A Review of UK Government Involvement in the Field of Semiconductor Technology Within the Research Establishments

by P.R. Morris

This paper deals with the influence of the UK Ministry of Defence research departments upon the development of the semiconductor industry in Britain. A survey of the organization of the relevant research departments of the Ministry of Defence (MOD) and the implementation of its procurement policies reveals that although fundamental work of an advanced nature was carried out successfully by these departments, lack of funding and constant organizational restructuring severely limited effectiveness. These problems appear to stem largely from lack of a national strategy involving both the establishments and industry, and the resulting short-term nature of government policy. Evidence for this view is supported by statements made by senior personnel both from within both the research establishments and industry. Because MOD policy was principally concerned with device acquisition rather than assisting the indigenous industry, research effort within the establishments was diverted from mainstream technology to concentrating on work of a non-commercial nature. Resulting government procurement contracts encouraged indigenous semiconductor manufacturers to produce short production runs of high-priced components for specialized military applications, rather than entering more competitive commercial markets.

The Role of the Ministry of Defence

The Ministry of Defence has always been the most important source of external funding for the British semiconductor industry, exceeding the industry's own expenditure until at least the early 1970s. The historical development of the organization responsible for that funding and its basic role must be briefly reviewed.

Military sponsorship in the electronic components field began in 1938 when the Inter-Services Committee for the Coordination of Valve Developments (CVD) was set up by the Royal Naval Scientific Service in order to coordinate the development of thermionic valves for military equipment. The committee was also responsible for procuring a satisfactory supply of electronic components for all three armed services and civil aviation. This objective could be achieved either by procuring components from suppliers within the United Kingdom or elsewhere. The Royal Navy was then the principal user of thermionic valves, and it seemed to be a logical step at the time to place these responsibilities under the Admiralty.

Although the Ministry of Supply became the principal purchaser of valves during the War, the CVD, based at the Admiralty, continued to be responsible for valve procurement through the Inter-Services Technical Valve Committee. In 1940, however, a reorganization resulted in the Ministry of Aviation, through the Radio Components Research and Development Committee (RCRDC) which become responsible for placing development contracts for passive components and materials. These committees functioned through a controlling committee and a number of specialist subcommittees; the function of these specialist subcommittees, together with associated research advisory panels, was to administer research contracts. These research advisory panels appear to have been almost entirely composed of government scientists who were experts within their particular field.

The basic CVD structure remained essentially the same during the 1950s and 1960s, but the emphasis changed from coordinating government research towards a more active role in determining its direction.[1] In 1972, the title was changed to Directorate: Components, Valves and Devices (still CVD), tardily reflecting current technical developments. Government funding of the semiconductor industry took place almost entirely through CVD until as late as 1976.[2]

Operations by CVD within the United Kingdom have consisted of carrying out research through government establishments in cooperation with industry, in order to develop devices principally for use by the Armed Forces. Contracts were awarded to selected firms in order to manufacture an agreed quantity of devices; it has not, at any time, been the function of government research institutions to set up production lines for manufacturing purposes. Instead, funding has been made available to support the government research establishments, and to also award grants to selected firms to carry out research and development on specified projects. The policy has been to award industrial contractors (i.e., semiconductor manufacturers) General Valve Development (GVD) contracts, permitting them to spend an agreed annual sum without further authorization by the Treasury.

For at least the first two decades of transistor manufacture, government research agencies were entirely confined to the role outlined above and did not consider the need to promote any commercial spin-off from their activities as part of their function. In 1969, Sir S. Zuckerman, chief scientific adviser to the government, summed up this situation: "If the results of Defence R&D can be exploited for commercial ends, including exports, the economy benefits; but this is a secondary objective of this kind of work."[3]

Despite a cutback in funds during the early 1970s, resulting in concern on the part of semiconductor industry executives, the total CVD budget for 1979, totaling about £20 million, was approximately the same in terms of purchasing power as ten years previously.[4] This suggests that a fairly stable situation existed regarding the CVD funding of industrial contracts, at least during this period. Consistent long-term funding of this nature could well induce a feeling of complacency in the recipients, who would have little incentive to seek alternative sources of profit within the commercial field.

Since the early 1980s, the government placed increasing emphasis on the need for commercial by-products from MOD research activities. MOD took the view that this was principally a problem for industry, rather than the research establishments and that successful spin-off was "market led" rather than "technology driven."[5] The department also argued that since over 80% of defense R&D expenditure was spent on product development programs within industry, and because it was normal practice to vest the intellectual property rights of the technology in question with the firm concerned, private industry was already in possession of the technology arising from these programs. Therefore, it followed that lack of spin-off was primarily due to the inability or unwillingness of industry to exploit defense technology.[6]

MOD Procurement: The Organizational Framework

Some idea of the significance of MOD assistance to industry may be gained from the fact that in 1968, total expenditure upon semiconductor R&D in Britain for government laboratories was $4.1 million, for government financed industrial research $3.5 million, and company financed was $6.4 million.[7] Because of the importance of MOD involvement in research activities, the organization of MOD project work, together with the manner in which it affected industrial contracting, strongly influenced industrial research activity in favor of MOD objectives, and thus reducing emphasis upon commercial activities. This trend was further reinforced by MOD's procurement policies. An appraisal of procurement policy and the industrial contracting process can help gauge the extent of these influences.

An examination of the organization of MOD's industrial contracting is necessary. The establishments cooperated with the private sector by inviting research proposals to be submitted to CVD by individual firms. These proposals might result in continued cooperation on some particular project, or could involve an entirely new field; they could be initiated by the firm concerned, or by the research establishment itself. The research proposals, if accepted, resulted in CVD sponsorship of development projects. CVD financial support under this system was dependent upon the satisfactory progress of a particular project, and usually reviewed on a yearly basis.

Development projects (known as VXs) usually consisted of two stages: first, a feasibility study would be conducted to determine whether it was possible to meet the required military service specifications, and second, an additional study would be conducted to demonstrate the ability to make these devices at an acceptable quality level. Success at the latter stage usually led the CVD granting the firm a certificate which entitled it to manufacture the device under government contract. However, there was no guarantee that an order would be placed at any time to purchase these devices, since this decision rested with a different department within the Procurement Executive,[8] and, consequently, a degree of uncertainty was introduced into the whole operation.

Unlike the situation within the United States, no funds were usually made available for production development; this was considered to be the responsibility of the firms concerned who were expected to recoup their expenses from profits made by device sales. Since production runs involving government procurement contracts tended to be short, unit costs remained high, ensuring that devices supplied under these contracts were correspondingly expensive. These costs reflected in turn in higher equipment values, leading to a disadvantage in export markets.

Procurement policy during the early years of semiconductor manufacture was of vital importance in shaping the future course of the industry. Because of an initial technical lag within the United Kingdom and limited research and development effort in silicon technology, there appears to have been little prospect of obtaining adequate supplies of components of the required type from British semiconductor firms, despite the negotiation of MOD contracts at an early stage. A vitally important decision was therefore taken to procure supplies of silicon devices as rapidly as possible, by encouraging Texas Instruments (the most technically advanced firm in the field) to construct and market these components within Britain. Reviewing this situation, Malerba states, "Public procurement followed a policy of low risk purchasing involving the purchase of established components which had already been successfully launched in the United States."[9]

Government purchasing policy was outlined in the 1967 White Paper entitled "Public Purchasing and Industrial Efficiency" and was stated to be: "To obtain what is needed, at the right time, and in such a way as to secure the best value for money." Within the narrow constraints of MOD requirements, this approach was no doubt sound and effective, although as it was to unfold, this purchasing policy was to have dire consequences for the future of the British semiconductor industry. The policy was restated in 1983 as "buy British defense equipment unless a foreign product offers substantial advantages of time scale, cost or performance."[10] Evidence suggests that at least in the case of MOD, these policies were implemented with regard to suppliers.[11] Furthermore, also evident is the compartmentalized, ad hoc nature of these governmental decisions in the absence of an overall, long-term industrial strategy.

It is notable that as early as 1959, development contracts were awarded both to American owned Standard Telephones and Cables and to Mullard, a Dutch controlled company.[12] From the beginning, government encouragement and assistance was given to the foreign companies from politically friendly countries who were manufacturing within the United Kingdom. The sole criterion for placing orders appears to be have been that they were capable of producing sufficient quantities of electronic components of the type required, in order to meet equipment needs. This policy strongly contrasts with the situation within the United States, where, through the operation of the "Buy America" Act, British companies were effectively excluded from lucrative military contracts.

MOD Procurement: The Strategy

Since a basic object of MOD policy was to acquire a reliable and adequate source of components for military equipment, the CVD assisted industry in research and development activities. At least until the late 1960s it was not the department's practice to use this assistance as a commercial springboard, although it was not unsympathetic to such an occurrence. An indication of the prevailing attitude towards industrial outgrowth was a research and development levy placed upon any commercial benefit derived from MOD funded activities. This levy was not fixed, but open to negotiation, and was criticized by industrialists on the grounds that it placed them at a disadvantage when compared with American competitors.[13]

Apart from any considerations of technical lag, the temptation to procure devices from the United States was considerable, since, due to military pump-priming, American manufacturers were able to supply technically advanced components at extremely low prices. Consequently, large orders were placed in America by the late 1950s for devices in short supply, such as silicon grown junction transistors (which were still being supplied to MOD in production line quantities by Texas Instruments at least as late as 1966). Furthermore, encouragement was given to foreign suppliers to locate their manufacturing operations within the United Kingdom. Under these circumstances, the obvious course—soon after pursued by British semiconductor firms—was to manufacture highly specialized devices outside mainstream production which could be sold to the government at premium prices. The result of government procurement policy, during at least the first two decades of manufacture, was effectively to steer the indigenous industry towards the production of devices which had limited commercial application.

MOD interest in semiconductor research had begun at an early stage because problems had arisen as a result of attempts to microminiaturize thermionic valves for use in military equipment. This led the CVD to fund investigations into alternative means of producing reliable electronic alternatives. Like their counterparts in the United States Department of Defence, MOD research establishment personnel were certainly quick to realize the significance of the transistor, and already by 1952 semiconductor materials and solid-state physics were major subjects of investigation. For example, the need for a more reliable electronic switch in guided weapon systems resulted in Treasury support for a Ferranti team to participate in the Bell Technical Symposium held in April 1952 and to fund the license fee from Western Electric, which was necessary for that company to manufacture transistors commercially. Government assistance through MOD, at least in Ferranti's case, was important in initiating work in this area; it is doubtful whether the company would have been able to afford such a venture using internal resources.[14]

Towards the end of the 1970s, the Department of Industry began to consider supporting important research projects with a significant defense electronics content in the civil sector, provided that they could not be assisted by MOD due to lack of funds. The companies concerned would usually be expected to contribute to the funding, although full support might be considered in exceptional cases where the work had wide civil value and did not directly benefit the individual companies.[15] In addition, further funding from the Department of Industry was possible for projects for which MOD assistance could no longer be justified, such as the modification of components in order to make them more suitable for export markets. The Department of Industry might also grant subsidies in order to pursue production engineering activities no longer required by MOD.[16] Due to the Department of Industry's increasing financial support and the influence of the Research Requirements Boards, R&D in the early 1980s' emphasis shifted towards more industrially oriented work, particularly in the microelectronics field.

Government R&D Establishments

A brief description of the various United Kingdom's government research agencies, together with their organizational history, follows. It is important to realize that these agencies were subject to fairly constant reorganization during the period under review and that these changes could hardly have failed to have had a disruptive effect upon research programs. An idea of the extent of the consequent changes within the agencies specifically concerned with semiconductor research may be obtained from the following brief account.

The leading government research and development establishment involved in semiconductor work has been the Royal Signals and Radar Establishment (RSRE), based at Malvern, Worcestershire. This establishment was formed in 1975 by the amalgamation of the Royal Radar Establishment (RRE) in Malvern, with the Services Electronics Research Laboratory (SERL) based at Baldock, Hertsfordshire, and the Signals Research and Development Establishment (SRDE) at Christchurch, Dorset. The RRE had itself been formed in 1952 by the amalgamation of the Radar Research and Development Establishment, which mainly worked for the Army, and the Telecommunications Research Establishment, supporting the Royal Air Force. The RSRE in turn became the principal center for all aspects of electronics, computing, and physics research. Its policy, according to its director, was to concentrate on "speculative research which industry at the present time at any rate would feel it could not attempt to do."[17]

Like other government establishments, the RSRE underwent substantial reorganization and redefinition of objectives, reflecting changes in government administration and policy. Prior to coming under the Ministry of Aviation in 1959, the RRE was part of the Ministry of Supply but in 1967 it became a Ministry of Technology establishment, changing to the Ministry of Aviation Supply in 1969. Following further government reorganization, it was placed under the Ministry of Defence in 1971. As the RSRE, it came under the Department of Trade and Industry in 1980, the move reflecting its newly perceived industrial role. Finally, in 1990, It became part of the Defence Research Agency, emphasizing still further its commercial outlook.

In April 1992, the Electronics Division was split into ten "business sectors," two of which are largely based in Malvern, while at the same time, further staff redundancies resulted in a fifty percent cut in support staff on a nationwide basis.[18]

In 1965, the RRE had been described as "a Ministry of Aviation research establishment with broad responsibilities for the application of electronics to equipment for the three fighting services and for civil aviation."[19] More specifically, the RRE was engaged in "the conception of military and civil systems"[20] and, in addition to "fundamental work in the study of physics of materials and techniques which may be expected to be applied to electronics,"[21] its remit extended to "such further work as is necessary to demonstrate that a new technique has a worthwhile potential capability."[22]

The RRE comprised two main technical departments: the Physics and Electronics Department, subdivided into a Physics Group, mainly concerned with solid-state research, and an Electronics Group, acting as a link between basic research being carried out within the Physics Group; and the

Military and Civil Systems Department, also divided into a number of groups, the largest being Applied Physics and Technical Services whose function involved the development of components, equipment, their packaging, and their environmental testing.

Until its association with the RRE, SERL did not formally collaborate with the RRE at either the working or management level, although some coordination of programs did occur. As part of the CVD, SERL was engaged in the field of electron physics and, during the 1970s, were experts in the construction of electronic devices such as Klystrons and Magnetrons. They also carried out work in the solid-state field, including solid-state lasers and on gallium arsenide, where in the latter area at least, practical liaison with RRE was close.[23]

The combination of research establishments resulting in the formation of the RSRE was carried out to reduce costs and to avoid duplication of effort. The complete rationalization of the various service establishments was, however, never fully implemented.

Other research establishments involved in semiconductor activities from 1959 included the Royal Aircraft Establishment, Farnborough, the Atomic Weapons Research Establishment, Aldermaston, the Radio Research Station, Slough, the Atomic Weapons Research Establishment, Harwell, and the Post Office Research Station, Dollis Hill, London.[24] Although a centralized approach was adopted in concentrating research at Malvern, widespread awareness and interest in semiconductor technology existed from an early stage amongst government research personnel.

Technological Innovation: Devices and Materials

A review of the nature of the work actually carried out within the research establishments reveals the breadth of research and its technically advanced nature, particularly in the investigation of gallium arsenide and materials such as indium antimonide and mercury cadmium telluride. Little interest, however, was shown in silicon until the early 1970s, and, consequently, the commercially important area of silicon integrated device technology was neglected.

From the earliest days of device production, MOD showed an interest in various microelectronic circuit techniques and concentrated its attention on work in this field, instead of assisting discrete device development. With the advent of the silicon integrated circuit, it was decided, rather than actively pursue this work, to encourage industry to acquire experience in the basic processes needed to make silicon integrated circuits and to establish techniques which could be subsequently utilized in developing specific circuits for equipment projects. It is evident that this approach was aimed specifically at satisfying MOD requirements, and did not refer to the possibility of commercial outgrowth. The consequence of this policy was to strengthen the tendency of indigenous semiconductor manufacturers to concentrate on producing microelectronic components for "niche" military requirements and to weaken their incentive to compete within commercial markets.

Prior to 1961, the CVD had initiated a small program to produce specialized germanium transistors and diodes and thin-film microcircuitry. Major support for microcircuit research and development in industry began in 1961, and in research specific to integrated circuits between 1961 and 1968, the total sum invested by CVD on a yearly basis amounted to £720,000.[25] Research and development on general silicon technology (relevant to integrated circuits and discrete devices) amounted during this period to approximately £500,000. In addition, over the same period a further £444,000 was allocated to firms as CVD support under various VX development projects, bringing the total financial support for microcircuit research and development during the ten year period to £1.64 million.[26]

The aim of the 1961 program was to encourage firms to undertake a feasibility study of the production of a digital integrator in integrated circuit form, however, the requirement ceased to exist before the study could be completed. Nevertheless, reports produced by the six firms involved enabled the concerned working party to conclude that Ferranti and Plessey were the most technically advanced within this field.[27] Significantly, when the CVD initiated its first two major projects, it chose these firms (specifically, the Ferranti Micronor l and a Plessey project involving two integrated circuits for intermediate frequency amplifiers). In 1962–63, the CVD provisionally allocated £250,000 to be spent during the following year upon circuit development for specific equipment. Although considerable discussion took place within the Research Establishments, no firm recommendations were made and the CVD transferred the money to other projects.[28] By the end of 1963, initial research studies were abandoned, and it was decided that the CVD would only support integrated circuit research in response to formal requests from user establishments. Until at least 1968 these requests were minimal, and CVD funding during these years was largely restricted to investigating new techniques.

It is evident that CVD support during the formative years of microcircuit manufacture took place on a relatively small scale. Furthermore, money was allocated to a large number of projects covering a fairly wide field, including work on specialized photocells and microwave devices, used largely in military applications and with little mass production potential. The main firms involved in these projects were Ferranti, GEC, Mullard (ASM), Plessey, Texas Instruments, and Standard Telephones and Cables; in addition to these companies, Elliott (Microelectronics) and Marconi received a small amount of CVD support.

Comparison between the commencement of research projects initiated within government research establishments and corresponding successful innovation within the United States during the early 1960s indicates a time lag of perhaps one or two years. The RRE was certainly aware of and quick to act in response to technical developments in the United States, as illustrated by the following table[29] indicating the time lag between initial commercial production of various devices and innovations and the date of their commencement at the RRE or, alternatively, when procured by the MOD:

Table 1:

Innovation within the U.S.	Initiation of Research Project by RRE or device procurement by MOD
Thin Films (Tantalum) (1959)	Jan. 1960 (RRE)
Thermocompression Bonding (mid-1950s)	End of 1960 (Although 1956 at GEC Hirst Labs)

Planar Transistor (Fairchild, 1960)	Planar facility set up 1961 at RRE, although original concept took place here, 1952 (G.W.A. Dummer)
Epitaxial Material (Bell Labs, 1960)	Material first received 1962 at RRE
Silicon Junction Transistor (TI, Dallas, 1954)	T.I. (Bedford) set up with UK Government assistance to produce Si Junction devices for military (1957)
T.T.L. IC's in limited production, (TI, Dallas) (1962)	TI (Bedford) 11 months later, on UK Government contract
MOS (Fairchild & GE 1962)	Work commenced 1964–65 at RRE

In 1965 G.W.A. Dummer described work on a variety of microelectronics projects (with an emphasis on thin film technology) carried out at the RRE and its support of a number of development contracts,[30] among which were sealed microminiature transistor and diode development, conducted by Mullard Ltd., and a thin film development contract awarded to the same firm. Following Plessey's early work in silicon integrated circuitry, in February 1960 a team was set up at the RRE to study semiconductor integrated circuit techniques. Contracts to study these techniques were also awarded to Texas Instruments and Standard Telephone and Cables. At this time, the CVD was also supporting Ferranti in the development of silicon mesa devices.

It has been suggested that no viable program existed for silicon at the RRE because a role could not be defined.[31] Some work was carried out on support technology, but there was little core work on circuit fabrication (which would have involved considerable financial outlay). Although the military noted the importance of silicon integrated circuit technology at an early stage, its was considered a low priority due to the perceived commercial significance of the technology as well as the available supply of advanced devices, which was ample to satisfy the existing demand. Other long research programs, dating from the early 1960s, focused on the fabrication of indium-antimonide and cadmium-mercury-telluride infra-red detectors and involved considerable collaboration with industry.

The resumption of work on silicon at the RSRE in the early 1970s was certainly beneficial to the industry and a good working relationship appears to have existed between RSRE and the major semiconductor companies. Research of an advanced nature into other materials also yielded dividends. For example, aid from the RRE, along with MOD funding, helped Plessey become a world leader in gallium arsenide technology during the late 1960s and early 1970s, although the devices produced as a result (gallium arsenide FETs) were too advanced for the existing market. Such successes, however, were on a relatively small scale, and did nothing to stimulate mass markets.

Fundamental work on military electronic devices at the RSRE was hampered by a severe shortage of funds[32] and this problem became increasingly greater as the cost of setting up fabrication plants escalated, due to increasing device complexity. In 1982, Dr. W. Fawcett, head of the Physics Group at the RSRE, explained that their facility for making integrated circuits was very poor in comparison with industrial facilities; thus any initiative in the military field should be linked to industrial schemes.[33]

SERL began to investigate silicon semiconductor technology in the early 1950s, but by the middle of the decade this work was phased out in favor of germanium and group III-IV compounds. Work on silicon ceased because of an urgent need to produce a highly reliable pulsed neutron source for field use as the initiator for a nuclear weapon. A gallium arsenide program begun in 1952, with the initial aim of producing a gallium arsenide *p-n* junction transistor while simultaneously carrying out fundamental research into that material. This developed into a lengthy gallium arsenide program, which evolved as follows:[34]

Technology	Research	Development
Varactor diode	1958	1969
Lasers	1962	1969
Gunn diode	1963	1967
Low Noise FET	1970	1976
IMPATT devices	1974	1977
Power FET	1976	1976
ICs	1980	—

In addition, work was carried out on a number of other projects, including photocathodes and image intensifiers; collaborative work on epitaxial growth of gallium arsenide began around 1973 and was still in progress over a decade later.[35]

Baldock became the main European center for gallium arsenide semiconductor devices, and work continued on this compound because so much of the material physics was yielding interesting phenomena.[36] In 1983, it was stated that this project was kept going because of its potential use in integrated circuit fabrication. Major work on the Gunn effect was done at the RSRE at Malvern, although IBM had obtained the patents some time after Gunn's departure to the United States; commercial devices then soon went into production. Baldock was successful in being the first to develop gallium phosphide light emitting diodes (LEDs).[37]

From this brief outline of the activities carried out within the research agencies, a general picture emerges of an extremely high degree of technical innovation, with research personnel working on the field's leading edge. The direction of research and consequent commercial outgrowth was, however, severely limited by financial considerations. The decision to neglect silicon technology until the early 1970s appears to have been a major policy error since little support could consequently be offered to indigenous firms. Conversations with research personnel suggest that the major factors involved in the decision were the ready availability of silicon devices from overseas sources and the unavailability of funding for an advanced silicon program.

Government Policy: the Research Establishment View

Conversations with a number of senior research establishment personnel suggest that, in general, government policy towards the research establishments was that of the less costly option to streamline, as opposed to rationalize, research. No matter what government was in power and despite declarations of intent, promises were never backed up with adequate resources and there was no understanding of how to implement stated intentions.

A strong feeling existed that choice of a research topic should rest with the establishment, rather than with the services (the Treasury or MOD administrators), on the grounds that their outlook was too short-term and they inevitably thought in terms of equipment. Since any success in research is usually the result of years of sustained effort, moves made during the 1970s toward outside control had resulted in "a strong element of the accountant's attitude requiring to be convinced of pay-off in a short time scale."[38]

Financial stringency during the 1980s had resulted in restrictions in the recruitment of research personnel. Consequently the numbers within research teams may well have fallen below the critical level and research momentum might have been lost in certain fields. Also, low pay on entry had also led to difficulty in recruiting first-class graduates, a situation exacerbated by a steady deterioration in salaries and terms of service.

Senior MOD personnel have suggested[39] that a constant difficulty in influencing policy appeared to be that the views of heads of research establishments were filtered through to ministerial level via administrators with a typical "Oxbridge" classics background and little interest in science; all administrators at First Secretary level, and the majority at Second Secretary level, had been recruited from this group. Perhaps, understandably, administrators did not like the technical language used to argue a case, suggesting that misunderstandings at this level were highly possible. Little direct contact existed between politicians and the heads of research establishments and what contact did exist was mainly through Parliamentary Select Committees, and occasional visits by ministers to the establishments.

Some efforts were made to change this situation, but met with only minor success. For example, prior to 1976, the post of Chief Scientific Adviser had been held by Sir Alan Cotterell, supported by a small number of scientific officers in the Cabinet Secretariat. This arrangement has been described as having "not worked well, since others had decided what was or what was not 'science' [and] in a classic Whitehall pattern the technical expert found himself largely excluded from mainstream policy making and limited to commenting mainly on technical issues."[40] Upon Cotterell's retirement in 1976, the post of Government Chief Scientist was created "as an indirect result of the 1971 Rothschild Report on Research and Development."[41] The first appointment to this new post was Professor John Ashurst, a biologist from Essex University, who also became a member of the Central Policy Review Staff; in this position he was able to alert the Callighan Government to the significance of microelectronics.

The criticisms also appear to be borne out both by the Chairman of an ACARD working party,[42] who approvingly quotes a House of Lords Select Committee Report that stated:

> In a system of government which separates civil servants into generalists and specialists, the paucity of scientists and engineers coming through as potential Permanent Secretaries is a structural weakness . . . there has been no progress since 1970 in increasing the proportion of recruits to the Administrative Group with qualifications in science, engineering and mathematics.[43]

This situation might explain why advice given by research establishment personnel appeared to carry less weight than that offered by either industry or academia. Consequently, much of the advice reaching government came from those who were not in contact with advanced technical thinking, and without the experience of controlling research teams engaged in this type of work.

Recruitment of scientific personnel of sufficient caliber was claimed to have been hampered by restrictions on direct entry into the establishments at an appropriate level. Evidence suggests a chronic shortage of first-class scientists existed in the establishments within the semiconductor field and that financial restrictions were a major reason for this situation. Cooperation with leading research institutions on an international basis, including the exchange of technical staff, was regarded as extremely important but due to financial restrictions was difficult to implement. For example, due to lack of funding, a scheme involving a fruitful exchange of personnel between the RRE and the Massachusetts Institute of Technology was abandoned during the 1960s by the Service Committees and the Treasury.[44]

Although a close relationship existed between government research establishments and the microelectronics industry, differences—some of a long-standing nature—did arise. One criticism argued that although advanced products were made available to industry for development, firms were often reluctant to take up the challenge. Getting devices into production was difficult, because someone had to put up the capital and a general reluctance existed among firms to do so. For example, Plessey refused to begin work in the field of integrated circuitry without an MOD defense contract.[45] When interviewed, the director-general of Establishments, Research and Programs(A) at MOD explained the situation thus: "The only way to get firms to take action was to initiate a military project—in general, firms strongly preferred to deal with research projects initiated by the ministry through cost-plus contracts."[46]

Predictably, opposition existed towards any suggestion that MOD actually hand over establishment R&D work to industry. In 1982, the defense procurement secretary, G. Pattie, commented that "although such a policy would give industry a sharper edge, many firms shy away from the cost and the responsibility."[47] By this time, however, the need to involve industry more closely in research activities was felt to be evident, and the procurement secretary also argued for closer partnership with industry.

Consortia involving the RSRE and private firms such as Mullard and GEC seemed to have worked well because the arrangement involved equal effort on the part of participating organizations and the relationship between the participants was good. An essential feature was the pooling of research resources and information which allowed the possibility of more effective competition with large foreign laboratories. University laboratories had also been involved in most consortia, wholly funded by research contracts. Liquid crystals, infra-red detectors, and solid-state microwave devices all came out of these partnerships. Although this plan has worked well in transferring ideas rapidly into the industrial laboratory, it has had much less success in accelerating the manufacturing or marketing processes.

Perhaps the most important criticism of government policy during the period under review centers on its short term nature, in terms of both funding and objectives, as well as commercially restrictive guidelines placed upon the research establishments which resulted in an inability to take advantage of commercial openings. For example, a project was set up in the late 1960s that required the Electronic Materials Unit at the RRE to supply indium phosphide crystals.[48] Treasury approval was granted, and work began on the project, which ran for two to three years and involved a team of five or six experimental officers. Although profitable and with excellent prospects of expansion, it was decided for financial reasons not to staff the project to a level which would make it a financially viable production unit, although it continued to be run on a reduced basis.[49]

The chronic lack of funding for solid state device development may partly be explained by the view, expressed by some of the RSRE staff, that solid state development was not as important as radar, particularly in view of the lack of all-weather capability afforded by infra-red devices. The development of radar during the Second World War had been highly successful, and it has been suggested that senior staff, whose research experience mainly dated from that period, might have been reluctant to concentrate effort outside their specialized field. Also, the relatively greater amount of work done on the development of materials certainly contrasts with the comparative lack of effort in the more costly field of device technology, supporting the view that financial restrictions strongly influenced the direction of research within the establishments.

Government Policy: The Industrial Viewpoint

Statements made by senior managers within both the research establishments and the principal semiconductor manufacturing firms perhaps best reflect industrial attitudes toward government investment policy and the general relationship between government and industry. Criticisms of the government centered on two major factors, namely, lack of continuity in policy, and inadequate financial support.[50] The following opinions are reflective of the major sides of the issue and largely agree with ideas expressed during interviews with representatives of the major semiconductor companies.

First, a frequent complaint was that, unlike Japan and France, the United Kingdom did not have a well developed national strategy. This view was expressed by, among others, Dr. Alun Jones, Managing Director of Ferranti Ltd., who also criticized the lack of continuity in policy, stating:

> We do not have a consensus that, whatever political party is in power, there is a generally accepted strategy of what is good for UK business which survives different governments. This is a terrible handicap.[51]

Furthermore, government departments were slow in seizing opportunities, and financial support was limited. For example, in 1978 Dr. Alan Shepherd, manager of the Ferranti Electronic Components Division, stated government assistance from the Department of Industry came at a time when the industry was suffering from world-wide recession and helped to smooth out the recession's worst effects but these funds were not adequate.[52] (Ferranti was heavily committed at this time to government contract business, with about forty percent of their output accounted for by government procurement, this figure rising to sixty percent if foreign government work was included). Support for this view also came from Dr. Derek Roberts, Managing Director, Plessey Microsystems Division, who observed that government investment programs had made:

> A useful contribution to maintaining and improving the UK's capabilities in the IC [integrated circuit] business. However, they have not been of sufficient magnitude to actually break out of the limitations of a small marketplace and put in the really massive investment that is necessary for the UK to become a significant operation by world standards.[53]

He also felt a more formal degree of technical interchange and collaboration between companies and governments within Europe was necessary to offset the advantages of high personnel mobility (on the part of engineers) which existed in the United States.

GEC did not see its role as a semiconductor manufacturer on an international scale, despite its size. In 1979, Christopher Turner, Manager of GEC Semiconductors, stated that if Government funding under the Microelectronics Support Scheme had not been available, "it is debatable whether the UK semiconductor companies would still be in existence."[54] This remark suggests a lack of commitment, at least on the part of GEC (given the scale of their resources), since they received only about £3 million under this scheme.

Ministry of Defence equipment procedures were a subject of criticism, in particular the practice of constantly changing specifications which often resulted in considerable delay and it has been suggested that this factor contributed to lengthy delays in the introduction of the CLANSMAN radio system, on which Plessey started work in 1962, although the first sets were not delivered until 1974.[55] In addition to widely criticized delays in the procurement process which contributed to loss of export orders, F. Chorley, the Deputy Managing Director of Plessey Ltd., felt the policy of encouraging export sales of defense equipment, through acceptance of export oriented specifications (with the Ministry recovering cash through a levy on export sales), had failed. He added that competition for orders within NATO were prejudiced because Plessey did not receive the same level of subsidies as foreign competitors.[56]

The government decision to set up and support INMOS,[57] rather than increase funding to existing semiconductor companies, predictably came under criticism. For example, Plessey's chairman, Sir J. Clarke was highly critical, and the company's technical director, G. Gaut, claimed Plessey offered a far more viable alternative for the NEB's money than INMOS; he asserted that it was not only the Plessey board, but others in the electronics industry who were dismayed by the proposal.[58] Gaut also stated that in 1965 Plessey presented a report, entitled "Microelectronics—Its Impact in the UK Electronics Industry," to the government that recommended establishing a microelectronics center to develop special microcircuits for British industry over a period of five years at an initial cost of £5 million. This scheme had the support of technical personnel at the RSRE but others, including staff at Plessey, were doubtful of such a venture on the grounds that a market did not (then) exist. In view of these doubts expressed within the company perhaps most fitted to play the role of national product champion, it is not surprising that the government decided to support the creation of INMOS rather than invest in existing companies.

Summary

Clearly, a major characteristic of the British government's relationship with the microelectronics industry has been lack of long-term planning and constant changes in policy, however, these changes in policy towards the industry appear to have been a by-product of wider policy decisions rather than specifically targeted towards semiconductor manufacture.

Faced with the problem of dominant American multinationals, successive British governments failed to put forward a national strategy for the industry; the first coordinated attempt to assist the industry took place as late as 1978, and followed shortly after the imminent collapse of Ferranti in 1974-75 , suggesting that this action was a response to a crisis rather than a positive commitment to building a viable industry. Governmental cooperation with industry was tardy; only in the late 1960s were industrialists invited to participate in decision making through the Research Requirements Boards. Attempts to set up structures in the 1970s to establish closer links between government and industry do not seem to have been particularly successful, as evidenced by the short-circuiting of formal channels of discussion by private lobbying of ministers and officials.

During the period under review, continual changes took place in the administrative structure of government research establishments. It is difficult to estimate the resulting degree of dislocation and effect upon the planning of research programs, but it would hardly have been insignificant. Furthermore, to the detriment of their technical work, senior research staff were unavoidably occupied in restructuring programs. The consequent problems and uncertainties were reinforced during the 1980s by financial problems involving, among other matters, the reorganization and reduction of staff .

Financial limits imposed by the Treasury precluded any major research in silicon device technology, and until the late 1960s any such program directed at commercial markets would have been strongly discouraged. Although some work was carried out in the microelectronics field, it was largely speculative in nature and aimed at satisfying specific MOD requirements; doubtless, as a consequence, throughout the period work on silicon was subject to a technical lag. Not until the mid-1970s did the role of the government research establishments begin to be examined with a view to their supporting commercial activities. The shift in emphasis towards more industrially oriented R&D within the establishments, which only really began during the late 1980s, came too late to help the industry to enter mainstream commercial markets.

This change in the research establishments' role has been a difficult and lengthy process; more recently, it has led to the creation of the Defence Research Agency (DRA), replacing existing government research establishments such as the RSRE and SERL. The principal aim of such major restructuring was to finally establish an organization capable of making a significant contribution to commercial objectives. Unfortunately, this development, although of undoubted value to industry generally, can hardly at this stage substantially affect the fortunes of what remains of the British semiconductor manufacturing industry.

---

1 K. Dickson, "The Influence of MOD Funding on

Semiconductor Research and Development," *Research Policy* 12 (1983): 113.

2 Dickson, 119.

3 House of Lords, Select Committee on Science and Technology, "Memorandum" prepared by Sir S. Zuckerman, *Sessional Papers 1968–69, Defence Research* (27 March 1969), 346.

4 Dickson, 118.

5 S. J. Pollard, private communication with author, 22 June 1983. Pollard was MOD Procurement Executive in London.

6 Pollard, private communication.

7 J. Tilton, *International Diffusion of Technology: The Case of Semiconductors* (Washington, D.C.: Brookings Institute, 1971), 129.

8 Dickson, 117.

9 F. Malerba, *The Semiconductor Business* (London: F. Pinter, 1985), 77.

10 Pollard, private communication.

11 House of Commons, *Public Purchasing and Industrial Efficiency,* Cmnd. 3291 (May 1967), par. 4: 3.

12 G.W.A. Dummer, "Integrated Electronics Development in the United Kingdom and Western Europe," *Proceedings of the IEE* 52, no. 2 (December 1964): 1416–18.

13 House of Commons, Estimates Committee, "Electrical

and Electronic Equipment for the Services," *Seventh Report of the Estimates Committee* (1965) par. 89.

14 J.F. Wilson, *Government and the Electronic Components Industry: The Case of Ferranti, 1953–73*, 3.

15 House of Lords, Committee on Science and Technology, "Engineering Research and Development," *Sessional Papers 1982–83,* vol. 1 (22 February 1983) par. 5.2: 21.

16 *CVD News,* no. 10, August 1977.

17 House of Lords, Committee on Science and Technology, evidence given by E.V.D. Glazier, Session 1968–9, *Defence Research* (27 March 1969), par. 1293: 293. Glazier was the director of the RRE.

18 "Job Changes at Town Base," *Malvern Gazette*, 13 December 1991.

19 G.W.A. Dummer, "A History of the Microelectronics Development at the RRE," *Microelectronics and Reliability* 4, (1965): 193.

20 Dummer, "History of Microelectronics," 193.

21 House of Lords, Committee on Science and Technology, "Engineering Research and Development."

22 House of Lords, Committee on Science and Technology, "Engineering Research and Development."

23 House of Lords, Committee on Science and Technology, evidence given by D.H. Parkinson, Session 1968–9, *Defence Research* (27 March 1969),

par. 1224: 291. Parkinson was head of Physics and Electronics, RRE.

24 Gee, C.C., "World Trends in Semiconductor Development and Production," *British Communications and Electronics* (June 1959): 450.

25 Ministry of Defence, *CVD Support for IC Research and Development 1961–1968,* Appendix 1 (13 March 1968). The report was written by D.S. Oliver.

26 MOD, Appendix 1.

27 MOD, Appendix 1.

28 MOD, Appendix 1.

29 Dummer; engineering staff, Texas Instruments, (Bedford); and A. M. Golding, "The Semiconductor Industry in Britain and the U.S.: A Case Study in Innovation, Growth and Diffusion of Technology" (Ph.D. diss., University of Sussex, 1971), 66.

30 Dummer, "History of Microelectronics," 193–217.

31 C. Hilsum, private communication with author. Hilsum was later director of Research, GEC Research Centre, Wembley.

32 "Semiconductor Industry News," *Semiconductor International* (September 1982): 20.

33 "Semiconductor Industry News," 20.

34 G. Wright, private communication with author. As secretary of CVD, Wright was involved in formulating CVD policy for a number of years.

35 W. Fawcett, private communication with author. Fawcett was former head of Physics, RSRE.

36 Wright, private communication.

37 B. Mullen, private communication with author. Mullen was former head of the materials section at RSRE.

38 D.H. Parkinson, interview with author, June 1982

39 Parkinson, interview; and G.W.A. Dummer, interview with author, July 1984.

40 T. Blackstone and W. Plowden, *Inside the Think Tank: Advising the Cabinet 1971–1983* (London: Heinemann, 1988), 144.

41 Blackstone and Plowden, 71.

42 P.E. Trier, "Is R&D Really Relevant to Industrial Performance?" *Physics Bulletin* 37 (1986): 456–7. Trier was chairman of ACARD working party on annual inter–departmental review of government R&D.

43 House of Lords, Select Committee, *Report on Science and Government,* Cmnd 8591 (1982).

44 Parkinson, interview.

45 Dummer, interview.

46 Parkinson, interview.

47 "Cover Story," *Engineering Today,* 26 July 1982, 20.

48 Mullen, private communication.

49 Mullen, private communication.

50 In 1973, Plessey and Ferranti expressed skepticism

(through their membership of the EDC) of the effectiveness of government support in ensuring the viability of the UK microelectronics industry. National Economic Development Office, *Electronics: Industrial Review to 1977* (1973), par. 3.37: 18.

51 Alun–Jones, "Ferranti Attacking Systems Markets," *Electronics Industry* 7, no. 4 (April 1981): 31.

52 A. Shepherd, "Still a Place for British Microelectronics," *Electronics Industry* 4, no. 2 (February 1978): 33.

53 D.H. Roberts, "R&D Pays Off," *Electronics Industry* 4, no. 4 (April 1978): 31.

54 "Face to Face," *Electronics Industry* (April 1979): 37.

55 M. McLean, "MOD Buying Policies Slammed by Plessey Defence Electronics Boss," *Electronic Times* (11 February 1982): 3.

56 McLean, 3.

57 In 1978, the Labor government, through the National Enterprise Board, initiated a project to set up a British semiconductor company under the name of INMOS, to manufacture advanced integrated circuits.

58 D. Erskine, "How Plessey's Voice Remained Unheeded," *Electronic Times* (27 March 1980): 12.