
Bridging the Gap Between Science and Industry: The Fraunhofer Model[†]

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Abstract

Fraunhofer was founded in 1949 and grew into Europe's largest application-oriented research organization. Fraunhofer currently employs over 20,000 members in Germany, is internationally networked, and manages an R&D budget of over 1,8 Billion Euros per year. An important step for Fraunhofer to become an integral component of the German innovation system was the introduction of the Fraunhofer Model of financing based on a performance-related system of financial management. The underlying model of the allocation and distribution of public funding to Fraunhofer that is subsequently allotted to specific research groups is one of the success factors of Fraunhofer. Fraunhofer is proud of its decentralized organizational model. Fraunhofer is comprised of 60 Institutes in Germany working in different fields, under one legal framework, and with a strong brand value. Every Fraunhofer Institute is affiliated with a German University and every institute director simultaneously holds a chair at the affiliated university. It is a challenge for the headquarter organization to balance the intended competition of individual Fraunhofer Institutes with complementarity cooperation in science among Fraunhofer-Institutes, especially when coming from different knowledge domains; however, this goal results in a significant advantage. The unique strengths of Fraunhofer offer system solutions in a world with increasingly complex R&D challenges. While growing to become the largest organization on Europe to focus on applied research it is the challenge to remain an agile organization that is flexible in organizational structure. Fraunhofer has reached a well-recognized position in the European innovation landscape. It is often referred to by science² and governments^{3,4} as a role model for innovation policy and a key element of the latest successes in the German economy that has recovered quicker from the latest

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[†]The following paper is an adapted and updated version of the paper "Strategic management of a Contract Research Organisation" (L. Behlau 2010) [1, 2]. Any data is taken from the latest Fraunhofer Annual Report 2011 [3].

²Fraunhofer is referred to as a global role model for innovation. As an example the Fraunhofer model is taught as a Business Case at the Harvard Business School (Comin, Trumbell, & Yang, 2011), Fraunhofer: Innovation in Germany, Harvard Business School 2011) [4].

³The Brazilian government launched an innovation initiative in 2011 that includes the set-up of Embrapii-Institutes (Empresa Brasileira de Pesquisa e Inovação Industrial). They are designed and implemented according to the Fraunhofer Model.

⁴Recent governmental initiatives around the world seek to strengthen the production sector in their economies and often refer to the success of Germany and the role of Fraunhofer, e.g. Richard A. McCormack, Obama Will Unveil \$1-Billion National Manufacturing Innovation Network Initiative Based On Germany's Fraunhofer Institute, Manufacturing & Technology News 2012

economic crisis than most other western economies. The paper explains Fraunhofer as an organizational paradigm and its underlying management model to elaborate on the challenges of managing a research organization. We wish to show how it is possible to transfer the management model and philosophy of Fraunhofer to innovation systems with different framework conditions and challenges. A universal conclusion may be drawn based on the description of Fraunhofer; however, changes in existing structures and innovation systems cannot be implemented over night.

Keywords

Fraunhofer Model, contract research, applied research, performance based funding, innovation, research for SME

1. ESSENTIALS

1.1. Fraunhofer in a Nutshell

The research of practical utility is the basis of all activities pursued by Fraunhofer. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector, and public administration.

Fraunhofer maintains more than 80 research branches in Germany that include 60 Fraunhofer Institutes. The majority of the more than 20,000 staff is qualified scientists and engineers, who work with an annual research budget of €1.8 billion. Of this sum, more than €1.5 billion is generated through contract research. More than 70 percent of the Fraunhofer contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding that enables the institutes to work on solutions that will not become acutely relevant to industry and society until five or ten years from now.

Affiliated international research centers and representative offices provide contact with the regions of greatest importance for current and future scientific progress as well as economic development.

Fraunhofer plays a prominent role in the German and European innovation process with a clearly defined mission of application-oriented research and a focus on future key technologies. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer. Through research and development work, the Fraunhofer Institutes help reinforce the competitive strength of the economy in their local region as well as throughout Germany and Europe. This is accomplished through the promotion of innovation, a resilient technological base, improvement in the acceptance of new technologies, and assistance in training future generations of scientists and engineers.

Fraunhofer offers its staff the opportunity to develop professional and personal skills that will allow them to take positions of responsibility within institutes, universities, industry, and society. Students who choose to work on projects at Fraunhofer Institutes have excellent opportunities to start and develop a career in industry through the practical training and experience they acquire. Fraunhofer is a recognized non-profit organization that takes its name from the illustrious Munich researcher, inventor and entrepreneur Joseph von Fraunhofer (1787–1826).

1.2. Mission

All strategies and operational activities of Fraunhofer are derived from a common understanding of its mission, shared member goals, management, public sponsors, customers, and the public.

The Fraunhofer mission:

Fraunhofer promotes and undertakes applied research in an international context that is of direct utility to private and public enterprises that represents a global benefit to society.

The development of customer solutions through technological innovation and novel systems development helps Fraunhofer Institutes reinforce the competitive strength of regional economies throughout Germany and Europe. Research activities help promote the economic development of an industrial society as well as attention towards social welfare and environmental compatibility.

Fraunhofer offers a platform that enables its staff to develop the necessary professional and personal skills that enables them to assume positions of responsibility within institutes, industry, and other scientific domains.

This mission statement is summarized as performing excellent research, efficiently transferring results into applications, and training qualified researchers.

1.3. Growth

Fraunhofer experienced substantial growth since 1977 due to its performance-related system of financial management. There are three significant dates in the expansion of the Fraunhofer Institute. In 1990, the organization took over ten research institutes in the former GDR after German unification. In 2000, it integrated the (GMD) with 8 institutes. In 2010, it integrated the (FGAN) with 3 institutes. In addition, Fraunhofer has continuously grown due to the remarkable success of a performance model that allows flexible market trend adaptations.

1.4. Location

The 60 Fraunhofer Institutes are located at over 80 different sites in Germany. The presence of Fraunhofer Institutes in every state is an intentional political necessity due to the federal administrative structure of Germany that entails the division of research funding responsibility between the central federal government (Bund) and individual state governments (Länder).

1.5. Research Portfolio

The Fraunhofer R&D portfolio is wide-ranging because it is the mission of the organization to support industry with natural science and engineering research services. It covers all scientific and engineering disciplines of major importance to the German economy that range from materials science and production engineering to microelectronics, information technology, and the life sciences. Each of the 60 institutes is dedicated to a specific area of technology (e.g. laser technology, IT security, or ceramics) rather than oriented towards a single sector of industry (e.g. furniture, automotive, or foods).

Certain functions are supported by the Fraunhofer central headquarters that include Fraunhofer public relations and the organization of joint Fraunhofer trade fair booths. One exceptional marketing element is the Fraunhofer Office in Brussels that directly reports to the central headquarters. This office operates in the background to facilitate contacts between the institutes and the European institutions in Brussels. A similar role that serves as a contact point for research cooperation is conducted by the Fraunhofer Representative Offices in certain countries in Asia (Japan, Korea, China, India, and Indonesia).

Several institutes (each with its own independent development process for R&D portfolios) can sometimes develop overlapping expertise in similar fields within Fraunhofer. This can make it difficult for customers to directly address inquiries to one institute because it is unclear which institute is the best qualified to provide an answer. Therefore, the central headquarters may have to intervene (in certain cases) as a coordinator and implement a suitable consortium to deal with customer inquiries. “Technology days” are one way in which these consortia present a coordinated range of services to customers. It is also important to have a central hotline that enquirers from the business community can use to contact experts at Fraunhofer. The search processes at companies must be minimized as far as possible.

1.6. Technology Transfer

The Fraunhofer mission cannot be fulfilled by excellent research alone, it has to be complemented by the transfer of research into real-life applications and innovation. Fraunhofer has various mechanisms to transfer knowledge to business and industry.

- **Direct bilateral contract research:** A Fraunhofer Institute is contracted to perform work for a company and invoices that work accordingly. The results to be delivered and the price are fixed in a contract. Negotiations on the use of intellectual property rights are often a critical step because it is essential for Fraunhofer to be allowed to use generated knowledge for further applications without compromising the interests of the “original” client. Fraunhofer is careful not to become dependent on a few individual companies for large portions of its contract work so as not to be exposed to financial risk if the customer relationship is discontinued.

- **Spin-offs:** Companies founded by ex-members of Fraunhofer staff. Former Fraunhofer staff members often retain close ties to Fraunhofer because their business is normally based on patented

Fraunhofer inventions. In some cases, Fraunhofer may take on a contingent role as a minority shareholder of a spin-off company as long as its shares are sold within 8 years (shareholder revenues are not yet a substantial funding source for Fraunhofer).

- **Licenses:** Certain Fraunhofer technologies (or intellectual property) are licensed to customers without any further contract research.
- **Transfer of skilled minds (see human resources policy):** Each year, several hundred scientists leave the Fraunhofer Institutes for positions in industry. Their high qualifications and education allows them to utilize their accumulated expertise of Fraunhofer in new environments.
- **Strategic direct cooperation with companies** or at the Fraunhofer laboratory. Fraunhofer establishes (in certain cases) small local project groups where researchers from both parties can provide companies with long-term cooperation and continuous support. An alternative option is for companies to lease laboratory space on the premises of a Fraunhofer Institute so that they can conduct local R&D with the assistance of Fraunhofer researchers.
- **Innovation clusters:** The Fraunhofer has adopted the concept of *innovation clusters* due to the increased complexity of innovations and the need to assemble teams composed of players in different specialist fields. Different companies that represent all links in the value chain are brought together to develop common standards and system solutions where Fraunhofer takes on the role of coordinator or prime contractor (for example the consortium of 18 partners formed to develop an *intelligent home*).
- **Fraunhofer Academy:** Fraunhofer has organized its activities in training and development as a separate business unit. Specialists and managers from business and industry can acquire additional skills at Fraunhofer as part of the process of lifelong learning. Knowledge from the research conducted by the various institutes is transferred directly to companies through seminars and complete study courses provided in cooperation with major universities.

1.7. Marketing of Research Results and Services

Marketing activities are largely the responsibility of the institutes rather than central management. About two thirds of an institute's budget is acquired from external sources; therefore, the effectiveness of its marketing efforts is of crucial importance. Each institute offers its services to a broad range of customers in different industrial sectors and obligates individual institutes to engage in intensive marketing activities to forge contacts with potential customers.

2. GOVERNANCE AND STRATEGY

2.1. Strategy Planning

Fraunhofer research planning initiatives takes place on three levels and is linked by iterative procedures. Each of the 60 institutes plans its own strategy based on specific market competencies and links. Strategic projects and joint marketing activities are initiated at the Group Level where groups of institutes with a similar research focus work together. Planning activities (that encompass the entire Fraunhofer) focus on major fields of innovation to develop competencies with a *critical mass* at the Corporate Level. All processes are consensual and cooperative; in addition, they involve intensive internal discussion with input and review by external experts.

2.2. Strategy Planning on the Institute Level

The Fraunhofer Institutes are individually responsible for their financial situation and scientific profile; subsequently, this requires a high degree of autonomy in their strategic planning. Only institutes are capable of judging future market needs through direct ties with the scientific community and their daily contact with customers; therefore, a projective technology roadmap (how will technology change?) and product roadmaps (what kind of products will be developed?) has to be drawn up at the institute level. This strategy planning process has to be quality-assured and a standardized process has been developed to ensure that all Fraunhofer Institutes apply professional strategy planning techniques. One main element of this process is the separate planning of core competencies (e.g., know how to ...) and business fields (a group of clients with common requirements and not necessarily one branch of industry). This well-structured process enables institutes to formulate a consistent strategy that includes marketing plans. Finally, the strategy plan is discussed with external experts who offer their input and recommendations on the proposed measures. This audit is organized by the institute, is focused exclusively on future planning, and does not fulfill the usual role of evaluating the past.

2.3. Strategy Planning on the Group Level

Individual institute strategies are compared and discussed with a view to harmonization at the Group Level of the Fraunhofer (from a university point of view being comparable with faculties and usually consisting of 5-12 institutes with competencies in related fields).

Fraunhofer Groups

- Microelectronics
- Materials and Components
- Production
- Light & Surfaces
- Life Sciences
- Information and Communication Technology

- Defense and Security

Fraunhofer Groups Levels are separate from the actual corporate management structure and have no official control functions. Their role is to serve as an informal platform for internal communication and cooperation in the area of research as well as in marketing. Major investments are planned conjointly; in addition, the harmonized interface between Fraunhofer and industry is defined for certain core areas of expertise in order to facilitate contacts with industry. However, the groups do not carry any specific financial responsibilities. Group Level strategy planning is based on the individual strategies of the institutes; however, the needs of the market and the priorities of the public research programs are separate.

2.4. Strategy Planning at Corporate Level

At the corporate level, a process has been established to identify the areas of research that represent the greatest innovation potential for Fraunhofer. These strategic topics are identified in an iterative process every 2-4 years with a combination of methods specifically adapted to the needs of Fraunhofer that are typically a combination of foresight methods and an analysis of specific Fraunhofer competencies [5, 6]. The strategic topics are selected and evaluated based on three main criteria:

- Is the field genuinely R&D-intensive?
- Are the results likely to lead to innovations (in terms of market success)?
- Does Fraunhofer possess the appropriate resources to take the lead in that field?

The strategic topics typically focus on specific challenges within the general R&D portfolio of Fraunhofer that is described by the 6 research areas of affordable healthcare in the research areas of Health and Nutrition.

FIGURE1. Fraunhofer R&D Portfolio with the Specific Strategic Topics of Each Sector



2.5. Horizontal Strategy Planning

A research organization has to plan its own systemic evolution as well as the planning of R&D content. In the short term, this means finding a response to general market and political factors based on a 1-5 year timeframe. These factors include shifts in the emphasis of funding programs or the introduction of new legislation such as European regulations on national R&D subsidies).

Medium-term strategies (on a 5-10 year timeframe) are planned in anticipation of social and political changes than as a technological outlook to deal with issues such as globalization (in general) and its local impact within Europe (in particular) with a need to establish the necessary networks at an early stage. Strategic groups also acquire a certain amount of time to mature. Visions of a European Research and Innovation Area have to be developed at an early juncture and systematically implemented. The present Fraunhofer funding model needs to be safeguarded over the medium term and must be repeatedly reassessed with respect to risks. An example of this situation is the internal organizational structure of the Fraunhofer with its control, communication, and business processes that need to be readapted to the size and spread of the organization. Fraunhofer needs to protect the principle elements of the Fraunhofer Model in the long term (i.e. beyond the 10-year horizon) that include assurances with regard to institutional funding, autonomy in the allocation of resources, access to the next generation of researchers, and close collaborative ties with universities.

2.6. Incorporation of Existing Research Facilities

There are a great many candidates aspiring to join Fraunhofer due to the complexity of German research structures and the large number of research groups working throughout the country. Applications are examined by the Executive Board based on the following criteria:

- Congruence with the present Fraunhofer R&D portfolio (overlaps/competition, possible areas of cooperation with existing Fraunhofer Institutes)
- Size of the respective present or potential contract research market
- Experience in the contract research market on the part of management (and/or staff) (current sources of third-party revenues)
- Exceptional funding by the *Bund* and *Länder* during the establishment phase and assurance of medium-term institutional funding

2.7. Human Resources Development

The Fraunhofer human resources policy surpasses the usual aim to develop employee skills exclusively suitable to the employer. The Fraunhofer mission also includes the objective of preparing qualified personnel for the whole German innovation system (for research organizations, companies, and politics) as well as for its own demand; in addition, Fraunhofer has established the concept “transfer through skilled minds”. The most effective transfer of expertise to a company is not by giving them printed report results but by integrating a well-trained researcher into their staff. After

such a transfer, Fraunhofer tries to maintain contact in the expectation that former employees will become future customers. Alumni activities have been expanded over recent years to encourage the formation of lifelong bonds between former employees and Fraunhofer.

There is a high turnover of scientific staff due to the large proportion of fixed-term contracts. Every new employee recruited by Fraunhofer is first offered a 3-5 year fixed-term contract; subsequently, the researcher has to leave Fraunhofer after this term unless they obtain an unlimited-duration contract. In total, about one third of the employees have short-term contracts. This enables the institute management to modify the size of the institute to the demands of the market and to adjust in accordance with business results.

The main advantage of having an institute director with a concurrent professorship at a local university is that they have access to the student population and are able to supervise postgraduate diploma and thesis papers.

The usual career path of a researcher at Fraunhofer is:

- **Students** are introduced to an institute director through their lectures at the university. Undergraduates have the possibility to work part-time during their degree courses at a Fraunhofer Institute (which is usually located near the university campus). The average timeframe is about 50 hours/month. In total about 3000 undergraduate students are employed at Fraunhofer. These human resources are essential for institutes because students are highly motivated, well-educated, and economical. They are involved in actual projects where they can work in contact with industry.
- They often write the **final dissertation** for their engineering diploma (equivalent of a master's degree in Germany) at the Fraunhofer Institute. This generally involves spending six months working on a short scientific/technical paper directly related to a current project at the institute.
- After completing their undergraduate studies, the best graduates are selected by Fraunhofer and offered an opportunity to work at the Fraunhofer Institute while writing their **doctoral thesis** (usually a fixed-term contract of 3-5 years). A PhD student post at Fraunhofer does not entail a total dedication to thesis work because all researchers (PhD students and senior researchers alike) are expected to work on actual projects in accordance with the research strategy of the institute. The thesis has to be written parallel to an ongoing project work, funding applications, customer relations, fairs, events and other institute business requirements that take priority over the PhD work. Therefore, it usually takes longer to complete a thesis at a Fraunhofer Institute than at a university. But a student who finally obtains his or her doctorate while working at Fraunhofer is rated more highly by industry than a university PhD graduate. Recruitment managers in industry know that a Fraunhofer PhD student has performed two jobs at once for 5 years, conducted good research for their thesis and has experience in the management of industrial projects.
- After obtaining their doctorate, when the fixed-term contract expires, the decision has to be made whether the researcher will **stay with Fraunhofer** or transit. It is dependent on certain conditions

on the part of the employer and the employee, such as outside career opportunities or vacant positions at Fraunhofer. Often doctoral students with experience in industrial projects receive an offer to move to the associated company (sometimes even before completing their thesis). In all cases, the institute tries to maintain the contact whenever a staff member leaves Fraunhofer.

Fraunhofer is rated highly even though its salaries are limited to public-service tariffs and therefore significantly lower than those offered by industry. A major factor that contributes to employee satisfaction is that the work is challenging and can be organized autonomously; in addition, it is interesting to note that the highest rating is not accorded to job security because the jobs are relatively secure under an unlimited-duration contract.

The training and development of staff used to create excellent researchers, creative inventors and entrepreneurial managers. This methodology follows two approaches. The method of learning by doing where every young researcher is assigned a senior researcher as a tutor who teaches them good scientific practices as well as project management and communication skills (e.g. how to present a project). The second is the abundance of internal and external seminars available for training management and personal skills. All Fraunhofer researchers are required to follow a standardized internal qualification scheme. Staffs destined for management positions at Fraunhofer are required to pass a fixed set of training modules before being given the responsibility to motivate people.

Fraunhofer has implemented strict rules to ensure good scientific practices. These rules include important principles related to the supervision of young scientists. Other rules are intended to minimize the risk of scientific fraud through the establishment of procedures for the review of scientific publications and specify disciplinary measures for cases of scientific fraud.

3. FUNDING AND CONTROLLING

3.1. Funding

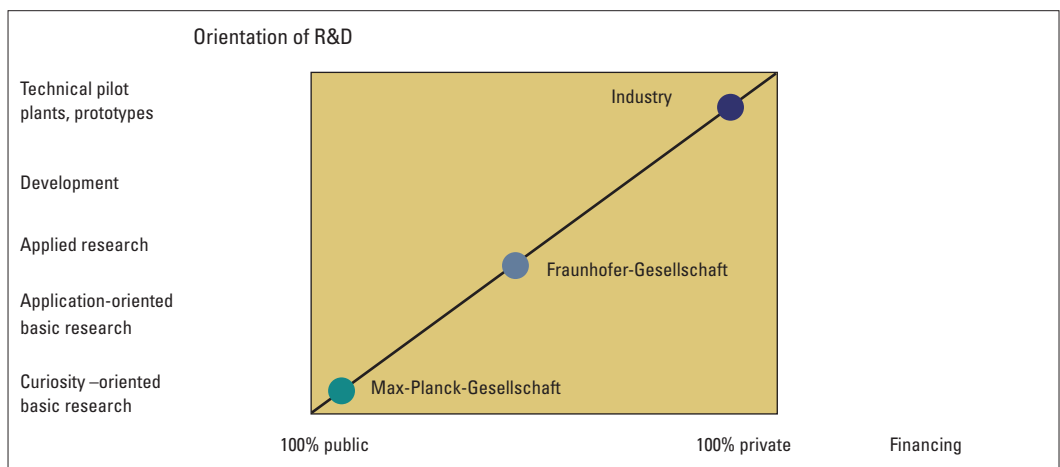
Fraunhofer is partially financed by public funds. Basic funding and project funding are the two different types of public funding. Basic or institutional funding is granted as a fixed lump sum to the research organization. The internal allocation of resources is determined by Fraunhofer management in order to implement appropriate instruments. The organization can expect a stable level of basic funding on a medium-term time scale. Major changes are unlikely and all modifications are negotiated between respective ministries and the Fraunhofer Executive Board. Fraunhofer reports retrospectively to the federal and Länder governments on the impact of its activities on the German innovation system and the use of basic funding resources. The other public funding scheme is project funding. The federal and Länder ministries for research and technology launch R&D programs to fund projects in selected areas of technology. Research groups that wish to participate in these programs are required to submit project proposals; therefore, research organizations and companies are in direct competition for public project funding. If a proposal is accepted, the funds must be dedicated exclusively to the proposed project and the associated working plan. Funds cannot be reallocated to other research topics (e.g. as a consequence of new findings); therefore, is a need for

additional sources of no-strings-attached money to finance fundamental and ‘blue-sky’ research in areas of greater risk.

Fraunhofer is financed by three different sources: a 35% of the budget is covered by basic funding, 30% is received in the form of grants obtained under national and international R&D programs, and 35% is from direct industry revenue. This represents a relatively well-balanced financial situation. Institutional funding allows Fraunhofer to conduct future-oriented research, public project funding allows the organization to engage in pre-competitive research, and industrial revenues allow Fraunhofer to demonstrate its ability to transfer research findings to the market.

Fraunhofer currently plays an active role in the development of new technologies from their conception (basic research) to industrial applications (following the technology push approach). This means a 3-5 year commitment of financial investment in personnel and other running costs. This lead time is the minimum to develop certain types of products and can be even longer for the development of new materials from scratch. When (or if, because certain types of research involve a high investment risk) a group succeeds, it will be able to offer contract research and services to the market based on a high level of know-how, competence, experience and hardware investments. However, Fraunhofer cannot compensate for past investments in preliminary research by earning profits from subsequent contract research projects. Fraunhofer is not allowed to sell products in high volume to make profits (non-profit association). There is a big difference in calculation methods when compared to commercial companies whose R&D investments can be retroactively financed by a share of the proceeds of each product sold. Tailor-made Fraunhofer research contracts for customers (each a unique product) are normally remunerated on a real-cost basis and rarely earn profits. In the research world, it is not possible to recoup the costs of pre-competitive research if it starts at an early stage in the technological development process.

FIGURE 2. Correlation of Funding and Research Activities



Consequently, the development of new technologies outside the commercial environment does not generate enough revenue to cover investment costs and needs to be supported in the form of public funding. It might be possible to earn quick money through the provision of certification, testing and consulting services. But this development would distance Fraunhofer from the true scientific community and oblige the organization to make an unwelcomed shift of its business emphasis into areas dominated by private companies.

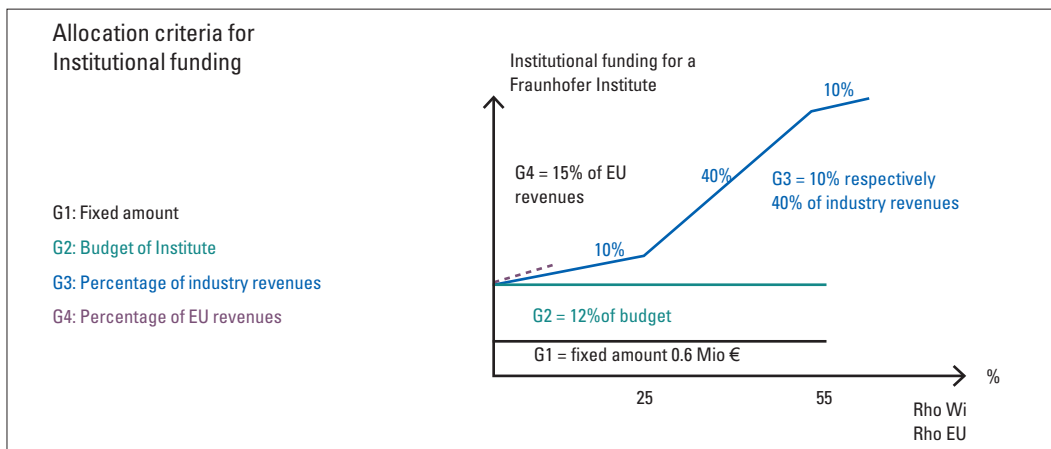
A comparative benchmark study of other contract research organizations in Europe (TNO in the Netherlands, VTT in Finland, and ARC in Austria) indicates that (in terms of capacity to innovative) it is necessary for over half of the organizational budget to be financed by public sources (institutional and project funding) in order to fulfill the mission pursued by Fraunhofer.

The basic funding awarded to the Fraunhofer is not tied to any specific conditions that concern research fields or the nature of the expenditures (e.g. for projects, stipends, and investments). Fraunhofer management is entirely free to allocate these funds to institutes as it deems necessary (in 2011 about 424 million euros). The following criteria are utilized to distribute these funds:

- The distribution formula should be transparent to all institutes (but does not necessarily imply equal shares to every institute)
- The institutes should be able to rely on a certain volume of funding that they can expect in a medium-term timeframe (algorithm or long-term regulations)
- There should be a performance-related component and competition among the institutes to ‘win’ the funding from management (without too much bureaucracy).
- Management should use part of the funding to promote defined corporate Fraunhofer strategies.

The allocation of basic funding is shared among the Fraunhofer Institutes as follows:

FIGURE 3. Allocation of Institutional Funding



- 65% of the basic funds are distributed on the basis of a defined formula, whose parameters are:
 - operating budget
 - revenues from industry
 - revenues from the European Commission
 - institutes can directly calculate their entitlement to basic funding out of their above-mentioned performance data

- 15% is spent on ‘internal programs’ where institutes apply for funding in competition with other institutes via project proposals. These proposals are evaluated internally (there are specific evaluation criteria for the different programs). There are four such programs, to stimulate internal or international cooperation and help institutes initialize new research fields. High-risk research topics are deliberately included here.

- 10% is spent on strategic investments that is used exclusively for the purchase of new or replacement equipment (machines, computers, and laboratory instruments). Institutes submit twice-yearly applications for these investments and the management decisions are based on the strategy plans of the institutes.

- 10% miscellaneous spending includes the different kinds of financing decided on by the Executive Board (e.g. ‘revitalization’ of institutes with financial problems, assets for starting projects for new institute directors, special strategic projects, and relocation of institutes).

The financial balance of an institute at the end of the fiscal year is carried over into the following year. Surpluses (which means that the institute has spent less institutional funding than it received) can be used in subsequent years; however, deficits have to be paid back as well (which means less spending of institutional funding in the following year).

The institutes have different annual financing structures and are free to determine them at their own discretion. In one year, a larger proportion of pre-competitive, self-financed research may be conducted; however, research contracts (vertical axis) or EU projects (horizontal axis) may be dominant in another year. For this reason, financing fluctuates within certain boundaries. It is important that an institute not consume more institutional funding than it is entitled to under internal algorithms so that it achieves a balanced budget. Ideally, the industrial portion is between 30%-50% and the public portion is between 25%-45% (gray segment of optimal revenue distribution).

The costs for the central headquarters are paid by the institutes and not directly taken from the basic funding. The whole amount of basic funding is distributed to institutes that pay for headquarters services as a function of size (for obligatory services) or based on the actual use of services (for facultative services).

3.2. Controlling and Performance Indicators

There are several possible ways to control a contract research organization like Fraunhofer and its

constituent entities:

- Performance indicators and quantitative targets. For some (only a few) performance indicators, fixed targets for a certain period are set by management. In companies this indicator is often the profit; however, for some research organizations it is the citation index of scientific publications. These quantitative data are easy to control and transparent, but they are also relatively unspecific.
- Negotiated targets: Individual goals are set for each unit (person) that includes quantitative and qualitative goals.
- Evaluation: A unit is evaluated by external experts with regard to its mission (because there are no clear performance indicators and the mission is multidimensional). Evaluation of the scientific performance of research organizations is often conducted by public funding authorities.

Fraunhofer applies all of these principles to establish specific ‘intermediate’ methods. It is obvious that there should be no difference of the goals for the whole organization (Fraunhofer) and the single operating units (institutes).

Fraunhofer is required to report twice a year to funding authorities such as the respective ministries in the federal and *Länder* governments. The government perception of the organizational performance is based on a spectrum of activities and not on a single indicator. Apart from industry revenues, there are many indicators which describe how well Fraunhofer is fulfilling its mission such as scientific awards, patents granted, spin-offs created, regional initiatives to attract industry, and activities to support small and medium-sized enterprises. A broad spectrum of instruments and activities need to be covered to adequately describe the complexity of the role of Fraunhofer in the innovation system. Certain indicators measure the excellence of Fraunhofer research work; however, the Fraunhofer strategy exclusively focuses exclusively on the optimization of these indicators. Any other approaches could lead to dangerously misleading conclusions as demonstrated by two examples.

First example: A useful and necessary indicator for an institute engaged in applied research is the number of patent applications. This data provides a certain idea of the volume of invention activities; however, it would be nonsensical for all employees to aim for a high number of patents as their personal target without considering the usefulness of the patents for their business field and the cost of maintaining patents.

Second example: Another indicator shows other Fraunhofer publications (not scientific papers) in the media that marketing can be equally as important as scientific publications for a contract research organization. This indicator is therefore used to show the intensity of communication with the public. It is obvious that this indicator is useful as a neutral means to show the competent position of Fraunhofer in the media; however, indicator is not a useful goal-setting tool (because it can easily be artificially raised by deliberately provoking some controversial issues that are immediately picked up by the media).

Contract revenues from industry is one dominant indicator for Fraunhofer as a ‘unique selling point’ compared to other research organizations. The average proportion of revenues from industry in relation to the total Fraunhofer contract-research budget is about 40%. This indicator provides a quantitative measure of the interaction with customers, and can be interpreted in the sense that Fraunhofer offers attractive research and that this research is also transferred into applications; however, additional elements and activities have to be taken into account (to prove that Fraunhofer earns its income from high-level research and not from low-level consulting).

Apart from the indicator ‘revenues from industry’, there is another essential goal: the balance of the budget. Fraunhofer does not use the term ‘profit’ due to the fact that more than half of the total budget is publicly funded. An institute is obliged to reduce its capacity if it fails to balance its budget (or if the costs exceed the income from basic funding project funding and contracts from industry). An early indication of this development can be detected by internal central controlling instruments. If such a case occurs, management intervenes in the strategy of the institute and asks other internal experts to take over certain operational responsibilities.

The essential Fraunhofer management principle is to focus more on the implementation of the enabling processes than on controlling the institutes via defined performance indicators.

Examples include:

- Development of internal cooperation: launching internal R&D programs
- Development of international cooperation: clarification of the political and financial parameters in various countries, studies of the international contract research market, and expansion of foreign offices
- Spin-offs: support services and advice through a central venture group and venture funds
- Technology foresight and new business fields: a standardized strategic plan (procedural model) that is moderated with an internal dialog platform on frontline themes

The Fraunhofer mission is clear, but the institutes differ in the ways they fulfill that mission. This flexibility and freedom is one of the pillars of the Fraunhofer Model.

4. COOPERATION

The rapid rate of technological progress and the growing demand for system solutions call for intensive networking within the scientific community. The Fraunhofer Institutes seek cooperation partners on different levels:

- Internal cooperation among the Fraunhofer Institutes
- Cooperation with other research institutes
- Cooperation with industrial R&D centers
- International cooperation

4.1. Internal Cooperation

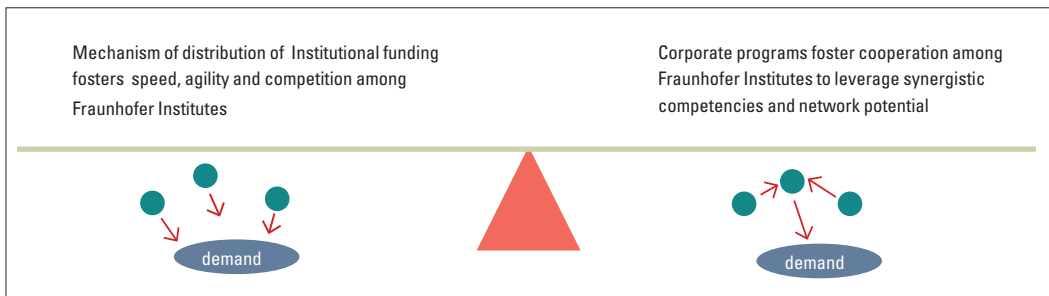
The stimulation of internal cooperation is essential to decentralized organizations like Fraunhofer; however, the physical distance between the institutes and their profit-center orientation mean that several obstacles need to be overcome. The Fraunhofer Executive Board has introduced a number of instruments designed to foster internal cooperation in order to minimize duplicate efforts, make efficient use of the existing infrastructure, build consortia to develop system solutions, and engage in joint marketing activities:

- Fraunhofer management provides funds for collaborative projects
- Fraunhofer management encourages joint activities by Fraunhofer Groups
- The central administration makes the first approach to major companies and creates a common point of contact (as a preliminary stage to establish a key account): see “Strategic Marketing”

The Executive Board uses about 15% of the institutional funding to promote projects within internal programs. It pursues a policy to create an internal competition for available funds and does not just automatically distribute them to various institutes. The effort to apply for funds and revenue received (project funding) are in balance so that misdirected activity is avoided inside the organization.

Internal programs play a very important role in the stability of the organization model of Fraunhofer. Every Fraunhofer institute is managed like a profit-center and the distribution of core funding is performance-related and induces some competition among the institutes. It is crucial that this competition remains at a ‘healthy’ level to motivate each other to get better; subsequently, a key-asset of Fraunhofer is its overall portfolio and its ability to quickly form internal consortia across knowledge domains. This ability may be a future differentiating factor when offering competitive solutions to complex problems.

FIGURE 4. Key Challenge of the Management of a Decentralized R&D Organization Like Fraunhofer: Keeping the Right Balance Between Competition and Cooperation Among Institutes



4.2. External Cooperation

The long-standing form of cooperation with external partners is with universities. An outstanding feature of the Fraunhofer Model is the common practice to nominate an institute director in consultation with a university (by preference a local university, if it can offer an appropriate chair) that

simultaneously appoints the institute director to a professorship. Such close associations are of benefit to Fraunhofer and the university. This cooperation offers numerous advantages; however, they can sometimes lead to difficulties over the choice of an appropriate candidate. Fraunhofer looks for a science-oriented manager with strong entrepreneurial skills; however, the university favors a brilliant academic scientist with relatively little experience in third-party projects. However, when an agreement is reached, the synergy effects of this dual function institute director and university professor are of profound importance to the success of the Fraunhofer Model (see also “Human Resources”).

Networking within the scientific community is mainly managed by the institutes. Each institute possesses a wealth of personal and institutional contacts within its respective community. Periodically, the Fraunhofer Executive Board signs a memorandum of understanding with other major research organizations in the interests of establishing an intensive bilateral cooperation agreement. However, it is up to the institutes to instigate such declarations of intent and it is they who need to be convinced of the need to take up such opportunities. A decision that cannot be imposed from the top down and it is the institutes that decide which partners they wish to cooperate with.

4.3. International Cooperation

International cooperation is a key element for Fraunhofer to continuously develop and improve its research and development capability. Fraunhofer seeks to cooperate with excellent global research partners to enhance its scientific expertise and Europe lies at the heart of Fraunhofer international activity. Fraunhofer is also interested in further knowledge about international markets outside Europe (e.g. BRIC States) as well as specific regional challenges (e.g. water scarcity).

Fraunhofer motivates international cooperation through a set of instruments such as:

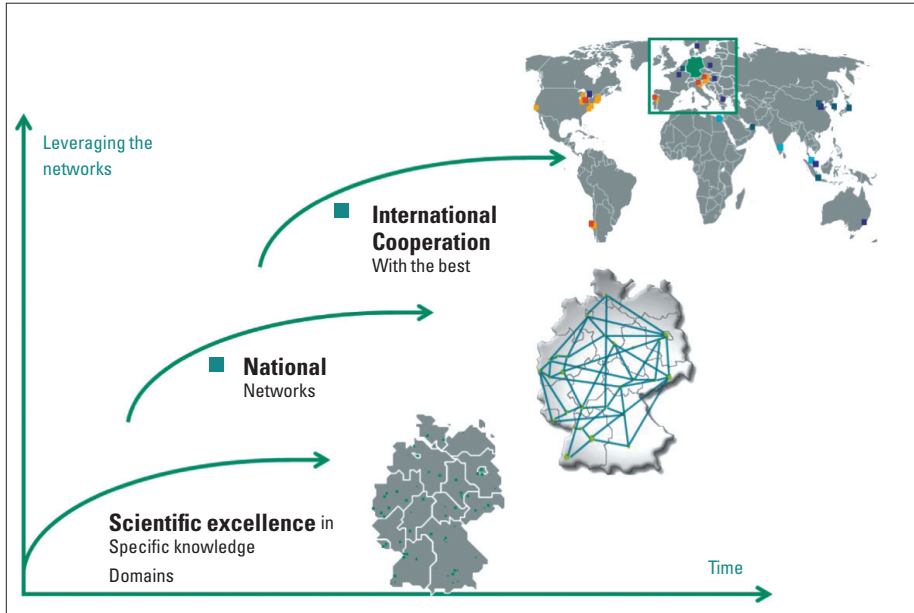
- Individual project cooperation - especially in some cases supported by regional representative offices such as in Asia
- Scientific cooperation programs with international Centers of Excellence
- Institutionalized, yet temporary, project cooperation located at universities abroad such as the Fraunhofer Project Center
- Fraunhofer Center abroad within the framework of Fraunhofer subsidiaries in Austria, Portugal, Italy, and the USA as well as (recently) Chile and the UK
- International cooperation involves researcher mobility that is supported by exchange programs

Internationalization at Fraunhofer is motivated by the belief that joint efforts with the best global R&D groups (as well as with market leading companies) enrich the capability and experience of each researcher and make the total organization more capable. This is especially true for a technology oriented economy like Germany where virtually all of the German Fraunhofer customers are globally active and demand this experience from its partners. Technology transfer through heads is an important part of the Fraunhofer mission with expectations by the German industry to recruit internationally experienced human resources.

A strategy of smart specialization follows the idea the specifically strengthened and complementary

strategic fields in the Fraunhofer portfolio. Guidelines for international cooperation reduce risk and establish the basis for successful cooperation at the international level.

FIGURE 5. Smart Specialization: Internationalization Along Fraunhofer-Internal Networks and Capabilities



5. CHALLENGES

A publicly funded research organization has to remember the wider operational context of the sociopolitical framework and has to satisfy the varied expectations of different stakeholders:

Companies

- applied research that can be directly translated into innovative products (market pull)
- certain customers require complete system solutions, whereas others are only look for short-term services to compensate for skills that are momentarily lacking in their own laboratories
- competitive prices
- exclusive exploitation of intellectual property rights

Political Bodies and Public Funding Organizations

- wide dissemination of research findings
- technological initiatives (technology push)
- minimal funding requirements
- application of public-sector pay scales and administrative schemes

- self-regulating mechanisms of resource allocation

Society

- significant improvement to the global competitive status of Germany (in terms of research excellence, training opportunities for young scientists, and business executives)
- creation of jobs in industry through the introduction of innovative products/processes
- research that contributes to sustainable development
- opportunities to publicize the usefulness of the organization

Scientific Community:

- research excellence
- training opportunities for young scientists

Employees:

- top-class equipment and motivating working conditions
- work-life balance
- secure jobs
- possibilities for career advancement

Fraunhofer is granted resources to invest in new technologies and raises the question of which technologies Fraunhofer should choose to invest in and at what point it should do so. If a new technology is adapted to soon, this creates the risk of running out of resources before commercial maturity can be reached; however, starting too late involves the risk of being delegated to the catch-up role. Technologies such as laser technology for materials processing in the 1980s, biotechnology for personalized medicine (biochips) in the 1990s, or nanotubes for new materials today need to be analyzed very carefully with regard to their anticipated roadmaps and the appropriate timing of a serious engagement. Technology developments often follow a course of initial hype that is followed by a phase of disillusionment before finally making a real market breakthrough.

Fraunhofer furthermore has to develop a kind of dual personality with respect to certain demands in order to fulfill its role and position in Germany:

- The Fraunhofer is one independent organization with a unique corporate identity (not a holding company) that consists of 60 individual institutes with a unique culture.
- Fraunhofer offers interdisciplinary system solutions and strategic partnerships; however, the institutes act autonomously in terms of strategic planning.
- Contract research is treated as a homogenous service and standardized profession that is a very diverse sector where Fraunhofer has to market to more than 250 different business fields and to communicate with more than 400 different core competencies.
- Fraunhofer produces excellent research; however, basic research is limited by the availability of financial resources and a strong application orientation towards.

- Fraunhofer is financially supported by public funding; however, it has to compete to acquire the two thirds of its budget from third-party sources.
- Fraunhofer has to act as a commercial undertaking; however, its internal business processes and administration are bound by the rules applicable to public-service organizations.
- Fraunhofer stimulates the transfer of skilled human resources to industry; however, it also constantly loses its best researchers.

These inconsistencies have to be overcome or changed into unique strengths in order to find an appropriate and flexible balance between the two extremes.

There are global trends to which the Fraunhofer is expected to respond to in addition to the sometimes conflicting expectations from private customers, public authorities, scientific partners, or German society:

- organizing processes to adapt to the fast pace of technological change and short innovation cycles
- coping with the increased complexity and interdisciplinary nature of research and innovation
- recognizing the need for global networking and being aware of the transparency of the contract research market vis-à-vis the customer

Fraunhofer has developed quite successfully over the last three decades as the result of a flexible and performance-oriented model of internal communication and management; however, the Fraunhofer Model will have to be constantly adapted to markets needs as well as to social and political developments. Future challenges that face Fraunhofer include the globalization of companies and the building of an integrated European Research and Innovation Area. Innovation cycles are accelerating and it is important to develop suitable tools to effectively and efficiently match R&D portfolios to future needs.

6. POLICY IMPLICATIONS

The Fraunhofer Model and the recent development of Fraunhofer within the German and European innovation landscape serve as a benchmark and blueprint for the design and set-up of similar organization in comparable national and regional innovation systems. However it is clear that the model has to be adapted to the specific framework conditions in place in the respective innovation landscape.

Fraunhofer celebrated its 60th anniversary three years ago. This milestone shows that it takes time and consistent performance for contract research organizations to establish themselves in the net-

work of customers, research partners, and funding bodies. Customers have to make positive experiences and profitable business cases to cooperate and connect with organizations like Fraunhofer. They have to build trust in the reliability and professionalism of the contract research organization to share their true demand for solutions. However, only if the contract organization is faced with specific challenges and demand from industry with the simultaneous ability to match demand with the latest scientific progress can it create added value and legitimate the investment of the company in outsourced R&D. This interplay takes time and the necessary freedom for a contract research organization to develop without interference from funding government with a clear and transparent performance based on framework conditions.

To connect the latest scientific developments with a specific industry demand for problem solutions, a contract research organization has to rely on a solid base of core funding from the government that is granted with a high degree of budgetary autonomy order to reach the targeted performance. The German government can rely on the well-established business processes, consistent results, and satisfactory performance of Fraunhofer to justify the high degree of freedom on how to spend core funding grants. The Fraunhofer financial model was introduced in the 1970s the history of solid performance was significantly shorter and the funding body then relied on the trust of an industry contract as the most reliable performance indicator. If the industry is willing to cover the full cost of the contract research project (ideally repeatedly) then the funded research organization is on the right track and core funding can be justified. The direct link of the amount of core funding to industry revenue is a very simple way to introduce performance based funding models. Yet this implies that a full cost calculation is done. Core funding has to be dedicated to pre-competitive and preparatory research. The customer has to cover the full cost of the offered contract research project. Only this way can the financial model become transparent and the funding mechanism act as a management model. In many countries a culture of direct R&D support or tax incentives by the government to industry has evolved that may dilute the suggested full cost model and the basis for performance measurement by industry contracts.

The described level of independence of Fraunhofer represents direct government intervention in daily business and continues within Fraunhofer in the management of individual institutes. An institution has to be organized in a decentralized way in order to manage a large R&D organization with a critical mass with an impact that is agile and adaptive to dynamic changes in the innovation landscape. The 60 institutes at Fraunhofer are organized as profit centers that are independent in strategy and operations to cope with performance based framework conditions. Embedded in this management model is a financial model that correlates the funding of industry revenue to institutes, awards the strong institutes, and penalizes weak institutes. A few research units within Fraunhofer had to be closed or merged under these framework conditions, yet the dynamic growth and success of Fraunhofer took place based on a system implemented in the 1970s.

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