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Rocketry and Space Flight

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THE FIRST hundred years of the Royal Aeronautical Society have seen nearly all of man's significant achievements in controlled flight by airships, aeroplanes and helicopters. This is hardly surprising, since the Society was formed in 1866, when the time was nearly ripe for such developments to begin. It is perhaps even more striking, however, to realise that throughout the second half of the same century, most of the early evolution of an even more ambitious form of flight has also taken place.

The vehicle for this has been the rocket, and it is the fundamental characteristic of rocket propulsion—its independence of an external atmosphere—which has made possible this further excursion of flight into outer space. The most exciting developments in this field have occurred during the last quarter of a century and they continue at an accelerating pace as the Society reaches its Centenary.

British contributions to this technological adventure have so far been relatively modest. While by no means entirely negligible, they certainly do not compare with the great pioneering achievements by British scientists and engineers in almost every other branch of technology. There are perhaps three exceptions to this statement, which will be mentioned. However, the broad generalisation remains true, and it is the reason why most of the references are to foreign achievements, even though here the primary intention is to survey British aerospace history, and in particular that of the RAeS and its members.

The pre-history of rocketry and space-flight is found in the many legends and romances about travel to other worlds, culminating in the novels of Jules Verne, H. G. Wells, and others, and the whole of modern science fiction. In parallel with these, the rocket was developed, probably by the Chinese first, nearly nine hundred years ago. It may be more accurate to refer to its "discovery" rather than to its "invention".

At all events, rockets were adopted as primitive war weapons in Asia, and used against the British in their Indian campaigns. This led to the first exception of a notable British contribution, since Sir William Congreve (1772-1828) developed the unguided "surface-to-surface" rocket into a refined device for its time. The British rocket corps played quite a significant role in the Napoleonic Wars and in the War of 1812 against the new United States of America—hence the reference to "The rockets' red glare" in one of their patriotic anthems. It refers to a British attack on Washington, incredible as that may sound in 1966.

All this was some half a century before the Society's foundation, but when it had been in existence for about a third of a century, a further significant development occurred. Just before the turn of the century, it began to be appreciated that the principle of rocket propulsion provided, in theory at least, the means of realising the dream of flight beyond the atmosphere. The Society's own early Journals contain some references to rocket and other forms of reaction propulsion, but the first major discussion in relation to space flight and before the end of the 19th century, was undoubtedly due to the Russian Konstantin Tsiolkovsky (1857-1935). This remarkable man continued to carry out theoretical investigations of rocketry and space-flight for several decades thereafter; he also wrote on the subjects of aerodynamics and metal-hulled airships.

After Tsiolkovsky, there came the great American pioneer, Dr. Goddard (1882-1945), whose first major publication was dated 1919, and who actually fired the world's first liquid-propellant rocket (although it travelled only 184 ft!) in 1926. His contributions would have been even more significant had he not persisted in working in secrecy.

A contemporary of Goddard's was Robert Esnault-Pelterie (1881-1957), the Frenchman who is also usually credited with invention of the aeroplane "joy-stick" control and with much early development of the static radial air-cooled piston engine. Our own Vickers Company began its manufacture of aeroplanes with a licence for his REP monoplanes in 1910, and soon after this Esnault-Pelterie was published papers on space-flight. Later, he made some of the earliest experiments with liquid-propellant rocket engines, after the First World War.

In the 1920's, there was also a significant development of theoretical interest in rocketry and space-flight in Germany and Central Europe. The greatest name to emerge from this was that of Herman Oberth (b. 1894), but those of Eugen Sänger (1905-1964), Guido von Pirquet (b. 1880), and many others, are also memorable.

The stage was now set for the next phase in rocket development—practical experiment, and the demonstration (albeit on a small scale) of the essential features of liquid-propellant engines. As far as the world at large was concerned, this was first accomplished by small amateur societies working with slender resources—negligible ones, by contemporary standards. The first was the German Verein für Raumschiffahrt, founded by Dr. Winkler in 1927, and largely stimulated by Herman Oberth and his amazingly farsighted ideas, which (in contrast to Goddard's) were well-publicised by books and other means. It also included such men as Nebel, the Riedels, Valier, Engel, Ley and the young von Braun. By the early 1930's VfR had built many small rocket engines and flown small rockets.

At about the same time, an American Interplanetary Society was formed (in 1930), and did similar work. It changed its name to the American Rocket Society in 1932, and finally merged with the Institute of Aerospace Sciences (in 1962) to become the present AIAA. During the war, several of its leading members formed Reaction Motors, Inc (now the RMI Div of the Thiokol Corpn), one of the earliest American organisations to develop rocket engines.

The British Interplanetary Society was founded in 1933 by P. E. Cleator. It never built rockets, and before the war it always had less than 100 members, who were largely regarded as cranks. Some of them undoubtedly were, but the allusion is made by the present writer in no derogatory spirit, if for no other reason than because he became a member himself in 1937, the year after joining the RAeS. Further reference will be made to the BIS later, as providing a third exceptional British contribution to the subject, but their "finest hour" really came in the first post-war decade. However, even in 1938, they achieved publicity with an outline design for a Lunar spaceship (Fig. 1).

Believing that the pumping problems of huge liquid-propellant engines would be prohibitive, this BIS proposal was based on the use of solids, but these were to be of a high-energy, "aluminised" formulation. Also, the configuration was not only of the multi-stage type, but "cellular"—each stage itself consisted of many solid motors, to be jettisoned as they were burnt. The manned capsule and its heat shield, the lunar landing gear, and the proposed instrumentation (a system of integrating accelerometers which contained the germ of the idea of inertial navigation), were all remarkably modern concepts, far ahead of most of the contemporary published ideas on "spaceships". The project was largely due to J. H. Edwards, R. A. Smith, H. E. Ross and A. Janser; the realism of the design features mentioned was hardly matched by the pre-war BIS's claim that "the money spent on a single destroyer would suffice to land men on the Moon".

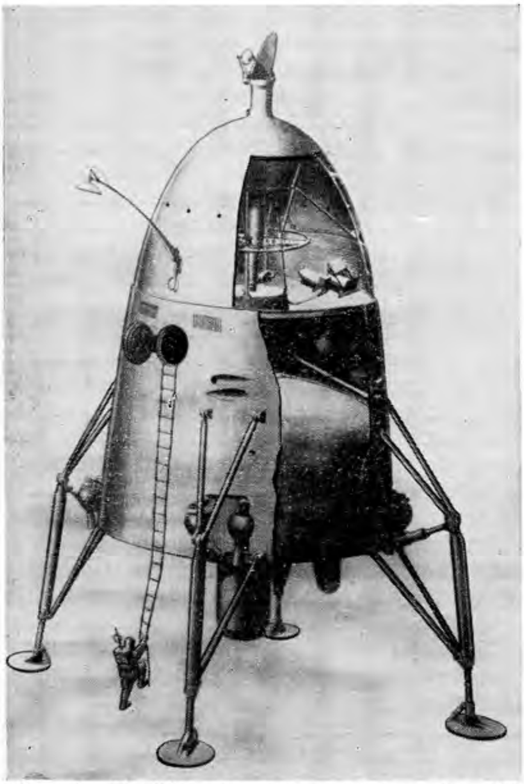

Figure 1. The BIS suggested Lunar spaceship, 1938.

While all this was going on, advances were being made elsewhere, although many were less well-known at the time. Reference has already been made to the practical experiments of Goddard and Esnault-Pelterie between the wars. Some also took place under Crocco in Italy, and a team at the California Institute of Technology was inspired by Prof. von Kármán to carry out both theoretical and practical investigations of rocketry. Early members were Malina, Seiffert, Mills and Summerfield, and the group provided the ancestry for both the present JPL and Aerojet organisations. Also, it is now known that various Russian organisations were independently active in the field—largely duplicating (and perhaps sometimes anticipating) the Western achievements. We still know very little of this work, or of the individuals principally concerned, but Prof. Tokaty of the City of London University has mentioned the names of Tsander, Glushko, Korolev, Tikhonravov, Dushkin, and others. Some of these are believed to be playing a leading part still in present Russian astronautical projects.

When the Second World War broke out in 1939, all this preliminary work had laid the foundations for renewed applications of rocket propulsion, on a vastly greater scale than the 19th century bombardment rockets of Congreve and others. Since then, apart from the researches already described, the rocket had, as it were, lain dormant as a firework toy, with only a few practical uses as a device for signalling or carrying life-lines for marine rescue work. Now, it paralleled the history of aircraft, and came to early maturity as a military weapon of destruction. Only in man's ceaseless wars, it appeared, could the necessary resources be spared to perfect a new advance in technology.

The British effort was almost entirely concentrated on small unguided solid rockets, which proved very effective during the war in air-to-surface, surface-to-air, and surface-to-surface roles. The development team was led by Sir Alwyn Crowe, but at various times it included a number of names which have since attained eminence in other fields, such as Sir William Cook, Lord Beeching, St. John Elstub, and (immediately before the war) Dr. S. G. Hooker. The only British wartime work on liquids was a small effort by Lubbock, with the RAE, on a liquid oxygen/petrol system; this was stimulated by reports of German work.

The Americans were also engaged on an intense comparable programme, but in addition they continued some work on liquid-propellant systems, with which Goddard, Truax, and the RMI and Caltech/JPL groups, were associated. None reached any state of significant application.

It was in wartime Germany that the rocket really came of age. In addition to work on small solid rockets, a large range of guided missiles was produced and many rocket propulsion systems were developed for aircraft, as RATO or super-performance boosters, etc. Most of this work involved liquid propellants, and two major developments may be singled out for mention in this short review. The first is the work of the Walterwerke concern, on high-strength hydrogen peroxide (HTP) as a mono-propellant and oxidant. Apart from the application to submarines and torpedoes, and various small missiles, the outstanding achievement with Walter rocket engines was Lippisch's Me163, a small, purely rocket-propelled, piloted interceptor with quite sensational performance in speed and climb for its time. Also the huge Peenemünde establishment, headed by Gen. Dornberger and with the redoubtable Dr. Wernher von Braun as technical director (born in 1912).

In many ways, Peenemünde provided the main German counterpart to the immense British wartime effort on radar and jet propulsion, and (initially, until the Americans substantially took over) on atomic weapons. It was a very large research and development establishment in the modern tradition; in addition to work on rocket aircraft and anti-aircraft missiles (*e.g.* "Wasserfal"), its major effort was on the A4 long-range rocket, popularly known as V2.

This 12-ton rocket had a range of only some 200 miles, but even that was a prodigious achievement for the 1940's, and a quantum jump in performance compared with any previous ballistic missile. The British rocketeers earned a dubious place in history by reason of their scepticism when faced with early Intelligence reports about V2; Lord Cherwell is quoted in a Cabinet minute as believing that the reports would prove to be "a mare's nest". This is eloquent proof of the advance which V2 represented at the time, and no further comment on subsequent progress is required than to point out that its range, in these days of ICBM's and satellite, lunar, and inter-planetary, rockets would reduce its description to that of a merely tactical weapon.

At the end of the war, the Peenemünde team had plans for a trans-Atlantic missile, the A9/A10 2-stage rocket. They had also given much consideration to space-flight and satellite rockets. Gen. Dornberger is quoted as commenting, on the first V2 flight in 1942, "Today the space-ship is born!", and von Braun and two of his associates were imprisoned briefly by the Gestapo on charges of sabotaging the German war effort by their excessive pre-occupation with space-flight.

After the war, the Allies competed for the services of the German rocket scientists and engineers who had made such impressive technical strides. A handful of them went to France, mostly from the BMW team which had worked with nitric acid as an oxidant. Many of the Walterwerke group, on hydrogen peroxide, came to British official establishments. Most elected to go to the US, persuaded even then that only there could their expensive developments be pursued on a significant scale.

Relatively few went to Russia, although there is evidence that good use was made of their knowledge and experience. In due course, they were returned home, and the myth of subsequent Russian achievements being wholly based on German work is just a myth, perhaps of wishful thinking. Although the Russians, like the Americans and the British, produced only small solid rockets for actual operational use during the war, their traditional interest in liquids and in space-flight had never died. After the war, it was immediately revived on a quite intensive scale, and even while the Russians were learning from their German ex-enemies, it is certain they had their own domestic programmes, of which the Germans were told little.

For a time after the war, progress in the West was at a relatively leisurely pace, by present standards, although it seemed impressive at the time. The Americans produced high-altitude research rockets such as the Aerobee and Viking, and began their ballistic missile programmes. The first Western advance on V2 was represented (in 1953) by the Redstone developed by von Braun and his old Peenemünde team, now working at Huntsville in Alabama, in what was then known as the US Army Ballistic Missile Agency. An impressive series of high-speed rocket-propelled research aircraft was produced. Of these, the Bell X-1 made the first level supersonic flight in 1947, and later (1959) the outstanding X15 flew, eventually at Mach 6·3 and 354 000 ft (67 miles). Both had engines developed by the RMI concern, as also had the Viking rocket which reached 158 miles altitude in 1954.

A firm programme for development of a ballistic missile of inter-continental range was not authorised in the USA until 1954. Before then, the problems of warhead weight, the consequently required size of rocket, and guidance accuracy, had seemed to the Americans to justify relegation of the project to a status of mere research and study. It now appears almost certain that different decisions were taken in the USSR. Faced with the need for a huge rocket to launch the early warheads of great weight, which were in turn demanded by the accuracies then thought to be attainable, they simply went ahead and built it. Moreover they developed this immense vehicle to a high standard of reliability, in a programme later duplicated by the Americans; no doubt, again as in America, the weight of nuclear warheads and the accuracies of guidance, were also substantially improved—but the most significant factor was that the Russians' earlier start gave them a temporary lead. Of immediate military significance, this also read across into the related field of the relative capability in space of the USA and USSR. Both nations, in 1955, announced their intention of launching scientific research satellites in the 1957-58 International Geophysical Year.

The consequences were electric, and created an unprecedented international situation. In 1957, the Russians first announced (in August) their successful development of an ICBM, and then (in October) launched their first Sputnik. A rocket engineer on my staff happened to be in the United States at the time, and wrote back "Over here, heads are shrinking so fast that you'd think the Javanese had landed". America was then only just beginning, with many early failures, the initial flight trials of her ballistic missiles of intermediate (Thor and Jupiter) and intercontinental (Atlas) range. Her consequent military disadvantage, the possible deficiencies of her systems of technical education, and her damaged prestige as a leading technological country, all became national questions overnight. Among other things, for perhaps the first time in history, a high priority was assigned to the attainment of a technical objective—that of space-flight—which was at least not wholly a military objective.

It is a tremendous tribute to both the resources and the resolve of the United States that, within only a few years, this position was retrieved. In 1958, the huge NASA organisation was formed, from the nucleus of the old NACA, with the development of space-flight (both manned and unmanned) as its main aim. The American military missiles soon attained operational status, with amazing levels of demonstrated accuracy and reliability, by reason of an enormous national effort in terms of money and personnel. The submarine-launched solid-propellant Polaris was introduced, as a powerful addition to the liquid Atlas and Titan ICBM's and the (solid) land-based Minuteman.

Russian space achievements continued, but before long the United States was very much in the picture, thanks to the immense NASA civil programmes. These have also been mounted on what had previously been only a military scale, with a current budget of nearly £2 000 000 000 per annum. The original American satellite programme, Vanguard, was subject to a quite undeserved degree of international derision because of initial failures, but it went on to achieve successful launches in 1958, and was indeed always a project with a high degree of technical success, at relatively low cost. Before this, however, von Braun's Redstone rocket had launched the first successful American satellite; his Jupiter later (1959) launched the first scientific payload to attain escape velocity from the Earth. Now, this pioneer from the pre-war German VfR, and the wartime V2 project, is responsible for the vast Saturn rockets of the American Lunar programme, for which President Kennedy (in May 1961) laid down the objective of landing men on the Moon by 1970. Mention should also be made of the Rocketdyne Division of North American Aviation Inc, which has provided the rocket engines for most of the vehicles responsible for American successes in space—apart from the Aerojet engines in Titan, the Bell engine in the Agena upper stage, and a few others.

All this is such recent history that it probably needs little recapitulation. Table I summarises a few dates for the most outstanding space achievements of the past decade.*

In addition, between 1959 and the present, the USA has conducted successful development programmes for operationally useful satellites, as well as those for pure scientific research. These have included Transit (for navigational aid), Tiros (for weather forecasting), Discoverer (for military reconnaissance), and Score, Echo, Relay, Syncom, Telstar, and Early Bird (for telecommunications). Most of these were launched by variants of the Thor vehicle. The Russians launched their own first communication satellite (Molniya I) only in 1965. Latterly, with the Cosmos series and others, they have tended to increase their activities with scientific research satellites to a level more comparable with that of the USA, but have still remained less successful than NASA with their long-distance, interplanetary, space probes.

Let us now digress from the mainstream of astronautical progress, which has become mainly the concern of the USA and the USSR, and consider the past two decades in Europe—in particular, in the UK, and (because of the special purpose of this review) in the RAeS.

After the war, early British plans for an extensive programme of missile development were centred on the Guided Projectile Establishment at Westcott. This was headed by Cook and Elstub, and had ambitious projects for guided weapons of all types, including long-range rockets. These, however, were short-lived; the GPE became first the Rocket Propulsion Department of the RAE (which was given all responsibility for British GW work), and later the autonomous Rocket Propulsion Establishment. Now directed by J. E. P. Dunning, in its earlier days this had A. D. Baxter as a very active superintendent. It has always been the mainstay of the British development and pre-production effort on solid-propellant rocket motors, along with the Summerfield Research Station of ICI (now IMI), which benefited from the move of St. John Elstub to that organisa-

*And on 15th December 1965, the two American manned spacecraft, Gemini 6 and Gemini 7, made the first successful rendezvous in space.

TABLE I

First orbital rocket	Russian 1957: Sputnik I American 1958: Explorer I (Redstone, or Jupiter C)
First escape rocket	Russian 1959: Mechta (or Lunik I) American 1959: Pioneer 4 (Jupiter, or Juno 2)
First lunar impact rocket	Russian 1959: Lunik 2 American 1962: Ranger 4 (Atlas-Agena)
First manned rocket space-flight	Russian 1961 (Orbital): Gagarin (Vostok I) American 1961 (Ballistic): Shepard (Redstone-Mercury) American 1962 (Orbital): Glenn (Atlas-Mercury)
First close lunar photographic reconnaissance	Russian 1959: Lunik 3 (back side) American 1964-65: Ranger 7, 8 and 9 (Atlas-Agena) Russian 1965: Zond 3 (high resolution pictures of back side)
First Venus fly-by, by instrumented probe	Russian 1961: telemetry failed American 1962: Mariner 2 (Atlas-Agena)
First Martian photographic reconnaissance	American 1964-65: Mariner 4 (Atlas-Agena)

tion, from the old GPE. Both teams have received research support, notably in propellant chemistry, from ERDE. RPE (Westcott) have also contributed greatly to British liquid-propellant rocket research and development, notably on HTP systems.

The British post-war guided weapon programme, as finally sponsored by the Ministry of Supply (later Aviation) and RAE, was less ambitious than the one originally planned by GPE, insofar as it neglected long-range weapons. However, so far as short-range missiles were concerned (air-to-air, surface-to-air, and air-to-surface) it bore comparison with anything attempted elsewhere in the world—at least for the first post-war decade. The missiles appeared in due course as the Firestreak, Bloodhound, Sea-Slug, Thunderbird, Blue Steel, etc.

Members of the Society of course played a large part in this important national programme; indeed, it is probably true to say that most of the leading members of the technical teams concerned belonged to the Society. It is always invidious to mention individual names, since the leaders tend to be quoted, and those below who often make vital (if more detailed) contributions are often forgotten. However, the names of L. H. Bedford, Guy Gardiner, David Farrar, Dr. Newman and "Chuck" Bayly, and Hugh Francis will always be among those most prominently associated with the early days of the British GW programme, together with Sir Steuart Mitchell, Sir George Gardner, Sir Robert Cockburn, Morien Morgan, W. H. Stephens, and D. J. Lyons, on the official side. Nearly all are Fellows of the Society.

In 1957, the Society recognised the importance of this new development in aeronautics, together with the still further extension of that subject into astronautics (or space-flight), by forming the Astronautics and Guided Flight Section. The first Chairman of the Section's Committee was Sir George Gardner (now President of the Society), to be followed by A. V. Cleaver, Dr. W. H. Hilton, and E. M. Dowlen, and the present holder of this office, W. N. Neat.

With the exception of Blue Steel and the ramjet-propelled Bloodhound, all the operational British missiles used solid-propellant rocket propulsion. The early versions of Sea-Slug and Thunderbird were planned for liquids, but the obvious superiority of solids for most military purposes (because of their ease of storage, field-handling, and short reaction time) led to the final adoption of solid motors. There was, however, a period during which significant British programmes of liquid-propellant rocketry were being pursued for the propulsion of manned aircraft, either in an auxiliary role (for RATO or super-performance), or as the main powerplant in an aircraft which might have a small turbojet as the auxiliary. Around about 1950, the concept of a supersonic, fast climbing, rocket-propelled, interceptor, armed with air-to-air guided weapons, appeared to have many attractions for the air defence of Great Britain. Many people believe the project should have been pursued to an operational conclusion, instead of falling victim (in effect) to the dogma of the 1957 White Paper. However, it found its expression, in prototype form at least, in M. J. Brennan's Saunders-Roe SR53 (Fig. 2), which was to have had a larger and more potent descendant, the SR177.

Figure 2. The Saunders-Roe SR53.

Together with other aircraft rocket engines, the kerosine/HTP Spectre for the SR53 was produced in the old de Havilland Engine Co, by a team headed by the writer and W. N. Neat. A parallel effort at Armstrong-Siddeley's, led by S. Allen and David Andrews, produced the Snarler, which flew in the Hawker P1072, and the Screamer, both using liquid oxygen. Yet a third team, led by Walter Shirley at the old Napier Co, produced the Scorpion kerosine/HTP engine. Installed in a Canberra for test purposes, this achieved a world's altitude record of 70 000 ft in 1957.

Early in this review, passing reference was made to three exceptions to the relatively unimpressive British record of contributions to rocketry and space-flight. Congreve was cited as the first, and perhaps all this work on aircraft rocket motors just merits an honourable mention as a second. Continuing a trend started by the Germans during the war, it was nevertheless not excelled at the time, and the demands of aircraft rocket installations for controllability and reliability (or what the Americans now call "man-rating") imposed a discipline which was not insignificant for future manned space vehicles.

An indirect off-shoot of this work was the Gamma engine for the highly successful Black Knight research rocket, which now enjoys the unique record of having achieved 22 launches without a single failure. The Gamma was developed by the Armstrong-Siddeley (now Bristol-Siddeley) team, from a design originating at RPE as a back-up for the rocket aircraft requirement, but it was eventually installed in an RAE-sponsored test vehicle for the Blue Streak LRBM programme (of which more later). This Black Knight rocket (Fig. 3) was built by Saunders-Roe and in its early days owed much to Maurice Brennan who was responsible for their SR53 interceptor. At the RAE, D. J. Lyons and H. G. R. Robinson have been prominently associated with Black Knight and Blue Streak.

The "third exception" to the British record is provided by the British Interplanetary Society, in the decade immediately following the war. The history and status of the BIS provides a striking parallel to the early days of the RAeS.

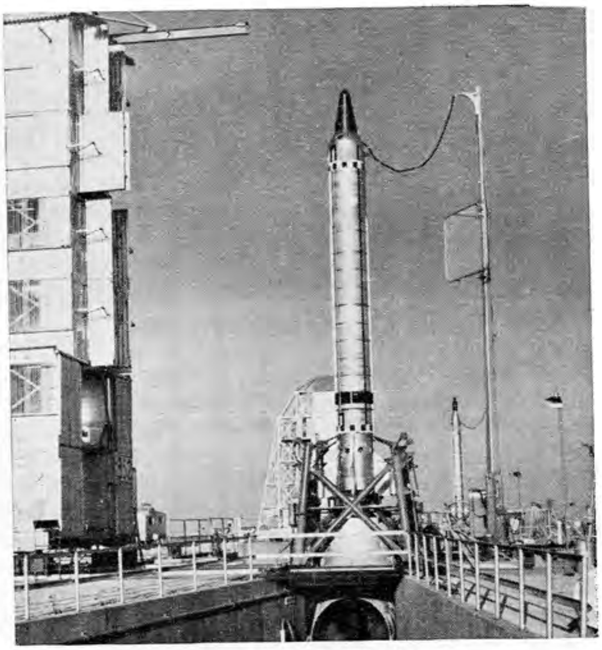

Figure 3. Black Knight.

Many joint meetings have been arranged, and in recent years the BIS has held many of its functions in the Society's lecture hall. In 1945, the status of the BIS was comparable to that of the RAeS around about 1900. Its members were enthusiastic supporters of a technical activity not yet widely supported in the world, and it had yet to gain full recognition as a serious scientific body.

After the wartime developments in technology—radar, jet-propulsion, atomic energy, and rocketry itself—there was a fairly widespread acceptance of the idea that interplanetary flight could be achieved at some time in the foreseeable future. This in itself was very different from the scepticism of pre-war years, but the more tolerant attitude was by no means universal, and in any case most people who adopted it would probably have placed the likely date for, say, even the first landing of men on the Moon, as being far into the 21st century. Germany was the nation in which the relevant technologies had been most highly developed, but she was in the throes of recovering from defeat, and most of her workers in the field had dispersed into other countries. In America, official support for rocket research and development (while on a much more energetic level than that in the UK) was so far still relatively modest. The American Rocket Society (as it then still was) followed a policy of striving for technical and professional respectability; it had already changed its name from the "American Interplanetary Society", and now it even called its Journal (somewhat misleadingly, to British ears) "Jet Propulsion". There was no general knowledge of the Russian activities, and any discussion of satellites, let alone of manned space-flight, was regarded as science fiction.

In this situation, during the first post-war decade (and especially between 1946 and 1952) the British Interplanetary Society exerted a considerable influence. It began to publish a Journal of quite high standard, which contained papers discussing possible future programmes for space-flight on a rational and realistic basis, including the aspects of finance and motivation. Most important of all, these were supported by sound technical papers on such topics as rocket technology in general, multi-stage vehicles of expendable construction, optimised orbits and rendezvous/refuelling techniques, space suits, advanced propulsion systems (nuclear, electric and solar), etc. Again, it is invidious to mention names, but those of Ross, Smith, Gatland, Kunesch, Dixon, Lawden, Clarke, Shepherd, Cleaver and Preston-Thomas, among others, recur.

Many public lectures were given, radio and TV talks, and articles for the press; in 1945, Arthur C. Clarke published the first proposal for communication satellites in *Wireless World*—including the suggestion to use the 24-hour synchronous orbit. Membership of the BIS and circulation of its Journal were international, and all this activity helped to prepare the ground for the great practical achievements of the late 1950's and the 1960's. In the United States, von Braun conducted a somewhat similar one-man campaign by his personal publications; he was not entirely alone in such efforts, but his were outstanding, since for a time there was no strictly comparable "platform" to the BIS on the other side of the Atlantic.

In 1950, the various rocket and space societies which had been revived since the war met in Paris, and agreed to form the International Astronautical Federation (IAF), to hold annual technical congresses on space-flight and to do everything possible to promote its achievement. A second meeting was held in London in 1951, under the auspices of the BIS; the Americans were represented for the first time, and ever since the AIAA (originally the ARS) has played an active part (in recent years, the leading one) in this organisation. The RAeS joined the IAF as an associate member-society in 1964, and was officially represented for the first time at the XVIth Congress in Athens in 1965.

In Europe as a whole, post-war interest in the possibilities of space flight began to develop at the same rate as in the USA, but on a much narrower front. The movement lacked the support of the rapidly-burgeoning rocket and missile military industries of the United States, and soon this had an inevitable effect. Only in the UK, and in France, was there any background of this kind which could be described as even remotely comparable, since military rocketry was forbidden to Germany after the war.

In France, an early start on various small missile projects was made, and the SEPR concern did some good development work on aircraft rocket motors (rather similar to the British programmes), which has culminated in the fitment of auxiliary rocket engines to some Mirage III fighters. The Veronique high-altitude rocket was also produced. The national programmes tended to follow the trend previously set by the German teams which had gone to the respective countries—the British with their hydrogen peroxide or HTP (after Walterwerke), the French with nitric acid (after BMW), and the Americans with practically all the possible alternatives! (All the countries also worked on solid propellants, because of their military advantages, but these have so far found relatively little use for major space applications because, among other reasons, of their generally slightly lower performance.)

In recent years, under the influence of General de Gaulle, the French have also embarked on an ambitious military ballistic missile programme, and on a modest national space programme which includes their own small Diamant satellite-launching vehicle. By these ventures, they have overtaken the British, at least in enterprise and potential capability; in November 1965 they became the third nation to inject a satellite into orbit with a rocket of their own. Our own recent record as been one of vacillating policy and indecision, which has made ineffective use of the technical background previously built up.

In 1955, the UK began the development of Blue Streak, a long-range liquid-propellant (kerosine and oxygen) ballistic missile of about 100 tons mass at lift-off. Technical assistance agreements with the US government, and with the NAA (Rocketdyne) and General Dynamics (Convair) firms, gave the project the benefit of the greater experience which had, even then, been gained in America. The main

British contractors were Hawker-Siddeley Dynamics (then de Havilland's), and Rolls-Royce; the Black Knight rocket, was an RAE test vehicle in support of this programme, originally for re-entry experiments.

Initial progress was rapid, but then the whole military project was cancelled in April 1960, for reasons which would now be described as arising from "cost-effectiveness". This is hardly the place to discuss their soundness, but it may at least be mentioned that the substitute policies (to provide a British "deterrent delivery system" after the V-bombers) have centered successively on the use of: first, the American Skybolt air-launched missile (subsequently cancelled by the USAF), then of the TSR2, and now the American Polaris submarine-launched weapon.

Consideration had long been given to the use of Blue Streak also as the first stage of a large space-satellite launching vehicle. Such studies by the RAE and the firms were naturally intensified when the military programme was terminated; a 3-stage vehicle called Black Prince was proposed, with a modified Black Knight as second stage, and a small new third stage (also using kerosine and HTP). After some months, it was decided that such an all-British programme was less desirable than a pan-European one, in which the costs and the technical work could be shared with other countries. These latter advantages would be even more valuable—indeed, essential—on any future (larger and more expensive) programmes, than on the initial one.

So, at the end of 1961, ELDO (the European Launcher Development Organisation) came into being, with W. H. Stephens as its Technical Director. The member countries were the UK (providing Blue Streak); France (providing the 2nd stage); Germany (3rd stage); Italy (test satellite); the Netherlands (telemetry); Belgium (down-range guidance); and Australia (the Woomera launch site). Three successful launches of Blue Streak by itself were made during 1964-65, and it is hoped to use the complete Europa I (or ELDO-A) vehicle (Fig. 4) to inject a satellite into orbit during 1968. Further programmes are under discussion, involving the use of an ELDO-B vehicle, which would consist of Blue Streak with upper stages of higher performance, burning liquid hydrogen and liquid oxygen as propellants.

ESRO, an organisation with wider national membership, handles problems of pure scientific research in space. Another (the ECTS, or "European Conference on Telecommunication Satellites") is concerned with the participation of Europe in the operation of a world-wide communication satellite system. The American achievements with Telstar, Early Bird, etc., have left no doubt that this will soon develop into a large international business, with considerable effects on society. A private industrial association, Eurospace, advocates more ambitious European space programmes and emphasises the interest and capability of European industrial firms in the space context.

The obstacle to any such future development is, of course, the cost involved, and the need for some compelling motivation which could justify this. Certainly Europe could afford some significant increase in her space programmes, if she could be persuaded of their necessity (her present effort, on a basis proportional to Gross National Products, is only less than 1/30 of that of the USA). For America, such persuasion is provided, in practice, mainly by the spur of Russian competition. For Europe, such arguments make little sense, since they would (in our case) amount to *folie de grandeur;* however, the unknown future rewards from operations in space generally (*e.g.* satellite communications) and the general technological stimulus provided by space research, are motives not to be overlooked.

At the dawn of the Society's Centenary Year, it is difficult to avoid some reference to prophecy and advocacy.

Figure 4. The Europa 1 (ELDO A).

Let it suffice, then, to say that if Europe cannot soon improve the recent status of her space programmes, then her future contribution to the new field of astronautics will be negligible, compared with her past one in the associated and preceding field of aeronautics. Delays in decision-making, in particular on matters of budgets and programmes, have so far reduced the European space effort to an almost negligible quantity, especially as far as ELDO is concerned; it seems almost certain that only collaborative projects of this kind can ever be significant, alongside the American or Russian activity. Smaller programmes (like the French Diamant or the proposed British Black Arrow) can be valuable as support to larger international ones, but alone are of little significance to the larger scene.

In the world at large, the future prospects for space-flight appear much brighter. Within three to six years of the Society's Centenary, and within less than seventy years of the Wright Brothers' first flight, it is likely that men will take off for the Moon and actually walk on its surface. Many of the early aviation pioneers will have survived to see this on their television screens.

Rocket vehicles will have been built with empty weights much less than 10% of their loaded weights, less payload (a notable achievement in airframe structures); also rocket engines, with internal working temperatures of 3000 to 4000°K, burning chemicals, such as liquid hydrogen or fluorine and many others, which were little more than laboratory curiosities only a generation ago. Nuclear-powered rocket engines will be undergoing ground test; indeed, they already are, in the United States (and perhaps in Russia also?). Advanced electrical rocket propulsion systems, plasma propulsion, nuclear power sources for space, exotic structural materials and electronic equipment, will all be the continuing subjects of research into space technology as the Society attains its first Century. All this will be part of the background to its second.