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The Strategic Position of Technology Research Organisations in Europe: Energy, Aerospace and Marine Technology

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Introduction and Summary

1 Introduction

1.1 The objective of this study

The Advisory Council on Science and Technology Policy (AWT) is currently addressing the issue of what the strategic perspective is for publicly and privately financed institutes of technology in Europe with regard to the sustained legitimisation of government support, the market potential of the technology base, and new opportunities for operating in markets for R&D. The main issue is how, within the European context, government support of contract research organisations with a public mission is currently legitimised, and what trends and developments can be expected to take place. The background is the current policy discussion (a discussion which is also under way in the international dimension) concerning the efficient organisation, better interaction with market and societal demands and, last but not least, the (private and public) financing of the knowledge base of these contract research organisations. TNO-STB was requested to present a study investigating this issue. The first and foremost goal of this study is to gather and interpret international data to be used to make an assessment of the Dutch situation with respect to the big Technology Institutes. The emphasis in this study is on three areas of technology: energy technology, marine technology and aerospace technology. Therefore, the study relates to three Dutch Technology Institutes:

- NLR; Dutch Aerospace Laboratory
- ECN; Energy Centre Netherlands
- MARIN; Marine Research Laboratory.

This study does not include a detailed policy assessment of the Dutch situation; this is a task for AWT. Nor does it contain an assessment of the Dutch situation concerning the three areas of technology but is limited strictly to foreign institutions in these areas. However, Part III of this study does present a preparatory analysis of the strategic perspective concerning European contract research organisations based on the empirical material available from country studies.

1.2 Scope and implementation

The AWT requested TNO-STB to cover three areas of technology:

- Energy technology (exploration, conversion, storage, distribution of energy; energy systems and equipment; energy efficiency etc.).
- Marine technology (ship design, simulation and building, computer simulation, water flow modelling and simulation etc.).
- Aerospace technology (aerodynamics, design of aircraft and spacecraft, simulator systems, construction and building, materials, avionics, sensing etc.).

We will not provide an extensive and complete picture of the technological knowledge infrastructure in this study. Rather, we will cover a number of characteristic European technology institutes (contract research organisations with partially a public mission) for each of the technology areas. To become eligible for this study, the technology institutes must be financed partly by public and partly by private funds and should operate at least partially on open (competitive) markets. The institutes we selected must also be comparable with ECN, NLR and Marin. Furthermore, they must be engaged in a substantial amount of technological research and development activity. Not considered are those institutes whose core emphasis is on technology transfer or policy research; university research centres; purely industrial R&D laboratories and the like.

On the basis of this empirical material, the core of this project is the description and analysis of the strategic perspective for each of the three areas of technology as a whole. While descriptions of separate European technology institutes are used as an illustration detailed analyses are provided at the organisational level of research centres in several of the country studies. It should also be understood that the technology portfolios of most of the institutes covered are not restricted to one of the three technology areas only; many of the institutes maintain technology portfolios that intersect several areas. For instance: portfolios in energy research which includes aspects of process technology, materials research, computational sciences, etc.

Ten European countries were covered In this study (UK, France, Germany, Sweden, Finland, Norway, Denmark, Italy, Spain, Belgium). For each country, specific areas of technology were taken into account because AWT already had information available on some of the technology-country combinations. Table 1-1 presents the countries and areas of technology covered.

We used our network of European partners in the area of science and technology policy to deliver the empirical material for the study (under the coordination and responsibility of TNO-STB). Part II of this report presents the ten country reports which provided this empirical material. Our partners were:

- UK: CEST (energy, aerospace, marine)
- France: ADEME (energy); OST (aerospace)
- Germany: VDI-TZ (energy, aerospace)
- Sweden: NUTEK (aerospace)
- Finland: VTT (marine)
- Norway: STEP (energy, marine)
- Italy: ENEA (energy)
- Spain: CIEMAT (energy)
- Belgium: VITO (energy, aerospace)
- Denmark: DTI (marine).

Table 1-1 **Coverage of the study: countries and areas**

AREA COUNTRIES	ENERGY	AEROSPACE	MARINE	Number
United Kingdom	v	v	v	3
France	v	v		2
Germany	v	v		2
Sweden		v		1
Finland			v	1
Norway	v		v	2
Italy	v			1
Spain	v			1
Belgium	v	v		2
Denmark			v	1
Number	7	5	4	16

1.3 Background aspects

The legitimisation issue of public-financed technology institutes is central in this study and deserves some reflection here. It is a subject which can be approached from different perspectives. This paragraph provides some thoughts and structures which might be helpful in shaping the presentation of the empirical material and policy-relevant conclusions of the final chapter, Chapter 13. From a market transactions point of view, the legitimisation of government support for technology institutes can be justified on the basis of the existence of market defects. In this view the existence of government-supported contract research organisations is a sign that the market for R&D (including R&D for public missions) shows certain failures for which the organisational arrangements provide solutions. However, such an argument could easily be used to 'rationalise' existing forms of government support (sometimes even seen as forms of 'natural monopoly'), perhaps overlooking the possibilities for new, more flexible arrangements for that what matters most: *creating access to knowledge*. A broader framework is needed to analyse the specific need for the governmental support of R&D organisations and the specific form needed for such support; support which could also encompass indirect support measures or incentives such as tax conditions or funding schemes to be used under industrial governance.

This framework departs from the observation that there are *different types of failures* in the markets for R&D. From this observation, it is easy to understand that - taking into account the different economic characteristics of the markets for R&D - *different strategies* can be developed to overcome the effects of market failures. Under certain conditions, one of the strategies might be to support government-funded R&D organisations.

In Table 1-2, we distinguish between four central types of failures in the markets for R&D according to those market failures that originate on the supply side, on the demand side or on both: 1. Missing markets (lack of supply as well as demand); 2. Lack of demand (which is an expression of lacking supply-demand interaction); 3. Lack of R&D supply; 4. Market dominance (non-competitive markets).

Table 1-2 Four types of market failures

SUPPLY OF R&D	DEMAND FOR R&D: no	DEMAND FOR R&D: yes
yes	**Lack of demand** (malfunctioning supply-demand interaction)	**Market dominance**
no	**Missing markets**	**Lack of supply**

- *Missing markets*. This is the case if there is no supply of a certain R&D, and there is no demand (or no articulated demand) for that R&D either. Whether this really is a market failure depends on national priorities and ambitions. A case is R&D of a more 'enabling' nature without a distinct direct industry-related demand.

- *Lack of supply*. This market defect occurs when R&D is found to be of prime importance for societal-strategic reasons (public need) but is not being carried out at all (lack of supply). The underlying reasons may involve the cost structure of R&D, risky demand structures, lacking protection of rights, external effects, and information problems (or combinations). This would justify government support of *supply-oriented measures*. One of these measures could involve the creation of an adequate supply of knowledge; other options could be the stimulation of new entrants or - more user oriented - the improvement of a more explicit articulation of the demand for knowledge.

- *Lack of demand (malfunctioning supply-demand interaction)*. This is the case when there is a supply of R&D, but it is not appreciated sufficiently by the demand side of the market. This could be in consequence of lacking needs or the insufficient demand articulation and supply-demand interaction. Underlying factors could include the market dominance of dominant suppliers of R&D (supply-led R&D), risky demand structures, the existence of external effects, and information and transparency problems (or combinations). In the Netherlands, and in other countries too, ongoing discussions on strengthening supply-demand interactions and on demand-led R&D show at least a perception of markets for certain types of R&D which do not function all that well.

- *Market dominance (non-competitive markets)*. A special case of badly functioning markets occurs when there is a supply of R&D and that supply meets the needs of users, yet this is under non-competitive conditions and at the same time competition is both feasible and desirable. Here, we focus on the existence of dominant parties in certain markets for R&D. This could be the case when publicly financed research organisations cross-subsidise their operations in commercial markets.

Table 1-3: Market defects and strategic options

MARKET DEFECT	MANIFESTATION	UNDERLYING FACTORS	STRATEGIC OPTIONS
Missing markets	Deteriorating national S/T position Underinvestment in R&D	Priority setting Information symmetries Entry barriers through R&D cost structure External effects	Re-setting of national priorities Provide access to international sources and networks
Lack of supply	Underinvestment in R&D Import of knowledge Unsolved societal problems	Cost structure, critical mass Risk profile Protection of rights External effects	***Create specific research organisations*** Enhance conditions for new entrants
Lack of demand (malfunctioning supply-demand interaction)	Under-utilisation of R&D Over-supply of R&D	Demand articulation Risky demand Supply-demand interaction	Improve demand-orientation of R&D organisations ***Create intermediary organisations***
Market dominance	Cross-subsidy Unfair price/quality level Entry deterrence	Cost structure of R&D Entrance barriers through cost structure of R&D	Regulation of access, pricing, certification Privatisation of ownership Increase influence of users

Italics: of especial importance concerning legitimisation of publicly financed research organisations

Table 1-3 sets out the strategic options available for each generic market defect. This table is interesting in the way it relates to the legitimisation discussion concerning contract research organisations with a public mission. The legitimisation of government funding of such R&D organisations is one of several options available, and the adequacy of this strategy depends strongly on the type of failure as well as on the precise nature of the underlying factors. In turn, this relates to the type of R&D and its associated economic characteristics.

Therefore, given that different R&D market structures with different economic characteristics require different forms of regulation, a distinction should be made between *markets for different types of R&D* (with different cost, risk and benefit structures). One useful distinction uses two kinds of drivers of R&D: a type of knowledge generated (monodisciplinary vs. systemic) and attractiveness of knowledge (scientific vs. societal). Four types of R&D thus can be distinguished.[1] Looking to the extremes, it can be said that the structural aspects of the two markets for knowledge differ strongly:

[1] Nederlands Forum voor Techniek en Wetenschap, *Naar een betere benutting van kennis in de industrie* (Dutch Forum for Science and Technology: *Towards better utilisation of knowledge in industry*), 1994.

- *Monodisciplinary, scientific research*. In many cases the cost structure of this R&D activity will prevent competition from being desirable or feasible. In some cases advanced research facilities can be viable through international cooperation only (ESA, CERN). Some (limited, or a least potential) form of competition however is still desirable and at the same time feasible (universities). The formulation of a national strategic policy orientation and priority setting with respect to this type of research is required.

- *Systemic, market oriented research*. In many cases the economic structure of this activity does not preclude competitive supply. There is room for multiple forms of cooperation and competition in the value chain of knowledge generation. Examples being the rise of small specialised R&D businesses, the multitude of intermediary R&D agencies, and the competition in national and international markets for applied R&D such as energy technology.

In each of the situations mentioned above there are structural as well as behavioural types of regulatory action related to justifying government support. Structural measures are directed towards improving the structure of the market for R&D, for example by creating supply through publicly financed organisations, by creating or stimulating competitors in markets for R&D, by introducing mechanisms for the demand-led steering of R&D, or by structurally separating operations on market segments to overcome cross subsidy. Behavioural measures are directed to regulating market behaviour. These may include the regulation of tariffs and quality, of access to R&D results, of protection of rights and so on. Each of the policy options in each of the four situations characterised by the specific type of market failure, as well as the specific characteristics of the type of R&D, involves its own kind of benefit, cost and risk.

Focusing on the specific issue of this report - legitimisation of the government funding of contract research organisations with a public mission - the main kinds of market failures are the lack of supply on the one hand, and the lack of demand (malfunctioning supply-demand interaction in knowledge infrastructure) on the other. A third legitimisation factor is simply the publicly financed research organisation as a client for the government. See Chapter 13.

1.4 Country surveys: outline of the issue covered

In the survey of the technology areas to be carried out by each of our partners, we specified the following research questions:

Q 1: Which European institutes are relevant ?
We asked our contacts to provide a list of the most characteristic technology institutes per country in the area of technology in question, supplemented with a brief argumentation in line with the project problem statement. Technology institutes were then selected for more detailed coverage on the basis of this information.

Q2: What are the basic characteristics of these institutes?
The emphasis was on providing statements of mission and strategy, overviews of activities, products, technologies and markets, basic data (personnel, sales, etc.). We were also interested in important market segments and main clients; this had to be illustrated with relevant data. An important element of the study deals with the financing structure: the flow of funds, how that flow is separated in terms of financing from commercial operations and government support, preferably by market area (e.g. 'nuclear energy').

Q 3: What are the relevant markets and technologies; important trends concerning these institutes ?
An overview of the most important current trends and developments regarding the relevant markets, clients, financial flows and government funding was needed to provide the necessary background to be able to understand the policies regarding legitimisation of government support. We were also interested in the future policy scenarios that should be anticipated. Regarding this issue, the 'elbow room' for strategy development, market strategy and commercial operation is another important matter.

Q 4: What are the most important strategy/policy discussions concerning the technology institutes ?
The issue of legitimising government support is surely central in this project. We focused on relevant discussion issues, i.e. legitimisation discussions with regard to government support, changes in controlling these institutes, the degree of independence and result orientation, and the evolving market for knowledge. Also, the different roles of the players (government, advisory councils, industry associations, etc.) with regard to financing and controlling technology institutes is of relevance here, along with the forces that are in play (political processes, economics and budgets, pressures of industry users, competitive forces in markets for R&D), with a particular emphasis on the role of government.

Q 5: What are the future perspectives concerning market orientation, government funding and organisation.
Here we are concerned explicitly with future scenarios concerning government policies on the technology institutes: government funding, mission and strategy, commercial policies. We also had an interest in the expected consequences for the relevant technology institutes.

1.5 Overview of this study

The introduction and main conclusions of the study are contained in Part I. Part II presents National Studies for each of the ten countries covered, subsequently dealing with the technology areas at hand. We chose for a presentation by country (instead of by area of technology) in order to focus on the specific national circumstances and the differences from one country to another. This would provide the best basis for comparison with the Dutch situation. The position of relevant research institutes is investigated in each of the area studies. Each Country Study is uniformly structured as follows: [2]

COUNTRY STUDY STRUCTURE

Overview
- **Introduction**

Situation assessment
- **Mission, strategy, activities, markets**
- **Key indicators and financial flows**

External Environment
- **Trends and developments**
- **Key forces**

Legitimisation: Strategic Perspective
- **Strategic issues**
- **Future perspectives**

Concluding Remarks

Finally, Part III contains our analysis of results, based on the framework introduced in par. 1.3. For each of the three areas of technology a comparison of country results is presented to provide an insight into the different aspects of the legitimisation discussions across countries.

[2] Country studies were contributed by our partners. TNO-STB was responsible for structuring, editing, and incorporating the final paragraph 'Concluding Remarks'. Part III is contributed by TNO/STB.

2 Summary of conclusions

This study assesses the developments and changes in the markets for technological knowledge, and their impacts on the strategic position of contract research organisations with a (partial) public mission. An important element of these changes is constituted by the changing basis for legitimisation of these organisations. Drawing upon empirical results from the country surveys we identified differences across countries and across areas of technology in the strategic position of these organisations.

The differences between the various countries studied are sometimes very big. Apart from national peculiarities and differences related to the choice on which source to base the national electricity production, most of the differences are in one way or another related to the stage in which the countries find themselves in the shift towards more market-oriented R&D systems. Some countries, like the UK, Denmark and Norway have already progressed quite far in this respect. Countries like Belgium, Italy and Finland appear to be somewhere in the middle, whereas countries like Germany, Spain and - to a lesser degree - France, are only in the initial phase of this drastic transformation process.

Considerable differences are also to be observed between the three areas studied. For long time the driving force behind the development of the R&D infrastructure in the area of *energy* was the development of clean and cheap electricity production based on nuclear energy. Changes in this sector relate considerably to the slowly growing awareness that nuclear energy production is not only not a sound option from a commercial point of view, but it also brings along huge environmental problems which are difficult to solve. This resulted in political support for nuclear R&D fading away, plus considerably decreasing budgets. This area is now in a dual transformation process. Apart from the shift to a higher level of market orientation these R&D organisations were also faced with the challenge of looking for new missions. They often found this new mission in the area of environmental issues and support of innovation processes in SMEs.

The situation in the area of *marine* technology is much easier, at least as far as the Scandinavian countries are concerned. For years now they have had a (modestly) public-financed R&D infrastructure with strong links with industry. In the future they are likely to continue along the lines set out in the past. Their main problem is one of maintaining a balance between public and private interests, geared towards the actual societal and economic situation. The situation in the UK regarding marine-related R&D is more complicated because, historically, this area has always had more close ties with the defence sector and hardly any with private enterprise. The challenge facing these organisations is to loosen the ties with the defence sector a little (not completely) and by doing so improve the conditions for increasing the number of contracts from private players.

The situation in *aerospace* is somewhat similar to that in the marine-sector in the UK. Almost all organisations involved in R&D in this area had by tradition very close links with the defence sector. Here too have they to make a dual shift: from less public to more private funding and from defence to civil. For many organisations this is a very difficult challenge, used as they are to almost exclusive public funding and functioning in closed and protected markets.

Quite clearly, there are major trends to be observed in all countries and areas studied. All these trends bring along their own problematic issues. These trends are:

- Shift to a more market-oriented R&D, coupled to a decrease in public funding.
- More efficient and effective organisation of R&D.
- Internationalisation (and regionalisation).

The shift to more market-oriented R&D constitutes by far the most important trend that can be observed. Some of the important mechanisms and strategies in this context are:

- Radical privatisation of public R&D organisations
- Introduction of programmatic funding of R&D and strengthening the influence of users
- Market-based organisation of R&D departments
- Institutionalised cooperation between universities, applied research organisations and industry
- Creation of agencies in the public domain with partly commercial goals (UK).

Associated with this shift is an important problem that relates to *the positioning of contract research organisations between public and private*. Up to now they were often almost completely in the public domain. Because of the shift to the market these organisations now run the risk to falling in between both worlds. The question is how these organisations will be able to develop a profile which clearly shows how the public and private functions relate to one another in such a way that the various parties in the public and the private sector know what they can expect from these organisations. It is quite remarkable to see that this very fundamental discussion (which lies at the very roots of the transformation processes these R&D organisations are going through at present) is not addressed more frequently. As far as the UK is concerned this can be explained by the fact that they have just been through a substantial review process, during which issues such as privatisation and legitimisation were discussed in depth. The surveys on the other countries however give no indication of such a fundamental debate. Whether this should lead us to the conclusion that this debate will not be conducted at all, or that this issue will be put on the agenda in the nearby future, is difficult to say. It seems that the strategies being developed by contract research organisations are constrained by history, by national policies, by organisational structures and by the peculiarities of the area of technology in question. Creating the flexibility in structures and strategies to cope with these transformations is an important challenge.

Country reports

3 United Kingdom

3.1 Introduction

This country study[3] describes the status of technology institutes in the UK. It covers three areas of technology, namely energy, aerospace and maritime.

Before examining the selected areas of technology in detail it is appropriate that we should consider the overall context for research in the UK. In recent years, the Government has carried out a programme of prior options reviews of public sector research establishments. Each review examined the relationship of an establishment to other establishments in related or similar fields and considered the scope for privatisation or rationalisation and for other aspects. An example of one organisation affected by this process is the Building Research Establishment which, until this year, was a public sector research organisation involved in research relating to buildings, including energy aspects. It was privatised in March and now operates on a fully commercial basis, although it retains responsibility for part of the GovernmentOs Energy Efficiency Best Practice Programme (see Section 3.2 below[IL1]).

As a consequence of the prior options reviews and earlier initiatives, the UK, unlike many other countries, has relatively few government-funded institutes. Instead, it typically seeks to achieve specific research objectives through targeted programmes which are open to competition from various types of organisation. These generally seek to enable, and have provision for, government funding to be augmented by funds from the private sector.

Instead of being fully privatised, some research institutes which by tradition were always in the public sector have been given agency status. This means that whilst they remain in the public sector, they are operated on commercial grounds and are encouraged to seek support across a broad range of public and private sector customers.

In line with the overall objectives of this study, this country study addresses both major organisations and programmes which characterise the status of technology areas to be addressed, and illustrate issues relevant to the sectorsO strategic perspectives and directions.
Whereas it does not examine individual academic institutions, it should be noted that they do play a more significant role in applied research in the UK than in some other European countries.

There are two key initiatives which define the research foci and public funding of the technology areas under consideration. These are:

3 Country study prepared by Celia Greaves, Centre for the Exploitation of Science and Technology (CEST).

- *Technology Foresight Programme*. This key UK policy initiative aims to identify opportunities in markets and technologies likely to emerge over the next 10-20 years, and the investments and actions needed to exploit them. The results of the first phase, published in 1995, comprised a series of reports covering the work of 15 sector Panels across areas such as energy, defence and transport. The findings contained in these reports continue to inform government decision making and spending, as do the ongoing activities of the Foresight Panels.
- *The Forward Look of Government-funded Science, Engineering and Technology*. This annually published document sets out the GovernmentOs general strategy for developing the science and technology base and its plans for specific research organisations operating in the public sector. In recent years there has been a particular emphasis on implementation of the Technology Foresight Programme.

In 1995, the *Office of Science and Technology*, which provides funding for the Research Councils (i.e. for academic research), was transferred to *the Department of Trade and Industry* (DTI). This is intended to facilitate progress in forging links between the academic and industrial sectors. This premise lies at the heart of much of recent Government thinking regarding publicly funded research. Related activities include efforts to extend and accelerate the operation of competition in the market for publicly funded science, engineering and technology (SET). Wherever possible, a fully open market for providers and funders of research and development is being sought.

It should be noted that the status of the technology sectors as reported here reflects the situation prior to the UK General Election on 1 May 1997. The new Government has already announced a Department of Trade and Industry (DTI) analysis of spending priorities, and this will inevitably include an assessment of support for scientific research. Whilst it is not possible to pre-judge the outcomes of any aspect of this analysis, it is helpful to note that, whilst in opposition, Tony Blair said Oa labour government will have policies to support basic and applied science. But the responsibility of government must be greatest for basic science where market is most likely to fail. I recognise that priority must go to investment in establishing centres of excellence, although I do believe there is scope for greater collaboration to use the strengths of all our institutionsO. He also stated that a Labour Government would consult widely before introducing any changes from current arrangements.

3.2 Energy

3.2.1 Introduction

Outside the academic community, there are no publicly funded institutes focusing specifically on energy related research in the UK. Government support for energy-related research is primarily targeted through specific programmes. The three most significant are the New and Renewable Energy Programme, the Clean Coal Programme and the Energy Efficiency Best Practice Programme. In the nuclear sector, research is mainly undertaken at the discretion of the publicly owned companies, such as Magnox Electric plc and British Nuclear Fuels Limited (BNFL). The UK AEA, which is a non-departmental public body, carries out some targeted Government funded research.

3.2.2 Mission, strategy, activities, markets

The New and Renewable Energy Programme
This ten year research, development, demonstration and dissemination programme operates in parallel with the UK Non Fossil Fuel Obligation Orders, which are the GovernmentOs main mechanism for working towards a target of 1,500 MW DNC of new or renewable electricity generating capacity in the UK by 2000. The overall aims are to stimulate the development of sources and industrial and market infrastructure so that new and renewables are given the opportunity to compete equitably with other energy technologies on a self-sustaining market.
The Programme covers a range of technologies, among which biofuels and solar energy.

The Clean Coal Programme
The Clean Coal Programme's main goal is that by the end of the decade, there is firm foundation for the exploitation of the technologies by UK industry for electricity generation and other uses in the home and overseas markets. This Programme aims to provide a framework for developing clean coal technology research and development in the UK. Research areas comprise exploration and extraction, preparation, handling and supply, combustion in conventional power generation, advanced power generation and other conversion and utilisation processes. There is room for collaboration between UK industry, Government, universities and overseas organisations.

The Energy Efficiency Best Practice Programme (EEBPP)
The Energy Efficiency Best Practice Programme provides support for various forms of research and development in the area of energy efficiency. Of most relevance to this study is the future practice element, which provides up to 49% of the eligible costs of relevant industrial R&D. Areas covered include advances in computing, furnaces, instrumentation and sensors, intensified reactor technologies, process intensification, catalytic combustion, high temperature filtration, biological processing, electrical processing, electromagnetic processes, energy storage and superconductivity, composites, heat recovery and separation processes.

UK AEA
As mentioned above, the UK AEA is a non-departmental public body. Its primary purpose is to decommission nuclear power stations and address issues relating to waste management and contamination. Research accounts for only a small part of its operations. The most significant research activity, in the context of this study, is the Fusion Programme. This forms part of the Europe-wide Fusion Programme which, in turn, comes under the umbrella of Euratom. The primary aim of the Programme is to develop an economic

method of generating electricity from a nuclear fusion reactor. This is anticipated to be achieved through the construction of increasingly sophisticated prototype machines. Under the European framework for fusion research, each country nominates a single organisation to participate. The rationale behind UK AEAOs involvement is that it is the only organisation with appropriate technical expertise. The current lack of commercial or military relevance, and long term financing required, acts as a constraint to interest amongst other organisations.

3.2.3 Key indicators and financial flows

In overall terms, net government funding for energy-related research has declined as a proportion of total research funding over the past 10 years. In 1986/87 it accounted for around 4.4% of the total, whereas in 1994/95 its share had decreased to around 1.1%. These changes have occurred against the background of privatisation of the electricity generating industry. As the nationalised sector disappeared, so did its publicly funded long-term strategic research.

Government contributions across the technologies covered by *the New and Renewables Energy Programme* and related activities for the year 1995/96 were as follows (Table 3-1).

Table 3-1 Government contributions New and Renewable Energy Programme

Wind	£ 3.4m
Wave	£ 0.04m
Solar	£ 1.9m
Biofuels	£ 3.4m
Tidal	£ 0.2m
Hydro	£ 0.1m
Technology transfer	£ 4.2m
Management	£ 3.7m
Fuel cells	£ 1.2m
Strategic studies	£ 0.04m
Total	**£ 18.18m**

It can be seen that current spending favours wind energy, biofuels and, to a lesser degree, fuel cells and solar energy. Industry contributions over the same period were £26.4m, that is around 60 % of the total. The mechanisms for government funding are very flexible, and seek to optimise industrial involvement and support from other sources such as the EC.

Within the *Clean Coal Programme*, twenty new research projects were initiated over the period 1995/96. The total value of the programme is of the order of £214 million, of which around 20% is provided by the government.

Government funding has been steadily declining over the past few years, with the budget for 1997/1998 (at £3.7m) representing slightly less than 60% of the 1996/97 budget (£6.3m). By 1995/96 the total programme of about 200 projects (including completed ones) involved 35 UK industrial concerns / Trade Associations / Consultancies, 25 UK Universities and 53 overseas organisations.

Total Government funding of the *Energy Efficiency Best Practice programme* in 1997/98 is expected to be around œ15m; this is comparable with that provided in 1996/97. The research component varies from year to year depending on the type and size of research proposals and the other activities planned. The programme has a fundamental objective of achieving an average saving of œ800m or 500m tonnes of carbon per annum by the year 2000. In 1995, when the programme had been running for five years, savings of £450m were achieved. This was considered reasonable.

UK Government support for the UK AEA, totalling around £14.5m per annum, is divided almost equally between support for the current proto-type (JET, Joint European Taurus, which is a large scale fusion demonstration experiment) and UK AEAOs related research. This research is targeted towards identifying alternative proto-type designs and resolving detailed problems associated with JET.

3.2.4 Trends and developments; key forces

In recent years, there has been a significant change in the profile of the UK energy industry, with large-scale privatisation across all sectors. Before this, public sector bodies such as British Coal, the Central Electricity Generating Board and elements of the nuclear industry each had their own research activities. As these organisations moved into the private sector, so did their research capabilities. More focused research organisations such as the Building Research Establishment, which covers aspects of energy use in buildings, have also recently been privatised.

The current programme of privatisation of the gas and electricity industries means that future developments in certain aspects of publicly funded energy-related research are subject to considerable uncertainty. Nevertheless, in energy-related research, opportunity technologies identified during the Technology Foresight Programme, and likely to continue provide the focus for publicly funded research, comprise nine main areas:

- oil and gas: high hit-rate exploration techniques and increased yields from existing reserves;
- nuclear: decommissioning of redundant facilities;
- renewable sources: cost-effective photovoltaic production;
- ‘clean coal’ power generation: covering stack gas cleaning, coal combustion and gasification;
- gas power generation: combined cycle units;
- motive power for transport: low emission power units;

- industrial processes: improved efficiency in energy intensive processes;
- buildings: greater energy efficiency in both new and retro-fit situations.

As concerns the individual programmes, in 1994 the Labour Party produced a report on its environmental policy, which included consideration of the energy sector. This made a number of interesting points on issues of relevance to the funding of research. These included:

- *Renewables*. A Labour Government would aim to generate 10% of electricity from renewable sources by 2010. This represents a higher target than that in place at that time, and was considered as important for sending a strong signal that policies favourable to renewables would continue. There would also be a greater concentration of publicly funded energy research and development toward renewables. Favoured renewables were on-shore wind energy, solar power and fast growing trees as a source of electricity.
- *Clean Coal Technology*. A Labour Government would support clean coal technology and research, and would channel funds for this purpose.

For the time being, the *New and Renewables Programme* is typical of Government initiatives aimed at stimulating the development of new technologies, in that the public funding element has always been anticipated to reduce gradually as the technologies move nearer to market and the GovernmentOs role diminishes. Industrial contributions are expected to increase in parallel. Government funding for this year is expected to be comparable to or slightly smaller than last year. Although currently scheduled to continue until 2005, the Programme will be subject to review in 1999. Continuation will be subject to the results of that exercise and at this stage it is not possible to anticipate any outcomes.

As for the *Fusion Programme*, traditionally in the UK this kind of energy research has been perceived as having little relevance for the private sector. However, the Government has now recognised that there are various technological areas which could have considerable commercial potential. These include such leading edge topics as materials science, robotics, plasma heating and data acquisition. In an effort to capitalise on research in these areas, the DTI is currently seeking to improve industrial involvement. A launch event was held in March of this year and a follow-up is planned in June. Issues under consideration include mechanisms for optimising the potential for spin-offs from both previous and future developments, methods of influencing the future of the programme to increase the likelihood of useful technologies arising, and systems for communicating with industry. At this stage, the outcomes are unclear, but there is certainly an emphasis on introducing a more market oriented perspective into the Programme. UK Government support for the Fusion Programme has remained at roughly the same level for the past five years. With respect to the future of UK Government funding, the European context of the research is likely to necessitate continued support, at least for the next few years. The longer term situation has yet to be clarified.

The *Clean Coal Programme* strategy is subject to review every three years. Recently, there has been a re-emphasis towards technology transfer and technology commercialisation. For the future, it was considered that the overall objectives would be unlikely to be met unless the Clean Coal Programme was continued and enhanced. It was recommended that it be continued beyond its planned end date in 1997/98, with a particular focus on power generation. Other areas where there is the likelihood of large market potential (either in the UK or overseas), or strategic benefits to the UK, were also proposed for further support. These included coal mining, steel production and other applications. Current management arrangements were considered to provide a good basis for the future. At the end of the current Programme there will be a review. Although the outcome cannot be predicted with certainty, it is envisaged that the Programme is likely to continue to form the focus of coal-related research in the UK, with future research areas being defined not only by the outputs of Technology Foresight, but also through consultation between the key players. A mechanism is already in place for this, in the form of the Advisory Committee on Coal Research, which comprises senior representatives from UK industry and academic institutions involved in the development of clean coal technologies. A major aspiration for a continued Programme would be that gearing of external contributions to those of DTI continue to be maintained at a level of 4:1 or higher. Collaboration between Government, industry, academia and overseas organisations would also to be a high priority.

Progress made by the *Energy Efficiency Best Practice Programme* is assessed on a yearly basis through an impact assessment, and it is accepted that this is likely to improve over time, as the impact of the programme increases. Because the targets for the programme are in the form of a public commitment, there is an assumption that it will continue, in some form, at least until 2000. Funding and the detailed make-up of the programme (including the size of the research element) will depend upon the results of the impact assessment. However, unless any major issues emerge, the funding may well remain roughly constant for the life of the current programme, possibly with a slight decrease towards the end. Key aspirations are to improve third party collaboration and dissemination: because of the nature of the Energy Efficiency Best Practice Programme, there is a presumption against being too prescriptive regarding the types of projects to be supported, but 'club' projects, involving a number of partners, are preferred.

3.2.5 Legitimisation: strategic issues and future perspectives

The tendency to achieve research objectives through targeted programmes and the transfer of research capacity to the private sector has eroded the R&D base in the UK, but at the same time it has provided more flexibility. For programmes like the *New and Renewable Energy Programme* government funding mechanisms are very flexible, and seek to optimise industrial involvement and support from other sources, such as the EC.

As was discussed, *reviews of public sector research establishments* have been carried out in order to examine the scope for privatisation and rationalisation. The

UK seeks to achieve research objectives mainly through targeted research programmes which are open for competition and seek to enable government funding to be augmented by private funding.

In 1996, the Government commissioned an international evaluation of its Clean Coal Programme. The evaluation concluded that, against a background of eroding core competencies and declining expertise, the Programme has a key role to play in assisting industry to maintain and enhance UK capabilities in clean coal technology. It recognised that significant benefits to UK industry, universities and 'UK Limited' had resulted, and that the Programme had been successful such that all market deficiencies had been reduced, although they were unlikely to be completely removed. There was little evidence that Government funding had displaced funds that would have been placed in the absence of the Programme. The 15% total funds allocated to the Programme managers (a private company) were considered to represent extremely good value for money.

The New and Renewables Programme is typical of Government initiatives aimed at stimulating the development of new technologies, in that the public funding element has always been anticipated to reduce gradually as the technologies move nearer to market and the Government's role diminishes.

With respect to the future of UK government funding, the European context of the research is likely to necessitate continued support, at least for the next few years. The longer term situation has yet to be clarified. The current programme of privatisation of the gas and electricity industries means that future developments in certain aspects of publicly funded energy related research are subject to considerable uncertainty.

3.3 Aerospace

3.3.1 Introduction

The UK Technology Foresight Panel defined the aerospace sector as comprising three discrete areas, namely defence, civil aerospace and space. In terms of UK defence technologies, the Defence Evaluation and Research Agency (DERA) is recognised as a key national resource. There are no comparable organisations in either the civil aerospace or space areas. The UK's interest in and public funding of space research is directed through the British National Space Centre. Public support for civil aerospace research is provided through the GovernmentOs Civil Aircraft Research and Demonstration (CARAD) Programme.

3.3.2 Mission, strategy, activities, markets

Defence Evaluation and Research Agency (DERA)
DERA is a Ministry of Defence (MoD) agency. It was established in 1995 and is derived from the MoD's four principal non-nuclear research establishments.

Its main role is to ensure that the highest standards of quality and service are maintained in support of UK defence. Of the seven operating divisions, the Defence Research Agency (DRA) provides the focus for aerospace research. Related and underpinning research is carried out across other parts of DERA. Major market segments covers both military and civil aircraft as well as space applications, and include:

- aircraft procurement: Eurofighter development and assessment of defence helicopter options;
- aerodynamics and propulsion: computational fluid dynamics, validation of theoretical methods, effects of engine installation on wing aerodynamics, improvements in composite rotors and development of turbo-machinery, combustors and control systems for power plants;
- structures and materials: airframe materials, propulsion materials, high temperature materials, design critical properties, advanced composites and alloys;
- systems and systems integration: thermal imaging, laser designation, functional interaction and vertical landing capability;
- simulation and evaluation: development of air combat simulator (JOUST) and simulator for networked helicopter cockpits for experiencing combat situations (HOVERS); technology advancement;
- remote sensing: new applications, analysis techniques, improved data delivery accuracy and speed, instrumentation and integration of data into geographic analysis;
- space technology: spacecraft reliability and propulsion and the interaction of the space environment with materials, electronics and sensors; and
- spacecraft instruments: microwave systems, synthetic aperture radar, control systems.

Private clients include British Aerospace, Westland, McDonnell Douglas, Shorts and Rolls Royce and GEC. DERA has negotiated bilateral 'strategic alignment' agreements with a number of major players. These are aimed at encouraging greater collaboration between DRA and aeronautics firms, and helping to ensure that its work is more closely aligned to the needs of industry.

Civil Aircraft Research and Technology Demonstration Programme (CARAD)
This national research programme seeks to help the UK aerospace industry compete effectively in world markets through pre-competitive research and demonstration in essential aircraft technologies. These include aerodynamics, propulsion systems, materials and structures, avionics and mechanical systems, helicopters and rotor craft and cryogenic technology. The programme is administered by DTI.

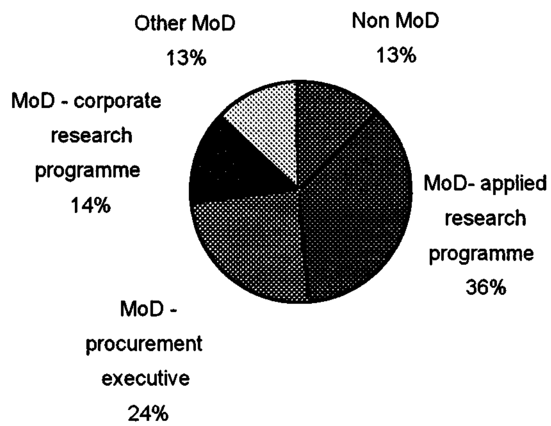
British National Space Centre (BSNC)
The BNSC is a partnership of the DTI, Foreign and Commonwealth Office, MoD, the Meteorological Office, Department of the Environment and two Research Councils. It acts as a focus for the civil space interests of Government departments. Its objective is to raise the competitiveness of the UK space sector. Whilst individual organisations retain responsibility for the funding of space programmes, BNSC provides overall coherence, facilitates links and sup-

ports the Minister for Science and Technology in his capacity as Minister of Space.

3.3.3 Key indicators and financial flows

DERA employs around 6800 staff and has a turnover of approximately £600m. Across DERA as a whole, the turnover is over £1bn and staff numbers comprise around 11000. At present, the MoD is DERA's largest customer, with the breakdown of revenues being as follows (Fig. 3-1).

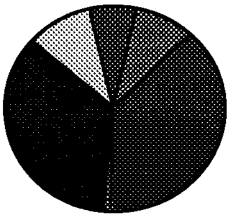
Fig. 3-1 DERA breakdown of revenues



In its first year of operation, DERA achieved savings of £50m and a substantial improvement in programme delivery. Public sector funding for DERA is derived from a number of sources. Firstly, the MoD provides support for research via its Applied and Corporate research programmes (ARP and CRP). The CRP is aimed at maintaining and developing the science base and covers innovative, underpinning and targeted research. To ensure relevance, the programme is subject to peer review and, to maximise financial gearing, it is structured to allow collaboration where appropriate. The ARP is defined by the MoD to meet specific technology needs in respect of equipment expected to come into service in the next 20 years. This MoD funding is currently provided on a non-competitive basis. The research agendas to be addressed by the ARP and CRP are defined by the MoD and the MoD and DERA jointly respectively. DERA is also at liberty to apply for MoD research funding on a competitive basis. Potential competition includes both companies and universities.

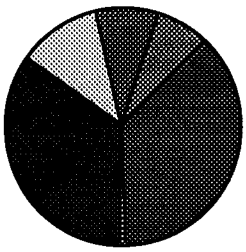
Other sources of public funding include the CARAD programme, which accounts for around £10 million of turnover, and the British National Space Agency. CARAD is currently in its third programme. This runs from 1996-2001. In the financial year 1995/96, expenditure on CARAD was £24.5m. This expenditure was allocated by support type as given in Fig. 3-2. The spend by technology is presented in Fig. 3-3.

Fig. 3-2: **CARAD fund allocation by support type**



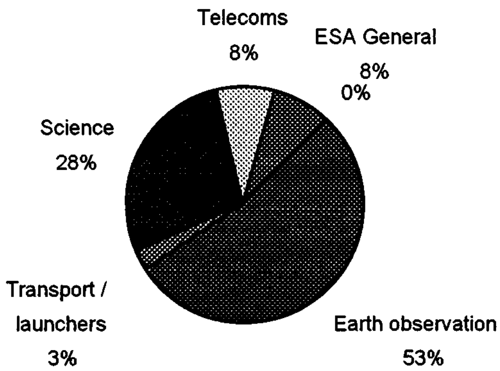
Note: ETW - European Trans-sonic Wind tunnel

Fig. 3-3: **CARAD fund allocation by technology**



The CARAD funding mechanisms are threefold. Direct grants stimulate collaborative work which is carried out in industry with the funding split between DTI and industry; financial support equivalent to up to 50% of eligible project costs is available. DRA intramural funds are directed to work carried out at DRA with CARAD funding, helping to maximise spin-off from the defence to the civil sector. DRA extramural funds stimulate collaborative work which is placed through DERA but is carried out in industry, higher education establishments, research and technology organisations and research establishments, with the funding split between DTI, MoD and industry.

Fig. 3-4: Allocation of government funding of civil space research by sector



The *British National Space Centre* directs the public funding of space research. Around 60% of the Government's £200m annual funding of civil space research is directed to the European Space Agency. The major public sources of basic funding are the DTI (50%), the Research Councils (over 25%) and the Meteorological Office (10%). The allocation by sector is presented in Fig. 3-4.

3.3.4 Trends and developments; key forces

Technology policy
Aerospace related technology areas mentioned in the Technology Foresight programme are: systems integration, life cycle cost reduction techniques, modelling and simulation environments, sensors, materials, high-integrity, real-time software, smart structures and skins, gas turbine propulsion technology, innovative manufacturing processes, data, signal and image processing, more efficient forms of energy storage and power generation, aerodynamics (including emissions and noise), avionics, airframe wings and aircraft structures. More recent Government policy has highlighted areas such as fuel saving and environmental aspects as being ones which are likely to receive support, particularly through the CARAD programme. In 1995, BNSC's Space Technology Advisory Panel identified five main future priorities for the future. These were system design tools, components and packaging, onboard data processing, satellite propulsion systems and satellite power systems.

DERA
DERA's future operations are likely to be significantly affected by decreasing support from the MoD and other Government income. It's 5 year plan is based on the assumption of a reduction of around 25% in revenue deriving from these sources. This reduction will be accompanied by changes in the distribution of revenue, with the air sector anticipated to reduce its share of the total by around 1.5%.

In the year 1995/96 DERA revenues from government customers outside the MoD and from commercial customers grew by 5% and 72% respectively. It is

anticipated that, over the next few years, the proportion of revenue deriving from the private sector will continue to grow. Corporate targets for 1996/97 embraced issues such as achieving an average return on capital employed of 4%, increasing overall utilisation from 57% to 62.4% and achieving non-MoD income of £117m.
Similarly, the 5 year plan assumes an almost four-fold increase in revenue from the commercial sector, from around £45 million to around £170 million.

Overall, DERA revenues are expected to decrease slightly, by around 12%. Changes in the balance of activities could result in the air sector's share increasing by around 1.5%, despite the reduction in support for this sector mentioned above. The air sector is clearly one in which DERA is expecting to do relatively well in terms of commercial revenues.

CARAD
The technologies to be covered by the CARAD programme over the next few years were the subject of consultation with industry and the research community in 1996. There is a regular dialogue with industry on technology priorities; a number of mechanisms, such as steering groups, are in place to achieve this. No significant change from the technology priorities as described are anticipated in the near future, but a steady decrease in CARAD funding in real terms has been evident since the mid-1980's. Future funding will depend on the outcome of DTI's analysis of all its programmes, which will be looking carefully at spending priorities.

Government role
Because of the Government's responsibility for defence, its role in the future of the aerospace sector is more important than any of the other sectors examined. As mentioned earlier, government support for science in general, over the next few years, will continue to be strongly influenced by the findings of the Technology Foresight Programme. The Panel Report on Defence and Aerospace identified a range of technology areas where progress could help the development of exportable equipment and lead to wealth creation through dual use or cost reduction.

The Government is in favour of developing future opportunities in specific space related market sectors by what is known as the 'two step' approach. This can be illustrated by the example of satellite systems. A major initial customer ('anchor tenant') guarantees to buy data from the first of a series of commercially provided satellites. The service providers then seek to fund further systems through sales to a customer base built up during the first phase of the programme (when the 'anchor tenant' agreement is in place).

The DTI is currently working to improve the mechanisms for the provision of aeronautics research advice and to upgrade the dissemination of research results. In the equipment sector it has decided to run a Challenge and determine the usefulness of this approach to the sector and to CARAD. The Challenge approach, which is increasingly favoured as a means of providing targeted public funding in research and related areas, allows a range of organisations to bid for funds competitively in a specific topic area, in this case in the area of more electric aircraft. More generally, efforts will be made to maintain the benefits of continued joint civil / military programmes.

BNSC

As a coordinating body, the British National Space Centre (BNSC) is viewed much more as a part of Government than organisations involved in carrying out research. It provides the mechanism for various government bodies to ensure that there is a consistent approach to public funding of space research, and that duplication is avoided. Consequently, it is perceived not as an initiative with a finite remit, but as an organisation with ongoing relevance; this could be compared with the status of a Government department. Though the funding provided by the various partners may change over time, BNSC can continue to make an important contribution.

In 1996, the BNSC produced a Space Forward Plan. This set out the aims and actions for the UK civil space programme and has been agreed by the BNSC partners and endorsed by Government. The Plan confirmed the Government's commitment to "invest in space where there are clearly identifiable returns to the taxpayer, carrying out a major part of its programme collaboratively, particularly through ESA" and "to engage private capital in the funding of space activities and promote the development of market mechanisms". It examined issues relating to resources and priorities and developed a number of key objectives for the short and medium term. These covered the role of BNSC in promoting dialogue, the Government as a user and various space related technologies.

Following on from the plan, work continues to set priorities for technical development, which will feed through to the funding activities of the various BNSC partners. This is being undertaken in conjunction with Technology Foresight Defence and Aerospace Panel, which is now the senior forum in the UK through which issues relating to collaborative research are addressed.

3.3.5 Legitimisation: strategic issues and future perspectives

Because of the Government's responsibility for defence, its role in the future of the aerospace sector is more important than any of the other sectors examined. DERA's future development however will depend increasingly on expansion into new commercial markets. DERA's involvement helps to ensure that maximum use for civil purposes can be made of the technologies developed for military use. DERA was created to facilitate rationalisation and, thus, cost savings and to achieve greater coherence in the delivery of defence related scientific and technical advice, primarily to the MoD. It was mentioned already that DERA's future development will depend increasingly on expansion into new commercial markets. DERA's Agency status allows it a relatively high level of flexibility in its mode of operation. Thus, it is able to undertake contract research for private clients and government funded research through both competitive and non-competitive mechanisms. It can also be involved in collaborative research programmes with industry which involve some public sector support. It should be noted that DERA has to earn all its income from customers, whether these be the MoD or private sector organisations. Thus, DERA needs to be able to convince the MoD to purchase the products and services which currently make up 90% of its revenue.

The operational relationship between DERA and the MoD is defined by a Framework Document. Key issues covered by this document, and not described elsewhere in this report, include:

- Responsibilities and accountabilities: The Secretary of State for Defence determines the policy and financial framework within which DERA operates and sets objectives and targets for it.
- Pricing policy: Pricing is generally in accordance with Government guidelines and should be sufficient to cover full costs.
- The allocation of surpluses: These will be subject to Government approval - in the case of operational surpluses, the Secretary of State and Treasury Ministers, and, in the case of disposal of assets, the MoD.
- DERA's relationship with the MoD: Within the MoD, staff with responsibilities relating to the ownership of DERA are separate from those concerned with its role as principal customer. Work carried out by DERA for the MoD is subject to conditions which are similar to those which would be applied to a commercial organisation. It is required to be comparable, in terms of value for money, with work carried out in industry.
- DERA's relationship with other customers: DERA relationships with and activities for other customers are such that they will not prejudice its obligations to the MoD, even where this puts DERA at a financial disadvantage. In particular, DERA agrees with the MoD the conditions under which support to defence equipment suppliers will be provided.

DERA's agency status is seen as representing a good balance between the needs for commercial sensitivity in defence related activities and the benefits which flexibility of operation bring. Whilst some organisations have seen agency status as a pre-cursor to privatisation, there is currently no presumption regarding the future of DERA in either the public or private sector. However, it may be noted that the Support Service Division, which handles finance, IT and related matters, is scheduled to be privatised.

The rationale for Government support via CARAD embraces three main themes:

- allocation of resources via the free market could result in certain failures in the civil aircraft market;
- unilateral withdrawal of state aid would leave UK companies at a disadvantage in a market where major competitors enjoy significant government support; and
- high technical and financial risk leads to an aversion to funding by money markets.

With regard to future perspectives, there is likely to be a continuing focus on linking publicly funded research more closely with industry, probably through market led programmes. A parallel trend is expected to be the continued decline in public funding for research, as highlighted above.

Against the background of declining public funding, It is acknowledged across DERA, the MoD and Government that DERA's future development will depend increasingly on expansion into new commercial markets. Because of its agency status, and with the exception of national security considerations, DERA is essentially free to undertake whatever commercial activities it chooses to. However, it recognises that, like other organisations operating in the private sector, its strengths lie in being able to build on its existing skills and knowledge base. This leads to a particular emphasis on identifying opportunities for the exploitation of defence related activities and outputs into new civil applications. There is, therefore, likely to be an greater focus on the opportunities for spin-out and spin-in between the defence and civil sectors. DERA has identified several mechanisms for achieving this, the most commercially significant of which include:

- placing relevant research work in industry through the Extramural Research programme (see Section 2.2) - this helps DERA to build closer links with industry;
- creating dual-use technology centres - these are open laboratories in which companies can participate and gain access to DERA's technologies and facilities;
- direct assistance to industry - this takes the form of consultancy or technological development, and helps DERA take defence originating ideas and solutions into the commercial arena.

The Government is keen to support DERA's efforts in these areas, in spite of the significant reduction in the MoDOs R&D budget. It plans to continue to use DERA as its primary source of science, engineering and technology (SET) advice, and to establish DERA as the 'custodian' of the technology base. This suggests that DERA will continue to receive a substantial proportion of the budget on a non-competitive basis. Nevertheless, MoD efforts to improve efficiency will include the delivery of research through open competition where appropriate.

DERA's changing status and increasing emphasis on efficiency has lead to some concern, expressed both in the UK media and in Government, that this could be accompanied by a decline in scientific quality. However, the experience to date is that, if anything, the reverse is true.

3.4 Marine technology

3.4.1 Introduction

The marine sector, as operating in the UK, is extremely diverse. As a consequence, there are a large number of public and private sector bodies with some element of interest in research, whether this be in relation to fisheries, navigation, meteorology, oceanography, water flow modelling or ship building. For the purposes of this report, and in the context of the technical scope of this study, two organisations are considered to be of particular relevance. These are DERA and the Southampton Marine Oceanographic Centre. A third body, the Inter-Agency Committee on Marine Science and Technology, has a key role in ensuring complementarity of research effort across the range of bodies involved.

DERA
In addition to its aerospace interests (see Section 1.2), DERA is also active in the area of marine technologies. These are based at the Centre for Marine Technology, which forms part of the DRA and is one of DERA's recently established dual-use centres. These centres have a specific role to play in DERA's efforts to encourage the civil application of both the expertise and experience of its staff, and the diverse range of technologies developed from its defence research activities undertaken for the UK MoD.

The Southampton Marine Oceanographic Centre
This Centre is operated by the Natural Resource and Environment Council (NERC), which is responsible for the funding of UK academic research in the environmental area. It is not a University Research Centre, and is one of four NERC Research laboratories, each of which covers a slightly different area of marine science.

3.4.2 Mission, strategy, activities, markets

Market sectors covered by the DERA Centre for Marine Technology include:
- vessels and platforms: propulsion, structural design, hydrodynamic modelling, anti-fouling and anti-corrosion treatments;
- ship systems: fuel and power systems, noise and vibration control, fluid engineering;
- marine electronics: navigation, management information and communication systems; and
- operations and safety: traffic systems, ocean modelling, pollution and spill tracking.

Customers and research partners include the MoD, NERC (see below), the Meteorological Office (an Executive Agency of the MoD) and UK Universities. Further details concerning DERA's status are provided in Section 3.3 (Aerospace).

For the Southampton Oceanographic Centre, relevant technology areas include marine equipment, materials, sensors, measurement technologies and submersibles. Customers include DRA, BP and British Gas.

3.4.3 Key indicators and financial flows

It has been estimated that funding across the full range of marine related research and development activities amounted to around £561m in 1994/95. The main sources of funding were Research Councils (17%), Government Departments (7%) and industry (7%). As a proportion of marine related contri-

bution to GDP, the level of spending on research is considerably lower than for the economy as a whole. In 1994/95, MoD funding of marine related research activities comprised £168m.
The Southampton Oceanographic Centre employs around 350 staff. In 1996, total revenues were around £17m, £5m of which was derived from contract work. Funding for the Southampton Oceanographic Centre is derived from three main sources:

- core strategic funding: This takes the form of a five year grant from NERC. It's function is to support excellent and relevant research, survey, monitoring and technology development. It accounts for around 20-30% of total funding and is subject to review on a rolling annual basis.
- thematic funding: This funding is also derived from NERC, but in competition with other research organisations and in respect of research in a defined area.
- contracts: These can be carried out on behalf of either public or private sector organisations. The main constraint is that they must be in line with the overall science objectives and mission of the Centre.

For more details on *DERA*, see section 3.3.

3.4.4 Trends and developments; key forces

An important coordinating body in marine technology research is the Inter-Agency Committee on Marine Science and Technology (IACMST). This Committee was set up in 1991 to ensure that marine issues, which cut across a number of disciplines, are addressed effectively by Government. The Committee works closely with the Technology Foresight Marine Sciences Panel, and provides a mechanism for coordination of national research activities and ensuring optimal use of UK facilities. It is also concerned with building effective links between the academic community and industry. A recent survey of industry perspectives on research needs by IACMST identified ship design, electrical engineering, sea bed studies and ship operations as priority areas.

Another coordinating body is the NERC (Natural Resource and Environment Council). A significant proportion of the Southampton Marine Oceanographic Centre's Government funding is channelled via NERC. NERC's marine science strategy, which has been in place since 1987, is currently being adapted to meet users needs more closely.

Strategy and policy issues relating to DERA as a whole are discussed in Section 3.3 above. As noted, overall revenues are expected to fall slightly over the next five years. Against this background, marine relate activities are anticipated to increase their share of total revenues by around 0.5%. A proportion of this will be accounted for by MoD research revenue.

The introduction of dual use technology centres within DERA has been broadly welcomed as an important mechanism for improving the productive translation of the results of defence related research into the civil sector. DERA plans to establish further centres over the next few years.

3.4.5 Legitimisation: strategic issues and future perspectives

The initial work under the Technology Foresight Programme did not have a specific Panel to cover marine related issues. However, the more recently established Marine Sciences Panel has identified several areas which should form priorities for research effort. These include environmental forecasting, continuous monitoring and real-time information, sensors, optimisation of ship speed safety and stability, cost-effective construction and conversion and rapid development technologies.

Perspectives related to DERA are discussed in section 3.3 above. As noted, overall revenues are expected to fall slightly over the next five years. Marine-related activities are anticipated to increase their share of total revenues by around 0.5%. DERA plans to establish dual use technology centres in order to improve the translation of results of defence-related research into the civil sector.

3.5 Concluding remarks

The technology areas discussed above highlight a number of common themes relating to the positioning of publicly funded research institutes in the UK. These are summarised below.

- There has been a move away from publicly financed research institutes towards either fully privatised organisations or, where this is considered inappropriate, much more flexible forms of operation.
- There is a strong emphasis on encouraging building links between publicly funded research and industry. This serves two purposes: first, it helps to ensure the relevance of research and, secondly, it maximises the potential for collaboration and leverage of public funds.
- There is generally considerable flexibility in terms of commercial activities, provided that these are not in conflict with overall objectives or other legitimate concerns such as national security.
- Where there is core government funding, research areas covered by such funding are typically defined through a collaborative approach involving researchers, funders and other key organisations.
- A favoured approach is for public funding to be targeted via themed programmes. These programmes are often managed by private sector organisations, and utilise a number of funding mechanisms, including collaboration and shared funding with industry, to achieve their aims. Regular reviews help to ensure continued relevance.
- Wherever practical, Government funded research is open to competition. This is seen as providing a cost effective means of achieving research objectives.

As mentioned earlier, the discussion presented here is based entirely on

Government policy and activity prior to the UK election in May. The new Government may well introduce significant changes, particularly in the light of its planned review of public spending. At this stage, it is not possible to determine the scale or nature of those changes, or the implications which they may have for technology institutions and related initiatives.

4 Belgium

4.1 Introduction

This country study[4] deals with the technology areas Energy and Aerospace. In the area of energy, we will address SCK (Studiecentrum voor Kernenergie) and VITO (Vlaamsche Instelling voor Technologisch Onderzoek); VKI (Von Karman Institute for Fluid Dynamics) is covered in the area of aerospace.

4.2 Technology Area: Energy

4.2.1 Introduction

The most characteristic institutes of technology in Belgium in the field of energy technology are: SCK (StudieCentrum voor Kernenergie), Mol; VITO, Vlaamse Instelling voor Technologisch Onderzoek, Mol; Institut Wallon, Namen. SCK and VITO will be dealt with in detail.

SCK and VITO are partly publicly financed (SCK by the Belgian federal government and VITO by the Flemish regional government). They are the largest technology institutes in Belgium that conduct activities in the area of energy. Both conduct a substantial amount of activities in the field of technological research: SCK has important test facilities (a research reactor, a materials testing reactor, an underground laboratory to study the disposal of nuclear waste). VITO is also an interesting case in the frame of this study since it evolved from what mainly used to be an applied research-oriented institute into a market and result-oriented research company. VITO has its roots in SCK, from where it was created within the context of the Belgian State Reform.
Institut Wallon is small in comparison with SCK and VITO, its only activities being to advise on policy. For this reason the Institut Wallon will not be included in this study.

4.2.2 Mission, strategy, activities, markets

Studiecentrum voor Kernenergie (SCK)
SCK encourages a responsible attitude towards nuclear energy and the continued development of civilian medical and industrial applications. SCK is committed to help provide current and future generations with energy-related comfort in a safe environment. This is why SCK focuses its research activities on the safety of nuclear reactor operation, and the protection of public health and the environment.

[4] This chapter was contributed by Matthieu Craye, VITO (Vlaamsche Instelling voor Technologisch Onderzoek).

The main research topics in the three areas of activity are:

- health: radiation protection, nuclear medicine and radiotherapy;
- safety: the study of safer fuels (MOX), the performance and degradation of barrier materials to confine radioactivity;
- environment: nuclear waste disposal, decontamination and decommissioning of nuclear power plants.

In the field of radiation protection, SCK develops risk assessment models for the main clients: the nuclear industry and NIRAS (Nationaal Instituut voor Radio-Actief Afval en Splijtstofelementen). SCK also produces medical isotopes for commercial businesses, and is carrying out research into an alternative molybdenum production in a smaller system.

SCK is the leader in research on Mixed Oxide Fuels (reactor calculations, reactor dosimetry, non-destructive analysis of reactor fuel, behaviour in off-nominal conditions). This research is carried out for nuclear fuel producers and vendors.
Another safety-related research topic is the study of the phenomena that lead to irradiation embrittlement. The main clients for this materials research are the nuclear power companies. SCK also became the leading expert on deep disposal of nuclear waste in clay repositories (feasibility of building stable galleries in clay, study of the impact on clay of a range of simulated conditions). For this research, SCK built an underground laboratory 225 metres below ground level (the HADES facility). Clients are the government agencies for nuclear waste disposal. Finally, the decommissioning of SCK's BR3 reactor has been selected as a pilot project by the European Commission to demonstrate the technical feasibility of decommissioning.

SCK operates in networks within the frame of the Joint Research programmes of the European Commission, the OECD Halden reactor project and in IAEA safeguards legislation projects.

Vlaamsche Instelling voor Technologisch Onderzoek (VITO)
VITO was established in 1991. As a consequence of the State Reform all non-nuclear activities of SCK were transferred to a new Flemish research institute: VITO. In 1994, VITO and the Flemish authorities concluded a Management contract, a contract which is of great importance for VITO's current mission and strategy. VITO's ambition is to become a true European research company and hopes to achieve this by carrying out market-oriented technological research. VITO wishes to fulfil its mission in the area of environment protection and stimulation of a sustainable use of energy and natural resources.

VITO's areas of activity are: non-nuclear energy, environment and materials. Energy-related research topics are:

- Rational use of energy: VITO actively promotes the use of combined heat and power systems and heat/cold storage in aquifers.
- Energy conversion in transport systems: alternative motor fuels, hybrid traction.
- Process optimisation, Life Cycle Assessment, technology assessment.
- Development of an energy information system (EMIS).

- Energy recovery from waste streams.
- Teledetection: earth and vegetation observation, remote sensing data integration and image processing (e.g. analysis of stratospheric and tropospheric ozone).

Among VITO's main clients are the Flemish authorities (e.g. the EMIS project, transport, rational use of energy), local authorities (energy savings projects), industry (process optimisation, LCA) and European organisations (e.g. ESA for the teledection expert centre). Within the framework of its energy activities VITO participates in the following networks:

- International Energy Agency: CADDET (Centre for the Analysis and Dissemination of Demonstrated Energy Technologies)
- International Energy Agency: Implementing Agreement on Energy Conservation through Energy Storage
- OPET: Organizations for the Promotion of Energy Technology
- ETSAP: Energy Technology Systems Analysis Programme
- IEA Experts' group on Energy Technology Assessment and Methodologies for R&D Priority Setting and Evaluation

4.2.3 Key indicators and financial flows

The Studiecentrum voor Kernenergie (SCK) employs a staff of 600 and has a turnover of BEF 3,000 million. Subsidy from the Belgian government amounts to 50% of SCK's total budget. The centre obtains BEF 1,500 million via contract research. In addition to the industrial clients mentioned above, the European Commission, the International Agency for Atomic Energy and the Belgian Federal Office for Scientific Affairs are the main financial sponsors of SCK research projects.

It is very difficult to determine the real cost of each research project and the part funded by government subsidy and contract. For instance: government subsidies are used for general operations, like the running of test facilities and these test facilities are used for different research orders at the same time. Any available overcapacity is sometimes used to carry out tests within the framework of additional research orders.

In general terms, funding by means of contracts with industry is most important for the research on 'safer fuels'. The two other research areas - health and environment - obtain most of their finances through contracts with public authorities or from government subsidies.

The Vlaamse Instelling voor Technologisch Onderzoek (VITO) employs a staff of 400 and has a turnover (1996) of BEF 1,400 million. Funding by the Flemish government in the form of subsidy amounts to BEF 990 million. In 1996 VITO obtained nearly BEF 400 million from contracts with industry, Flemish, Belgian and European authorities. Sales achieved by the Energy division amount to BEF 300 million, nearly 50% of which is financed through its own revenues (contracts). This break down (50% subsidy / 50% own revenues) is virtually the same for all energy-related research subjects.

4.2.4 Trends and developments; key forces

Studiecentrum voor Kernenergie (SCK)
The government's attitude implies that SCK is kept under strict control with regard to its strategy: the government decides in which areas of research SCK may remain active. In this context, SCK's strategy is to develop several core competencies in well-defined niches. With regard to the industry itself, the needs could also be met within the frame of international cooperation (e.g. the co-financing of other European institutes). They are not the demanding party or the driving force for nuclear research activity in Belgium. As a consequence, industry's influence on SCK's operations has also declined.

Each department has a departmental advisory committee which is overseen by an international Scientific Advisory Committee. The influence of these committees should not be neglected but should primarily concern more scientific issues (e.g. relating to interesting research topics) and not SCK strategy and policy.

Government funding of SCK decreased dramatically in the early nineties. With the maturation of nuclear technology, SCK developed a multitude of diversification activities. The regionalisation of industrial and technology policy (within the framework of the Belgian State Reform) led to SCK's non-nuclear activities being transferred to a new Flemish research institute: VITO. Other factors responsible for this dramatic restructuring operation include: the Transnuklear case (corruption concerning nuclear waste), involving certain persons at SCK; political discussions and public opinion on safety and the environmental consequences of nuclear techniques (Chernobyl, etc.) and the loss of the 'national pride' argument (when nuclear research was still 'high tech', every nation that 'took itself seriously' strived for a national nuclear research centre).

In addition to these factors (and in line with the specific Belgian context) the general international trend is to reduce funding for nuclear research institutes (since nuclear energy itself is questioned). Nuclear activities are either stabilising or decreasing in most countries of Western Europe.

As a result of all this, SCK had to confine its activities to safety-related issues and its financial resources and workforce were decreased substantially (from 1,400 to 600 employees). This meant a clear shift in SCK's markets and clients. The 'centre of gravity' shifted from commercially interesting applications for private firms (fuel producers and vendors, nuclear power plants) to research 'in interests of the general public' for government agencies and other bodies concerned with safety matters and the management of nuclear waste. In its remaining areas of research, SCK chooses specific niches, i.e. fields of research in which it can assume the role of international leader, e.g. disposal in clay.

Current trends and developments of strategic importance for SCK are given below:

- SCK states that a global decline in the amount of attention given to a particular sector, can (at least in the medium to long term) be profitable for those institutes that have developed very specific, specialised research activities, e.g. within the framework of an international restructuring operation (by way of promoting cooperation between several European research institutes), all MOX and clay repository research could be grouped at SCK. SCK's 'survival' strategy is then to remain or to become the international leader in very specific niches.
- Russia and Eastern Europe are becoming interesting markets for aspects of nuclear safety and a great deal still needs to be done in these countries in the area of environmental protection.
- Even though it does not create important opportunities in the short term, SCK still wishes to be included in large, international research programs like these on nuclear fusion. This is more a question of keeping on 'stand-by' in case interest in nuclear energy should unexpectedly rise again.
- To use the facilities in the most efficient way, interesting alternative uses are given special attention, e.g. doping of silica for the electronics industry. Diversifications requiring large investments are not considered.
- SCK is attempting to convince industrialists not to play the 'competition game' too hard by arguing that fair prices are necessary in order to maintain competition between several research companies.

Vlaamsche Instelling voor Technologisch Onderzoek (VITO)
Subsidy from the Flemish government has remained constant over the past few years: the amount was established for four consecutive years in the Management Agreement. Nevertheless, it is still possible for VITO to obtain additional subsidy depending on how certain performance indicators evolve. These indicators (e.g. scientific output, valorisation of research, cost of personnel) are followed closely by the Flemish authorities.
VITO's growth over the past few years (a 30% growth in the energy activities during the period 1992-1996) was largely financed by an increase in its own revenues (the energy division more than doubled its revenues over the period 1992-1996). However, a substantial part of these internal revenues are gained from projects commissioned by public authorities (e.g. EMIS, the energy information system for the Flemish government). Since its foundation VITO's activities have shifted from fundamental research to applied research. The institute now plays a major role in the transfer of useful and workable technologies to the Flemish industry, especially to SMEs. Technological advice and technology transfer are becoming VITO's core activities. Because of the special character of its services, there is no fierce competition involved with regard to the institute's activities for its main clients.

Current trends and developments of strategic importance for VITO are the following:

- In order to guarantee future growth, VITO wishes to increase its revenues. One interesting line of thought is to bring the contract price in contracts with industry more into line with the market value (what is the impact of a technical solution in terms of productivity improvement). Currently, the prices generally only cover the costs. The additional financial resources available could be used for the in-house development of new market-oriented competencies.

- VITO's special status (a government-subsidised company) could form a legal impediment to such a commercial strategy (for instance, it is currently forbidden by law for VITO to undertake production activities, or even to invest money in spin-off companies).
- Active marketing and promotion should help the institute to become better known in industrial circles.

For each of its three research domains, VITO has a 'Scientific-Technological Advisory Committee' at its disposal. These committees are made up of academics and industrialists. The influence these committees have on the strategy and research orientation is not very pronounced.

4.2.5 Legitimisation: strategic issues and future perspectives

Studiecentrum voor Kernenergie (SCK), Mol

Generally speaking, the climate concerning the public financing of SCK is extremely uncertain and it is anticipated that government funding might be constrained even further, being reduced only to a sum which is necessary for the dismantling of nuclear activities in Belgium.

In the legitimisation discussion on SCK there are of course certain environmentalist movements that want to see SCK shut down as quickly as possible. Nevertheless, within the context of Belgium's energy supply (more than 50% of Belgium's electricity is produced through nuclear fission) this is an unrealistic scenario for the near future. There is political consensus that Belgium needs a research institute in order to train its nuclear engineers and to provide the authorities with 'objective' information on the subject of nuclear activities.

But this is where consensus among politicians stops: the question is how big should a nuclear research institute be, what facilities are needed, number of personnel (e.g. discussion is under way on whether to restart the recently refurbished BR2 test reactor). Some politicians go as far as questioning the very existence of SCK, yet most of them agree with the current position of status quo and adopt an attitude of 'wait and see' (no expansion of nuclear activities, developing know-how for decommissioning, decontamination and waste disposal).

With a view to future perspectives, SCK expects government funding to stabilise (or slightly decrease) over the next few years. In the longer term, they anticipate a boost in international cooperation. International cooperation will result in a further restructuring of national nuclear research centres. Each centre will then only be able to maintain its core activities; activities in which it is the international leader.

A revival of nuclear activities is unlikely, certainly not in the near future. In this context it is very important that public opinion is into account. Previous experience shows that on the subject of nuclear matters, public opinion is more of a determining factor than political majority. Other factors of influence are energy prices, and discussions on the greenhouse effect.

Vlaamsche Instelling voor Technologisch Onderzoek (VITO)
There is no legitimisation discussion under way at the present time with regard to VITO. On the political front, there seems to be consensus that VITO has a role to play in Flanders' innovation policy. The Flemish Government plays an important role in VITO's policy by virtue of the Management Agreement. The Flemish Government wants to make sure that it gets 'value for money' by way of the performance indicator evaluations. The outcome of this is that result orientation has now been incorporated in VITO's 'business culture'. The government clearly wants to involve VITO in its industrial innovation policy (which focuses on improving the technological innovation capacity of SMEs) This implies that VITO will have to put an even stronger emphasis on directly applicable technologies. It also implies that results regarding technology transfer will take on more importance as a performance indicator.

This obligation of market orientation and result orientation increases VITO's dependence on market needs. Yet in this respect VITO's strategy is not a defensive but a pro-active one. It is VITO's intention to become an important player on the competitive 'markets for knowledge' and to broaden its range of action to the international scene. In addition, VITO wishes to consolidate its position as a contractor for public-commissioned research (by Flemish, Belgian or European authorities) given that this will form a strong basis for the company. Within the frame of its strategy (which is largely determined by the governments subsidising it) VITO can take initiatives for new projects and partnerships in a fairly independent way.

A new management agreement with the Flemish government has to be concluded in 1998. Whereas VITO is confident that government funding will not decrease, it does not expect a substantial increase either. Over the next few years VITO wants to bring the share of its own revenues in the total budget up to the 50% mark.

4.3 Technology Area: aerospace

4.3.1 Introduction

The relevant technology institute in Belgium in the area of aerospace is the Von Karman Institute for Fluid Dynamics (VKI), located in Sint-Genesius-Rode. VKI is the only publicly funded institute of technology in Belgium with important activities in the field of aerospace. Although the emphasis at VKI is on education and training, the institute does have important test facilities at its disposal. VKI is financed by a number of nations within the NATO context.

4.3.2 Mission, strategy, activities, markets

The governments of Belgium and the USA founded the Von Karman Institute for Fluid Dynamics in 1956; it was housed in Belgian Ministry of Defence laboratories. Since 1959 other NATO nations have been invited to participate in the funding and running of this institute. The basic mission of VKI has not changed since it was founded, but the scope of research subjects has been considerably broadened. VKI is primarily an international training or educational institute; secondly, it is a research institute in which the research it does perform is largely integrated into the training activities. The area of research and education is 'fluid dynamics' in the broad sense (originally it was only aeronautics). VKI has the legal status of a 'vzw' (a non-profit association).

VKI organises various courses and training sessions: the diploma course (one year) for graduated engineering students, a PhD programme (three years), an applied research programme (six months to one year), series of lectures (ten sessions of one week each year), and a short training programme for undergraduate students. Research activities are integrated into the training programmes and are brought under three departments, each covering a research area: aerospace/aeronautics (wing contamination, supersonic viscous/ inviscid interactions, dynamic stability, non-equilibrium high temperature flows, multi-dimensional upwinding methods, unstructured grids), turbomachinery (heat transfer and blade cooling, flows in axial compressors and turbines, radial compressors, inverse design methods, analysis with chaos theory, active control of surge), environmental and applied fluid dynamics (wind engineering, film coatings, sprays, process engineering, flow acoustic coupling, turbulence, bioengineering). Research is carried out within the framework of EU projects, NATO projects, national programmes and for industry. The main clients for the three departments are:

- aerospace department: ESA and other government agencies, airline companies, aircraft construction industry;
- turbomachinery department: aircraft engine constructors, power supply industry, process industry;
- environmental and applied fluid dynamics department: while the clients of this department are very diverse they are all from industry: e.g. coatings, process engineering, biological flows (pharmaceutical industry).

Within the framework of European research programmes (ESA, Brite Euram), VKI collaborates with other research institutes, companies and universities. Additionally, there are many informal contacts between professors and industrialists.

4.3.3 Key indicators and financial flows

VKI employs a staff of 100, of whom 20 are professors, and has a turnover of BEF 250 million. Half of VKI's financial resources are government funds; the other half it brings in itself from contracts. Government funding is divided as follows: Belgium (45%), Denmark (0.7%), France (13%), Germany (12%), Greece (1%), Iceland (0.07%), Italy (5%), Luxembourg (0.14%), Norway (1.8 %), Portugal (1%), Spain (1.5%), the Netherlands (5%), Turkey (1.5%), USA (13%).

Each of the three departments accounts for one third of the overall budget. The amount allocated to the three departments from contract financing and subsidy is virtually the same (50/50). It is difficult to estimate the extent to which each project is funded through subsidy and how much comes from contract financing.

Every research topic is incorporated into the training activities as a subject for research for PhD or other students. In this way, all research contracts are co-financed in the form of subsidy. There are no fully 'self-supporting' research contracts, and consequently contract financing never covers the full research costs.

4.3.4 Trends and developments; key forces

Subsidies from the governments have increased approximately with inflation over the past ten years. The income VKI generates through research contracts has increased by approximately double the rate of inflation. VKI's growth during the past few years has been financed by its own revenues.

Since its foundation, there has been a shift in VKI's activities from almost 100% aeronautics to a much broader set of research subjects, all in the field of fluid dynamics. Research in aeronautics has shown a cyclic pattern (linked to defence spending and the economic situation in the air transport industry). Activities in turbomachinery have stabilised.

Conversely, the 'environmental and applied' department has seen its activities boom. Several factors are responsible for this: the initiatives of VKI researchers, industrial demand for VKI expertise, demands from the subsidising governments via the Technical Advisory Committee. This has led to a substantial increase in financing via contracts with industry.

It is difficult to predict the future importance of the different activities: a project in a declining sector can constitute a very important line of activities for a small institute like VKI. New activities will include a defence conversion training programme and training in code validation. More in general: Eastern Europe is expected to become an interesting new market in the near future.

Many of VKI's contracts are acquired through the graduates. VKI would like to think that when being assigned a contract, firms and other organisations often prefer them to universities because of their flexibility, result-orientation and their 'entrepreneurial' spirit. VKI is often contacted by government agencies: thus proving that VKI is well-known.

VKI is controlled by an international Board of Directors that guides policy, appoints the director and the faculty. VKI is advised by a NATO-related Technical Advisory Committee. This TAC informs VKI about the future needs of the governments and draws up an annual report on VKI's activities. A NATO working group examines VKI's budget each year and reports on this to the NATO Council. There is also a two-yearly control by the Belgian accounting office. Each government partner examines its investments on a regular basis. Via the Technical Advisory Committee each government gives an indication of the subjects it is interested in, e.g. nations with major industrial activity in aeronautics will ask for research in that area, while others will stress other subjects. Each government seeks to obtain 'value for money', wanting research and training with a high national relevance in exchange for funding.

Other forces which are of importance for the aerospace division include: defence policy (research within the scope of military aeronautical programmes), the economical situation in the air transport industry, policy on international aerospace programmes (e.g. the European contribution to 'manned re-entry vehicle' programmes). These factors fall out of VKI's range of control and can affect the volume of VKI's activities. These potentially disadvantageous factors are set off by activities for a wider range of applications, mainly via the 'environmental and applied' department. General methodologies for problem solving in fluid dynamics are also developed to tackle a wide range of very diverse fluid dynamics problems.

In this context of a potential decrease in subsidy, a more intensive market orientation is necessary, but, as has already been said, this could affect the singularity of the institute and could even increase the cost of this market-oriented research. Market orientation increases the dependence on industry's demand. Although there is a certain amount of control by the governments in the current financing system, VKI considers subsidy as a means to achieve greater independence.

4.3.5 Legitimisation: strategic issues and future perspectives

Whilst the existence of the institute is not in question each government partner regularly examines its investments. Via the Technical Advisory Committee each government gives an indication of the subjects it is interested in, e.g. nations with major industrial activity in aeronautics will ask for research in that area, while others will stress other subjects. Each government seeks to obtain 'value for money', wanting research and training with a high national relevance in exchange for funding.

One potential point of discussion VKI will have to take into account is whether the institute must be subsidised within the framework of NATO. Today, VKI research has no direct military impact. VKI wishes to retain its financing via NATO because this guarantees a 'multinational' financing. It is quite possible that loss of the NATO link could result in the loss of funding from various countries as well. A reduction in the amount of subsidy would create a problem for VKI's singularity as a training and educational institute. The crucial question is whether - should this indeed be the case - the current method of working (incorporating research into the training) could be maintained. More contract financing and less subsidy means an increase in the number of research orders per professor and, consequently, less time for and lower quality of the educational function.

Uncoupling research from training (academic staff working on research only) would raise the cost of research since a graduated researcher is more expensive than a student researcher. Moreover, this would be departing from the original mission, and this is not considered advisable. In the current situation, students from various countries study at VKI to obtain a degree or PhD and carry out research before returning to the industry or research institutes in their home countries: this intensifies international exchanges and guarantees the transfer of VKI's scientific and technological know-how.

In this context of a potential decrease in subsidy, a more intensive market orientation is necessary, but, as has already been said, this could affect the singularity of the institute and could even increase the cost of this market-oriented research. Market orientation increases the dependence on industry's demand. Although there is a certain amount of control by the governments in the current financing system, VKI considers subsidy as a means to achieve greater independence

Despite all these speculations, financing within the NATO framework is expected will be retained at the current level, at least for the near future. Given that VKI wishes to adhere to its mission the institute does not aim to increase the amount of contract financing. Up to now there has been no clear strategy set out to be pursued in the event of a serious decline in subsidy (review of the mission? sponsoring of students by industry?).

Although the existence of VKI is not in question, the diminishing importance of aeronautical activities with a direct 'defence-related' impact can form a danger for the NATO link at VKI. VKI argues that its research can be of importance for military activities. This is also the stand taken by the Technical Advisory Committee, who wrote in its 1996 Report: "The committee has concluded that the VKI continues to offer programmes of importance to NATO by continuing to offer high quality training programmes, and by facilitating cooperative international partnerships involving industry and academia, and by contributing to the body of knowledge necessary to develop and operate superior military systems."

It is expected that government subsidies over the next few years will increase at a rate which will be slightly lower than the rate of inflation. VKI believes that the relative decline of government funding (compared to its own revenues) is a general, long-term trend which is more or less the same in all countries. For VKI, the opening up of Eastern Europe brings the possibility of new members into the funding formula. As for control of the institute: no great changes are expected for the near future. VKI states that its generated income cannot continue to increase at past rates because that would be detrimental to the training/educational function at some point. The Advisory Committee referred to earlier believes that VKI has already reached the boundaries of possibility.

4.4 Concluding remarks

In the field of energy, the Belgian situation reflects international trends regarding the position of nuclear research, internationalisation and regionalisation. These trends have resulted in the division of the nuclear energy centre into a national part (SKC, dealing with nuclear issues) and a regional part (VITO, becoming increasingly involved in supporting industrial innovation). Belgium is also an example in terms of the rise seen in market orientation in R&D.

In the short term there is consensus on SCK's continuation. However, SCK's future depends strongly on decisions regarding the future provision of nuclear energy. The expectation is that alternative energy resources, clean coal and gas will replace nuclear energy, leaving a role in training and decommissioning for SCK in the long run. This strategic environment forces SCK to develop other/related niche areas and markets.

5 Denmark

5.1 Introduction

This country study[5] covers only one area of technology: marine technology. Within the area of marine technology the only technological institute in Denmark (within the framework of the definition for this project) is the Danish Maritime Institute (DMI).

5.2 Maritime research

5.2.1 Introduction

DMI is part of the Danish GTS network, a nation-wide organisation of 14 technology institutes providing technological service to Danish industry and business. These institutes are partly publicly and partly privately financed. DMI is an institute which works in the field of marine technology and provides a range of services within specific aspects of maritime technology.

5.2.2 Mission, strategy, activities, markets

DMI is an independent non-profit technological service organisation which offers consultancy services in the fields of hydro and aerodynamics. DMI's services are provided on the basis of model investigations, advanced numerical methods and/or field tests. DMI has at its disposal a range of modern facilities such as a 240 x 12 x 5.5 m towing tank and PMM apparatus, three wind tunnels, including a 14 m wide boundary layer wind tunnel, and multiship marine simulators with quality software and visual systems. The activities of the institute fall within the following areas:

- Naval architecture: Propulsion, safety, manoeuvring and seakeeping of ships, calculations and sea trials and damage stability;
- Simulation of marine operations: Determination of optimal harbour configuration, training and evaluation of pilots, navigators and operators, evaluation of strategies for ship manoeuvres and offshore operations, navigational analysis and development of software;
- Ocean engineering: Determination of motions, forces and risk conditions for offshore installations, anchoring systems, risers, towed vehicles, etc.;
- Wind engineering: Investigations regarding wind energy, load, flow and climate in connection with buildings, bridges, ships, vehicles and offshore constructions, flow visualisations, aero-elastic studies;
- CAD/CAM: Production services to shipyards;

[5] This country study was prepared by Stine Kruse of DTI (Danish Technology Institute).

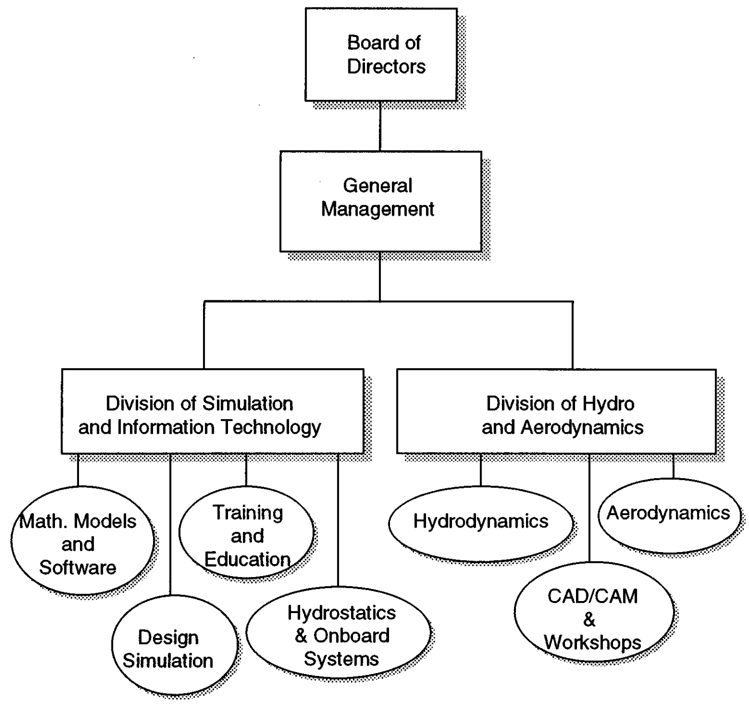
- Information technology: On-board decision support systems, voyage planning.

The majority of the tasks with which DMI is occupied are commercial jobs for private clients within the shipping industry, building and construction industries, harbour design, and machine industry from both international and domestic markets. Within the shipping industry clients come from enterprises such as shipyards, shipping companies, consulting naval architects, harbour authorities, oil companies and offshore enterprises.

DMI also carries out a range of applied research and development programmes, for instance with reference to the EU Framework Programmes, as well as training and evaluation of navigators in the in-house navigation simulators.

As can be seen in Figure 5-1, DMI's organisational structure is such that the board of directors is the highest authority followed by the general management which includes the managing director, the directors of the two divisions, the quality manager, an accounting/ administration member of staff, and the technical coordinator. Under general management, DMI's activities are divided into two divisions: the Division for Hydro and Aerodynamics and the Division for Simulation and Information Technology.

Figure 5-1: DMI's organisational structure



In the Division for Hydro and Aerodynamics the activities are divided into three main groups: hydrodynamics, aerodynamics and CAD/CAM and workshops. The management of the division comprises a division manager who is in charge of the whole division, a secretary and a marketing coordinator. The three work groups each have a department manager and a technical manager within the specific work areas.

This structure is also characteristic for the other division for Simulation and Information Technology. The activities of this division are divided into four main groups: the work areas for design and simulation, mathematical models and software, onboard systems and hydrostatics, as well as training and education.

Cooperation
DMI often cooperates with other institutes of technology, both within the Danish GTS network and with foreign clients as well as with competitors. However, cooperation often occurs in connection with individual projects and does not constitute long-term strategic arrangements.

Cooperation with other institutes within the GTS network is only sporadic and is generally with the Danish Hydraulic Institute and DIFTA (the Danish Institute for Fisheries Technology and Aquaculture) whenever projects fall within mutual interests. For example, cooperation with DHI takes place approximately once in every one or two years, particularly in connection with harbour projects.

However, DMI often cooperates with other knowledge-intensive institutions such as the Shipping and Ocean Engineering Institute at DTU (The Danish Technical University), and with competitors on EU projects, for example projects on simulation and decision support systems.

5.2.3 Key indicators and financial flows

Table 5-1 summarises some key figures. At the beginning of 1997, DMI employed a total of 106 persons and had a net turnover of DKK 55 million.

Table 5-1: Key figures 1996 (including the amount of basic funding)

KEY FIGURES 1996	AMOUNT IN DKK MILLION
Turnover	55.0
Basic funding	6.6
Clients, domestic	24.7
Clients, international	16.0
Externally financed R&D	7.7

As a general rule the approved technological service institutes receive around 10-20% public financing. This financing is called 'basic funding'. It must not be used for operational purposes but is restricted to the development of internal competence, the development of new services, standardisation and communication of activities in general. This basic funding is granted on the basis of 3-year strategy plans of the different institutes.

At DMI only a limited share of the financing is in the form of basic funding: approximately 12% (or DKK 6.6 million). A small number of the tasks undertaken by DMI are for public institutions (apart from basic funding), and in 1996 this totalled DKK 2.6 million. Thus, a large percentage of the financing is based on commercial clients in private enterprises; this is summarised in Table 5-2, showing the representativeness of different sectors.

Table 5-2: Percentage of commercial contracts in the different sectors (rough estimates)

Maritime sector	60%
Building and construction	20%
Machine industry	15%
Public authorities	5%

Usually, the share of international and domestic assignments is more or less equal; however, as can be concluded from Table 5-1, in 1996 commercial contracts with Danish enterprises represented 45%, and work for international clients only 29%. DMI provides services in over 40 countries all over the world, but generally speaking, clients from Europe and Asia are dominant on the international market.

5.2.4 Trends and developments; key forces

Expansion, internationalisation

Within the last couple of years DMI has undergone extensive expansion, and this is expected to last at least another year. This expansion is reflected in the number of employees which has increased from about 106 in the beginning of 1997 to 112 now (May 1997); a further increase is expected before the end of 1997.

This increased growth level is mainly due to the following:

- a centre contract between DMI, university institutes and industry helped to open a new market for DMI in the machine industry. The market for investigating internal flows underwent an enormous increase and DMI now provides both numerical modelling and physical modelling for this market;
- DMI initiated the use of their new simulation facilities, while the demand for simulator courses and training/education of ship's crew members has increased drastically thanks to DMI's agreeing to supervise the training of navigation students in the educational programme under the Danish Maritime Authority;
- DMI is in a process of internationalisation, particularly now that they are establishing themselves in the Far East. This includes a management deal with a shipping company on the establishment of a training centre for simulation;

It is difficult to estimate whether the present development will continue in the future. However, in the short run DMI hopes that the expansion process will continue and, based on the tasks with which DMI is currently occupied, it would seem that there is a solid basis for continuous expansion, also in the long run.

Important actors regarding the GTS institutes
The secretariat of the GTS institutes comes under the authority of the Danish Agency for Trade and Industry. This body is responsible for checking that the way the institutes use the basic funding is in accordance with the regulations of the GTS network. Thus, the funds provided by the government to the GTS institutes are administered in this forum.

Legislation governing national industrial development assigns the responsibility of the technological service to the Council for Technological Service. The minister's only function in this respect is to approve the GTS institutes after they have been recommended by the Council for Technological Service.

The Council for Technological Service was established for the purpose of securing development of the legal objectives of the technological service, and it is the council's task to plan and coordinate social action towards the development of technological service. Additionally, the council supervises and supports the development of the technological service; this takes place in private and independent service institutes.

Therefore, the specific role of government is to approve the institutes which qualify for the system of approved service institutes (the GTS network), while the Council for Technological Service has control and is responsible for coordination. However, the individual institutes themselves are responsible for the day-to-day running and internal development.

In connection with the discussion on the advantages and disadvantages for the members of the GTS network it is important to emphasise that the institutes in the GTS network are members on a voluntary basis. These institutes applied for membership of the GTS network because the provision of public funding in return for a technological service which is at the leading edge of international development is obviously beneficial for the institutes. It gives them the opportunity to provide a service which otherwise would not have been possible. Consequently, the restrictions or disadvantages which they encounter should be viewed in the light of the unique benefits they achieve from membership.

The critics of the GTS system have been particularly concerned about two developments which were formulated by the Advanced Technology Group, the industrial organisation representing the GTS institutes.

- With regard to the development of competencies it could be argued that the financial support could be given to all enterprises in a different way than it is usually given to the technology institutes. This would support direct development in all enterprises instead of having to depend on the transfer of knowledge from technology institutes to private enterprise.
- The technology institutes' strategies stipulate that they must function as non-profit institutions. The consequence of this is that income and profit can only be spent in accordance with the regulations, and that they must provide their services to any enterprise or institution that requires them. Meanwhile, centre

contracts with the individual technology institutes covers the financial support of strategic cooperation agreements with other institutes among the technological service institutions, research institutions and private enterprises. If a GTS institute enters into such a contract, it is placed in a somewhat paradoxical situation since it is expected to function independently of any commercial interests and still provide services on a non-exclusive basis. However, it must also establish cooperation with other enterprises during longer periods of time and give up the principle of non-exclusiveness.

A third issue which has also been focused on by Danish industry (and others) is the internationalisation of activities in the GTS institutes. Critics have questioned the increasing tendency of GTS institutes to become involved in international activities. They argue that the idea of using public finances to support enterprises which offer services to Danish industry competitors is a misinterpretation of the position held by GTS institutes. On the other hand, it can also be argued that international activity upgrades the competence of the GTS institutes and helps them to be at the leading edge of the latest developments.

On the other hand, the fact that the technological service institutes rely on the terms of the market is one of the strengths of the Danish system for technological service institutes[6]. These institutes function as regular enterprises since they provide consultancy and other kinds of technological services on a commercial basis at current market prices. This means that the institutes must ensure that the services provided correlate with the demands of the both the market and enterprises. In other words, market orientation functions as an operational controller of quality and secures a continuous renewal of technological service.

Important DMI actors

As a result of the technological institutes running their own operations, decisions regarding strategic development and internal arrangements in DMI are taken by DMI's professional board of directors and general management. The board of directors is appointed by the Academy of Technical Sciences (ATV). The Academy of Technical Sciences is an institution whose task it is to carry out research in the field of technical science and to secure the use of research results to serve Danish business and society in general. This institution comprises eight GTS institutes, and even though ATV has no legal or economic responsibility for them it approves the individual institutes' regulations and appoints the board of directors.

The only control carried out by the authorities is on how the institutes employ the basic funding. As stated in the above, the contract with the Council for Technological Service is based on three-year strategy plans and the contract stipulations must be strictly adhered to. However, apart from that the position of DMI in relation to the authorities is a relatively independent one. This relationship can be explained by the fact that the institutes themselves are

[6] The Agency for Development of Trade and Industry 1995, *Technological Service, Review 1995*.

very independent, bringing in about 80% of their total turnover from commercial contracts; the public funding only constitutes a small part of the turnover.

5.2.5 Legitimisation: strategic issues and future perspectives

The establishment of a system for technological service institutes was stimulated because the government felt that the continuous development and efficiency of the Danish system for research, technology and innovation were among the main tasks of society. One of the main objectives of this system was to secure the efficiency of technological service and professional standards when supplying services to the enterprises. In other words, as part of a technology policy oriented towards the dissemination of knowledge to a wide range of enterprises, it was the government's original intention that the technology institutes would provide a technological service to public institutions and private enterprise.

The discussion issues regarding the technology institutes in Denmark mainly concerned the status of those institutes which, by virtue of the fact they were receiving public financing and competing on market terms, were positioned somewhere between state and market. Critical voices focused their criticism on the relevance of the technology institutes for the public that provides them with subsidy. The legitimacy of the institutes is questioned because the favourable framework conditions of the institutes may seem problematic in the face of other private enterprises providing a service similar to that of the technology institutes[7]. Even though the issues mentioned above tended to surface from time to time in connection with the special status of the GTS institutes, the fact that there is a technological service in existence for all enterprises is an incentive within the industrial policy which strengthens the competitiveness of Danish business and industry.

Despite the ongoing discussion about the technological service institutes, providing a technological service to enterprises is considered one of the crucial elements of national industrial policy since access to technological service is a necessity if enterprises are to remain competitive in the face of increasing global competition. Technological service is of particular value to many enterprises which do not base their innovation on the latest research results but have a fundamental need for efficient consultancy and services geared towards their specific demands. Public financing is therefore a significant contribution to the development of the national technological service, and contributes towards securing the development and maintenance of the skills the institutes must possess if they are to provide the best possible services to the business community.

[7] The Advanced Technology Group 1996, *Technological Service: Trends and Challenges*.

Individual institutes are not mentioned separately in the current terms and conditions for the GTS institutes given that the general discussions and strategic perspectives are drawn up for the system as a whole. The overall framework of how the individual institutes are run is determined by the general statutory regulations; day-to-day operations fall under the competence of the individual managements and thus include strategic decisions and implications for the individual institutes.

Even though the fact that the technological service institutes are publicly funding restricts them to a certain extent, they still have a large degree of flexibility. The requirements imposed on the institutes serve as a condition for being granted the title of an approved service institute. These requirements include that the institutes must impart knowledge to enterprises in an efficient manner, that they possess the relevant skills on a high level, that the service has to be easily accessible and finally, that they must be efficiently managed. These requirements leave the operation of the institutes up to the individual management: investments in equipment, day-to-day management, preparing policy on salary and staff, etc., are, just like in private enterprise, tended to by management.

As a member of the GTS network, DMI experiences both advantages and disadvantages. If the requirements imposed on an institute for it to become a GTS institute also stipulate that it must be private, impartial and operate on a non-exclusive basis (also mentioned in the above), then a number of restrictions are also imposed. One of the
conditions is that an institute may not invest in new company contracts. For DMI, this implies that it cannot invest in shares in the business for which they are currently establishing new facilities in the Far East (mentioned in the above). Instead, it may only be employed to help the shipping company to establish and use the training centre.

This is obviously a restriction imposed on DMI. Yet by the same token, such restrictions can also serve as a barrier which could be beneficial in the sense that it restricts the number of adventurous commitments and safeguards the institute's survival.

On the other hand, membership of the GTS network also has advantages for DMI because in their market it is essential to be at the forefront in terms of know-how. In order to be able provide the best services to the industry it is absolutely necessary for DMI to have state-of-the-art knowledge and know-how regarding the latest trends within their specific field of technology. Given that building up and maintaining this level of knowledge costs a great deal, plus the fact that it could never be achieved on a commercial basis only, the basic funding element is absolutely essential for it to maintain a sufficient level of competence in the field of marine technology on an internationally competitive basis.

As a component of the continuous development of technological services for the business community, attention has been given to formulating a future strategy for the technological service institutes. The general strategic aim of future development falls within four main areas[8]:

- the GTS network's position in the Danish knowledge system should be more distinctive;
- the GTS network must maintain an explicit market-oriented profile;
- the international impact must be increased, and
- a dynamic, structural development must be secured.

The position of the GTS network in the knowledge system
The Danish knowledge system consists, among others, of the universities, the institutions for sector research and the GTS institutes. Within the context of this system it is vital that the GTS institutes are marketed in order to improve the profile recognised by private enterprise. More information must be sent out to business and industry about the knowledge and skills of these technological service institutes. This must be done by increasing the level of strategic cooperation among enterprises, research institutions and the GTS institutes. This will create equal conditions for all institutions within the Danish knowledge system, and also a sort of bonus scheme for referring clients to universities, the institutions for sector research and the GTS institutes.

Strategic cooperation between the various service institutions has already been initiated with the centre contracts mentioned above. These centre contracts are agreements which regulate cooperation
on research and development between enterprises, universities and the technological service institutes. The objective is to unite the cream of Danish industry and the business world with the know-how which exists in the technological service institutes, the universities and other research institutions.

Maintenance of a clear market-oriented profile
A high degree of market orientation in the GTS institutes is required if the institutes are to maintain continued adjustment to the demands of the market. The provision of services supplied by the GTS institutes must still be directed at both public and private clients. In this connection it is important that services are provided at prices which are competitive with those of other consultancy service providers and which reflect the actual costs connected with supplying these services. While interaction between the institutes themselves and the system of industrial development calls for measures to be implemented which improve the institutes' market orientation, it is essential that the boards of directors and the individual managements of enterprises focus attention on the commercial interests.

Increasing the international impact
In the face of the increasing level of globalisation, it is significant for the future development of the GTS institutes that a conscious and strategic international development is considered not only for the GTS network as a whole but for the individual institutes as well. In this connection, the key words are cooperation and competition. Technology development and the building up

[8] The Agency for Development of Trade and Industry 1995, *Technological Service, Review 1995*.

of knowledge require well-functioning international cooperation agreements between private enterprise and institutions. However, the international sale of technological services is dominated by an increasing amount of international competition, since in trying to win access to new markets within the field of technological service, the service institutes tend push into new markets, competing with other technological service institutes for a share of the market.

Securing a dynamic, structural development

Technological service institutes retain dynamic development through a number of aspects: their market orientation, contact and cooperation with other knowledge-intensive institutes (both in the national and international dimension), the basic funding, and by producing the 3-year strategy plans. However, new incentives for improving and maintaining dynamic development in the institutes are called for so that the institutes can remain competitive and to intensify the continuous development in the supply of technological services in Denmark.

The objective is to improve the technological service so that it becomes an outstanding and professional element in the knowledge infrastructure and in the use of knowledge in business and industry. In other words: the general technological service institutes will need to continue to attract the professional community and thus enable them to function as enterprises that supply knowledge with a competence profile which is sustained by public financing.

A better framework should be created in order to facilitate the movement of professionals from one technological service institute to another, e.g. universities and GTS institutes, and thus initiate a process of exchange between the different parts of the service system, thereby increasing flexibility. Furthermore, a higher level of integrating the competencies in the different institutes helps to improve the dynamic structure of the GTS network. Synergy effects can have beneficial consequences in the individual institutes and will contribute to increasing proficiency in the GTS network.

Consequences of the future GTS network strategy for DMI

The most significant development for DMI constitutes the change towards internationalisation of activities. This was previously an area of much debate since the issue of providing service to foreign enterprises (i.e. competitors of Danish industry) by using money issued by the state has been the subject of strong criticism. However, this attitude has now changed and undertaking international activities is now virtually a requirement for a GTS institute. Involvement in international sales or cooperation agreements implies increased competitiveness and an excellent quality of service.

This acceptance of internationalisation is of particular value to DMI since, within DMI's area of technology, internationalisation is an absolute necessity for competitiveness on an international scale. Because the maritime sector was the first sector to internationalise its activities, businesses operating within this sector are not restricted by national boundaries. Therefore, a technological service institute like DMI must be just as international as its customers are if it is to survive the intense competition from other institutes.

5.3 Concluding remarks

DMI is an interesting example of an organisation which, in a process of rapid market development and internationalisation, is engaged in new cooperative and competitive structures. One major aspect is the role it plays in the GTS network, a system of technological service institutes. This is a network which has its roots in a clear and explicit strategy which facilitates the balance between public and private functions. Of particular interest is the changed view towards internationalisation within the context of the GTS network: from threatening the position of other Danish institutes to *demonstrating* quality and competitiveness.

Literature:

- The Danish Ministry for Business and Industry 1995, *Business Review 1995*.
- The Danish Ministry for Business and Industry 1996, *Business Review 1996*.
- The Agency for Development of Trade and Industry 1995, *Technological Service, Review 1995*.
- The Advanced Technology Group 1996, *Technological Service, Trends and Challenges*.
- The Advanced Technology Group 1997, *Den Gronne* (an information brochure about the GTS institutes).
- Various booklets from the Danish Maritime Institute.

Interviews:

- Erik Kasper, Technical Coordinator at DMI.
- Jens Dinesen, The Agency for Development of Trade and Industry.

6 Finland

6.1 Introduction

This country study[9] deals with the area of marine technology and covers the activities of the Maritime Institute of Finland.

6.2 Marine technology

6.2.1 Introduction

In Finnish marine research, the main technology institute is the Maritime Institute of Finland (referred to here as the 'Institute'), a joint venture in the research area of maritime and mechanical engineering of the Technical Research Centre of Finland (VTT) and the ship laboratory of the Helsinki University of Technology (TKK). The Institute coordinates and substantiates research efforts in the fields of ship and ocean technology by utilising public funding and resources from commissioned research. The main principle is that all research projects and programmes carried out are in those areas which are regarded as essential for the Finnish maritime industry. The Institute is unique in that there are no other research organisations with similar interests or capabilities in Finland.

TKK's role in the Institute is to perform basic and applied research, and to ensure that the Finnish industry has a supply of well-trained engineers capable of innovative thinking and with a sound understanding of marine technology. VTT, on the other hand, focuses on applied and commissioned research. On the whole, the ability to offer competitive skills in the international R&D market is critical to the Institute.

6.2.2 Mission, strategy, activities, markets

The mission of the Institute is to support the business activities of its customers in the long term by supplying research results and expert services in the form of efficient and flexible collaboration. In view of this goal, the Institute's competencies are improved so as to contribute towards innovativeness in marine technology. They are also enhanced through international collaboration, joint efforts which also include opportunities for establishing alliances with foreign institutes.

[9] This chapter was contributed by Dr. Ahti Salo, VTT (Technical Research Centre of Finland).

The Institute has an extensive client base which includes shipping companies, shipyards in Finland and abroad, equipment manufacturers and ship design agencies. Furthermore, the Finnish Navy and Finnish Maritime Administration have developed a long-term collaborative relationship with the Institute. On the whole, characteristic, ongoing cooperation exists between the industry and the Institute, even though the relative importance of the different client segments varies somewhat from year to year.

For the purpose of improving the Institute's capabilities, in terms of the service it provides to its customers, commissioned research in VTT is channelled through the product groups. Since the beginning of 1996 there have been three such groups: arctic technology, ship technology and small craft technology. The introduction of these products groups was motivated by the need to provide market-driven services because the former, more technically-oriented organisation, had become less responsive to the client's needs.

Development of the Institute's competencies is based on the recognition of coherent and interdependent activities in the design, development, production and use of marine vessels. On one hand, basic capabilities in ship technology will be harnessed for the purpose of creating integrated design capabilities (e.g. performance, loads, materials); on the other hand, these competencies will be used for developing systems for the users and operators of ships (e.g. safety, reliability, usability). Compared with technology institutes of marine research in other countries, the Institute has specific strengths in the synergistic modelling of ship construction and hydrodynamics, ice research, and safety technologies.

The Institute participates in several EU-funded projects and concerted actions. Some of the EU-funded projects include:

- MASSTER (harmonisation of maritime education when using ship simulators, DG VII);
- ECDIS (electronic chart display and information system, COST);
- COMFORTABLE, VTMIS (vessel traffic management and information system, DG VII);
- INCARNATION (Inland waterways VTS, DG VII);
- POSEIDON, VTMIS (vessel traffic management and information system, DG XIII).

In addition, the Institute has an extensive network of informal contacts in universities, research organisations (e.g. MARIN in the Netherlands), potential clients and representatives of maritime administration. This network is important for the Institute's ability to keep up to date on the relevant developments in maritime research. In turn this makes it possible to launch and participate in new joint projects and collaborative actions. At the same time, the network makes it possible for the Institute to offer more comprehensive services to its clients given that the skills which are not available in-house can be located and acquired through the network if need be.

The following is an itemisation of some areas in which the Institute is active.

Hydrodynamic design
The Institute performs research on the optimal shaping of ships' hulls, the analysis of propulsion properties and propulsion equipment, and on the assessment of a vessel's usability aspects, with the aim of contributing to the development of economic and environmentally safe vessels. In addition to the model testing facilities already available, extensive capabilities in computational fluid dynamics in the context of ship design are under development.

Ship structures
The Institute has several projects on direct dimensioning, fatigue resistance, and the management of vibration. Moreover, analyses of novel structural concepts and transportation risks are also undertaken. The aim of such projects is to contribute to the development of ships which are superior to present-day ships in terms of weight, durability and noise level.

Marine operations, safety
The Institute performs extensive research on ship manoeuvring, ship fairways and VTS systems. The reason for this being the difficult fairways in the Finnish archipelago where precise navigation is essential. The Institute has access to a full size bridge simulator which is operated by the Finnish Educational administration for training purposes. The Institute has developed its own system simulator which is used for crisis management training, and a desk top simulator which is in use on several ships in Finnish waters. Ship safety projects related to human behaviour are performed in association with the Safety Engineering Department of VTT Manufacturing Technology.

Machinery
The Institute has worked on the reliability of ship machinery, whereby extensive reliability data has been collected from Finnish ships for use as input to the optimisation of machinery system models. Comparisons of various propulsion and electric power generation systems have also been made in collaboration with industrial partners. Engine room training simulators are being commissioned by the Finnish Educational Administration.

Arctic technology
Stimulated by Finland's northern location and harsh winters, the Institute has developed an exceptional understanding of arctic navigation and associated technologies. These strengths will be further developed through focused research efforts on the modelling of ice conditions, the analysis of ships' operational capabilities in arctic conditions, and the modelling of interactions between ships' hulls and the surrounding ice. Here, one of the goals is to resolve questions related to a ship's advancement in arctic conditions by way of direction dimensioning. Special areas for research services include risk analyses, assessment of operational capabilities and the modelling of ice conditions.

Testing
Activities in measurement and testing is an instrumental way of complementing theoretical research work. The Institute performs hydrodynamic and wind tunnel model tests and offers a wide range of testing and measurement

services, including expeditions and ship field measurements. Among the testing facilities, the 40 m x 40 m combined ice and ocean basin is unique.

Small craft
To support the designers, the Institute offers tools with the help of which the relevant parameters can be properly balanced in the design of a workboat. Several methods and tools have been developed to assist the analysis of composite structures in order to answer questions related to material selection, laminate design, sandwich construction and detail geometry.

6.2.3 Key indicators and financial flows

Although both the ship research units in TKK and VTT are much older, the Institute has been operational in the form of a joint venture since 1990. It employs a staff of about 90 and its commissioned research activities grew considerably in 1996, reaching FIM 26 million (around NLG 9,7 million) including commercial and public funding. Moreover, since Finland became a member of the EU its international research activities steadily increased and accounted for 14% of the Institute's funding last year. The volume of international activities in the Institute are expected to grow in significance. However, detailed projections are not available as yet.

The funding structure of the VTT part of the Institute is in many ways similar to that of VTT as a whole: about one third of its resource base consists of government funding, one third of jointly funded projects and one third comes from external sources. In TKK, the teaching staff is budget funded, whereas other researchers are funded through the respective projects.

An important source of funding for jointly funded projects is TEKES (Technology Development Centre Finland), a national organisation that promotes technological R&D and the cooperation between companies, universities and research institutes, with the aim of promoting technological competitiveness in Finnish industry[10]. In 1995, the amount of public funding allocated by TEKES was FIM 1542 million (approximately NLG 575 million).

6.2.4 Trends and developments; key forces

It seems that the level of direct public funding to VTT, which in 1996 accounted for 36% of its funding, might decrease somewhat over the next few years. At the same time, however, the Government's decision to increase the national R&D expenditure to 2.9% of GNP by 1999 will offer more resources to research-related activities. A large proportion of this additional funding goes to the Technology Development Centre (TEKES) which in turn allocates these funds onwards to applicants from VTT and other organisations.

[10] See http://www.tekes.fi/

One change which seems to be taking place, is that an increasing proportion of TEKES's R&D support is being organised in the form of large programmes which are often lead by industrial companies. From the perspective of technology institutes such as VTT, this structural change implies that the Institute acts more like a subcontractor than an independent research organisation which promotes its deliverables to industry only after much of the research has already been done.

Another, perhaps more fundamental change is the associated shift towards short-term research which is usually better aligned with the immediate interests of industrial companies. As a result, there is a risk that the increased focus on short-term activities will undermine the Institute's opportunities to concentrate on long-term research which is expected to provide vital results only after a few years.

The following developments are considered relevant for the Institute's future.

Technology

- Fast ships, and ships with new types of propulsion mechanisms will become more commonplace. At the same time, developments in materials science will result in the adoption of novel structural concepts required by the new vessels.
- The need to build ships quicker creates a demand for more effective tools to support design work which, ultimately, will be fully CAD-dependent.
- The integration of logistic chains (land and sea transportation) calls for novel solutions and associated technologies in cargo handling. On the whole, the importance of logistics will grow.
- Information technologies will be exploited extensively. Satellite technologies, on the other hand, will offer new possibilities to optimise routing and the real-time monitoring and steering of ships. Ultimately, the conjunction of these trends may lead to unmanned ships.

Markets

- The markets for ship construction will either remain as they are or grow slightly. Shipping companies will expand at the same pace of general economic growth.
- In the aftermath of the Estonia accident in 1994, safety considerations retain a central position in the technology.
- The potential of the gas and oil resources in the Arctic Ocean offers considerable potential for arctic ocean technology. The exploitation of these resources, however, depends on the political developments in Russia.
- Political concerns for sustainable development will be a decisive factor in the execution of marine projects, and environmental impact assessments will be required more often than at present, with a consequent increase in the demand for technologies for estimating and mitigating such impacts.

Customers

- Shipyard production volume will remain at the current level.
- Shipbuilders will operate with lean organisations in which the increasing complexity of ships, as well as the pressure to develop and build faster ships, necessitate more extensive usage of external resources.

- On the whole, shipyards - and other institutions as well - will typically focus on doing what they know best and complement these skills by acquiring resources from other organisations. This will imply an expansion of the role of ship design agencies and commercial consultancies which, from the Institute's perspective, will comprise a new group of demanding clients with specific needs and unusually flexible modes of operation.

Competition

- The market for R&D activities in marine technology will become increasingly international and more highly competitive. From the Finnish perspective, membership in the EU continues to contribute to the internationalisation of the R&D environment.
- Consultancies, which are sometimes created as spin-offs from the R&D departments of major ship builders, offer a viable alternative to publicly funded technology institutes. This is due to the fact that they are capable of providing fast and flexible services which are tightly integrated with specific processes in ship design and development.

Funding

- The overall public funding of the effects of R&D will increase due to the Government's decision to raise the national R&D expenditure to 2.9% of GNP by 1999. Emphasis in the allocation of public funding will shift towards industry-driven projects because this has been acknowledged as a means of contributing to more effective exploitation of results.
- Particular attention will be given to the product development efforts of SMEs, since they are considered to be short in means for rapid and effective commercialisation.

The Institute has a high-ranking Advisory Committee - consisting of representatives from the Finnish shipbuilding industry, the Finnish Navy, technical universities, etc. - which acts as an agent for promoting the interests of maritime research in the Finnish debate on technology policy. While maritime technology as such has not been extensively debated, the Advisory Committee is nevertheless central in that it is authoritative enough to exert influence over the shaping of technology programmes at TEKES, for instance, and also in many other ways capable of defending the maritime sector in Finland, even if the broad lines of technology policy are set by the Government.

The Institute is also represented in the high level research committee organised under the shipbuilding group of the Federation of Finnish Metal, Engineering and Electrotechnical Industries. Joint industrial research projects and the research strategies from the industry point of view are discussed in this forum. The contacts to COREDES, the research committee of CESA, are also arranged through the shipbuilding group. The committee has launched two major TEKES and industry funded national research programmes, of which the Shipyard 2000-programme in the early and mid nineties concentrated on hydrodynamic and structural challenges of big fast ships, and addressed productivity as well. At present, a programme called Seatech Finland is going on, with research into the productivity, safety, environment, the geographical position of Finland and basic technologies. The Institute acts as subsupplier in these industry driven programmes.

6.2.5 Legitimisation: strategic issues and future perspectives

The Institute coordinates and substantiates research efforts in the fields of ship and ocean technology by utilising public funding and resources from commissioned research. The main principle is that all research projects and programmes carried out are in those areas which are regarded as essential for the Finnish maritime industry.

Government funding for marine technology in Finland is dependent on the general trends in publicly supported R&D. From the Finnish perspective, membership in the EU continues to contribute to the internationalisation of the R&D environment. Emphasis in the allocation of public funding will shift towards industry-driven projects because this has been acknowledged as a means of contributing to more effective exploitation of results.

The mission of the Institute is to support the business activities of its customers in the long term by supplying research results and expert services in the form of efficient and flexible collaboration. In view of this goal, the Institute's competencies are improved so as to contribute towards innovativeness in marine technology. They are also enhanced through international collaboration, joint efforts which also include opportunities for establishing alliances with foreign institutes.

One effect of the internationalisation of the R&D markets is that the technology institutes will increasingly seek to form alliances and networks. With the help of these networks, the specific needs and capabilities which are not available in-house, will be made accessible to the institute's customers at a reasonable cost. Another direct implication of this development is that the institutes will identify and develop their specific strengths, which will then be marketed not only to domestic customers, as the case may have been some years ago, but to foreign customers as well.

Government funding for marine technology in Finland is dependent on the general trends in publicly supported R&D. It would seem that the level of direct public funding to VTT, which accounted for 36% of its funding in 1996, could drop slightly over the next few years. At the same time, however, the Government's decision to increase the national R&D expenditure up to 2.9% of GNP by 1999 will provide more resources to research-related activities. A large proportion of this additional funding is given to the Technology Development Centre (TEKES) which in turn allocates these funds onwards to applicants from VTT and other organisations.

Against this background, it would seem likely that the Maritime Institute of Finland will have access to the same, or possibly even an increased level of public funding over the next few years. One change which seems to be taking place, however, is that an increasing proportion of TEKES's R&D support is being organised in the form of large programmes which are often lead by industrial companies. From the perspective of technology institutes like VTT, this structural change implies that the Institute acts as a subcontractor than an independent research organisation which promotes its deliverables to industry only after much of the research has already been done.

Another, perhaps more fundamental change is the associated shift towards short-term research which is usually better aligned with the immediate interests of industrial companies. As a result, there is a risk that the increased focus on short-term activities will undermine the Institute's opportunities to concentrate on long-term research which is expected to supply vital results only after a few years.

6.3 Concluding remarks

Like DMI in Denmark, the Maritime Institute of Finland is operating in extensive networks and is expanding its market orientation in order to cope with the shift towards the short-term research needs of industry and even industry-led programmes (as is reflected by the changing role of TEKES). The Maritime Institute itself, as a joint venture of VTT and Helsinki University, is an interesting new organisational form. As a consequence of further internationalisation more networks and alliances will be formed, even if the amount of public funding expected over the years to come will probably remain at the current level.

7 France

7.1 Introduction

This country study[11] covers two areas of technology: energy and aerospace. Sections 7.2 and 7.3 show the complexity and peculiarities of the French technological infrastructure and the legitimisation discussions at hand.

7.2 Technology area: Energy

7.2.1 Introduction

First and foremost, in order to show exactly where the differences in definitions exist between the different countries it is useful to understand precisely what is meant by the term 'technology institute'. We will therefore first of all briefly discuss the different types of research institutes involved with technological research in France before selecting a set which are appropriate for the requirements of this study. On the one hand this will give an insight into the kind of institute that will be discussed in the France report. On the other hand, it will also serve as an overview of the heterogeneous character of the densely populated French research landscape. The different types of public institutes involved with technological research in France are summarised in Table 7-1. It is easy to understand that in general none of them completely covers the definition of Technology Institutes as given in the project description. This is expressed in Table 7-2.

Taking into account the considerations set out in the above, the following French 'technology institutes' in the field of energy to be discussed in this report, were selected:

- CEA - Commissariat à l'Energie Atomique (Atomic Research Institute)
- IFP - Institut Français du Pétrole (Oil and Oil-related Research Institute)
- BRGM - Bureau de Recherches Géologiques et Minières (Geology and Mining Bureau)
- CEMAGREF - Centre National du Machinisme Agricole du Génie Rural et des Eaux et des Forêts (Institute for Agricultural Machinery, and for Rural, Water and Forest Engineering)
- CSTB - Centre Scientifique et Technique du Bâtiment
- INRA - Institut National de la Recherche Agronomique (Agricultural Research Institute).

[11] Chapter 7.2 on Energy was contributed to by dr. B. de Laat (Écoles des Mines) and dr. Daniel Clément (ADEME). Chapter 7.3 on Aerospace technology was supplied by dr. Rémi Barré, Observatoire des Sciences et Technologies (OST).

Table 7-1: Public institutes involved in technological research

Type of institute	*Description*
EPA - Etablissement public administratif	Performs fundamental research and is responsible for higher education (universities). Although this kind of institute is asked more and more to perform applicable and applied research they are evaluated on their production of knowledge.
EPST - Etablissement public à caractère scientifique et technique	The main preoccupation of this type of research institute is to perform basic and/or applied research. There are, however, large differences in this category. For instance, most of CNRS research can be called basic or fundamental (though over the last 10 years a marked increase in contracts with industry can be noted), whereas institutes like the CEMAGREF operate mainly in the field of applied research.
EPIC - Etablissement public à caractère industriel et commercial	This type of institute is allowed to have an industrial and commercial interest and to make profits (though this is not its main objective). They operate in a similar way to private enterprises. There is no control a priori on expenses made (i.e. no signature is needed beforehand from public administration officers; this is not the case for the previous two types).
CRT - Centre de ressources technologiques	These are research platforms established through agreements between industrial companies, research institutes and public authorities (or agencies). A well-known example in the energy field is the GRETh: a test site for heat exchangers which can be used by industrial companies or research institutes to try out newly developed technologies.
Regional technology centres	The main function of these regional technological research institutes (e.g. the CRITTs) is to see to technology transfer in the regions.
CTI - Centre technique industriel	The (roughly 20) CTIs are research centres which work directly for industrial sectors / branches of industry. Their main source of funding comes from taxes paid by companies of the branch, but they are also allowed to find funding elsewhere (e.g. European funds). CTIs relevant to the field of energy are the CETIAT (Centre technique industriel d'aérolique et thermique) and the CETIM (Centre technique des industries méchaniques).
Research institutes of public companies	In the field of energy especially the research centres of Electricité de France and Gas de France should be mentioned here.
IFP	This is a special type of institute which is devoted specifically to oil and oil-related research, and whose funding comes from levies on oil products.

Table 7-2: Relevance of French organisations for this study

Type of institute	*Evaluation of relevance for this study*
EPA	None of the EPAs may be considered as a TI as understood in this study.
EPST	CNRS (Centre National de Recherche Scientifique) will not be discussed since up to now its core activity was on publications in academic journals (although the number of contracts with industry has grown enormously over the last ten years). Other EPSTs like CEMAGREF or INRETS, however, do seem to correspond with the definition and will thus be considered as TIs here.
EPIC	Several EPICs may be regarded as TIs (the CEA for instance, which will be discussed below). However, some EPICs (e.g. ADEME, a national agency) could never be considered as such.
CRT	CRTs cannot be considered as TIs since they mainly serve to test technologies which have been developed elsewhere or provide other services to businesses and organisations which do not have the means to carry out such work themselves (note that they differ from the CTIs in that they are not defined by sector but rather by technology).
Regional technology centres	These aim at technology transfer and, following the definition, are thus excluded from the analysis.
CTI	The CTIs intervene (often at the request of a branch of industry or individual firm) on very precise issues, and their mission is not to perform technological research in general. Therefore they can not be considered as TIs.
Research institutes of public companies	These function mainly with own resources and, even if they belong to public companies, will be considered as the R&D laboratories of big (private) companies, not as TIs.
IFP	The IFP will be considered as a TI.

The main mission of the first two institutes concerns energy research and the development of energy technologies. However, energy is not the main mission of the other institutes on the list even though the research they perform is often closely related (transport, buildings, etc.). It is for this reason that they are briefly discussed in the Annex to this chapter.

7.2.2 Mission, strategy, activities, markets

CEA - Commissariat à l'Energie Atomique
The CEA employs some 17,000 researchers, engineers and technicians. The institute is organised in different layers: general management, directorates, departments, services and laboratories. The general management[12] decides on the main missions of CEA, following the general orientations given by the public authorities. The CEA has the following directorates:

- the directorates responsible for the scientific and technical programmes: seven operational directorates, plus the *Institut national des sciences et techniques nucléaires,* and the *Institut de protection et de sûreté nucléaire*;
- central directorates which are responsible for logistic support common to the various units on site;
- the functional directorates.

The departments are the operational units of the CEA. They consist of sub-departments, which in turn are divided into laboratories. The head of department is answerable to his director for realising the objectives and for administering the associated financial resources; both are defined in the *Contrat d'objectif* which is signed along the hierarchical lines.

The CEA is an EPIC (see Table 7-1) 'tutored' by the ministries of defence, of industry and of research. CEA's main mission is to give France 'control of the atom' in the following sectors: energy, industry, research, health, environment, and defence. The strategic issues currently confronting the CEA are set out in the *Contrat d'Objectifs 1995-1998 entre l'Etat et le CEA* (on which this section of the report is based). Financial information has been taken from the CEA's 1995 annual report.

CEA's mission in the field of defence research concerns nuclear naval propulsion, the development of new nuclear warheads for the purpose of maintaining and renewing dissuasion policies, and the development of the Simulation Programme (cf. French nuclear testing in the Pacific in 1995-1996) which should guarantee the feasibility and security of new weapon systems. The defence part of the CEA activities is defined in the White Paper of 1994. Although one of the CEA's goals is to develop synergy between the military and civil dimensions of its research, the present paper will focus specifically on the civil part.

Apart from its nuclear research mission, the CEA is also expected to contribute to more general research objectives such as non-nuclear fundamental research and technological development, technology diffusion and education and knowledge transfer (e.g. its central role in the development of medical scanning techniques). As mentioned in the first section of this report, about 80% of electricity in France is nuclear-generated. This prominent place of nuclear energy implies

[12] Formed by the General Administrator, assisted by the Adjunct General Administrator, as well as the General Inspection, consisting of the Inspector General for nuclear safety, the 'Chargé de mission' for the environment and the Director delegated to nuclear propulsion.

an important role of nuclear energy-related public and private organisations and companies, and the CEA must be able to meet the needs of these organisations; they are:

- CEA Industrie[13]
- Electricité de France (a chiefly state-owned company) is the producer and distributor of electricity and hence the main operator of nuclear plants
- Framatome (private) builds nuclear reactors[14]
- COGEMA is the institute responsible for the management of radioactive waste
- ANDRA is the agency responsible for dealing with radioactive waste

CEA strategy issues
The first issue is CEA's position between public authorities and industrial partners. In order to respond to the considerable stakes confronting France in the field of nuclear energy, major research efforts will need to be mobilised which are complementary in dealing with:

- short term considerations, particularly a better utilisation of fuel, life extension of power plants and their availability; this research is to be lead by industrial partners and should be financed for the greater part by them; the CEA having the role of the supplier of research capacity;
- medium and long term considerations, since nuclear energy will remain one of the key-elements of France's energy supply, and will continue to be beneficial for France, it must be safeguarded; whereas this type of research has to be lead by the CEA in association with the industrial partners, it will for the greater part continue to be financed by the State.

The second issue is *orienting nuclear energy research with a view to the future*. The considerations set out above imply that nuclear research is mission-oriented research per se. However, according to the Contrat d'objectifs, such research cannot be conducted without devoting attention to issues with a more fundamental research character. Therefore, the second strategic issue for the CEA is to establish a cross-link with research other than nuclear fundamental research alone, especially:

- research on nucleus structure: in order to understand the transformation of actinides and long-life nuclear products;
- research on materials and microstructures, surfaces and interfaces: necessary for the design, safety and life time of mechanical components and nuclear combustibles, and particularly to gain an understanding of degradation and ageing mechanisms;

[13] CEA Industrie is a holding which controls the industrial participations of CEA. It consists of about 300 companies, most of which have direct links with the nuclear field (e.g. COGEMA, FRAMATOME, TECHNICATOME, etc.), jointly employing some 40,000 people. The turnover of CEA Industrie was 52.2 FRF billion in 1995, representing a 3,4% increase in comparison with 1994. The activities of CEA Industrie are very closely linked to the nuclear sector (representing some 86% of the holding's turnover) as well as to the evolution of the CEA.

[14] This organisation also has a very important secondary activity in wiring.

- research on cellular organisation and function, related to radiobiology: to gain an understanding of DNA lesions, and lesions of cells, tissue and organs, as well as the mechanisms of repair;
- chemical and physicochemical research (radiolysis, corrosion, molecular architecture and structures, cage molecules, colloids, aggregates, etc.): relating to the reactors, re-treatment of waste, waste deposits and the life sciences;
- research on the interactions between radiation and materials, i.e. interaction between materials and neutrons, electrons, ions, photons, irradiation of materials and kinetics.

The third issue is *concentrating on fundamental research and non-nuclear technological research*. Apart from the selected issues mentioned in the previous paragraph, the CEA should, where possible, contribute to issues and needs of general interest outside the nuclear area in which an added value can be provided by the skills acquired at CEA in connection with its nuclear mission constitutes. To this end, closer partnerships with other research institutes and institutions will be developed (with CNRS, INSERM, INRA, CNET, etc.), and, where necessary, new organisational structures which enhance such collaborations should be established (shared laboratories, joint ventures, participation in international laboratories, etc.).

The fourth issue is to *improve the interaction between CEA's three pivotal research areas*.
Another important objective for the period 1995-1998 is to improve the interaction and develop synergies between CEA's three main kinds of research, i.e. nuclear research, fundamental research and non-nuclear technological research. Particular attention will be devoted to interaction between fundamental research and nuclear research (see above), and to interaction between the nuclear and non-nuclear components of technological research.

More specifically, the goal is to amplify the diffusion of the technologies emerging from the nuclear sector in non-nuclear fields and, conversely, to see that nuclear technologies benefit from innovations in other branches of industry. For example:
in relation to instrumentation, microsensors and microsystems, technologies of radioprotection and nuclear medicine as well as of radiation detection might be used. Also, the technologies developed by the CEA for the aerospace and aeronautics sector are useful in the field of materials, polymers, laser diodes, integrated circuits, etc.

These objectives will have consequences for the structure and functioning of CEA since they imply more mobility of personnel within the organisation.

The fifth issue is to *transfer industrial activities to industry and improve technology transfer*. In order to reorientate itself entirely on its research mission, the CEA plans to transfer to industry all the industrial activities the organisation was engaged in when the Contrat d'objectifs was concluded with the State. This process of transfer has already been crystallised in part by transferring the Atelier Pilote in Marcoule (APM), the Ateliers de traitement de l'uranium enrichi (ATUE) in Cadarache, etc. The CEA will also give more attention to transferring technology to industry during the early stages of technological research.

IFP - Institut Français du Pétrole[15]

The IFP is a national research institute which operates in the field of oil products and oil-related products, and whose main funding comes from levies on fuels. The mission of the IFP is fourfold: research and development; valorisation; education (notably through the ENSPM, the 'Ecole Nationale Supérieure du Pétrole et des Moteurs; and supplying information to the hydrocarbon industry (oil and gas) and the automobile industry. This description will be limited to the research part of IFP's mission. Research at IFP revolves around the different elements of its mission. This means that apart from the directorates and services concerned with valorisation, education (the ENSPM) and documentation, research is managed on the lines of two different structures.

On the one hand, there are the four 'Directions d'objectif', each having one of the four IFP objectives set out above: exploration & resources; industrial production; engines & energy; refining/ petrochemicals. On the other, there is the scientific organisation which is subdivided into 12 research divisions. These are: geology-geochemistry; geophysics-instrumentation; sources ('gisements'); applied mechanics; applied physical chemistry and analysis; kinetics and catalysis; applied chemistry, biotechnologies, materials; development; process engineering; technology; techniques for energy applications; informatics and applied mathematics (including information services).

IFP's valorisation department is divided into a) a service for relations with SMEs, with four regional offices in France, and b) an industrial directorate. The latter is subdivided into an engineering division, an industrial division (which manages IFP's foreign offices), and a thematic industrial division 'exploration-production-engines-energy'.

Like the CEA, the IFP has close links with its industrial and commercial partners through a tight web of subsidiaries. These are managed by the ISIS group of which the IFP, with a participation of 57.3% in 1996,[16] is the principal shareholder. The companies in which the ISIS group participate had a joint turnover of several tens of billions of francs in 1996.[17] The aim of the companies that make up the ISIS group is to commercialise IFP's research results, processes and technologies, in the following fields:

- Exploration and production (Beicip-Franlab, Compagnie Générale de Géophysique, Coflexip Stena Offshore, Geoservices, DV Offshore);
- Catalysis (Procatalyse, Eurecat, Eurecat US);
- Engineering (Technip, Ipedex, NAT);
- Potential growth SMEs (ISIS Developpement, Saf-ISIS, Novasep, Vinci Technologies).

[15] Unless stated otherwise this section is based on IFP, 1997

[16] The ELF group holds 39,1% and the BNP group the remaining 3,6%.

[17] The major ones being Technip with a turnover of 10,1 FRF billion, Coflexip Stena Offshore with a turnover of FRF 4,9 billion, and the Compagnie Générale de Géophysique with a turnover of FRF 3,1 billion in 1996.

Apart from collaborating with industrial partners, IFP also collaborates with other research institutes, university labs and CNRS in France, and with similar institutions abroad.

Strategy issues IFP
During the years 1995 and 1996 strategic discussions were held in IFP itself and between the institute and the ministries responsible. As is also the case at CEA, the results of these discussions have been laid down in a 'contrat d'objectifs' concluded between the State and IFP. The following table, Table 7-3, gives an overview of this 'contrat' for each of the fields of competence (source: IFP annual report 1996).

Table 7-3 Major points taken from the 'Contrat d'objectifs' concluded between IFP and the State (signed on 25 June 1996)

	IFP's strongholds	*technical stakes*	*strategic goals*
exploration & production	recognised international scientific & technical competence internal synergies on multidisciplinary subjects an equilibrium between experimental research, quantitative modelling of phenomena and validation on real cases	reduction of risks and costs of exploration and discovery of new sources to optimise the exploitation and level of source recovery in view of the reduction in drilling costs, to develop systems adapted to advanced well technologies, like multidrains, etc. to render new reserves accessible, both in the technical and economic sense,: marginal fields, deep sea fields, heavy crudes, difficult crudes, etc. to optimise the treatment of production effluents	to focus IFP's efforts on the possibilities that exist for attaining a critical mass to propose a wider range of different high-level R&D-activities and services, particularly by developing valorisation (commercialisation) activities through strategic partnerships
refining & petrochemicals	high-level research into processes and catalysts the structure of international commercialisation world leader in the field of commercialisation and sales of refining and petrochemical technologies	dispose of processes which are adapted to the anticipated demand trend, quantitative (e.g. conversion of residues) as well as qualitative ones (stricter regulations, octane constraints, etc.) complete the portfolio of different refining processes which the IFP presently offers develop activities in the field of olefines and aromatic compounds	to reinforce IFP's position as a licencer by significantly increasing its share in the world market to quickly achieve a critical mass on entire process chains to assure a continuous presence as close to the market as possible to pursue selective activities in the field of additives for fuels and lubricants
engines & energy	continually more stringent environmental constraints which benefits IFP's position in the field of clean conversion and energy efficiency strong synergies of IFP's competencies in the field of fuels and engines a recognised position of IFP in the field of direct injection of petrol, of the mutual adaptation of engines and fuels, as well as of post-treatments (e.g. catalytic converters) a demonstrated competence in industrial heat	to reduce unitary fuel consumption of vehicles, notably of petrol to reduce vehicle emissions, particularly from diesel engines to develop alternatives for both fuels and engines: liquefied petrol gas, natural gas, etc.	to improve IFP's specific activity in the field of technological design, in view of extending this activity into the test stage of new engines to demonstrate IFP's activities, not only in the field of research but also in the field of development to valorise IFP's competencies in the field of industrial heat

These actions are accompanied, as indicated, by activities in higher education through the ENSPM.

7.2.3 Key indicators and financial flows

CEA - Commissariat à l'Energie Atomique
The CEA employs some 17,000 researchers, engineers and technicians. In 1995 CEA's financial resources stood at FRF 18.3 billion (about NLG 6 billion). The defence programme, which totals FRF 8.2 billion, was funded almost entirely by the Ministry of Defence. A sum of FRF 10 billion was provided for civil programmes, financed for 59% by virtue of the State Budget (the Ministry of Higher Education and Research, and the (then) Ministry of Industry, Post and Telecommunications), the remainder (some 4 billion) financed from external funding and FRF 200 million from Defence funds for civil research.

The Contrat d'objectifs states that public funding of CEA will remain constant (if the Franc remains stable) from 1994 onwards for the duration of the contract (i.e. until 1998). External funding needed for additional investments should come from contract funding (with a shared funding goal of 50-50%) with partners.

The civil sector of CEA generates nearly 40% of its budget from external sources: FRF 3,584 million (35.8% of the budget) in 1994, FRF 3,968 million (39.3% of the budget) in 1995. A more detailed analysis of the income in CEA's civil sector shows that approximately one third is generated through collaboration with other nuclear research parties and another one third is generated through commercial research and research-related products. Sales of products and services add up to 10% of the external sales. Most customers are from the Groupe CEA (46.3%); the public sector (17.4%); industry (8.3%); EdF (18.5%); CEE (4.7%).

CEA's defence sector is financed almost entirely from subsidies. Income from external sources accounted for about 1% of the resources: FRF 89 million (1% of the budget) in 1994 and FRF 74 million (0.9% of the budget) in 1995.

IFP - Institut Français du Pétrole[18]
The number of employees in this institute has grown steadily from 300 in 1950 (the institute was established in 1949) to slightly above the 1,800 mark in 1985, remaining stable since then. Currently, the personnel age histogram shows a large peak at 50-54 and a smaller one around 35-39. Table 7-4 gives a summary of some of the key figures.

Table 7-5 shows how IFP's total income of FRF 1,844 million is distributed over the various sources. Distribution of its expenditure is set out in Table 7-6.

Research at IFP is divided into the following fields: exploration & resources, industrial production, engines & energy, refining/petrochemicals; the activities 'exploratory research & quality' and 'valorisation' should be added to these. The budget breakdowns over the different themes are presented in Fig. 7-1.

[18] Unless stated otherwise, this section is based on IFP, 1997.

Table 7-4: IFP: Key indicators 1996

number of employees	1829
budget	FRF 1.8 billion
PhD theses underway	127
valorisation contracts signed	106 (of which 90% abroad)
patents applied for	1203
number of students at the ENSPM	348 (of which 42% foreigners)
number of 'trainees'	774
number of scientific papers & articles	450
number of scientific books published	6

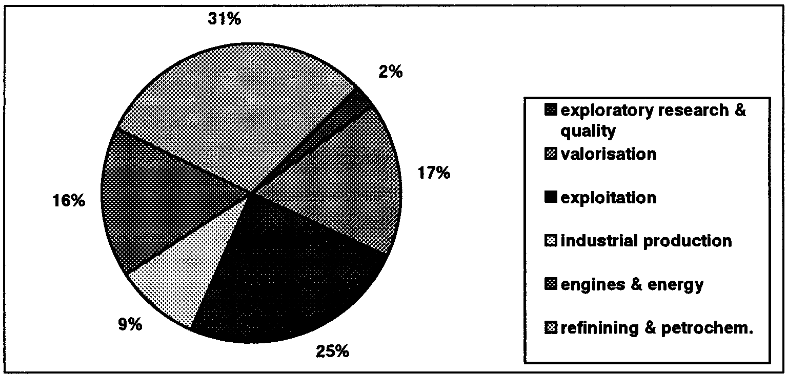
Table 7-5: IFP revenues 1996 (in FRF million 1996)

taxes	1193
income from technology transfers	178
reimbursement of externally contracted work, national and European funding	343
miscellaneous	130

Table 7-6 IFP expenses 1996 (in FRF million 1996)

taxes	1193
income from technology transfers	178
reimbursement of externally contracted work, national and European funding	343
miscellaneous	130

Fig. 7-1 Budget shares of the various themes (total budget FRF 1.8 billion)



The pie chart shown in Fig. 7-1 clearly shows that nearly one third of IFP's budget is dedicated to exploitation. Given that domestic fossil fuel sources are negligible, this is interesting: even if markets for this research lie primarily outside France, the IFP has managed to build an international reputation in this field. Other relevant data concerning commercialisation are shown in Fig. 7-2 (patents) and Fig. 7-3 (concluded commercialisation contracts).

Fig. 7-2: IFP patents in 1996 (1203)

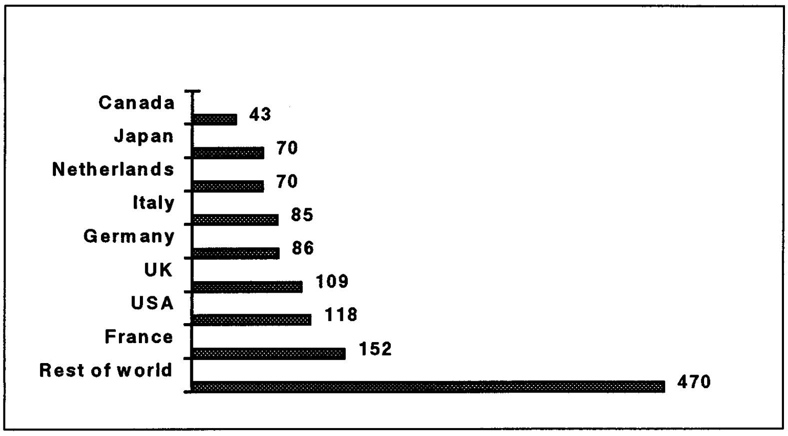
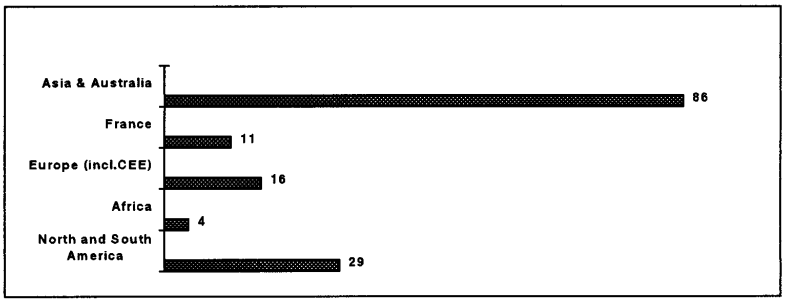


Fig. 7-3: IFP: commercialisation contracts concluded in 1996 (106)



7.2.4 Trends and developments; key forces

Recent political developments. The new minister for research, installed after the elections in June '97, is said to have asked the research institutes to reflect on their respective missions and their 'raison d'être', since there are so many big technological institutes. This could be the first step towards a new policy of strategic re-evaluation of the research infrastructure in France. Also, an association of the French big technology institutes (Centre national de recherche technologique) will probably have to make sure that the contact between the various research institutes is intensified .

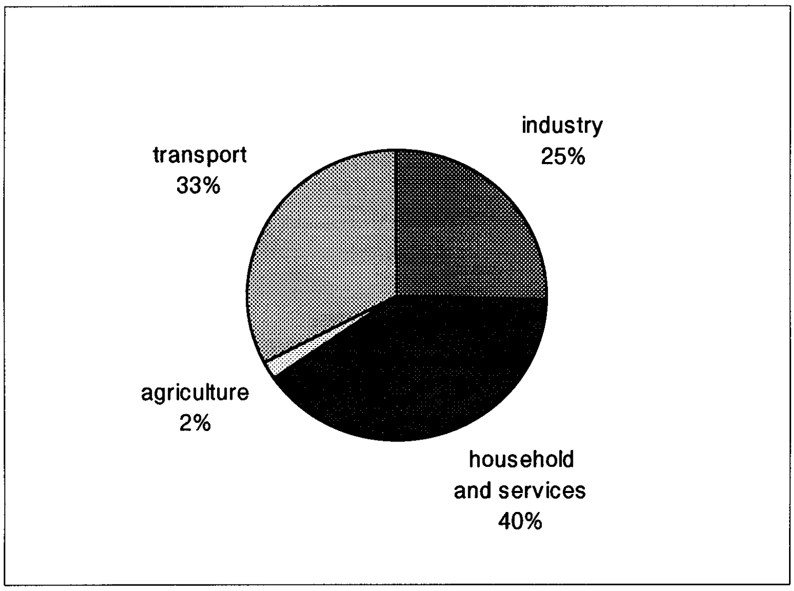
Supply and demand. France is very dependent on foreign imports in the coal, oil and gas sectors: it is a country with only a marginal domestic production of oil, its coal deposits are to be closed down progressively, and domestic production of gas at the Lacq site (in the south-west) is low. Generally however, energy dependence is now well below the 50% mark, whereas at the beginning of the 1970s - when the nuclear programme was started - it was way above 75%. Despite this progress, energy independence remains France's main objective regarding energy, and this will grow in the coming years thanks to the further development of the electricity production sector. All in all, 78% of the electricity production is of nuclear origin. France exports electricity to Italy, Great Britain, Germany and Switzerland.

The energy demand over 1993, 1994 and 1995 is presented in table 7-7 and Fig. 7-4.

Table 7-7: Energy demand

	1993	1994	1995
total energy consumption	140.9	144.7	144.2

Fig. 7-4: Energy consumption by sector



While the total consumption appears relatively stable in industry and agriculture, it tends to increase in the transport sector due to the increase in road transport[19] and in the household and service sector. With regard to the latter this concerns electricity in particular: in 1994, electricity represented 54% of the final energy consumption in the household and service sector. Final energy consumption will continue to increase in favour of electricity and gas.

[19] Road transport benefits, among other things, from the dense road infrastructure developed since the end of the 1950s.

Key forces in energy policy. French energy policy is aimed at several objectives. First, to improve energy securement by reducing dependence on imported fossil fuels, maintaining reliable inexpensive energy supplies to ensure the competitiveness of French economy and to protect the environment. Second, to concentrate on developing nuclear power generation. Third, to diversify energy sources and their geographic origin. Fourth, to improve end-use efficiency and to cooperate with other countries through EU, IEA, and other organisations.

At the same time, it should be noted that[20] the industrial energy sector is in a healthy condition. France is no longer engaged in conserving energy and has therefore disrupted a trend that started in the 1980s. A new drive has been given to renewables and combined heat and power ('cogénération', in French). From 1998 onwards, changes in the structure of the internal electricity market can be expected due to the adoption of a European directive on competition.

Moreover, the 1994 national debate on energy ('the *Souviron* report') concluded with the following main recommendations:
- The need for more democracy and transparency in the electricity sector policy-making and decision-taking.
- The government should set up a standing committee of experts to audit EDF's activities. All proposals to build new transmission lines should be subjected to independent review by a commission set up by the government or local authorities. A strategic plan for the disposal of nuclear waste should be presented to Parliament.
- Action is needed to promote the diversity and flexibility of the energy supply. Renewables should be encouraged more, e.g. by maintaining EDF's obligation to purchase power based on renewables, even if EDF no longer needs more capacity. The system of energy taxes should be reviewed, consumers should have more choice regarding the mode of household heating, and EDF should be prevented from promoting electric space heating where it is uneconomical.
- France's international commitments to limit CO_2 emissions and local environmental problems require more efforts in improving energy efficiency.
- Existing efficiency standards in the transport and building sectors should be properly applied.

These considerations form today's major guidelines for technological energy research in France.[21]

An important 'steering mechanism' is the *Contrat d'objectif*. This is a contract between the State and a technology institute establishing objectives and financial means for the *'Organisme de recherche'* concerned. These contracts are usually the result of a priority setting process conducted within the institutes concerned on the one hand (for the CEA in 1993-94, and 1995-96 for the IFP[22]), and on the other hand, on discussions with the public (research) authorities

[20] Cf. Ministère de l'Industrie, 1997.

[21] For a more detailed overview of non-nuclear energy research activities in particular see ADEME's recently published research programme for 1997-2000.

[22] For the BRGM - Annexe I - early in the 1990s, for INRA - Annexe IV - still running.

about general orientations. These contracts do not consist of general statements but are precise, stipulating concrete research themes for the technology institute concerned.

However, the *Contrat d'objectifs* is only one of the devices which defines the role of the technology institutes discussed here. One of the most striking features of at least the two main French *public* technological institutes described in this report is that *both have legal associations with companies*. Both CEA and IFP (and to a lesser extent the BRGM) are the main shareholders of a holding company (CEA Industrie and ISIS, respectively). These holdings control those companies responsible for the commercialisation of research results of these respective technology institutes (such subsidiary will have - at least some - public capital, at least one of the shareholders being a public institution). From the outset, this probably gives these technology institutes a very different status in techno-economic networks than that of their counterparts in other European countries.

The following two remarks are appropriate with regard to 'steering mechanisms':

- First of all, even if most of the technology institutes have a *'Contrat d'objectifs'*, and even if they all have in common that they are strongly embedded in a network of companies and related research structures, *it is still difficult to identify more general steering mechanisms*. The reason for this is that the missions of the different institutes and the networks they relate to are far too different to be able to make a general statement. For instance, the CEA cannot be viewed without considering the military-nuclear complex, which, despite the recent addition of new items to CEA's mission (non-nuclear for instance) still constitutes its main reason of existence. This will continue to be so in the short, the medium and the long term, and this gives the CEA and its subsidiaries (through the CEA Industrie holding) their important role in the French research landscape (after CNRS it is France's largest research institute). A comparison with IFP (or any other research institute) therefore hardly makes sense. For instance: IFP is a factor 10 smaller, both in terms of its budget and number of staff, and moreover, France's domestic fossil fuel production being negligible, a large share of its commercial activities lie abroad.
- Not only is it difficult to make a comparison within France, a comparison with technology institutes abroad is probably even more difficult. Similar reasons as the ones given above are the reason for this:

On the one hand, this is because of the typically French energy situation, with a strong focus on nuclear energy; a situation that exists nowhere else in Europe.[23] CEA's strength and position is directly related to France's energy history. But at the same time, technology institutes can be very successful even if there are no domestic resources or markets in existence (which is true in the case of IFP).
On the other hand, the close and direct legal relationships with the industrial

[23] The UK comes second where nuclear power is concerned, but the national report did not state that nuclear research was as important in the UK as it is in France.

partners of the research institutes might also be unique in Europe. Both CEA and IFP, France's most important energy research institutes, are main shareholders of the holdings of the companies that have to commercialise their research results.

7.2.5 Legitimisation: strategic issues and future perspectives

CEA - Commissariat à l'Energie Atomique

Nuclear energy research is located at the intersection of different political 'stakes':

- *energy policy* - to guarantee France's energy supply, France being a country which has only scarce natural energy sources. The two main issues here are national energy independence on the one hand and economic competitiveness on the other (the cost per kWh);
- *industrial policy* - to guarantee the competitive position of France's nuclear industry which is an exporter of electricity and one of the world's leading nuclear industries. All parts of the sector, from conception to construction of reactors, and from the exploitation of raw materials to the decommissioning of nuclear installations and waste disposal, are covered by the French nuclear industry;
- *environmental policy* - because of the management of radioactive wastes on the one hand, but on the other, because of the greenhouse effect and pollutants; security and risk;
- *international policy*, especially relating to issues of non-proliferation;
- control of the atom ('maîtrise de l'atome') is also an important issue for such fields as medicine, notably linked to diagnostics and new therapies, as well as to the sources and detection of particles and radiation.
- *defence policy* which attributes a major role to nuclear dissuasion.

CEA is charged specifically to respond to these political stakes, by giving France 'control over the atom' in the fields of research, health, energy, industry and nuclear safety in the short, medium and long term. It has to fulfil the roles of expertise and consultancy for public authorities and must support industry in these fields which are so strategic for the countries future. More specifically, apart from defence research, it also has to perform fundamental research in order to prepare the country's nuclear energy future for the long term; and it has to prepare for the medium term (the beginning of the 21st Century) by developing technological research, nuclear and non-nuclear, in collaboration with both industrial and public partners.

With a view to the future, there is one general tendency (which still has to be confirmed) that might be distinguished. CEA, BRGM and to a lesser extent, IFP, have been requested to *concentrate more on their research missions and less on their commercial activities*. The commercial and industrial activities should be delegated to subsidiaries. Yet in the same move, which could at first glance appear to be a withdrawal from the market and a return to more fundamental research, the technology institutes should warrant their links with these companies, since when all is said and done it is they who have to guarantee the commercialisation of the research results.

In other words, the major French technology and research institutes are asked to get away from the market concerned with their own activities. However, they can do this by simultaneously reinforcing their relationships, through their holding companies and collaborative agreements, with the markets they themselves helped to create in the past. This seems to be a tendency which goes against most of the trends seen in Europe where research institutes are becoming more and more directly dependent on, and working for, the market.

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ANNEXE 1
Other energy research organisations in France

1. Bureau de Recherches Géologiques et Minières

BRGM is an EPIC falling under the responsibility of the French Ministry of Industry. BRGM's activities are of a scientific nature and cover the following subjects: geological knowledge; exploration and exploitation of mineral resources; research into and management of underground riverbeds; environmental protection and pollution abatement; underground studies for public works; analysis and protection of natural risks and the protection and enhancement of vulnerable areas.

Complementary to the public mission related to geology and mining carried out by BRGM, the more commercial activities (geo-engineering in particular) are carried out by commercial subsidiary companies. Exploitation activities are carried out by firms specialised in gold mining, industrial minerals and metals, which are organised in the Source Compagnie Minière and its subsidiary MINEOR.

BRGM was recently reorganised. In 1992, after it had been observed that the activities of the BRGM were starting to resemble the activities of the commercial sector, it was decided that the BRGM should concentrate more on its mission as a research institute and a public service; its more competitive activities were to be carried out by its subsidiaries.[24] This process has now almost reached completion and has resulted in the following:

- *Environmental division*. The decision was taken to form an environmental division of the subsidiaries operating in the fields of water, civil engineering, spatial organisation and the environment. This resulted in Antéa, a company under the full control of BRGM through the Sagéos holding. In March 1995 a contract was signed with Heidemij, a Dutch company operating in the same fields and well established abroad; the foremost European company. Heidemij has a 35% interest in Sagéos.
- *Mining division*. BRGM enjoys international recognition as one of the world's leading prospecting institutes, having the same level of competence as the prospecting departments of major multinationals.[25] However, the institute had no experience or competencies in the field of exploitation of already discovered mines at its disposal. Consequently, at the beginning of the 1990s the Government invited BRGM to reorganise all its mining activities, bring them into a subsidiary and to find an industrial partner to manage them. No partner could be found in France and finally, in 1993-94, an Australian mining group, Normandy Poseidon Ltd., expressed interest in becoming a partner

[24] These activities should be 'filialisées' i.e. turned into a 'filiale' - a subsidiary.

[25] E.g. BRGM was responsible for discovering the mines at Yanacocha (gold) and Neves Corvo (copper).

with BRGM. Since these activities have no direct links with the field of energy they are not discussed here.

2. Centre National du Machinisme Agricole du Génie Rural et des Eaux et des Forêts (CEMAGREF)

CEMAGREF is an EPST falling under the responsibility of the ministries in charge of research, agriculture, and the environment. CEMAGREF's goal is to develop methods and tools for public action and the transformation of economic activities in these fields, or to be more specific: in the field of territories and continental waters. The Centre is divided into four departments:
- the department in charge of the management of aquatic environments;
- the department for the development of water and environmental equipment;
- the department dealing with territorial management and land planning (forests etc.);
- the department dealing with the development of agricultural and agro-food related equipment.

Each department has drawn up a strategic plan defining mission-oriented ('finalised') research programmes. Running parallel to this is the development of projects on preventing water-related and snow-related risks, and projects concerned with integrated resource management.

CEMAGREF employs a workforce of approximately 950 permanent members of staff and about 850 temporary workers. Its budget is in the region of FRF 360 million, 30% of which is covered by its own resources.

3. Centre Scientifique et Technique du Bâtiment

The CSTB (an EPIC), established in 1947, falls under the responsibility of the Ministry of Housing. While it supports public policies in the field of housing, it is still at the service of the various other actors in this field: consultants, architects, firms, entrepreneurs, etc. The CSTB is indirectly involved with energy research (e.g. through energy saving measures such as housing insulation) and will therefore be discussed in brief here.

CSTB's main activities concern research and development, technological development (standardisation, qualification, certification, etc.), scientific and technical consultancy (participation in major projects like the Biblioth□que de France), and the diffusion of knowledge.

CSTB conducts work in the following areas:
- the environment, health, comfort (aerodynamics, indoor climate and environment, indoor air quality, acoustics, lighting, energy engineering, domotics) and risk prevention (fire, wind, etc.)
- quality and technology of the built-up environment (structure, life cycle analysis, materials engineering, etc.)
- economic and social sciences (economics of construction, sociology of living

habits, innovation sociology, foresight, etc.)
- knowledge industries (conditioning of technical information, databases, modelling, standardisation of computer programmes, etc.)

The CSTB employs a total of 600 staff, half of which are engineers and researchers. Its annual budget is in the region of FRF 320 million, 35% of which stems from the public research budget.

One of the major issues the CSTB is currently confronted with is the decrease in (public) funding[26]; this will oblige the centre to seek additional funding from the private sector. However, there seems to be a lack in demand.

4. Institut National de la Recherche Agronomique

The INRA (Institut National de Recherche Agronomique), an EPST since 1984, was established in 1946. It falls under the responsibility of the ministries in charge of agriculture and of research. INRA has 8,700 members of staff on its payroll and has an annual budget of FRF 3 billion. It has three general objectives:
- to promote a well-performing agriculture and agro-industry;
- to ensure safe and high quality food for the consumer;
- preserve the rural environment.

As was explained in the first part of this report, the research carried out at INRA is not geared specifically towards energy. However, in the past, and even today, this institute is involved with non-food agro-applications and, for this reason, with energy crops.

7.3 Aerospace

7.3.1 Introduction

This chapter elaborates on the position of aerospace research centres in France. It aims to explain the French context in this area, to describe the most relevant institutions and their activities and finally to provide assessment and perspective. This chapter is essentially descriptive, although some background and contextual analysis will also be provided.

7.3.2 Mission, strategy, activities, markets

Even though the focus is on public research institutes involved in Aerospace research, it is essential to first of all say a few words on publicly financed Aerospace research in France in order to establish the proper context.

[26] A decrease of some 1.2% over 1996 implying a 3 to 3.5% drop in volume. Five jobs were lost in 1996 and another six will become redundant in 1997.

Space
The civilian space budget is managed by CNES (Centre National d'Etudes Spatiales). Its workforce numbers 2,500 in FTE. The budget of CNES for 1995 was 1.77 billion ECU, of which 0.55 billion is obtained by CNES itself (non-private contracts as CNES is a public institution). The state contribution towards this budget is 1.22 billion ECU, a small part being provided by the Ministry of Defence and the rest from the Ministry of Industry. A total amount of 0.72 billion ECU is transferred from this budget of 1.77 billion ECU to ESA (European Space Agency) as France's contribution. Therefore CNES operates on a budget of 1.05 billion ECU.

It is important to state that, basically, CNES is an agency which finances research and development in order to realise its own operational objectives. CNES has no in-house technological research activities. It is not an institution for consideration in this report.

CNES essentially subcontracts to industrial firms (to the tune of 650 million ECU); its only two significant subcontractors in the field of public research are CNRS (15 million ECU) and ONERA (9.2 million ECU). Most of CNRS contracts relate to the CNES science programme, which has no connection whatever with space technology research.

There is also the military space (and missiles) R&D, which includes experiments and trials, which totalled 0.84 billion ECU in 1995; this was also executed mainly in firms.

Civilian Aeronautics
Public policy on Aeronautics is prepared and implemented by DGAC (Direction Générale de l'Aviation Civile) which is a part of the Ministry of Transport. It not only has the regulatory and technical control responsibility for air transport, but is also in charge of public infrastructure. It has also a Directorate for civilian aeronautics programmes (Direction des Programmes Aéronautiques Civils), which is in fact a funding agency with a similar role for aeronautics as CNES's role for space. R&D publicly-funded programmes for aeronautics correspond with 0.23 billion ECU annually (in 1995); these are subcontracted almost entirely to industrial firms. A total of 14 million ECU is subcontracted to ONERA.

Here too, the military aspect (military aeronautics R&D), which includes experiments and trials and totalled 1.12 billion ECU in 1995, is chiefly executed in firms.

Relevant institutes
The criteria for selecting technology institutes in this study are: that they are at least partly publicly funded, that they are not transfer or policy research institutes, and that they are not university research centres. CNRS laboratories belong to the 'university' category; nevertheless, it might be worthwhile mentioning some large CNRS laboratories which do have technological research contracts in the aerospace field:

- Laboratoire d'Etudes Aérodynamiques - Université de Poitiers, Institut National Supérieur d'Aérotechnique (a staff of 150)
- Laboratoire des Ecoulements Géophysiques et Industriels - Institut Polytechnique et Université de Grenoble (a staff of 145)
- Laboratoire d'Energétique et de Mécanique des Fluides Internes - Université Paris 6, CNAM
- Laboratoire de Mécanique Appliquée - Université de Besançon (a staff of 45),
- Laboratoire de Mécanique des Structures - Institut National des Sciences Appliquées - Lyon (a staff of 10).

Finally, we are left with one institution which is completely dedicated to aerospace research: ONERA (Office National d'Études et de Recherches Aérospatiales). Another institution is partly concerned with this area of research: INRIA (Institut National de Recherche en Informatique et en Automatique). We will also consider the recently founded 'Consortium de Recherche et d'Innovation pour l'Entreprise' (CRIE).

ONERA - Office National d'Etudes et de Recherches Aérospatiales
ONERA has the status of a 'scientific and technological public institution with a commercial and industrial character' (EPIC); while this is a civilian institute it is still placed under the Ministry of Defence. Its missions are:
- to perform research in the field of aerospace;
- to provide industry with an experimentation infrastructure;
- to disseminate the results of its research for the benefit of the aerospace industry;
- to facilitate applications outside the aerospace sector;
- to contribute towards training.

ONERA is financed for 60% by contracts provided by the state or by industry; the remaining 40% is financed through the state budget (Ministry of Defence) in view of long-term research. Total workforce: 2,230, 1,080 of whom are engineers and scientists, 210 are PhD students, and 940 miscellaneous staff.
In terms of technological activities, specialties of ONERA are:
- aerodynamics: a workforce of 156 plus 25 PhD students;
- energetics (reactors): a workforce of 165 plus 25 PhD students;
- artificial intelligence, images treatment, aerospace mechanics: a workforce of 215 plus 28 PhD students;
- large experiments infrastructure: a workforce of 280;
- materials: a workforce of 111 plus 35 PhD students;
- data treatment and computers: a workforce of 55;
- general physics: a workforce of 184 plus 25 PhD students;
- structures: a workforce of 93 plus 15 PhD students.

INRIA (Institut national de recherche en informatique et en automatique)
INRIA has the status of a 'scientific and technological public institution' (EPST); it falls under the jurisdiction of the Ministry of Research and the Ministry of Industry. INRIA's mission is to develop research projects and interact with industry through contracts, as well as to establish 'strategic partnerships', joint ventures and to help start up companies. INRIA has a workfor-

ce of 715, of whom 325 are researchers. Through the establishment of 'joint laboratories' with CNRS, universities and engineering schools ('Grandes Ecoles') INRIA has a potential of 1,400 researchers. Among its many activities, the following concern aerospace:

- man-machine interaction;
- cognitive systems, knowledge bases;
- analysis and synthesis of images, vision;
- simulation and optimisation of complex systems (automatics, robotics, signal treatment, modelling, scientific calculus).

CRIE (Consortium de Recherche et d'Innovation pour l'Entreprise)
The CRIE Consortium was established in March 1997 by the following institutions:

- ONERA and INRIA, already discussed.
- CEA (Commissariat à l'Energie Atomique) through its DTA (Direction des Technologies Avancées). This is CEA's industrial link, with major skills in electronics (LETI laboratory in Grenoble), materials and optronics (CEREM). DTA employs a staff of 1,400 and 180 PhD students.
- CNRS, which has several laboratories on aerospace topics (see above).
- Bertin and contract research organizations ('SRCs'), private bodies.
- The Industrial Technical Centers network ('CTIs'), about 12 technical centres funded through a special tax on industry. However none of them is specialised in aerospace technologies.
- INRA and CEMAGRE89F, both of which are public research institutes, but with no competencies in aerospace technologies.

The goal of this consortium is to offer integrated high quality capabilities to industrial clients, tailored to individual problems. The activities of CRIE are organised under ten different themes, among which the following are directly related to aerospace technologies:

- materials and associated technologies (theme 1),
- modelling, virtual reality, synthetic images (themes 2 and 3),
- electronic and optical components and micro-systems (theme 4),
- instrumentation and metrology (theme 5)
- energetic systems - hydrogen technology, modelling of thermal fluxes (theme 7)
- complex systems security (theme 8).

7.3.3 Key indicators and financial flows

Section 7.3.2 provides some relevant data as well as the financial structure of the organisations concerned.

7.3.4 Trends and developments; key forces

For the producers of aerospace technology, the main market development is the decline in military contracts. The military technologies funding agency

(Direction générale de l'armement - DGA) has been reorganised completely, as also have military procurement procedures. Another important aspect is the way large firms are developing, particularly at European level: changing perimeters, changing alliances and partnerships. Examples of such changes are the planned privatisation of Thomson, the merger between Aerospatiale and Dassault, and the changing status of the Airbus consortium. It therefore cannot be doubted that the market perspectives are not all that good, or that there is an increasing amount of competition at all levels; this is also true with regard to institutions that offer technology capabilities and services.

With regard to the institutes themselves, ONERA, INRIA (and related institutions such as CEA) we can say that their references and capabilities are world class, in both the scientific and technical sense.

Institutes such as CEA and ONERA, and to some extent INRIA too, still have missions that concern aspects of national security. The following section will elaborate on the changes that are occurring in their environment and the consequences for legitimisation.

7.3.5 Legitimisation: strategy issues and future perspectives

The 'technology institutes' considered here (ONERA, INRIA, also CEA) have either EPIC or EPST status. Staff of an EPST are de jure civil servants; the staff of EPICs are de facto civil servants. Whatever the case, the members of staff of these institutes cannot be forced to leave against their will. In other words, the institutes under consideration here are not businesses which are run on public capital; they are 'in the public service' in the wider sense.
Budgetary restrictions and rigidity of human resources management puts strain on the institutes. Yet to date there have been no crises in any sense whatever, nor are any expected to occur: the basic level of government funding is guaranteed on the grounds stated above.

CEA and ONERA had (and still do) missions concerned with aspects of national security which justified both their creation and further existence. To a certain extent, this is also true of INRIA. The original idea was the State as client, since the user of these technologies were the armed forces (nuclear weapons, planes, rockets), EDF (the national electricity company) - for nuclear power plants - and, more in general, companies that were 'national leaders' in theirs own sector. Three basic changes are now under way which tend to rock the entire system:

- the assessment of national security is now looked at chiefly from the European point of view, and less at the national level; the aspect of national self sufficiency is consequently changing;
- technologies are becoming so diversified, and companies are entering into so many international partnerships (especially in the aerospace sector) that the one-to-one relationship between a technology institute and a 'national' company is neither no longer possible, nor desirable;

- nuclear technologies face an uncertain future; this is of crucial importance for CEA.

These changes imply that CEA and ONERA, and also INRIA to a certain extent, must redefine their ‘raison d’être’ - at least implicitly. This ‘raison d’ètre’, obviously now includes the notion of utility for a diversity of industrial clients. Thus, there is an ‘existential’ need to have more, and more diversified, industrial clients; the question is therefore what kind of relationships these institutes can establish with a variety of firms beyond their traditional clients. Important steps have been taken recently to develop such relationships, essentially in France, and the CRIE is a good example here. However, this is also occurring within Europe too - ONERA, for example, belongs to the European consortium AEREA, and DTA-CEA is opening up offices in Italy and Germany. INRIA is a little different and more advanced since it was created more recently, stressing industrial linkages since its inception.

In any case, it is important to point out that orientation towards the market is not simply a means of bringing in more money, nor is it a natural trend (to say the least, since the culture in these institutes is overwhelmingly scientific and technical). In other words, the process is under way, but the question is: have all the implications been identified?

The policy-strategy debates take place on two different levels:

- One is the level of the individual institutes, in an explicit way: What competencies for which clients? What organisation and procedures to establish in view of that? How to keep the proper balance between short term contracts, long terms contracts and one’s own research?
- The other is the governmental level, in an implicit way: What is really expected from these institutes? How far should they go to be competitive on the market? And if they are simply contract research organisations, why should they be public organisations? Is there not the risk of unfair competition arising with private organisations doing the same kind of work? And is it really possible that such work can be proposed by purely private institutions? This would prove that there is indeed a legitimacy for such public institutions, but then shouldn’t their goals be reformulated? And, last but not least, wouldn’t Europe be the most appropriate scale on which to develop the corresponding strategies?

Finally, these institutes represent an asset of accumulated talent and experience. The conditions by which society can benefit from these assets are changing. The challenge which both these institutes and the government face is to identify what those new conditions are, and what they imply in terms of strategy for the institutes and their governing bodies. A central piece of the national research policy is at stake here.

7.4 Concluding remarks

This chapter has presented an interesting assortment of organisations in the French technological research landscape. With regard to energy research, attention was given to CEA, which is a public research organisation allowed to have commercial interests and make profit. The French situation concerning energy policy is by tradition determined by the strong focus on nuclear energy. Nuclear energy research is located at the cross-roads of different, yet at the same time at least partly coinciding interests: the energy policy which is directed to energy independence; industrial policy directed to competitiveness of the nuclear industry, the defence policy, and so on. One interesting observation is that CEA, BRGM and also IFP are in a position to concentrate strongly on their research missions (defined by a number of steering mechanisms), and less on commercial activities which can be delegated to their subsidiaries.

With regard to aerospace, the technology institutes considered here are related strongly to those missions concerned with national security. A number of challenges have been identified for these organisations: the reassessment of national security interests, the diversification of technologies and the uncertain future for nuclear technologies. CEA, ONERA and also INRIA will need at least to partly redefine their reason of existence. Important steps have been taken to develop and strengthen industry relations. The CRIE consortium is an innovative form in which public agencies, public and private research organisations and firms participate to offer integrated high quality capabilities to industrial clients.
As was stated quite clearly in section 7.3, the new challenges will influence the policy and strategy debates at two levels: the institutional and the government level. It is reasonable to expect that policy discussions concerning redefinition of missions, internationalisation and cooperation, competitiveness versus the public function, competition with other organisations and so on, will intensify in the near future.

8 Spain

8.1 Introduction

This country study[27] covers the area of energy technology. The focus is mainly on CIEMAT, Spain's main centre of relevance for R&D activities in energy.

8.2 Energy

8.2.1 Introduction

The most characteristic institutes in Spain in the field of energy technology are:

- CIEMAT (Centro de Investigaciones Energéticas Medioambientales y Tecnológicas);
- ITER - Instituto Tecnológico y de Energías Renovables (Tenerife);
- IES - Instituto de Energía Solar - Universidad Politécnica de Madrid;
- ITC - Instituto Tecnológico de Canarias.

8.2.2 Mission, strategy, activities, markets

CIEMAT

CIEMAT is Spain's main centre for technological research and development activities in the field of energy. CIEMAT's infrastructure, as well as its main experimental facilities, are concentrated at Moncloa. The history and actual location of CIEMAT, comparable with that of ECN and other Europeans Institutes, makes it of relevance for this study. CIEMAT is an institute with some share of public financing. In addition to CIEMAT, other regional and local centres are emerging in Spain, driven by the need for decentralisation.

CIEMAT's activities are focused on the realisation of research projects, innovation and technological development and technical services in the field of energy, contributing towards the penetration of energy technologies in society under the best economics conditions and with the least possible environmental impact. Cooperation with others research groups with similar objectives at international level is essential to achieve this goal. CIEMAT's activities are basic research, technological innovation, technology development, testing and certification and training. The main areas in which CIEMAT is active include:

[27] Contributed by Ana Claver and Prof. Fernando Sanchez Sudón (CIEMAT).

- Improving the efficiency of fossil fuels and environmental quality (gasification, fuel cells, hazard agents, safety, risk perception)
- Nuclear fission energy (structural materials, radioactive waste, safety improvement)
- Demonstrating the future role of nuclear fusion (through the Association Agreement Euratom-CIEMAT, as well as the National Plan of High Energy Physics, associated with the CERN-programmes)
- Renewable energy (solar energy, wind energy, biomass)
- Environmental energy impact studies
- Socioeconomic studies.

CIEMAT operates several facilities:

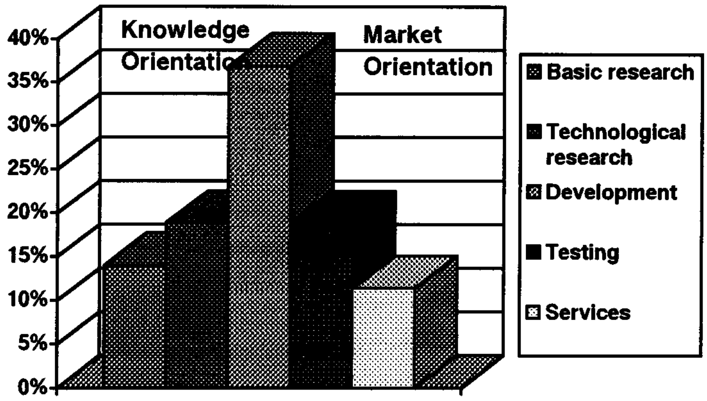
- The Solar Platform of Almer¡a is located in the Tabernas desert and is the most important European Centre for the development and application of solar thermal energy. It has been jointly managed by the CIEMAT and the German Institute DLR (Deutsche Forschungsanstalt f□r Luft und Raumfahrt) since 1987. This organisation has a wide range of facilities comprising different systems for solar energy concentration. The high level of prestige and international recognition of this centre is backed up by the fact that is has taken part in the European Programme of Access to Large-Scale Facilities Activity since its creation in 1990.
- The CEDER Centre for Development of Renewable Energy carries out activities concerning energy crops, and processes and technologies for the use of biomass energy. It is located in the Community of Castilla y Le¢n, a region that has enormous resources for the utilisation of biomass, and this makes it interesting from the point of view of regional development in terms of energy.

The CIEMAT addresses its activities according to the demand for research, technological development, and technical support in the areas of energy, the environment and related technologies. This demand focuses on the specifics needs of the private and the public sector, mainly on the different research programmes. CIEMAT's activities are focused on energy technology producers and users. It provides technical support for electricity companies, manufacturers, energy and engineering businesses, university and training centres and other regional technological research centres. The sectors in which R&D takes place are:

- nuclear sector: industry, safety and waste management;
- environmental technology development: safety, social and environmental impact companies, consultants, administrative bodies;
- renewable energy technology applications: wind energy producers and industry, the building sector, solar energy sector, agricultural sector.

CIEMAT addresses its activities in accordance with the demands of the private and the public sector. There is a distinction between the activities orientated towards knowledge and those orientated towards the market demand (testing and external services). The activities are distributed as shown in Figure 8-1.

Figure 8-1: Distribution of CIEMAT-activities



The different demand profiles are derived directly from the level of development in the energy technologies. How CIEMAT operates depends on the demand; flexibility in activities is therefore necessary. For instance, wind power is emerging as a competitive energy source and the response to the need is orientated towards industrial services, technological support and market acceptability. On the other hand, efforts in the photovoltaic sector are focused on basic research in order to improve technologies and pv-solar cells. Nuclear energy, with its problems of safety and waste disposal, requires activities orientated towards the market and the development of new nuclear technologies with a high investment in basic research in long lead time (fusion).

Other energy centres
The Technological Institute for Renewable Energies (ITER) was founded in 1990. It is financed mainly by the 'Cabildo Insular de Tenerife' and was established for study into and application of Renewable Energies at the Canary Islands. This Institute is collaborating with the main universities and foreign research institutes (Jülich, ISET, New Delhi). The Institute's main objectives are:

- Economic objectives: to minimise the dependency on imported oil, to reach competitive and stable prices in the canary Islands, to generate employment;
- Strategic objectives: to guarantee minimum least energy supplies for the production of drinking water and electricity generation;
- Technological and scientific objectives: To promote research on renewable energies; the development of conversion systems for exploiting renewable forms of energy; to create the framework necessary for the development of engineering and local industry; to promote national and international scientific agreements; the training of scientific and technical personnel in areas concerning renewable energies.

The *IES-UPM (Instituto de Energía Solar - Universidad Politécnica de Madrid)* is a centre integrated in the Polytechnic University of Madrid and devoted almost exclusively to photovoltaic research. It was founded in 1968 from the former Laboratorio de Semiconductores, whose work in photovoltaics started as a one of its major activities in 1975. At present the IES has a workforce of about 46. Its main activities are in semiconductor technology (Si and GaAs systems) and in solar optics (non-imaging optics, photovoltaic cells, prototypes) as well as in solar energy systems.

ITC - Instituto Tecnológico de Canarias. The Canary Island Technological Institute was established under the direction of the Government Department of Industry and Trade of the Canary Islands. The aims of this Institute are to rationalise technological and industrial development in the Canary Islands by promoting applied research activities. This facilitates the transfer of the corresponding results to the academic and business communities, and thereby promotes important 'value added' activities as well as general industrial development on the islands. ITC consists of a technological bureau, which is engaged in standardisation and technical advice, an energy development department, which carries out development projects (gas processing, renewable energy), and a research and development department engaged in energy and water research.

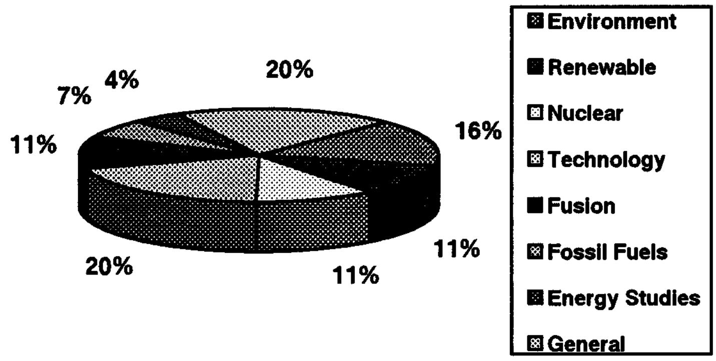
8.2.3 Key indicators and financial flows

CIEMAT employed a total of 1,330 staff in 1996 (including temporary professional staff). Many of the staff are employed under project-funded contracts.

Table 8.1: Distribution of resources.

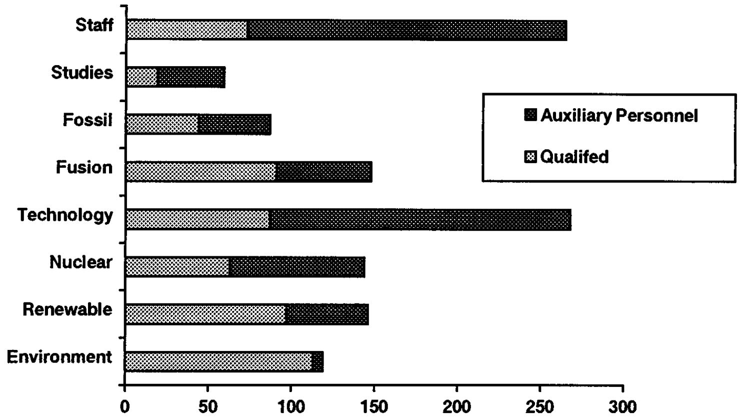
Qualified	Civil servants	173
	Personnel under contract	407
	Grants and training contract	13
Auxiliary personnel	Civil servants	264
	Personnel under contract	473
TOTAL		1330

Figure 8-2: Distribution of human resources by department (1996):



There is a trend towards increasing the share of qualified staff; this is currently 45% of the total. A rejuvenation of staff is also taking place.

Figure 8-3: Distribution of university graduates - assistants in the different departments:



CIEMAT's funding originates from governmental fund transfer, dividends from companies in which shares are held, and external income obtained from R&D activities. The income from external sources constitutes an important part of the Institution's budget. Income from external sources represents approximately 40% of the Institution's budget, including the European Union contribution, and government funding represents 60%.

Table 8-2: Sources of funds of CIEMAT:

Development of Economic Resources (KPtas)						
	1991	***1992***	***1993***	***1994***	***1995***	***1996***
R&D Activities	2416	2486	2852	3957	3104	3363
Companies*	409	590	289	498	723	577
Others	59	81	109	109	19	-2
State contribution	6298	5971	7142	6260	6136	6155
TOTAL RESOURCES	9182	9128	10392	10824	9982	10093
CIEMAT/State relation	***0,46***	***0,53***	***0,46***	***0,73***	***0,63***	***0,64***

** Resources ensuing from participation of CIEMAT in two national companies, ENUSA & ENRESA*

Table 8-3: Distribution of external income:

	MPtas.-	MPtas.-	%
State contribution		*331*	*10%*
National R&D Plan	167		
CSN*	41		
Rest	123		
Firms			
Public Companies		*873*	*26%*
ENRESA	807		
ENDESA	43		
Others	22		
Private Companies		*300*	*9%*
UNESA - OCIDE	65		
ELECTRICAL	81		
Others	155		
European Community		*1326*	*39%*
EURATOM	758		
Others	568		
OTHERS		*534*	*16%*
Total resources for 1997		**3363**	

* *Nuclear Safety Council*

CIEMAT's main market segments and clients are:

- Energy companies: electrical sector and others.
- International Framework.
- European Union Programmes.
- Supra-national bodies OCDE, ONU.
- Support to the Ministry of Industry and Energy. Energy policy and planning.
- CSN (Nuclear Safety Council), ENRESA (National Company for Handling Nuclear Wastes)
- SME (Small and Medium Enterprises). Technological centres.
- Training centres & University.

8.2.4 Trends and developments; key forces

Energy markets

The future energy industry implies a radical move towards a liberalised energy market. This, and other aspects, means more intense competition between electricity companies. Because of this new element of competition, R&D activities will probably be threatened in the short-term. This will call upon the public administrations to do all they can to avoid these adverse effects, possibly through regulatory mechanisms. One of the essential factors in the energy sector is that the technological institutes adapt to meet this changing market. Liberalisation policy is modifying the strategies of the technological institutes in the electricity sector. National programmes which include the stimulation of R&D and market stimulation must be implemented in view of a harmonised Europe. In Spain, the penetration of new technologies has been encouraged by means of a favourable pricing policy for energy generated by renewable energies as well as subsidies.

Funding of R&D
With regard to financial flows, it is unlikely that public funds will be increased in the near future. This a general tendency throughout the whole of the European Community. This decrease in public support must be supplemented with new resources. Technological institutions like CIEMAT are gradually being restructured and reoriented to bring them into line with the new trends of liberalisation and the associated, new market conditions.

Cooperation
CIEMAT cooperates with technological and research centres, electricity companies, energy companies, and universities at both national and international level. The degree of participation is set out in the different agreements with public and private organisations. In 1996 there were 556 ongoing agreements between CIEMAT and other organisations: 79 collaborations with public companies, 85 with public administration, 61 with universities, 85 with national private enterprises, 134 with foreign companies and 112 with the European Union. It should be pointed out that participation in the European R&D Framework Programme is one of the most relevant activities carried out at CIEMAT. It is one of CIEMAT's priorities to continually analyse the possibilities of cooperation in other programmes of a horizontal nature, and to open up new branches for cooperation with other countries, especially North-Africa and Latin America. The commitment to collaborate with the Spanish energy companies at national level, particularly with those in the electricity sector, has been a constant factor at CIEMAT.

There is strong collaboration with the university sector, and this is reflected in the total number of agreements with universities. All in all, 35% of these agreements are in the field of Research and Development, 35% in technological support and 30% are general agreements. One of the essential aims of CIEMAT is to act as an effective intermediary between university and industry.

Policy networks
CIEMAT operates in many networks, both national and international. At the national level it is engaged mainly with the Spanish Nuclear Safety Council (CSN) and the National Company for Handling Nuclear Wastes (ENRESA). The relations with the Spanish Nuclear Safety Council are regulated through an agreement that was established recently to harmonise the present collaboration. A Joint Commission CIEMAT/CSN is monitoring the activities on a regular basis. The areas of collaboration refer to R&D projects, training activities and technical services. ENRESA is the most important client from the point of view of resources generation. ENRESA R&D policy will be the main determinant of CIEMAT's activities. The relation between CIEMAT and electricity companies is also regulated through several agreements of collaboration for R&D projects.

8.2.5 Legitimisation: strategic issues and future perspectives

Given the growing global energy market, characterised by high competitiveness and rapid penetration of new technologies, a forceful intervention of governments in the implementation of fundamental policy changes and major RTD push is still found necessary. Of key importance in this scenario is the existence of publicly or partly publicly financed technological institutes.

Spain's energy policy is set in the European context. The targets for 1991 to 2000 are contained in the Energy Saving and Efficiency Plan which is part of the Spanish National Energy Plan. This plan presupposes a major increase in the use of new technologies, an interest in energy efficiency and an improvement in existing technologies. The Spanish Ministry of Industry and Energy intends to achieve these objectives through its various bodies for technology, policy research and technology transfer. CIEMAT, as a technological research centre in the field of energy, has both financial and institutional support from the government and addresses its actions to these main goals of the national energy policy.

CIEMAT is a public R&D institute which operates under the authority of the Spanish General Secretariat of Energy and Mineral Resources of the Ministry of Industry and Energy. The Ministry of Industry and Energy feels it essential to have an energy technological R&D centre to implement its energy policy. CIEMAT's budgetary policy is based on the Spanish Ministry of Industry and Energy budget debate. However, the trend seems to focus on future pressure from the Ministry to increase the self-financing capability. Integration of the R&D embedded in CIEMAT activities in the Spanish National R&D Energy Plan has always been an issue for discussion, yet up to now it has remained independent. However discussions are under way and more coordination with other R&D institutions is being established.

CIEMAT, as a public institution with a complex structure, has difficulty in anticipating the structural changes in energy markets. CIEMAT is already modifying its operational mechanisms in order to adjust to this newly changing market. CIEMAT's current structure can be typified by its focus on flexibility in contractual agreements. Institutions with more easily adaptable mechanisms would have a considerable advantage in the more competitive global market place.

In this respect, and in support of the new CIEMAT strategy, the most relevant activity in the restructuring process is the creation of a new R&D Commercial Directorate. The aims of this department are to achieve a better balance between clients, professional staff and promoters, at both national and international level, with the energy R&D Administration. This directorate will be responsible for generating external income to achieve the main objectives.

8.3 Concluding remarks

The transformation of the global energy market, which is characterised by the elements of liberalisation, a high level of competitiveness, a rapid penetration of technologies and a shift in the importance of energy approaches, requires that energy research organisations such as CIEMAT must adapt to the new situation. In the short term, R&D activities probably will be threatened. Technological institutions like CIEMAT are gradually being restructured and are becoming reorientated towards the new trends of liberalisation and the resulting new market conditions. At the same time, national policies (taxation, energy planning) are accommodating these restructuring processes.

9 Norway

9.1 Introduction

This country study[28] focuses on a range of strategic issues pertaining to publicly financed technology institutes in Norway. Central are aspects such as the institutes' market potential, sources of funding and vehicles for financing. The scope of this Norwegian study is limited to covering technology institutes focusing on the following two areas:

- Energy technology (exploration, conversion, storage, distribution of energy, energy systems and equipment, energy efficiency, etc.).
- Marine technology (ship design, simulation and building, computer simulation, water flow modelling and simulation, etc.)

The heart of the project encompasses both description and analysis of the strategic perspective for a technology area as a whole whereby descriptions of individual institutes are used for illustrative purposes. A certain amount of basic data on the institutes, such as money flows, etc., is also provided.

The selection of technological institutes was limited to those that have at least some share of public financing. More specifically, these institutes should be in accordance with the descriptions set out above. It must also be pointed out that these institutes should be engaged in a substantial amount of technological research and development activities. Nevertheless, there are certain kinds of technological institutes which may appear to be within the confines of our study but which do not lend themselves for this purpose. Typical institutes that have been excluded are those whose core activities are technology transfer or policy research, industrial R&D laboratories and university research centres.

This section presents the most characteristic Norwegian energy and marine technology institutes and is subsequently substantiated in brief. In the category of Marine Technology Institutes there seems to be one candidate only, namely MARINTEK (Norwegian Marine Technology Research Institute). In contrast, the category of Energy Technology Institute contains at least five eligible candidates. They are:

- SINTEF (Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology)
- IKU (IKU Petroleum Research)
- IFE (Institute for Energy Technology)
- EFI (Norwegian Electric Power Research Institute)
- CMR (Christian Michelsen's Research A/S).

[28] This chapter is contributed by J. Hansen and K. Smith (STEP).

The technology institutes will be given their official Norwegian abbreviations in order to facilitate reference to specific institutes. MARINTEK, EFI, IKU and SINTEF, which are all relevant technology institutes to our study, constitute the SINTEF Group. Given the dominant role in this study of SINTEF Group related institutes it goes without saying that this organisational superstructure should be presented in greater detail.

The SINTEF Group performs contract research and development for industry and the public sector in technological areas and in the natural and social sciences. With 1,950 employees and a turnover of NOK 1.4 billion, the SINTEF Group is Scandinavia's largest independent research organisation. Contracts for industry and the public sector account for 90 percent of their operating revenue. The SINTEF Group works closely with the Norwegian University of Science and Technology (NTNU). Experts in various disciplines collaborate on projects, sharing laboratories and equipment. Together with NTNU, the SINTEF Group functions as a source of expertise of high international standard. They also collaborate with the University of Oslo.

In closing this section we note that at least three other Norwegian technical institutes come close to qualifying as candidates for the energy category: TEL-TEK (Telemark Teknisk Industrielle Utviklingsenter); RF (Rogalandsforskning); and NR (Norsk Regnesentral). This trio is mentioned on the grounds that they all perform basic research on inter alia energy related issues. They are excluded from the study because of their lack of concentration in the relevant field; this applies in particular to TEL-TEK and NR. Whereas RF does perform a number of projects relevant to our topical focus we have to draw the line somewhere in terms of number of selectees.

9.2 Marine technology

9.2.1 Introduction

MARINTEK is the only Marine technology institute in our survey. However, MARINTEK can be divided into five departments:

- Marine Vehicles
- Offshore Structures
- Machinery
- Technical Operations
- Fisheries and Aquaculture

All of these departments, save the last, meet our selection criteria. Consequently, our focus will rest on these. The company carries out R&D projects for industry and the public sector, primarily in the national market for developing new technological solutions in the following sectors:

- Ship development
- Shipyard technology
- Shipping

- Offshore industry
- Marine equipment industry
- Fisheries and aquaculture

9.2.2 Mission, strategy, activities, markets

Ship development
MARINTEK has actively contributed to the development of new improved vessels for Norwegian and overseas clients. Ships with lower fuel consumption, reduced emissions and better seakeeping properties and manoeuvrability have been developed with the aid of MARINTEK's specialist expertise and laboratory facilities. For shipyards this means better products and greater competitiveness; for shipowners, lower operating costs and safer vessels. The development of a new passenger vessel for a Norwegian shipyard in collaboration with a shipping consultant, and the development of more efficient engine-rudder combinations, are just two examples of Norwegian projects that MARINTEK has carried out. Internationally, MARINTEK has carried out a number of concept studies of cruise ships, with the emphasis on manoeuvrability and ship-handling characteristics, for one of the world's leading shipyards.

Shipyard technology
MARINTEK has taken the initiative to put greater effort into this area and is currently a major initiator of joint research projects in which new construction methods, manufacturing and planning processes for more efficient building of special vessels are given priority. The VP Forum has now been established as a full value shipyard research programme in which most Norwegian shipyards are participating. Of MARINTEK's special projects, 'Station-oriented manufacturing for hull section construction' is worth a special mention. This is being carried out in cooperation with several Norwegian shipyards. 'Purchasing during the sales phase' is another project for a major shipyard.

Shipping
Shipowners are keen to improve their competitiveness via cheaper and more rational operation. In collaboration with shipping companies, MARINTEK is developing new operating models based on a critical study of work processes that aims to identify activities that do not add value. Onboard and onshore training of shipping company personnel is a topic under scrutiny. MARINTEK supplies computer-based training systems that help to raise the quality of services and make vessel operation safer. This area has been addressed via the Research Council's user controlled programme 'Maritime IT Operation'. Strategic efforts based on value chain analyses are of importance for the ability of shipping companies to make profit. MARINTEK has been heavily involved in processes of this sort through its involvement in the user-controlled programme 'Marine Transports and Logistics'. MARINTEK's wide knowledge of the field of optimal vessel operation and logistics makes them an attractive partner for shipowners in analyses of complex problems of this sort.

Offshore industry
For a number of years MARINTEK has been a centre of expertise in the development of floating offshore installations that operate under extreme weather conditions. Dealing with structural loads caused by wave forces and currents demands specialised knowledge in a number of different fields, such as hydrodynamics and construction technology. The development of oil fields at great depths makes heavy demands on new, advanced mooring systems and riser technology. MARINTEK carries out theoretical and physical modelling of such concepts for Norwegian and international actors in this sector, with the aim of producing cost efficient, novel and safe technology. MARINTEK's Ocean Basin was in great demand in 1996. Deepwater projects for the Brazilian oil company Petrobas and trials of concepts for the Troll C and Åsgård fields are among the important projects that MARINTEK has carried out.

Marine equipment industry
The equipment industry is an important element of the Norwegian shipping industry. Norwegian equipment is renowned for its quality and serviceability. TBL Skipsutsstyr has initiated an interdisciplinary R&D programme focusing on the manufacturing efficiency and total lifetime costs of equipment, with the aim of maintaining the international competitiveness of companies in this sector.

MARINTEK carries out applied research in a wide range of subjects for Norwegian and international equipment industry. Topics here include improvements in engine processes for lower exhaust emissions and higher coefficients of efficiency for diesels and the new generation of natural gas engines. Other activities include MARINTEK's involvement in the development of new maritime transportation systems. Starting out from MARINTEK's workshop and laboratory facilities prototype construction and tests of machinery and equipment have offered interesting challenges.

9.2.3 Key indicators and financial flows

Table 9-1 displays the total revenues measured in million NOK of MARINTEK by type of income. Core funding denotes the income constituted by the Norwegian Science Council's core funding in tandem with other public and private transfers. The private component of funding is very small. As a result, one may for all practical purposes consider the heading core funding to reflect the magnitude of annual public lump sum transfers. One should note that the figures listed below the heading '1996' reflect temporary estimates of 1996 accounts. The heading 1997 shows the budget for 1997 and the last heading, 1998, denotes the proposed budget for that year.[29]

[29] One problem is that the figures are not really directly comparable in any meaningful way, as they just seem to be nominal NOK without being anchored to some specific year.

Table 9-1: Funding of MARINTEK

	1996	1997	1998
Core funding	15.6	12.3	18
Contract revenue	150.1	168	167
All other revenues	3		
Total revenues	168.7	180.3	185

The private element in the funding of these institutes is by and large of a contract nature. Table 9-2 shows the degree to which contracts stem from different kinds of funding.

Table 9-2: Sources of funds (contract revenues, 1996, Mln NOK)

SCIENCE COUNCIL	GOVERNMENT ADMINISTR.	R&D INSTITUTES	PRIVATE SECTOR	FOREIGN
1996	1996	1996	1996	1996
6,5	9,9	2,7	97,4	33,4

9.2.4 Trends and developments; key forces

Prospects in shipping, shipbuilding and the equipment industry
In its discussion of the Maritime White Paper, parliament set out the general conditions that will affect actors in the maritime industry. The importance of continuing to develop a total maritime industry in Norway will be given high priority. In order to follow this up, the Research Council has launched a new research programme known as 'Maritim'. In collaboration with the Norwegian maritime industry, MARINTEK has actively contributed to defining the contents of this programme, which is divided into the following subprogrammes:

- Vessel operation and technology
- Marine transport and logistics
- Shipbuilding and technology
- Ship equipment and technology

MARINTEK participates actively in these projects which form the basis of Norwegian research in shipping and shipbuilding for the coming four years.

Prospects in the oil and gas industry
The main challenges facing the oil-related industry in the near future will be in the field of production at depths of up to 2,000 m. The petroleum industry contributes directly to MARINTEK's development of expertise in this field, in which wave and current loads on floaters, moorings and risers offer completely new challenges for safe operation. Among other things, MARINTEK is commencing strategic co-operation with Norsk Hydro in this type of deepwater research. A rapid rise in the use of production vessels for the development of marginal fields has brought about a major increase in activity at MARINTEK, and the board expects this tendency to result in a large volume of contracts in

the near future. MARINTEK possesses unique competence in the use of liquid natural gas (LNG), and is one of the world's leading centres of expertise in gas-fuelled engines. For reasons related to natural resources and the environment the board expects a movement towards the use of LNG, where cost-efficient distribution methods make this possible.

9.2.5 Legitimisation: strategic issues and future perspectives

The scope for and setting of basic research at MARINTEK
MARINTEK holds that every research institute must stay at the leading edge of developments within the sectors of industry it serves. In addition to contract research, therefore, it is essential to do long term basic research in order to build up a general level of competence within critical subjects. This type of effort is implemented via strategic institute programmes that are financed by MARINTEK's profits, through contributions from the Research Council and through direct contributions from major industrial companies. In the course of 1996, MARINTEK completed the strategic institute programmes known as 'Operating Technology Laboratory' and 'Extreme Conditions at Sea'. Ongoing strategic institute programmes include 'Development Tools for the Coming Generation of Machinery', 'Maritime Logistics- Local Shipping' and 'Hydrofish'. At least two further strategic institute programmes relevant to our line of inquiry, will be launched during 1997: 'Fisheries in 2010: New Vessel Concepts' and 'SKIPRO 2001: Resistance and Propulsion'.

Policy discussions at the national level
A description of the general policy framework concerning R&D is described under section 9.3.5 (Energy). An important R&D programme in the area of marine technology is MARITIM (1996-2000; 175 million NOK). Its stated intentions are as follows:

- Enhance profitability and competitiveness in the maritime industries.
- Uphold, through R&D, Norway's leading status in maritime activities.
- Contributing to sustainable shipping through a cost efficient regulatory framework, in addition to developing Norwegian maritime services and products meeting the highest international standards.
- Ensure quality control and increase the volume of Norwegian maritime research through active cooperation with foreign research milieus.

The target group is widely defined as a totality of the maritime cluster, shipping, technical and commercial services, wharves and supplying industries, relevant authorities.

Generally spoken, the Norwegian government foresees an active participation in designing the production of knowledge in the years to come. As seen from earlier tables, the share of contract revenue of private/foreign origin is very high. Hence, beyond core financing and strategic institute programmes, the technology institutes are very much in need for showing competitiveness in attracting additional funding.

9.3 Energy

9.3.1 Introduction

We presented our selection of Norwegian energy technological institutes in section 9.1. Emphasis is on SINTEF, IKU, IFE, EFI and CMR.

9.3.2 Mission, strategy, activities, markets

SINTEF
SINTEF is the largest technology institute conglomerate in our survey. In 1996 it reorganised its research activities, resulting in a move from roughly 30 departments to 9 research institutes. This organisational structure already seems to have had beneficial effects. In particular, individual research institutes appear to have developed stronger identities. As a direct result of reorganisation, individual institutes are allowed greater focus on their core activities. The SINTEF institutes perform multifaceted tasks with greater and lesser relevance to our survey. In light of this we selected the following SINTEF institutes:

- SINTEF Material Technology consists of eight departments, ranging from areas such as welding of steel and aluminium, remote welding of pipes at great depths, to mechanics of fractures and materials testing.
- SINTEF Applied Chemistry. Its single most relevant department is Oil and gas refinement.
- SINTEF Energy also encompasses a couple of departments in our area of focus. The multiphase laboratory has unique facilities for examining the characteristics, transportation and storage of natural gas. Other relevant elements in this department are for instance the group working on low temperature process techniques and the group working on hydrate removal in petroleum pipes. Another department that deserves mention in our context is the Department for Thermic Energy and Hydro Power.
- SINTEF Applied Mathematics delivers mathematics for application to industrially oriented problems by means of computers.
- SINTEF Electronics and Cybernetics performs R&D in areas bordering on our topic of interest. Most relevant are probably issues pertaining to analyses of seismic signals.
- SINTEF Civil and Environmental Engineering encompasses departments focusing on concrete, geotechnic, construction technology, mining, hydrology and waterfalls, etc.

EFI-Norwegian Electric Power Research Institute
The latest annual report available is the 1995-edition. Of the strategic work done by EFI during 1995, mention should be made of development work in applying new technology to large scale transmission systems, diagnostic methods for solid insulation, high frequency power electronics construction and the description and means for handling energy market uncertainty. EFI is also engaged in two Norwegian Research Council Programmes, one to investigate the influence of extreme weather conditions on electric power systems

and a second concerned with operating and developing hydrothermal power systems in deregulated markets. This has reinforced EFI's position as Norway's dominant research institute for the electric power industry.

EFI has been accepted as a partner in three projects in the EU's 4th framework RTD programme. These are concerned with maintenance planning, the transmission system and lighting technology. EFI has ongoing contact with Elforsk in Sweden, DEFU in Denmark and VTT in Finland to discuss Scandinavian cooperation.

EFI divested in 1996 a software enterprise consisting of 40 co-workers, which is the largest single divestiture in twelve years. The newly established enterprise is called Powel Data and foresees future cooperation with EFI on the development of new products.

Future prospects for EFI
One of the Research Council's programmes, EFFEN, ended in 1996. As of 1995 EFI could inform that the successor programme had already been planned and that EFI had been allocated central tasks. The new programme is titled EFFEKT and is to last from 1996 until 2000.

IKU Petroleum Research
IKU presently encompasses several research areas. These are as follows:
- Production Oriented Geo Research
- Petroleum Oriented Formation Physics
- Reservoir Characterisation
- Drilling- and Well- technology
- Oil Pollution and Contingency Planning

IKU strengthened its commitment to strategically important areas of expertise in 1995 through enhanced efforts and access to so-called strategic resources. Developing new spheres of expertise and technology is a huge task entailing a long-term commitment (3-5 years). Nevertheless IKU considers this strategically important and necessary. Through its contact with industry the company has been encouraged to continue developing their spheres.

Within reservoir characterisation, the goal is to contribute towards a better understanding of reservoirs in order to optimise oil- and gas production strategies. This is based on IKU's basis of expertise within geology, reservoir description, formation physics, seismic methods and logging technology.

Reservoir characterisation is divided into the sub-programmes formation, evaluation and quantitative geological description. IKU has succeeded in giving this area a technological content that is of interest to oil companies. Its development potential was confirmed in 1995 by the establishment of major projects on the basis of the company's efforts. With the support of the Norwegian Research Council, a strategic collaboration with the Norwegian Computing Centre has got off to a good start.

The Exploration department's focus on migration studies will be expanded in 1996 to include source rock studies. However, the oil companies' focus on applications for the 15th licensing round in 1995 made it difficult to access the industry as early as expected. Hence, IKU did not get the clarifications necessary for advancing its sales efforts. The company's aspirations in these two priority areas are based on a solid knowledge of the oil companies' needs and may be an important source of income for IKU in the future. The department has attained a key position within the Norwegian Research Council's user controlled programmes where it is a main applicant for three long term projects, two within the 'LETE' programme and one within the deep sea technology programme.

CMR-Christian Michelsen Research

CMR carries out research in the following relevant areas:

- Industrial instrumentation (gas metering, multiphase metering, process monitoring, environmental monitoring)
- Process and safety (separation, gas explosions, dust explosions, dust explosion test laboratory, gas explosion consultancy).

FLACS, a simulation program for gas explosions, was launched by CMR late last year. The results of more than 15 years of research and development were thus made available to oil companies and engineering contractors throughout the world. Three international oil companies now specify the use of FLACS in the design and modification of gas processing plans. The challenge now facing CMR is to ensure that FLACS is established as the industrial standard for the assessment of gas explosions. Since 1980, CMR has cooperated with leading international oil and gas companies to promote safety at industrial gas plants through an improved theoretical understanding of the nature of gas explosions. In the last decade, work has concentrated on developing FLACS, which simulates gas explosions in offshore as well as onshore processing plants. In 1996, FLACS was verified against full-scale gas explosions in a realistic offshore processing module.

In 1996, CMR carried out 237 projects, 158 of which were industrial projects, in particular for the oil and gas industry. Industrial projects account for about 63% of turnover and are primarily aimed at product and process development.

Partners in research and development

For five years the Norwegian Research Council has contributed basic funding which has enabled CMR to renew its offer of internationally competitive product-oriented development projects. The Board therefore considers the further funding of CMR to be a great challenge. Through TEFT, the national programme for transfer of technology from research institutes to SMEs, CMR is developing its services aimed at smaller companies.

In terms of academic cooperation, The University of Bergen is the most important partner. However, there is also collaboration going on between CMR and Rogaland Research.

IFE-Institute for Energy Technology

IFE is a national research centre for energy and nuclear technology. The greater part of the institute's total activity still revolves around the two research reactors in Kjeller and Halden. Remaining activities fall into the categories of petroleum technology and other energies technology with shares of total volume in these areas of respectively 30 and 15 percent in 1995.

The research programme at Halden is oriented towards safety and reliability of operations at nuclear power plants and other highly complex process facilities. The work done has received great and still growing international attention. The interface of the Halden programme with leading international technology institutes enables IFE to access the very latest research results and technology, consequently enabling its expanding contracting for Norwegian industry.

The scope of this activity grew from 38 million NOK in the three year period 1988-1990 to more than 80 million NOK in the period 1994-1996.[30]

A committee appointed by the Norwegian Research Council evaluated the benefit accruing from the Halden project to Norwegian authorities and concluded very positively about its performance. Moreover, the committee recommended further continuation of the Halden project for another three year period and that the institute should prepare an application for renewed concession to operate the Halden nuclear reactor beyond the year 2000.

IFE's nuclear activities at Kjeller still depend on the operation of the research reactor JEEP II. Activities at Kjeller have been restructured as a consequence of the fact that the core funding for IFE is transferred from the Ministry of Industry and Energy to the Research Council.

Other parts of IFE - that is activities in areas of energy efficiency, renewable energy and energy systems' analyses - have also been regrouped into one single new department, in response to shifting energy market structures and public set framework conditions. IFE is taking part in a series of big projects developing IT systems for processing industry and the hydro power system. With respect to petroleum technology, IFE has concentrated on larger projects in close cooperation with oil companies and supplying industry. IFE's multiphase-related research are central to the development programmes of Statoil, Hydro and Sagas in the area of multiphase transport technology. In tandem with IKU, NGI and a number of oil companies IFE has contributed to shaping the Research Council's LETE programme. This programme aims at the development of improved methods and computer tools for simplifying and enhancing efficiency in making new hydrocarbon discoveries.

[30] However, the annual report does not say whether or not these amounts are measured in nominal NOK at different points in time, if which it would thereby be effectively making such a statistic very rough at best. Calibration would be need to be able to judge this kind of result on an equal footing. Secondly, as regards the reported increase in contracting it is extremely important to allow for the time dimension here as the former of these two three year periods were a very low rough, conjuncture wise. How much of the increase is owing to improved IFE behaviour and how much is attributable to other factors?

The IFE board stresses the importance of international cooperation for the activities of the institute. The export earnings of the Halden project alone contributed more than 150 million NOK in 1995. Also Kjeller is characterised by its cooperation with international R&D milieus and industrial enterprises in the set of IFE activities performed there.

IFE has very actively endeavoured to be involved in a variety of research directions in the European Union's new common research initiative, the so-called framework for R&D. IFE partook in roughly
50 project applications and aims to collaborate with Norwegian businesses, industry and government in 'its' EU projects.

9.3.3 Key indicators and financial flows

Table 9-3 a-d displays the total revenues measured in million NOK of the selected energy technology institutes by type of income. Core funding denotes the income constituted by the Norwegian Science Council's core funding in tandem with other public and private transfers. However, for all the technology institutes in our study the component private lump sump transfers is negligible. As a result, one may for all practical purposes consider the heading core funding to reflect the magnitude of annual public lump sum transfers. One should note that the figures listed below the heading '1996' reflect temporary estimates of 1996 accounts. The heading 1997 is shows the budget for 1997 and the last heading, 1998, denotes the proposed budget for that year.[31]

Table 9-3a Core funding

	1996	1997	1998
CMR	13	7.8	9
EFI	8.3	8.4	8.4
IFE	92.4	90	94.4
IKU	5.3	6.5	6.5
SINTEF	90.4	90.2	95

Table 9- 3b Contract revenue

	1996	1997	1998
CMR	42.3	46.8	50
EFI	87.3	76.3	76.3
IFE	291.5	293	303.7
IKU	91.9	79.9	83.5
SINTEF	911.3	860	865

[31] One problem is that the figures are not really directly comparable in any meaningful way, as they just seem to be nominal NOK without being anchored to some specific year.

Table 9-3c: All other revenues

	1996	1997	1998
CMR	2.6	3.9	4
EFI	4.4	1.1	1.1
IFE	1.7	3.3	2.9
IKU			
SINTEF	19.9	27	15

Table 9-3d: Total revenues

	1996	1997	1998
CMR	57.9	58.5	63
EFI	100.6	85.8	85.8
IFE	385.6	396.3	401
IKU	168.7	86.4	90
SINTEF	1021.6	977.2	975

The private element in the funding of these institutes is by and large of a contract nature. Table 9-4 shows the degree to which contracts stem from different kinds of funding, for the energy technology institutes in this concerned.

Table 9-4: Source of funds (contract revenues, 1996, Mln NOK)

	SCIENCE COUNCIL	GOV. ADMIN.	R&D INST.	PRIVATE SECTOR	FOREIGN
YEAR	1996	1996	1996	1996	1996
CMR	6,80	3,3	1,1	21,7	9,5
EFI	2,1	1,9	0,7	74,3	9
IFE	6,5	40,6	2,6	56,8	185
IKU	5,5	3,3	2,9	72,8	7,4
SINTEF	116,5	160,5		500,6	133,8

9.3.4 Trends and developments; key forces

The total R&D expenditures in Norway amounted to only 1.94 percent of GNP. The average for the OECD countries is 2.22 percent, while countries such as Japan, Sweden and USA invest in R&D in a order of magnitude of 3 percent of GNP. *Industrially oriented* R&D financed by the Government has, when measured in fixed currency, not grown during the latest seven years. This starkly contrasts the fact that in the same period of time the total of governmentally funded R&D in *all other areas* has grown in excess of 50 percent!

In the years to come, the Norwegian Government foresees an active participation in designing the production of knowledge. This is illustrated in the next section where strategic programmes of energy research are discussed. Needless to say, by defining and officially stating objectives of programmes the Government actively shapes the direction and scope of the research undertaken at the various technology institutes. However, the share of contract revenue of private/foreign origin is very high. Hence, beyond core financing and strategic institute programmes, the technology institutes are very much in need for showing competitiveness in attracting additional funding. In this regard, one may consider the public revenues as somewhat more certain than the private funding. However, recessions usually lead to cutbacks on all expenses, research outlays being no exception to the rule.

As regards the question about the consequences for the relevant technology institutes, one should note that they expect a moderate increase in their turnovers hence there is not expected any dramatic change in the volume of activities in the years to come.

9.3.5 Legitimisation: strategic issues and future perspectives

This section focuses mainly on issues pertaining to the legitimisation of and strategic orientation of energy technology institutes and their government funding. Central to our assessment will be an evaluation of inter alia the role of the various actors in financing and controlling the technology institutes, and the forces that are into play such as politics, financing, markets and industry.

The Government employs two institutional vehicles, in addition to direct Governmental cooperation with the institutes, for handling the system of innovation in Norway, the Norwegian Science Council (NFR) and the Norwegian Industrial and Regional Fund (SND). In relation to the technology institutes, it is NFR which coordinates, designs and allocates funds, programmes and projects among applying technology institutes. SND, on the other hand deals more directly with SMEs.
As shown in earlier sections, the Government finances the technology institutes mainly through two channels; the Science Council and the direct contracting for departments. The funds channelled through the Science Council to the technology institutes stem chiefly from two departments; the Department of Industry and Energy and the Department Culture and Education.

There are two divisions in the Norwegian Science Council which are of particular relevance to the technology institutes, namely the Division for Industry and Energy (DIE) and the Division for Science and Technology (DST). The six programmes described above are all part of the DIE's strategic programmes, which encompass enterprises, technological institutes and universities. One should note that in the DIE strategic programmes DIE is a partner for those parts of industry and cooperative technology institutes which are able to identify projects with great growth potential domestically, and in which a R&D investment will bear positively on its realisation.

Voiced criticism of the present arrangement of affairs in NFR centres on the fact that the industrially focused research is bifurcated into two divisions in NFR, DST and DIE. This contrasts the other topical divisions in NFR, in which the distinction between applied and basic research is not drawn divisionally. In fact, it was precisely one of the driving motivations for the creation of the more centralised institutional body of NFR, to replace the preceding conglomerate of coordinating institutions like NAVF, NFFR, NLVF and NORAS.

In spite of the fact that it is the Government through the Norwegian Science Council who allocates funds to the technology institutes in the form of various types of programmes' funding, it is also undeniably so that the strategic programmes are initiated by the R&D environments and are in turn given priority by the administration of faculties and institutes according to strategic aspects of R&D.

These strategic DIE programmes are so-called user oriented which in the terminology of the research council means that they presume a funding participation from industry of at least 50 percent. Factors affecting the Science Council's share of funding are the degree of risk involved and the novelty of the ideas being developed.

In contrast to these strategic programmes are the core fundings allocated to the technology institutes. The total core funding of technology institutes as discussed in the beginning of this chapter is for all practical purposes financed by the DST in the Co Science Council. The Science Council's funding of technology institutes constitute 19.2 percent of their total funding in 1996 as compared to 19.5 percent in 1995.

It seems natural to discuss the policy programmes that will be effective during next few years in energy technology. There are at least five programmes to consider:

- EFFEKT; a programme for power transmission and grid monopolies
- NYTEK; a programme for renewable energy technologies
- NATURGAS; a programme for developing profitable goods, services and processes related to use and distillation of natural gas
- RESERVE; a programme for search, well and development technology
- UTBYGG; a programme for environmentally sound and profitable development of small sized petroleum lots and deep sea technology.

An obvious reason for bringing forward the governmentally funded R&D programmes, is that this exposes important trends in governmental approach towards Norwegian technology institutes.

As will come clear from table 9-5, all these programmes are rather large financially. This table shows that there will continue to be a large government funding in energy-focused R&D. The legitimisation for these programmes are as follows.

Table 9-5: Overview of programmes

Program	Duration	Amount
EFFEKT	1996-2000	140 million NOK
NYTEK	1995-1999	89 million NOK
NATURGAS	1996-2000	95 million NOK
RESERVE	1996-2000	127 million NOK
UTBYGG	1996-2000	145 million NOK

EFFEKT aims to sustain the public investment in user oriented R&D on energy supply, but also other forms of energy which are relevant in conjunction with the supply of electricity. The target group of the programme is the energy industry, the energy supply and the administrations. The programme has three main focuses:

- Power transmission
- Effective net monopolies
- Outdoors environment and safety

The programme seeks to increase the rate of profit of Norwegian enterprises focusing on electric power within the confines of a presumably sustainable development. Moreover the programme is supposed to yield new environmentally acceptable systemic and technical solutions:

- Improving upon the Norwegian power exchange with abroad
- Increasing the efficiency in the running of the national net monopolies
- Contributing to greater value added in the sector by strengthening the competitiveness stimulating the export of goods and services from the sector.

NYTEK is a programme oriented towards research on renewable sources of energy and is mandated a support function for developing until a concept reaches the stage of prototype. The kinds of energy encompassed in this programme are bio, solar, wave and wind. Notably hydropower is not included in the programme. The programme focuses on efficiency and transformation aspects of these alternative energies. The main purpose of the programme is to promote increased value added related to the development of efficient renewable energy technologies. This main purpose divides into three sub targets defined as follow:

- Contribute to developing new products which plausibly total 1 billion NOK in turnover for Norwegian enterprises within 2005.
- Contribute to paving the road for future industry activities and operations within development and use of efficient renewable technologies
- Contribute to establishing at least 10 EU programmes with Norwegian participation, of which five should include the participation of Norwegian enterprises

The target group for the programme is mainly Norwegian enterprises seeking to develop efficient renewable energy technologies. Norwegian R&D milieus embody great knowledge and these milieus will constitute the main cooperative partners in developing new technology and new products.

The programme NATURGASS aims to:

- Contribute to the development of profitable products and services based on the application of natural gas.
- Contribute to the development of new and existing gas-related processes and applications in a process context.

The first of these two targets is oriented towards products for direct usage of natural gas in a distributed system, with many relatively small users. This activity is export oriented. The second target bears mostly on the process industry. However, one should bear in mind that it is clearly stated in documents from the Norwegian Research Council that priority is given to projects in which its participation triggers R&D activities. Relevant technological institutes for this programme are amongst others CMR, SINTEF and RF.

RESERVE is a user-managed R&D programme including topics such as search technology, well technology and reservoir technology. This programme seeks to implement the Norwegian authorities intention to secure an optimal management of resources and to further the development of the Norwegian oil industry and R&D standard by means of:

- Developing new or bettered technologies which reduce costs and increase the potential of the reservoirs.
- Triggering the completion of R&D projects involving high risk in tandem with great profit potential whilst accommodating standards of environmental risk and safety.
- Increase the extent to which Norwegian industry partakes in R&D within the petroleum sector.

The programme UTBYGG states as its main ambitions to:

- Developing methods and technical solutions (processes and products) which are accessible and marketable and which enable the oil producing companies to perform safe, environmentally sound and profitable development of oil fields situated down to depths of 2000 meters below the surface. Moreover, the programme holds that the investment projects undertaken in R&D should have potential markets worldwide to justify such outlays.
- For fields located at medium depths there is a need for a technical solution which can render production profitable at oil prices as low as $10 per barrel.
- The Norwegian energy supply industry is seeking to achieve a better position for the possible contracting of supplies for the development of new oil fields, both Norwegian and foreign.
- The discharge of environmentally damaging compounds to ambient air and water is to be lowered. A stated target is a reduction of 50 percent within the next five years.

The target group for the programme is Norwegian supplying industry and the sub- contracting sector. The implementation of the programme requires active R&D participation from the technology institutes and the universities. From this description of strategic institute programmes it can be concluded that the Norwegian government foresees an active participation in designing the production of knowledge in years to come.

9.4 Concluding remarks

In the area of marine technology research, emphasis is strongly on market orientation, competitiveness and efficiency. MARINTEK is very successful in realising commercial goals. The amount of basic subsidy is rather low and in line with examples from other Scandinavian countries. There is no evidence of important changes in the policy environment of maritime technology research.

Energy research is carried out by a number of institutes of which SINTEF is the dominant one. The amount of basic subsidy varies between 10-20%, illustrating the strong market orientation of research and competitiveness of research organisations.

10 Germany

10.1 Introduction

This country study[32] provides an overview of the situation of publicly financed institutes working in the fields of energy and aerospace in Germany. It is based on a survey of the relevant literature (in particular, annual reports and research programmes) and interviews with relevant institutes and the responsible ministries.

In Germany there is a wide system of publicly supported institutes. Institutes funded by the federal and länder (state) governments (within the context of article 91b of the German basic law) and publicly funded institutes (supported by the federal government only) play an important role in national R&D tasks. This country study focuses in particular on institutes which also undertake contract research, funded by the federal and l„nder governments only, allowing them to work on a fairly long-term basis with regular funding. It does not include institutes supported only by the länder and/or industry, nor does it include the universities[33]. These institutes receive at best restricted support depending on the nature of their projects, although they do carry out a substantial percentage of energy and aerospace research. In most cases these institutes benefit from the support of the federal government in an indirect way, for example, by using large-scale equipment or by taking on research assignments.

In Germany in particular, those publicly funded institutes working in the energy and aerospace sector tend not to work very closely with the industry. The cooperation between them is still in its infancy and is being encouraged and promoted by the research ministry.

The structure of this country report differs slightly from the other country reports. The technology fields of energy and aerospace are dealt with under their own specific heading where the relevant institutions in the field are described. Most institutes examined operate in the field of energy. Institutes working in the aerospace sector are concentrated in DARA or DLR. The subsequent sections describing the external environment for German research institutions are relevant for both technology fields.

[32] This country study was contributed by Christine Wennrich (VDI TZ Future Technologies Division).

[33] The federal government is involved in the university infrastructure through the Gemeinschaftsaufgabe (Joint Task). This is a major project for which the federal and state governments are jointly responsible.

10.2 Energy

10.2.1 Introduction

The most characteristic publicly financed institutes working in the areas of energy and aerospace can be divided into supporting bodies and major research facilities.

Supporting bodies
Here, a number of institutes are combined under the patronage of one society, but each institute is autonomous. Characterisation of these institutes is difficult because the supporting bodies are subdivided into a large number of institutes. Data is only available for the supporting body as a whole. The Max Planck Gesellschaft (Max Planck Society) and the Fraunhofer Gesellschaft (Fraunhofer Society) select their own research profile of the 150 research institutes and working groups themselves. Data are given for these two organisations.

Major research establishments
The major research establishments represent an important part of research capacity in Germany. The concentration of considerable financial and human resources, a highly qualified scientific/technical infrastructure and a management structure similar to that operating in the private sector allow the establishments to work on complex scientific/technical issues and cross-section tasks, to use large-scale scientific and technical equipment and to develop system solutions. Dealing with tasks that demand continuity and cooperation across institutional, national and technical boundaries. Thus, basic, preventative/foresight research and the research and development of future technologies chiefly determine the projects and research programmes of these establishments.

The major research establishments are characterised by autonomy and decentralisation. Although not involved in the actual research themselves, they are of particular consequence for the support of new themes because of their flexibility. They work independently within the limits of the federal government research programmes. They also have close links with the universities. On account of their diverse integration in international agreements and consortia they are able to occupy a key position in international dialogues and cooperative ventures.
The major research establishments receive institute-specific funding from the federal government (90%) and the *land* in which they are situated (10%).

The following research establishments are briefly described:
- Hahn Meitner Institut Berlin (HMI)
- Kernforschungszentrum Jülich (KFA)
- Forschungszentrum Karsruhe, Technik und Umwelt (FZK)

Establishments on the ”Blue List”
If they are of national significance, independent research institutions and establishments with research services departments also receive public funding. These institutes receive institute-specific funding from the federal government (50%) and the land (50%). Described is the Institut f□r Erd”l und Erdgasforschung (IfE).

10.2.2 Mission, strategy, activities, markets

Max Planck Gesellschaft zur Förderung der Wissenschaften (MPG)
The *Max Planck Gesellschaft zur Förderung der Wissenschaften (MPG)* is a supporting body which coordinates around 100 institutes as well as labs, research establishments and working groups which differ in size, structure and tasks; carries out basic research in specific selected areas including natural sciences, social sciences and arts; supports new research fields thus supplementing the research done by universities; and cooperates with the universities and puts its equipment at the disposal of university researchers. Since 1972 the Max Planck Gesellschaft has established some 70 departments and institutions and closed around 50.

Example: *Max Planck Gesellschaft für Plasmaphysik (Max Planck Institute for Plasma Physics, IPP)*
The fusion research being conducted here is aimed at reproducing on earth the energy production process occurring on the sun. A fusion power plant will derive energy from the fusion of atomic nuclei. The research activities are concerned with investigating the plasma physics principles underlying a fusion power plant: the confinement of high-temperature hydrogen plasmas in magnetic fields, heating and refuelling, plasma diagnostics, magnetic field technology, electrical and electronic engineering, data acquisition and processing, system studies, plasma theory and plasma-wall interaction. For this purpose the IPP is conducting two large-scale experiments, the ASDEX Upgrade tokomak and the Wendelstein 7-AS stellarator. A successor to the present stellarator experiment, Wendelstein 7-X, is under preparation which is intended to demonstrate the reactor relevance of the stellarator concept developed at IPP.
The Plasma Diagnostic Division is primarily concerned with investigating the behaviour of impurities in plasma. For this purpose a variety of measuring equipment is being used to investigate plasmas in the fusion experiments.
IPP has hosted the European NET Study Group and, since 1988, the planning group for the International Thermonuclear Experimental Reactor (ITER). Since 1961 IPP has been an associate of the European Fusion Programme, coordinated by Euratom, which comprises the fusion laboratories of the European Union and Switzerland. This involves IPP in the joint European experiment JET (Joint European Torus). IPP also participates in international fusion research through numerous co-operation projects.

The Max Planck Gesellschaft is a self-administering organisation which carries out independent basic research in new research fields important for the future which have not yet been established at the universities. Scientists at the Max Planck Gesellschaft (in particular the senior scientists) may decide on the field and theme of their research and the manner in which they will carry it out themselves.

The financing structure of the Max Planck Gesellschaft includes funding designed specifically for individual institutions (henceforth referred to as institute-specific funding) from the federal and l„nder governments (50% each) as well as project-related and private funding.

Fraunhofer Gesellschaft zür Förderung der angewandten Forschung (FhG)

FhG is a non-profit-organisation, which sees itself as occupying a position between the basic research of universities and industrial practice. In its 47 institutes, the FhG conducts research according to the demand of the domestic and international R&D markets. It stimulates demand by developing innovative technologies, taking responsibility for them up to and including the demonstration of new products and processes, and identifies their benefit for the scientific community and the public sector. In doing so the FhG pursues those issues which are of pressing or medium-term importance for industry. The FhG has three main working areas:

Contract research

- For business. Business and industry use the FhG's innovative potential in the form of research contracts and joint combined projects. The FhG develops concrete practicable, innovative solutions and contributes to the wider use of new technologies. The FhG is an important partner for small and medium sized enterprises which do not have their own R&D capacities, enabling them to secure competitiveness.
- For state and society: On behalf of and with the support of the federal and l„nder governments, the FhG carries out strategic research projects to develop new technologies, to determine and optimise their potential for industrial use. Prospective research concentrates on state-of-the-art-technologies and key-technologies.
- Self-instigated research projects (which receive institute-specific funding) for maintaining consistent scientific quality, protecting market chances and opening-up new research fields.

Defence research

The FhG carries out departmental research for the German defence ministry (100% basic and project funding from defence ministry).

Services

Within the FhG there is a *Patent Office for German Research* as a service for public research institutes and private inventors. It also operates an 'Information Centre for Space and Construction' which supplies data banks in regional planning, urban development, housing authorities and building regulation sectors.

The FhG is managed by an executive board and is supported in this by the central administration. The senate is elected by the assembly of members and decides on the central features of research policy and research and extension planning. It also selects or disbands institutes. The advisory board of scientists and technical experts supports the organs of the society in fundamental scientific and technical questions. The institutes support the research work of the

FhG. The heads of the institutes and the organs of the FhG are supported by the Committee of Institutes whose members are chosen by the board.

Example: *The Fraunhofer Institut für Solare Energiesysteme (ISE)*
The Fraunhofer Institut für Solare Energiesysteme conducts research on the technology needed to supply energy efficiently and in a manner compatible with the environment in industrialised threshold and developing countries. To this purpose, it develops systems, components, materials and processes in the fields of thermal use of solar energy, photovoltaics, solar architecture, electrical power supplies, chemical energy conversion and rational use of energy. The institute finances itself with applied research projects and services on commission to public and private bodies. With more than 110 permanent employees the ISE is the largest institute working solely in solar energy research in Europe and the second one in the world.

Aside from the ISE, other institutes of the Fraunhofer Gesellschaft conducting research in the energy sector include institutes for construction physics, chemical technology, factory operations and factory automation, and information and data processing.

Hahn Meitner Institut Berlin (HMI)
The *Hahn Meitner Institut Berlin* carries out basic and applied research in the natural sciences, in particular condensed matter, also operating the facilities and equipment required for work in this field. The institute concentrates on solid-state and material research focusing on structural research, research on solar energy and other issues such as trace elements in health and diet, treating eye-tumours with protons and nuclear physics. In order to strengthen efforts in solar energy research (an area which emerged from earlier activities in the field of radiation chemistry), the new photovoltaics department is dealing with the basic issues related to silicon-based solar cells. The HMI is one of six members of the Solar Energy Research Alliance. Within this network the HMI has taken the responsibility for basic research, including the processes and materials used for converting sunlight into electrical or chemical energy.
Structural research at the HMI is chiefly carried out using the Institute’s central research reactor BER II (Berlin Experimental Reactor II). This reactor is used solely to generate neutron beams for research purposes. Like X-rays, these neutron beams can be used to investigate the inner structure of substances. Since neutrons penetrate all matter, the beams can be used to study all sorts of samples: liquids or solids, crystal, metals or ceramics. In contrast to X-rays, even biological samples, such as cell components or protein macromolecules can survive exposure to neutron beams without damage. In addition, neutron beams can also be used to activate and analyse chemical elements, and in particular to identify biologically important trace elements. A ”Berlin Centre for Neutron Scattering BENSC” has been formed at the Hahn Meitner Institut to organise the experiments with neutron scattering. It coordinates the various interests of visiting scientists from Germany and foreign universities, research institutions and industrial firms.

Forschungszentrum Jülich (KFA)
The research and development activities of the Forschungszentrum Jülich (Jülich Research Centre) are oriented towards the support programmes of the federal government and to the requirements of science, industry and government. They are often part of national and international supporting programmes. Its work on nuclear fusion is part of the fusion programme of the European Nuclear Society. FKA is engaged in technological development and basic research, both of which require an extensive scientific and technical infrastructure. Important elements of this work are the considerable technological and economic risks involved and the need to work continuously as part of a multidisciplinary grouping. This naturally entails a corresponding effort in terms of planning and management. The KFA is managed by a board which decides on all important issues, in particular KFA's research aims. The board also has the authority to issue directives regarding important research-policy and financial matters to the administrative and scientific/technical boards.

Since 1993 the research programme has been divided into five central activities (figures listed below for employment of funds in R&D are for 1997):

- structure of matter and material research (32%)
- information technology (15%)
- life sciences (10%)
- environmental precaution research (13%)
- energy technology: environmentally-friendly energy-conversion methods such as fuel cells, electro-chemical energy storage, photovoltaics, R&D in the exploration and extraction of fossilised fuels, research into safety, nuclear fusion and plasma (32%).

The controlled fusion of atomic hydrogen nuclei into helium and neutrons with the release of energy represents a fascinating option for the long-term security of energy supplies. The *Nuclear Fusion and Plasma Research Programme* at the KFA concentrates on one of the key issues, namely the interaction of the hot plasma with the wall of the plasma chamber. Here, heat must be given off to the wall and the so-called ash must be removed from the hot fusion plasma. The central test facility in Jülich is the specially developed TEXTOR tokomak. A 'pump limiter' system has been developed in TEXTOR to remove the helium ash and other impurities. It has thus been possible to demonstrate adequate removal of helium for the first time worldwide. Since all wall components are subjected to high thermal loads and are in the threshold region of permissible material stressing, the reduction in temperature near the wall and the avoidance of local wall overheating is of great significance.

Material problems are very important in fusion research. Materials research is therefore also orientated to the requirements of future thermonuclear fusion reactors. Attention is focused on the qualification of materials for the plasma-facing wall of the burn chamber, which is not only exposed to thermal stress but also susceptible to damage by neurons.

The *Energy Conversion Technologies* mainly deal with fuel cell development and solar energy conversion. The studies at Jülich relate to the solid oxide fuel cell of zirconia for the direct production of electricity and heat from natural gas. The aim is to develop a planar cell to be operated with natural gas at normal pressure and temperatures as far as possible below 800°C and which is to form the basis for the concept of a stationary energy supply plant. Work ranges from the development and optimisation of materials through the investigation of reaction kinetics and processes at the electrodes, to the clarification of the influence exerted by the cell parameters, for example, on plant efficiency. In future, the low-temperature fuel cell in combination with an electric motor can provide an alternative to conventional combustion engines in vehicles. Work at Jülich is directed towards the development of important components and investigations for system optimisation. As one of the components, the polymer electrolyte fuel cell is being studied and further developed.

The direct conversion of sunlight into electricity with the aid of solar cells is a promising possibility for energy conversion. The photovoltaic technology currently available is based on solar cells of crystalline silicon. Work at the KFA is being devoted to thin-film solar cells in close cooperation with the programme on basic research in information technology. Attention is focused on amorphous semiconductors, particularly amorphous silicon, since their absorbance in the region of visible light is higher than that of crystalline silicon.

Photovoltaics and fuel cells can be combined into an overall system. In order to investigate this overall system the KFA is operating a photovoltaic electrolysis fuel cell demonstration plant together with other partners for the autonomous supply of part of a building with electricity throughout the year.

In the *Safety Research and Reactor Technology programme*, considerations are being pursued on ‘passive’ safety systems in order to meet the more stringent requirements in technical systems - particularly in nuclear engineering. In cooperation with other partners, for example, a test was set up in Jülich which is unique worldwide and serves to test the passive afterheat removal system - the emergency condenser - envisaged for the SWR 600 boiling water reactor under different operating conditions. Moreover, future reactor plants are being devised which will limit the nuclear power and fuel element temperatures in all cases of accidents in a self-acting manner and remove the afterheat from the shut-down reactor system without resources to active measures and also maintain the fission product barriers of the fuel elements, the reactor pressure vessel and the containment. In particular, it is being verified whether the safety-engineering potential of the high-temperature reactor makes a solution possible. The major issues in nuclear engineering also include the disposal of radioactive waste which, in Germany, is to be finally stored in deep-seated geological formations. Special work is being performed in Jülich concerning final disposal in salt.

The aim of the programme on *Exploration and Extraction of Fossil Fuels* is to understand and describe the processes which, in course of geological history, have led to the formation of oil and gas deposits. On this basis, exploration projects can be planned and performed more selectively in conjunction with geological surveys and findings in nature.

Beside these activities the KFA carries out systems analysis. The KFA's work is interdisciplinary in all fields and it cooperates and collaborates with the universities. Especially in the field of applied themes, the KFA works together with companies.

Forschungszentrum Karlsruhe, Technik und Umwelt (FZK)
The FZK is a large-scale research centre with central activities in the natural sciences and engineering. Research and development activities are carried out in the fields of applied, industrial forerunner research, precaution research and also, but only to a limited extent, in basic research. The FZK works closely together with universities, research institutions and industry. Particularly in the field of industrial forerunner research there are a number of applied projects carried out in cooperation with industry to acquire a fast and efficient transfer of knowledge to industrial development.

The reduction of the number of old nuclear plants in the Karlsruhe Research Centre Technology and Environment and care of other old nuclear plants are still important additional tasks. The original task of the FZK and the reason for its establishment was the development of nuclear energy. This has extended to the wide-ranging field of tension between technology and environment and now concentrates on the following central activities of research: environment and energy.

The research into energy can be divided in three main activities: fusion technology, superconductivity, nuclear technology including nuclear safety and nuclear waste disposal. The energy research is characterised by long term projects on safeguarding nuclear reactors and nuclear waste disposal. Most of the projects are integrated in international programs.

Institut für Erdöl- und Erdgasforschung (IfE)
The *Institut für Erdöl- und Erdgasforschung* conducts research in the fields of improved natural gas and oil production, the physical-chemical properties of contact surfaces between oil-water and natural gas-water, colloid chemistry of oil, material aspects of the multiple phase transport of oil/natural gas/water systems in offshore pipelines, heavy distillation residues and bitumen, harmful chemicals in oil and natural gas, environmental analysis and the treatment of waste oil.

10.2.3 Key indicators and financial flows

Max Planck Gesellschaft zur Förderung der Wissenschaften
The financing structure of the Max Planck Gesellschaft includes funding designed specifically for individual institutions (henceforth referred to as institute-specific funding) from the federal and länder governments (50% each) as well as project-related and private funding. The amount of basic funding is by far dominant.

Table 10-1a: Personnel at the Max Planck Gesellschaft[34]

Personnel	1992	1993	1994	1995
Researchers	4,395	4,996	5,127	5,251
Technical staff	3,330	3,429	3,377	3,406
Other	2,922	3,058	3,148	3,244
Total	10,6447	11,483	11,652	11,901

Source: BMBF (1996a), p. 409. Data: MPG

Table. 10-1b: Total budget of the Max Planck Gesellschaft[35]

DM in millions	Actual			Target
	1992	1993	1994	1995
Current expenses	1,165.5	1,208.7	1,264.8	1,267.5
Personnel expenditure	675.2	696.8	718.3	729.0
Investments	167.6	233.2	231.0	271.3
Building	55.8	97.1	95.2	126.0
Total	1,333.1	1,441.9	1,495.8	1,538.8

Source: BMBF (1996a), p. 409. Data: MPG

Table 10-1c: Basic funding received by the Max Planck Gesellschaft

Joint basic funding (in DM millions)	Actual			Target
	1992	1993	1994	1995
Federal gov.	568.4	618.5	647.9	712.0
länder	573.2	624.0	654.8	717.9
Total	1,141.6	1,242.5	1,302.7	1,429.9

Source: BMBF (1996a), p. 409. Data: MPG

Table 10-1d: Detailed example: Max Planck Institut für Plasmaphysik

Actual		Target/Estimate	
1993	1994	1995	1996
Institute-specific funding from federal gov./*länder* (in DM millions) (below: fed. gov.)			
99.0 (89.1)	99.3 (89.4)	105.6 (95.1)	110.0 (99.2)
Other Financing			
50.7	60.2	61.5	63.3
Total personnel not incl. apprentices (below: institute-specific funding)			
946 (946)	947 (947)	1,022 (1,022)	994 (994)

Source: BMBF (1996a), p. 452. Data: IPP

[34] Max Planck Gesellschaft not including apprentices, Institut für Plasmaphysik and the independent Max Planck Institut (MPI).

[35] Not incl. the Max Planck Institut für Plasmaphysik (IPP); incl. project funding and subsidies to the independent Max Planck Institut (MPI) for Iron Research and the MPI for Coal Research.

Fraunhofer Gesellschaft

Institutes carrying out contract research are 70% self-financed and provided with 30% institute-specific funding which is success-related. Of this institute-specific funding 90% is provided by the federal government/research ministry and 10% by the länder. Defence research receives 100% institutional and project funding from the federal government/defence ministry; Services are 25% self-financed and receive 75% institute-specific funding. Of this institute-specific funding 90% is provided by the federal government/research ministry and 10% by the länder.

The form of financing known as the Fraunhofer Model derives from the FhG's market-oriented approach. A prerequisite is that members of staff, in particular senior members of staff, possess a high-level of scientific and business skills. Each scientist at FhG is required to review his academic work in the light of customer demands. The applicability and benefit of findings for the client have to be examined and research concepts designed to exploit their full market potential. Consequently, the success of an individual scientist is seen not only in terms of the number and quality of his/her publications, rather it is also measured in terms of his/her contribution to the financing of the institute, i.e. the economic outcome of the scientist's activities. In certain cases the success of a piece of contract research may effectively prohibit it from being published.

Table 10-2a: Personnel of the Fraunhofer Gesellschaft (fig. converted into no. of full-time staff) not incl. apprentices

	1992	1993	1994	1995
		Actual		Target
Scientists	2,481	2,499	2,509	2,568
Technical and clerical staff	2,320	2,270	2,284	2,338
Other	1,146	1,066	1,165	1,193
Total	5,947	5,835	5,958	6,099
Staff plan	2,351	2,366	2,336	2,310
financed by project funding	2,450	2,403	2,457	2,596

Source: BMBF (1996a), p. 427. Data: FhG

Table 10-2b: Expenses of the Fraunhofer Society 1992-1995 (in DM millions)

	1992	1993	1994	1995
		Actual		Target
Current expenses	702	744	797	809
Personnel expenditure	(448)	(472)	(497)	(534)
Investments	239	256	345	452
Buildings	(105)	(106)	(192)	(270)
Total	941	1,000	1,142	1,261

Source: BMBF (1996a), p. 427. Data: FhG

Table 10-2c: Financing of the Fraunhofer Society 1992-1995 (in DM millions)

	1992	1993	1994	1995
	Actual			Target
Institute-specific funding from federal gov. and *länder*	385	412	478	525
Fed. gov.	313	334	400	527
länder	72	78	78	108
Institute-specific funding from defence ministry	60	59	56	53
R&D revenues[36]	496	529	608	683
Total financing	941	1,000	1,142	1,261

Source: BMBF (1996a), p. 427

The major research establishments receive institute-specific funding from the federal government (90%) and the *land* in which they are situated (10%).
It is difficult to isolate figures concerning personnel, expenses and financing for the specific area of energy research. Table 10-2d presents some data concerning the different research areas of FhG. In this table energy research is part of the category 'Energy and building, environment and health'. Tables 10-3, 10-4 a-d, 10.5 and 10-6 provide financial and other data concerning respectively the Hahn Meitner Institut, Forschungszentrum Jülich, Forschungszentrum Karlsruhe, Institut für Erdöl- und Erdgasforschung.

Table 10-2d: Research areas of FhG

Research areas	Personnel 1994	Expenses 1994 (Mln DM)
Materials technology	1020	187
Production technology	761	174
Information technology	510	100
Micro-electronics	881	184
Measuring and Sensors	334	67
Process technology	443	77
Energy, building, environment, health	575	119
Techno-economic studies and information transfer	269	42
TOTAL	4793	950

Source: BMFB (1996a). Data: FhG

36 Contract research revenues of the FhG from the federal government, länder, industry, trade associations, research funding, other.

Table 10-3: Hahn Meitner Institut Berlin

Actual		Target/Estimate	
1993	1994	1995	1996
Institute-specific funding from federal gov./*länder* (DM in millions)			
121,1 (109.0)	114,3 (102.9)	113,3 (101.9)	114,2 (102.8)
Other financing			
13.5	12.2	16.4	18.6
Total personnel not incl. apprentices (institute-specific funding)			
818 (737)	745 (659)	770 (694)	749 (676)

Source: BMBF (1996a), p. 451. Data; HMI

Table 10-4a: Forschungszentrum Jülich (KFA)

Actual		Target/Estimate	
1993	1994	1995	1996
Institute-specific funding from federal gov./*länder* (DM in millions) (fed. gov.)			
495.1 (435.2)	471.4 (413.6)	463.9 (407.2)	470.4 (412.0)
Other financing			
192.8	275.7	184.7	188.9
Total personnel not incl. apprentices (institute-specific funding)			
3,953 (3,473)	4,013 (3,536)	3,958 (3,468)	3,828 (3,328)

Source: BMBF (1996a), p. 453. Data: KFA. Figures include the Institute of Biotechnology which receives 100% funding from the *land* of North-Rhine Westphalia.

Table 10-4b: KFA: Staffing plan for 1995-2000 in the energy technology sector

	Actual 1995	Target 1996	Target 1997	Target 1998	Target 1999	Target 2000
Established posts	421.2	342.2	345.3	337.6	329.3	334.4
Annex personnel	71.0	71.4	71.0	70.0	70.0	70.0
Personnel funded by third parties	65.5	50.8	53.0	53.0	53.0	41.5

Annex personnel, which includes undergraduates and PhD students, are counted in terms of contracts - usually part-time (19 hours a week).

Table 10-4c: KFA: Costs, employment of funds, financing (DM million) for 1995-2000 in the energy technology sector

	Actual 1995	Target 1996	Target 1997	Target 1998	Target 1999	Target 2000
Costs	155.4	130.3	127.9	128.1	127.5	127.8
Employment of funds (Investments)	139.3 (7.4)	127.5 (5.7)	127.6 (8.2)	128.3 (8.6)	125.5 (6.5)	124.1 (5.5)
Financing						
Institute-specific support	112.9	103.3	106.2	106.9	104.1	105.2
Third party funds	26.4	24.2	21.4	21.4	21.4	18.2

The 'Employment of Funds' figure including third-party funding arises from costs minus depreciations and plus investments.

Table 10-4d: Costs, employment of funds, financing (DM million) for 1995-2000 at the Forschungszentrum Jülich

	Actual 1995	Target 1996	Target 1997	Target 1998	Target 1999	Target 2000
Costs	702.4	663.4	691.0	706.6	724.7	731.5
Employment of funds (Investments)	668.0 (77.8)	650.5 (74.9)	686.6 (75.5)	704.5 (77.6)	721.0 (78.1)	724.3 (79.3)
Financing						
Institute-support	493.5	504.5	510.0	528.5	545.0	553.3
Third party funds	174.5	146.0	176.6	176.0	176.0	171.0

Table 10-5: Forschungszentrum Karlsruhe, Technik und Umwelt (FZK)

Actual		Target/Estimate	
1993	1994	1995	1996
Institute-specific funding from federal government/*länder* (in DM millions) (fed. gov.)			
515.1 (464.6)	471.4 (413.6)	463.9 (407.2)	470.4 (412.0)
Other financing (shutdowns and old sites)			
491.1 (245.0)	550.6 (369.1)	529.3 (441.5)	532.1 (432.7)
Total personnel not incl. apprentices (institute-specific funding)			
3,622 (3,205)	3,488 (3,054)	3,516 (3,171)	3,313 (2,968)

Source: BMBF (1996a), p. 454

Table 10-6: Institut für Erdöl- und Erdgasforschung

Actual		Target/Estimate	
1993	1994	1995	1996
Institute-specific funding from federal government			
2.2	2.3	2.3	2.4
Total personnel not incl. apprentices (institute-specific funding)			
99 (50)	89 (50)	89 (50)	77 (49)

Source: BMBF (1996a), p. 476

10.2.4 Trends and developments; key forces

Regulation

In consequence of the European directive on electricity, which was finally adopted in January 1997 after ten years of discussion, there will be some changes in the energy and electricity sector, which also may influence the research institutes for some time to come. The directive demands that the member states of the European Union open up their power market to the European supplier. This has also resulted in a new regulation of the energy industry law, which was adopted in Germany in 1933. The new regulation is under discussion. It plans to open up the market immediately. The main objection to the proposal is that it does not fully exploit the competitive potential entailed in the EU-directive. Another critical point is that the environmental targets are only options and are not fixed. The local authorities are anxious to lose a great deal of power.

The power supply regulation, which is also under discussion, demands that a part of the energy supply has to come from renewable energies. Critics claim that this is a restriction on trade.

These conditions and new regulations might also have an influence on research activities in the field of energy and might also enforce a closer cooperation between research institutes and industry.

Research objectives[37]

The Fourth Energy Research Programme launched in 1996 was assigned the task of creating the technological basis for a permanent reduction in the damage to the environment and climate caused by the energy sector. This involves a broad spectrum of research activities for developing new, highly innovative products and processes. A number of projects are being implemented with international cooperation. The main research focuses of the programme include:

- reducing the energy requirement. This may be implemented via more efficient energy conversion, rational energy use and the improved utilisation of secondary energy sources.

[37] The following explanations refer to the *Government Research Report*, which describes the activity centres of research.

- developing long-term energy sources without CO_2 emissions. This entails providing support for renewable energies, the continued use of nuclear energy (reactor safety, radiation protection, final disposal of waste and dismantling power stations) and the further development of nuclear fusion.
- dealing with all-embracing topics such as systems analysis, information distribution, reducing barriers to innovation.

Relevant technologies
Nuclear fusion. To develop a new energy source of almost limitless potential which produces no CO_2 emissions is one of the greatest challenges of the coming decades. Unfortunately nuclear fusion is a highly complex research field which can only be developed in stages. There will probably not be a commercial fusion reactor before the middle of the next century.

Reactor construction technology is also increasing in importance as regards research. The development of technically essential reactor components will therefore also influence the direction of fusion research in the future.
Some DM 171 million was provided by the BMBF for fusion research in Germany in 1996. A further DM 17 million was provided by the German länder and DM 65 million by EURATOM. German research in this field is integrated in the joint European fusion research programme. At the Max Planck Institut für Plasmaphysik, the Forschungszentrum Jülich and the Forschungszentrum Karlsruhe, experiments in plasma physics and technical development work is being carried out in large-scale testing centres. Findings to date have achieved international recognition. The same applies for the continued development of the stellarator principle which anticipates continually working plasma. The next generation of stellarators are already being planned: Wendelstein W 7 X, equipped with supraconducting magnets, is to be built in Greifswald to demonstrate the stellarator principle's fundamental suitability for fusion reactors. The EU nations, Japan, Russia and the US have been jointly planning a further step in fusion research with the building of the 'International Thermonuclear Experimental Reactor' (ITER). This experiment is to show the physical feasibility of plasma burning over the long-term and to test new technologies and materials for a future power-producing nuclear fusion reactor

Reactor safety. The chief objective of preventative research in the reactor safety field is creating a scientific-technical basis for evaluating the safety of nuclear engineering systems and to provide impetus for the continual improvement of safety technology. This kind of research measure in the past has produced new data on materials and fracture mechanics for reactor components in cases of operational difficulties or breakdowns and continued to develop methods of analysis. Important projects include:
- optimising existing test and computing processes for long-term safety (up to 10,000 years) and developing new methods of evaluation for anything exceeding this period,
- investigating the long-term behaviour of cavity filling materials (clay, betonite) under the influence of varying temperatures in final repositories in crystalline rock,
- developing a quick, i.e. fast motion, 3D program for describing the movements of saliniferous groundwater

- contributions to realising the new IEAO fission material monitoring concept "93+2" in terms of measuring technology
- continuing to develop the sensitivity of measuring processes, the miniaturisation of measuring techniques and remote data transmission.

Radiation protection research. Funding in this field is centred on:

- analysing natural and civilisation-related exposure to radiation and its somatic and genetic effects,
- measuring technology and determining dosage (the objective is to improve existing dose rate meter systems),
- registering radio-ecological data and developing radio-ecological models,
- improving preventative measures against malfunctioning and accidents,
- assessing the radiation risks in dealing with radioactive materials and ionising radiation,
- seeking processes to optimise radiation protection, when dealing with and disposing of radioactive waste,
- biological indicators and pathogenesis of radiation damage (including diagnosis and therapy),
- drawing up an official register of contaminated mining sites for the new federal states.

New additions to research include investigations on the effects and risks of non-ionising radiation. Radiation protection findings to date have allowed researchers to make realistic assessments of the radon concentration in domestic homes. New findings have also been made available on the radiation exposure in uranium mining and the effect on the health of human beings. Progress has also been made through improved dose rate meters and new models on determining exposure. Other research projects aim to determine typical job-related exposure levels, further improve radiation prevention measures and develop biological indicators.

International cooperation in the field of nuclear energy. International cooperation is extremely important in the fields of nuclear energy, radiation protection and reactor safety. Special advisory bodies coordinate radiation protection research in the EU, the OECD (NEA) and the IAEO. German representatives present German research findings to the International Commission for Radiation Protection (ICRP) and UNO's radiation protection committee (UNSCEAR) and these are then included in international radiation protection rulings. In addition, the German government has concluded bilateral and multilateral agreements with the aim of improving the distribution of the scientific workload, project cooperation and the exchange of information internationally.

The German government also supports development projects and studies as part of the EU energy research programme, the nuclear energy agency of the OECD and the International Atomic Energy Association. There are also agreements with all those countries using nuclear power including central and eastern Europe. These agreements also consolidate scientific-technical cooperation in the reactor safety field. Special Community projects aim to improve reactor safety in the central and eastern European states over the long-term.

Coal and other fossil fuels. Coal, or rather bituminous coal and lignite, is the only fuel of which there are sizeable deposits in Germany. It represents roughly a third of the primary energy consumed in the country. Research aims to continue developing power station and firing technology to achieve higher levels of conversion efficiency in order to reduce CO_2 emissions and to use fossil fuels in a more environmentally friendly manner, including the lignite mined in the new länder. Targeted, application-oriented basic research will make further gains in effectiveness and discover new ways of reducing the burden on the environment. Selected research emphases include the employment of new materials, the further improvement of combustion, the hot-gas cleaning of flue and coal gases and the continued development of high-temperature gas turbines. Energy-supply and plant construction companies will test new and improved components for combined-cycle power stations in a number of different demonstration units. The objective is to increase the efficiency of combined-cycle, gas and steam power plants from around 42% to over 55% within the next 10 to 20 years.

International research cooperation continues to be a central concern. Under the umbrella of the International Energy Agency (IEA), Germany is involved in multilateral R&D projects in the fossil fuel sector. The EU funds research, development and demonstration projects by German research institutes and companies. There are also a number of bilateral projects. A German-Norwegian project is dealing with petroleum production. Joint projects to improve oil and gas extraction and pipeline safety are being carried out with some of the former CIS states, owners of the largest reserves of fossil fuels.

Renewable Energies. The continued development of renewable energy sources has been strongly promoted. Considerable achievements have been made in the photovoltaics field with mono and polycrystalline silicon cells and these have now matured into marketable products. The technical maturity and functional reliability of networked and non-networked photovoltaic energy supply systems in the roofs of domestic houses and farms have also been improved considerably.
The ten-year 'Photovoltaics 2005' programme is intended to reduce the specific costs of solar cells. This can be achieved in a number of ways, for example, via increased efficiency, reduced production costs and lower energy expenditure in production - in particular with crystalline silicon cells and the thin-film solar cells of amorphous silicon and compound semi-conductors.

Progress has been made in the use of wind power and hydrogen above all via new system components for producing, storing and using hydrogen. Relevant research work has been carried out as part of the major project 'Solar Hydrogen Bavaria'; collaboration with Saudi Arabia on the 'Hysolar' project was successfully complemented in 1995. Electrical and internal combustion heat pumps have also reached market maturity. Other projects include:

- Developing high-energy batteries (i.e. lithium battery systems) as energy storers for electric vehicles.
- Testing high-temperature fuel cells as energy converters for use in power stations. Molten carbonate fuel cells are almost ready for demonstration and oxide ceramic fuel cells are still at the lab stage.
- Developing membrane fuel cells which work at low temperatures for the elec-

trotraction field.

- Developing hydrological, geological and physical-chemical thermal storage systems for using renewable energy sources in joint systems.
- Researching the 'hot dry rock technique' for the energetic use of geothermal energy. A research project on this subject is currently being funded by the EU in Soultz-sous-Foret in France.

Energy from renewable raw materials. The main focus in the field of energetics is on funding technology for using solid biomass to produce electricity and heat - from making the materials available (planting, harvest, transport) to utilisation. In so far as operating concepts which are economically, technically and ecologically viable have been developed by current projects, the establishment of large-scale demonstration units is to be funded by investment subsidies.

Rational energy use and saving fossil fuels in final energy consumption. On one hand, a characteristic of this field is that the use of new technologies for the rational use of energy depends largely on companies, authorities and private households. The spread of available knowledge in practice is often delayed, potential for making savings is often poorly developed. On the other hand there are a large number of R&D projects in small and medium-sized companies which could have a knock-on effect throughout the entire sector, providing impetus for new ideas. Research funding is concentrated chiefly on the fields of solar power/saving energy in households and energy-saving industrial processes.

Energy-saving industrial processes. As energy-saving industrial processes have been supported for many years, there is a well-founded base of technical data on which further work can be founded. State R&D funds are not allocated according to sector but according to processes and are focused on strategically important areas - for example, the provision of process heat or mechanical energy, both of which are electricity-intensive and therefore also CO_2 intensive. The same is true of coal and oil. More emphasis must therefore be given to saving energy and substituting it with less CO_2-intensive production processes.

Cross-sector processes (unit operations) follow the same principles of process engineering, for example, the increased use of materials in cycles, using catalysers to influence processes, various drying processes and separating materials using cyclones, membranes or adsorption. Cross-section technologies used in a number of fields are also provided with support - for example, single units and their use in systems in the following areas, refrigeration and compressed air production, compression, pump technology and air conditioning. In addition, special attention is being paid to the interfaces with other modern technical fields such as new materials, sensor technology, microelectronics, laser technology, plasma technology and physical chemistry processes as these are the driving force behind a number of new innovations.

10.2.5 Legitimisation: strategic issues and future perspectives

In order to ensure future energy supply and knowledge base, research on both the economic and environmental significance of the energy sector is at the centre of government funding. Further issues regarding legitimisation are discussed extensively in section 10.4.

10.3 Aerospace

10.3.1 Introduction

Institutes working in the aerospace field are concentrated in Deutsche Agentur für Raumfahrtangelegenheiten (DARA, 'German Agency for Space Issues') or Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR, 'German Aerospace Research Institute'). The DLR is the largest engineering research institution in Germany. It works in the field of future provisions and forward planning, aiming to provide solutions in the transport, environment, energy, safety and communication sectors. DARA is the central institution for aerospace management in Germany. DARA's job is to carry out planning for the German aerospace industry, to implement programmes in space and to take care of German interests in the international arena particularly within ESA.

The effort and expense required for aerospace research can only be carried out with international cooperation. In consequence, 75% of the budget for aerospace is used for the ESA. Of the remaining 25% of the budget for national research activities, 80% is implemented in cooperation with national partners.

10.3.2 Mission, strategy, activities, markets

Deutsche Forschungsanstalt für Luft- und Raumfahrtangelegenheiten (DLR)
The DLR wishes to strengthen the technological basis for a competitive industry. The development of innovative technologies and processes in cooperation with scientific institutes and industry is the focus of activities. Most findings have an industrial application. The DLR works with an entrepreneurial spirit and its main focus is research and development in the following areas: aerospace, energy and, in the environment/climate field, flight mechanics, fluid mechanics, materials/ construction methods, telecommunications/reconnaissance and energetics. Further focal points of DLR research lie in aircraft guidance, fixed-wing aircraft and helicopter technology, engines and trial technology (i.e. wind tunnels). Some recent findings include:

- the DLR's work in the helicopter field on actively steering rotors, which has produced promising results. These findings are now being utilised in projects for industry in order to significantly reduce noise levels and vibrations which in the case of helicopters in particular are often an extremely disruptive factor.
- the greatest limiting factor for increasing air traffic in future is the capacity of commercial airports. A major part of the DLR's work is therefore focused on fully utilising the physical capacities of existing airports by employing state-

of-the-art technology - in particular for approach, take-off and taxi-ing. The DLR-developed system TARMAC is a good example of the type of contribution that can be made. With the aid of various sensor systems on the taxiway, TARMAC is able to simultaneously display a clear overview of the situation on the airfield for the actors involved, i.e. air-traffic controllers, pilots, drivers of service vehicles etc.

These projects are closely linked with European and NASA research programmes. The results of the initial phase of this unique, coherent approach to atmosphere research and engine technology already form the basis for research and development objectives for the next generation of minimal emissions engines.

The work of the DLR requires an immense, concentrated, interdisciplinary effort. Work must be carried out consistently over a lengthy period of time, making the work unsuitable for industry as it has to operate under market conditions. The same is true for dealing with complex interdisciplinary focal themes, long-term projects and extensive research and technological tasks at the forefront of industrial applications.

These include the construction and operation of large-scale experiments prior to industrial use for example wind tunnels, research aircraft, testing facilities for aircraft and rocket engines, data-centres for long-range reconnaissance and an earth-based infrastructure for organising manned and unmanned space navigation projects. Other activities associated with the above include planning and implementing research projects, funding and training young scientists and advising and supporting the German institutions responsible.

Deutsche Agentur für Raumfahrtangelegenheiten (DARA)
The job of DARA is to carry out planning for the German aerospace industry, to implement programmes in space and to take care of German interests in the international arena particularly within ESA.

10.3.3 Key indicators and financial flows

Deutsche Forschungsanstalt für Luft- und Raumfahrtangelegenheiten(DLR)
Like other major research establishments institutes DLR receives specific support funding from the federal government (90%) and the *land* North-Rhine Westphalia (10%). For further details see Table 10-7.

Deutsche Agentur für Raumfahrtangelegenheiten (DARA)
The effort and expense required for aerospace research can only be carried out with international cooperation. In consequence, 75% of the budget for aerospace is used for the ESA. Of the remaining 25% of the budget for national research activities, 80% is implemented in cooperation with national partners.

Table 10-7: Deutsche Forschungsanstalt für Luft- und Raumfahrtangelegenheiten (DLR)

Actual		Target/Estimate	
1993	1994	1995	1996
Institute-specific funding from federal gov./*länder* (DM millions) (fed. gov.)			
447.2 (391.0)	439.2 (396.4)	430.7 (389.9)	440.8 (399.0)
Other financing			
334.7	268.4	210.3	240.6
Total personnel not incl. apprentices (institute-specific funding)			
4,256 (3,001)	3,999 (2,799)	4,193 (2,943)	4,082 (2,832)

Source: BMBF (1996a), p. 444

10.3.4 Trends and developments; key forces

The German government has set new accents in the national research program in the field of *aerospace*. They try to integrate the capacities of the new länder, to strengthen cooperation with Russia and Japan and to extend capacities in the field of earth observation.

The German activities in space are only carried out very seldomly on a national level. More or less every project is done at least bilaterally. Support is given for the following objectives:

- earth-orientated research about the condition, development and resources of the land, atmosphere, ocean and ice-covered areas of the earth; technologies for data collection examining and monitoring environment control,
- extraterrestrial research in the fields of astronomy/astrophysics, physics of the upper atmosphere, magnetosphere and plasma physics, physics of the planets, comets, moons and the interplanetary space,
- areas of metallurgy/composite materials, growing crystals, electronic semi-conductors, critical phenomena and dispersion, fluid physics, gravitation and radiation biology and human physiology,
- development of technologies, for satellite supported communication and navigation, preparation of new exploitation possibilities,
- pre-examination and pre-development of orbital and terrestrial infrastructure particularly in space transport systems, orbital systems and their use,
- preparation for the European participation in the international space station with elements of the orbital infrastructure, logistics transport systems, pre-development of technologies for manned space transport systems.

The new civil aeronautical research programme of the German government 1995-1998 supplements the government's existing aeronautics activities. The main focus of this new programme is technology for strategic product developments for planning up to the year 2010. This includes technology projects for:

- Megaliners (long haul subsonic aircraft upwards of the Airbus A 330 and A 340),
- Eurojet (100-seater jet aircraft - the smallest member of the Airbus family),
- Regioprop (turbo prop aircraft for short and medium distances, in particular

as a feeder),
- Helicopters (quieter and with all-weather flyability for emergency rescues etc.),
- More environmentally-friendly engines (reduction of NOx, CO_2 and noise emissions),
- Cross-sectional projects especially for KMU, e.g. in navigation, communication, modular avionics and general aeronautics.

One important overall aim of technological development in the aeronautical research programme is to reduce the adverse impact on the environment, in particular by using less energy, thus cutting CO_2 and nitrogen oxide emissions. In the medium-term, fuel consumption is to be reduced by 25% per passenger and per kilometre flown. A further aim is to reduce aircraft noise.

As a precursor to this, a national programme entitled 'Aircraft emissions' was established in 1993 headed by the DLR and with the involvement of wide sectors of industry and research establishments. In the sub-programme entitled 'atmospheric research', the aim is to ascertain the effects of the emissions of the world's air traffic on the atmosphere, in particular on ozone distribution and climate, and to provide basic knowledge for the development of more environmentally compatible air traffic.

10.3.5 Legitimisation: strategic issues and future perspectives

The targets of German space research policy are intensive participation in the European cooperation with ESA and further cooperation with France and other ESA-members, USA, Japan and the CIS states. The main targets are still valid: to gain new scientific knowledge of earth and space and to stimulate technological progress. In practice, space research should participate in solving environmental problems with the aid of earth observation by satellites or to improve the commercial infrastructure e.g. telecommunication.

The aim of the government's overall programme is to promote the technological competence of the German aeronautical industry and specialist research establishments and institutes and to strengthen their position within European cooperative ventures, thus contributing to securing Germany's standing as a technology location. It also aims to support cooperation between companies within Europe and thus improve competitiveness on world markets and to maintain the industrial basis for meeting the requirements of the armed air forces as part of a move towards international cooperation and work sharing.

10.4 Concluding remarks

As regards the discussion on government funding, the main issues are reducing the *Fehlbedarfsfinanzierung* (deficit funding)[38] of these institutes and how to improve the research programme so that the institutes can finance themselves with third party funds. This not only includes funds from industry, but also from the federal government or länder.

The institute-specific support from the federal and länder governments provides only basic funding. Even if a 100% award has been granted, this form of financing does not cover all the expenses. In recent years, support has effectively been reduced since federal and l„nder governments have forced research institutes to obtain more third-party funding, meaning that institute-specific support covers around 50% of their budget and the remainder (at least 50%) has to be procured from industry. Some institutes such as those at Max Planck receive more institute-specific support and only need to obtain around 25% from third parties, whilst the Fraunhofer society receives more external funding. The Munich-based headquarters of the Fraunhofer Gesellschaft receives the full support of the federal government. It distributes support to each institute according to the number of people each employs. In general, the institutes receive basic funding of 20%. They are usually forced to obtain another 30% from industry and a further 50% from other projects. Therefore the Fraunhofer institutions are required to find funding for 80% of their budget.

Institute-specific support is intended to cover the maintenance of infrastructure, and in most cases third-party funding is needed for the research work. It is extremely difficult to obtain 100%-reliable data on the percentage of funding provided by third parties as the institutes do not disclose detailed breakdowns of their budget especially where such sensitive data is concerned. Third-party funds are usually included under the heading ‘Other financing’, they comprise support from industry as well universities and supporting bodies for projects, with the consequence that ‘federal’ funds are often placed in the ‘solicited funding’ category. On account of the above circumstances, the institutes keep a low profile as far as a breakdown of external sources of funding is concerned. In general, the policy of both federal and länder governments is developing in the direction of reducing the size of the major research establishments. In order to discover which areas attract the most sup port from industry, one has to look at the numbers of employees in each speci fic area, which is quite difficult. For example, if the major research establishments are supported to 90% by the federal government and to 10% by the land in which they are situated, the total budget is continuously reduced by providing a limited number of posts which are discontinued once the occupant reaches retirement age. Thus in order to create new posts and to carry out the

[38] *Fehlbedarfsfinanzierung* is a contribution which covers the deficit remaining insofar as the recipient is unable to cover those expenses which are entitled to receive contributions with its own funds or funds from external sources. Proportional *Fehlbedarfsfinanzierung* is when the deficit is met proportionally by more than one grant awarding body (in practice, this is often the federal government and länder) according to a specific scale.

work which they are contracted to do, the institutes are forced to obtain funding from industry.

In 1994, the institute-specific support received by those establishments funded jointly by the central and local governments amounted to DM 7.7 billion[39], of which DM 5.3 billion (some 70%) came from the federal government and around DM 2.4 billion from the länder. Therefore a deficit has arisen of DM 8.1 billion and DM 8.4 billion respectively overall - an increase per year on average of 4.5% between 1994 and 1996. The major research establishments received the lion's share of institute-specific funding - in 1994 this amounted to about DM 2.9 billion. DM 3 billion was budgeted for 1996. At an annual growth rate of 1.2% since 1994, the increase is significantly below average. As a result, the share of institute-specific research received fell from 37.5% in 1994 to 32.3% in 1996. In 1994, the institute-specific funding of the Max Planck Gesellschaft amounted to DM 1.3 billion in total. For 1995 and 1996, around DM 1.4 and 1.5 billion respectively were earmarked. Thus MPG's share of joint research funding has risen from 16.9% (in 1994) to 17.7 % (in 1996).

The financing structure of R&D expenditure has altered over the years due to changes in the weighting of the individual sectors. During the eighties, there was a dynamic increase in R&D expenditure from industry compared to a more moderate increase in central and local government spending. The industry share increased from 55.9% to 63.7% and the share of federal and länder governments from 43.7% to 35.8%. By 1995 the industry share dropped to 60.3% and that of the central and local governments increased to 39.4%. One crucial factor was the trend in industry toward saving money by reducing R&D expenditure, to which the streamlining process in the industries of the new länder post unification contributed. A further element was that the federal and länder governments significantly expanded their spending to build up the research landscape in Germany. Generally, R&D funding to industry from the coffers of BMBF is characterised by the following trend: overall R&D funding has been reduced in space research and technology (by 24%), fossil fuels (by 82%), renewable energy sources (by 34%), nuclear energy research (by 47%) and the disposal of nuclear plant (by 53%).

The only trend which can be ascertained for certain is that there is a marked change in the way funding is organised as institutes have to obtain an ever increasing share of funding from third sources. If they are unable to achieve the percentage of external funding specified, then institute-specific support is reduced further. In consequence, institutes earmark the largest or the most attractive areas for obtaining outside funding, as these areas offer the best opportunities for procuring funds from industry. Although biotechnology is one of the most attractive areas the energy and aerospace sector is also still important to industry and continues to receive support for some projects. The problem here is that employees in these areas tend to be young, and more flexible and independent, and that if these institutes are closed down (because the areas are deemed unattractive by third parties) these employees (who are

[39] Reliable data only exists up to 1994, which is why we chiefly refer to these data.

only on short-term contracts anyway) are the first to lose their jobs. One consequence is also that the institutes try to find new partners for cooperative ventures with other institutes and also bid for project contracts from the European Commission.

An initial step towards the major research establishments becoming more independent from the institute-specific funding from the federal government and länder is represented by the strategy funds provided by the Helmholtz Gesellschaft (HFG). HFG is an umbrella organisation which oversees Germany's 16 national research centres (including the Hahn Meitner Institut, Kernforschungszentrum Jülich and the Forschungszentrum Karlsruhe). The funds are worth DM 150 million and the centres have to apply competitively for them. In future each centre will have to contribute 5% of its institutional budget, which covers running costs, investment cost and salaries, to the new fund. This money will be redistributed through competition. Centres can apply for research projects worth upwards of DM 10 million, limited to three years. In the first round, the centres must submit applications to a senate committee of scientific and industrial members. Proposals will then be reviewed by a scientific panel that will include members from abroad. Areas likely to be covered by the new fund will include bioinformatics, environmental technologies and superconductors. In addition an important element of the strategy funds is the 'young scientists programme' set up to support some 150 young scientists during the initial phase.

In future, the research establishments will be granted a greater degree of flexibility in their budget management, allowing them to convert the findings of their R&D activities more quickly. All the research establishments will be able to keep the revenues from licensing and know-how agreements and surplus income from contracts without this being deducted from their basic financing. In this way they will be able to build reserves for the following year. It will also be possible for each establishment to transfer funds between personnel and operational budgets, which has not been possible up to now.

Often in the past, the federal government and *länder* governments have taken the initiative in establishing the institutes and brought together the founder/donor. In the future the institutes will be forced to obtain more third party funding. This might also have an influence on their research work. In the most cases the federal government or the *länder* are the main source of financing. Influence is not taken by the government itself, it is delegated to industry and the interested ministries. The founders and also representatives from the ministries are members on the executive boards, where they can influence decisions. Ideally, they should function as contacts for research and financial matters as well as critical partners in talks. The specific role of the government is to be the coordinator and initiator. The legitimisation behind the institutes' receipt of public support will continue to be that they should establish and maintain a scientific research infrastructure, in particular for the production industry.

In future too, the institutions will be interested in intensifying cooperation with industry with whom they try to cooperate very closely. Both sides have agreed on a consensus-oriented planning process. The institute plans to further develop the external advisory service, for example at the research centre in

Jülich there is an 'industry committee' which is integrated in the R&D planning process. In most institutions, the relevant industry sits on the board. Technology transfer centres and advice centres for industry cooperation have been installed, especially in the fields of nuclear safety, supercondensity and microsystem technology. These efforts are accompanied by symposia and workshops. Since the federal and länder governments have forced institutes to increase the proportion of funding received from external sources, they are naturally extremely interested in cooperating more closely with the relevant industries.

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11 Sweden

11.1 Introduction

This country study[40] deals with the area of aerospace technology. Focus is on FFA - Flygtekniska Försöksanstalten (The Aeronautical Research Institute of Sweden).

11.2 Aerospace

11.2.1 Introduction

FFA is the central government agency for aeronautical research and testing in Sweden. Its principal role is to provide scientific support and technical assistance to Swedish Government authorities, to domestic and foreign industries and to other organisations. The main commissioner and client is FMV (the Swedish Defence Materiel Office).

11.2.2 Mission, strategy, activities, markets

The role of FFA is to

- Develop new technology and new methods which are important for the Swedish industrial development of new aerospace products, and for operation, maintenance and modification of the Swedish Military aircraft and weapons.
- Provide knowledge, ramrods and equipment for development and testing.
- Be an independent aeronautical knowledge centre who can support/assist the Air Force with evaluations/assessments during acquisition of materiel and in education and tactical developments; with long term assessment of international developments; aeronautical education and research at universities.
- Support Swedish National Space Board (SNSB) with aeronautical research for space programmes[41].

In addition to the above goals FFA should use its aerotech competence within other areas of application, such as traffic control, energy and environment, as well as making the research investments more effective by extending international cooperation with (mainly) Europe and the USA.

The main areas of research are aerodynamics, structures, acoustics and flight systems. Since the late seventies this experience has also been applied in a

[40] This chapter is contributed by Christian Svanfeldt (NUTEK).

[41] From AEREA (Association of European Research Establishments in Aeronautics) brochure.

wind energy research programme. Although the main task is aeronautical research and development, work is also carried out in the fields of energy research, offshore, transport and manufacturing.

The organisation consists of three business areas and eight competence-oriented departments. It also has three administrative and support departments. FFA is headed by a board with members appointed by the Swedish Government.

Research areas / departments
Experimental Aerodynamics. The Experimental Aerodynamics Department is devoted to wind tunnel testing and analysing the results of these tests. FFA has several wind tunnels ranging from low, through transonic and supersonic, to hypersonic speed. The most commonly used wind tunnels for applied testing are the low speed tunnel LT 1 and the two high speed tunnels S4 and T1500. Clients are both private and public, as well as Swedish and foreign.

Computational Aerodynamics. The FFA's Computational Aerodynamics Department is devoted to the development of theoretical methods and application-related work in the areas of military and civil transport aeronautics and space transportation. The department's clients are the Swedish Government and Swedish and foreign industry. Its work is funded chiefly through external research contracts. A certain amount of longer term research, code development and international cooperation projects are funded internally. The basis for the application-oriented work is the development of theoretical models, numerical algorithms and numerical tools. Research and code development is to a large extent carried out in association with other national and foreign academic institutions, institutes and industry.

Structures and Materials. The work carried out within the Structures Department is often a combination of experimental work and computational analysis, mainly within the fields of Fatigue and Fracture, Composite Mechanics and Computational Mechanics. These activities aim at:

- Developing more time and cost-effective methods for reliable structural design and development.
- Identifying new material systems with a potential for further structural weight savings, an up-grading of aircraft performance and a reduction in life cycle expenditure, and if necessary, developing reliable design procedures and data for their usage.
- Evaluating the capabilities of existing sensor systems and developing in-service monitoring of structural soundness in order to increase structural flight safety and reduce maintenance costs.
- Developing competence to assist the Swedish authorities to perform air worthiness assessments, damage tolerance analyses and strength examinations.

Flight Systems. FFA flight systems activities focus on pre-procurement and operational development. This work involves tracking down the best air materiel or system layout, as well as the most efficient and safe operations. The tasks of the Flight System Department includes work for both the defence sector and the civil air transport sector. This work (which involves both consultancy and research) is carried out for the domestic market and in collaboration with foreign partners.

Acoustics. The goal of the acoustics group at FFA is to support industry with relevant know-how in acoustics technology by following the current research trends and by actively participating in the development of new ideas and methods. The strength of this group is in its ability to deal with the whole chain of predicting acoustic problems, from noise generation, via propagation and transmission to the resulting noise levels, and it is the group's ambition to strengthen all the links in this chain.

FFA Wind Energy. The Wind Energy Department develops methods and collects data to support the further Swedish development of wind energy technology in terms of higher cost effectiveness and safety. The department also carries out consultative activities for both the Swedish and foreign wind energy industries and power companies. A substantial part of the research is done within the EU research programme JOULE (Joint Opportunities for Unconventional Long-term Energy). A wind energy consortium led by FFA has recently been established. The wind energy research programme of NUTEK (Swedish National Board for Industrial and Technical Development) is directed mainly to this consortium as a three year programme which started in July 1994 and will finish in June 1997.

Design and Workshop. FFA has resources for the design, manufacture and mechanical maintenance required by the operational units (the Experimental Aerodynamics unit, the Structures unit, and the Flight Systems unit). This unit's tasks are to supply the operational units with the design and manufacture of wind tunnel models and test equipment, as well as other items and products, such as prototypes and tools for single component manufacture. The servicing part of its tasks are related to the products manufactured by the unit, as well as the mechanical maintenance of other FFA facilities. The Design and manufacturing unit also undertake work for external clients.

The National Laboratory for Pressure. The Laboratory performs commissioned calibration activities for customers in Sweden and abroad under the supervision of SWEDAC - the Swedish Board for Accreditation and Conformity Assessment. This laboratory participates in international intercomparisons and in international cooperation such as EAL and EUROMET.

International research cooperation
In the wake of the European aerospace industry's on-going restructuring operation, FFA considers it vital to take part in European research cooperation in preparation of a future, more integrated Europe. FFA is a member of AEREA (Association of European Research Establishments in Aeronautics), represents Sweden in GARTEUR (Group for Aeronautical Research and Technology in EURope) and participates in several EU framework research projects (18 projects were accepted in the first call of the 4th framework programme).

Most European cooperation programme focus on non-military projects. There are also bilateral agreements for military projects. FFA has been involved recently in joint projects, for instance those with DRA (now DERA) in Great Britain and DLR in Germany. Bilateral cooperation programmes have been entered into with different research groups in the USA and groups at universities in several other countries.

11.2.3 Key indicators and financial flows

FFA is currently one of the most financially-healthy cost-effective institutes in Europe. A major restructuring operation was undertaken in 1991 resulting in substantial cuts in costs and redundancies. The workforce was reduced from around 250 to 190. Most of the redundancies were made in the administrative section. Currently, all new jobs must be sanctioned by the director-general. The entire restructuring operation was instigated by a forward looking general director who wanted to avoid government cutbacks by taking the lead in a cost cutting operation to make the FFA, then an organisation with a SEK 10 million deficit, profitable. This resulted in the FFA having a very strong position when the present government demanded general cost cuts in the 1995/1996 and 1997 budgets. For instance, whilst FOA has had a 10 percent cut in its budget, FFA has only had a 2 percent cut. This restructuring operation called for an assessment of all the activities in terms of cost-effectiveness and projections; areas with good potential for future development were prioritised. A continuous implicit evaluation is now being made of all areas and subareas as they must be self-financing.

Direct research subsidies have increased from 10 to 20% over the last five years. As can be seen from the data, the FMV (Swedish Material Defence Office) remains the most important client even though its share has decreased slightly.

Table 11-1: Development of financing structure (MSEK)

	91/92	92/93	93/94	94/95	95/96 (18 months)
Revenues	120.9	109.5	101.6	104.6	169.6
Direct R&D subsidies	9.5	10.5	21.3	22.3	32.3
Costs	117.8	104.5	105.8 (*)	104.6	152.2
Profits	3.1	5.0	-4.2	0.04	1.1
Investments	9.9	4.8	6.3	14.5	21.8
Employed	211	178	176	176	190
Indexed hourly rate (89/90=100)	133	103	103	103	106

*: including an exceptional reservation of SEK 6.5 million

Table 11-2: Main commissioning bodies / clients

	92/93		93/94		94/95		95/96 (18 months)	
	MSEK	%	MSEK	%	MSEK	%	MSEK	%
FMV	64.4	66	51.5	63	44.4	57	80.4	58
NFFP			-	-	-	-	11.9	9
SAAB	3.3	3	7.7	9	6.8	9	7.5	5
NUTEK (ex STU)	6.3	7	4.1	5	4.6	6	3.9	3
NUTEK (ex STEV)	7.9	8	4.3	5	6.0	8	4.4	3
Other Swedish - public	3.3	3	5.3	6	4.3	6	11.6	8
Other Swedish - private	5.8	6	5.2	6	6.8	9	11.6	8
Foreign	6.6	7	4.1	5	4.0	5	8.0	6
TOTAL	97.6	100	82.3	100	76.9	100	139.3	100

FMV: Försvarets Materielverk (the Swedish Defence Materiel Office)
NFFP: Nationellt flygteknisk forskningsprogram (National Aerotech Research Programme
NUTEK: The Swedish National Board for Industrial and Technical Development

Table 11-3: Financial result by area of activity (18 months)

	Aero-dyamics	Struct. Materials	Flight systems	Acous-tics	Wind energy	Nat. lab f. press.	Admin. support	TOTAL
Revenues - missions	65.2	29.7	20.1	8.9	6.3	3.5	3.6	127.2
- subsidies	18.0	4.2	3.0	2.6	0	0	4.5	32.3
Net profits	15.7	8.8	5.9	2.4	1.5	0.05	-33.3	1.05

11.2.4 Trends and developments; key forces

The situation for FFA is a very stable one, not only financially but also politically. No major changes are anticipated, neither in military nor civil aerospace research. The Air Force is still considered a vital part of the Swedish Defence system. Even though development of the new military aircraft SAAB JAS 39 Gripen called for a major effort from all parties involved, work at FFA did not come to a standstill after the delivery of the first aircraft to the Air Force. FFA plays a major role in the continuous development, upgrading and maintenance of this aircraft. If the main private actor, SAAB, were to disappear from the scene, then the role of FFA would change, but not dramatically so. The most recent SAAB military aircraft will be in service until 2030. A great deal of development and maintenance work will still need to be carries out during this period, implying smooth transition to a new role.

It would not be realistic to think that a small country like Sweden will develop a successor to the JAS 39 Gripen all by itself and some sort of partnership will probably be sought. Nevertheless, aerospace is still a highly prioritised area in Sweden. The National Aerotech Research Programme (NFFP) was extended in 1997 from its initial three years to include a further three years at the same level. Air defence was prioritised in the 1996 Government Defence Bill. Development work on the JAS 39 Gripen has been extended and a third series has been ordered. An extraordinary government-funded investment of SEK 20 million has been granted for the renewal of the major wind tunnel's compressor system. FFA's position and role in relation to FMV (the Swedish Defence Materiel Office) is now much clearer than ever before. A new research and technology acquisition process was initiated in 1996 which has led to greater transparency.

Whereas FFA is dependent on others it has a relatively strong international position. While it still manages to attract foreign customers for its wind tunnels, there is a radical over-capacity in Europe. One of the FFA's ambitions is to increase the capacity of its wind tunnel by installing new compressors and by operating the main transonic tunnel on a one and a half shift basis. A great deal of space work is being done for ESA in this tunnel. FFA has gained a competitive edge by reaching its deadlines, by being reliable and by charging reasonable fees. Compared to its sister organisations in Europe, FFA has already gone through a slimming process and is now more industrially-oriented in its core areas, being system-oriented rather than discipline-oriented.

11.2.5 Legitimisation: strategic issues and future perspectives

There is a clear political ambition to maintain FFA in its current form. Normally it is the defence activities within the aerospace industry that leads technological development. All investigations made in this area have recommended that FFA remains under the supervision of the Ministry of Defence's. Hence FFA describes the situation as a very stable one for many years to come.

FFA is trying to specialise within the AEREA network and take the lead in some of AEREA's so called Virtual Centres of Excellence. This aim to achieve specialisation is also part of FFA's efforts to be self-financing. All areas and sub-areas are now supposed to be self financed. Previous areas which were lacking in efficiency or which had only a small customer base have been dropped in favour of emerging areas, such as environment-related technologies, air traffic control, acoustics, etc. New fighter simulation capacity is being built up (many against many), consisting of a virtual air force unit for JAS 39 Gripen. At a later date this will be extended to cater for helicopters too. A technical and economic agreement makes provision for accepting customers other than the Swedish Air Force. The acoustic area has been built up to cater for special demands from SAAB (problems with noise in the 340 and 2000). FFA has become a leader in the field and the Air Force is now financing its work. EU funding has also become more important for FFA in all fields.

11.3 Concluding remarks

FFA is one of the most cost-effective institutes in Europe. The situation for FFA is clearly a very stable one, both financially and politically. There is a clear political ambition to maintain FFA in its current form.

12 Italy

12.1 Introduction

This country study[42] deals with the area of energy technology. In the field of energy there is only one institute in Italy that falls within the scope of the study: ENEA (*Ente per le Nuove tecnologie, l'Energia e l'Ambiente*, or the Italian National Agency for New Technologies, Energy and the Environment). The main subject of discussion in the energy policy field in Italy today is the privatisation of ENI and particularly the privatisation of ENEL. The fact that this privatisation operation could imply a decline in the strategic R&D effort is mentioned occasionally. In this chapter, the position and strategy of ENEA in Italy's rapidly changing energy arena is dealt with in detail.

12.2 Energy

12.2.1 Introduction

ENEA is a public institution, technically a 'public statutory institute', i.e. whereas it is public it is still not a part of the Administration as such (the staff work under the terms of a private contract) and has administrative elements which lie somewhere between those of the ministries and those of private companies. It relies for the major part on public funding, and is definitely involved in strategic energy issues.

Other institutions which could have been taken into consideration in the past are the research sections of the two state energy holdings: ENEL (the national electric utility company) and ENI (the national agency for hydrocarbons). Although in the past the majority of R&D activities in these companies was functional to their core business and fell within the scope of industrial R&D, the public nature of ENI and ENEL, the broad mandate they had from the government and the relative abundance of financial means, ensured that a steady part of their R&D activities were of a strategic nature with results that went beyond their own, direct utilisation.

The process of privatisation (even in the initial stage) has radically changed this picture. ENEL and ENI are now managed completely as if they were private companies; their R&D efforts have on one hand been strongly reduced, and on the other have been restricted to the core business. There R&D efforts are also now focused on the short-term objectives; there is no reason to see their R&D in a different light as that carried out in other industrial R&D institutions. Their source of financing is chiefly from the revenues of the companies

[42] This chapter was contributed by Prof. Ugo Farinelli (ENEA).

themselves. This applies even more so with regard to the third state holding is active in the field of energy (IRI-Finmeccanica, especially through the Ansaldo group) which is also being privatised, and which performs an important share of industrial energy R&D (some of this also has a strategic value), but is to the larger part self-financing.

The energy research situation in Italy is therefore (and also for other reasons that we will discuss later) undergoing rapid change, and there are certainly grounds for discussion on and preoccupation with maintaining strategic R&D on energy technologies at a reasonable level. In this respect, the Italian situation is certainly not unique.

12.2.2 Mission, strategy, activities, markets

ENEA (likewise ECN and many other energy technology institutes) emanates from nuclear energy research. Its origins are in CNEN (the Italian National Committee for Nuclear Energy), the body which was responsible for the development of nuclear energy, nuclear safety and regulations. Its mandate was changed in 1981 to include forms of energy 'other than hydrocarbons' (which were included in ENI's mandate), the environmental effects of the energy cycle and the application of technologies emerging from nuclear research in fields other than nuclear. This was an extension of the activities which were already emerging unofficially; its name was then changed to ENEA (which at that time stood for something different than it does today: originally ENEA stood for Comitato Nazionale per la Ricerca e lo Sviluppo dell'Energia Nucleare e delle Energie Alternative, i.e. National Committee for R&D on Nuclear and Alternative Energies). ENEA underwent a second transformation in 1991, again in consequence of the Italian decision in 1987 to abandon nuclear energy: its mission was extended to cover all energy and environmental issues, as well as unlimited 'new technologies'. However, its 'basic budget' (i.e. the one allocated on a three-year basis under the stipulations of the State financial law) was greatly reduced as a result of the past, and ENEA was asked to 'look to the market' for additional funding. Its acronym remained the same, but the meaning changed (see 12.1).

ENEA is now divided into three departments: Energy (ERG), Environment (AMB) and Innovation (or New Technologies) (INN). Table 12-1 presents some basic data. Energy is the largest of the three, both in terms of personnel and budget (accounting for slightly less than half of the total). The rest of this paper will deal with the Energy Department only, even though some activities of relevance to energy are carried out in the two other departments (e.g. cultivation of biomass at INN) some of the activities carried out at ERG are not energy-related (e.g. seismic protection of buildings). In presenting these figures it is assumed that a rough compensation is made for 'overlapping' activities.

However, it should be mentioned here that there is a very strong synergy among the activities carried out by the three departments, and this is regarded as one of ENEA's strong points. For instance, ERG and AMB cooperate on issues like urban mobility and traffic (which include both energy saving and atmospheric pollution), recuperation of materials and energy from waste, issues concerning global climate change etc.; ERG and INN cooperate on advanced technologies such as laser, robotics and new materials; all three departments may be involved in the introduction of energy efficient, low pollution new processes in industry.

Table 12-1: Basic data on ENEA and on its energy department (ERG)

	ENEA	ERG
Personnel (1997)	3860	1606
Budget (1996) Glit *(in $ millions)*	707 *(430)*	310 *(190)*

Source: ENEA

ENEA's Energy Department is engaged in a broad spectrum of activities:

- Nuclear fusion takes up about one third of the effort; this programme is carried out almost entirely within the frame of the Association with Euratom. The activity is split more or less evenly between physics (especially in the FTU facility at Frascati) and technology (mostly in support of ITER, on superconductivity, robotics and materials). The Italian fusion programme is the third largest in Europe, after Germany and France. ENEA also coordinates (through an association contract) the fusion activities of the National Research Council (CNR) and has set up a consortium in Padua with CNR and the University, first to build and now to experiment on RFX (a reversed field pinch machine). ENEA is also working (at present outside of the EU programme) on the Ignitor concept proposed by Bruno Coppi (a high-field compact fusion device capable of demonstrating ignition), for which special funds have been ear-marked by the Italian Parliament.
- Most of the nuclear fission activities have been phased out, except for the conditioning and disposal of nuclear wastes generated by the one-off nuclear programme of Italy. This programme, which is subjected to considerable pressure from political quarters, local worries and legal actions, is rather complex and costly in comparison with the relatively small quantity of waste. In addition, some activities are carried out in the frame of international programmes on severe accidents, on the safety of reactors in the former USSR, and in the follow-up of the design of innovative reactors. Recently, an activity has begun on the exploration of the accelerator-driven, thorium fuelled system for the incineration of wastes proposed by Carlo Rubbia. Altogether, nuclear fission activities account for 22% of the ERG budget.
- Non-nuclear energy, with 42% of the budget, has the largest share of the activities. Although it covers a very large field, there are well-defined points of concentration of R&D. For renewable energies, the largest effort is carried out in the field of solar photovoltaics (PV); an entire Centre (at Portici near Naples) is devoted to the development of innovative PV materials and systems; relatively smaller efforts go into biomass and wind energy; very little or no activity goes into solar thermal, geothermal or hydro energy. Little activity is devoted to hydrocarbons as such (management of pipeline networks and multiphase flows are being studied), and practically no activity is related to coal, although ENEA participates (with ENEL, ENI and the Sardinia Region) in Sotacarbo, a

consortium set up by a special law to investigate exploitation of the Sardinian coal mines and the utilisation of low-grade coal. A relevant effort, however, is made in basic studies into combustion (both experiment and theoretical modelling on high power parallel computers). High efficiency energy conversion is investigated, especially in connection with fuel cells, small-scale combined heat and power systems, and to a minor extent, external combustion turbines and heat pumps. ENEA also participates in SIET, a research company having large loops for the testing of components of thermal power plants.

Activities for the end-uses of energy concerns all sectors; there has recently been an increase in the level of activity for the transportation sector, both for the development of new vehicles (electric, hybrid and fuel-cell vehicles) and for the management of traffic and urban mobility. In the residential and services sector, the activities concern high-efficiency heating and cooling systems, electric appliances, lighting, bioclimatic architecture and domotics. Although some activity has been devoted in the industrial sector to the most energy-intensive industries (in particular steel and aluminium manufacturing) by far the most effort has gone into the medium energy-intensive sectors, like ceramics, bricks and tiles, fabrics and clothing, glass, leather, etc., where the dimension and the structure of the industries makes intervention from internal sources more difficult. Particular emphasis was given to the specialised industrial districts.

In addition to R&D activities ENEA provides technical support to central and local authorities.

With regard to the energy activities of ENEA, the most important 'clients' are the Ministry of Industry (MICA) for the activities on non-nuclear energy, the European Commission (Euratom) for nuclear fusion activities, and the Ministry of Education, Science and Technology (MURST) for a range of activities that will be mentioned later.

12.2.3 Key indicators and financial flows

Tables 12-1, 12-2 and 12-3 provide some basic data on ENEA and its activities. ENEA has a 'programme agreement' with MICA (the Ministry responsible for energy matters in Italy), the financing of which is based on law 10 (1991) for the promotion of energy efficiency. This funding will expire in 1997. All activities carried out within the scope of this agreement are compatible with the needs expressed by the Ministry; they are decided upon by a joint MICA-ENEA management committee, and the costs are shared between the two in proportion with the amount of action called for, MICA paying from 100% (for consulting and services) to about 60% of the total expenditure if in-house research is concerned. Table 12-2 provides a breakdown for each type of activity.

Table 12-2: Programme agreement ENEA-MICA. Cost of activities for each area and contribution from MICA (billion It. Lira)

	COST OF ACTIVITIES/(MICA CONTRIBUTION)					
AREA	1991-93	1994	1995	1996	1997	
Development of components and systems		5.1 (3.9)	24.7 (18.2)	34.3 (24.8)	69.9 (43.0)	
Demonstration projects		3.2 (2.3)	14.7 (10.0)	18.9 (11.2)	78.4 (48.6)	
Diffusion of information; training		2.9 (1.5)	13.8 (11.5)	7.9 (6.3)	13.5 (10.8)	
Support of public administration		2.2 (2.2)	6.7 (6.6)	7.9 (7.9)	9.3 (9.3)	
TOTAL	54.7	13.4	59.9	69.0	171.1	*368.1*
Contribution by MICA	32.9	9.9	46.4	50.2	111.7	*251.1*

Source: ENEA

Research activities carried out within the scope of this programme include the development of components, systems and photovoltaic plants in a joint programme, the costs of which are shared with industry (the industrial partners were selected by a public tendering procedure); some support and normative R&D concerning wind energy; the development of molten carbonate fuel cells; some basic studies on combustion, including the formation of pollutants.

Another area covered by this programme agreement concerns local intervention, demonstration and promotion of demand: included are activities in the field of urban mobility, the application of informatics and telematics for automatic traffic management, and in the field of developing innovative vehicles (e.g. hybrid buses); the demonstration of small-scale innovative CHP systems; the setting up of two test stations for biomass fired boilers and small methane boilers; some demonstration activities for improved or advanced processes in steel making, glass and brick industries; a test station for lighting. A third area concerns the diffusion of information and preparing energy managers and controllers for their tasks (the latter for heating plants in particular as this is now required by new legislation). The last area covered by the agreement is the provision of support to public administrations; this covers a very wide range of activities connected with the management of energy-relevant legislation; one important item of this activity is the development of models and procedures for energy monitoring and planning at various levels (state, regions, cities).

The activities for the fusion programme follow the usual Euratom rules with a contribution of 25% of the total cost for 'general support' actions, and 45% for 'priority actions'. On average, Euratom support has been equivalent to about 35% of the total expenditure. In addition, a special law instituting a rotating fund for financing part of the expenditure in EU contracts not paid by the EC and managed by MURST actually covers some 5 to 10% of the fusion programme.
Support from MURST is made through different channels and is generally (but not entirely) managed through a programme agreement between MURST and ENEA. This agreement (functioning similar to the one concluded between

ENEA and MICA) covers many of ENEA's non-energy activities. In the field of energy, in addition to the support given to fusion mentioned above, MURST pays 60% of a programme worth 6.5 million ECU carried out by ENEA on 'Technologies in the fields of photovoltaics and microelectronics'. This programme is financed within the framework of objective 1 of the EU (FESR), for providing structural support to regions. Other projects financed from structural funds are the integrated Portici project (PIP), which also relates to work on photovoltaics, and the integrated Trisaia project (PIT) which includes some activities in the field of biomass. Another form of financing from MURST is based on Law no. 95 of 1995 which reserves 5% of the budget normally allocated to research institutions to projects that are of strategic value to industry, proposed by the institutions (including ENEA) and with participation of industry itself. At present ENEA has two energy-related projects in this area: one in the field of combustion modelling (for a total of 9 GL) managed by ENEA, and the other concerning accelerator-driven incineration of actinides (for a total of 12 GL, 8 of which is supplied by MURST) a project jointly managed by ENEA and INFN (the National Institute of Nuclear Physics). Table 12-3 sums up the financial flow by source and destination in 1996.

Table 12-3: Expenses of ENEA on energy programmes by source and by destination (1996, billion Lira)

	FUSION	FISSION	NON NUCLEAR	TOTAL
Min. of Industry	0	0	50.2	50.2
Min. of Research	15.5	0	0	15.5
EU and others	44.3	4.3	4.7	53.3
Ordinary budget	44.1	65.2	81.9	191.2
TOTAL	103.9	69.5	136.8	310.2

Source: ENEA

12.2.4 Trends and developments; key forces

As in virtually all other countries in the world, the *amount of government funding is on the decrease*, particularly in the field of energy where the urgency resulting from the oil crises has disappeared. Energy prices remain low and the general tendency is to feel that other problems are more urgent and that energy can wait. Even the environmental factors that (in most cases) play a minor role; climate change and greenhouse gases are given little more than lip service in the media. A notable exception is urban air pollution which is chiefly caused by traffic and subsequently linked to fuels and energy: this has a direct effect on the citizen (failing all else, by banning private transport when certain concentration thresholds are surpassed) and this explains the growing demand for intervention and innovative developments in this field.

Another important development taking place in Italy is *the regionalisation (or better: decentralisation)* of energy issues. Up to 1992 the Regions had played no role whatever in the field of energy; nor were they able to legislate on energy matters. This situation has gradually changed since then, the Regions started to be given more powers on energy matters, and this trend is continuing and accelerating as a part of a general shift of powers from central to local government. The Regions (and to a certain extent the Provinces and at least the larger Communes) are becoming just as much the 'clients' of ENEA on energy-related issues as the central Government. When the Programme Agreement between MICA and ENEA expires in 1998 it is expected that it will be replaced by a trilateral agreement that will involve the Regions (through their coordination body) as well. This agreement is currently being negotiated and the actual contents could not be anticipated. However, it is easy to imagine that all three parties will contribute towards the funding (ENEA will contribute by providing part of the manpower working on the agreement).

Revenue for the Regions will to the largest extent be in the form of taxes on petrol sales; it is expected that a small proportion of this revenue (say 1%) will go into energy matters (e.g. for the setting up of the regional energy offices). Part could go to financing the trilateral agreement. In terms of demands on ENEA there is a marked difference between those Regions that are the most highly organised (these are chiefly located in the North and Mid-North areas of the country) and the others. The most highly organised Regions tend to refuse general support, as this reduces their powers of decision; they have specific demands geared towards their own policies. Conversely, other regions require a higher level of assistance in order to establish a structure for energy policy management.

It is quite conceivable that the future agreement could look at three types of activity: those which are of interest to the central government and not the Regions; those which are of interest to all Regions; and those which appeal to a single or a few Regions only. It is possible that the financing scheme might follow this subdivision, with the third group of activities being subjected to 'variable geometry' or 'multiclient' schemes of financing.

From this analysis, and from section 12.2.2, it will be clear that the key forces in the Italian energy scene are as follows:
- Reduction in the level of government funding.
- Regionalisation or decentralisation of energy issues.
- The process of privatisation and associated reduction of energy R&D.

12.2.5 Legitimisation: strategic issues and future perspectives

The single most important ongoing discussion in the frame of this chapter concerns the role that ENEA, as the energy technology institute of Italy, should have in terms of the government versus the market. Particular emphasis should be laid on the fact that the main subject of today's discussion in the field of energy policy in Italy is the privatisation of ENI and particularly ENEL. The fact that this privatisation could involve a diminished effort in strategic R&D is occasionally brought up.

With regard to ENEA, it should be pointed out that this is the first, and to date, the only public research institute with a financing scheme which involves the necessity to seek programme financing from external sources for a substantial part of its activities. Other major institutes, such as the National Research Council (CNR) and the National Institute for Nuclear Physics (INFN) have their entire budget assigned to them from the State on the basis of generic proposals; they do look for additional funds, but this is only to expand their activities, and do not have to rely on them in order to survive. So the principle of 'operating on the market' only applies to ENEA and although it is generally recognised as reasonable and stimulating in abstract terms, it still puts ENEA at a disadvantage when competing with other public research organisations that do not need external financing. (This situation is more critical in the field of new technologies where there is competition from other public institutions, than in the field of energy where ENEA is practically alone.) Although at least for the time being ENEA's 'external' financing is only about one third of the total (40% in the area of energy) the proportion of activities involved in this financing is much larger (closer to 75%) since most of the projects are financed on a basis of shared costs. This situation has different effects: on the one hand, it ensures that what is done is in the interests of some of the potential users and keeps up the pressure to either maintain or reach a high standard (especially on the international marketplace as far as EC funding is concerned). On the other hand, it presents the danger of concentrating on short to medium terms objectives (which is true for most demands), neglecting long-term strategic research, and worse still, the danger of excessive dispersion of efforts, resulting in the need to chase up the various opportunities of financing without being able to follow the objective criteria of priority setting.

Another possible point of controversy is the Institute's public-private function. The two roles of ENEA: supporting industry and supporting government, may be seen as alternative roles and even conflicting roles. In the past, ENEA has been an important instrument (especially in the nuclear field) in promoting Italian industry; this was done chiefly through association contracts with shared costs (ENEA taking upon itself the larger part of the expenditure, typically two thirds) and with joint R&D activities, decided by a joint management committee. The situation has now changed: ENEA no longer has the finances to invest externally in such programmes unless they come from other sources of financing. EU rules limit to a large extent the possibility to discriminate between Italian and other European industries. Yet even if these conditions are met, transparent procedures are now followed and thus the freedom to choose one's own industrial partners is limited. At the same time, ENEA increasingly needs support from government. As a consultant to the public administration, ENEA must maintain a record of independent judgement and avoid bias. But when ENEA acts in conjunction with industry (for instance on the development of certain technologies or systems) it can hardly be expected to remain neutral when evaluating alternatives, including alternatives for the technology or system it has helped to develop. There is no clear-cut solution to this dilemma, which to date has created problems but they were not major ones. For its work in the field of certain technologies and for some aspects, ENEA generally takes on the role of supplier in collaboration with industry; for others, it assumes the role of independent evaluator.

Nevertheless, it should be pointed out that the discussion concerning ENEA's future role deals with more aspects than energy alone; on the contrary, ENEA's current role in the energy field is taken more or less for granted. The discussion concerns all public research institutions, and it may have a bearing on ENEA's energy activities inasmuch as its general role is shaped: should ENEA be mostly a research institution? or should its role as an 'agency' prevail (i.e. in support of the diffusion of innovation in SMEs or as a consultant to the government and public administrations)?

ENEA's strong points are to be found in its 'systems' approach (looking not only at specific technologies but complex projects too, and to the interaction between different technologies and the different aspects of their application); it is project-oriented, and has shown that it has the ability to manage large-scale programmes (not only in the nuclear field but, for instance, by coordinating all Italian activities in Antarctica); it is multi-disciplinary. It is expected that these characteristics will be maintained in the future.

Future perspectives
The present trends have been summed up in the previous sections. Given that the restructuring process of the whole sector has only just begun ENEA's position in the frame of public research institutes is still somewhat vague, yet its role in the field of energy technology should not be subjected to major change. It is expected that the basic functioning of ENEA will be guaranteed through the allocation of state funds, and that funds needed to carry out specific activities will come from different sources, mostly public or European. The main anticipated change is an increase in the role the Regions will play as 'clients' in the field of energy.

The ratio between basic funding and programme funding should not undergo any drastic change (of the order of 3:2). The process of privatisation could reinforce ENEA's role as the only remaining public body in the energy field. The present share of activities among R&D, demonstration, services and support to Administrations should also be left unchanged for the greater part.

The current legislation that regulates the operation of ENEA allows a reasonable amount of flexibility in all matters excluding personnel. There is no way that personnel can be dismissed, and there is little opportunity to take on new staff, not even as replacements. Because of the uncertainties with regard to future pension schemes, as well as the uncertainties regarding the ageing staff (the majority of whom took up employment in the sixties) ENEA's workforce has been reduced (simply by not replacing members of staff when they retire) from some 5,000 in 1990 to the present 3,860; and this trend is continuing. This is considered a major problem, not so much in numerical terms but in terms of loosing specialised competencies, plus the fact that it is impossible to rejuvenate the workforce, thus causing a lack of fresh ideas. Although in principle it is possible to employ highly-qualified people for limited periods of time (usually two years) provided they are paid entirely from income from external contracts, the procedure is so long and cumbersome that little use is made of it. Other areas of little or no flexibility at all concern the incentives for personnel to take up particular jobs or to move from one job to another.

ENEA has the possibility to set up, or participate in consortia and other forms of enterprise. The legal stipulations are such that ENEA may set up, and participate in companies or industrial consortia having as their objective the industrial development of technologies of a direct interest to ENEA in the frame of policies established by the government; that its share in such a company may be paid in money if the company is not a commercial one; and that should the company be involved in commercial production, ENEA's contribution may be in kind only (patents, know-how, facilities, plants, infrastructures or personnel). In the field of energy ENEA is actually participating in several private-type initiatives: SIET, for research and testing on thermal cycles; Sotacarbo, for research and industrial development of coal technologies; FN, originally for the fabrication of nuclear fuels and now for the development and fabrication of advanced materials such as fuel cell electrodes; RFX, a consortium for the development and experimental exploitation of a reversed-field pinch fusion machine; Nucleco for the management of low-level nuclear waste; and internationally Eurodif, for the enrichment of uranium.
Administrative procedures which are partly the result of the inefficient state system, which ensures observance of a large number of regulations and procedures, implying that system response times are often very slow. This is a serious handicap when trying to meet the demands of private customers, especially SMEs. Something can, and is, being done to improve the situation, yet certain aspects depend on the general legislative framework and it will take some time before a change is achieved.

12.3 Concluding remarks

The key forces in the Italian energy scene are: the reduction in level of government funding, regionalisation or decentralisation of energy issues and the process of privatisation and the associated reduction of energy R&D. In this changing environment ENEA's position in the energy area is not being subjected to a large degree of change. On the one hand the partial orientation towards an external funding of ENEA - exceptional in the Italian research landscape - ensures demand orientation, on the other it could result in the neglect of long-term strategic research and a dispersion of resources. A potential point of controversy is the Institute's mixed public-private function: supporting both industry and government. While these two separate roles could result in a conflict of interests no major problems have arisen to date.

Discussion and outlook

13 Strategic perspective

13.1 Introduction

The main theme of this final chapter is the raison d'être of the hybrid organisation which is so splendidly defined as the 'contract research organisation with a public mission'[43]: the technology institutes that receive considerable subsidies from government but at the same time are active in the (free-) market. Why do governments establish and fund these organisations? What are the recent changes in their motives and how does this influence the future of these organisations?

Of course there is the basic idea that these organisations are entitled to a certain amount of government funding to enable them to perform a number of tasks in the knowledge market; tasks which private firms are unable to undertake, or which they can only take at a much higher cost, while at the same time they are found to be of strategic importance. There is usually considerable consensus on this basic idea. However, there is less consensus on the level of funding and the activities on which the money should be spent. Given that (as has already been pointed out) these organisations are also active in the free market, subsidising also implies an intervention in the free market with all the risks of distorting the functioning of this market. This dual function sometimes results in commercially operating research organisations accusing CRO+ organisations of frustrating competition, for example by means of cross-subsidising activities in commercial R&D markets.

In other words, there is reason enough to stop and think about the legitimisation of CRO+ organisations, the way in which they develop and the safeguards that are needed. Chapter 1 already stated that the broader problem is the legitimisation of the role of government funding in the knowledge market. Focusing on the legitimisation of a CRO+ should not prevent us from reflecting on the fundamental forces that shape the structure of the market for knowledge in which CRO+ organisations will have to develop their strategies. Basically there are two sets of arguments[44] to legitimise the existence of a CRO+.

The first one relates to the *functioning of markets* in performing socially desired activities. The question as to the whys and wherefores of CRO+ organisations in the market is best answered by referring to the long-standing debates con

[43] In the remainder of this chapter we shall refer to these organizations as CRO+, the Contract Research organization with a public mission ('plus').

[44] The following set of arguments is based on R. Smits, 1997, *The role of a contract research organisation with a public mission on the free market* in: F. Zwetsloot (ed.) *Steering of scientific research*, Delwel, 's Gravenhage, (in Dutch) and J. van Dijk & N. van Hulst (1988), *Foundations for technology policy*, Ministry of Economic Affairs, 's Gravenhage, (in Dutch).

cerning the functioning of markets and organisations. Complex and intertwined issues such as introduction of competition, transfer of ownership (privatisation) and regulation of public institutions in relation to incentives and behaviour have attracted much attention, especially in traditionally 'public enterprise' sectors such as energy, telecommunications and transport. It shows that for many activities in the public domain neither pure market arrangements nor pure public organisational forms are suited.

It goes without saying that Adam Smith's 'invisible hand' is definitely not always infallible; this also applies with regard to the knowledge market. Like the other markets, the market for technological knowledge also shows many imperfections which, if the government or some other mandated body fails to intervene, from a societal point of view will lead to sub-optimal investments in the development of knowledge or to under-utilisation of the stock of knowledge.

Based on the framework developed in Part I, in the following table the two most important categories of this type of market failure - *lack of supply and inadequate functioning of the knowledge-infrastructure* - are listed. In the second and third column manifestations and examples of these categories are presented. The second set of arguments - *public need* - is also included in the same table. These arguments are related to the notion of the government as a client of the knowledge-infrastructure. Of course, the *validity of these arguments* still has to be proved by assessing alternative options and associated benefits, costs and risks. This is not however the subject of this study and will require further attention and research.

In this study the structure set out in Table 13.1 only serves as a 'search instrument' and a means to help us arrange our findings. In no way is this structure restrictive; additional arguments that appear to be relevant will be incorporated into the structure, and arguments that fail to show up in the analysis of the country studies will be left out.

Table 13.1 Legitimisation arguments for CRO+ organisations: an overview

LEGITIMISATION OF CRO+	MANIFESTATION *(examples)*
Imperfection 1: Lack of supply	• Underinvestment in R&D because of risk and/or high costs (*nuclear fusion*) • Underinvestment in R&D because of the fear of external effects; knowledge as collective good *(software)*
Imperfection 2: Malfunctioning of the knowledge infrastructure (KIS)	• Insufficient quality, strength, openness of networks *(relation 'basic - applied')* • Critical mass due to economies of scale may require concentration of resources and one-stop shopping *(R&D capacity of SMEs, internationalisation space research)* • Coordination/efficiency *(fragmented R&D capacity in multimedia, rationalisation of R&D organisations)* • Tuning supply and demand *(tendency to increase influence users on targeted programs)* • Linking supply and demand *(tendency to break down financial, cultural and other barriers standing in the way of SMEs approaching research institutes)*
CRO+ fulfilling public needs	• House-laboratory for government *(defence-related research)* • House-laboratory for industry *(R&D function for enterprises that lack R&D facilities)* • Independent advice *(Acquisition material, testing)* • Training *(nuclear specialists)* • Policy competition (level playing field) *(equal fiscal regimes, creating S&T to guarantee competitiveness of industries)* • National projects *(Space, nuclear, employment)* • Societal problems, government as the problem owner *(Sustainable society, health)*

On the basis of the empirical material set out in the previous chapters in the following sections we will discuss, for each of the three areas - energy, marine and aerospace technology - the basic arguments for legitimising the CRO+, what the main issues in the debate are, and what conclusions can be drawn concerning the future perspective of these organisations. We have chosen to present the analysis by area because with regard to issues related to legitimisation our interest is in differences across countries. This also makes it easier for us to provide an overview of the differences between the relevant areas.

As explained in Part I, it will be evident that the *establishment and funding of CRO+ organisations is only one of the many ways that government can intervene in the knowledge market*. Other - Dutch - examples of such intervention are:

- the Techno-Lease construction (lease and sell-back construction between Rabobank and Philips)
- R&D support given to Philips and OCE*
- the establishment and (partly government-funded) financing of Top Technology Institutes

* OCE is a major Dutch 'copier' - firm

- the Technology Development Loans (which have been successful for many years)
- the Promotion of Research and Development Act.

In the context of this report however, we focus explicitly on the arguments that can be distinguished to make the decision to establish and fund a CRO+ and to decide upon the mission, organisation and institutional setting of the CRO+.

From the many, often heated discussions that take place regularly on a number of these initiatives, we may deduce that they all have in common that they balance on the borderline of what is permissible from the point of view of market forces. Given the fact that in our society we attach a great deal of value to the functioning of markets, at the same time we realise that the functioning of markets is in need of correction now and again. Nevertheless, the fact that it is never absolutely clear exactly what corrections are required, or to what extent they are required, implies that this seems to be a situation we must learn to live with. The discussions that keep on flaring up should therefore not be seen as an attempt to bring these initiatives to a halt, but rather as attempts to look again, in the light of changed circumstances, at what should and should not be regarded as permissible in view of the open market.

13.2 Energy

13.2.1 Legitimisation, issues and trends

Legitimisation

For many years the involvement of government in energy-research in Europe was based on two considerations:

1 The importance for society of an effective, safe and commercially sound electricity system based on nuclear energy (France, Italy, Belgium)[45].
2 The need for support of a major economic sector as the gas and oil sector of the Norwegian economy.

In terms of the arguments, as presented in the first section of this chapter, the major arguments backing the political legitimisation of investments of public funds in energy-research can consequently be summarised as follows. The majority of these arguments accounted for all countries (A) involved in nuclear research.

[45] Whereover possible the countries are listed for which the respective statement is must valid. If the trend or statement accounts for (almost) all countries studied, this is indicated with (A).

Table 13.2: Main arguments to legitimise public energy research from the past[46].

- Underinvestment in nuclear R&D because of high risks and high costs (A)
- Bridge between industrial applications and basic research (A)
- Realising economies of scale (A)
- Creating sufficient critical mass (A)
- Independent advice on complex technological issues, especially in the area of nuclear research (A)
- Training of specialists (A)
- Realising an independent position as a country with regard to the supply of energy (France)
- Nuclear as 'prestige project' (France)
- Policy competition, more in particular (R&D) support of an important economic sector (France, Norway)

A strong, heavily publicly funded, nuclear R&D infrastructure was established in many European countries on the basis of this legitimisation in the fifties and the sixties. This development can be observed in most of the countries studied but especially in those countries in which a major slice of the electricity production is based on nuclear energy (France, Belgium and - to a lesser extent - Italy).

Trends and issues

Over the last decades this situation has changed considerably, especially as far as nuclear-related issues are concerned. Although many differences can be seen among the countries that were studied, the following four trends underlying these rather dramatic changes have a more generic character:

- Due to the immense problems connected with the removal of nuclear waste, the risks related to nuclear energy production and society's strong resistance against nuclear energy, the *political support for nuclear energy has decreased* very rapidly over the last two decades. This development was further reinforced by the growing awareness of the fact that nuclear energy was no longer an attractive alternative to electricity from other sources - also from a commercial perspective. This resulted in the loss of one of the most important pillars supporting the motivation for public investments in nuclear energy - the perceived societal importance of this source of energy source. This is a trend which is the most visible in those countries that still have room to manoeuvre. Countries like France and Belgium, however, that are already heavily committed to nuclear energy face a more complex situation.

- In a number of the countries studied, processes of *regionalisation* had or will have a big impact on the mandate, size and programming of the 'national' energy institutes (Belgium, France, Italy).

[46] Countries studied are: UK, Belgium, France, Sweden, Norway, Germany, Italy.

- Along with the trend from mode 1 to mode 2 science[47] which is also visible in other technology areas, there is a major tendency to *increase the market orientation of the R&D institutes* (A).

- The growing importance of the *environmental issue* causing a shift in R&D programming of energy research to environment related issues, especially in the areas of transport and building (A).

  Although the impact of these trends on the public R&D infrastructure in the area of energy varies considerably from country tot country, there are still some general comments that can be made on this impact.

- First of all, in almost all countries the *mission* of the nuclear R&D institutes shifted from a focus on nuclear energy production (fission and fusion), via a focus on fusion and fission (as far as safety issues, independent advice and training are concerned) and renewable energy sources, to a focus which also includes a growing emphasis on (non-energy) research related to industrial innovations, particularly on behalf of SMEs. These shifts are also visible (be it sometimes not so evident) in countries where a major share of the electricity system is based on nuclear energy.

- As a consequence of the dwindling political support for nuclear energy the *budgets* for this type of research shrunk considerably.

- The trend towards *a more market-oriented energy R&D infrastructure* is reflected in a remarkable shift from basic to applied science, an increase of private funding (and a corresponding decrease in public funding), privatisation of - sometimes considerable - parts of the public R&D infrastructure, as well as in a whole series of initiatives to create 'more market-oriented' institutions. Running parallel with this trend, a strong tendency to improve the effectiveness and efficiency of the management of the R&D institutes can be observed. In many cases this involves a considerable shift in the organisation, institutional setting and culture of the organisations involved.
  This trend also differs from one country to another, the UK and Italy being the leaders, Spain and Germany tend to lag behind. In the UK, there is very little publicly funded energy related R&D since the so called 'review process', and those institutes and programmes that still do exist are geared strongly towards a combination of societal and economic goals (for instance the development of commercially sound clean coal production). On the contrary, in Germany, the Fraunhofergesellschaft being an exception, the shift from public to private funding of energy-related research is still in its infancy. Despite these differences however, it is quite clear that this trend - reinforced by the liberalisation of energy-markets - has a truly universal character.

  A remarkable observation that can be made relates to the issue of 'unfair competition'. Although one would expect this to be a hot issue in the debate, it is

[47] Michael Gibbons et al., (1994) *The new production of knowledge: The dynamics of science and research in contemporary societies* London: Sage Publications.

an issue which is hardly addressed in the country studies.

- The trend towards a more *regionalised R&D infrastructure* has and will continue to have an important impact on the national energy R&D institutes. In Belgium this trend has already resulted in the splitting up of the nuclear energy centre in a national part (SKC, dealing with nuclear issues) and a regional part (VITO, increasingly involved in supporting industrial innovation). In other countries like Italy, Spain and Germany the consequences of a further regionalisation of R&D infrastructures are still more uncertain.

As a consequence of the developments outlined above, the basic elements of the legitimisation of public funding of the institutes concerned changed over the course of time. These changes can be summarised as follows.

Table 13.3: Actual main arguments to legitimise public funding of energy research.

- Bridge between industrial applications and basic research (A)
- Realising economies of scale and creating sufficient critical mass is broadened to include research into renewable energy sources and environmental technologies (A)
- The need for independent advice on complex technological issues, especially in the area of nuclear research (A)
- Support of innovation in SMEs becomes a more important element
- Training of specialists (A)
- Realising an independent position for a country with regard to the supply of energy continues to be an important argument for countries (France)
- Policy competition, especially (R&D) support on behalf of an important econo mic sector is still important. The Norwegians, for instance, formulated as one of their main goals the wish to create a recognised international position in those areas of expertise of importance for (specific sectors of) their economy. This argument is extended to include not only specific sectors such as the gas and oil sector but also the innovative capacity of SMEs in more generic terms.

13.2.2 Outlook

It will be clear from the foregoing that the institutions in the publicly funded energy-related R&D organisations are going through a radical transformation process. Some of the institutions are already (almost) through this process (UK, Belgium, Italy, Norway) and their future looks quite stable. Other institutions (France, Germany, Sweden) have still to go through the major phases of this process of restructuring, and for them the future is somewhat more uncertain. However, all organisations will have to cope with the following trends in the future:

- Driven by the liberalisation of the energy markets, including new EU regulations liberalising the market for electricity, and stimulated by a more general trend to link research more closely to societal and economic goals, the trend of *more applied, more market-oriented and more effective/efficient R&D organisations* will continue. One important element of this development is the expectation that the influence of private parties on public research will increase over the next few years. The country studies provide many examples of innovative new structures (France, UK, Belgium) in an attempt to deal with this trend.

- The development of a stronger market orientation, in addition to retaining the public function, will lead to *more cooperation between R&D institutes, governments and industry*. These country studies show some interesting examples of how this cooperation can develop (UK, Belgium, Norway, Italy).

- This trend has, and will continue to lead to complex discussions on matters such as how to position these institutes *between public and private* and how to organise their work. Issues of relevance in this context are:

a how to warrant strategic research with a longer time horizon?
b how to remain credible as an independent advisory body?
c how much room is there in which to manoeuvre - for instance to enter joint ventures with purely commercial organisations - and, related to this, who is in charge of the institutions?
d which institutional settings are available to combine the commercial and public functions in such a way so as to minimise the distorting effect on the free market (the issue of ‘unfair competition’) and at the same time guarantee the public function?
e how to prevent the ‘splintering’ of the R&D infrastructure?

- *Processes of regionalisation* will affect the mandate, the institutional setting and the programming of publicly funded energy-related R&D. The impact of regionalisation on the R&D organisations is context dependent and yet difficult to foresee (Belgium, Italy).

- *The internationalisation* trend will continue. This relates not only to an increase in international cooperation but also to processes of division of labour and the associated strategic choices. For instance, in Belgium the possibility is being discussed of abolishing the country’s own nuclear research capacity and purchasing the required knowledge and assistance from foreign countries. This is despite the fact that 50% percent of Belgium’s electricity consumption is from nuclear sources.

- The pressure on the budgets, together with the increasing pressure to become ‘more relevant’, forces the R&D organisations to better underpin their strategic choices. To this end we can expect that processes for *priority-setting* like those developed in the UK (the UK Foresight process) will become more and more popular.

13.3 Marine

13.3.1 Legitimisation, issues and trends

It becomes clear from the country studies that it is necessary to make a distinction between the Scandinavian countries (Norway, Denmark and Finland) and the UK. In the Scandinavian countries public support for R&D is rooted in the

wish to boost innovativeness, and thus industry's competitiveness by contributing to the development of a strong R&D infrastructure that is geared to the needs of the branch of industry concerned. This drive is expressed very well in the mission statement of the Maritime Institute of Finland:
"To support business activities of its customers in the long term by supplying research results and expert services through efficient and flexible collaboration".

While in Denmark the mission statement has a somewhat different flavour, it still expresses the same basic message:
"Therefore, the original intention with the technology institutes was a wish of the government to provide technological service to public institutions and private enterprises as part of a policy on technology oriented towards dissemination of knowledge to a wide base of enterprises".

In this sector the focus of political legitimisation of public investments in marine-research consequently can be summarised as follows.

Table 13.4: Actual main arguments to legitimise public funding in marine research[48]

- Underinvestment in high-risk R&D, necessary to maintain a knowledge base relevant for industry on the longer term (A).
- Building bridges between industrial applications and basic research (A).
- Contributing towards the development and maintenance of an outstanding knowledge base geared to the needs of (specific sectors of) the economy by financing high risk R&D (A).
- Providing a 'house-laboratory' for those enterprises that lack the scale, the money or the will to conduct research themselves (A).

Looking at the sources of funding we can conclude that the Scandinavian institutes are very successful in realising their commercial goals. The Norwegian and Danish institutes only receive between 10 and 20% basic subsidy from government. These figures are not expected to change dramatically in the future; 10-20% basic funding is considered to be the minimum required to maintain a high level knowledge base. To date, the Maritime Institute of Finland has received a considerably higher amount of basic funding, but the trend here too is towards more private and less public funding.
Strengthening the market orientation, improving the efficiency and effectiveness of the organisations, and the growing internationalisation, are the major trends in this area over the last few decades. All organisations studied have been successful in coping with the consequences of these trends. In Norway and Denmark the creation of networks like SINTEF and GTS played an important role in this context. These networks facilitate the bridge between and tuning of basic research and the needs of the market by improving the interface between publicly financed R&D and industry's needs. At the same time they allow a great deal of flexibility and, maybe even more important, they finance the R&D institutes without distorting their commercial attitude.

[48] Countries studied are: UK, Denmark, Finland, Norway

The situation is somewhat different in the UK. Two institutes are mentioned in the country study, one having its roots in the academia (Southampton Oceanographic Centre), the other in the defence sector (DERA).

The core mission of the Southampton Oceanographic Centre is to support excellent and relevant research, to conduct surveys, to perform monitoring exercises and to carry out technology development. The Centre may perform contract research but only if the frame of these contracts is in line with the overall science objectives and mission of the Centre. In 1996 approximately 30% of the work performed here was based on contracts. In terms of legitimisation, the emphasis is clearly on 'underinvestment because of the risk and/or high costs', 'improving the quality of networks, particularly between the academia and institutes of applied research', and to a lesser degree, 'giving support to industry'. As far as total volume and share of contract work is concerned there are no drastic changes to be expected in the near future.

The situation is less stable with regard to DERA. The core mission is strongly related to the defence sector: *DERA's main role is to ensure that the highest standards of quality and service are maintained in support of UK defence.*

In terms of legitimisation the emphasis is clearly on a 'house-laboratory for the government in the area of defence', supplemented with issues such as 'coordination' and 'the realisation of economies of scale'[49].

Like most other publicly funded UK R&D organisations, DERA is shifting more to the private sector. The most important mechanisms to support this process of commercialisation are:

- To open up all public R&D contracts for competition;
- To reinforce a programmatic approach and increase the influence of private parties in the steering committees linked to these programmes;
- The so called dual-use centres, where a deliberate attempt is made to achieve civil spin-offs from defence research.

In 1996 a total of 90% of DERA's funds were still from public sources. The rapid rise of civil contracts, together with the expected decline in public funding, however, strongly suggests that this figure will change very rapidly over the next five years. Nevertheless, these developments do not imply that in the future DERA will not remain to be government's main source of science, engineering and technology. In the future DERA will consequently have a truly dual mission with a heavy emphasis on 'government house-laboratory in the area of defence' coupled to an similarly heavy focus on 'support of industry'. With regard to the research done for private parties (as applies in the field of energy in the UK) the conditions are: that an element of risk is involved, that it is relevant from a societal point of view and there is a clear perspective on commercialisation in the nearby future.

[49] One of the main reasons for the recent creation of DERA was government's wish to realise savings through a better coordinated research effort.

13.3.2 Outlook

Although there are some major differences between the countries studied, some *general trends* can also be observed.

1 By far the most important trend is the *strengthening of the market orientation*. It is perfectly clear that this trend will continue in the nearby future. For countries like Norway and Denmark, which already have marine R&D organisations with a strong position in the market, this trend implies a further tuning of the public and private functions of the R&D institutions. For countries like Finland and the UK, in which the R&D organisations still have large shares of public funding, far more drastic transformation processes are underway at present. The mechanisms used for strengthening the market orientation both now and in the future are varied and often very innovative. The most important ones are:

- *radical privatisation* of public R&D organisations (often together with those organisations in which the R&D department is embedded) (UK);
- *from institutional funding to programmatic funding* together with a strengthening of the influence of users in the programme steering committees (Finland);
- changing the organisation of R&D institutions *from 'science and technology based departments' to 'market based departments'*. The product groups of the Maritime Institute of Finland illustrate this trend;
- creating *institutionalised cooperation between universities, organisations for applied research and firms* (UK);
- creating *agencies in the public domain with (some) commercial goals*. The UK 'dual use centres' are an excellent example of this;
- *umbrella networks* like SINTEF and GTS, rooted in a clear and explicit strategy which makes it easier to maintain the difficult balance between public and private functions within one organisation without distorting the basic culture and core business of the participating organisations to too great an extent;
- *supporting mechanisms* like the UK Technology Foresight Programme[50] that could help to improve the articulation and indeed link the supply of and demand for knowledge.

2 The trend towards more market orientation will be further facilitated and reinforced by an expected *rapid growth of the private market* (Norway, Finland, Denmark).

3 This trend towards more market orientation, together with the need to maintain some of the public functions of these R&D organisations such as, the 'linking pin position' between basic and applied research, provider of independent advice and the need to invest in relevant but risky research, institutionalised will have a considerable impact on the development of all types of *cooperation between public organisations, publicly funded R&D organisations (universities and applied R&D organisations) and industry.*

4 *Internationalisation* is also a prominent trend in the area of marine related research. This is not only because of the internationalisation of science and technology system itself but also because the marine sector is a highly international one. Processes of internationalisation have important consequences for all countries studied, for instance:

- internationalisation leads to a process of international division of labour in the R&D sector; this implies that R&D organisations will have to focus their activities and decide on their 'core business';
- a direct consequence of the foregoing is that R&D organisations active on the private market and willing to offer their clients an 'integral solution' will need to develop strong strategic alliances with colleagues and competitors in order to guarantee easy and rapid access to expertise they themselves do not possess.

Apart from these anticipated trends there also are certain issues that will have to be solved in the nearby future. These issues are linked to two of the major trends as described above. These concern particularly 1. the position of R&D organisations in terms of the public and the private domain, and 2. the process of internationalisation of markets in which R&D organisations are active.

Position of R&D organisations in the public and private domain

As in the energy case, here too the trend towards more market orientation leads to discussions on the precise position of these R&D organisations in the public and private domain. Issues in this debate are how to:

- develop a clear profile and the corresponding institutional settings and missions, making it clear what private partners may and may not expect from these organisations;
- maintain a position as an independent source of expertise;
- keep quality standards at an adequate level;
- guarantee that enough resources are allocated to strategic research with a long term orientation.

Although these issues play a role in most of the countries, in none of the countries are there any serious barriers that hinder or prevent this development towards more market-oriented R&D organisations. This does not imply that governments do not pay attention to the legitimisation of their resource-allocation. On the contrary, far more than in the past are governments asking themselves why they should invest in marine-related R&D. In the UK for instance this has lead to the privatisation of almost all publicly funded R&D. Only academic, defence-related and applied research meeting the conditions of 'risky', 'societal relevant' and 'with a clear perspective on commercialisation' will be funded. However, the latter category incorporates a grey zone in which purely commercial R&D organisations also operate. Despite this, hardly any debate on 'unfair competition' can be traced to date.

Internationalisation of markets

The second issue relates to the process of internationalisation, especially to the internationalisation of those markets in which these organisations are active. There is a certain amount of tension between a government's goal of funding R&D organisations in order to strengthen the competitiveness of its national industries, and the goal of these R&D organisations to strengthen their position in international markets. Although the debate on this issue will continue

[50] The fact that the UK Office of Science and Technology, the body that holds prime responsibility for UK Foresight, was transferred from the Office of the Prime Minister to the Department of Trade and Industry, also illustrates the trend towards a more market-oriented R&D.

in the future it is not thought that it will seriously slow down the process of internationalisation. The main reason for this is the fact (as is quite clearly shown by the Danish example) that being active in international networks and markets is prerequisite for these organisations to be at the forefront in their sector.

13.4 Aerospace

13.4.1 Legitimisation, issues and trends

Legitimisation
There are considerable differences between the different countries in the field of aerospace. The most important differences relate to the dual transformation from public to private and from defence to civil. Some countries have already gone through considerable changes in this respect (UK and Sweden). Others are still in the first phase of this process (France, Germany). Also underway, and running parallel to this dual shift, is a process of further rationalisation and professionalization. In this process too UK and Sweden seem to have taken the lead while countries like France and Germany still are wrestling with this difficult process.

However, these differences do not alleviate the fact that there are also important commonalities between the countries that were studied. Especially the following are worth mentioning:

- Almost all organisations have strong links with public and private actors in the defence sector;
- All organisations are heavily publicly financed;
- All organisations have a well developed international perspective and a corresponding position in international networks. More than half of the budgets of these organisations are allocated within the frame of international programmes;
- Almost all organisations are moving towards a core mission with a dual character:

a to support the national defence sectors
b to support the scientific and technical competence of industry.

These commonalties - together with the strong international character of the arena in which these organisations function - allow us to make some general statements regarding legitimisation, trends, issues and outlook. Starting with 'legitimisation' we can note that from the country studies, apart from the two dominating missions already mentioned in the foregoing, a whole series of arguments can be identified. These arguments can be classified as follows:

Table 13.5: Actual main arguments to legitimise public funding of research in aerospace[51]

- High cost and high risk research with a long time horizon, making the work unsuitable for industry operating under market conditions
- To gain new scientific knowledge on earth and space
- Rationalisation through coordination, improving coherence and realising scale effects (by further internationalisation, etc.)
- Bridge between industrial applications and basic research
- To promote scientific and technical competence, and thus boost industry's competitiveness by means of pre-competitive research and demonstration projects
- House-laboratory for SMEs, the provision of an experimental infrastructure for industry
- Create spin-offs of use to the civil industry
- To match the support industries in other countries receive from their governments
- To support cooperation between companies within Europe and thus improve competitiveness in world markets
- To ensure that the highest standards of quality and service are maintained in support of the defence sector (Ministry of Defence house-laboratory)
- Independent advice on testing, acquisition of material, tactical development and on long-term assessment of international development; allocation of R&D resources via the free market could result in certain failures in the civil market
- Defence-related knowledge to solve societal problems in areas like transport, the environment, telecom infrastructure and energy use
- Training

Issues and trends

All countries are confronted with several major trends in the field of aerospace research.

1 First of all there is the *dual shift from public to private and from defence to civil*. The underlying causes of this dual trend are threefold:

- the general trend to cut public R&D expenditure and stimulate the market orientation of the R&D organisations;
- pressures on the defence sector to slim down and reorient its mission related to the well known changes in the geo-political constellations as induced by the fall of the Berlin-Wall.
- the further commercialisation of the space sector. In the recent strategic plan of the British National Space Centre this trend is clearly reflected in the following phrases: *"...the goal is to invest in space where there are clearly identifiable returns to the tax-payer.", and " ... to engage private capital in the funding of space activities and promote the development of market mechanisms" (Space Forward Plan, BNSC, 1996).*

[51] Countries studied are: UK, Belgium, France, Germany, Sweden

2 These trends are further reinforced by the growing complexity of technological systems which lead to more specialisation and thus to *the need to create more strategic alliances* in order to have access to all relevant expertise. For those R&D organisations used to strong, one to one links with enterprises as was (and still is) the case in France, this will have strong repercussions for their marketing strategy and position in national and international networks.

3 In all the countries studied the shift from public to private and from defence to civil has lead to the development of many initiatives *to strengthen the market orientation*. In doing so many new and innovative approaches have been developed. This applies in particular to the so-called agencies; organisations in the public domain which are run on a commercial basis. Worth mentioning here are:

- the previously mentioned UK dual use centres which constitute open laboratories in which companies can participate and gain access to DERA's technologies and facilities;
- DERA also places relevant research work in industry through the Extramural Research Programme;
- introducing more competition - also from private actors - in the allocation of public R&D-funds (A);
- involving commercial clients in a two-step approach in which a leading customer is used to develop the service and acquire more clients;
- the French CRIE: Consortium de Recherche et d'Innovation pour l'Enterprise. The goal of this very recently established consortium in which public agencies, public and private R&D organisations and firms participate is to offer integrated high-quality capabilities to industrial clients, tailored to each problem;
- some years ago the French had already created institutions like EPST (Etablissement Public a caractère Scientifique et Technologique) and EPIC (Etablissement Public a caractère Industriel et Commercial) with comparable goals. However, from the country study on France it appears that these organisations, their roots still being firmly planted in the public domain, were not so successful in realising stronger links with the private sector.

Although there are still many problems, countries like the UK and Sweden, and to some extent Belgium too, demonstrate that the strategy to increase the number of private contracts may turn out to be a very effective one. Both countries are successful in enlarging their share in the private market. However, even though Germany and France basically have the same opportunities they must first resolve some difficult organisational and institutional problems before they can enter these markets to any substantial extent.

4 An important strategy to lower the dependency on the defence sector is *diversification*. A considerable share of the organisations studied choose this strategy by developing new markets in such areas as: the environment (remote sensing) environment-friendly aircraft, traffic control and telecom infrastructures.

Linked to the shift to private markets is the strong tendency to *improve the efficiency and effectiveness* of the organisations. In the UK the wish to improve the performance of the R&D system was one of the major driving forces behind the recent establishment of DERA. DERA's initial results lead us to draw the conclusion that there is considerable opportunity to cut the costs in these organisations. It should also be noted that further internationalisation could make a considerable contribution towards improving efficiency given that, especially in the aerospace sector, the international level is the level 'par excellence' to create economies of scale.

5 The process of *internationalisation*, and other processes fuelled by the shift in safety policy from the national to the European level, and the increasing need to realise (more) scale effects in order to improve the efficiency of the R&D organisations, has led to processes of specialisation and the building up of strategic alliances as those described for the 'marine-sector'. In Germany in this context integration of the so called New Länder should be mentioned because they provide an excellent bridge for opening new markets in the former East bloc countries and Russia.

The three major trends mentioned in the foregoing - dual shift, internationalisation and rationalisation - confront the R&D organisations with many problems. The most important issues they have to deal with can be summarised as follows:

- First of all it should be noted that the shift away from the public sector does not imply that the organisation's public mission will become redundant. On the contrary, in all countries the public mission related to defence is emphasised very clearly. Indeed, one of the main problems that accompanies this shift is quite obvious: how to strike the *right balance between public interests linked to safety issues and open competition in the private sector*? More in particular: how can these organisations become more market oriented and shift away from defence yet maintain full integration with the defence sector?

- A second issue is the *transformation of science-driven, public organisations accustomed to operating in a closed and protected defence market into (more) commercial organisations*. This is evidently a major problem, especially in France and Germany because of the rigid and strict and formal rules that make it very difficult to develop a flexible human resource management. One of the problems German organisations are facing is that slimming down automatically leads to a system of 'last in, first out', thus generally affecting the youngest members of staff. Thus, slimming down becomes equivalent to ageing.

- Another major problem which is also visible in the marine and energy sector, is the *positioning of the organisations between public and private*. How will these organisations be able to develop a profile which clearly shows how the public and private functions relate to each other in such a way that the various parties in the public and private sector know what to expect from these organisations.

13.4.2 Outlook

Looking into the future in this area means extrapolating already visible trends: dual shift from public to private and from defence to civil, further internationalisation and rationalisation. It is quite clear that these trends will continue in the nearby future. Public funding will decrease further and the opportunities for increasing the position on the private market, for instance via diversification in environmental issues, opening up of markets in the former East bloc and Russia and developing civil spin-offs, are clearly present. Internationalisation of the area will continue to be driven by commercial interests and attempts to improve the efficiency of organisations through further exploitation of economies of scale.

One of the consequences of these developments, especially from the pressure on budgets and the need to serve external clients, is that organisations - far more often than has been the case in the past - will have to make choices. Choices that have to be based on sound information on trends in the supply of and demand for knowledge. In the UK this issue is already being addressed as can be seen from the creation of the UK Technology Foresight Programme and the use made of the results of this programme by the Forward Look of Government-funded Science, Engineering and Technology. Today, the Technology Foresight Defence and Aerospace Panel, together with the British National Space Centre, is the senior forum in the UK through which issues relating to collaborative research in this area are addressed.

The future will be uncertain and turbulent, especially for those organisations that still have to go through the major phases of the transformation processes related to these trends. The examples from the UK and Sweden, and to a lesser degree Belgium, do however show that it is quite possible to realise these changes. Nevertheless, whether these organisations will be successful depends very much on the answer on the following two questions:

- will they be able to turn science-driven, governmental organisations into market-oriented organisations with the necessary professional and flexible human resource management?
- will they succeed in defining their positions between public and private and thus develop a clear profile towards potential partners and clients?

13.5 To conclude

13.5.1 Introduction

We have analysed the developments in the three science and technology areas under consideration and will try to draw some more general conclusions in this section. Before we do so however in 13.5.2 and 13.5.3 we first give attention to the main differences between the countries and the three areas studied. These short summaries of the relevant passages from the foregoing sections may help us to better assess the robustness and the scope of the more general conclusions as presented in the 13.5.3 and 13.5.4.

13.5.2 Differences between countries

The differences between the various countries that were studied sometimes can be quite major ones. Apart from national characteristics and differences related to the choice on which source to base the national electricity production, most of the differences are in one way or another related to the phase in which the countries find themselves in the shift towards more market-oriented R&D systems. Some countries like the UK, Denmark and Norway have already made quite a lot of progress in this respect. Countries like Belgium, Italy and Finland appear to be somewhere in the middle, whereas countries like Germany, Spain and France, are only in the first phase of this drastic transformation process.

13.5.3 Differences between areas of science and technology

Considerable differences can also be observed between the three areas studied.

In the *energy* area for long time the driving force behind the development of the R&D infrastructure was the development of a clean and cheap electricity production based on nuclear energy. Changes in this sector are very much related to the growing awareness that not only is nuclear energy production far from a sound option from a commercial point of view, it also brings along with it huge and difficult to solve environmental problems. In consequence, development the political support for nuclear R&D diminished and the budgets decreased considerably. This area now finds itself in a dual transformation process. Apart from the shift to more market orientation these R&D organisations are also faced with the challenge to look for new missions. These were often found in the area of environmental issues and support of innovation processes in SMEs.

In the area of *marine* technology the situation is much easier as far as the Scandinavian countries are concerned. For years now they have a (modest) publicly financed R&D infrastructure with strong links with industry. In the future they will most probably continue along the lines set out in the past. Their main problem is to maintain the balance between public and private interests in line with the current societal and economic situation. In the UK the picture regarding marine-related R&D is more complicated because this area has by tradition always been closely linked with the defence sector and had very few links with private enterprise. The challenge facing these organisations is to loosen - only a little, not completely - the links with the defence sector and thus improve the conditions for increasing the number of contracts from private actors.

In *aerospace* the situation resembles the marine sector in the UK. Almost all organisations involved in R&D in this area traditionally had very close links to the defence sector. This also required them to make a dual shift: from less public to more private funding and from defence to civil. For many of these organisations this is a very difficult challenge, accustomed as they were to almost exclusive public funding and functioning in closed and protected markets.

13.5.4 Major general trends

There are three clear trends observed in all countries and areas studied. Each bringing with them their own problematic issues. These trends and issues are summarised below. For a more detailed description and/or background information we refer to the sections above.

Shift to more market oriented R&D, together with a decrease in public funding

This constitutes by far the most important trend observed. It confronts all organisations, and they are all attempting to cope with it. The most important mechanisms and strategies in this context are:

- *radical privatisation* of public R&D organisations (often together with the organisations in which the R&D department is embedded) (UK);
- *from institutional funding to programmatic funding* together with a reinforcement of the influence of users in the programme steering committees (UK, Finland);
- changing the organisation of R&D institutions from *'science and technology based departments' to 'market based departments'*. The product groups of the Maritime Institute of Finland illustrate this trend;
- creating *institutionalised cooperation between universities, organisations for applied research and firms* (France);
- creating *agencies in the public domain with (some) commercial goals*. The UK 'dual use centres' are an excellent example of this. Many other innovative examples can be found in the country studies;
- *umbrella networks* like SINTEF (Norway) and GTS (Denmark) rooted in a clear and explicit strategy which make it easier to maintain the difficult balance between public and private functions within one organisation without distorting too much the basic culture and core business of the participating organisations;
- *supporting mechanisms* like the UK Technology Foresight Programme which may improve articulation and link the supply of and demand for knowledge;
- *diversification* in order to enter new markets (A).

Three important problems appear from the analysis in connection with this shift. The first is how to make these organisations more market oriented given the fact that many of them develop in a public context and in closed, protected markets. Although there are clearly differences with regard to this aspect between the various organisations, especially in Germany, France and Spain, this problem is still a great hindrance to the development of a more commercial approach.

The second problem relates to the positioning of these organisations between public and private. Up to now they were generally almost completely part of the public domain. Because of the shift to the market these organisations now risk falling in between both worlds. The question is how will these organisations be able to develop a profile from which it is clear how the public and private functions relate to each other in such a way that the various parties in the public and the private sector know what they can expect of them. This problem is clearly formulated at two levels in the French report:

- *One is at the level of the institute, or to be more explicit: what competencies for which clients? What organisations and procedures to establish in view of that? How to keep the proper balance between short-term contracts, long-term contracts and own research? The other is the governmental level, implicitly: what is really expected of these institutes? How far should they go to be competitive on the market? And if they are simply contract research organisations, why should they be public? Is there not a risk of unfair competition with private organisations doing the same kind of work? And is it really feasible for such work to be proposed by purely private organisations? This would prove that there is indeed legitimacy for such public institutions, but then should their goals not be reformulated? And, last but not least, would not Europe be the proper scale to develop the corresponding strategies?*

and,

- *Finally, these institutions represent assets in the form of accumulated talent and experience. The conditions by which society can benefit from these assets are changing. The challenge facing both institutes and governments is to identify these new conditions and indicate their implications in terms of strategy for the institutes and their governing bodies. A central piece of national research policy is at stake here.*

As already mentioned, it is remarkable to see that this very fundamental discussion (which lies at the root of the transformation processes these R&D organisations are going through at the moment) is not addressed more frequently. As far as the UK is concerned this can be explained by the fact that the UK went through a substantial review process only recently, and during that process such issues as privatisation and legitimisation were discussed in depth. The reports on the other countries however give no indication of any such fundamental debate. Whether one should therefore conclude that this debate will not be conducted at all, or that the issue will be put on the agenda in the nearby future is difficult to say.
The third problem is related to the foregoing and deals with the impact of more market orientation on the type of research done. Many fear that more orientation towards the market will drive out long-term oriented strategic and more fundamental research. Although some of these problems are clearly present in some of the country studies, the comment is also heard that a higher level of user involvement has even had a positive effect on quality.

More efficient and effective organisations

Related to the foregoing trend, and reinforced by budgetary constraints, we see a strong trend towards improving the effectiveness and efficiency of the

R&D organisations. From the experiences gathered to date it is evident that there is a certain amount of opportunity to make considerable gains. It is to be expected that this trend will continue for some time to come.

Internationalisation

Internationalisation is a dominant trend in all three areas. Not only internationalisation of the science and technology system but also of the markets in which these organisations functions. These processes of internationalisation have important consequences because:

- internationalisation leads to a - bottom up - process of division of labour in the R&D sector, and thus R&D organisations will have to focus their activities and decide on their 'core business';
- a direct consequence of the foregoing is that R&D organisations active in the private market, and are willing to offer their clients an 'integral solution', will need to develop strong strategic alliances with colleagues and competitors in order to guarantee easy and rapid access to expertise they themselves do not possess.

Another, logical, consequence of this development is that a growing share of public funding will be allocated in the frame of supranational, e.g. EU programmes.

Internationalisation not only provides challenges but problems too. There is a certain amount of tension between a government's goal to fund R&D organisations in order to strengthen the competitiveness of its national industries and the goal of these R&D organisations to strengthen their position in international markets. Although the debate on this issue will continue it is not expected to seriously slow down the process of internationalisation. The main reason for this is the fact that being active in international networks and markets is prerequisite for these organisations to be at the forefront in their sector.

Regionalisation

Although not so pervasive as the three trends mentioned in the foregoing, processes of regionalisation will also have an impact on the mission and mandate of the R&D organisations with a 'national mission'. In some countries this impact is clearly visible already (Germany, Belgium). In other countries like France and Italy it is obvious that regionalisation will have an impact, yet up to now it is uncertain what form this will take on.

13.5.5 Legitimisation

It will be clear to all that the trends sketched in the foregoing both had and will have an impact on the basic legitimisation of these R&D organisations. In order to give an overall impression of this impact the winners and losers have been categorised in the following table. This table also lists those arguments which, after all, apparently played no role of any significance, neither in the past nor the present, nor which are likely to play such a role in the future either.

Table 13.6 Winning, losing and hardly relevant arguments to legitimise public funding of R&D organisations.

WINNERS	LOSERS	HARDLY RELEVANT
- (direct) support of industry/house-labora tory for SMEs	- underinvestment in high cost/high risk R&D	- underinvestment in R&D because of the fear of external effects (knowledge as a collec tive good)
- create S&T base to warrant industrial competitiveness in the long run	- national (prestige) projects	- lack of competition
- quality of networks, particularly the buil ding of bridges between basic and applied research	- independent advice	
- coordination/efficiency	- gain new, basic know ledge in areas relevant for society	
- societal problems, particularly the envi ronment		