise lens systems using diffraction based evaluation criteria. This performance can be assessed practically by various methods using interferometry, transverse ray aberration analysis, and line-spread function techniques. A microprocessor-based on-line application of the latter is being developed for quality assurance purposes.


The Small Arms Weapon Effect Simulator (SAWES) for which RARDE provides technical advice

Laser-based products being developed in conjunction with industry include man-portable laser rangefinders, laser target markers, advanced laser designators for use with precision guided weapons – and a variety of direct fire weapon effects simulators for small arms, anti-tank guided weapons and air defence systems.

So the work spans many areas of rapidly developing technology, with growing applications to many future defence needs.


Commanders computer based battlefield Scenario

Command, Control and Intelligence

The scope of modern weaponry makes it even more necessary for the battlefield commander to have real control over his resources and to deploy them to maximum effect. This involves knowing the disposition of his own forces and as accurately as possible those of the enemy, then having an ability to communicate information or orders very quickly.

It is the Command, Control and Intelligence task to aid him in doing this.

RARDE's work is a combination of research and field programmes, with computer models playing a very important part. The starting point is defining what the commander needs to know on the battlefield and the kind of systems he needs to get information to the right people; then it's a question of researching the best methods of achieving these objectives and ultimately evaluating the programmes that emerge.

The intelligence gathering area shows the greatest growth; here the objective is to produce efficient, easily read intelligence which will give a picture of what enemy forces are doing, from all available sources, and compare it with our own situation.

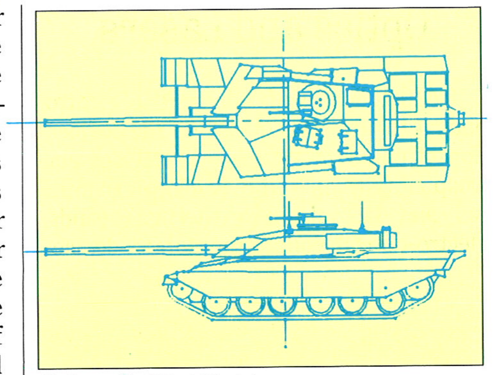
A prime task of the research programme is to enable information to be displayed to the battlefield commander in a way he can understand. To help get this right a sophisticated capability has been built up whereby a mobile data logging equipment laboratory is taken on to the battlefield, so that the accuracy and usefulness of the system can be checked.

Low Level Combat Modelling

Our Low Level Combat Model is a digital computer programme which is used to simulate detailed aspects of armoured warfare in order to study the interaction and trade-offs between the firepower, protection and mobility of an armoured fighting vehicle.

Broadly speaking the model contains a piece of a typical European battlefield upon which tanks and other weapons may be deployed to represent defenders and attackers. The computer moves these antagonists across the terrain in a realistic manner; targets are exposed to enemy detection and fire; and the outcome of each engagement is determined from an estimate of the probability of survival. The tactical decision rules, which govern if and when an engagement starts, may be varied to suit a particular study.

Our purpose is two fold. Firstly in the design stage we seek to reduce the number of possible options in order to reduce the cost and time needed to construct viable proposals. Secondly in support of Operational Analysis studies we counteract the grossing-up in the higher level models which tend to obscure the differences revealed by more detailed modelling. For example our simulation of a static firer engaging a moving target would include the performance of the human gunner, the fire prediction algorithm and the variations of the target's mobility whereas a higher level model would simply sample from a distribution of probability of a hit and kill for the target being either static or moving.


Mathematical Tank Model

Tank Modelling

Aircraft or ground troops can fire at old tank hulls and the effects physically examined. But these trials are infrequent, due to cost, and being against a limited number of tanks it is difficult to draw positive conclusions on all aspects of the effect of shot against modern armour. And, of course, it is not possible to trial tanks used by other countries.

RARDE is applying computer graphics to study the effect of armour-piercing shot hitting any part of a tank to determine both depth of penetration and resulting damage inside the tank. So, without firing a shot, we can provide a picture of the result of an attack on any tank, British or foreign, by anti-tank weapons or missiles.

'Teaching' the computer the key features of a battlefield scene

Multiple Launch Rocket System - Stage 3

"MLRS III" is a project aimed at providing a terminal guidance warhead for an existing American rocket system. Each rocket will carry several intelligent sub-munitions, capable of detecting bulk targets autonomously, and homing on to them. The weapon will be part of the NATO response to the threat posed in Europe by the vast numerical superiority possessed by the Warsaw Pact.

This phase of the MLRS project is collaborative with US, French, German and the UK as partners. The partnership extends from the initial choice of best technical approach right through to eventual production and RARDE has had, and will continue to have, a key role as Co-ordinating Research Establishment. In this way all technical advice to the national project office is co-ordinated. In addition certain RARDE expertise and capability has been directly harnessed by the international partners.

The most demanding technical feature of the intelligent sub-munition is its ability to distinguish targets from the general clutter background which will be present during any battle in the European theatre.

The "brains" of the munition are contained in the seeker whose job it is to detect possible targets from a range of 1000 metres and then confirm that one of these possible targets is a real one, hopefully a tank rather than one of the vast number of other battlefield features which might at first sight seem to be tanks.

The problem faced by the seeker is much more difficult than that of the more familiar surface-to-air missile.

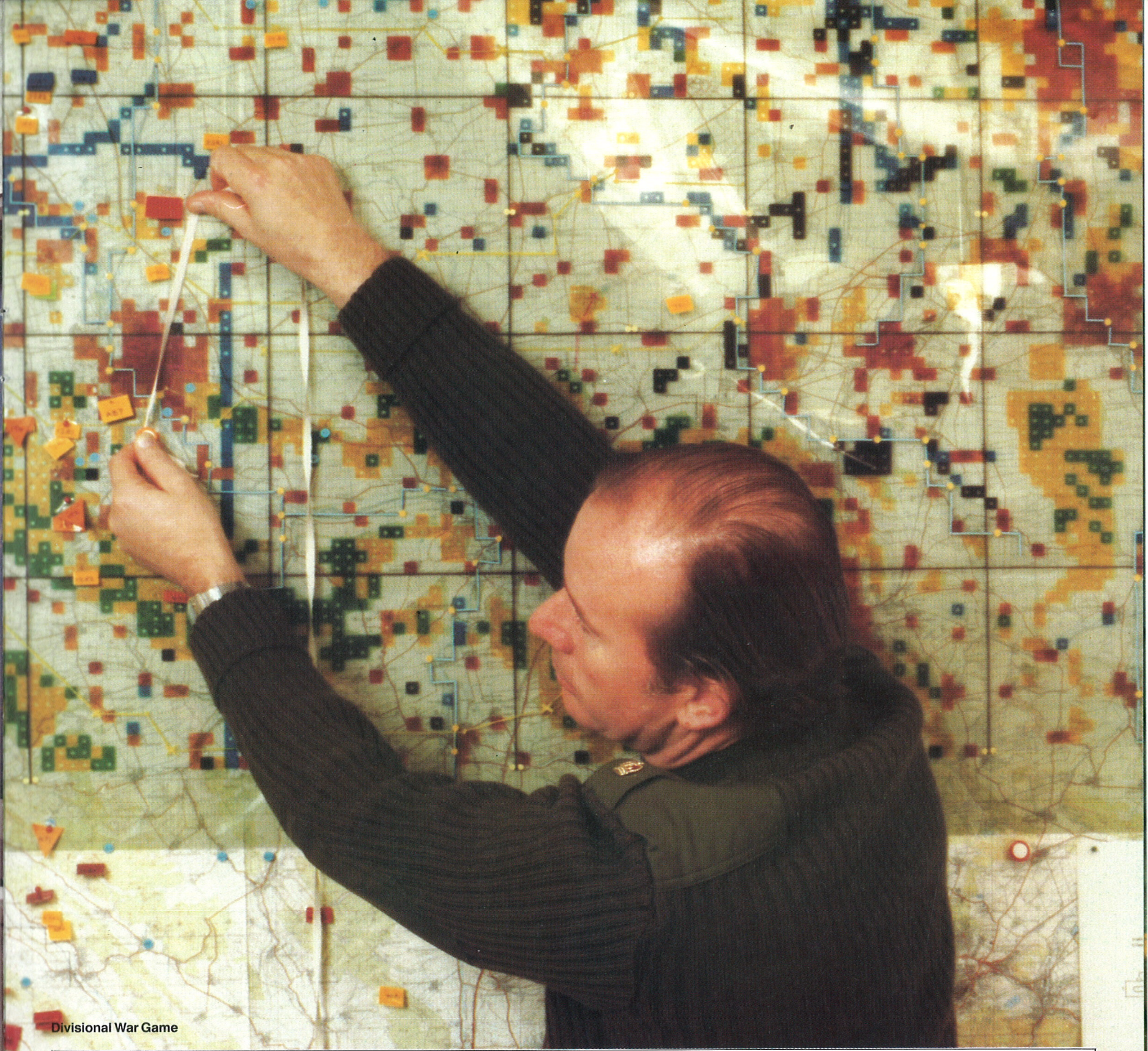
RARDE has developed an impressive armoury of techniques for evaluating the performance of seekers for anti-tank munitions including a suite of computer-based mathematical models.

Development of these techniques has included detailed studies of the terrain in which the battle will be fought and the illustrations show one of our newest recruits engaged in 'teaching' the computer about the key features of a typical battlefield scene.

RARDE models of the acquisition and tracking features of seekers have been adopted by the four partners and will provide definitive statements on seeker performance on which decisions to proceed beyond the present phase of development will be based.

RARDE also leads the international evaluation of the lethal mechanism and has provided the primary means of evaluating overall effectiveness.

Most groups within RARDE have contributed at one time or another to the MLRS III project. As well as having the satisfaction of making an important contribution to Western Defence, staff have welcomed the opportunity to make contacts with technical experts in the partner countries.



Divisional War Game

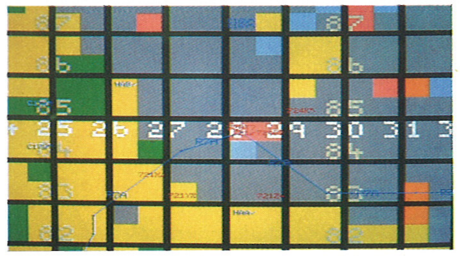
Operational Analysis and War Gaming

RARDE is responsible for the operation analysis of future weapon systems either under development or being considered for purchase by the British Army. Studies being carried out include the evaluation of a future attack helicopter, anti-tank guided weapons and remotely piloted vehicles.

A wide variety of analysis techniques are used, most of which are based on the rapid and powerful computing facilities at Fort Halstead. Areas of interest encompass lethality assessment, combat modelling, battlefield simulation and war gaming.

Separate war games for the direct and indirect fire weapons are used to investigate future tactical concepts, procedures and performance in a battlefield environment where the effects of enemy counter-measures can be introduced. The direct fire battle is being updated to an interactive computer-based game which will permit the representation of improvements in weapons as systems become more sophisticated.

The indirect fire battle is studied in the Divisional War Game, set up to permit explicit representation of the military command relationship and also the simulation of the future battlefield in an electronic warfare environment. Military officers with appropriate specialist knowledge play all the game positions. The Divisional War Game is a unique facility within NATO and has attracted interest from the USA, in particular, who regularly supply players.



Screen display for DWG

DWG Control Room

Studying the effects of explosions upon buildings

Materials

More demanding requirements for new materials has fostered original research at RARDE.

Some of the current work is described.

Metallic Engineering Materials

The aim of the research being conducted under this subject is to exploit developments in new and improved metallic materials; their methods of processing and fabrication procedures to improve performance, reliability and durability of armoured vehicles and to reduce their cost.

Quantimet Image Analyser

The areas being researched include, welding of high strength materials, evaluation of materials for heavy duty applications, novel materials for suppression of noise and vibration, and the development of materials properties data in general.

Research on the welding of high strength alloys has always been an important area in armoured vehicle development: current studies are being done on the welding of ultra hard steels and a range of high strength aluminium alloys, including the newly developed aluminium-lithium alloys, using a variety of manual, semi-automatic and automatic welding techniques. This research covers both the development of welding procedures and the assessment of weld joint properties.

In the general area of materials for use in heavy duty engineering applications, current emphasis is being placed on the cost effective use of castings. Components produced in aluminium alloys by the squeeze-casting process are being evaluated and a new, high strength aluminium alloy produced by sand casting is being assessed. Work is also being done on the evaluation of castings produced in spheroidal graphite (SG) cast irons.

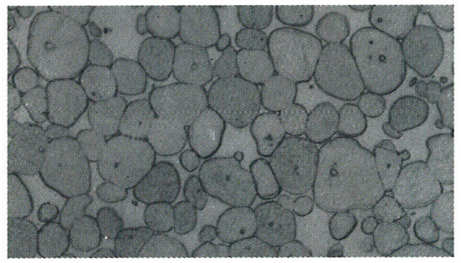
Research is also being conducted into the development of high damping capacity alloys to reduce noise and vibration.

Tungsten Research for KE Penetrators

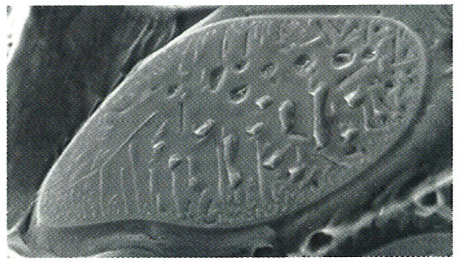
In the 1970s RARDE began research on high density tungsten alloys for use as Kinetic Energy penetrators. These alloys, based on tungsten-nickel-copper and tungsten-nickel-iron, offered significant ballistic improvement when compared with tungsten carbide penetrators.

In particular they are more effective in the attack of complex targets at high angles of obliquity.

In order fully to exploit the potential of tungsten alloys great diligence must be shown during manufacture, by liquid phase sintering elemental powder compacts, to ensure that a sound, fully dense structure is produced.



Microstructure of Tungsten – Nickel – Iron Alloy



Precipitation on exposed tungsten grain boundary

After the manufacturing process is completed, the microstructure, and hence properties, can be controlled by the use of a high-temperature heat treatment.

Recently we have found that this heat treatment produces a previously undetected precipitation reaction at the tungsten-tungsten grain boundaries which makes a significant contribution to the improved mechanical properties.

We are carrying out an extensive research programme on the effects of cold working the tungsten alloys; so far a two-fold increase in strength has been achieved and further benefits in properties have been gained by a heat treatment after cold working.

Testing Explosives

There is a constant search for new explosive compositions and filling techniques to improve the performance, reliability and safety of munitions.

High-speed cameras and flash X-ray equipment are used with a variety of miniature gauges to probe the initiation and propagation of detonation waves in explosive charges, providing input data for hydrodynamic models of weapon systems.

Of equal interest is the study of the response of explosives to a variety of accidental impacts, including high velocity.

Here knowledge of the chemistry of the reaction processes is needed in addition to physical data to allow models to be constructed.

The CRAY computer is being employed in molecular orbital calculations of the effects of high pressure on energy levels in explosives molecules with the aim of aiding calculations that give a clear picture of reaction mechanisms.

This work is supported by experimental programmes and is aimed to achieve a fundamental understanding of and capability to predict explosive hazards.

How Long do Gun and Rocket Propellants Last?

As part of its studies into the chemistry of propellants aimed at the prediction of the Service life of gun and rocket propellants, RARDE is investigating the mechanism of degradation of nitrate ester based propellants. The Service demands for longer lifetimes, particularly for the largest service motors, places an increasing burden on the scientist to develop reliable models for prediction.

Since the break down of a nitrate ester leads to the production of oxides of nitrogen, the research centres on chemical rate studies using the Chemiluminescence Analyser developed at RARDE. This highly sensitive technique has been successfully adapted to provide vital chemical information on propellants and their ingredients which is not only increasing the basic understanding but also a sounder foundation for the prediction of Service life.

Airfield Damage Repair

Airfields have long been prime targets for enemy attack both to destroy installations and by cratering the runways to render them unusable by aircraft. Further, in an attempt to frustrate the rapid repair of the runways, explosive devices are left scattered around the craters.

Although this problem has been faced for many years, and solutions found, it is still of immediate concern as the enemy's airfield denial weapons are becoming increasingly more sophisticated.

Our principal areas of research into airfield damage repair are:

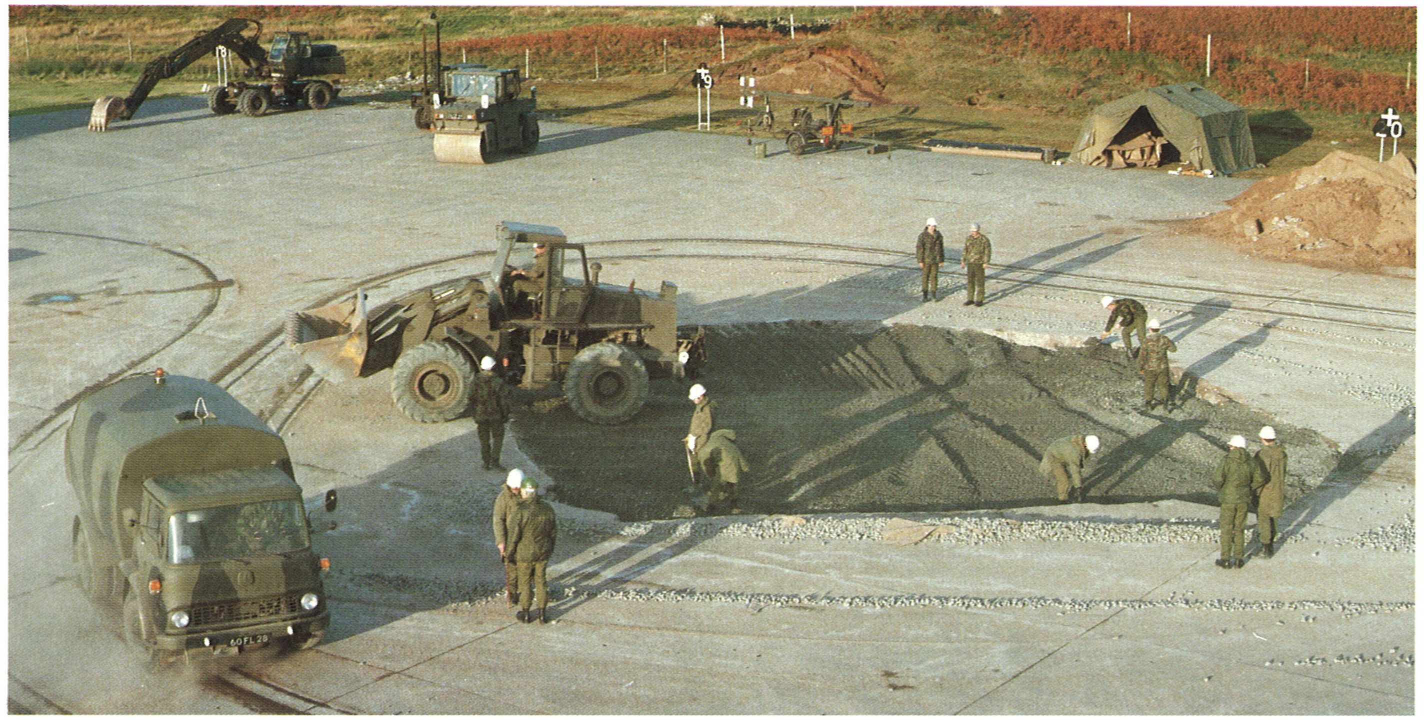
a) As airfields are large areas; to study the use of aerially-carried sensors for post attack runway reconnaissance, the information being fed directly to ground displays together with automatic processing of the data to aid decision making, tasking and control.

b) To examine means for the detection and safe disposal of all unexploded devices.

c) Developing pile driving equipment for the dynamic compaction of crater fill.

d) Investigating the range of fast-setting materials for the rapid resurfacing of crater repairs, capable of withstanding use by modern high-performance aircraft. Success has been achieved using magnesium phosphate materials for minor damage repair and now research is concentrating on extending the capability and matching the materials to mixing and dispensing systems.

Crater fill trials



Fibre-Reinforced Materials

Process developments by industry are making available carbon, aromatic and ceramic fibres which all have high values of strength and stiffness.

These are gradually approaching the limiting values available from the strongest chemical bonds. The fibres also have intrinsically low densities, so that they can be incorporated in polymeric, metallic or ceramic matrices to generate a range of lightweight structural materials.

These materials have controlled mechanical, thermal and electrical properties which conventional metals do not possess. By using them the mass of some major aerospace components has already been reduced by 25 to 50%.

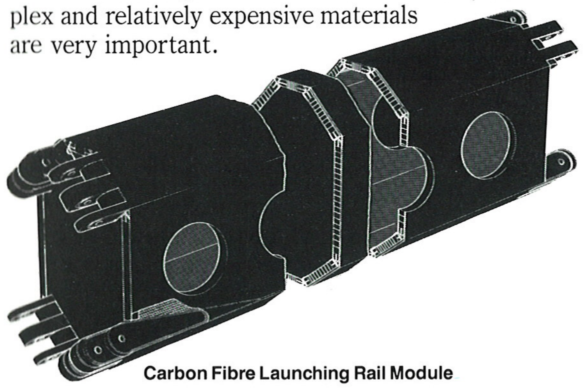
Efficient design and use of these complex and relatively expensive materials are very important.

RARDE researches the subject of fibre-reinforced materials in order to introduce them, often in combination with other materials, within the defence field.

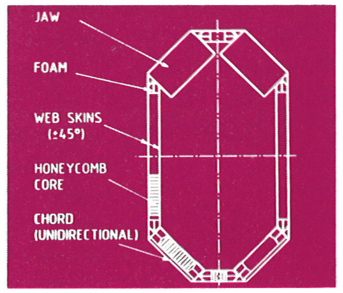
The key areas of interest are:

Synthesis and prediction of specific properties
Measurement and modelling of long-term behaviour in military environments
Stress analysis and thermal analysis for components and structures
Novel low-cost processing

These reinforced materials are required for the structure of future craft, missiles and projectiles in air and space; for air-portable and man-portable arms and equipment; and for engineering structures and components stressed by their own mass or inertia such as bridges, flywheels and pistons.



Carbon Fibre Launching Rail Module



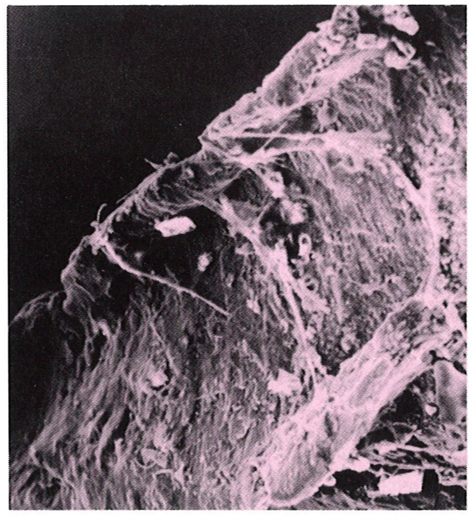
Launching Rail Section

Forensic Science

Forensic science investigations are often of great importance evidentially, primarily to establish the cause of the incident but, occasionally, in subsequent legal proceedings. As a result of the expertise and reputation built up by RARDE in explosives technology and materials science, the Establishment is often involved in investigations where there is a suspicion that explosives may have been used.

Forensic work requires people with wide experience together with great expertise in a diverse range of advanced analytical techniques – knowing where and in what circumstances to look for explosive traces is as important as being able to recover and identify them. Research is being undertaken to investigate the rate of uptake by, the mechanism of persistence in, and the recovery of, volatile explosive ingredients from materials of both natural and synthetic origins.

One particular interest is assistance in aircraft crash investigations where it is important to be able to distinguish damage patterns resulting from mechanical break-up of the aircraft caused by a system failure or impact, from those that may have been caused by the detonation of an explosive device. Studies are being undertaken to determine any unique features exhibited by materials, metallic or non-metallic, damaged by a detonating explosive and the high velocity fragments so produced which are not seen in damage resulting from 'slow' impact.



Scanning electron micrographs (x25)

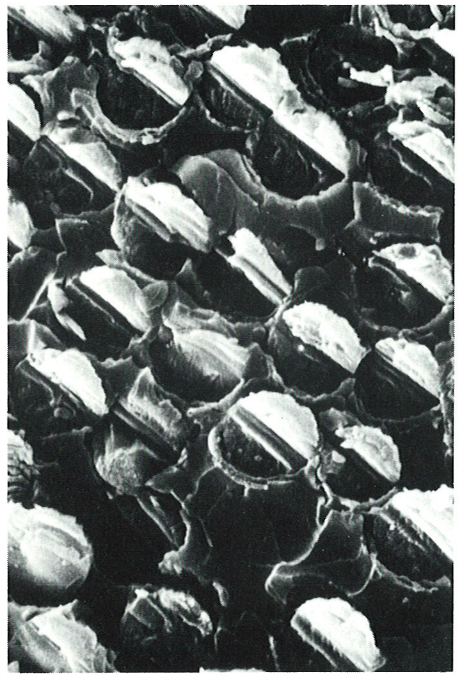
Characteristics of explosive damage in aircraft. Rolled edges of fragments and debris pitting surrounding metal.

Advanced Fibrous Composites for Bridging

Modern military bridging demands materials of high specific strength and stiffness.

Advanced fibrous composites are being evaluated because of their favourable properties compared with aluminium alloys and high strength steels and research is being conducted at Christchurch to investigate weight reductions and costs.

Materials under scrutiny include long fibres of carbon, Kevlar and glass in epoxy resin matrices.



Photomicrograph (x1000) of a compression failure in a carbon fibre reinforced plastic military bridge component

The main research project is the design and fabrication of a 60 m concept demonstrator launching rail which will be a mid-life improvement for an existing system.

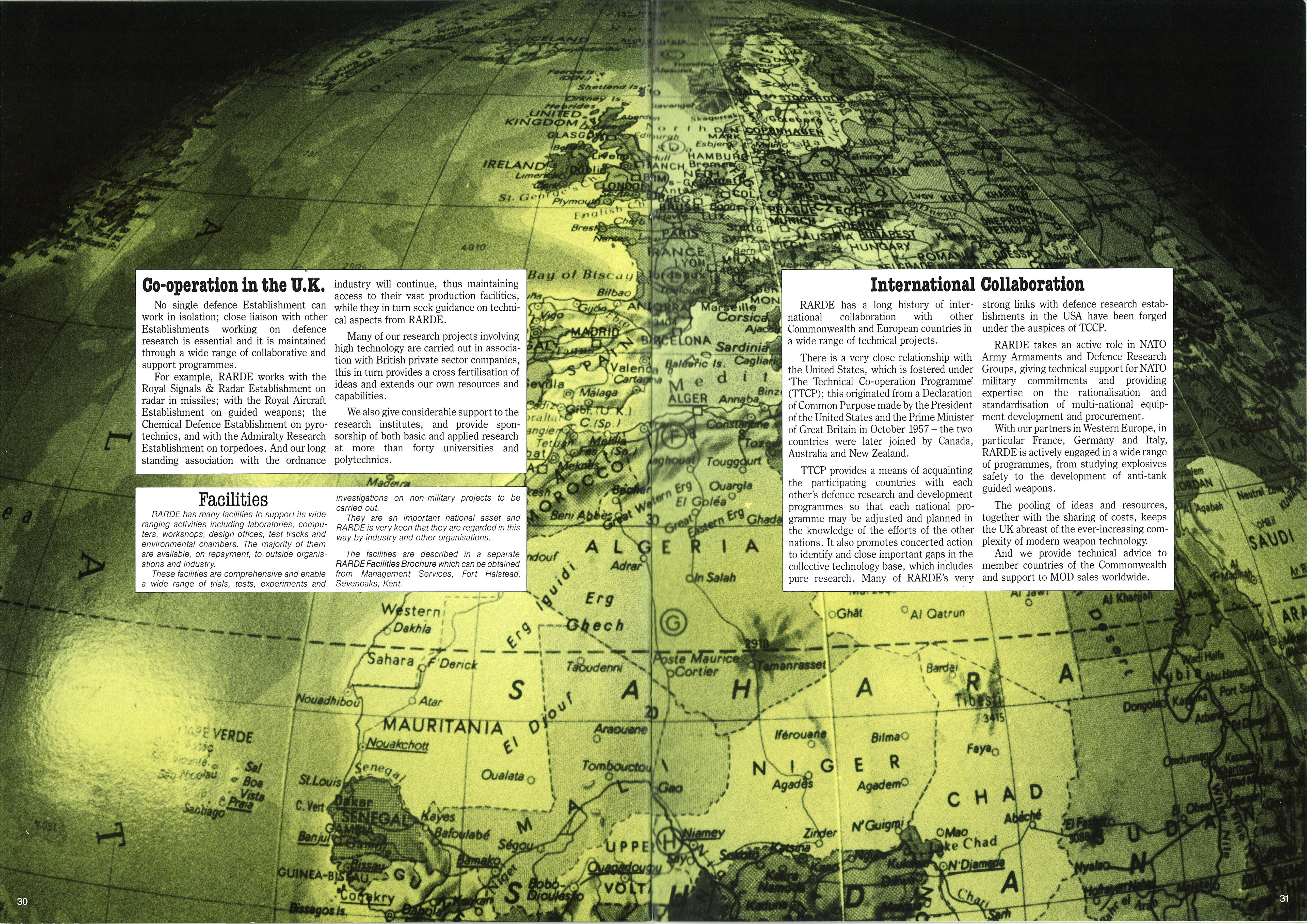
Research includes studies of concentrated loads normal to fibres, compressive properties, joints, impact protection, drag coefficients, lateral instability, vibration and warping effects.

Other areas of investigation include effects of thermal flash, napalm and ballistic damage, environmental degradation and NDT techniques.

Fabrication methods being considered include card and filament winding, and vacuum bag techniques.

It is hoped to include rigid carbon composite tension links for reinforcement, and Kevlar scissoring ropes in one system, with 40% weight savings over conventional materials.

This work is being carried out by an integrated section of bridge designers and materials scientists, with on-site design office, materials laboratory and workshop support. The work aims to introduce robust composite minimum weight components into service at a reasonable cost and thus develop technology that could benefit other MOD structures.



Co-operation in the U.K.

No single defence Establishment can work in isolation; close liaison with other Establishments working on defence research is essential and it is maintained through a wide range of collaborative and support programmes.

For example, RARDE works with the Royal Signals & Radar Establishment on radar in missiles; with the Royal Aircraft Establishment on guided weapons; the Chemical Defence Establishment on pyrotechnics, and with the Admiralty Research Establishment on torpedoes. And our long standing association with the ordnance industry will continue, thus maintaining access to their vast production facilities, while they in turn seek guidance on technical aspects from RARDE.

Many of our research projects involving high technology are carried out in association with British private sector companies, this in turn provides a cross fertilisation of ideas and extends our own resources and capabilities.

We also give considerable support to the research institutes, and provide sponsorship of both basic and applied research at more than forty universities and polytechnics.

Facilities

RARDE has many facilities to support its wide ranging activities including laboratories, computers, workshops, design offices, test tracks and environmental chambers. The majority of them are available, on repayment, to outside organisations and industry.

These facilities are comprehensive and enable a wide range of trials, tests, experiments and investigations on non-military projects to be carried out.

They are an important national asset and RARDE is very keen that they are regarded in this way by industry and other organisations.

*The facilities are described in a separate **RARDE Facilities Brochure** which can be obtained from Management Services, Fort Halstead, Sevenoaks, Kent.*

International Collaboration

RARDE has a long history of international collaboration with other Commonwealth and European countries in a wide range of technical projects.

There is a very close relationship with the United States, which is fostered under 'The Technical Co-operation Programme' (TTCP); this originated from a Declaration of Common Purpose made by the President of the United States and the Prime Minister of Great Britain in October 1957 – the two countries were later joined by Canada, Australia and New Zealand.

TTCP provides a means of acquainting the participating countries with each other's defence research and development programmes so that each national programme may be adjusted and planned in the knowledge of the efforts of the other nations. It also promotes concerted action to identify and close important gaps in the collective technology base, which includes pure research. Many of RARDE's very strong links with defence research establishments in the USA have been forged under the auspices of TCCP.

RARDE takes an active role in NATO Army Armaments and Defence Research Groups, giving technical support for NATO military commitments and providing expertise on the rationalisation and standardisation of multi-national equipment development and procurement.

With our partners in Western Europe, in particular France, Germany and Italy, RARDE is actively engaged in a wide range of programmes, from studying explosives safety to the development of anti-tank guided weapons.

The pooling of ideas and resources, together with the sharing of costs, keeps the UK abreast of the ever-increasing complexity of modern weapon technology.

And we provide technical advice to member countries of the Commonwealth and support to MOD sales worldwide.

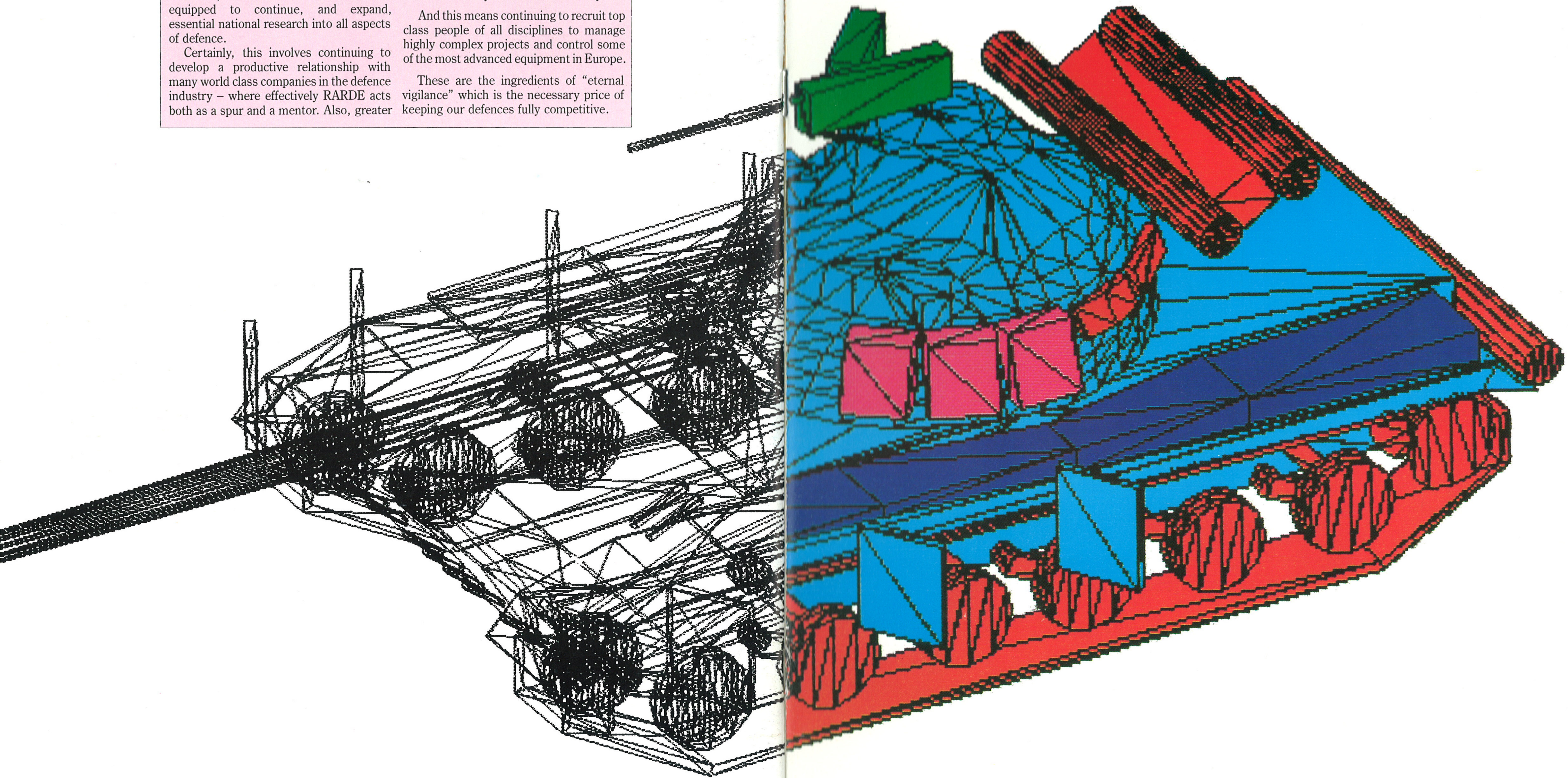
A continuing and expanding role

Technology is becoming ever more sophisticated, but with its new, cohesive structure, RARDE is better than ever equipped to continue, and expand, essential national research into all aspects of defence.

Certainly, this involves continuing to develop a productive relationship with many world class companies in the defence industry – where effectively RARDE acts both as a spur and a mentor. Also, greater emphasis will be placed on promoting the commercial exploitation of our work and achievements by British civil industry.

And this means continuing to recruit top class people of all disciplines to manage highly complex projects and control some of the most advanced equipment in Europe.

These are the ingredients of "eternal vigilance" which is the necessary price of keeping our defences fully competitive.



Computer lethality analysis of a target vehicle