THE DITCHLEY FOUNDATIONS
CONFERENCE
18-20 March 1988
Space Exploration: scientific luxury, commercial enterprise or prudent investment in the technologies of the future? Who should pay?

A Note by the Director

The conference was fortunately timed, following as it did the agreement between the European Space Agency and the US Administration on the Columbus project (the joint manned space station). With Britain's decision not to take part, unless last minute second thoughts prevailed, the spotlight inevitably tended to focus on British scepticism and to that extent the debate became an exercise in British soul-searching which the other participants endured with commendable patience, even sympathy. The subject was wide, but under firm chairmanship participants focussed on the essentials.

Various motives were identified for pursuing activity in space (the word exploration in the title was deplored), and an interesting distinction was drawn at the start between the aspirational and the utilitarian. In the opening sessions and in the groups, the underlying assumption was that space activity was self-evidently "a good thing" and that the only task was to convince the sceptics who controlled the purse. Some suggested that the case had to be argued on the basis of a multiplicity of benefits none of which alone, perhaps, would justify expenditure, but which taken together made an overwhelming argument: others that the case was weakened by relying on a variety of aims, which only made it easy for sceptical treasuries to knock down each argument piece-meal, and that it would be strengthened by concentrating on one principal purpose. There was some discussion whether it was necessary to fire the imagination of the public, notably the young at school and university, with a view to moving governments by popular demand; or whether it was necessary to convert governments so that the public could be given a lead. While the problem was most acute in Britain, none could feel themselves immune: in the US NASA was trying to carry out a $15 bn programme with a $9 bn budget; and even in France and Japan, where to outsiders the space programmes seemed most secure, those involved were very conscious of the need to fight for funds. The countries where programmes were most securely funded, it was noted, were those where the motivation was furthest towards the aspirational end of the spectrum; conversely where funding was most parsimonious, the accent was more on utility. Finally, although the terms of reference excluded defence (in order to avoid a debate on the SDI), it was recognized that the link between defence and civilian space programmes was important, even crucial in some fields.

These themes were further developed in three groups, one devoted to research, one to applications and one to international cooperation. No alternative to governmental funding was seen for basic research. Governments which opted out, would probably find themselves out of space activity altogether. It was suggested that at its level of funding of research, the UK might fall between two stools, too much to be economical and too little to exert influence. Apart from the importance of pure science in itself, the technological spin-off was essential if a country was to remain competitive. Space programmes pushed the bounds of technology and pulled nations and industry behind them. In that context, industry might be brought to see the importance of basic research in its own interests, though government funding would remain paramount.

There was some inconclusive discussion of institutional arrangements (direct government programme, independent agency (or agencies as in Japan), industrial management) and also of the need for space to be given a separate budget or to take its place in a general science budget. There was some preference, it seemed, for an agency or agencies, but for space to be considered in the context of scientific research as a whole.

The second group looked at applications under four heads: communications and navigation satellites; earth observation and remote sensing; micro-gravity (probably better considered as research); and transportation systems and ground services. Communications and navigational applications had matured (if any technology ever matured), the problem being to ensure that the researchers and developers received their share of the profits, one of the principal obstacles being the regimes established by governments within which both producers and users had to operate. Earth observation and remote sensing would begin to show a return on investment in the next 10-15 years. The problem would be to identify the users (mostly governments and governmental or international agencies) and to convince them that the costs were justified. Transportation and services were thought to be areas where commercial criteria could increasingly be applied. The demand for launchers would rise dramatically over the next decade, when the present sellers' market disappeared (the Soviet and Chinese quotations for launches were noted). The need was to reduce the overall cost of putting pay-loads into space, probably in the longer-run by horizontal re-usable launchers. The problem was that in all fields, government funding, whether direct or, through defence programmes, indirect, was essential in the early stages, given the high costs and the uncertainties (a matrix composed of technological risk, commercial risk and time-scale might be a useful tool of assessment); and there was not as yet a simple or established route to engage the private sector and funding at the appropriate time.

The third group concluded that given the cost of so many space projects, international cooperation was essential, as a form of cost and labour saving, if they were to be realised at all. In the purely scientific field such cooperation was relatively trouble-free (cf. the Inter-Agency Consultative Group for the Halley's Comet project); but at the point when research gave way to application, competition tended to obtrude (cf. the negotiations on the Columbus project). Cooperation between equal partners was best, but cooperation with those countries of the developing world with space programmes should not be ignored, if only for political reasons. The role of the United Nations itself, as opposed to such affiliated bodies as the ITU, was minimal and the group saw no need, as yet, for further international bodies, e.g. in the field of earth observation, although it might not be too soon to be thinking about the requirement: indeed some thought that Intelsat and Inmarsat required re-assessment, having become too inflexible. However work was needed soon on measures to prevent the pollution of space, especially by debris.

The concluding session concentrated on the unresolved question of how to convince the sceptics, several of whom voiced their doubts (from a position sympathetic to space aspirations) on grounds that in the competition for resources, space had overall done pretty well. Another theme was the need to involve private industry at an early stage, perhaps through devices similar to those employed in the defence field whereby development contracts were let initially on a cost-plus basis, but moved over, once feasibility had been established, to competitive tendering, i.e. at the point when at least the technological risk factor in the suggested matrix had been reduced. If then the commercial risk factor could also be reduced, by giving producers a chance to "capture the revenue streams", perhaps through operating agencies which could sell the product to the users, eg. in the earth observation field, the transition from public to private funding could be made.

In conclusion it was suggested that the proponents needed to study further the psychology of those they sought to convince: they needed to produce soundly-based, factual arguments, not extravagant flights of fancy lacking credibility; and while they might do well to concentrate on one primary argument in each case, they could make the points that some early space activity was already paying off, that technological advance in space served to inspire other sectors, especially the young, that in 25 years time the technologically strong nations would probably be those which were active in space, and that competition in technology had to a large extent replaced competition for territory.

Further practical arguments could rest on the arms control need (was it right to leave verification to the US and the Soviet Union?) and on the possibilities of involving potential users (e.g. the PTT's) - a point for any future conference at Ditchley on space.

In the end, though, it was my impression that the professionals of the space industry departed recognising that even in a sympathetic group the case for increased funding had not been deployed with sufficient persuasiveness. Some participants even went so far as to say that having started from a position of interest and mild enthusiasm they had been turned off by the arguments of the space community. It is clear that ways need to be found to marshall all the arguments in the most effective manner.

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THE DITCHLEY FOUNDATIONS CONFERENCE 18-20 March 1988

SPACE EXPLORATION: SCIENTIFIC LUXURY, COMMERCIAL ENTERPRISE OR PRUDENT INVESTMENT IN THE TECHNOLOGIES OF THE FUTURE? WHO SHOULD PAY?

List of Participants by country

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The Rt Hon the Lord Chorley
Mr Roy Gibson
Mr Anthony Gottlieb
Mr Paul D G Hayter
Mr John Holt
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Mr Jack Leeming
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Professor Timothy Scratcherd
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Mr John Pike
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SPACE EXPLORATION: SCIENTIFIC LUXURY, COMMERCIAL ENTERPRISE OR PRUDENT INVESTMENT IN THE TECHNOLOGIES OF THE FUTURE? WHO SHOULD PAY?

Anthony Gottlieb

An essay on a Ditchley Foundations conference held at Ditchley Park, Oxfordshire, England, on the weekend of 18-20 March 1988

Participants may hardly have noticed it, but the two questions which make up the title of this Ditchley conference, and especially the second, were answered clearly and unanimously. Governments should pay for the lion's share of space exploration, which is — for now — a prudent investment in the technologies of the future. But these two propositions were taken more as premisses than as conclusions. This is hardly surprising in a gathering consisting mainly of those concerned with public policy, and space scientists — rather than government ministers, treasury officials, or scientists from other fields. Fortunately, however, these two propositions leave undecided plenty of other related questions about space exploration and its funding.

Start with a contrast: space versus superconductivity. In 1987 and 1988 superconductivity, the ability of materials to conduct electric current with little or no resistance, has been the focus of an extraordinary amount of work in the physical sciences. This is because of the recent discovery of materials that superconduct at markedly higher temperatures than hitherto. Such materials hold out the promise of considerable economies for power storage and distribution, high-speed ground transportation, fast computing and other things. The commercial applications of high-temperature superconductivity were publicised as soon as the scientific breakthroughs themselves. Although the pay-off is, in many respects, far less certain than might be assumed from popular accounts, the effect of this publicity, and of intensive, focused work all over the world, is to make the job of a fund-raiser for superconductivity a straightforward one. While it is not by any means an easy one — in some parts of the world, the superconductivity lobby is already sufficiently mature to regard itself as under-funded — it contrasts sharply with the job of a lobbyist for space. The field of space science and exploration is far less well-defined. That, probably, is why the case for space seems to be that much harder to put.

The exploration of man's environment used to consist in the exploration of the earth. Now space travel has taken on that role (although the earth has not yet been fully explored). So lobbying for space is, in part, lobbying for man's sense of adventure. The exploration of space inevitably involves stretching man's technological ingenuity to its limits. So this, too, becomes part of the case for space. Since the age of the brotherhood of man has not yet arrived, the adventurous aspect of space contains a nationalist element, too. A nation's efforts in space are a high-profile public expression of its view of itself. It is, at least for some, a nationalism in itself. To some extent this is so precisely because other countries have that view. Thus part of America's aim in space is not to be outdone there by the Soviet Union; part of France's aim in space is not to leave it all to the two superpowers.

These three factors — exploration, innovation and national pride — add up to what were described in this conference as the aspirational aspects of space. It would be a misunderstanding to think that these aims could be achieved once and for all at any given point; but working towards them will surely bring commercial rewards at some stage, in addition to the rewards of pursuing such aims for their own sakes. Such commercial rewards, however, will be by-products, not the objects of aspiration. Similarly, space is not a science — or technology — that is utilisable in and for itself. It is an "enabling technology": space, for example, happens to be the place where communications, or earth-observation, satellites can most usefully be put. It happens to be (for now and the foreseeable future) the only place where the effects of the earth's gravitational pull can be rendered negligible for any reasonable length of time. And so on. Space, unlike superconductivity, is not useful in itself. All of this muddies the space-lobbyist's waters.

None of this would matter if space were cheap, or if governments were well disposed towards the exploration of it. While many of them are — at least relatively speaking — the British government is not, or not at the moment. And space certainly is not cheap. It is bound to become increasingly expensive, because the goals of space-exploration inevitably become more ambitious as each milestone is reached. We could, if we wanted, soon go to the moon for rather less trouble and money than before; but because we have already been there the goal is now Mars instead. The obvious, and cheaper, aims have already been achieved; that leaves only the more expensive. This situation is not unique to space science. The time is past when physics could be researched with the aid of little more than falling apples. The physical mysteries which are left require expensive instruments, such as the proposed American superconducting supercollider (a particle accelerator costing billions of dollars).

Similarly, it will not be possible to design the next generation of air-transport vehicles, Wright brothers style, in a shed. The expense of space has three implications. Firstly, that it is beyond the pockets of most companies and so must be paid for by governments, or not be done at all. (Hence the argument that governments have an obligation to do it, since otherwise it will not be done). Secondly, that the financial burden often needs to be shared between several countries. And thirdly that space science is, in this respect, the shape of things to come. The difficulties faced by some countries in finding the money for space will probably be paralleled in other scientific fields. So Britain's crisis in space-funding may be a model in two respects: other countries will encounter similar difficulties in space as space programmes become more expensive; and the problem of Britain's space programme may be repeated in other areas of learning and endeavour. It is not, therefore, a parochial problem.

Also, Britain has an important role in the European Space Agency (ESA) and in European science in general. It is not only Britain which is the loser when it refuses to come out and play. Britain, it has been noted, is not exactly brimming over with enthusiasm for CERN (the joint European particle accelerator outside Geneva), or the Joint European Torus, (an experimental nuclear fusion reactor). Do the short-term financial savings of skimping on these projects, and space ones, really outweigh the less tangible disadvantages of being a technological party-pooper? The British contribution to ESA has been derided as "diplomatic science". This is meant to imply that it is no more than a luxury — perhaps to be compared with the fine cellar at the British Embassy in Paris. But the choice of phrase also reveals the weakness of the implied criticism. Diplomacy has had some notable successes — averting wars, to take the most extreme example. Is it wise for a trading nation which will depend increasingly on success in high technology not only to avoid the company of competitors in high technology but also to antagonise them?

Aspiration, like motherhood, is something of which everybody is in favour. It is thus hardly surprising that those who are sceptical about the benefits of spending money on the exploration of space are also sceptical about what might be termed its aspirational value. It might be asked, for example, whether adventures of the human spirit necessarily lead in the direction of outer space. Many scientists who have worked in the field of space research then move out of it into fields that they find more challenging. Sometimes, no doubt, this will be because they have run out of research grants. But there are other scientific challenges that are even more attractive to the young. Molecular biology, or the examination of self-organising systems, are two such examples. If one plank of the aspirational case for space made at this conference is that a vigorous space programme draws the young into science and technology — something that has a clear economic pay-off for countries later on — then a certain type of sceptical challenge must be answered. Is space really the most efficient way of stimulating interest in science? It could be claimed that if you want to discover things quickly, space science is not the field to head for. After all, plenty of time and effort in space programmes is taken up trying to ensure that nothing goes wrong in the hostile environment of space (although the hostility of the space environment has some advantages: studying the welfare of man in space provides some unique opportunities for medical research that could benefit the earth-bound). At this point it is necessary to distinguish two quite different questions

Firstly, is space research a cost-effective way of achieving scientific results and knowledge, compared with other scientific and technological fields? Secondly, is space research a comparatively effective way of drawing talented young people into science and technology? The two questions are not, of course, entirely independent. If space science were widely regarded as being a dead-end, it would presumably not attract many people. On the other hand, it is quite possible that some other feature — apart from its ability to deliver, as it were, a comparatively high number of scientific results per pound invested — makes it attractive to young people, and will draw them into science. It is widely believed in the space community — and this is supported by a considerable amount of anecdotal evidence, in Britain and America at any rate — that space has a uniquely wide appeal on account of its adventurousness. Space, after all, is the clearest example of man pushing against the limits that seem to have been imposed on him by nature. Is there anybody who has not, at some stage, at least entertained the fantasy of being an astronaut? It is also noticeable that space is still by far the commonest subject of science fiction. So even if space does not itself offer quite the scientific pot of gold that some of its supporters claim, it might still serve as the great motivator. The motivation of young people can be seen both as a desirable end in itself (such an idea seems to have slightly more support in America than it does in Britain), and as a prudent investment in the technologists of the future.

The attractiveness of space as an object of adventure raises another, slightly darker, question. Should embattled space lobbyists perhaps consider adopting a double-standard in their lobbying? The people they really have to persuade are politicians, since it is politicians who hold the strings to the purses which, for reasons already given, are the only ones large enough to pay for space. Politicians these day seem to be moved by only one thing: public opinion. If, therefore, public support for space can best be stimulated by stressing the adventure of space — "You, too, can be an astronaut!" — is this not the line that should be taken with politicians? The problem is, of course, that this is to some extent a distortion of most space-researchers' belief in their subject. Among other things, they believe that space research will pay off eventually, in terms of knowledge of and control over the environment, and in terms of wealth-creation. If they stressed adventure above all else, would they not be proposing a double-standard: one way of talking about space among themselves, another for the cameras? Also, some people doubt whether adventure really is the thing to stress at this stage. Although sending a man to the moon was a great adventure, that particular adventure is now over. Adventure is perhaps not quite so important at this phase of the space programme — though it will become so again when it is time to go to Mars. Science, it could be argued, is the proper justification for now. Also, a distinction should be drawn between space exploration *qua* adventure and the great sea-faring adventures that preceded it. Putting a man into orbit does not achieve very much for national sovereignty (nor, arguably, does planting a flag in a lunar crater). In this respect, space exploration is unlike its antecedents and does not have quite the same justifications.

What, then, is the best way to sell space? In Britain it seems that only ministers are hostile to it. They alone, it seems, spoke out against space at the House of Lords Select Committee on Science and Technology's hearings on the subject. Assuming that their hostility, or rather scepticism, is based on the belief that there is no commercial return to be won from space in the near future, the prospects for selling it to them look bleak. Their premise is, after all, broadly correct. Perhaps the first point to be made is that in the case of space it is the nature of the investment called for which makes it unprofitable in the short term; it is not, in general, some sort of failure on the part of space scientists to come up with the most efficient way of turning space to profit. There are, however, some direct benefits of space exploration and research which can be highlighted already. These are, for the most part, concerned with two types of satellites: communications ones, for routeing telephone traffic and television; and earth-observation satellites (commonly called "remote-sensing" satellites). Both of these are part of the infrastructure of industries and services that are successful on earth. The next generation of such types of equipment requires investment long before their profitability is in sight. Perhaps one way to sell such projects is by stressing that they are connected with relatively mundane businesses on earth: space is not such foreign territory after all. Consider such projects as Intelsat (television programme distribution and telephony), Inmarsat (Marine navigation) and the several nascent DBS projects (television direct from space to home). Far more money is spent on earth — for reception equipment and terminals, and ground-stations — than is spent in space.

Another type of space work that has already paid off in a broader sense is the exploration of other planets. Learning about their atmospheres and geology has taught us about our own. It may be asked whether we would understand as much as we do about ozone depletion in the atmosphere of our own planet if we had not studied the atmospheres of others. The connections between space exploration and utilisation and matters of defence and security may also help to break the deadlock with sceptics. In most countries, research and development expenditure for defence is not subjected to quite such stringent demands. Space certainly has a growing role to play in defence, not just in the form of President Reagan's Strategic Defence Initiative, but also in intelligence gathering and the verification of arms-control agreements.

Some other examples are worth mentioning. the Eutelsat and Intelsat communications satellites carry a much smaller proportion of telephone traffic than was originally hoped — this is largely because of the competition from undersea cables (competition that will intensify as more fibre-optic cables are laid). Luckily a use was found for the excess transponder-capacity of these satellites, to relay television programmes to cable-television stations and a relatively small number of individual viewers with backyard reception dishes. On the other hand, higher-powered direct-broadcast (DBS) satellites dedicated to individual television reception have so far flopped. In America, several projects have failed for commercial reasons. In Europe the projects have been delayed for a mixture of technological, commercial and regulatory reasons. The first DBS satellite to be launched by Europe, West Germany's TV-SATI, has failed to work and now appears to be space-junk. Britain's DBS project is threatened by the likelihood of unforeseen terrestrial competition from a fifth national broadcast channel. The lesson to be learned is not to claim too much too early, since the failure to deliver provides splendid ammunition for the adversaries of space. It can take time to find the right use for space resources.

Before the right commercial applications of space can be found, it is necessary for a considerable amount of basic space research to be undertaken. Such infrastructure work can only be undertaken by governments. Any country whose government does not play a part in building this infrastructure is unlikely to be able to reap the commercial rewards later. But, even given this point, space lobbyists will get nowhere unless their case is a little more focused. Without giving too many hostages to fortune, it is necessary to specify at least some of the possible applications of space. Using the vantage point of space for remote-sensing and navigational aids is a very good candidate to focus on. With about 200 such satellites now in operation, this is the most commercially active aspect of space. There is a sharp contrast between the "open skies" policies of the United States and the PTT monopolies in Western Europe. Presumably, if Europe had a more open-skies approach there would be more companies involved in space today in Europe. The national focus of each PTT hardly helps. Britain is at least moving in the right direction, with its telecommunications duopoly. But, on the other hand, America, with its commercially dominated approach, is not developing satellite technology fast enough. American companies are unwilling to pay for the research that will ultimately lead to the second generation of communications satellites, with their eventually greater commercial value.

High-resolution pictures of the earth have an obvious attraction for governments because of the role they can play in security. In general, the military applications of remote-sensing are obvious. If other people are in space looking at you, you want to be able to look at them. It is worth noting that former Defense Secretary Caspar Weinberger was knighted, among other things, for helping the Falklands war effort from space. It is conceivable that at some stage commercial news agencies will be in the business of remote-sensing. (It was suggested that one could build and launch a remote-sensing satellite for less than the cost to the BBC of televising the Olympics). But there was a general consensus at the conference that it will be 10-15 years before there is any direct commercial involvement in remote-sensing. Much depends on how fast the cost of very high-resolution (1 metre) images falls.

Of all the possible commercial applications of space infrastructure, it is perhaps space-manufacturing that grabs the imagination most effectively. President Reagan gave it particular prominence when he originally urged NASA to build its space station. But it is clear that much more research, primarily in space, needs to be done before it can be known just how useful space might be as a manufacturing environment. The economics of space manufacturing depend crucially on the cost of hoisting each pound of material into orbit. Such costs did not fall steadily during the course of the shuttle programme, as had been expected; and the Challenger disaster has put the clock back quite a long way. One catch-22 snag is the question of the extent to which people should be involved. On the one hand, people make space research more expensive. On the other hand, it is easier to raise the money for manned programmes because it is easier to stimulate public interest in such programmes. (There are, of course, other reasons for preferring manned programmes: men add a degree of flexibility and reliability to experiments in space). Also, it is not at all clear what exactly has been learned from previous work about the economics and potential of space manufacturing. It may be that a special module will be needed for each materials-processing experiment. Supporters of the space station argue that the reason why materials-processing experiments did not go well aboard the Spacelab is that it was too cramped — a failing that the space station will correct. Others claim that there are not enough well-designed experiments ready for evaluation of the usefulness of a space station in this regard. One reason why there are not enough experiments ready is that there are not enough people working on them. Catch-22 again: you need more money to make a more cogent case for space, which is, in turn, required to raise more cash.

It would be useful to know more about the spin-offs from space so far. Most people have only heard of one: Teflon for non-stick frying pans. This was the spin-off from space research most often referred to at Ditchley.

Ironically, it is wrong. Teflon was patented by DuPont back in 1938. There are plenty of other good examples, but they seem to be less instantly evocative and less easy to grasp. For people to grasp the spin-offs from space research, they have to be able to see space solving problems on earth. Plenty of today's techniques in micro-electronics were developed for the challenge of the space programme over the years. Some new fire-fighting technologies now in fairly common use were originally developed by NASA. It has been estimated that some 22,000 companies were involved, one way or another, in the Apollo moon-programme. No successful attempt has been made to quantify what they learnt. NASA once commissioned some work from Chase Econometrics to track each dollar that was spent in space and work out what exactly paid off. But this turned out to be a mistake: the methodology used was highly questionable and the effort did more harm than good. Yet it can be argued that it is possible to devise a proper methodology for such work, preferably by focusing more narrowly on a particular space project. Governments tend to think that if benefits cannot be quantified they do not exist. This is clearly a mistake, but an understandable one for bodies faced with competing claims for a finite amount of money and resources. One cautionary note for anyone tempted to bolster the case for space by citing intended or unintended spin-offs from space research is that it is not enough to identify and quantify them. It has to be demonstrated, for any given spin-off, that space is the cheapest way of achieving it. There might always be a cheaper way, in which case the spin-off argument fails.

To some extent there is a tension between the commercial aspects of space research and the need for international collaboration. Some evidence from a NASA study suggests that there there is less need than some people think to be worried about the possible gains to competitors from international collaboration in space. America does not appear to have lost by collaborating with other countries. Collaboration has its own diplomatic benefits — and they do not just apply to co-operation between countries. While the NASA-led space station used to be thought of as a matter for just NASA, ESA and space agencies in Japan and Canada, it has also caused a re-allocation of responsibility among departments in Washington. There are several unanswered questions for the future about international co-operation in space. They range from the serious to the fairly light-hearted. Sometime in the next 10-15 years, less-developed countries are going to want a degree of co-operation with rich countries in space. How will that be handled? And there are plenty of unanswered legal questions: what happens if one national hero kills another national hero in orbit?

One problem for international co-operation is the variety of ways in which countries go about approving their space projects, and the different national motivations. The Japanese approach to space is unique in that all space science is done by the academic community, while matters of exploration come under a different ministry. This rather complicates the Japanese attitude to the NASA-led space station. In France, the aeronautics and space sectors of industry have always been inextricably linked. Also, space and aeronautics are linked by the nuclear deterrent force; rockets of the "force de frappe" must be tracked and their ballistics researched. Another specifically French interest in space comes from the French territories abroad and their military and other links. Satellites are needed for communication, tracking and monitoring — watching the Chad conflict, for example. The West German approach to space has relatively less to do with aspiration, either national or more generally (at least when compared with the United States). Space science is generally seen as the cutting edge of science and technology (though there is some dissent from this position among scientists from other fields). But there is a clear recognition that there is no prospect of early commercial return; that is why the federal government is involved. Britain provides a contrast with both France and West Germany. Britain does not have any ambitions towards sovereignty and leadership in space — it just wants to use it where possible.

America takes a catholic approach. Every argument for space is used, which is perhaps why debate on the subject is so heated. The first aim, however, is and always has been national security, followed by scientific and technological advance. Also, the long-term goal is human expansion: colonisation of some sort. On a more mundane note, the point was made at Ditchley that in America the space station is running out of support and will be in trouble for the next few years. It does not have the strong support of the science community, and this leads to scepticism in Congress. This may be because the claimed uses for the station are so diverse: the case looks confused. The space industry in America is liable to become more confused in future. The gradual opening up of a private launch market will lead to a "dirty market". It will be hard to compare real costs (the prices offered by Russia, for example, in their attempt to win customers in the West, will not reflect accurately the costs involved).

It is hard to agree on a strategy for arguing the case for space, let alone to win the argument. The main difficulty is an apparently irreconcilable difference between those who think that the breadth of the case is its principal strength and those who think it is its principal weakness. A related disagreement is the one between those who think that some attempt to quantify the benefits of space exploration is required and those who argue that any such attempt is bound simply to give ammunition to the sceptics. A sceptic might argue that (1) even if a case has been made for the present level of, say, America's spending in space, it still has to be proved that the considerably larger budget NASA is asking for is justified; (2) the case for manned as opposed to unmanned exploration has not been successfully made; (3) although a convincing case can be made for space exploration in the abstract, it is quite another matter to produce the sort of evidence that will convince governments to transfer funds that might be used for other purposes to space. Since the space lobby, especially in Britain, is faced with sceptics rather than agnostics, it is the comparative case for space that has to be made.

Why is scepticism so strong and so wide-spread in Britain? It may be wrong to blame the present government. Some think that a Labour government would be unlikely to back speculative high technology projects. So perhaps the problem is a national one; it has even been suggested that Britain's lack of aspiration stems from some feeling of guilt, or at least weariness, with empire. What has been clearly lacking is something to fire the imagination of the British public. Had it not been for, for example, the Challenger disaster, there would by now have been British astronauts aboard the NASA shuttle. With British astronauts in front of the television cameras, might the British Treasury have come under public pressure to spend more, rather than less, money on space?

A few weeks after the conference, the British government seemed, as *Nature* put it, to relent. Mr Kenneth Clarke, the minister in charge of space, announced that Britain would, after all, take part in the Columbus space-station project. It will contribute some £250m (5.5% of the total compared with West Germany's 38%, Italy's 25% and France's 14%) to be spent mostly on a remote-sensing satellite known as the "polar platform". The satellite will be able to gather radar data, and so will be useful for analysis of the weather. At the same time, Mr Clarke announced that Britain would not, after all, take part in the Canadian Radarsat remote-sensing satellite project — which leaves Radarsat with an uncertain future.

Mr Clarke changed his mind about the polar platform because it has been redesigned and is now projected to cost £315m instead of £500m. This new version will not be serviceable in space, and so will have a shorter life. The British Government seemed confident that much of the work for the platform would be given by the ESA to British Aerospace. If it is not, Britain's space community will probably blame the government's procrastination.

LIST OF PARTICIPANTS

Conference Chairman: **The Rt Hon Sir Geoffrey Pattie MP,** Member of Parliament (Conservative),Chertsey and Walton; Parliamentary Under-Secretary of State for Defence for the RAF (1979-81), for Defence Procurement (1981-83); Minister of State for Defence Procurement (1983-84); Minister of State, Department of Trade and Industry (Minister for Information Technology) (1984-87); Member, Committee of Public Accounts (1976-79).

Herr Herbert Allgeier, Head, Directorate H, Stimulation of scientific and technical development, and design and evaluation of programmes, Commission of the European Communities, Brussels. (FRG)

Dr Jeremy Bray MP, Member of Parliament (Labour),Motherwell South (since 1983), (Motherwell and Wishaw, 1974-83); Opposition Spokesman on science and technology (since 1983); Joint Parliamentary Secretary, Ministry of Technology (1967-69); Director, Mullard Ltd (1970-73); Member, Select Committee on Expenditure (1978-79), Select Committee on Treasury and Civil Service (1979-83) (Chairman, Sub-Committee, 1981-82); Visiting Professor, University of Strathclyde (1975-79). (Britain)

Mr Crawford F Brubaker Jr, Member, Brubaker & Associates, International Aerospace Consultants (1987-); Deputy Assistant Secretary of Commerce for Aerospace, US Department of Commerce (1983-87); Lockheed Corporation (1948-60), (Director, International Market Development, Policy and Communication 1976-82). (USA)

The Rt Hon the Lord Chorley, Partner, Coopers & Lybrand, Chartered Accountants and Management Consultants, London; Member, House of Lords Select Committee on Science and Technology; Visiting Professor, Department of Management Sciences, Imperial College of Science and Technology, University of London (1979-82); President, Royal Geographical Society. (Britain)

Professor Thomas M Donahue, Distinguished University Professor of Planetary Science, University of Michigan; Director, Space Coordination Center (1966-74); Chairman, Department of Atmospheric and Oceanic Science and Space Physics Research Laboratory (1974-81); Vice Chairman, Executive Committee, trustee, University Corporation for Atmospheric Research (1978-85); Chairman, board of trustees, Universities' Space Research Association (1978-82); Henry Russel lecturer, Michigan University (1986) Member, US National Academy of Sciences, Chairman, Space Science Board, US National Academy of Sciences (1982-). (USA)

Madame Marie-France Garaud, Institut de Geopolitique,Paris.

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M Jean-Louis Gergorin, Directeur de la Stratégie, Groupe Matra, Paris. (France)

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Mr Roy Gibson, Special Adviser to the Director General, International Maritime Satellite Organization (INMARSAT); formerly Director General, British National Space Centre (1985-87); Director of Administration, European Satellite Research Organisation (1967-75); Director General, European Space Agency ((1975-80); aerospace consultant (1980-85). (Britain)

Mr William H Good, Staff Manager for Space Transportation Market Analysis, McDonnell Douglas Astronautics Company, California; Pilot, later Captain, Braniff International (1973-83); Consultant, Earth Space Transport Systems Corporation (1978-); Systems Engineer, TRW; Staff Engineer, Rockwell International. (USA)

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Dr William R Graham, Science Advisor to the President. (USA)

Mr Jerry Grey, Director, Science and Technology Policy, The American Institute of Aeronautics and Astronautics; formerly past President, International Astronautical Federation; Member, US Commercial Space Transportation Advisory Committee, Office of Technology Assessment's Advisory Panel on Advanced Space Transportation Technology; Trustee, Scientists Institute for Public Information; Director, Applied Solar Energy Corporation; formerly Professor of Aerospace Science and Engineering, Princeton University. (USA)

Mr Paul D G Hayter, Principal Clerk of Committees, House of Lords. (Britain)

Dr Wolfgang Hoffmann, First Counsellor (Scientific Affairs), Embassy of the Federal Republic of Germany, London. (FRG)

Mr John Holt, Managing Director, Space and Communications, British Aerospace. (Britain)

Air Vice Marshal P Howard, Senior Consultant, RAF Institute of Aviation Medicine. (Britain)

Dr Bhubendra Jasani, Research Fellow, leading programme on space and international security, Royal United Services Institute for Defence Studies. (Britain)

Dr Peter F Krogh, Associate Professor of International Affairs and Dean, School of Foreign Service, Georgetown University, Washington DC; writer and broadcaster; Assistant to the Dean and later Assistant Dean, Fletcher School of Law and Diplomacy, Tufts University (1962-67); White House Fellow assigned to Secretary of State Dean Rusk (1967-68). (USA)

Mr Jack Leeming, Retired as Director General (1988) (previously Director, Policy and Programmes); British National Space Centre. (Britain)

Commander David C Leestma, NASA Astronaut (1980-); US Navy (1971-); Mission Specialist, 6th flight of the Orbiter Challenger, 13th flight of the Space Shuttle system; Mission Specialist, Space Shuttle Missions. (USA)

Dr Reimar Lüst, Director General, European Space Agency, Paris; Chairman, German Research Council (1969-72), Deutsche Gesellschaft für Luft und Raumfahrt (1968-72); President, Max-Planck-Gesellschaft (1972-84). (European Space Agency)

Mr Peter Marsh, Industry Reporter, *The Financial Times.* (Britain)

Mr Michael Marshall MP, Member of Parliament (Conservative), Arundel; Member, House of Commons Select Committee on Defence; Chairman, All-Party Parliamentary Information technology Committee; Parliamentary Under Secretary of State, Department of Industry (1979-81); Vice-Chairman, Conservative Party Parliamentary Industry Committee (1976-79), All Party Committee on Management (1974-79); Parliamentary Adviser, British Aerospace and Cable and Wireless. (Britain)

Mr Michael A G Michaud, Director, Office, Advanced Technology, Department of State (1986-); Deputy Director, Office of International Security Policy, Bureau of Politico-Military Affairs (1976-78); Officer-in-charge, UK and Bermuda Affairs, Bureau of European Affairs, Department of State (1979-80); Consul General, Belfast (1980-83); Una Chapman Cox Fellow, Foreign Service Institute (1983-84); Divisional Chief, Foreign Service Counseling and Assignments (1984-85); Special Assistant for Space Policy (1985-86); writer. (USA)

Professor Minoru Oda, Professor Emeritus, Tokyo University; Director-General, Institute of Space and Astronautical Science (ISAS) (until 1988); Special Assistant, Space Activities Commission (SAC); Member, Science Council, Ministry of Education, Tokyo; Special Advisor to the Director General of ISAS; President, Commission Astronomy from Space, International Astronomical Union. (Japan)

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Dr Geoffrey Pardoe, OBE, Chairman and Managing Director, General Technology Systems Ltd; Executive Director, British Space Development Co Ltd (1960-74); Chairman, Procogen Computer Systems Ltd (1981-86); President RAeS (1984-85), Vice-President, (1981-83); Chairman, Watt Committee on Energy, (Vice Chairman, 1981-86). (Britain)

M René Pellat, Scientific Counsellor, Centre Nationale d'Etudes Spatiales, Paris. (France)

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Mr Leo J Schefer, Vice President, British Aerospace Inc (1979-); first President, Washington Dulles Task Force (1982); Member, Boards of the Washington Airports Task Force and the Aero Club of Washington; President, Air and Space Heritage Council. (USA)

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Mr Duncan Slater CMG, Assistant Under Secretary of State, Foreign and Commonwealth Office; First Secretary, UK representation to EEC, Brussels (1973-75); UK Resident Representative to IAEA and UK Permanent Representative to UNIDO, Vienna (1975-78); Counsellor and Head of Chancery, Lagos (1978-81); Ambassador to Oman (1981-86). (Britain)

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