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DILEMMATA INHERENT IN THE PUBLIC PROMOTION OF HIGH TECHNOLOGIES

- Observations from Europe -

Helmar Krupp and Uwe Kuntze
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1. Introduction

In addition to being a stimulus for technical and economic change, and an essential ingredient for further militarization, high technologies are used worldwide as a national symbol. "Americans were the first and only people ever to walk on the moon. An entire nation watched with pride. The entire world watched with awe". (President's Commission 1985 - underlining by the authors of this paper).

On the occasion of the EXPO fair 1985 in Tsukuba, many thousands of Japanese school children were driven past gigantic displays of space colonies - a technical fairy-tale - in a Walt Disney-type exhibition hall. Gradually, after decades of post-war modesty, the Federal Republic of Germany is also entering this arena. On the occasion of space flight "D 1", the Ministry for Research and Technology expressed its conviction that West Germany should become the first nation in micro-gravity research and in "space manufacturing". Likewise, countries of the third world consider high technologies as essential to their national prestige, whatever their economics may be.

Therefore, in a thorough discussion of the promotion of high technologies by our respective governments - the main purpose of this paper - also criteria other than the technical and the commercial would have to be used. However, we have excluded them from this paper for lack of space and professional competence, and because of the irrationalities involved.

By definition, "high technologies" are either new points on already existing technological trajectories or new trajectories altogether. An example of the first type is large-scale integrated circuits. They are new points on the old trajectory of transistors or the even older one of solid diodes. An example of the second kind is lasers, a trajectory which started in 1960. [1] At the present time, major general technological trends include, for instance,

- micro-technologies, i.e. micro-mechanics, micro-electronics, micro-optics, micro-biology and their interdiffusion as in optical fibres, micro-opto-electronics, "biochips" etc.
- miniaturization of products

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[1] This last classification is also ambiguous, because the laser can be considered as a new point on the trajectory which started with the maser in 1950.

- an approach to the limits set by the laws of physics, e.g. the mechanical strength of some materials approaches the internal strength of molecules; the spectral line width of lasers approaches its "thermodynamic" minimum; superconductivity is based on the minimum resistivity of materials; the chemical and structural composition of solid surfaces of catalysts and solid state components of micro-electronics is being structured at a resolution within mono-molecular dimensions, etc.
- technical design of whole systems, e.g. controls, computers, automation of manufacturing and office work, co-generation of electricity and heat in power plants integrated with coal gasification etc.

The major driving forces behind such technological trajectories are economic. They result in the saving of materials, in automation and thus labour saving, in higher efficiencies of processes as well as in environmental protection and thus in an increase in the productivity of natural resources, etc. Furthermore, new consumer products are being developed, for example, in consumer electronics. National interests of prestige and militarization lead to extreme points on technological trajectories, as in SDI (e.g. giant versions of computers, lasers, space platforms, rockets, particle guns).

A conceptual classification of high technologies as distinct from, say, low or medium technologies is ambiguous for the following reasons:

(1) In many areas, the evolution of technologies is proceeding quite fast and classifications tend to become obsolete within increasingly shortening periods of time, typically within ten years. To many, in comparison to a very large scale-integrated circuit VLSIC, a standard IC is no longer a high technology product. However, in less developed countries, it still is.

(2) Some high technology products, such as chips, sensors, optoelectronic devices, new high strength composites, superalloys, etc. diffuse into a great variety of low or medium technology products. For an accurate classification these would have to be taken apart and classified according to parts and pieces. Examples are new ceramic materials for the cylinder and the piston of an otherwise classical combustion engine or a gas-laser scanner in a cash register.

Thus, all classes of products of the Standard International Trade Classification SITC, even at their highest resolution of 5 digits, are heterogeneous mixtures of high and low technologies, e.g. compact discs figure side by side with standard ones and adaptively controlled robots with pneumatic lifting apparatus.

Several economic criteria have been developed to distinguish product groups of high technologies from low technology ones. Products of high technologies are classified according to

- above average intensity of research and development in the sector of industry involved (typically 5 per cent of sales or beyond)
- world market shares or
- a threshold of value per unit weight or per piece.

These classifications suffer from problems of artificiality of thresholds and they do not consider cross-industry impacts. Further, if we want to measure international competitiveness by way of export figures, it must be taken into account that trade in high technology products, such as nuclear technologies and weapons, is strongly affected by regulation, e.g. COCOM list.

As a function of the classification used (Legler 1985), the share of high technology products in all exports of manufactured goods of the Federal Republic of Germany varies from 6 to 41 per cent, in the USA between 22 to 50 per cent and in Japan between 6 and 49 per cent and, concomitantly, time series of these shares vary quite erratically as well.

As stated above, there is no clear-cut dividing line between high and low technologies and it is unfortunate that many people identify high technologies with items such as fast breeders, equipment for manned space flight and advanced weapons. As a consequence, commercially important items of high technologies such as optical fibres, solid state optoelectronics, new biological materials, "superalloys", membranes, large-scale processes of coal appreciation, etc., and their role for international competitiveness may be underrated by the general public. As a remedy, Legler (1985) subdivides high technology products - research intensity 5 per cent and above - from superior commodity products, whose research intensity is defined to be between 3.5 and 4.9 per cent. This subdivision reveals quite a strong export position in superior commodity products for the Federal Republic of Germany and Japan, whereas the U.S. lead in high technology exports seems to rely heavily on military and proto-military products.

These considerations and those below may help to correct popular misconceptions about the nature and relevance of high technologies.

2. The post-war history of high technology policies in Europe

2.1 Filling the technological gap

The USA emerged from World War II not only as a military, but also as a technological winner. Its country and industry had not been hit and its predominant position in high technologies had been established, in particular in areas such as nuclear fission and aircraft. At the same time, a major institutional innovation had been demonstrated, the ability to organize and manage large projects, teams and research institutions. Henceforth, innovations could be programmed, particularly in very large corporations and big national research centres. In Europe therefore, the feeling that there was a quite general technological gap between the US and Europe gained ground.

When Europe scrambled to its feet, the first priority was to fill the presumed technological gap and to establish, rebuild or expand major public research centres for atomic energy and aircraft research. Major examples are:
- in France, the Commissariat à l'Energie Atomique, CEA, and the Office National d'Etudes et de Recherche Aérospatiales, ONERA
- in the Federal Republic, the big national research centres in Karlsruhe, Jülich, Porz-Wahn, etc.
- in the UK the Atomic Energy Research Establishment at Harwell and the Royal Aircraft Establishment at Farnborough.

Of course, a strong innovation-oriented industrial base was recognized to be of prime importance. Therefore, high technology companies such as AEG, Dornier, MAN, MBB/Erno, Siemens etc. - as German examples - started to receive growing public support.

From the late 1960s onwards, the hypothesis of a technological gap started to disappear in our political discussions (OECD 1968, Majer 1973).

2.2 Autonomous national technology policies

Starting in the 1960s, autonomous national technology policies were developed in Europe. Broadly speaking, they were designed on two fronts:
- Firstly, in order to push the frontiers of best practice forward, by picking winning companies and supporting them by direct aid within selected projects. Often this was done in collaboration with public research centres.

- Secondly, by promoting the advance of average practice, i.e. by diffusion of new technologies within and across sectors. This was predominantly done by the public support of an institutional network, in particular research associations and contract research.

At that time, typical high technologies (other than nuclear reactors, aircraft and weapons) supported by public programmes were data processing, measuring and control equipment, materials, advanced optics, etc. Typically, technologically leading companies played a major role in the design and execution of such programmes.

When we compare the European policies and instruments of innovation with those of the USA, a peculiar feature of the public promotion of high technologies in Europe is the reliance on an institutional network supported by public funds, both for their inception and their diffusion. This network interacts strongly with industry. To give a precise example, we are taking that of the Federal Republic of Germany, because in our view it is the most elaborate one (Krupp 1983, 1984).

An analysis of the institutional scenery of research and development in the various countries reveals a wide range of "customers" for its services, mainly government departments and the different sectors of industry, but also trade unions, cities, etc. Therefore, the services rendered by the research institutions range from basic and applied research and development all the way to testing, consultancy, etc. The essential feature of the German research system is the fact that almost for every class of customer and type of service, special institutions have evolved and we come to the conclusion that mono-functional institutions may be made more cost-effective and qualified than multifunctional ones. An example of the latter type is universities, which in many countries including the Federal Republic, are asked to deliver services such as education, basic and applied research as well as consultancy and diffusional technology transfer, all at the same time - and not very successfully (Stankiewicz 1984). Another example is TNO in the Netherlands, whose periodic reforms seem to indicate that its wide range of services is hard to organize efficiently under one roof.

In this context, the principal German institutions are

- the national research centres with a staff of about 19 000, concentrating on long-term application-oriented research and development. They are almost 100 per cent publicly supported.

- the Fraunhofer Society with a staff of about 4 000, specializing in the inception of new technologies and their diffusion into particular sectors of the economy and inter-sectorwise. The Society is financed mainly by contract research equally sponsored by government and industry.
- the industrial research associations with a staff of about 4 000, which are organized according to sectors of industry and provide for sector specific research. Their support is 1/3 government and 2/3 industry.

Broadly speaking, all three categories provide for generic and high technologies. They are differentiated from each other according to the time horizon and the type of interaction with industry. It is essential to note that the funding mechanisms of the two last mentioned institutions are such that industrial sponsorship is a prerequisite for public support. Naturally, there are close links with universities, both institutional and otherwise.

2.3 Towards comprehensive innovation policies

Through innovation research, it has become progressively apparent, how science and technology interacted with industrial and public innovation. It has been shown that technology transfer from science into practice and between different sectors of the economy plays a major role. Therefore, science and technology policies have been and are still being transformed into more comprehensive innovation policies. They focus on an integration of policies related to new technologies with sectoral and regional industrial policies. With respect to high technologies, this has the following elements (Krupp 1985 I):

- The institutional set-up described in section 2.2 has been strengthened with a view towards its dynamization and towards more inter-institutional interaction and technology transfer.
- In view of the economic importance of small and medium-sized enterprises, particular programmes for the diffusion of new technologies have been designed, both on a sectoral and on a regional basis.
- Special government programmes are dealing with the generation of new technology-based companies and their provision with venture capital (although doubts on their cost-effectiveness have been expressed).
- Comparative studies in the framework of our "Six Countries Programme" (Sweeney 1985) have shown that innovation policies in all member countries are more or less alike and provide for subsidies to companies through almost all stages of innovation.

On the national level, the budgets of programmes in areas of high technologies are being stepped up, as is shown in Table 1, where - by way of example - major high technology programmes of the Federal Republic of Germany are listed.

Projects	1977	1979	1981	1983
Min. for Res. & Technology				
fast breeders	321	265	334	521
high temperature reactor	183	275	271	523
gas centrifuge for isotope separatn.	84	97	86	99
coal technology	63	91	217	284
magnetic train	4o	73	87	138
TV satellite	33	31	65	115
space lab	151	161	186	57
microelectronics	62	72	67	97
Min. for Econ. Affairs				
airbus	30	143	309	177

Table 1 Public promotion of research and development for high technologies in the Federal Republic of Germany

Source: BMFT 1984

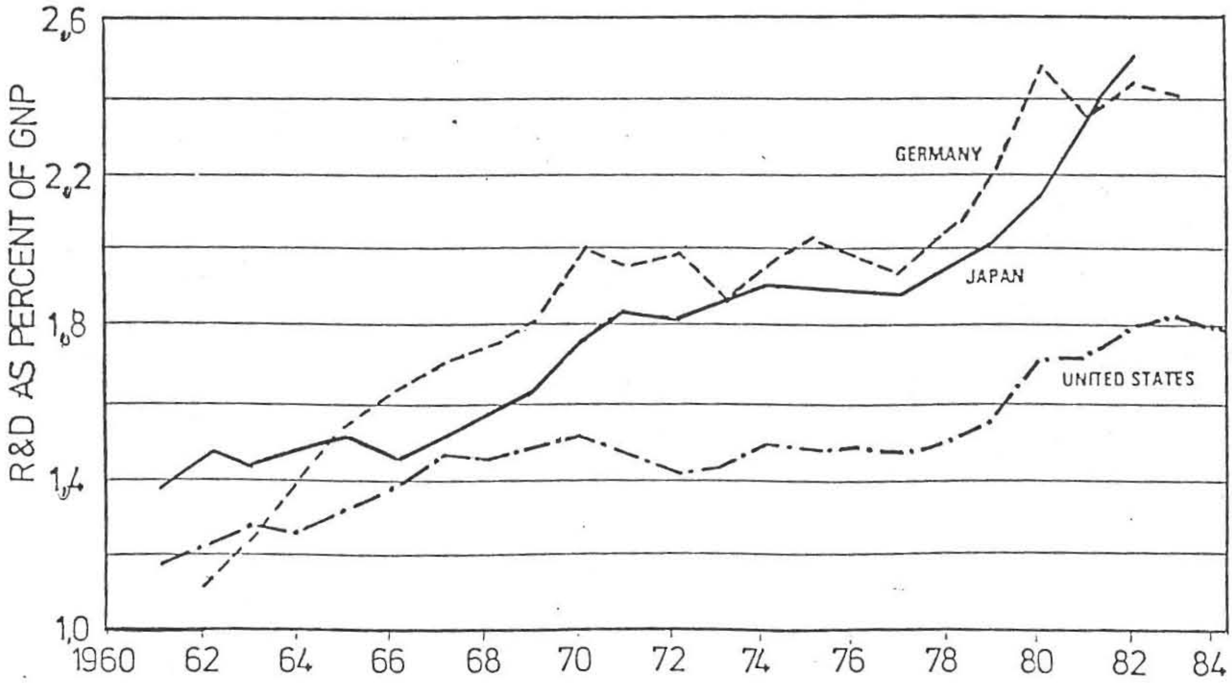
Meanwhile, the European rates of expenses for research and development have reached those of the USA, see Table 2. If we subtract military research and development, the US figures - as shown on Graph 1 - are about one third below those of Germany and Japan. This graph, taken from the report of the President's Commission on industrial competitiveness of the USA, 1985, is commented therein as follows: "Roughly half of the total R&D done in the United States is funded by the Federal Government which spends most of its money (about two thirds) on defence and space programmes. And in those two areas any commercial spillover is not a prime objective. Thus, when we look at what the United States spend on civilian R&D - areas of innovation from which we can reap the greatest commercial reward - we find ourselves behind both Germany and Japan". We will return to this quote in section 3.5 when we discuss "spillover" in more detail.

	1975	1977	1979	1981	1983[1]	1985[1]
FRG	2.1	2.2	2.4	2.5	2.6	2.8
France	1.8	1.8	1.8	2.0	2.2	2.3
UK	2.1	.	2.2	2.4	2.3	.
Italy	0.9	0.9	0.9	1.0	1.2	.
Netherlands	2.1	1.9	1.9	1.9	2.0	.
Japan	1.7	2.0	2.1	2.4	2.6	.
USA	2.4	2.4	2.4	2.5	2.7	2.8

1) partially estimated

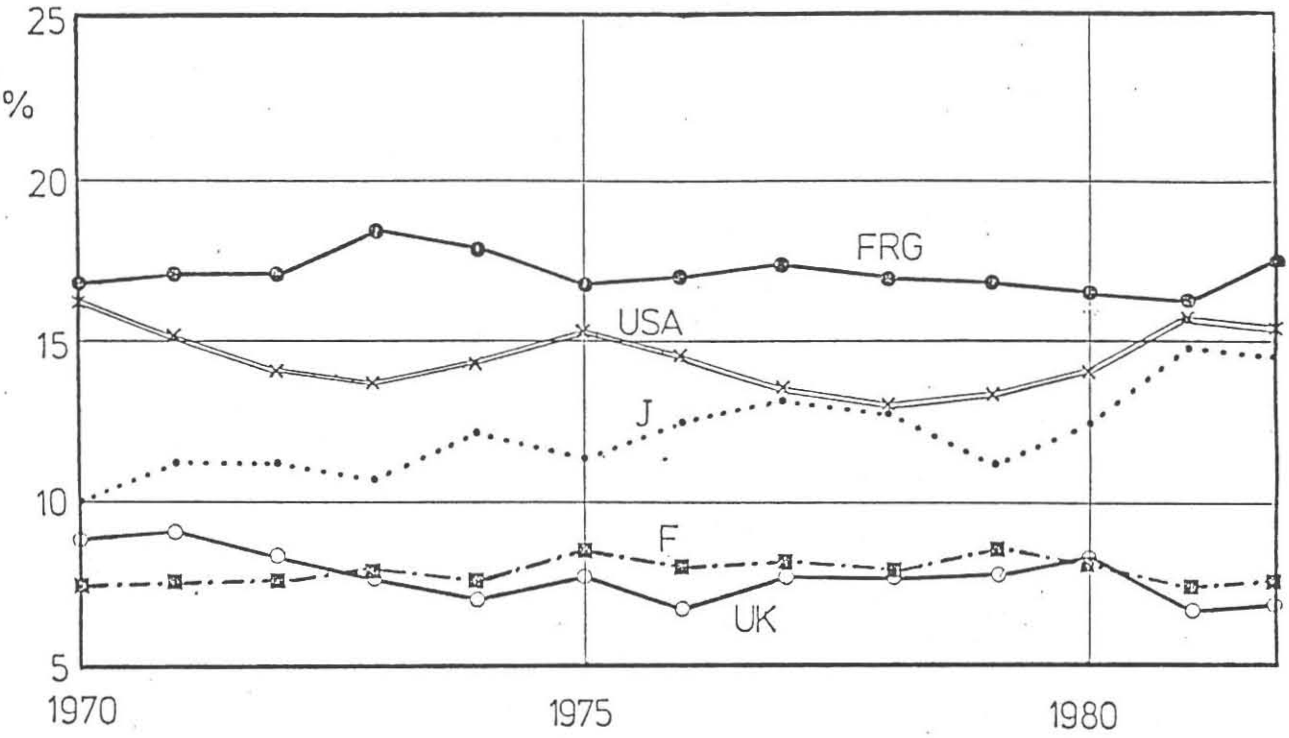
. no data available

Table 2 Gross domestic expenses for research and development as a percentage of gross domestic product (including the military sector)
Source: OECD 1985



Graph 1 Civilian research and development as a percentage of the gross domestic product of the Federal Republic, Japan and the USA
Source: President's Commission 1985

Finally, Graph 2 shows that on the whole, European competitiveness seems to be compatible with that of the US and Japan, if measured in export shares of industrial products. Technometric comparisons (Grupp 1985) show a far more differentiated picture, of course, without however affecting this general conclusion.



Graph 2 Share of world trade a) of OECD countries in industrial products b)
a) exports of OECD countries plus imports from non-OECD countries
b) OECD trade of SITC 5 to 8: excluding 611, 613, 661, 896; including 233,266

Source: BMWi 1984

2.4 Joint European high technology policies

Already in the 1950s, it was recognized that individual European nations were too small and the relative risks of some new technologies too high not to attempt European collaboration and cost sharing.

Particularly interesting and probably quite successful - although still subsidized - is the joint Airbus project, which was started in 1963. Participating countries are the Federal Republic of Germany, France, Spain and the UK. Their respective shares are 38, 38, 4 and 20 per cent. So far, the three models A 320, A 310 and A 300 have been developed and about 50 airline companies have ordered 482 planes, 330 of which have meanwhile been delivered. From 1963 to 1984, the project was subsidized by a total of 4.2 billion DM from the Federal Republic of Germany alone. Parallel to this, a small passenger plane, the F 28, and a helicopter, the BO 105, have been developed and are being marketed quite successfully. 218 F 28s and about 1000 BO 105s have been sold so far (BMF 1985 and recent press releases). As a comparison, in 1985 Boeing received orders for 362 civilian planes, Airbus for 92.

However, the Concorde project of France and the UK has failed. In the 1960s and 70s, we witnessed various national and transnational attempts to compete with IBM and develop large European computers. They too resulted in a series of failures.

Apart from the continuing efforts of the major joint research institutions within the European Community (the European Space Agency ESA and the four Joint Research Laboratories, for example) there has been, within the past few years, a noticeable political move towards an intensification of research and development in the area of high technologies, both on the European and the national levels. Thus, the European Community has reached a new level of promotional activities through her ESPRIT (European Strategic Programme for Research in Information Technologies) programme, which foresees direct aid to the European electronics industry at a level of 650 million ECU within a period of 5 years. After this forerunner, BRITE (Basic Research in Industrial Technologies for Europe) and RACE (Research in Advanced Telecommunications Technology for Europe) have been and are being launched. From 1985 to 1988 BRITE will cost about 125 million ECU. The preparatory phase of RACE will cost 22 million ECU, until RACE eventually enters its 5 year project period from 1987 to 1991. Simultaneously, both major national programmes and a variety of industrial joint ventures have been set up.

Spurred by SDI, the EUREKA programme was conceived in 1985. EUREKA stands for European Research Coordination Agency. The programme is still in its infancy and as yet no prediction as to its future can be made. But it appears that for the time being its main use is one of symbolic politics to further the cohesion of Europe.

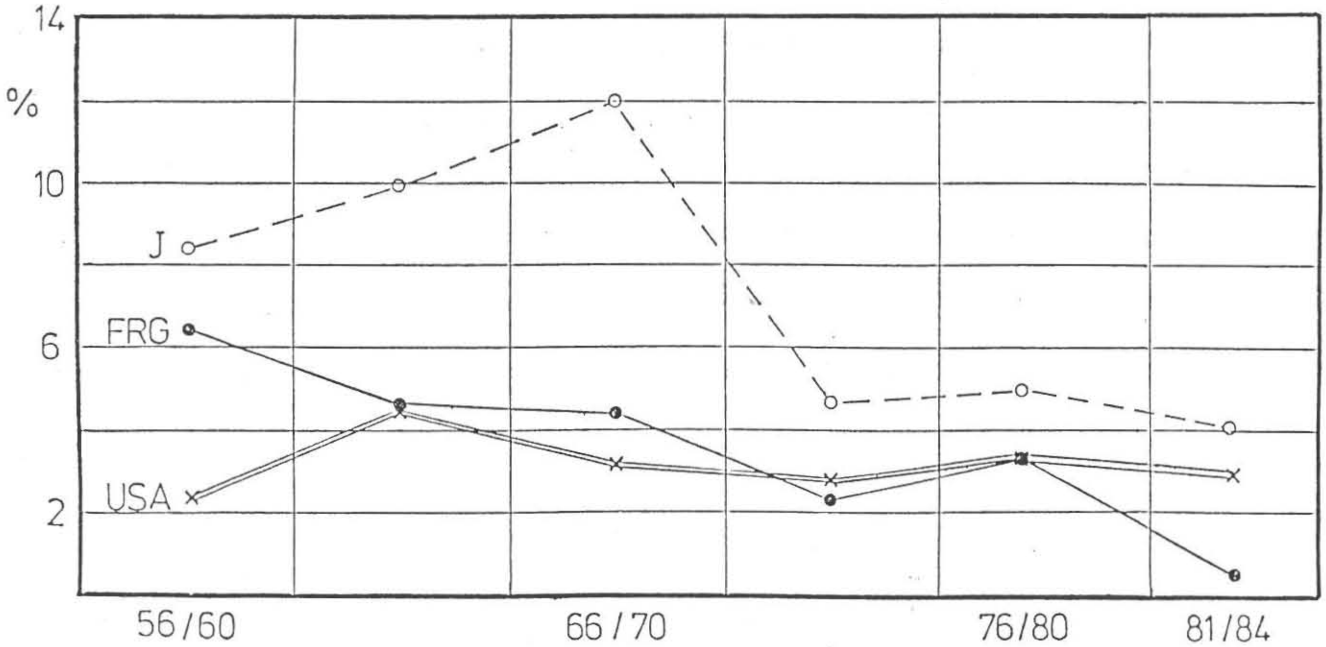
The various international institutions and programmes in Europe outside the Airbus project cannot be measured by the best national standards of cost-effectiveness. The international coordination is necessarily costly and bureaucratic; nationalistic reasonings may prevail over those of efficient technical management. But the trade-off are prospects of advances towards a truly European market.

Thus, the whole field of high technologies is in a state of fast evolution, not only technically, but also as to public - national and international - interaction and inter-industrial cooperation. On the one hand, we do not want to paint too bright a picture of European politics and the European situation. On the other hand, despite the deplorable absence of a truly common market and in view of the small size of the individual European nations compared to the USA and Japan, Europe seems to have done quite well.

3. Political dilemmata

3.1 The economic change of the 1980s

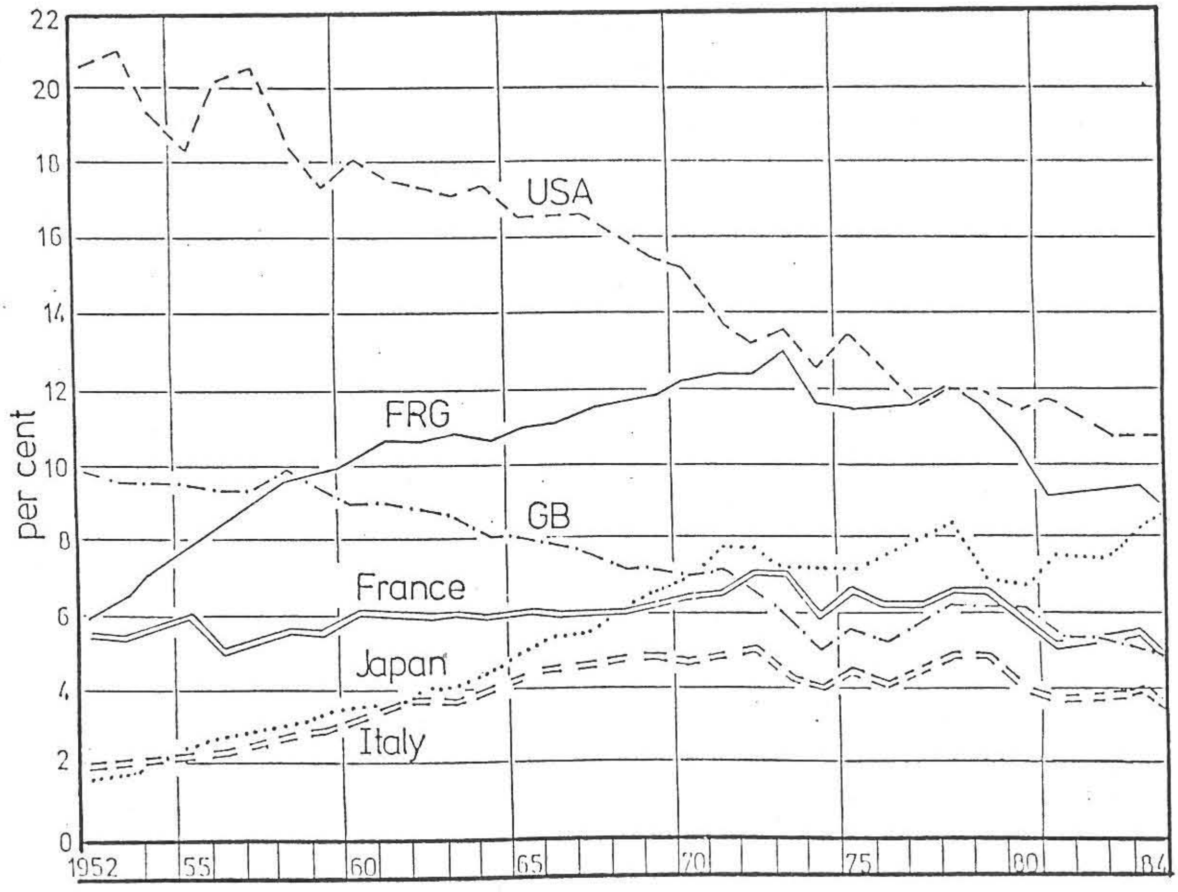
After the booming 1950s and 1960s of post-war recovery, the growth rates of the gross national product of the industrialized countries started to readjust to their long-term values of perhaps 2, at a maximum 3 per cent annually - see Graph 3. Also the Japanese growth is now settling down. At the same time, unemployment started to climb. It is important to note that, although unemployment has a demographic component, it also contains a strong "structural" one.



Graph 3 Annual growth rates of the real gross national product - 5 years' averages

International competition grew accordingly, in particular under the pressure of Japan, who between 1952 and 1984 increased her share of the world export market from 2 to almost 9 per cent - see Graph 4. Simultaneously, that of the US decreased from over 20 to 11 per cent. Thus, the range of export shares of the three top exporters narrowed down between 8.7 and 11.1 per cent. All sorts of reasons have been put forward to explain why such growth as in the 1950s and 1960s did and does not continue (OECD 1977, 1980). They range from the accusation that governments and supranational bodies mismanaged finances and trade, to the jumps in oil prices. [2)]

Now, all industrialized countries consider the public promotion of high technology development as an important growth strategy. But there are a number of political dilemmata involved in the public promotion of high technologies in Europe. In order to be specific, we have focussed on the West German situation. It appears, however, that similar considerations also hold for other European countries, although possibly to varying degrees.



Graph 4 Market shares in foreign trade

2) To be precise, one might more intelligently ask why the excessive growth of the post-war decades could be sustainable in the future.

3.2 New liberalism versus new mercantilism

In the Federal Republic of Germany, presumably much more so than in other European countries, a quite controversial and polemic discussion is being held on the relative merits of the new liberalism on the one hand and the presently wide-spread new mercantilism on the other (Blum 1983). The new liberalism wants to minimize public interventions and believes in the optimal function of the "free market", whereas the new mercantilism wants an optimal national synergism between an interventionist government and private industry. Of course, this is a very crude schematization of a highly intricate ongoing discussion among economists and political scientists, whose documents would fill a library. However, much of the present political debate which shapes political decisions is equally crude.

Concerning the public promotion of research and technology in the Federal Republic, orthodox neo-liberals, such as the Confederation of Young Entrepreneurs, go so far as to propose the abolition of the Ministry for Research and Technology. They claim that the government should restrict itself to the support of fundamental research and procurement in the narrowest sense of the term. This neo-liberal discussion has affected the present administration. In fact, it has lowered the formerly more prominent profile of the Ministry for Research and Technology so that in some areas of public support it overlaps with that of the Ministry for Economic Affairs (Krupp 1985 II). So the German government distributes over 1 billion DM annually to industry by general tax reductions or grants, outside direct aid within particular research and development programmes, some of which have been reduced noticeably. But at the same time, new programmes of direct aid to small and medium-sized enterprises were enacted, so that by and large the change in administration in 1982 resulted in no major change of policies - although a variety of pragmatic modifications were introduced. The most relevant one in our context is more cooperative research projects (Verbundforschung) between groups of companies and public research institutions in areas of high technologies (such as sensors, robots, controls, computer integrated manufacturing, very large scale integrated circuits, advanced materials, etc.). They involve an annual budget of 1.4 billion DM in 1984.

Some of the German states (Länder) have complicated matters. Ignoring the ideological reticence in Bonn [3], states such as Baden-Württemberg and Bavaria are quite overtly enacting vigorous industrial policies. A few examples out of many may suffice:

- "Research parks", "start up-" or "technology centres" which aim at synergizing science, innovation, entrepreneurship and banking in an environment nucleated and subsidized by public funds have been installed. (However, part of this programme is supported by the Federal Ministry for Research and Technology too.)
- Through state visits, the state governments, including their prime ministers, assist in the marketing in foreign countries. They also promote trade fairs and training programmes, etc., e.g. in China.
- The prime ministers or their ministers for economic affairs intervene personally in the selling or merging of private companies.
- Loans are granted to suffering companies at rates far below those available on the financial market.
- Sites for new companies are heavily subsidized, often in open competition with other states.

Other states are copying these examples, in particular Hesse, Lower Saxony and North-Rhine-Westfalia.

Through these examples, we want to show that, unlike the situation in countries such as Japan or France, for instance, where the neo-mercantilism of their governments is not seriously contested, in the Federal Republic of Germany there are hefty ideological debates on one level and neo-mercantilistic activities on another. As a result of such discrepancies her policies have become less predictable. The current ideological and political confusion is demonstrated by the fact that in international organizations, such as the European Community, OECD, GATT, etc., the Federal Republic of Germany is among those countries which support the neo-liberal positions most strongly, whereas on the other hand she is also among those countries that have the most differentiated and interventionistic policy for the public promotion of technology and technical innovation.

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3) It was only in the middle of the 1970s, after strong controversies that the German Ministry for Economic Affairs started to commission reports on the ongoing "structural change" of the German economy and society. The very establishment of such scientific research projects conflicted with its official neo-liberal orthodoxy. However, the Airbus project is administered by that same ministry.

Our conclusion is that ideological disputes between neo-liberals and neo-mercantilists have not been fruitful. The contradictions of public actions taken, if judged by one or the other ideological position, remain unresolved. In the final analysis, this is due to the lack of operational depth and range of application of the economic theories which are said to underpin the ideological debate (Krupp 1985 II, Meyer-Krahmer 1985 I). Pragmatically, it looks as if the ideological dilemma is resolved best by the pragmatic approach taken by MITI, provided that a balance of power is maintained by sufficiently strong sector departments. MITI tries to understand the structural changes in terms of new technologies, markets and demand as well as in the light of changing international conditions. Therefore, its measures try to respond to all of these aspects. In contrast to this, our ideological disputes and those between governmental departments erect barriers to such a holistic approach, however fragmented in actual practice it may be.

3.3 Enforced diffusion of high technologies versus unemployment

Economically, the most effective high technologies developed and diffused are integrated circuits, sensors and controls because they permit an automation of manufacturing and office work and consequently a continuation of the trend of increasing labour productivity in industry and some sectors of the services by up to 3 per cent annually. It is for these reasons that all European countries run major programmes at costs to the order of $ 8 annually per capita of population in order to activate the diffusion of micro-electronic equipment into and within all sectors of the economy. The argument that the manufacture of the resulting new products involved compensates or even overcompensates their labour saving effects can be refuted as follows: In the Federal Republic of Germany, about 60 000 employees manufacture chips and sensors, 600 000 employees mount them into equipment used for automation in manufacturing and offices, and by order of magnitude 6 000 000 employees will use automation equipment at their work places once their diffusion is nearly complete. Increases in the first two categories, even if they amount to 20 per cent, will be overcompensated by labour-saving in the third category within a very few years. Nevertheless, international competition forces everybody into the same boat of rationalization.

This dilemma between enforced diffusion of labour-saving high technologies and the resulting high unemployment might be resolved by policies which compensate the social costs incurred by the labour-saving effect by more integrative labour policies focussing on a reduction of work hours on the one hand and growth stimuli by more demand-oriented innovation policies on the other - see next paragraph 3.4. Neither of these policies are being carried out in our countries to any appreciable extent.

We do not want to be misunderstood: Increase in labour productivity is a valid national goal, be it only in order to provide for leisure. But the disaggregation of so many unemployed from employed people is uneconomic and socially intolerable.

3.4 Supply versus demand orientation of high technologies

Innovation research has revealed a push-pull interaction between innovative products and markets in both directions (Rosenberg 1979). As to high technologies, we may, broadly speaking, distinguish between three types of markets:

- The market of consumer and investment goods, where marketing devices of individual companies mediate between the supplier and the demand of individual customers.
- The public procurement market in particular in high technologies for armaments and manned space flight. Although companies complain about stochastic changes of procurement programmes and budgets, this gigantic market is divided up quite harmoniously between a few national oligopolists in our countries.
- The infrastructure and meritorious goods market. This is the most intricate market, but in the perspective of welfare economics also the most important one. The problem is that such "markets" depend on an agent, typically local, regional or state governments, to organize, articulate and quite often to regulate or re-regulate them. In areas such as energy, environmental protection, public transport, agriculture, rebuilding of cities, medication, education and retraining, etc., re-regulation of frame or context conditions is required, until markets can start to work, however imperfect they may be (Krupp 1985 I).

This classification, however rudimentary, is quite adequate for our present discussion.

Looking at technology push, to finance major projects of high technologies, a typical entrepreneur will resort gladly to the procurement market because - in view of the risks and the size of the capital involved, as well as of more "flexible" criteria of performance - it is most easily accessible. Such high technologies are developed primarily by large corporations which have good lobby access to the procurement market. This is probably the single most important reason why high technology policies tend to be rather supply-oriented towards public procurement in areas such as armaments, space flight, super-fast trains, supersonic aeroplanes, etc. Through international competition and mediation through international organizations and individual lobbyists, such programmes are diffused internationally. In this manner, competition is started also in areas which are economically not worthwhile, so that the abstention of governments from particular projects, and hence from this competitive race may be the best economic choice. Several case histories which corroborate this view have been described (SPRU 1980). But it is in the interest of industry to fuel this competitive race, and the evaluatory capabilities of government often do not suffice to develop an independent view.

Thus the two first mentioned types of markets provide for quite easy mechanisms of mediation between technology push and market pull. Their disadvantage is not only the possible predominance of technology push over "true" demand, but also the possibility that the third type may be neglected.

In order to illustrate the third type of market, that of infrastructure and meritorious goods, and to demonstrate the vital role governments must play, a few examples must suffice:

(1) Economically, it makes sense to internalize the costs of environmental pollution into traffic systems by appropriate re-regulations. As a result, a distribution which is different from that prevalent today between private and public transport will evolve.

(2) When, after the present stagnation, energy costs start to rise again, housing and city standards should be changed to provide for more energy conservation.

(3) By reducing the monopolistic rights of the large public utilities providing for electricity, new energy distribution systems will develop, characterized by more decentralized sources, cogeneration of heat and electricity, etc. Such "systemic innovations" constitute a vast potential for demand pull, also for high technologies.

But up to now, industry finds the markets of infrastructure and meritorious goods hard to serve, because governments are ill-equipped for their articulation and organization. The main reasons are that most governments have difficulties in coping with oppositions which are encountered whenever systemic innovations are attempted, and departmental fragmentation and egotism impede interdepartmental coordination.

It is such problems, far more than the economics of systemic innovation in infrastructure and meritorious goods, which cause their underdevelopment as compared to private goods and public procurement (see also Nelson 1977). But environmental problems in particular have demonstrated the necessity for more complicated innovation policies, in particular those which increase the productivity of natural resources, i.e. energy, air, soil and drinking water. It is a general problem that the lobbies of the present are always stronger than those of the future, which will only form after structural changes towards, for example, higher productivities of natural resources, have been achieved. In terms of the neo-liberal theories, there are structural rigidities in our nations, which present barriers to an adaptation to the future; see the first paragraphs of this section and also OECD 1983. If the economic difficulties persist, and in all probability they will, our countries may discover the vast unused demand potential of the markets of infrastructure and meritorious goods. In addition, in the more crowded European countries at least, problems of environmental protection might enforce such a trend. However, quite strong governments will be needed to cope successfully with opposed private interests and the difficulties of interdepartmental collaboration in the government, in order to achieve major re-regulations of "meritorious markets". The economics of such markets cannot be discussed in general. Our institute has analysed the particular example of substituting oil or gas imports by investments to increase the energy productivity (Hohmeyer 1984). It turns out that in the long run positive economic effects prevail, even if consumption is temporarily reduced. As a general rule, we find that in many such projects of infrastructure and meritorious goods, even if the economics are favourable, it is deficient management and the lack in re-regulation which prevents systems innovations.

It is for exactly this reason, and because of the great innovatory potential involved that we plead for drawing the attention of politics to innovations in infrastructure and meritorious goods. Europe has particular comparative advantages in these fields in that it has quite a sophisticated institutional set-up for handling them. The resulting products (e.g. equipment for energy-saving and environmental protection) contribute already now to our exports.

3.5 US versus European innovation policies

In spite of the controversial political debates described in section 3.2, the science, technology and finally innovation policies in most European countries have followed quite a logical path: government agencies, publicly supported research laboratories and private companies work in a network, which provides for a differentiated division of tasks and for cooperative synergism, in particular with respect to the development and diffusion of high technologies (see section 2).

It appears to European observers that it may be the absence of an equivalent, jointly public and private institutionalization and financing of high technology policies, which - in addition to the strong lobbying positions of major US companies and nationalistic public opinion - causes the USA periodically to take recourse to highly advertised super-programmes (Junne 1985). In particular, this seems to apply to programmes such as manned space flight and SDI. It is argued that such programmes provide for radical innovations, new technologies and an activation of science, technology and the economy, which for political reasons cannot be otherwise achieved, although it is admitted that this detour is more costly (Nelson 1984).

The European debate on this subject takes place on two quite different levels:
- An ideological and military one (themes are our particular European East/West relations, coherence of NATO, difference between the respective geographic positions of the USA and Europe etc. etc.), which we shall not comment on here (see for instance OTA 1985);
- the level of civilian technology and its economic impact, which we elaborate on further below.

Be it for reasons of symbolic politics (motivation of the electorate, profiling of politicians), be it in good faith, some European politicians repeat that SDI will probably provide a jump forward in civilian technologies via civilian spillover. It will provide still more densely integrated circuits, faster microelectronics and opto-electronics, new sensors, computers of the fifth generation and beyond, giant lasers, new materials, etc. In addition, serendipity effects may occur.

Critics answer:

- In civilian applications many of these products are not really needed, e.g. super-computers and giant lasers.
- Those items which are of potential use can be developed much more cheaply by a direct approach and tight coupling between perceived markets and development.
- Serendipity items can be waited for and taken up soon enough, all the more since being second in innovation may be more cost-effective than starting too early on the learning curve.

But let us take a closer look at the argument of spillover.

In our view, the following evidence seems to speak for a low probability and cost-effectiveness of technology transfer from the military into the civilian sector:

(1) Recently, a comprehensive literature study has been carried out, commissioned by the German Ministry for Research and Technology (IABG 1985). IABG searched in 65 data banks and found 800 literature references, 200 of which had direct relevance to the problem; 67 % from the US. The result is that only in cases of direct compatibility of military and civilian products significant technology transfer occurs such as in the earlier days of aviation. However, once products have proceeded in their product cycles and become more differentiated due to their different applications, the probability of technology transfer decreases steeply. Claims of a massive technology transfer in areas such as ship-building, manufacturing processes, micro-electronics, computer hard- and software are shown to be quite exaggerated. Certainly, the relative cost-effectiveness of this detour via military projects is very small.

(2) All basic inventions of high technologies have been made in the civilian sector: Nuclear fission, the automatic computer, the transistor, integrated circuitry, basic opto-electronic phenomena, the maser and the laser, fibre optics, genetic engineering, new superplastic materials, superconductivity and superfluidity, etc. As soon as enough commercial potential was perceived, civilian research was put into action for the commercialization of these inventions. In a counter-productive manner, military funds may even have substituted for private funds in some cases. But overall and in the long run, civilian funding far outweighs military funding. As a consequence, technology transfer from civilian into military applications tends to predominate over the inverse route.

(3) Since "spontaneous" technology transfer was felt to occur insufficiently, in the 1960s NASA initiated comprehensive projects of activated technology transfer. The costly programmes have been evaluated by numerous authors. The success and the cost-effectiveness have been found to be very low. Similarly, in a purely civilian European context, it has been felt that "spontaneous" technology transfer is too slow, and that universities, national research laboratories and lone inventors have "technologies on the shelf" which might be diffused into practice. Therefore, major programmes of activated technology transfer into small and medium-sized enterprises have been started in all European countries. The results of these programmes of activated technology transfer have not been very encouraging. [4)]

(4) In the course of a ten year project of our institute, we attempted to sell licenses from about 7 000 high technology patents to industry. The patents had originated from direct public aid to industrial companies and, to a lesser extent, to public research institutions. The result was close to nil: On the basis of an effort of 38 man years only 10 license agreements have been concluded. A major reason is the great contextual specificity of inventions, so that re-adaptations to another context are often not cost-effective or possible.

(5) Somewhat more indirect evidence is the following: In the 1960s, big US companies established basic research laboratories in Europe in the hope that basic research might result in seeds of innovation to be developed within the parent companies. It was discovered that cost-effective innovation requires a tight and very specific anticipative coupling between perceived markets in all stages of research. This was hard to achieve from across the Atlantic - and so these laboratories were closed. That is why true fundamental research is hardly carried out in industry, and long-term application-oriented research is continually trimmed to concrete objectives. This speaks against both high probabilities of "spillover" and great expectations of serendipity effects.

(6) As an example, Battelle Memorial Institute, after its success with Xerox, founded a special company, Battelle Development Corporation, in the hope that by combining a high technology development institute with a marketing device,

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4) The evaluatory work of our institute has shown that their main benefit is more indirect: Personal interactions between different institutions are being triggered in which the actual technology "on the shelf" does not play a primary role. However, in SDI such effects are impeded because of the secret nature of SDI projects.

the fruits of technology transfer could be harvested quite systematically. The attempt failed as it did in the two European Battelle laboratories.

(7) It has been shown again and again that revealed comparative advantages in particular product groups of nations do not correlate with public expenses in research and development. Many other factors intervene, such as the fitting of particular models of products into particular niches of the market as well as short delivery times, reliable servicing, marketing, etc. Therefore it is not enough to argue that SDI means more money for research.

(8) Most European companies with strong positions in military or space procurement are weak on civilian markets. Their publicized attempts at developing civilian markets have failed. Possibly, the quite easy marketing of big projects in public procurement results in weakened marketing capabilities on competitive civilian markets.

(9) The economic success of Japanese technology has been achieved with almost no input from military sources.

(10) On an international scale, the USSR is economically quite unsuccessful despite a massive military effort. The large French and British military efforts have apparently not led to particularly favourable positions on civilian markets of high technologies either.

Even if one or several of these ten arguments can be criticized, their sum appears convincing to many. This is in accordance with the cautious comment made by the President's Commission quoted at the end of section 2.3. Following the line of this general experience, the German Ministry for Research and Technology has stated repeatedly that German participation in SDI cannot be justified on grounds of civilian technology transfer.

A final comment: It appears that on average, European companies, whatever their size, are quite active in research and innovation because their average export ratio is much higher than that of their homologues in the USA. This keeps them on their feet and no particular technology push campaigns seem warranted.

The resolution of the dilemma between the SDI approach and European interests lies on two levels:
- European companies may accept US projects, if they get them.
- From a civilian perspective, SDI is not needed in Europe.

It looks as though this pragmatic stand has been taken by the majority of European governments. [5)]

3.6 Symbolic versus rational policies

For about a decade or more, attempts have been made to enact innovation policies in terms of an experimental science (Meyer-Krahmer 1985 II):

- policies are being planned and implemented for limited periods of time;
- evaluations of policies and policy instruments are being carried out, be it ex ante, ex post or during policy implementation;
- international comparisons are being made in order to accumulate international experience and to measure the influence of national specificities.

This can lead to self-correcting cycles of policy implementation and evaluation, although for the time being this may appear as wishful thinking to many.

Further, technology assessment seems to be gaining ground in Europe. At least in the Federal Republic of Germany, a parliamentary commission (one of the authors of this paper is a member) will probably make a more or less unanimous recommendation to the parliament on the basis of which some kind of "office of technology assessment" may be established. However weak in actual practice such a body will be, more general societal criteria beyond the economic seem to be gaining growing support.

[5)] Technology transfer from military to civilian applications is a side question compared with the symbiosis of "war and peace" in big industry: As soon as new high technologies emerge in laboratories, big industry looks for a sponsor, no matter wherefrom. If, for example, micro-electronics is initially adopted by the military, the military is first in line, and military funds rather than funds obtainable from the civilian market are employed. Gradually, however, the civilian market becomes so big that military "procurement" falls behind. Inversely, robots have been developed for civilian applications. Robot companies looking for new markets propose to replace gun loaders in armoured cars by a robot, etc. It is in this intimate way that at the source of new technologies in countries of large military spending, civilian and military "innovation" are not being separated. So the "military-industrial complex" is generated whose controversial influences US President Eisenhower deplored in his famous farewell address in 1961. For the time being, this is still different in countries with less military spending such as the Federal Republic of Germany and Japan. Since military spending is uneconomical, tying European countries into SDI means that their competitiveness is reduced, a policy which is not in their interest.

Some European programmes in areas of public procurement conflict with this "rationalization" of policy making due, at least in part, to their overload of symbolic and military politics. In order to be more specific, we have concentrated here on the example of programmes of manned space flight of the Federal Republic of Germany. This example may apply to some other European countries too, to the extent that they also participate in the relevant programmes, and it may apply to other programmes as well (e.g. fast breeding reactors, magnetic train, Concorde etc.).

It is being claimed by interested parties that apart from nationalistic and military purposes, manned space flight has two kinds of civilian application:

- Experimental research outside the gravitational field of the earth, so-called micro-gravity research, will provide important inputs to material sciences. In particular, experiments on diffusion, sedimentation, thermal convection, surface tension, crystallization, alloy formation and - in bio-technology - on electrophoretic separation and cleaning are being proposed.
- Consequentially, some authors and companies propose space manufacturing. The two examples quoted most often are special drugs and turbine blades.

Our critique is twofold:

- By varying gravity, neither a widening nor deepening of scientific concepts of material science can be expected. The dimensionless variables of Froude, Bond, Grashof and Rayleigh have been tested in numerous experiments and their ranges of application are quite well-known. But apart from that, variable gravity can be simulated by centrifuging, electromagnetic suspension, immiscible mixing, etc. Compared with the costs of micro-gravity research, the scientific level of argumentation of its proponents is low (e.g. Sahm 1977). We may note in passing that the cost of micro-gravity research is in the same order of magnitude as major national programmes, a hundred million DM, annually.
- Similar arguments hold with respect to space manufacturing. We have not been able to obtain any proposal on space manufacturing which would have a chance to qualify on the basis of standards common in industrial planning.

Therefore it is not surprising that neither the scientific community at large nor industry is showing interest. As a consequence, the Ministry for Research and Technology asked a management consulting company to conduct an enquiry into the interest of industry in space manufacturing and to propose how to promote it.

As no industrial interest was discovered, the management consultant suggested government support for the founding of a lobby for the government programmes. This appears to have been done in the meantime. [6] Worldwide, similar national and international lobbies are being formed and financed publicly, either directly or indirectly via procurement of hardware.

An intricate problem which governments are facing is an entanglement of civilian and military objectives. Let us stay with the example of manned space flight: through "civilian" objectives such as walking on the moon, astrophysics research, telecommunication satellites, etc., NASA paved the way for SDI. Whether by intent or not, the European Space Agency may follow the same route. A major European version of SDI, whether as an appendix to the US approach or as a separate E(European)DI, may ensue. This gigantic scientific-industrial-military complex was never planned the way it has actually evolved, but disperse private interests have become collimated and synchronized, because in the procedures of public funding the diverse objectives are mixed up:

- Military objectives are defended by pointing to civilian "spillover" and basic research;
- Economic reasons (e.g. alleged space manufacturing) are put forward to justify large manned space-craft wanted elsewhere.

The unifying interests behind these disperse motivations are those of big industry, providing the gigantic hardware. The role of politicians is often reduced to that of being the spokesman of such reasonings. International competition activates and synchronizes these developments.

Thus, the dilemma we wish to point out is the following:
<u>The growing sophistication of planning and evaluation instruments in industry and innovation research are in opposition to the programming in major cost-intensive areas</u> of high technologies, where <u>the power of lobbies and political symbols</u> is believed to be so strong that more rational legitimations of their

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6) The press reports (Blick durch die Wirtschaft, 9.1.1986) that a society named "Intospace" has been founded in Hannover. Its founding capital of 1 million DM has been provided by some 20 German companies, banks and research institutions. Through this one-time capital input, the promotion of public funding to the order of 1 to 2 billion DM annually will be influenced. The developing commercial interest is of course that of the manufacturers of space hardware.

draw on public money is not required. [7)]

These are some, certainly not all, of the highlights of the discussions on the European politics of high technologies. In the next section we attempt to formulate a few policy recommendations which seem to emerge from this analysis.

4. Conclusions and policy recommendations

High technologies contain a large potential from which important consumer and investment products as well as infrastructure and meritorious goods can be obtained. In the development of the latter Europe is in a good competitive position because of an available appropriate social and infrastructural network.

From the preceding analysis, we derive the following policy recommendations:

- The competitive pressure is such that for Europe a more integrated innovation policy between the private and the public sector, as opposed to unilateral neo-liberal ideologies, is indispensable.
- The fast technological development should be complemented by more comprehensive policies, in order to buffer technological extremism by better planning procedures, cost/benefit analyses of alternative projects and, finally, technology assessment, in order to include other societal criteria into the analysis.

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7) As an example, we quote from an official document of the European Space Agency (ESA 1985): "In order to support the space programme, it is absolutely necessary to mobilize the public and political circles; this requires large publicity-intensive projects such as Ariane and Spacelab". ESA/C (84) 46, rev. 1, page 3 (our translation from the German version). Here, lack of public acclaim is used as an argument for pushing those elements of the programme which have television appeal. A further study of this ESA document shows that

- cyclical argumentation is used: since a market is not in sight, strengthening of micro-gravity research is requested in order to fill the capacity of the otherwise not needed Columbus platform, and inversely;
- lack of commercial interest is given as a reason for asking for more public money.

- The high level of infrastructure and meritorious goods in Europe provides for a unique potential to diffuse high technologies into fields of energy, environmental protection, public transport, agriculture etc. This requires systemic innovations, largely through re-regulation of related national contexts. We maintain this, although we are aware of the cautioning considerations of renowned economists (Nelson 1977, 1984); however, world problems are too serious not to ask for new policies, however small the chances of success may be.

These recommendations are consistent with worldwide attempts to equip parliaments with institutions of technology assessment, in order to permit politicians to draw on independent sources of information and to provide them with a wider view of society as a whole, a necessary complement to more technocratic approaches. Like all technologies, high technologies embrace "good" and "bad", politics must guide them, where possible for the better.

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