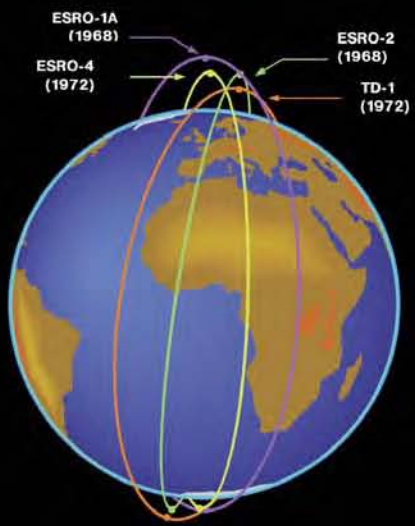
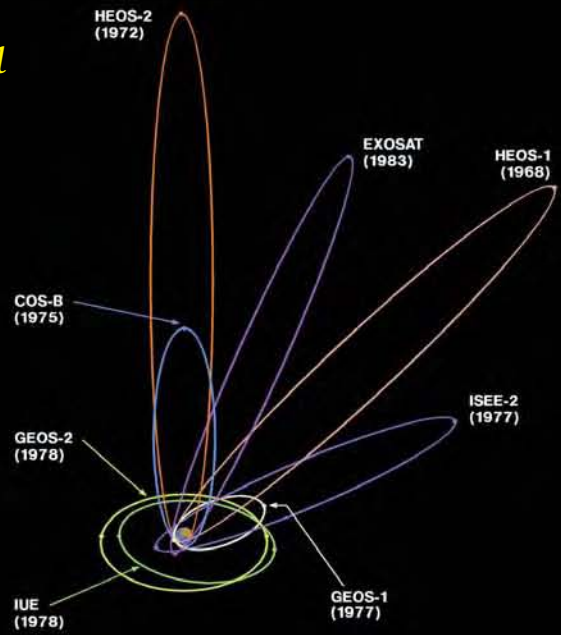
HSR-36
April 2005

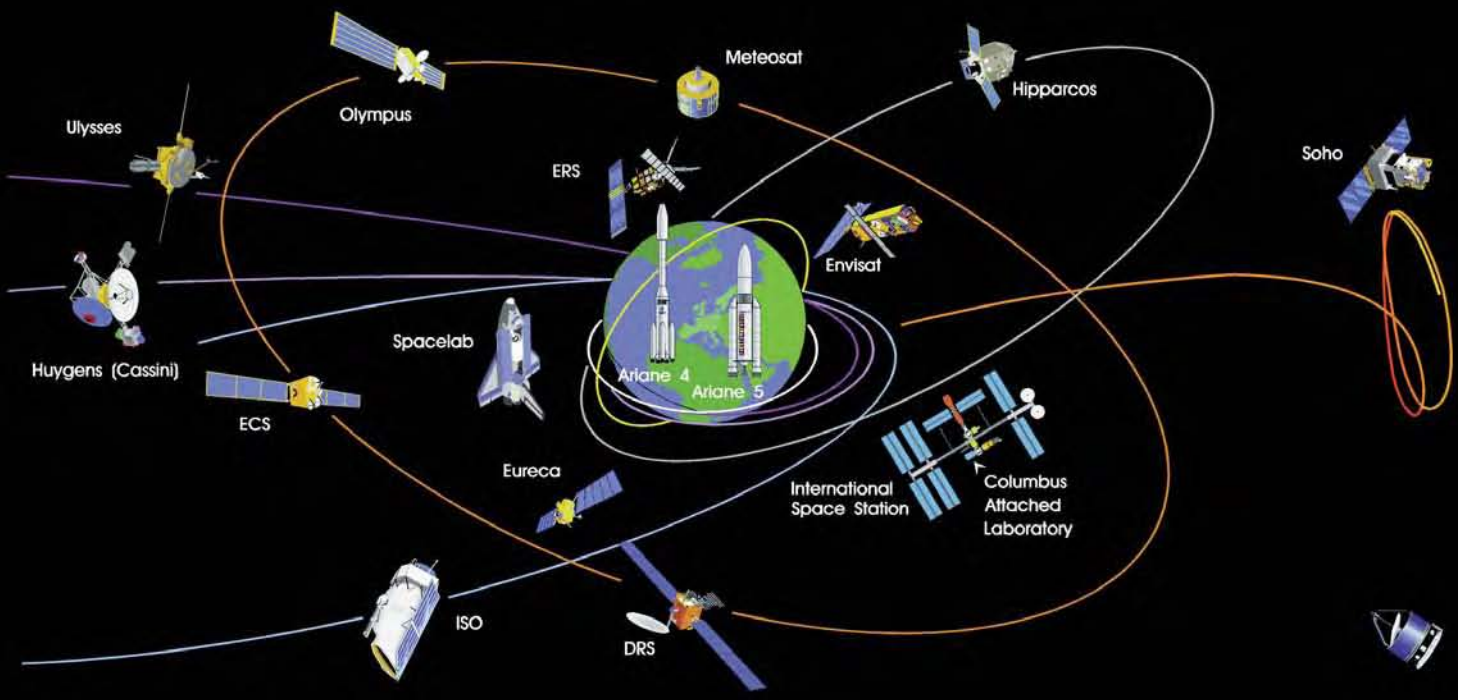
An Overview of United Kingdom Space Activity 1957-1987

by

Douglas Millard







European Space Agency
Agence spatiale européenne

HSR-36
April 2005

An Overview of United Kingdom Space Activity 1957-1987

Douglas Millard
Senior Curator of Information, Communication and Space Technologies
Science Museum, London

HSR-36

Erratum on page 36

The Spacelab-2 mission's launch date should read 29.07.85, and the payload listing should have included the X-Ray Telescope (XRT) from the University of Birmingham.

Published by: ESA Publications Division
ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands

Editor: Bruce Battrick
Price: €20
ISSN: 1683-4704
ISBN: 90-9092-547-7

Printed in: The Netherlands

Contents

Introduction

This history has two main objectives: to provide an overview of United Kingdom civil space activity between 1957 and 1987; and to provide a concise history document that indicates the location of more detailed and specific histories and sources. It is hoped that it provides also some additional national context to the extensive official history of the European Space Agency[1].

The history is divided into five main parts. In the first the author offers a personal impression of UK space policy in this 30-year period. It addresses and attempts to rationalize the perception, held by many participants and commentators, of under-commitment by successive UK governments to space activity. The second part reviews the organization and range of UK space activity during this time. The third focuses on significant aspects of UK space concerns, while the fourth provides a brief historiography. The fifth part comprises appendices that include listings of all the spacecraft that the UK has had significant involvement in during this period, and the associated main centres of expertise. The history does not dwell on the UK's highly significant sounding-rocket programme, for which the reader is directed to Massey and Robins (1986) and Godwin (2005).

[1] See Krige and Russo (2000) and Krige, Russo and Sebesta (2000).

Acknowledgments

There were many people who helped directly or indirectly in the preparation of this short history. The author would like to thank particularly:

- Alan Cooper, Tom Perriment and Martin Shelley of the British National Space Centre for support and for access to the Centre's records.

- Flore Pirard for working so quickly and assiduously with a daunting array of source material to provide a preliminary research-scoping document.

- Matthew Godwin for numerous discussions and conversations about the political context to UK space activity and its representation in the National Archives at Kew.

- Peter Barker, Bruce Battrick, Jeremy Curtis, Roy Gibson, Preben Gudmansen, John Krige, Barry Martin, Alistair Scott, David Southwood, Graham Thomas and Brian Walker, all of whom helped with or provided guidance on the drafts of this paper.

This said, any errors, misperceptions or oversights in this history are entirely the author's responsibility.

Part 1 – UK Space Policy: An impression

In the thirty years covered by this review the UK conducted activities in almost all of the recognised space sectors[2]. It designed, built, launched and operated spacecraft. Its industries operated at the forefront of European space endeavour[3]. Its space scientists and engineers established and maintained an enviable reputation of innovation and excellence in a range of disciplines[4]. It participated in international programmes and played leading roles in the establishment of all three European space agencies[5]. But all of these activities operated within a policy framework that defied the very notion of space as a field for dedicated government activity[6]. Rather, the framework comprised a far looser structure based on an amalgam of other, terrestrial government activities[7]. Thus, the UK's space programmes never came under the aegis of a single government department or ministry with its own dedicated vote or budget. Accordingly, although many government ministers held a space portfolio in this period, most did so only as part of a wider field of ministerial responsibility. Similarly, the UK never formed a government space agency in the style of the United States' National Aeronautics and Space Administration[8] or France's Centre National d'Etudes Spatiales [9]. The National Space Centre, formed belatedly in 1985 just before the end of this review period, provided a coordinating forum for national activities and a focus for international ones, but actually lacked the power to offer definitive coordination, let alone perform an executive role. While this was not peculiar to the UK, commentators have repeatedly chastised governments for their attitude to space, accusing them of pursuing policies that at best were incongruous to the country's relative economic strength, and at worst incoherent[10]. It could be argued that such a line is specious, given the relatively small number of nations capable of contemplating such activities during this period; how could the UK be said to have failed to achieve its potential when there were so few examples against which to gauge it? Further, if actual outputs – technological, industrial and scientific – are considered, then the UK's record in space ranked at the very highest level of achievement, and in many instances set standards of intellectual endeavour, ingenuity and organization that were second to none. Nevertheless, the feeling of underachievement was real and the principal aim of this history, besides reviewing the UK's space activities in the thirty years following the 'launching' of the space age in 1957[11], is to seek an explanation for this perception.

When Sputnik 1 orbited the Earth in October 1957 the UK was perceived by many to be well-placed to develop and launch its own spacecraft[12]. It was the only other nation, after the Soviet Union and the United States, that possessed the level of scientific and technological expertise – especially so through its Blue

---

[2] For a comprehensive survey of the UK's space activities up to the early 1990s see Jane's Space Directory 1993-94 (Wilson, 1993). But possibly the best indication of the sheer range of activity is provided in the parliamentary reports of 1967 (House of Commons, 1967), 1971 (House of Commons 1971) and 1987 (House of Lords, 1987).

[3] See Adams (1976), for example, to gauge the significance of UK industry to the early European space programmes.

[4] See Massey and Robins (1986) for a detailed, first-hand account of the UK's formative and early space science programmes at home, with the United States and within Europe.

[5] See Krige and Russo (2000) and Krige, Russo and Sebesta (2000).

[6] In 1971, the House of Commons Select Committee on Science and Technology commented on how, '… the United Kingdom does not have a centrally co-ordinated, overall space programme… projects involving the use of space are treated separately on their individual merits', see House of Commons (1971, vii, 9).

[7] See Appendix 5.1 for a listing of all those government departments with some sort of interest in space in 1967. While the specific departments change over the thirty years of this history, the dispersion of interests is entirely representative of the whole period in question.

[8] See NASA SP-4406

[9] See McDougall (1985) for a pithy appraisal of France's space ambitions under De Gaulle and Carlier (1993) for a history of CNES. It should be added that many UK commentators, often outside the space fraternity, asked why space should have its own agency when other national endeavours in the UK – ship building, aviation, car manufacturing and so on – had no agency to direct them.

[10] See, for example, Gould (1988), who enunciates a familiar line of criticism, while Chorley (1988) offers a more reasoned critique.

[11] In this context the term 'space age' relates to the era opened with the Soviet Union's orbiting of Sputnik 1, the first artificial satellite, on October 4, 1957.

[12] See King-Hele (1992) for an authoritative account of both the UK's space potential in the late 1950s and the subsequent reality. See Edgerton (1991) for a strong and cogent essay that provides a useful and astute survey of the UK's huge aviation industrial complex, including the associated guided weapons programmes – essential precursors to space activity. See Twigge (1993) for a good overview of the UK's missile programme and industry up to 1960. There are also many contemporary journal and magazine articles that provide useful information – see annex to this history's bibliography.

Streak intermediate range ballistic missile programme – necessary to pursue an equivalent space programme[13]. But Prime Minister Harold Macmillan's response to the new space age was measured. He rebuffed calls to utilize the country's rocket capability in the development of a national space programme and instead accepted the US's offer to launch international science satellites (almost) for free[14]. In so doing he was establishing a national policy norm for space concerns, a blending of scepticism and pragmatism, that ebbed and flowed in degree, but remained present in successive UK governments through to 1987.

But (and ironically) it was the failure of his own succeeding 1959 administration[15] to adhere to this implicit approach that enabled the misperceptions over the UK's attitude to space activity to take root. Macmillan's initial sober attitude to space policy was masked in 1960 when his government employed the space ticket, understandably perhaps, to help wider political ambitions.

For many months the limitations of the UK's planned replacement strategic deterrent, based on the Blue Streak missile delivery system, had become increasingly clear[16]. In 1960 the decision was taken to abandon it and procure the US Skybolt system in its place. The vexed question of what to do with the now redundant Blue Streak rocket system had exercised the Macmillan government in the immediate run up to and during the fallout from the cancellation decision. Studies had long been carried out on the feasibility of employing Blue Streak as the first stage of a UK satellite launch vehicle, usually with a Black Knight derivative forming its second stage, but had been considered as impractical and too expensive[17]. But by offering Blue Streak and the bulk of the associated UK infrastructure, experience and expertise for a possible European satellite launch vehicle programme, Macmillan not only recovered some of the political ground lost as a result of that missile's cancellation but, far more importantly for Macmillan, demonstrated the UK's pedigree as a prospective member of the European Common Market. He was wooing Charles De Gaulle. After some significant French uncertainty and, indeed, reluctance, De Gaulle eventually acquiesced and in January 1961 Europe, with the UK in the vanguard, embarked on the road to ELDO[18].

This political legitimacy added to a momentum being built by the UK's space scientists who had, largely through the offices, members and Fellows of the Royal Society, thrown themselves into the organisation of the country's first science satellite programme, courtesy of the US[19], and were contributing their expertise to the putative European space science programme, to be run by ELDO's sister organisation, ESRO[20]. In a little over three years the UK had apparently moved from space sceptic to space champion.

But 'national' space policy built on such expedient foundations was perhaps doomed to unravel when the political climate changed as, with the election of Harold Wilson's first Labour government in 1964, it duly did. Wilson's administration axed costly, defence-orientated technological programmes, and his cabinet struggled to justify the continued commitment of large amounts of public finance to space ventures that appeared to have little support at home[21]. With the fast developing tribulations of ELDO all too clear, it was

---

[13] See Whyte (1996) for an excellent, in-depth account of the inter-departmental discussions on the possible use of the UK's ballistic missiles for space activities.
[14] See Whyte (1996) and Logsdon et al. (1996).
[15] Macmillan's Conservative government was returned to power in the general election of October 1959.
[16] See Whyte (1996). Finch (2001) provides an illuminating and fascinating account of the bureaucratic politics in which a strategy for the UK's strategic nuclear systems in the 1960s was painfully honed.
[17] Black Knight was the ballistic test vehicle for Blue Streak. At the time the UK was number three in the World in ballistic missile technology, with only the Soviet Union and the United States ahead. See Whyte (1996) and Finch (2001) for the political context. See also Robinson (1990 –1&2) for a rounded overview from the technological aspect. Robinson (1992) and Millard (2001) place such discussions in the context of what became the UK's small satellite launch vehicle programme, Black Arrow.
[18] European Launcher Development Organisation. See Krige and Russo (2000) and Krige, Russo and Sebesta (2000) for detailed accounts of the tortuous discussions that led, eventually, to the creation of the ELDO.
[19] Referring to the US offer to help design, build and launch international spacecraft on US launch vehicles. See Logsdon (1996).
[20] European Space Research Organisation. See Massey and Robins (1986), Krige and Russo (2000) and Krige, Russo and Sebesta (2000).
[21] See Zuckerman (1988) for a first hand account of science and technology policy under Wilson. See also Crossman (1975) for a candid personal account of cabinet government under Harold Wilson, and in particular the author's bewilderment over the nature and raison d'etre of the Black Arrow programme.

therefore perhaps inevitable, despite the shock and anger around Europe, that the UK would announce its eventual withdrawal from the launcher organisation[22]. It is ironic that this decision, dripping with very real economic and political justification, came alongside Blue Streak's own, very real, one hundred percent launch record[23].

But the picture appeared inconsistent. There was still plenty of space activity going on. For example, Wilson's government backed, albeit hesitatingly, development of a small satellite launch vehicle based on Black Knight technology – a programme initiated by the outgoing Conservative government in 1964[24]. The design authority for this project was the Space Department of the Royal Aircraft Establishment (RAE). The RAE was the main government space technology centre, run from the defence budget, and was involved in most of the UK's space projects which, in the mid-1960s, included sounding rocket, launch vehicle and satellite design, testing, construction and operation, both in-house and in association with industry. And the science programme was flourishing; the UK was continuing its bilateral arrangement with the US to launch science satellites and its commitment to ESRO was solid, if less financially forthcoming than had originally been hoped[25]. In reality, the UK was reverting to the selective involvement in space activity that had been pioneered by Macmillan before his government harnessed Blue Streak for, at least partially, ulterior motives.

Nevertheless, many commentators witnessed the gargantuan expenditure, by the superpowers, on space technology in the 1960s and felt that the UK, which after all was still one of the most powerful nations on the planet, was muddling its approach to the space age. It was understood that billions of pounds Sterling could never be made available for space activity, unlike their Dollar and Ruble equivalents, but at least the UK could spend a sensible amount on a coherent and focused policy programme. The need for clarity of vision and purpose was declared forcefully and purposefully in the conclusions of the parliamentary enquiries in 1967 and 1971[26] which, amongst other recommendations, argued for the setting up of a dedicated UK space agency. Their committees' frustrations are understandable: witness the full, unwieldy dispersal of Britain's authorities for national and international space activities as laid bare in their reports[27].

The challenge to streamline Britain's space policy was at least partly taken up by the government of Edward Heath in the early 1970s. Heath, like Macmillan, was pushing for the UK to join the European Community. With ELDO on the wain and ESRO increasingly unable to balance a programme of scientific and applications objectives, there was a broad welcome for Heath's Minister for Aerospace, Michael Heseltine, when he resurrected the idea of, and argued strongly for, a new European space agency[28]. The UK's space expenditure, he felt, should eventually be channeled entirely into such a European venture. This last aim was not to be realized entirely, but the European Space Agency (ESA), at least, became a reality. And so matters rested for the rest of the decade and the years of James Callaghan's Labour government. There were changes elsewhere, however.

---

[22] See House of Commons (1967) and (1971). Both these parliamentary reports make clear the domestic pressures under which the UK's involvement in ELDO had to operate.

[23] See Martin (2002). This first-hand, comprehensive, technological account of Blue Streak includes a whole chapter on some of the key personnel involved and so comes some way to recognising the achievements of the many thousands involved in this technologically successful programme.

[24] See Millard (2001) for an introduction to the factors that influenced this decision.

[25] See Krige and Russo (2000), especially Chapters 2,5,6 and 8, for a highly informative outline of the domestic constraints under which the UK science delegations had to operate.

[26] For example, the conclusion of the House of Commons Estimates Committee of 1967 reads, 'Your Committee have examined the past and present state of British space activities. On the whole it has been a story of wasted opportunities brought about by lack of purpose and the absence of any coherent organisation. There has been no real space policy and no space programme as such. Money has been poured into expensive international projects without a properly conceived national programme to ensure that an adequate return accrued from the international ventures. Many departments and many committees have spent much time looking at aspects of space, but it has never been considered as a whole' (House of Commons, 1967, xxiv). See House of Commons (1971) too.

[27] See Appendix 5.1 for a listing of all those government departments with some sort of interest in space in 1967.

[28] See Heseltine (1999, 25), who reported saying the following to his officials, '…look I realise that we are in it for the Brits, but isn't it just conceivable that there is a wider picture here?'.

In the late 1950s and early 1960s the sprawling UK aircraft industry had undergone a massive consolidation, leading to the formation of two behemoths – the British Aircraft Corporation and the Hawker Siddeley Group[29]. In 1977 these in turn were finally amalgamated as British Aerospace with the government swiftly becoming the major shareholder[30]. Although driven by aviation, these mergers also affected the associated space business[31].

In the early 1980s, and during the second administration of Prime Minister Margaret Thatcher, the political climate for space seemed once more to be changing. Concern had once again been expressed at the piecemeal way in which the UK continued to organise and finance its space activities. For example, the space science programme had been run now for some years by the Science and Engineering Research Council[32] (SERC) as one of its many scientific research fields, all of which had to compete for funding from the same SERC pot of money. The situation had not been helped by the country's horrendous inflation rates of the 1970s that had squeezed still further the funds available to the Council; by 1980 it was spending almost two-thirds less on space science than it had been just six years earlier. A report conducted by the Vice Chancellor of Manchester University, Sir Mark Richmond, recommended, as Heseltine had done ten years earlier, that ESA should become the focus of the UK's space expenditure. Such sentiments coincided with expression of ESA's own plans for the rest of the century that sought to exploit the opportunities promised by NASA and its space station programme[33]. There was genuine UK enthusiasm for certain elements of these plans, and in particular the Polar Platform element of Columbus, ESA's contribution to the US space station plans[34]; the UK was keen to invest significantly in this venture[35]. Its major space industries were also anxious to help construct and operate Europe's proposed direct broadcasting satellites[36]. But if the UK was to emphasise its role in ESA over any national programmes, then it seemed increasingly sensible to coordinate its space activities under one body.

There were other developments that added to a general feeling of dynamism in the UK space arena. In 1984 it was announced that the UK's Skynet 4A defence communications satellite (prime contractor to be BAe Space Systems [BAeSS] with Marconi Space systems supplying the payload) would be launched from NASA's Space Shuttle. Squadron Leader Nigel Wood[37] would be a member of the crew and so become the UK's first astronaut. The same year saw the unveiling of a revolutionary UK launch-vehicle concept called HOTOL[38]; for the first time in a generation Britain was once again looking seriously at space rocketry[39]. In 1985 the innovative Surrey Satellite Technology Limited was established by the University of Surrey to build on its success in constructing small satellites[40]. And then there was the Strategic Defence Initiative (SDI); with the UK's likely involvement in this US programme, many players and commentators felt a need to clarify and distinguish the country's civil and defence space activities[41].

---

[29] See Edgerton (1991)
[30] See Green (1988) for details of British Aerospace's formation and first years of existence and its precursor companies, while SBAC (1988) provides a useful review and appraisal of the UK's industrial space capabilities up until the mid to late 1980s.
[31] See, for example, Adams (1976)
[32] The SRC was replaced by the Science and Engineering Research Council (SERC) in 1981.
[33] See Krige, Russo and Sebesta (2000), Chapter 15.
[34] Ibid.
[35] See British National Space Centre (1986).
[36] See House of Lords (1988) and especially the illuminating written and oral evidence from UK space industry representatives.
[37] Wood was selected after training candidates from the RAF, Navy, Army and the Ministry of Defence.
[38] HOTOL (Horizontal Take-Off and Landing) was devised in direct response to France's Hermes shuttle concept, the feeling being that the latter was anachronistic: a costly variation of an existing launch vehicle design (the US Space Shuttle). At the heart of the British Aerospace/Rolls Royce HOTOL was a novel propulsion system that breathed atmospheric air during the vehicle's ascent. See Cox (1992) for a fascinating incite into how the HOTOL project was conceived, gestated but still-born.
[39] See House of Lords (1988) and in particular both the oral evidence of Roy Gibson, former Director General of the BNSC, and the enthusiasm with which his questioners of the Science and Technology Committee viewed HOTOL.
[40] At least one former member of the space science community remembers that the SRC was refused permission to build its own satellites in the 1970s; such practices would remain the preserve of the Ministry of Defence (MoD), the decision apparently '… enshrined in Cabinet minutes.' The member goes on, 'I asked to see the relevant paragraphs and was told it was not permitted. Subsequently, Surrey University, unhampered by such baggage, just went ahead and built them – apparently with the tacit approval of the MoD (in the form of RAE Space Department).' Private correspondence with author.
[41] See House of Lords (1988) and oral evidence of Roy Gibson.

With so much going on in the space field at home and abroad, the government looked quizzically at the Space Division of its Department of Trade and Industry[42], instructing it to set up an ad hoc committee to examine and make recommendations for the organisation of UK space activities. The Committee's initial brief was to draw up a space plan for the UK that addressed the decisions taken at the ministerial meeting of ESA in Rome in 1985[43]. In November 1985 the Committee was transformed into the British National Space Centre with the former Director General of ESA, Roy Gibson, appointed as first Director General. Gibson's space plan was ready in mid-1986 and is reported[44] to have recommended a significant increase in funding for Britain's space activities – this rise reflecting the increased expenditure proposed at the ESA Rome meeting. However, the months passed and no response was forthcoming from the UK government. It seemed increasingly likely that Gibson's proposals had not been well received by Margaret Thatcher's government. This was borne out in the summer of 1987 when Gibson was told that there would be no extra funds made available for space activity[45]. Gibson resigned as Director General and the BNSC settled into the form of a government 'agency' that would assist in coordinating and communicating space policy, and offer advice on it for ministers but, with no dedicated budget, would be unable to direct it[46]. The return to type, as set under Macmillan's first government nearly thirty years before, was almost complete. The UK would pursue space activity, but in a selective fashion and not for space's sake.

---

[42] Since 1971 and the reorganisation of the UK's defence procurement (and the formation of the Ministry of Defence), responsibility for space matters had been passed from the disbanded Ministry of Technology to the Department of Trade and Industry.

[43] See Krige, Russo and Sebesta (2000), Chapter 5. Roy Gibson recalls that it was on the basis of the UK government's Nicholson Report (Sir Robin Nicholson, Chief Scientific Advisor to the Cabinet Office) that he was subsequently appointed first Director General of the BNSC. Private correspondence with author

[44] The report has never been published.

[45] See House of Lords (1988) and in particular the oral evidence of Roy Gibson. The year 1987 was a crucial one in the history of UK space activity and is deserving of further, detailed historical research. Political factors national and international, civilian and military all impinged on the UK space scene in a relatively short period. Amongst this plethora, ESA's forward plan for a manned space programme received withering criticism from the UK government and played a significant part in the decision to restrict further funding.

[46] See House of Lords (1988, 203) for the space minister's pithy explication of why the BNSC would not receive the autonomy its first Director General would have wished: 'I do not want to put together some glorious commercial lobby within government but apart from government, which spends its time busily pushing and pushing for its own activities.'

Part 2 – The Organization of UK Space Activity

In 1962 a United States Thor-Delta vehicle launched Ariel (UK) 1[47], the first spacecraft to contain UK technology and the world's first international satellite. Ariel 1 was built by the National Aeronautics and Space Administration, but contained seven scientific experiments devised and constructed by UK universities and industry[48]. A further five Ariel satellites were launched over the next 17 years[49]. The Ariel programme was initiated following a US offer of international co-operation in the launching of satellites, made through the International Council of Scientific Union's (ICSU) Special Committee on Space Research (COSPAR) in March 1959[50]. The provision of the UK's experiments for Ariel 1 was organised by the British National Committee on Space Research (BNCSR)[51].

The BNCSR had been formed in December 1958 both to liaise with COSPAR and to rationalise the organisation of various UK national space activities[52]. With the inception of the US/UK bilateral programme, a Steering Group for Space Research (SGSR), advised by the BNCSR, was set up within government to look after the financing of the UK's space activities[53]. In 1960 the BNCSR had also started to advise the SGSR on the nascent European space research programme and Britain's key role within it[54]. In 1961 the BNCSR was able to propose costs for this and all of the UK's space science programmes to the SGSR. The SGSR accepted these recommendations and put them to the Minister for Science, who asked the government's Advisory Council for Scientific Policy (ACSP) to advise on the size of the proposed budget. The Chair of the ACSP duly set up a study group that recommended acceptance of the proposals.

For the next four years the BNCSR and SGSR managed the shaping of the UK's bilateral and European space science programmes. The DOE sub-committee fed the BNCSR with proposals from university groups for the design of space experiments. Those recommendations were passed up to the SGSR which, via the assistance of another BNCSR forum, the University Projects Expenditure Sub-committee, received them in a form appropriate to DSIR practice.

Running parallel to the European space-science negotiations were those for the proposed European launch vehicle based on the cancelled Blue Streak ballistic missile[55]. The UK's team was led by the Minister of Aviation, Peter Thorneycroft – his Ministry's Guided Weapons Department (GWD) having acted as design authority for the development of Blue Streak. GWD's technical research centre was at the Royal Aircraft Establishment (RAE) at Farnborough in Hampshire[56]. GWD had already established a significant space-

---

[47] The Ariel series of satellites is referred to also as 'UK'. The convention adhered to here is that the satellite was re-named once in orbit; hence, UK1, 2, 3 etc. were renamed Ariel 1, 2, 3 and so on, once successfully launched.
[48] See Massey and Robins (1986). Harrie Massey was the pivotal actor in the early UK space science programmes and was directly involved with and often chaired many of the national and international committees.
[49] As the Ariel programme proceeded, the level of UK involvement in each satellite increased: Ariel's 3-6 were designed and constructed in the UK.
[50] See Massey and Robins (1986), Chapter 4, and Logsdon et al. (1996).
[51] Massey and Robins (1986), Chapter 4.
[52] The first of the UK's plethora of space (age) committees was that for the International Geophysical Year (National IGY Committee or NIGYC), formed by the Royal Society (RS) in 1953. In September 1956, following president Eisenhower's announcement that the US would launch a satellite during the IGY, Britain's NIGYC set up its Artificial Satellite Sub-committee (ASS). Meanwhile, the RS's Gassiot Committee (GC), originally formed in 1871 to supervise the management of the Kew Observatory in London and since 1942 engaged in meteorological and atmospheric research on behalf of the Air Ministry, had created Sub-committee D to advise on the programme of upper atmospheric research using rockets. Following the launch of Sputnik 1 by the Soviet Union on October 4, 1957, the ASS set up three working groups to consider radio, optical and computing satellite tracking methods. Just over one year later the RS formed the BNCSR to liaise with COSPAR and, thankfully, to co-ordinate national scientific space activities, previously represented by the various rocketry and satellite sub-committees, under the Tracking and Data Recovery (TADREC) and Design of Experiments (DOE) sub-committees.
[53] The SGSR was part of the Lord President's Office and its accounting officer was the Secretary of the Department of Scientific and Industrial Research (DSIR).
[54] See Massey and Robins (1986), Chapter 6, and Krige & Russo (2000).
[55] See Whyte and Gummett (1994) and Finch (2001).
[56] See Bud and Gummett (1999), Twigge (1993) and RAE (1962). Other main government research establishments involved in space activities were at Bedford (RAE, aerodynamics), Malvern (Royal Signals and Radar Establishment) and Westcott (Rocket Propulsion Establishment).

technology capability through its development of the Skylark[57] and other sounding-rocket programmes[58]. The momentum of the UK's evolving space activities in the early 1960s necessitated a reorganisation at the RAE; in January 1962 the Armaments and Guided Weapons departments – the latter having included space activities within its brief – were reconstituted into a Weapons and (new) Space Department (SD).

While emphasising the significance of space research to the RAE, this restructuring appeared to do little to encourage an equivalent coherence of government policy with respect to space activities. Thus, it seems that the appearance of a small satellite launch vehicle programme, later known as Black Arrow, from the cooling embers of the Black Knight ballistic research vehicle programme in 1962, perhaps owed as much to the organisational momentum and initiative of RAE's Space Department and industry, principally Westland Aircraft and Bristol Siddeley Engines, as anything else[59].

Certainly, there was concern at the ACSP regarding the existing mechanisms by which British science projects, of which the burgeoning space sector formed a significant proportion, were prioritised[60]. A committee under the direction of Sir Burke Trend was established to recommend what improvements could be made. The Trend Report was published in 1963[61] and many of its recommendations were implemented by the new Labour government of Harold Wilson in 1964. Thus, the DSIR gave way to a new Science Research Council (SRC), with industrial research becoming the responsibility of a new Ministry of Technology (MoT). The responsibilities for space science previously undertaken by the SGSR and BNCSR were now shifted to the SRC, and the SGSR was abolished. The SRC's budget came from a new Department of Education and Science (DES), with the Minister receiving advice from the Council for Scientific Policy (CSP), a body of independent scientists that replaced the ACSP. This new arrangement meant that space science bids from university departments for SRC funds had now to compete with other terrestrial science projects. The SRC also assumed responsibility for the bilateral and European space programmes.

However, the new MoT did not include aerospace, which remained under the wing of the Ministry of Aviation (MoA). This was duly remedied in 1967 when the two ministries merged, but not before a House of Commons report had criticised the organisation of British space activity as fragmented (see Appendix 5.1) and recommended that the MoT should assume *complete* responsibility for the UK's space programme[62]. It stopped short of advising the setting up of a central space agency along the lines of France's Centre National d'Etudes Spatiales (CNES), but four years later another parliamentary report argued for just such a move[63].

By this time much of the UK's putative space activity had started to shrivel: the former Minister of Technology (Anthony Wedgewood-Benn) had already announced the UK's intention to pull out of the European Launcher Development Organisation altogether, and in July 1971 the Conservative Aerospace Minister, Frederick Corfield, announced the cancellation of Black Arrow, the nation's own small satellite launch vehicle development programme. But the report's suggestion for an agency again fell on stony

[57] Still the World's longest running space programme beginning in 1957. Over 430 skylarks have been launched to date.
[58] The RAE issued hundreds of technical reports covering all aspects of their many aerospace research and development activities. A significant number of these are now in the public domain and can be found in the National Archives at Kew. In 1962 the RAE's Guided Weapons and Armaments Departments were superseded by the new Weapons and Space Departments – see RAE (1962).
[59] See Millard (2001).
[60] See Nicholson, Cunningham and Gummett (1991).
[61] Trend Committee (1963).
[62] House of Commons (1967).
[63] House of Commons (1971).

ground and, following the recommendation of the Rothschild Report[64], ministerial responsibility for space instead moved from the abolished MoT to the Department of Trade and Industry (DTI); departmental responsibility for the RAE moved into the new Ministry of Defence's (MoD) Procurement Executive[65].

Little changed in the following years. The DTI retained its ministerial responsibility for space matters despite the involvement of other departments in the UK's space activities. By 1987 the British National Space Centre, its feet firmly anchored in the DTI, had been formed and had begun its coordination of UK space concerns.

[64] Rothschild (1971). The Rothschild committee enquired into and recommended on the organisation of science and technology in the UK.
[65] Rayner Report (1971). The Rayner committee enquired into and recommended on the organisation of the UK's defence procurement.

Part 3 – Space Concerns

The following four brief sections, dealing with launch vehicles, space science, space industry and space interest groups, provide a little more comment on some of the more important aspects of the early history of UK space activity. There is much more that has been left out and merits further attention. For example: a definitive listing of ministers with responsibility for space has yet to be produced[66]; a history of the RAE's Space Department is long overdue; new histories of UK space industry are needed to, on the one hand, encompass and represent the totality of the country's expertise and contribution to space activity and, on the other, focus on the geographical spread of that expertise – the Bristol BAC/BAeSS site, for example, warrants particular attention[67]; an equivalent account or set representing the centres of scientific excellence in universities, government laboratories and, indeed, industry too, is needed; a good outline of the UK's (London's) role in the space insurance sector would be useful; and an especially interesting objective would be to represent, analyze and interpret some of the thousands of future studies conducted by industry, academia and government that progressed little further than the concept stage.

Launch vehicles

At the end of the Second World War the UK was able to share, alongside the United States, the Soviet Union and France, in the assimilation of German missile expertise and in particular that of the V2 [68]. The UK, unlike the US and the USSR[69], did not exploit the V2 technology directly and pursued instead a programme of research geared initially to guided-weapons development and aero-engine augmentation[70]. This meant the UK lacked the immediate means for reaching high altitudes through rocket propulsion. However, as the UK moved into ballistic-missile research, so the need for a high-altitude launch vehicle grew and, from the Controlled Test Vehicle (CTV) series, the Skylark sounding-rocket programme was initiated[71]. This in turn enabled the UK to announce a significant space science research programme as part of the country's contribution to the International Geophysical Year[72]. Skylark went on to become a stalwart of the UK's and the European Space Research Organisation's (ESRO's) early space science programmes[73].

In 1955 the UK embarked upon development of its Blue Streak intermediate range ballistic missile and, as part of the associated re-entry research studies, initiated the Black Knight test vehicle programme[74]. Blue

---

[66] It was hoped that such information could be included in this history. However, there is no single source that provides the names, not least because of the scattering of space portfolios amongst different government departments. Establishing the continuum of ministerial responsibility is not a trivial research objective.

[67] Existing histories tend to work from the top down – political accounts, straight chronological narratives, the recollections and interpretations of senior government, scientific, industrial players, and so on. One aspect missing here is a more geographically localised type of study – one centred more on the actual communities of scientists, engineers and technicians that designed, developed, manufactured and operated the space technologies.

[68] In 1945 the UK invigilated three test launches *(Operation Backfire)*, by German firing teams, of V2 missiles at Cuxhaven – see War Office (1946). The bulk of the remaining V2 hardware and documentation was taken to the US, the UK satisfied that, through interrogation of German scientists, *Operation Backfire* and the acquisition of representative V2 and related missile hardware, it had sufficient information for its own prospective missile programmes.

[69] See DeVorkin (1992) and Hall and Shayler (2001).

[70] See Twigge (1993) for a good overview of the UK's early guided missile programme and Harlow (1998) for an excellent account of the early UK liquid propellant rocket engine programmes. Millard (2001) sets the latter as precursors in the Black Knight and Black Arrow launch vehicle programmes, while Harlow (2002) concentrates further on those parts of 1950s UK rocketry directed at aviation.

[71] See Massey and Robins (1986) for a comprehensive account, Chapter 3, Dorling (1959) for technical notes on the first six firings, and Godwin (2005) for the political context.

[72] See Massey and Robins (1986), Chapter 3.

[73] See Massey and Robins (1986), Chapters 6 and 9. The UK developed also Skua, Fulmar and Petrel sounding rockets, the latter made available to ESRO too.

[74] See Whyte (1996).

Streak was eventually cancelled[75] as a weapon system and incorporated within the European Launcher Development Organisation (ELDO) as the first stage of the Europa satellite launch vehicle[76]. Black Knight was continued, however, as part of an extended re-entry physics research programme conducted with the US and Australia[77]. Parallel to this, the Ministry of Aviation's Royal Aircraft Establishment and industry had produced designs for a small satellite launch vehicle based on Black Knight technology. When further Black Knight trials were cancelled, the way was open for initiation of this satellite launch vehicle programme, later to be named Black Arrow. UK governments from the beginning funded this programme reluctantly and parsimoniously and, come the first successful orbiting of a satellite by a Black Arrow launch vehicle in 1971, the Heath administration had already cancelled further launches[78]. This, alongside the withdrawal from ELDO, but with the exception of the continuing Skylark series, signalled the UK's exit from any further substantive development of space launch vehicles[79].

Space science

The UK was able to build on its distinguished history of ground-based space science when the defence-research-derived Skylark sounding rocket was made available in the mid-1950s. The Royal Society played a leading role in initiating and coordinating the subsequent UK space science research programme based around Skylark. The momentum so developed allowed the UK to exploit the US offer of satellite launches, producing the UK series of science satellites[80], and to play a leading role in translating European space science aims into reality via ESRO[81]. Many UK centres of space science excellence were developed further or established[82], both in university departments and in government and research council laboratories, and the scientists therein made highly significant contributions to most of the national and European space science missions[83].

While space science was always considered a worthy activity by successive UK governments (in contrast to others such as launch vehicle development and manned exploration), the nature of its funding, competing as it had to against other science disciplines, meant that its true potential, built upon the expertise and innovation of many hundreds of globally pre-eminent scientists, although well-represented, was always underplayed.

That said, the achievements in the period 1957 to 1987 are legion, as the long listing in Appendix 5.3 of this history reflects. It would be churlish to single out any one UK space science mission as being uniquely significant in this thirty-year period. Some would argue for UK (Ariel) 1 – the nation's first (and the world's first international) spacecraft. Many scientists would cite the X-ray expertise developed in the

---

[75] The cancellation decision warrants further history study. A consensus now holds that Blue Streak was flawed as a retaliatory weapon system; insufficient numbers of missiles could have survived a Soviet first strike. It could therefore only be retained as a first-strike weapon system – a politically unacceptable position for the UK government. Others, however, argue that the technology was sound and that it could still have operated as an effective retaliatory system. Such an argument points towards other reasons for the cancellation: the escalating cost of the programme and especially that of the silo network across southern and eastern England, or perhaps the near presence of competing (US) air and sea-based systems; the latter, of course, that would come (as it ultimately did with Polaris) under the purlieu of a (domestically) competing UK armed force: the Royal Navy.
[76] See footnote 18.
[77] See Robinson (1990), Morton (1989) and Millard (2001) for comprehensive descriptions of the Black Knight programmes.
[78] See Millard (2001)
[79] The UK contributed to the Ariane development, albeit in piecemeal ways. Ariane's guidance gyros were developed by Ferranti and its Spelda for satellite attachment by British Aerospace. As a direct repost to proposals for the Ariane-launched Hermes shuttle, studies were initiated for the revolutionary, single-stage-to-orbit spaceplane employing air-breathing propulsion known later as HOTOL (see footnote 38).
[80] It should be remembered that while the UK gained from it bilateral relationship with the US, so too did the US with this direct line to the expertise of UK upper atmosphere and space scientists.
[81] See Appendix 5.3 for a definitive listing of the UK involvement (national and international) in space science missions during this period. See also the three parliamentary reports listed in the bibliography below, where copious details of UK space science (and, indeed, all other) activities are included as written, oral and assessed evidence.
[82] Ibid.
[83] ibid. See also Pounds (1999) for a view on the UK's space science programme as a part of ESA's.

country and single out UK (Ariel) 5, a wonderfully productive space science platform that helped pave the way for the bigger space observatories that followed. Others would highlight the UK's principal role, industrial and scientific, in Giotto, the quintessentially successful international spacecraft and ESA's first deep-space probe[84]. There are many missions that might qualify, each of which would need to be judged with different criteria.

Space industry

In the 1950s the UK's extensive aircraft and guided-weapons industries meant it was very well placed to meet the new challenge of space. Further, the Ministry of Supply, charged not only with supplying the armed forces but also with assisting the associated industries, was able to channel public funds their way too. This arrangement was a direct legacy of UK industry's organisation to meet the exigencies of the Second World War and one that was continued through until the mid- to late-1960s[85]. As the European space programmes developed, so UK industry was able to tender for contracts, independently at first, but increasingly as members of pan-European industrial consortia[86]. UK industry could meet almost all types of space technology requirement through to the early 1970s, but as the respective national priorities within the European Space Agency were established thereon, the prime UK companies concentrated on the potentially lucrative communications satellite business. Prime industrial centres were located at Stevenage, Bristol and Portsmouth[87], and by the end of the 1980s British Aerospace Space Systems, the UK's main space company, was leading on or contributing significantly, together with sub-contractor companies, to most of the European Space Agency's missions. In the 1980s an innovative small satellite business was established at the University of Surrey[88] - the first time that space technology transfer had been energetically pursued from within the UK's academic community.

Space interest groups

Interest groups played a significant role in the formative years, especially, of UK space activity. Bodies like the British Interplanetary Society and the Royal Aeronautical Society acted as fora for the assimilation and dissemination of research, information and news both within and without the UK's space communities[89]. The BIS, in particular, gained a global reputation for visionary thinking backed up by the solid scientific and technological expertise of many of its members. Such societies both lobbied, and were consulted by government, and acted also as gateways to the activities and concerns of international space communities. Industrial and commercial trade associations were also formed to coordinate the interests of companies. For example, the National Industrial Space Committee was formed from the Society of British Aerospace Companies, the Electronic Engineering Association and the Telecommunications Engineering and

---

[84] See Giotto: an historical perspective, JBIS, 55 supplement 1, 2002

[85] See Edgerton (1981) for a general background and history of the UK's aviation-based industries.

[86] See Adams (1976), Krige and Russo (2000) and Krige, Russo and Sebesta (2000).

[87] The histories of these three centres reflect the gradual consolidation of the satellite construction industry in the UK. The Stevenage site ushered in the space age under the de Havilland company and led on development of Blue Streak. The famous de Havilland name at Stevenage gave way to Hawker Siddeley Dynamics in 1961 and this in turn to British Aerospace in 1977. Between the 1960s and 1980s Stevenage led or assisted production on a range of spacecraft including ESROs 2 and 4, Intelsat III, TD1A, OTS, ECS, Marecs and Olympus. The British Aircraft Corporation, based at Bristol, led or assisted on a range of spacecraft including UK 3, 4 and X3. It too came under the BAe banner in 1977, its space science specialisation focused on Earth observation in the 1980s and in particular as lead site for development of ESA's Polar Platform, later known as Envisat. Perhaps Bristol's finest hour came in 1986 as ESA's Giotto probe, for whom BAe Space Systems at Bristol was prime contractor, successfully passed through the tail of comet Halley. The Marconi Space Systems Company at Portsmouth was prime contractor for two of the UK science spacecraft and sub-contracted on a range of spacecraft, particularly payloads and ground systems. For a listing of those spacecraft with UK prime contractors see Appendix 5.4, and for a comprehensive and detailed review of the UK's space industry through to the early 1990s see Turnhill (1984) and Wilson (1993).

[88] See Footnote 40.

[89] See Journal of the British Interplanetary Society (JBIS), Spaceflight and the Journal of the Royal Aeronautical Society. There is little in the history literature that assesses the activities and impacts of these societies. Winter (1983) describes the BIS's early history, but significant studies of its, and the RAeSoc's, role during the space age are long overdue.

Manufacturing Association. In 1975 it was renamed the United Kingdom Industrial Space Committee (UKISC). In 1985 the British Association of Remote Sensing Companies was formed to coordinate the concerns and interests of those companies involved in what was predicted to become a key area of UK space activity. The parliamentary All-Party Space Committee was formed in the late 1970s to bring together members of both Houses of Parliament who had interests in space.

Part 4 – Literature Survey, Archival Resources and Bibliography

There is a paucity of literature offering comprehensive histories of UK space activity. Two accounts stand out but, despite their high levels of detail, still only provide selected narratives: Massey and Robins (1986) recount the story of UK space science; Morton (1989) describes the major UK launch vehicle programmes from the perspective of the Australian Weapons Research Establishment (AWRE). UK rocketry programmes receive selected attention from Twigge (1993), Hill (2001), Millard (2001), Martin (2002) and Godwin (2005). Eberle and Wallace (1987) consider the country's space activity as an aspect of UK international policy-making, while Marsh (1991) outlines the main programmes and their organisation within government. The early bilateral relationship with the United States (US) is listed by Logsdon (1996). Much of the UK space activity during the 1960s was involved with the establishing and development of the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO) and is therefore covered by Madders (1997) and Krige and Russo (2000) in their general histories of European space activity. The UK's contribution to the European Space Agency (ESA) is similarly reviewed by Madders (1997) and Krige, Russo and Sebaesta (2000), while Wilson (2001) provides a very handy compendium of ESA (and ESRO) space missions, many of the entries including brief details of the respective national industrial and scientific contributors. This history draws heavily on all of these sources.

Articles and papers on UK space activity are more widespread and include both contemporary and historical accounts. Useful titles include *Space Policy, Journal of the Royal Aeronautical Society, The Aeroplane and Aeroplane Monthly, Aircraft Engineering, Interavia, Spaceflight, Journal of the British Interplanetary Society* and, more recently, *Quest*. More sporadic, but offering a wealth of detail, are UK parliamentary and government reports. These rely heavily both on submitted written evidence from individuals and organisations involved in UK space activity, and also on oral submissions from the same sources as heard and questioned by committee. The period under review in this history is particularly well represented by these in-depth investigations with two House of Commons reports published in 1967 and 1971 and a House of Lords one in 1988. Research theses are also in short supply, although a notable contribution to our understanding of early UK space policy is made by Whyte (1996), while Finch (2001) provides some excellent background to the decisions taken by the Macmillan government over rocketry, and Godwin (2005) suggests some fascinating new angles of enquiry with which to investigate the UK's sounding-rocket programme of the 1950s and 1960s.

UK government space archives are accessible, largely following the 30-year rule (although the recent Freedom of Information parliamentary act makes for the earlier release of many papers), from the National Archives (formerly known as the Public Records Office) at Kew in London. Its database can be searched on-line (http://www.nationalarchives.gov.uk/default.htm) and files may be reserved for inspection before visits. As might be expected, those relating to UK space activity are scattered across a range of government department classes, but those relating to the Ministry of Technology, its predecessors and successors, and the omniscient Treasury, are especially worth consulting. The Royal Society's archives can also be searched, but while minutes of the BNCSR are available, many of the Committee's reports are not. Other archival sources are more scattered, but include the Science Museum's collection of early rocketry technical reports and associated papers from the RAE and industry.

Bibliography

Adams, A.R. (1976), *Good Company: the story of the Guided Weapons Division of British Aircraft Corporation*, (Stevenage: British Aircraft Corporation, 1976).

British National Space Centre (1986), Columbus/Space Station United Kingdom Utilisation Study 1985/6 Report, (London: BNSC, 1986).

Bud, R. and P. Gummett (1999), *Cold War, Hot Science: Applied Research in Britain's Defence Laboratories 1945-1990*, (Amsterdam: Harwood, 1999.).

Carlier, C., M. Gilli and L. Laidet, 'CNES: The French Space Agency 1962-1992', IAA-2-1-93-669, presented at the 44th Congress of the International Astronautical Federation, October 16-22, 1993, Graz, Austria.

Chorley, Lord (1988), 'Economics of Space and the Role of Government', *Space Policy*, (August 1988).

Cox, N.P.G. (1992), *Ideas and Action... Emergence of Technical Innovation and Financial Discourse*, PhD. Thesis, Magdalen College Oxford, 1992.

Crossman, R., *The Diaries of a Cabinet Minister*, (London: Jonathan Cape, 1975).

DeVorkin, David H., *Science with a vengeance: how the military created the US space sciences after World War II*, (New York; London: Springer, c1992).

Dorling, E.B., (1959), 'The First Six Skylark Firings', Royal Aircraft Establishment Technical Note G.W. 530, October 1959.

Eberle, J. and H. Wallace (1987), *British Space Policy and International Collaboration*, Chatham House Papers 42, (Routledge and Kegan Paul, London, 1987).

Edgerton, D. (1991), England and the Aeroplane: an essay on a militant and technological nation (London: Macmillan, 1991).

Finch, G. (2001), Replacing the V-Bombers: RAF strategic nuclear systems procurement and the bureaucratic politics of threat, (University of Wales thesis, 2001).

'Giotto: an historical perspective', *Space Chronicle, Journal of the British Interplanetary Society*, 55, Supplement 1, 2002.

Godwin, M. (2005), Skylark, (University of London thesis, European Space Agency History Project, 2005).

Gould, B. (1988), 'No Future for Starship Free Enterprise', *Space Policy*, (February 1988).

Green, G. (1988), *British Aerospace: a proud heritage*, (Gloucester: Green, 1988).

Hall, R. and D. Shayler, (2001), *The Rocket Men: Vostok and Voskhod - The First Manned Soviet Spaceflights*, (Chichester: Praxis Publishing, 2001).

Harlow, J. (1998), 'Alpha, beta and the RTV-1: the development of early British liquid propellant rocket engines', in P. Jung (Ed.), *History of Rocketry and Astronautics*, 22, (American Astronautical Society, 1998, pp 173-201).

Harlow, J. (2002), (Ed.), 'UK Manned Rocket Aircraft', *Space Chronicle, Journal of the British Interplanetary Society*, 55, Supplement 2, 2002.

Heseltine, M. (1999), 'Britain and ESA', *The History of the European Space Agency: Proceedings of an International Symposium*, SP-436, (European Space Agency, Noordwijk, 1999).

Hill, N. (2001), *A Vertical Empire: The History of the UK Rocket and Space Programme, 1950-1971*, Imperial College Press, London 2001).

House of Commons (1967), 'Space Research and Development', *Thirteenth Report from the Estimates Committee*, (HMSO, London, 27 July 1967).

House of Commons (1971), 'United Kingdom Space Activities', *Fifth Report from the Select Committee on Science and Technology*, (HMSO, London, 27 October 1971).

House of Lords (1988), 'United Kingdom Space Policy, I and II, Reports, HL 41-I and 41-II', *Select Committee on Science and Technology*, (London: HMSO, 1988).

King-Hele, D. (1992), *A Tapestry of Orbits*, (Cambridge University Press, Cambridge, 1992).

Krige, J. and A. Russo (2000), 'The Story of ESRO and ELDO, 1958 to1973', Volume 1 of *A History of the European Space Agency*, 1958-1987, (ESA Publications Division, Noordwijk, 2000).

Krige, J., A. Russo and L. Sebesta (2000), 'The Story of ESA 1973 to 1987', Volume 2 of *A History of the European Space Agency*, 1958-1987, (ESA Publications Division, Noordwijk, 2000).

Logsdon, J.M., D.A. Day and R.D. Launius (1996), *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume II: External Relationships*, NASA SP-4407, 1996, (National Aeronautics and Space Administration, Washington DC, 1996).

Martin, C., *De Havilland Blue Streak: an illustrated story*, (London: British Interplanetary Society, 2002)

McDougall, W.A., 'Space-Age Europe: Gaulism, Euro-Gaullism, and the American Dilemma', *Technology and Culture*, 1985.

Madders, K. (1997), *A New Force at a New Frontier – Europe's development in the space field in the light of its main actors, policies, law and activities from its beginnings up to the present*, (Cambridge University Press, Cambridge, 1997).

Marsh, P. (1991), 'Britain in Space', in R. Nicholson, C.M. Cunningham and P. Gummett (Eds.), *Science and Technology in the United Kingdom*, (Longman, Harlow, Essex, 1991).

Massey, Sir Harrie and M.O. Robins (1986), *History of British Space Science*, (Cambridge University Press, Cambridge, 1986).

Millard, D. (2001), *The Black Arrow Rocket: A history of a satellite launch vehicle and its engines*, (Science Museum, London 2001).

Morton, Peter (1989), *Fire Across the Desert: Woomera and the Anglo-Australian Joint Project, 1946-1980*, (Canberra: Australian Government Publishing Service, 1989).

Nicholson, Sir R., C.M. Cunningham and P. Gummett (Eds.), *Science and Technology in the United Kingdom*, (Harlow: Longman, 1991).

NASA SP-4406 (1990), *Orders of Magnitude: a history of the NACA and NASA 1915-1990*, (Washington DC: NASA, 1989).

Pounds, K. (1999), 'The ESA Space Science Programme: A view from the United Kingdom', *The History of the European Space Agency: Proceedings of an International Symposium*, SP-436, (European Space Agency, Noordwijk, 1999).

RAE (1962), *Formation of Weapons and Space Departments*, Technical Memorandum No: Dir. 9, RAE, January 1962.

Rayner Report (1971), *Government Organisation for Defence Procurement and Civil Aerospace*, Cmnd 4641 (London: HMSO, 1971).

Rothschild Report 1971, 'The Organisation and Management of Government R&D', *A Framework for Government Research and Development*, Cmnd 4814 (London: HMSO, 1971).

Robinson, H.G.R. (1990, 1), 'Suggested Developments of Black Knight', *Journal of the British Interplanetary Society*, 43, 7 (July, 1990), pp 317-318.

Robinson, H.G.R. (1990, 2), 'Overview of the Black Knight Project: Black Knight, its genesis, *Journal of the British Interplanetary Society*, 43, 7 (July, 1990), pp 291-295.

Robinson, H.G.R. (1992), 'The Genesis of Black Arrow', *Journal of the British Interplanetary Society*, 45, 4 (April, 1992), pp 149-154.

SBAC (1988), Britain in Aerospace, (London: Society of British Aerospace Companies, 1988).

Trend Committee 1963, *Committee of Enquiry into the Organisation of Civil Science*, Cmnd 2171 (London: HMSO, 1963).

Turnhill, R. (1984), (Ed.), *Janes's Spaceflight Directory*, (London: Jane's Publishing Company, 1984).

Twigge, Stephen Robert (1993), *The early development of guided weapons in the UK, 1940-60*, (Harwood Academic Publishers, 1993).

War Office (1946), *Report on Operation Backfire*, (London: War Office, 1946).

Wilson, A., (1993), *Jane's Space Directory*, (Coulsden, Surrey: Jane's Information Group, 1993).

Whyte, N. (1996), *United Kingdom Space Policy, 1955-60*, (University of London thesis, 1996).

Whyte, N. and P. Gummett, (1994), 'The Military and Early United Kingdom Space Policy', *Contemporary Record - The Journal of Contemporary British History*, VIII, 2, (Autumn, 1994).

Wilson, A. (1993), (Ed.), *Jane's Space Directory 1993-94*, (London: Hutchinson, 1993).

Wilson, A. (2001), (Ed.), *ESA Achievements: More than thirty years of pioneering space activity*, BR-200, (ESA Publications Division, Noordwijk, 2001).

Winter, F.H., *Prelude to the Space Age*, (Smithsonian Institution Press, Washington DC, 1983).

Zuckerman, S. (1988), *Monkeys, Men and Missiles: an autobiography 1946-88*, (London: Collins, 1988)

Annex – Articles relating to 1950s rocketry and missile programmes

Allen, S., 'Rocket Engines', *Journal of the Royal Aeronautical Society*, 61, March 1957, pp 181-207.

Andrews, D., 'Rocket Engines for Satellite Launchers', *Spaceflight*, 8, January 1966, pp 24-30.

Andrews, D., 'Advantages of Hydrogen Peroxide as a Rocket Oxidant', *Journal of the British Interplanetary Society*, XLIII, 7, July 1990, pp 319-328.

Andrews, D. and H.L.G. Sunley, 'The Gamma Rocket Engines for Black Knight', *Journal of the British Interplanetary Society*, XLIII, 7, July 1990, pp 301-310.

Baxter, A.D. and S.W. Greenwood, 'British Rocket and Ramjet Engines – A Survey of Work to Date in this Important Field', *Aircraft Engineering*, September 1958.

'Britain's Guided Weapon Industry', *The Aeroplane*, May 20, 1955, pp 658-660.

Cockburn, R., 'Guided Weapons and Aeronautics', *Journal of the Royal Aeronautical Society*, 62, August 1958, pp 562-570.

Cownie, J.R., 'Background to Britain's Guided Weapons', *The Aeroplane*, August 30, 1957, pp 275-278.

Diplock, B.R., D.L. Lofts and R.A. Grimston, 'Liquid Propellant Rocket Motors, *Journal of the Royal Aeronautical Society*, 57, January 1953, pp 19-28.

Garner, G.W.H., 'Guided Missiles', *James Clayton Lecture*, The Institution of Mechanical Engineers, 19th November, 1954.

"Hush, It's Top Secret": Britain and Guided Missiles', *Interavia*, X, No. 5, 1955, pp 314-315.

'Operation Neptune', *Flight*, October 16, 1947, pp 446-448.

Pincher, C., *The Problems of Guided Missile Development*, 'Discovery', October 1955, pp 406-411.

Serby, J.E., Guided Weapons and Aircraft – Some Differences in Design and Development, *Journal of the Royal Aeronautical Society*, 62, March 1958, pp 187-202.

Slater, V.W. and W.S. Wood, 'High Strength Hydrogen Peroxide for Rocket Propulsion', *Journal of the British Interplanetary Society*, VII, 4 July, 1948.

Smith, T.L., RAE Guided Weapon Test Vehicles in the 1950s, *Journal of the Royal Aeronautical Society*, 69, February 1965, pp 101-115.

Transonic Research: Details of the Vickers Rocket-Propelled Model for Investigating Sonic Speed Flight, *Flight*, pp 36-38, July 11th 1946.

Part 5 – Appendices

Appendix 5.1: Departmental space interests, 1967

	DES	MoT	MoD	GPO	BoT	CO	FO	DoEA	T	Co-ordinating Dept.
Civil communications satellites	√	√		√	√	√	√	√	√	Not known
Military communications satellites		√	√				√		√	MoD
Scientific research satellites	√	√							√	DES
Reconnaissance satellites		√	√				√		√	MoD
Meteorological satellites	√	√	√			√	√	√	√	Not known
Military space systems		√	√				√		√	MoD
Aircraft control and surveillance satellites		√	√		√		√	√	√	Not known
Navigation satellites		√	√		√			√	√	Not known
Earth resource satellites	√	√			√	√	√	√	√	Not known
Technological satellites		√	√	√	√				√	MoT
ESRO	√	√					√		√	DeS
ELDO		√							√	MoT
CETS	√	√		√	√		√		√	FO
INTELSAT		√		√		√	√	√	√	GPO

Source: House of Commons, 'Space Research and Development', *Thirteenth Report from the Estimates Committee*, (HMSO, London, 27 July, 1967).

BoT	Board of Trade
CO	Commonwealth Office
DES	Department of Education and Science
DoEA	Department of Economic Affairs
FO	Foreign Office
GPO	General Post Office
MoT	Ministry of Technology
MoD	Ministry of Defence
T	Treasury

Appendix 5.2: Space expenditure 1965-1987 (£m)

	Total	ESRO/ESA	Non-ESRO/ESA
1965-67	18.56	10.66	7.9
1966-67	26.76	17.19	9.57
1967-68	24.15	13.85	10.3
1968-69	34.18	15.68	18.5
1969-70	27.82	14.4	13.42
1970-71	24.44	8.83	15.61
1971-72	18.2	5.4	12.8
1972-73	22.5	11.1	11.4
1973-74	31.1	19.6	11.5
1974-75	45.2	29.1	16.1
1975-76	54.6	38.3	16.3
1976-77	54.5	39.6	14.9
1977-78	52.9	39.8	13.1
1978-79	56.3	42.4	13.9
1979-80	63.2	49.3	13.9
1980-81	78.2	62.3	15.9
1981-82	81.6	64.3	17.3
1982-83	85.7	65.1	20.6
1983-84	93.8	73.2	20.6
1984-85	99.4	78.8	20.6
1985-86	98	75.7	22.3
1986-87	116	78	38

Sources

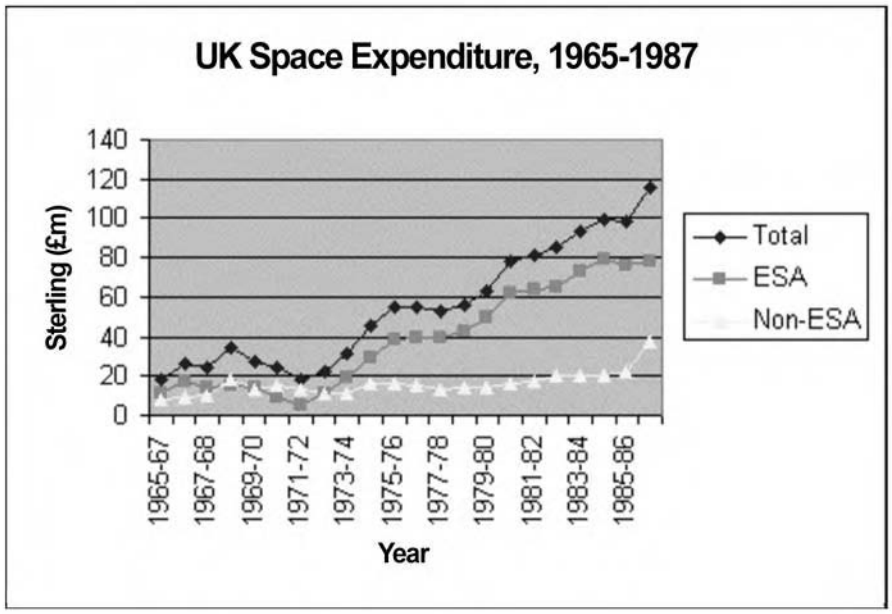
1965-66 —> 1967-68
House of Commons (1967), p 345.

1968-69 —> 1970-71
House of Commons (1971), p 291.

1971-72 —> 1985-86
Marsh (1991), p 201.

See Appendix 5.2a for detailed breakdown of expenditure for the years 1965-1972

1986-87
House of Lords (1988), p 21.



Appendix 5.2a: Detailed breakdown of space expenditure, 1965-1972

£000's	1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72 (estimates)
International Civil Programmes							
ELDO	8, 770	12, 540	8, 750	9, 640	8, 170	2, 390	--
ESRO	1,750	3, 850	4, 500	5, 00	5, 200	5, 620	7, 370
INTELSAT	140	800	600	1, 040	1, 030	720	770
POST-APOLLO studies	--	--	--	--	--	100	50
Total international	10, 660	17, 190	13, 850	15, 680	14, 400	8, 830	8, 190
National Programme							
Defence	3, 790	3, 500	4, 000	10, 700	5, 360	6, 190	10, 100
Commercial satcoms	570	1, 070	1, 170	1, 340	1,300	940	3, 110
Scientific space research	1, 800	2, 230	1, 960	2, 350	2, 930	4, 320	4, 530
Space technology and other	1, 740	2, 770	3, 170	4, 110	3, 830	4, 160	5, 260
Total national	7, 900	9, 570	10, 300	18, 500	13, 420	15, 610	23, 000
Total space	**18, 560**	**26, 760**	**24, 150**	**34, 180**	**27, 820**	**24, 440**	**31, 190**

Source: House of Commons (1967, 1971), Appendices 1 and A, respectively

Appendix 5.3: Science missions with UK involvement

The listing adopts the following scheme:

Year

Spacecraft
Nation/Agency

ESA	European Space Agency
ESRO	European Space Research Organisation
F	France
G	Germany
J	Japan
UK	United Kingdom
US	United States
Sw	Sweden

Launch date
Experiment or system
UK space science group (international collaborators included)

This listing does not include those ground-based activities essential to most of the missions listed. For example, in 1983 and beyond, the IRAS spacecraft's data were received via the Rutherford Appleton Laboratory's large S-band antenna, previously sited at the Laboratory's Datchet site. And both NASA and ESRO/ESA benefited from the ground stations at Winkfield, Berkshire and on the Falkland Islands and in Singapore, respectively. Neither does this listing reflect the work carried in the later years of this history during the conception and gestation of missions that were launched after 1987. As an observation in the course of preparing this history, it has been noticeable how poorly recorded the UK involvement in international space missions can be in the general literature – physical and electronic. Many of the UK instruments on international missions listed below have little or even no citation in the prime mission reference sources.

1962

Ariel (UK) 1
US/UK
26.04.62

Radio-frequency plasma probe to measure electron density.
Bir

Langmuir probes to measure electron density and temperature.
UCL

Positive ion mass spectrometer.
UCL

Solar X-ray spectrometer.
UCL/Lei

Solar Lyman-alpha radiation detector.
UCL

Solar aspect angle detector.
UCL

Cosmic-ray detector.
IC

1964

Ariel (UK) 2
US/UK
27.03.64

Galactic radio noise received on long wire aerial.
Cam

Spectrometer and broadband detection of ozone distribution.
MO

Micrometeorite detector.
Man

Explorer 20
US
25.08.64

Measurement of positive ion energy
UCL

1965

Explorer 31
US
29.11.65

Electron temperature probe and positive ion mass spectrometer
UCL

FR-1
F
06.12.65

Electron density by radio-frequency probe
Bir

Gemini GT-10
US
18.07.66

Surface collection of interplanetary dust
Bk

Gemini GT-12
US
11.11.66

Surface collection of interplanetary dust
Bk

1967

Ariel (UK) 3 (BAC Prime)
UK
05.05.67

Electron density and temperature of topside ionosphere by plasma probe.
Bir

Radio reception of galactic noise over 2 to 5 mHz band.
Man

Radio reception of very low frequency.
Shf

Vertical distribution of molecular oxygen by ion chamber detector.
MO

Radio reception of terrestrial radio noise.
RSRS

OSO-D
US
18.10.67

Total solar soft X-ray flux
MSSL/Lei

Total flux of solar He 2 radiation at 304 Angstroms
MSSL

1968

OGO-E
US
04.03.68

Electron temperature in magnetosphere by probe measurement
MSSL

Direction of incidence of energetic galactic gamma-rays
Sth

ESRO-2 (IRIS) (HSD Prime)
ESRO
17.05.68

Detection of high energy cosmic-ray electrons.
Lee

Total flux of solar X-rays.
Lei/UCL

Measurement of trapped radiation, Van Allen belt protons and cosmic-ray protons.
IC

ESRO-1a (AURORAE)
ESRO
03.10.68

Temperatures and compositions of positive ions.
MSSL

Temperature and density of electrons.
MSSL

Energy spectra and fluxes of auroral electrons and solar protons
RSRS

HEOS-A1
ESRO
05.12.68

Measurement of interplanetary magnetic field by fluxgate magnetometer.
IC

Detection of high energy cosmic-ray protons.
IC

Detection of solar protons.
IC

1969

OSO-5
US
22.01.69

Solar X-ray detection with scanning proportional-counter spectrograph
MSSL/Lei

OSO-6
US
09.08.69

Solar He 1 and He 2 resonance radiation measured with grazing-incidence polychromator
MSSL

ESRO-1B (BOREAS)
ESRO
01.10.69

Temperature and composition of positive ions.
MSSL

Temperature and density of electrons.
MSSL

Energy spectra and fluxes of auroral particles and solar protons.
RSRS

Energy spectrum of electron flux.
RSRS

1970

NIMBUS 4
US
08.04.70

Measurements of upper atmosphere temperature by six-channel selective chopper radiometer
Ox/Re (later HW)

1971

X-3 (Prospero) (BAC Prime)
UK
28.10.71

Micrometeoroid flux detector.
Bir

Experimental solar cells.
RAE

Experimental solar finishes.
RAE

Hybrid electronic assemblies.
RAE

Ariel (UK) 4 (BAC Prime)
UK
11.12.71

Improved electron density and temperature probes.
Bir

Improved radio reception at very low frequencies.
Shf

Lightening flash impulse counter.
Shf/RSRS

Measurement of ionospheric radio noise in the mHz range.
RSRS

Measurement of energy spectra of electrons and protons.
University of Iowa

1972

HEOS-A2
ESRO
31.01.72

Measurement of interplanetary magnetic field by fluxgate magnetometer.
IC

ESRO TD-1A (HSD – power supply and gyros)
ESRO
12.03.72

All-sky UV survey, 1350 to 2740 Angstroms
ARU/ROE/RL/Atlas Labs

OAO-3 (Copernicus)
US/UK
21.08.72

Detection of cosmic X-ray sources by a triple telescope array
MSSL/Lei

ESRO-4 (HSD Prime)
ESRO
22.11.72

Measurement of positive ion densities by counters.
MSSL

NIMBUS 5
US
11.12.72

Upper atmosphere temperature sounding by selective chopper radiometer
Ox/HW

1974

X-4 (Miranda) (HSD Prime)
UK
09.03.74

Ferranti Type 125 gyro. (first all-UK three-axis-stabilised satellite)

Spectra of discrete sources in the 2 to 30 keV energy range.
UCL

X-ray sky survey in energy range 1.5 to 20 keV.
Lei

Measurement of polarization of X-rays in energy range 1.5 to 8 keV.
Lei

Study of high-energy X-ray sources up to 2.0 meV.
IC

All-sky monitor in the energy range 3 to 6 keV.
Goddard Space Flight Center, NASA

Ariel (UK) 5 (MSS Prime)
UK
15.10.74

Measurement of source positions and X-ray sky survey in energy range 0.3 to 30 keV.
UCL

Spectra of discrete sources in the 2 to 30 keV energy range.
UCL

X-ray sky survey in energy range 1.5 to 20 keV.
Lei

Measurement of polarization of X-rays in energy range 1.5 to 8 keV.
Lei

Study of high-energy X-ray sources up to 2.0 meV.
IC

All-sky monitor in the energy range 3 to 6 keV.
Goddard Space Flight Center, NASA

1975

NIMBUS-6
US
12.06.75

Upper atmosphere temperature sounding by pressure modulator radiometer
Ox/RL

1977

GEOS-1 (BAC Prime)
ESA

20.03.77

Measurement of suprathermal electrons in range 5 to 500 Angstroms.
MSSL/ESA

ISEE-A
ESA/US
22.10.77

Magnetospheric measurements as part of a three-satellite project jointly with NASA.
IC/University of California

1978

IUE
ESA/US
26.01.78

UV spectroscopy at wavelengths between 1150 and 3200 Angstroms
UCL/AL/Goddard Space Flight Center (NASA)

Vidicon cameras
ARU/RSRS/AL/UCL

Pioneer Venus Orbiter
US
20.05.78

Temperature sounding of the high atmosphere of Venus
Ox/Jet Propulsion Laboratory (NASA)

GEOS-2 (BAC Prime)
ESA
14.07.78

Filter bank analysis of very-low-frequency wave fields.
Shf/MSSL

Measurement of suprathermal electrons.
MSSL

ISEE-C
ESA/US
15.08.78

Magnetospheric measurements as part of a three satellite project
IC/ESA/Sterrekundig Institut Utrecht

NIMBUS-7
US
24.10.78

Stratospheric and mesospheric sounding giving measurements of temperature and constituents distribution.
Ox

1979

Ariel (UK) 6 (MSS Prime)
UK
02.06.79

Detection of heavy cosmic ray primary particles.
Bri/AL

Observation of rapid time fluctuations in X-ray sources.
Lei

Observation of very soft X-ray emissions.
UCL/Bir

1980

Solar Maximum Mission
US
14.02.80

Hard X-ray imaging spectrometer
Bir/Lei/University of Utrecht

X-ray polychromator
MSSL/AL/Lockheed Palo Alto Research Lab

1981

Dynamics Explorer
US
03.08.81

Direct global thermospheric wind observations by use of single etalon Fabry-Perot interferometer
UCL/University of Michigan

1983

Exosat
ESA
26.05.83

Medium energy detector array
Lei/MSSL

Ferranti Type 125 gyro.

Spacelab-1
ESA
28.11.83

Cosmic X-rays – gas scintillator
MSSL

IRAS
Ferranti Type 125 gyro.

1984

AMPTE
UK/G/US
16.08.84

UKS (UK Satellite)
RAL

Electron experiment
RAL

Ion instrument
MSSL

Spacelab-2
ESA
29.07.84

Coronal Helium Abundance Spacelab Experiment (CHASE)
RAL

Solar Extreme UV Spectrometer
MSSL

1985

Giotto (BAeSS Prime)
02.07.85

Johnstone Plasma Analyzer (JPA) – solar wind and cometary ions
MSSL/RAL

Dust Impact Detector (DID) – mass spectrum of dust particles
Ke/RAL

1986

Viking
Sw
22.04.86

MICS instrument
RAL

1987

Ginga
J
05.02.87

Astro C
RAL

Appendix 5.3a: Key to main UK space science groups and space companies

AL	Appleton Laboratory
ARU	Astrophysics Research Unit of the Culham Laboratory
Bk	Birkbeck College, London
Bir	University of Birmingham
Bri	University of Bristol
Cam	University of Cambridge
ESA	European Space Agency
HW	Heriot Watt University, Edinburgh
IC	Imperial College of Science & Technology, London
Ke	University of Kent
Lee	University of Leeds
Lei	University of Leicester
Man	University of Manchester
MO	The Meteorological Office
MSSL	Mullard Space Science Laboratory, UCL
OU	Open University
Ox	University of Oxford
PSSRI	OU Planetary & Space Sciences Research Institute
QMWC	Queen Mary & Westfield College, University of London
RAE	Royal Aircraft Establishment
RAL	Rutherford Appleton Laboratory
RL	Rutherford Laboratory
Re	University of Reading
ROE	Royal Observatory Edinburgh
RSRS	Radio & Space Research Station, later Appleton Laboratory (AL)
Shf	University of Sheffield
Sth	Southampton
SRC	Science Research Council, later Science and Engineering Research Council (SERC)
UCL	University College London

Space Companies

BAC	British Aircraft Corporation
BAeSS	British Aerospace Space Systems
DHP	De Havilland Propellers
HSD	Hawker Siddeley Dynamics
MSS	Marconi Space Systems
SSTL	Surrey Satellite Technology Ltd.

Appendix 5.4: Application satellites with UK (including Prime) involvement

Date	Spacecraft	Prime contractor
1969	Intelsat 3 F4	TRW with HSD
	Intelsat 3 F5	TRW with HSD
1970	Intelsat 3 F6	TRW with HSD
1971	Intelsat 4 F2	Hughes with BAC
	Intelsat 4 F3	Hughes with BAC
1972	Intelsat 4 F4	Hughes with BAC
	Intelsat 4 F5	Hughes with BAC
1973	Intelsat 4 F7	Hughes with BAC
1974	Intelsat 4 F8	Hughes with BAC
1975	Intelsat 4 F6	Hughes with BAC
	Intelsat 4 F1	Hughes with BAC
	Intelsat 4A F1	Hughes with BAC
1976	Intelsat 4A F2	Hughes with BAC
	Comstar D1	Hughes with BAC
	Comstar D2	Hughes with BAC
1977	OTS-1[90]	HSD (Prime)
	Intelsat 4A F4	Hughes with BAC
	Intelsat 4A F5	Hughes with BAC
1978	OTS-2	BAeSS (Prime)
	Intelsat 4A F6	Hughes with BAeSS
	Comstar D3	Hughes with BAeSS
1980	Intelsat 5 F2	Ford with BAeSS
1981	MARECS-A	BAeSS (Prime) with MSS
	Intelsat 5 F1	Ford with BAeSS
	Apple	ISRO with BAeSS
	Intelsat 5 F3	Ford with BAeSS
	Comstar D4	Hughes with BAeSS
	UoSAT-1	UoS (Prime)
1982	MARECS-B1[91]	BAeSS (Prime) with MSS
	Intelsat 5 F4	Ford with BAeSS
	Intelsat 5 F5	Ford with BAeSS
1983	ECS-1	BAeSS (Prime)
	Intelsat 5 F6	Ford with BAeSS
	Intelsat 5 F7	Ford with BAeSS

[90] Launch failure
[91] Launch failure

1984	ECS-2	BAeSS (Prime)
	Intelsat 5 F8	Ford with BAeSS
	Intelsat 5 F9	Ford with BAeSS
	UoSAT-2	UoS (Prime)
	MARECS-B2	BAeSS (Prime)
1985	Intelsat 5 F10	Ford with BAeSS
	Intelsat 5 F11	Ford with BAeSS
	Intelsat 5 F12	Ford with BAeSS
	ECS-3[92]	BAeSS (Prime)
1986	Intelsat 5 F14	Ford with BAeSS
1987	ECS-4	BAeSS (Prime)
	Intelsat 5 F13	Ford with BAeSS

[92] Launch failure

Appendix 5.5: Abbreviations

ACSP	Advisory Council for Scientific Policy
ASSC	Artificial Satellite Sub-committee
BAC	British Aircraft Corporation
BAeSS	British Aerospace Space Systems
BNCSR	British National Committee on Space Research
CNES	Centre National d'Etudes Spatiales
COSPAR	ICSU's Special Committee on Space Research
CSP	Council for Scientific Policy
DES	Department of Education and Science
DOE	Design of Experiments Sub-committee
DSIR	Department of Scientific and Industrial Research
DTI	Department of Trade and Industry
GC	Gassiot Committee
GWD	Guided Weapons Department
ICSU	International Council of Scientific Unions
IGY	International Geophysical Year
M	Marconi
MoA	Ministry of Aviation
MoD	Ministry of Defence
MoT	Ministry of Technology
NASA	National Aeronautics and Space Administration
RAE	Royal Aircraft Establishment
RPE	Rocket Propulsion Establishment
RS	The Royal Society
RSRE	Royal Signals and Radar Establishment
SD	Space Department
SGSR	Steering Group for Space Research
SRC	Science Research Council
TADREC	Tracking and Data Recovery Sub-committee

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel. (31) 71 565 3400 - Fax (31) 71 565 5433