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The Rocket Propulsion Establishment, Westcott

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IN THE first issue of the JOURNAL for 1966, the Centenary Year of the Royal Aeronautical Society, an account of the history of the Rocket Propulsion Establishment, no matter how brief, may appear to some as an unwarrantable intrusion. It is in this year, 1966, that the Establishment will complete only its second decade of existence, but it may claim to have contributed to the advancement of aeronautics, in the broadest sense of this term.

The founding of the Establishment in April 1946 did not mark the beginning of rocketry in this country. The British Navy used rockets in 1801 at the Battle of Copenhagen, but we can claim a continuous story for military development only from just before the last war.

Dr. H. J. Poole, who died in 1963 soon after retirement, is regarded by some as the Father of British Rocketry. First at Woolwich and then at Fort Halstead he created the basis of a sound rocket technology and under his technical leadership the Projectile Development Establishment, of the Ministry of Supply, at Aberporth was engaged in the intensive development of short duration solid propellent rockets for anti-aircraft use and as aircraft armament. Also within the Ministry of Supply, the Armament Design Department and the Armament Research Department had engaged Isaac Lubbock of the Asiatic Petroleum Company to develop a rocket operating on liquid oxygen and petrol.

Sound though it was, the British effort was puny compared with that of the Germans and it is generally recognised that German wartime developments constituted the greatest possible post-war stimulus to Britain, America and Russia to adopt rockets as major propulsive devices.

The Wasserfall, a supersonic rocket-propelled surface-to-air guided missile was approaching operational use. The X4, a subsonic rocket-propelled wire-guided air-to-air missile was approaching operational use. The HS293, a glide bomb rocket launched from an aircraft, was used against the Allied Navies. The ME163, fitted with a variable thrust liquid bipropellent rocket, was the first fighter aircraft to be so propelled. The V2 was the first rocket-propelled ballistic missile.

It was only with the end of the war that the full significance of the German developments could be appreciated and credit must go to Sir Alwyn Crow and Mr. (now Sir) William Cook for setting up the Guided Projectile Establishment, which came into being at Westcott in April 1946. Concurrently, the Director of the Royal Aircraft Establishment, Mr. W. G. A. Perring, set up the Controlled Weapons Department at Farnborough. It soon became clear that some rationalisation was necessary and this was achieved in 1947 by concentrating all research and development, other than propulsion, in the newly named Guided Weapons Department at Farnborough and concentrating research and development on rockets at Westcott, which now became the Rocket Propulsion Department of the RAE. With these changes, Bill Cook moved to the Admiralty and Alec Baxter was transferred from Farnborough to Westcott as Superintendent, having sole charge until late 1947, when Air Commodore Charles Dann was appointed Chief Superintendent.

Shortly before Dann took up his appointment, Westcott suffered its first serious accident in which there was tragic loss of life and many injured. One cannot undo what happened, but one can and must learn from events. Westcott did learn and no fatalities or injuries have been incurred due to any incident on a test site since that date. Unfortunately, our safety record was again marred in 1956 by an accident in one of the laboratories, but since then we have suffered no fatalities.

Under Dann, the Establishment settled down to a period of growth with the scientific and technical effort deployed along two main lines. The first was the development of liquid bi-propellent rockets, using liquid oxygen, hydrogen peroxide and nitric acid as oxidisers. The second was the development of solid propellent rockets, using extruded cordite and plastic propellent, this latter being a continuation of a wartime concept of Poole. To cater for these developments, test beds were built, incorporating principles promulgated after the 1947 accident, to ensure operational safety of personnel, such as no direct vision between the test team and the rocket. The solid propellent laboratory area was established, incorporating what was considered best from ordnance factory experience in the way of building construction, protecting earthworks and safety distances between buildings. In the general planning of the solid propellent laboratory great credit must be given to Dr. K. D. Errington, a protegé of Poole and then a member of Westcott staff but now Assistant Director, Guided Weapons (Propulsion and Warheads) in the Ministry of Aviation.

Alec Baxter, who had devoted most of his efforts to building up the programme on liquid propellent rockets, left the Establishment in 1950 to take up the appointment of Professor of Propulsion at the College of Aeronautics, Cranfield. Two Superintendents were then appointed, Dr. W. R. Maxwell in charge of Research and Garth (G. O.) Jones, from the GWD, RAE, in charge of Projects.

In 1951, Charles Dann was appointed to the British Defence Research Staff in Washington and was succeeded as Chief Superintendent by Dr. T. P. Hughes, then Head of Chemistry Department, RAE. Under Tom Hughes, the Combustion and Materials Division was set up, headed by Dr. W. G. Parker, who is now Professor of Chemistry at the University of Aston, Birmingham. Towards the end of 1955 Tom Hughes took up a research post in Industry and was succeeded by the writer on the 1st December 1955. It is pleasant to record that he is still supported by two founder members of Westcott, Dr. W. R. Maxwell and G. J. Peebles (known as "P"), Head of Technical Services. In addition there are two other Superintendents, not founder members, but nevertheless with good years of service behind them, namely Dr. J. H. Crook in charge of the Solid Propellent Division and Dr. J. D. Lewis in charge of the Liquid Propellent Division. Other names are mentioned later and it would give the writer much pleasure to refer to many more, of whom some have moved on to other fields, some have retired but many are still active and continue to contribute to rocket technology. Some have justly acquired international reputations. It is by the collective efforts of all these people that the Establishment has built up and maintains a programme on those research items considered necessary for an understanding and control of basic rocket phenomena and contributed in a direct tangible manner to the success of projects by designing and developing the rocket power units.

Thus far the emphasis of this brief history has been on personnel and it is now necessary to move on and, being as succinct as possible, describe some of Westcott's contributions. However, before doing so the historical record on the metamorphoses of the name of the Establishment must be completed. On the 1st August 1958 the administrative links with Farnborough were severed and Westcott became the Rocket Propulsion Establishment, answering directly to the Controller of Guided Weapons and Electronics, Ministry of Supply, but soon to become Ministry of Aviation. At the same time, the Head of the Establishment changed his title from Chief Superintendent to Director. The severance of the administrative links with Farnborough in no way impaired the scientific and technical liaison with that great Establishment. The development of rockets creates and demands much worthwhile and interesting research, but nevertheless rockets are a means to an end and not an end in themselves. Westcott cannot therefore exist in isolation and must work closely with its sister establishments, particularly the ERDE at Waltham Abbey, RAE at Farnborough and Aberporth and RRE at Malvern. With them and with Industry, Westcott shares in the vicissitudes stemming from both technical development and the evolution of defence policy.

In the immediate post-war years the emphasis in the guided weapon programme lay in the development of air-to-air and surface-to-air defensive missiles, the effective ranges of both types being limited by the guidance and control systems. For the air-to-air missile, adequate propulsive power was provided by a solid propellent boost motor of short duration, for which a loose inhibited cordite charge was satisfactory and for which an adequate technology existed. A more severe propulsion problem was created by the surface-to-air weapons, of which three types were being developed, namely Red Duster, Red Shoes and Seaslug. Red Duster, with twin ram jets to provide the sustained thrust, was the forerunner of Bloodhound; Red Shoes, with a hydrogen peroxide/kerosine sustainer motor, was the forerunner of Thunderbird; and Seaslug, with a nitric acid/methanol (later kerosine) sustainer motor, was the forerunner of Seaslug. The inelegant name unfortunately persisting due to an Admiral's post-Trandial indiscretion.

A common requirement of these three missiles was rapid acceleration off the launcher to supersonic speed and it was accepted without question that the only way to achieve this was by a solid propellent boost motor or motors. At that time similar requirements in America for missiles such as Talos, Terrier and Nike were being met by single tandem solid propellent boost motors, which by the prevailing standards were large and beyond the immediate range of British technology. The British solution was to use a cluster of motors, still of a size yet to be developed.

For thrust during sustained flight, Red Duster differed from Red Shoes and Seaslug, but the ram jets for the first and the rockets for the second and third had to be developed from scratch. As with the large single tandem boost motor, a solid-propellent sustained motor was too far along the development path to be acceptable for Red Shoes and Seaslug and the only course open was to adopt liquid bi-propellent rockets. In later years this course met with some criticism which was not really justified. The critics were overlooking the state of British rocket technology in the late 1940's and the war-time achievements of the Germans with liquid bi-propellent rockets. There is no doubt that the correct choice was made, having in mind the urgent requirement to get test vehicles flying as soon as possible.

Napier's and Armstrong Whitworth's respectively were responsible for the design and development of the propulsion units for Red Shoes and Seaslug. The RAE had requirements for flight test vehicles to study aerodynamic, structural and control problems under supersonic flight conditions and, by way of general support to the two firms and specific support to the Establishment, Westcott developed some simple fixed thrust rocket engines using pressurised propellent expulsion systems. For the first research vehicle (R.T.V.I*) liquid oxygen and a mixture of methyl alcohol and water were used. For R.T.V.II, the KP1 motor was developed using hydrogen peroxide and kerosine with C Fuel (57 per cent methanol, 30 per cent hydrazine hydrate and 13 per cent water) as the igniting fuel. This was followed by a series of motors using hydrogen peroxide, of which one type powered the General Purpose Test Vehicle, GPV2, made by Short Bros & Harland. Because of its storable characteristics, nitric acid was selected as the oxidiser for Seaslug, and in support of this programme Hagerty began the development of the NK1, a test vehicle of which the complete propulsion unit constituted the major structural component. The propellents were nitric acid and kerosine. This vehicle reached the flight stage and demonstrated the feasibility of storing nitric acid in a rocket propellent tank for periods greater than one year.

Although guided weapons were the major stimulus for rocket development, Val Cleaver at de Havilland's and Sid Allen at Armstrong Siddeley Motors were developing liquid propellent rockets for potential use in aircraft either as units to assist take-off, or as main power units. The development of the Sprite and Spectre at de Havilland's and of the Snarler and Screamer at Armstrong Siddeley Motors is already well recorded, but this is not so for the parallel development of the Gamma by Broughton and Walder at Westcott. As a research and development exercise the Gamma incorporated many pioneering features. It operated on hydrogen peroxide and kerosine and was the first British rocket engine to have self-driven pumps feeding the propellents to the combustion chamber. More important, it incorporated a silver-plated nickel gauze catalyst for decomposing the peroxide and this permitted the adoption of the thermal ignition system whereby the kerosine was ignited automatically in the combustion chamber by the hot steam and oxygen. The use of a solid catalyst and thermal ignition may now be regarded as a *sine qua non* in any rocket engine using peroxide and is a major contributor to the success of Black Knight, which is powered by Gamma engines made by Bristol Siddeley Engines who, as Armstrong Siddeley Motors, acquired the Gamma design in 1955. The performance of the Gamma engine is critically dependent on the behaviour of the solid catalyst and this opportunity must be taken to give recognition to Dr. F. T. Maggs, whose painstaking and patient work has established sound design and manufacturing techniques.

Returning now to the late 40's and to the solid propellent side, effort was concentrated on improving the technology associated with the use of loose inhibited cordite charges and in creating the technology associated with the use of the new plastic propellent, based on ammonium perchlorate and polyisobutene, which ERDE had devised. Out of the former emerged a series of motors of which Magpie, Linnet, Scarab, Ladybird and Gosling are typical examples. The last mentioned was used in clusters of four as the boost for the early trials of Red Duster, Red Shoes and Seaslug. A modern version of Gosling is still used as the boost for Bloodhound and Thunderbird.

The creation of the technology on plastic propellent is worthy of its own historical account. Here, all one can say is that its advent presented the rocket motor designer with many more degrees of freedom. Within limits, the restriction on motor diameter was removed, a wide range of burning rates became available and, as the propellent could be bonded to the walls of the motor tube, the charge was provided with structural support throughout its whole length. Case bonding also permitted higher loading densities. The characteristics of plastic propellent demanded

*A development from LOP/GAP, an anti-aircraft missile designed in 1944 by the then Armament Design Department with the assistance of the Asiatic Petroleum Co. (Isaac Lubbock) and the then Armament Research Department. These two Departments were later combined to form the present RARDE. The original motor was designed to use liquid oxygen and petrol, but this combination was abandoned in favour of liquid oxygen with methyl alcohol/water in 1947 when Westcott took over the development.

new techniques for the filling of the motor case and for the shaping of the charge and here acknowledgement must be made to Dr. J. H. Crook who invented the "short former", an elegant device which takes full advantage of the rheological properties of the propellent. By the early 1950's sufficient confidence had been gained for a design to be undertaken of a sustainer motor for Red Shoes. The success of this development, and of the parallel development on cast double base charges by ICI at Summerfield, may be judged by the fact that by 1953 solid-propellent rockets became the sole means of propulsion for British guided weapons with the one exception of the ram jet sustainer engines in Red Duster. The almost complete monopoly which the solid-propellent rocket then acquired for the propulsion of guided missiles remains to this day. There are one or two notable exceptions, but without denigrating the liquid-propellent rocket, it is generally true to say that the solid-propellent rocket better meets the needs of the Services who rightly demand durability, minimum maintenance, ease of handling and instant readiness. The writer is well aware that the foregoing statement will create some cries of dissent. He is also aware of the arguments on which this dissent will be based and accepts that the liquid bi-propellent rocket can fill certain roles not open to the solid-propellent rocket.

Following the deliberations of the Gassiot Committee of the Royal Society and the preparations put in train for British participation in the International Geophysical Year, which began in July 1957, the RAE undertook the design and development of an upper atmosphere research vehicle, Skylark, and called upon Westcott to design the propulsion unit. The outcome of this design study, started by Maxwell in 1955, was the Raven motor, nearly 18 inches in external diameter and 17 ft long, containing nearly one ton of plastic propellent. As the propulsive unit of Skylark, Raven is its biggest component. The first static test firing of the motor took place at Westcott towards the end of 1956 and the first projection of Skylark at Woomera was in February 1957, and since that date over 100 have been successfully launched, carrying payloads to altitudes of 100 miles or more. This development was closely followed by the Rook motor, dimensionally similar to the Raven but with a faster-burning propellent and used as the first stage boost of the Jaguar supersonic test vehicle. Inevitably higher payloads and greater altitudes came to be demanded from Skylark and this was met by improvements to the Raven and by the design and development of the Cuckoo motor, also filled with plastic propellent, which acts as a boost for Skylark and as a second stage on the top of Black Knight. The success of rockets in providing means for upper atmosphere research stimulated the interest of the Meteorological Office and jointly with Bristol Aerojet, Westcott developed the Chick and Bantam motors, respectively the boost and sustainer for the Skua Meteorological Test Vehicle. The first firing of Skua took place in January 1964 and over 50 have been launched, taking meteorological payloads to altitudes approaching 400 000 ft.

Although the full range of Westcott solid-propellent rockets cannot now be given, sufficient has been said to indicate that they are playing a vital role in the British defence and research programme.

Once more going back in time, to 1953, two concepts were being mooted, namely a mixed powerplant fighter aircraft and a ballistic missile. For the former, the intrinsic merits of the liquid bi-propellent rocket and the limitations of the solid-propellent rocket eliminated all doubts on what was the correct choice. The Westcott Gamma engine was given serious consideration, but the decision was taken to use the de Havilland Spectre which, like the Gamma, operated on hydrogen peroxide and kerosine. As a preliminary exercise to demonstrate the feasibility of the mixed powerplant concept, Saunders-Roe designed the SR53, of which two were built, and Westcott's contribution lay in its advisory role to the two firms. Unfortunately, the first crashed during trials at Boscombe Down in June 1958 but the second is to go to the RAF Museum at Henlow.

For the ballistic missile concept, being in the pre-Polaris and pre-Minuteman days, there was also no hesitation in selecting the liquid bi-propellent rocket and in 1955 Rolls-Royce contracted to build an engine, of Rocketdyne design, using liquid oxygen and kerosine. The introduction of the ballistic missile brought about entirely new requirements in the way of test facilities, even for the propulsion unit alone. Spadeadam Waste in Cumberland was selected as the site for the development of Blue Streak, as the missile was now known, but it was evident that actual engine testing would be required while "Waste" was still an operative word. Accordingly, Westcott began preparing its P2 Site, which had been modified in 1955 for vertical firing, to take the Rolls-Royce engine, designated RZ1. In so far as liquid-propellent rockets were concerned, this meant catering for thrusts one order of magnitude greater than anything yet tested at Westcott. It also necessitated the design and introduction of new measuring and recording equipment and new devices to comply with our principles on safety. In May 1958 the joint RPE—R-R team began engine tests and one can assess the success of this combined operation from the fact that, including ignition tests, over 500 firings were made by April 1960 when Blue Streak, as a ballistic missile, was cancelled.

Following this cancellation, negotiations began between Britain and many European countries on a co-operative programme for space research, out of which the European Space Research Organisation and the European Launcher Development Organisation have been formed. Under this latter body, the development of the de-militarised Blue Streak has continued with the intention of making it the first stage of the launching vehicle, Europa I. Although not so intensively as in the pre-April 1960 period, Westcott has continued its collaboration with Rolls-Royce on detailed problems associated with the RZ engines. Also within the past five years a programme on cryogenics has been instituted, aimed particularly at the use of hydrogen as a rocket fuel. In this field of cryogenics there is much room for technological advance, extending well beyond the limit set by rocket applications, but it is these latter which are setting the pace for the team led by Dr. B. W. A. Ricketson who, before 1960, had worked on the underground launching site for Blue Streak.

Earlier in this story mention was made of the vicissitudes stemming from technical development and from the evolution of defence policy. Blue Streak is a representative case which gives emphasis to the stabilising value of a sound research programme. Yet little has been said about research. Perhaps this is because research cannot be "dated" in the manner of projects and is therefore not so amenable to chronological accounting, notwithstanding the hard knocks which the writer has just inflicted on chronology. However, it is by research that technology is advanced and by which experts are created, to be available to meet the fluctuating demands of project development. Thus the existence of projects in this rapidly advancing field of rocket applications gives implicit recognition to the existence of a research programme at Westcott, which is now contributing to the future advancement of aeronautics and astronautics.