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INNOVATION AND COMPETITIVENESS THROUGH TECHNOLOGY TRANSFER AND UNIVERSITY-INDUSTRY LIAISON IN EUROPE: IMPLICATIONS FOR KANSAS

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INTRODUCTION

Tremendous changes are occurring in worldwide economic activity, due to globalization, rapid advances in science and technology, and changing market needs and preferences.

Most nations have been placing increasing emphasis on improving the transfer of technology from the research infrastructure to industry, with particular focus on university-industry linkage and collaboration, and the pressing needs of small- and medium-sized firms (National Economic Development Office, 1989). Many approaches and mechanisms have been developed to facilitate this process, but in each instance nations are responding to significant barriers to timely and effective technology transfer that seem to be generic to all countries. Competitive pressures and short-run orientations in business often reduce, rather than foster, R&D expenditure: smaller firms do not undertake R&D at all and often lack the capacity to absorb and exploit it, let alone access it. Research institutions, on the other hand, are driven both by a traditional culture and reward system that favors basic research, and by public funding that reinforces this orientation.

A recent study, *Technology Transfer and Industry Liaison for Kansas Economic Development* (Redwood, 1989), responded to these significant problems by exploring the barriers to university-industry R&D collaboration in the United States, and the various approaches and mechanisms developed to solve them in the framework of state economic development strategies. The purpose of this study is to explore how two representative European countries, Germany and the United Kingdom, have addressed these problems, and what mechanisms they conceived and implemented to strengthen innovation.

The focus of this study is to discover what, within the framework of its overall science and technology programs, is each country's basic approach to fostering both 1) higher education-industry linkage and collaboration with respect to research and development, and 2) technology transfer to enhance innovation and entrepreneurship. This report describes and assesses the approach of the two countries studied, and it derives some implications that would be relevant to the attempts of American states, including Kansas, to design and implement similar mechanisms themselves.

The basis of this report is a field study undertaken in Germany and the United Kingdom that involved visits and extensive interviews at the following representative organizations:

Germany

Fraunhofer Gesellschaft Headquarters, Munich
Fraunhofer Institute for Production Technology, Aachen
Steinbeis Foundation for Economic Promotion, Stuttgart
Technology Assistance Center at Karlsruhe Polytechnic, Karlsruhe
Innovation Center (Technologie-Fabrik), Karlsruhe
Aachen Center for Innovation and Technology Transfer (AGIT), Aachen

United Kingdom

The following Universities, including the industrial liaison office, science park, and innovation center/incubator (where appropriate) of:

Aberdeen
Aston
Cambridge
Dundee
Glasgow
Heriot-Watt
Manchester, and

Agencies: Scottish Development Agency
British Technology Group

For a description and assessment of innovation center/incubator development arising from these visits, see *Incubator Development in Europe: Some Implications for Kansas* (Redwood, 1990).

GERMANY

An underlying strength of the German economy has been its technology-oriented industrial structure. The German viewpoint is that research and development, broadly defined, underpins innovation, and that innovation underpins economic growth. The basic elements of this viewpoint are perceived to be:

i) basic research on a broad scale;
ii) applied, application-oriented research; and
iii) technology development and rapid transfer of knowledge. (Goerdeler, 1989)

There is a further dimension to this basic view: because of the economic industrial structure of Germany, companies with the most to gain from technology transfer and technological assistance--the small- and medium-sized firms--are those with the poorest access to technological resources. In particular, the limited internal resource base of small- and medium-sized firms makes it difficult for them to undertake research and development activity, and such firms lack the time, resources and specialized personnel to access external sources of technological expertise (Miliband, 1990). Germany, therefore, has implemented a technology transfer system to solve the R&D problems of its small and medium size businesses.

I. AN OVERVIEW OF SCIENCE AND TECHNOLOGY POLICY IN GERMANY

The structure and recent funding of the implementation of the German philosophy of R&D is shown in appendix Figures A and B. Sources of funding (Figure A) include 13.8 billion deutschmarks (BnDM) (approximately $8.1 billion*) from the federal government, 7.6 BnDM ($4.4 billion) from the state governments, and 34.7 BnDM ($20.3 billion) from industry. The research is undertaken largely in the university system (7.1 BnDM or $4.2 billion), university-related and other research institutions (7.7 BnDM or $4.5 billion), and within industry itself (40.3 BnDM or $23.6 billion). A breakdown of the research institutions and the broad nature of their research is shown in Figure B. The university expenditure on research is largely funded from the public sector and generally relates to basic research and longer-term applied research. This is supported by basic research undertaken by specialist research institutions, including the Max-Planck Institutes (1.02 BnDM or $600 million), national research centers (3.3 BnDM or $1.9 billion), and federal ministry research institutions (1.86 BnDM or $351 million). Applied research (short- to medium-term) and development is undertaken by the Fraunhofer-Gesellschaft Institutes (600 MnDM or $351 million) and industry sector research institutes (400 MnDM or $234 million).

The funding for these programs invariably involves some combination of federal-state-local-private sector mix. In general, the federal government is the predominant source of basic research funding, but with some state and private sector support also. The state government is to be the predominant source of available public sector support for applied research, and local government is the primary public sector source of support for technical assistance funding. The predominant private sector support goes to applied research and to technical assistance/technology transfer support.

There are nine programs fostering research cooperation that are supported by the federal government. These are as follows:

(1) Support industry funding of research at the universities (traditional and polytechnic)--which in 1987 amounted to 450 MnDM ($263 million)--and at the Fraunhofer Institutes (120 MnDM or $70 million).

(2) Collaborative Research--the promotion of joint research projects between research institutions and industry through matching grants and subsidies and with a focus on areas of key technologies such as production engineering, information technology, and materials research;

(3) The Eureka Initiative--fosters intra-European economic community collaboration between companies and research institutions from different countries;

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*All conversions to US dollars are based on the exchange rate at the time of preparation of this report, and are therefore approximate.

(4) Cooperative industrial research--fosters cooperation between research institutions and specific industrial sectors;

(5) Contract research--additional support for R&D collaborative research involving small- and medium-sized firms;

(6) Subsidization of company R&D personnel at research institutes;

(7) Financing support for technology-based start-up companies;

(8) Establishment of technology transfer organizations and innovation advisory services: support chambers of commerce and other industrial associations or foundations establishing networks of technology transfer mechanisms and networks of information banks, foster contacts between small- and medium-sized firms and R&D institutes, provide information brokerage for specialized literature, and so on; and

(9) Information and guidance through demonstration centers in relation to new areas of technology (Federal Ministry for Research and Technology, 1988)

Some key elements of the overall approach to funding research cooperation can be identified:

i) the locus of effort is at the regional/state level;
ii) it is a comprehensive system covering all research dimensions;
iii) it is integrated and networked both horizontally and vertically; and
iv) the key forces are cooperation and partnerships, within the public sector and between the public sector and the private sector.

II. MECHANISMS FOR RESEARCH AND DEVELOPMENT AND TECHNOLOGY TRANSFER

The primary vehicle or mechanism for applied R&D is the *Fraunhofer Gesellschaft system*. There are a myriad mechanisms throughout Germany to undertake technology transfer and technical assistance, the most noteworthy and highly developed of which is the *Steinbeis Foundation* system, in the State of Baden-Württemberg, and its network of technology transfer centers throughout the state. Representative of other vehicles is *AGIT*, a chamber of commerce-local government mechanism in Aachen. These organizations are described in some detail below.

A. Applied Research and Development

1. Fraunhofer-Gesellschaft System

The Fraunhofer-Gesellschaft is the largest organization responsible for applied R&D in Germany. It maintains 35 research institutes in eight states and employs a staff of around 6,000: 4,000 permanent employees, 2,000 temporary employees, and one-third of the overall total are scientists and technologists.

Measured in expenditures, the Fraunhofer Institutes had an output of 664 MnDM ($388 million) in 1989. Of this amount, 12 percent was devoted to defense research, and 88 percent engaged in non-defense research. Of the non-defense research budget, 30 percent constitutes basic funding provided by the federal government, and the remaining 70 percent consists of funding for projects, about half being from industry and about half from the public sector (Figure C).

Other than the basic funding provided by the federal government, all funding is project specific, and the institutes are expected to become self-supporting on achieving maturity. This means that the institutes themselves must generate contract research support through their own credibility; if they do not, they will be closed. The focal fields of contract research are: microelectronics, information technology, production automation, sensor technology, production technologies, materials and components, process engineering, energy technology and construction engineering, environment and health, and technical and economic studies. New fields are established on the basis of a perceived market demand, rather than being university discipline driven, and in general, each institute will start as a pilot effort, with the expectation that after several years the market demand and support will be confirmed.

The contract research system is focused on cooperation with industry and the translation of research results into innovations in the focal fields as rapidly and as broadly as possible; special measures are taken to ensure cooperation with small and medium-sized companies. Each institute is devoted to one focal field and will have an advisory board of 10-15 persons, drawn from industry. The operating policy is, however, determined by an executive committee comprised of the directors of the divisions of each institute. The overall heads of the institutes, and the directors of the research divisions, are generally drawn from university professors, although institutes occasionally will also be headed by polytechnic professors. These director/professors generally maintain a joint appointment with the university, a structure that is cultivated to foster close collaboration between the Fraunhofer Institutes and the universities. One function of the institute heads and directors is to determine whether a research opportunity is related to basic research and therefore should be referred to the university departments, or if it is applied research and development and undertaken at the Fraunhofer Institute. Again, the attempt is to cultivate the linkage of education-research-application continuum.

a. Fraunhofer Institute for Production Technology (IPT), Aachen.

This institute, part of the Fraunhofer-Gesellschaft System, is closely linked with Aachen University, a major institution with about 40,000 students. The Institute is located close to the university and Institute and university facilities are shared.

The annual funding of IPT is around 10-12 MnDM ($6-7 million). Fifty percent of the funding is received from industry for projects, including projects for small and medium companies on a group basis; 30 percent funding is for public sector projects, and the remaining 20 percent comes from institutional funds provided by the federal government.

IPT has four research divisions, or areas of research, and each division is headed by a professor from Aachen University; these four professors constitute the operating board of IPT. The activities of the four divisions are closely integrated. IPT is networked also to other technology transfer mechanisms such as AGIT, which will be described below; also, IPT participates fully in technology fairs, seminars, and other mechanisms to bring its capabilities to the attention of companies in its region.

The IPT staff consists of 100 permanent staff: 60 have academic equivalent status and 40 are non-academic. In addition, there are 170 students associated with IPT, usually on a one-quarter to one-half time appointment, in the same manner as the research assistant model in the United States.

It is worth reiterating that this mechanism is designed to overcome the barriers to an efficient transfer of technology from the university system to industry. These barriers are listed in Figure D, and the means to overcome these problems are reflected in Figure E, which sets out the requirements for the improvement of technology transfer between university system and industry.

The Fraunhofer Institute system is a highly effective way to link higher education, and to transfer new science and technology, to industry. The only negative comments related to the delay in publication potential arising from the proprietorship of company research and to the tendency for there to be pressure for short and medium-term research to prevail over longer-term research. Despite their importance, neither of these issues detracts from the immense significance of this system in underpinning the competitiveness of German technology-oriented industry.

B. Technology Transfer and Technical Assistance.

1. Steinbeis Foundation

The Steinbeis Foundation, headquartered in Stuttgart, sponsors a network of 100 technology transfer centers and technical consulting services throughout the State of Baden-Württemberg to bring existing technology to new products and processes in industry. These centers and service offices are largely set up in some relationship with the polytechnic universities in the state. This situation is parallel with the Fraunhofer Institute role with respect to applied research and development, and the associated linkage with the traditional universities.

The State of Baden-Württemberg has a high concentration of technology-driven and technology-oriented economic activity in its highly developed industrial structure. This structure includes concentrations of export-oriented companies, growth-sector companies, diversified industrial sectors, and a strong cluster of small and medium-sized companies, in addition to major corporations. The underlying economic development philosophy of the state is to build on these strengths in the economic structure. Driving this approach is the consideration that industry is decentralized throughout the state and that the larger companies will be more competitive if the associated small and medium-sized companies are also efficient.

Besides the 100 technology transfer centers at the Steinbeis Foundation, the research infrastructure of the State of Baden-Württemberg includes nine universities, twenty-three polytechnic colleges, three federal research institutes, thirteen Max-Plank Institutes (for basic research), fourteen Fraunhofer Institutes (for applied research), an extensive research associate program, and six research foundations at the universities.

The technology transfer centers are an integrated element of the research infrastructure, but they are very much at the lower end of the overall R&D spectrum. The whole emphasis is on the transfer and application of existing knowledge, hence the primary association with the polytechnics. Furthermore, in response to the decentralization of industry in the state, the centers are located no more than 15-20 kilometers apart, so they are within easy access to all industry within the state.

Each technology transfer center has a single focus, such as industrial data processing at Karlsruhe Polytechnic, described below. It is usually headed by a polytechnic professor, and the program enjoys the full support of the polytechnic colleges. Staff is comprised of polytechnic students, professional engineers (say 4 or 5 per center), and other faculty from the polytechnic, including business professors.

Limited state government money is available to leverage operations, usually in the initial phase only, in order to assist with physical infrastructure and the initial development of the center. It should be noted that the funding for the initial phase of these centers can also be provided from other sources, including local governments, chambers of commerce, and industrial consortiums. The Foundation itself provides 200,000 deutschmarks (approximately $120,000) for the initial phase. In relation to their activity, the centers are project driven and, in general, undertake single company problem-related activity. Often these projects will involve multiple centers because they need to include several research areas. Each project will generate a 7 percent overhead to support the Steinbeis Foundation headquarters. Ultimately these centers are expected to be somewhat self-supporting and independent financially of both the Foundation and the supporting college. The extent of the activity is reflected in 1989 data showing that the centers as a group undertook 17,000 assistance activities, including 4,000 R&D projects.

The fundamental objective in establishing the semi-independent centers is to create a mechanism that will foster interaction between the private sector and higher education institutions that would not otherwise occur. Note that the Steinbeis Foundation centers must be careful not to compete with private engineering or consulting firms but, instead, maintain a focus on innovative problem-solving projects only. This innovative dimension is conducive to university/college support, as it enhances the research and teaching relevancy of those supporting organizations.

a. Karlsruhe Polytechnic Industrial Data Processing Center

The Karlsruhe Polytechnic is the largest Polytechnic in the State of Baden-Württemberg, having ten departments and 300 academic staff. As the name reflects, the institution is technology-oriented, and it has a much more applied curriculum and research program than the traditional universities.

The Industrial Data Processing center visited is one of several technology transfer centers associated with this Polytechnic. Others at this institution have a focus on: i) refrigeration, and ii) optical electronics and sensoring.

The center has a staff of twelve full- and part-time employees, and has ten faculty associated with it. The annual budget is in the vicinity of 2 to 3 million deutschmarks ($1.17-1.75 million). This center has achieved an international status and has expanded its operations to include a number of international projects. The Polytechnic is extremely supportive of this activity and sees great advantages in terms of the enhancement of its own faculty as well as the opportunities it provides for students at the institute.

The Steinbeis Foundation program is tailormade for the state of Baden-Württemberg and its characteristics, and it is not replicated in other states of Germany, where other mechanisms of technology transfer have been adopted. Again, as with the Fraunhofer Institutes, this is a very effective program to support technology transfer and technical assistance, and it is largely paid for by the private sector, undoubtedly because these linkages have proven to be of tremendous benefit to the industrial sectors of Germany.

2. AGIT (Aachen Center for Innovation and Technology)

AGIT is an intermediary or broker mechanism whose task is to link the universities, colleges and related research centers, such as IPT in Aachen, with small and medium-sized firms in this immediate region.

AGIT was formed five years ago. It was initiated by Professor Eversheim of Aachen University at the request of the Ministry of Economics in Düsseldorf. It is sponsored and funded by all local government jurisdictions in the Aachen region, who also provide the bulk of the 24 representatives on the governing board; this board also includes one professor and one public sector representative. One of its problems is considered to be the lack of significant private sector representation.

Encouraged by the state, North Rhine/Westphalia, AGIT is sponsored by the Aachen area Chamber of Commerce and by all local government jurisdictions in the Aachen region. It is seen as an arm of the Chamber of Commerce.

AGIT undertakes three activities, the last of which is the one relevant to this study:

1. It manages an innovation center/incubator that has about 50 companies in it. Note that there are six innovation centers in Aachen, with a further two or three in development stage (see *Incubator Development in Europe: Some Implications for Kansas* for further information).

2. It provides information and outreach to international companies in order to attract them to the Aachen region--a somewhat typical Chamber of Commerce activity.

3. It serves as a technology transfer organization for the Aachen region.

The specific task of AGIT is to link the universities and colleges with small and medium-sized companies for joint research projects in the field of production technology. This task is undertaken on a competitive project basis, with the opportunity for up to 50 percent funding subsidy being provided from public sources. To date, the value of joint research projects involving these companies and higher education have amounted to 24 MnDM ($14 million), of which 12 MnDM ($7 million) is provided by the sponsoring private companies.

The nearest analogy in the U.S. to AGIT in terms of its focus is the research-matching grants program in many states' technology programs. The difference is that AGIT acts as a broker mechanism, or marketing arm, to link the university/colleges with the companies that seek joint research arrangements.

AGIT is not a general model in Germany. As noted earlier, there is an array of technology transfer mechanisms, and the only common element is the clear perception that this outreach/linkage is difficult to cultivate from within the research institutions themselves and will only occur if this broker mechanism exists. Germany is engaged in a wide spectrum of organizational experiments aimed at strengthening these higher education-industry linkages, and the Steinbeis Foundation and AGIT constitute two of a wide array of forms adopted for this purpose.

III. KEY CHARACTERISTICS OF THE GERMAN SYSTEM

The German scene is characterized by a multiplicity of technology transfer initiatives at all governmental and geographic levels. There are certain common elements to this activity that are worth observing.

A. Public sector involvement occurs at all governmental levels, namely federal, state, and local. All initiatives enjoy some financial support, even if only in the developmental phase, from public funding sources. Nevertheless, the primary funding burden is borne by the private sector, who pay for the research undertaken and for services provided. Aside from infrastructure support, the public funding is used either for leverage or to ensure a desired policy goal, such as the linkages including small and medium-sized firms. Almost all initiatives are approached on a partnership basis, with usually at least two governmental levels involved and, with the exception of basic research, almost universally involving the private sector.

B. The organizational dimension that is common to all initiatives is the notion of brokering or intermediary function. This does not pertain to basic research, but it certainly is the organizational form for the other research dimensions of applied research and development, and for technology transfer and assistance. It is accepted that the barriers to linkage are so great that effectiveness and efficiency can only be achieved through the use of intermediary mechanisms.

C. The German approach can be characterized as a system, for it covers all dimensions of research; nevertheless, it also recognizes that different mechanisms are needed for the different research and development dimensions. The corollary of this is that the research infrastructure is involved in linkages only in relation to those dimensions which are of interest to it; that is, the universities are largely involved with basic research and applied research of a longer term dimension. Applied research and development is primarily linked to the Fraunhofer Institutes, which draw their strength from the universities; the technical transfer and assistance is related to the practical application orientation of the polytechnic universities and technical colleges. The universities are not involved in problems that relate, for example, to the application of existing technology to new processes. In the same manner, issues of research significance are not dealt with by technology transfer centers but network up to the appropriate university or polytechnic.

D. The system approach is reinforced by extensive networking. All organizations in the overall system know what their purpose and function is and are aware of where other dimensions should be referred. There seems to be a minimum of turf conflict and a clear propensity to refer problems and issues to the appropriate level and the appropriate institution.

E. The science and technology approach at the regional level, essentially involving applied research and development and technology transfer and assistance, is not independent of broader regional economic development strategies but is perceived to be integral to the success of those policies. That is, the science and technology thrust is closely linked to broader initiatives relating to the other foundations of economic development. Consequently, it would seem that it enjoys broad public and private sector support, including extensive chamber of commerce and industry association involvement, than would otherwise be the case if these were somewhat independent of the broader underpinnings of economic growth.

UNITED KINGDOM

In the United Kingdom, the need for effective technology transfer and diffusion of technology is perceived to be acute for two major reasons: first, British spending on R&D in general, and civil R&D in particular, is low in comparison to competitor countries; and second, British R&D productivity--for example, the number of innovations obtained from the R&D investment--is also low relative to other countries (Miliband, 1990). The per capita commitment by industry to R&D in Britain is about half the level of that in the United States and Germany, and the rate of growth of industry R&D expenditure has been about one-quarter that of the United States and Germany. Furthermore, there has been virtually no increase in government expenditure or government support for R&D in recent decades (National Economic Development Office, 1989).

Many factors have been identified as key influences on this situation. These include a reluctance on the part of British companies to take up external technology, and an inability on the part of British firms to view technology as a long-run asset and technology transfer as a long-run process. The problem is compounded in relation to the small and medium-sized firms that are the backbone of British industry. Particular problems in this regard include the inability of the small internal resource base of such firms to support R&D activity in the first instance, and the lack of time, resources and specialized personnel to access and make use of external technology (National Economic Development Office, 1989; Miliband, 1990).

Recently, however, there has been a rapidly growing recognition in Britain of the need to exploit rapid advances in science and technology. British institutions' response to this need has been to implement the programs, initiatives and mechanisms which are assessed in this section of this paper.

I. AN OVERVIEW OF SCIENCE AND TECHNOLOGY POLICY IN THE UNITED KINGDOM

In 1985, British expenditure on industrial R&D was £5.1 billion ($8.67 billion), of which £1.1 billion ($1.87 billion) was provided by the government; of the government expenditure on R&D, about half has been devoted to defense. British industry expenditure on contract R&D with research organizations has been increasing since then, but has been only about 5 percent of total industrial R&D expenditure. In essence, industry linkage to research organizations in the form of funded research has been severely limited.

Funding for basic research at British universities has been largely provided by the United Kingdom government through the Research Councils. There have been two important changes in this funding in recent years: 1) it grew only modestly in real terms through the 1980s; and 2) it has been transformed to a more competitive basis of allocation (Irvine, 1990)--a factor that has created the need for British higher education to seek to expand its private sector funding of research in order to take up the slack caused by the decline in government funding.

In 1988, the Department of Trade and Industry, the lead ministry with respect to government funding of R&D, implemented new initiatives to enhance applied R&D, and technology transfer. Funding for these programs reached a peak of £14.3 million ($24.3 million) in 1991, but is budgeted to decline thereafter in anticipation of increased private sector funding and support for this activity. Included among these initiatives are the Regional Technical Centers that will be described below.

The major technology transfer mechanisms in the United Kingdom are shown in Figure F. This scenario reflects the growing emphasis being placed on stimulating and enhancing technology transfer from the research infrastructure to industry. A primary sub-focus in this regard relates to the linkage between higher education institutions and small to medium-sized firms. It would seem that higher education institutions are undertaking more industry-related research, but that this is still modest relative to traditional basic research at such institutions.

A number of factors have been identified in developing a growing recognition in Britain of the considerable importance of higher education-industry collaboration in the overall technological and industrial competitiveness of national and regional economies. These factors include:

(1) a growing awareness that although the universities are good at basic research, there has been a general inability to feed this through to commercial developments;

(2) industry has recognized the need for collaboration in order to achieve economies of scale in research and that universities are an important source of such research;

(3) higher education can facilitate economic development through new high technology entrepreneurship and firm spinoffs and through technical assistance to local industry;

(4) universities have been ineffective at selling their research capabilities to industry;

(5) that there are benefits to the research and teaching mission of higher education through shorter to medium-term applied research in science and technology as well as from basic research (Charles and Howells, 1990).

The following organizational mechanisms and program thrusts have been developed in, or linked to, the university sector in order to support their participation in applied and technology transfer:

(1) the development of an Industrial Liaison Office at all British universities;

(2) the fostering of science/research parks in association with virtually all universities, (many include incubator/innovation centers);

(3) the formation of university companies and similar mechanisms to market university research capabilities and to commercialize research output;

(4) the formation of British Technology Group (BTG) to patent and license university research results;

(5) the development of a national database of academic research expertise called BEST (British Expertise in Science and Technology);

(6) regional technology transfer centers that are networked to higher education institutions.

II. MECHANISMS FOR RESEARCH AND DEVELOPMENT AND TECHNOLOGY TRANSFER

A. The University-Industry R&D Collaboration and Linkage

1. Industrial Liaison Office

An industrial liaison office has been established at all sixty-three United Kingdom universities. This approach to university/industry liaison was initiated in the 1960s, and it received a strong impetus in the 1980s in the context of a changing philosophy on the part of the United Kingdom government to university funding in general and for research in particular. The basic role of the university director of industrial liaison is to foster university/ industry collaboration.

Purpose

Initially the primary impetus for establishing this office to develop alternative funding sources for the university was in response to the Thatcher government cuts by which many universities lost up to one-quarter of their core funding. Funding for basic research was also reduced and transitioned into a more competitive mode, and the universities were directed to seek alternative funding sources, although several of them had taken the initiative in this regard earlier. These government cutbacks, and the associated pressure on the universities to offset them through new funding sources such as the private sector, were not driven, it would seem, by national policy directed at increasing United Kingdom industry competitiveness in the global context, but rather by short-run budget considerations.

While this funding imperative remains the overall driving force, other motivations have increased as the university system adjusts to the new funding context, and the opportunities and benefits of research development and research exploitation become more evident. These opportunities include the potential to broaden the research base of the university, to improve the relevance of university research, and to better support the traditional research and teaching mission of the university. Some institutions, such as Heriot-Watt University, already had a strong philosophy of interface with industry, and hence were well-placed to respond to the funding imperative and to build upon a philosophy of interaction with industry.

Functions

The industrial liaison offices can be described as the focal point of contact in the university for the private sector. This office will be responsible for, at a minimum, responding to inquiries in relation to the following list of activities (taken from the Directory of Industrial Liaison Offices):

Problem-solving;
Consultancy;
Expert witnesses, professional opinions;
Collaborative and contract research and development;
Access to equipment;
Student projects;
Teaching company schemes;
Postgraduate awards;
Technology transfer and licensing;
Joint university/industry ventures;
New company formation;
Courses and industrial training;
Testing and analytical services.

In most universities this office has changed from being somewhat reactive in relation to these functions to having a more proactive and catalytic role, and hence its primary functions can be characterized as follows:

a. Develop contract research, both public and private sector funded. This will generally include research funded by the various government Research Councils and other public sources such as the EEC, as well as private sector research. In relation to the latter, this initially involved interface with large companies only, but more recently it has progressed in a proactive sense to the development of consortia of companies, and their linkage to centers or pockets of research excellence in the science and technology units of the universities. In this regard, a general identification of areas of expertise for each of the universities that are 'marketed' by the industrial liaison offices is contained in Figure G. An example of this proactive approach is at the University of Manchester, where eleven focus areas have been developed. The most advanced of these at this stage relates to most advanced of these at this stage relates to information storage in the electrical engineering field. A team of four faculty, twelve postgraduate students, three research associates, and several technical staff have been assembled to build and market this capability. This approach of forming groups of faculty into disciplinary or inter-disciplinary centers is evolving at many institutions.

b. Exploit university intellectual property rights through licensing (the favored route), patenting, assisting spinoff companies involving faculty, joint ventures, and the marketing of university services through university companies (which will be described below).

c. Link the university to industrial research support. As noted above, some links usually existed in the past in relation to larger individual companies, and new initiatives now involve the formation of consortia of companies, including attempts to link to smaller and medium-sized companies, as well as forming faculty teams in the manner described above.

These functions are developing in a dynamic sense. The evolving philosophy is one of interaction with industry in an array of university activities rather than through a limited set of specific programs. The approach is now proactive rather than reactive, although still somewhat limited by the traditional culture of the universities.

Budget

The industrial liaison offices are small units with budgets in the vicinity of £100,000-150,000 ($150,000-255,000). Initially funded from internal resources of the university, the units in general are becoming, or have become, self-supporting from overhead generated from research contracts. The overall level of research contract activity would seem to be from £7.5 million ($12.75 million) upwards at the institutions visited for this study. The trend is distinctly and strongly upwards, and about half the funding would be from private sector sources.

Organization

The industrial liaison officer will answer either directly to the university vice chancellor/principal (equivalent to chancellor or president of U.S university), or to the highest nonacademic officer of the university. There are apparently both advantages and disadvantages associated with both models, stemming from the nontraditional nature of the role of this office. In general, there would be an advisory board or committee with somewhat equal university/private sector representation whose purpose will be guidance, enhancement and linkage. The industrial liaison officers will usually be non-faculty persons with extensive industry experience. One overriding impression was the high energy and enthusiasm level of a very capable group.

The Link to Regional Development

While there is some feeling of responsibility to the region where the university is located, and some recognition that the university should make a contribution to the region, this does not constitute a priority, nor is there in general any strategy in this regard. There are examples of linkage and involvement-- for example, with the new regional technical service centers (described below)--and there is very selective participation in regional activities through task forces and so on, but, in general, the universities are not networked locally and do not have a direct focus on regional development. In the same manner, there is no focus on local industry nor any particular emphasis on small and medium-sized companies. Given the overriding imperative to enhance funding to the university, it is simply more effective to link with large companies rather than small and medium local industry.

Effectiveness

Overall, there have been some significant benefits emanating from the activities of these units, although there is still considerable difficulty in getting United Kingdom industry to participate in joint R&D. There has been a significant increase in the generation of research proposals, and success in obtaining new funding from the EEC as well as from private industry. Furthermore, there are clear signs that the university culture is slowly changing to perceive industry-related research in a more favorable light. Nevertheless, university resistance remains strong, and industry research is second choice on the part of faculty to publicly-funded basic research. It has proven to be very difficult to undertake a proactive role at the traditional decentralized university with highly independent faculty. The scope for resistance is exacerbated by the difficulty of ensuring all parts of the university benefit from a focus that relies on the sub-parts. Consequently, even industry-oriented universities such as Heriot-Watt are cautious in marketing their capability because of the lack of assurance that faculty will engage in projects that have been generated; therefore, the approach is still often reactive rather than proactive. Overall it can be said that the general perception is one of modest return from this activity to date, but that the potential exists that further benefits will come if the effort is sustained and expanded.

2. University Companies

Though not universal, many United Kingdom universities have formed wholly-owned holding companies for the exploitation for university research. The general model is for the holding company to be the umbrella for a series of subsidiary companies to market university capabilities or research spinoffs, and to undertake joint ventures with private companies. Examples include LINKSVAIL (Cambridge), VUMAN (Manchester), and AURIS (Aberdeen).

To illustrate the general approach, Aberdeen University Research and Industrial Services Limited (AURIS) has the following subsidiaries:

A. Aberdeen University Computing Services (AUCS)--the focus for commercial work carried out by the University Computing Center;

B. Aberdeen University Marine Studies (AUMS)--focus on biofouling on offshore oil and gas installations;

C. Aberdeen University Petroleum and Economic Consultants (AUPEC)--focus on petroleum economics;

D. Center for Environmental Management and Planning (CEMP)--focus on environmental management and impact assessment;

E. National Collections of Industrial and Marine Bacteria Limited (NCIMB)--part of the United Kingdom network of national microbial culture collections.

As well, AURIS oversees these joint venture companies:

A. Aberdeen Center for Land Use (ACLU)--focus for research expertise with respect to land use matters;

B. Aurora Instruments Ltd.--develop innovations stemming from research work in the faculty of medicine at Aberdeen University;

C. OMS, Ltd.--provision of off-shore medical support services;

D. Scotgen, Ltd.--focus on new improved rapid microbiological techniques.

Heriot-Watt University has developed an alternative approach to university companies through the establishment of a number of Technology Transfer Institutes. These are not university companies, but they have the same mission, namely, taking new technology, finding suitable applications, developing appropriate products, and then licensing those applications/ products to the private sector. These are staffed by full-time research staff and have some, though limited, faculty involvement. Each TTI has a board of advisors. The first was started in 1969 in relation to computer microelectronics. This TTI and has generated a profit for 20 of its 21 years of existence. In 1989, the Technology Transfer Institutes generated £300,000 ($510,000) profit for the university.

B. <u>Technology Transfer and Technical Assistance</u>

1. <u>Science Parks</u>

There are thirty-eight science parks in the United Kingdom. Science parks have been developed in proximity to most, but not all, British universities. There appear to be three models with respect to linkage.

a. Link in name only;

b. the park is a university development;

c. the university is a co-investor.

The most common form of science park is that which has been government-sponsored, usually involving some combination of local, regional and national government funding support. The role of the university is somewhat restricted (i) to the use of its name as a sponsor for status purposes, (ii) the opportunity for university spinoff companies to locate in the park if and when they occur, and perhaps (iii) some other loose linkages through the industrial liaison offices with respect to university seminars, access to university equipment, and so on. Some university membership on the park's board is usual in these circumstances.

The universities generally see these as "property ventures" and not much else. There is no ownership sense and no real interest. If assistance or some other linkage is requested, it will be responded to favorably, but other than that the university involvement is very limited. This is not to say that these ventures are not desirable and productive from a regional development perspective. On the contrary they are, in general, good ventures; rather, from a university-industry liaison perspective, little benefit would seem to have accrued from this model.

At the other extreme is the model where the university is the developer of the science or research park. The Cambridge Science Park was sponsored by Trinity College as a real estate development and to foster university-industry links. The university is active in cultivating that linkage through weekly seminars, access to equipment, joint research, and the like. More than one-quarter of the companies in the Cambridge Science Park are spinoffs from Cambridge University research. The park only allows technology-driven enterprises, there are associated incubator facilities and venture capital companies located in the park, and overall it is a highly successful venture.

The Heriot-Watt Research Park is established on campus, as distinct from being in proximity, and is integrated into the campus as part of the university. There are unique elements of this venture, including the fact that it is totally university-sponsored, fully integrated into the university both functionally and topographically, over 60 percent of the companies are Heriot-Watt spinoffs, it includes large company R&D establishments, and it is self-supporting. By covenant, only companies that need and desire a high degree of collaboration with the university are permitted to locate in the park. Hence, these companies mirror the academic strengths of the university. As well, the university's technology transfer institutes, and other research institutes including those jointly sponsored by the private sector, are located in the park. This park, which was started in 1971, is near full, and the university is seeking to expand through a further phase. As for Cambridge, it is an impressive development.

The third model is that in which the university is a co-investor of the science park. An example of this would be the University of Manchester, where the science park is co-located with the University in the inner-city area of Manchester. Phases one and two of this park were government funded, while the current Phase three is private sector-sponsored. The university investment has been considerable, particularly in terms of complementary support. The University's objective is to cultivate university-company collaboration. Of the twenty-two companies in the Manchester Science Park, fourteen have a close relationship with the university, and of these, nine are spinoffs from university research. The park is more technology-oriented, through covenant, than would be the case for those science parks of the first model of loose linkage to the university. The advantage of this approach is that it does provide a home for university spinoffs and lays the foundation for expanded university industry linkages; and yet there would seem to be some disappointment that this park has not progressed more rapidly than it has.

The development of science parks in Britain has undoubtedly been a productive venture. That value, however, may be more tied to desirable regional development objectives than to a broader goal of enhancing university industry linkages. Aside from the notably successful Cambridge and Heriot-Watt model, which also exists at several other institutions, it would not seem that the universities themselves have benefitted greatly from this development, nor have they seemed to be motivated to capitalize from it. One inherent problem could be that the multiple sponsorship of these ventures is based on conflicting objectives. The cities of Birmingham (Aston Science Park) and Manchester (Manchester Science Park) are primarily interested in job development in the inner-city area, and this can lead to distinct conflicts with a more longer-term university objective of enhancing university research.

2. Regional Technical Centers

While extensively developed throughout Europe, a system of regional technical centers was not implemented in the United Kingdom until 1988, when the British government commenced funding the formation of such centers. Their purpose was described at that time as to "play a crucial part in regenerating British industry through the introduction of new technologies supported by the research and training expertise in higher education, and to enable business to capitalize on the opportunities created by new research developments" (King, 1990). The functions of these centers were to be: i) to arrange access to the latest technological discoveries and innovations; ii) to develop acceptable forms of delivering technological information to industry; and iii) to form a network with other regional technical centers.

According to King (1990) the fourteen Regional Technical Centres (listed in Figure H) can be broadly classified into three categories:

a. Industry-based. For example, NIMTECH (The North West Technology Centre) has nearly 100 participating (that is, subscription-paying) organizations, including all five of the region's universities, as well as three polytechnics. It is very much industry-led, both in its operation and client-base, and hence is based on "market needs."

b. University/Polytechnic-based. There are six RTCs in this category. This RTC is seen as a natural vehicle to further university/polytechnic contact with local industry. These RTCs are therefore more "technology push" in character.

c. Agency-based. These have been set up by major regional economic development agencies, such as the Scottish Development Agency (SDA) and the Welsh Development Agency (WDA). These tend to be focused on a better integration of technology development and transfer into overall regional economic development strategy rather than being somewhat independent programs as is the case with the other models.

This is a new program, and it is difficult to derive any implications on its effects overall, or that of the various models. It is worth reiterating, however, that the United Kingdom has chosen to implement the regional technical service center model that is highly developed throughout Europe, and that has been highly successful in bringing technical assistance to small and medium-sized companies in European countries.

3. BEST (British Expertise in Science and Technology)

The BEST database contains computerized records of expertise, research interests, and industrial relevance of the work of centers and faculty in United Kingdom higher education establishments and government laboratories. This is complemented by another source of information in this area, namely Higher Education Resources for Industry. These are national information databases and are widely used in the United Kingdom. While negative comments were often passed in relation to BEST, these largely reflected the usual problem of the fit between databases and the assorted uses that can be made of them; nevertheless, there was perceived to be tremendous value in having a national resource of this nature on a wide scale.

4. British Technology Group (BTG)

British Technology Group was formed for the purpose of fostering the commercialization by United Kingdom companies of research coming out of United Kingdom universities. It undertakes two main core activities: 1) the transfer of technology from public and private sources to manufacturing, marketing and service organizations under license; and 2) the provision of funding on commercial terms for United Kingdom companies undertaking innovative product and development programs. The constituent activities of the technology transfer process include: assessment of commercial potential of ideas, patent protection and enforcement, finance for development within the academic inventor's institution, licensing, revenue collection and license enforcement, and revenue sharing resources. The industrial finance function includes support for innovative projects, seed capital and early-stage funding availability, provision of equity participation, and, in general, leveraging product development out of research.

The basic premise is that universities would find it too expensive to do this themselves; hence BTG was set up as a quasi-public agency to undertake this on the part of the universities. BTG works closely with the industrial liaison offices in this regard. In general, the universities will utilize BTG, although it has been noted above the emergence of alternative routes to commercialize research such as university companies.

III. KEY CHARACTERISTICS OF THE UNITED KINGDOM SYSTEM

The following observations can be made about the British effort to enhance university industry liaison and technology transfer:

A. Miliband (1990) describes the German approach as a 'system', characterized as a national interaction between suppliers and users of research and development. It describes the United Kingdom approach as a 'non-system', characterized as a myriad of somewhat independent and uncoordinated programs whose effects are patchy at best. It concludes that the British approach is not effective because it has been implemented in an ad hoc manner and lacks a sense of permanence. In essence there would seem to be a lack of purpose in national policy.

B. As well, there is little linkage to regional economic development, other than through the embryo RTCs in the area of technical assistance. This is in contrast to the European scene where the approach is regional in orientation and closely integrated with regional economic development strategy and related programs.

C. The focus is largely on linkage with large companies, because this is cost effective in the context of a primary objective of enhancing university funding. This is paradoxical in that the technology problem in the United Kingdom is acute in particular at the small and medium-sized firm level, as it is in the United States.

D. While university-industry liaison is still on the periphery, relative to the mainstream of focus at the traditional universities in particular, some significant strides would seem to have been made in improving the acceptability of industry-related research at such universities. Similarly, more interest would seem to have been generated in British industry to undertake R&D in collaboration with the universities and polytechnics. Nevertheless, it is still valid to say that the major barriers in this regard continue to be 1) the reluctance of United Kingdom industry to undertake and support R&D; and 2) the reluctance of the universities to modify their culture and perception of such research.

E. The backbone of the United Kingdom system is the industrial liaison office at each university. Initially reactive in concept, the approach has become much more proactive and catalytic in nature as acceptance grows of its functions, and success is achieved with new initiatives. These offices are finding it a daunting challenge to generate the level of new funding from industry and other non-traditional avenues that are needed to offset the real declines from government sources. This constituted the initial basis for their formation. The foundation would seem to have been laid, nevertheless, for this mechanism to achieve a broader set of objectives over the long term, namely significant new funding from industry, enhancement of the research and teaching mission through broader university-industry interface, and possibly closer involvement with regional economic development on the part of provincial universities.

IMPLICATIONS FOR PUBLIC POLICY

The following observations or lessons emerge from this study. They have particular relevance to public policy formation in the United States, particularly at the state level. States, who provide the bulk of public funding to higher education in the U.S., are currently experiencing unparalleled budget difficulties that have been compounded by the national recession. Most of the states have initiated extensive science and technology programs in the past decade, and have done so through an array of models and approaches, with varying degrees of success, as part of their economic development effort (Redwood, 1989; Stella et al., 1990; Atkinson, 1991).

1. Many factors undoubtedly explain the strong economic performance of Germany relative to that of the United Kingdom and the United States in recent decades. The German system of collaborative research and development, and proven mechanisms of technology transfer and technical assistance to German firms in support of innovation and competitiveness, must be one of the more important.

2. A comprehensive approach that covers the spectrum from a) basic research, through b) applied R&D, to c) technical assistance, and is networked both vertically and horizontally, will be more effective in enhancing innovation and competitiveness than an eclectic set of programs that are targeted somewhat independently to narrow needs.

3. There would not seem to be 'one best way' of technology transfer--different mechanisms work well in different circumstances and environments. Creative organizational mechanisms, however, would seem to be necessary to overcome or circumvent the relatively strong barriers to university-industry collaboration.

4. There is a clear and growing recognition that higher education institutions have more to gain, than to lose, in terms of their research and teaching mission and funding availability, from linkage and collaboration with industry.

5. Programs of research development and technology transfer are most effective when implemented as an integral component of a broader regional/ state economic development strategy, rather than as a national or state initiative independent of other foundations of regional economic development (such as finance, human capital, infrastructure, tax policy).

6. Technology development and transfer programs are much more effective with private sector participation and partnership.

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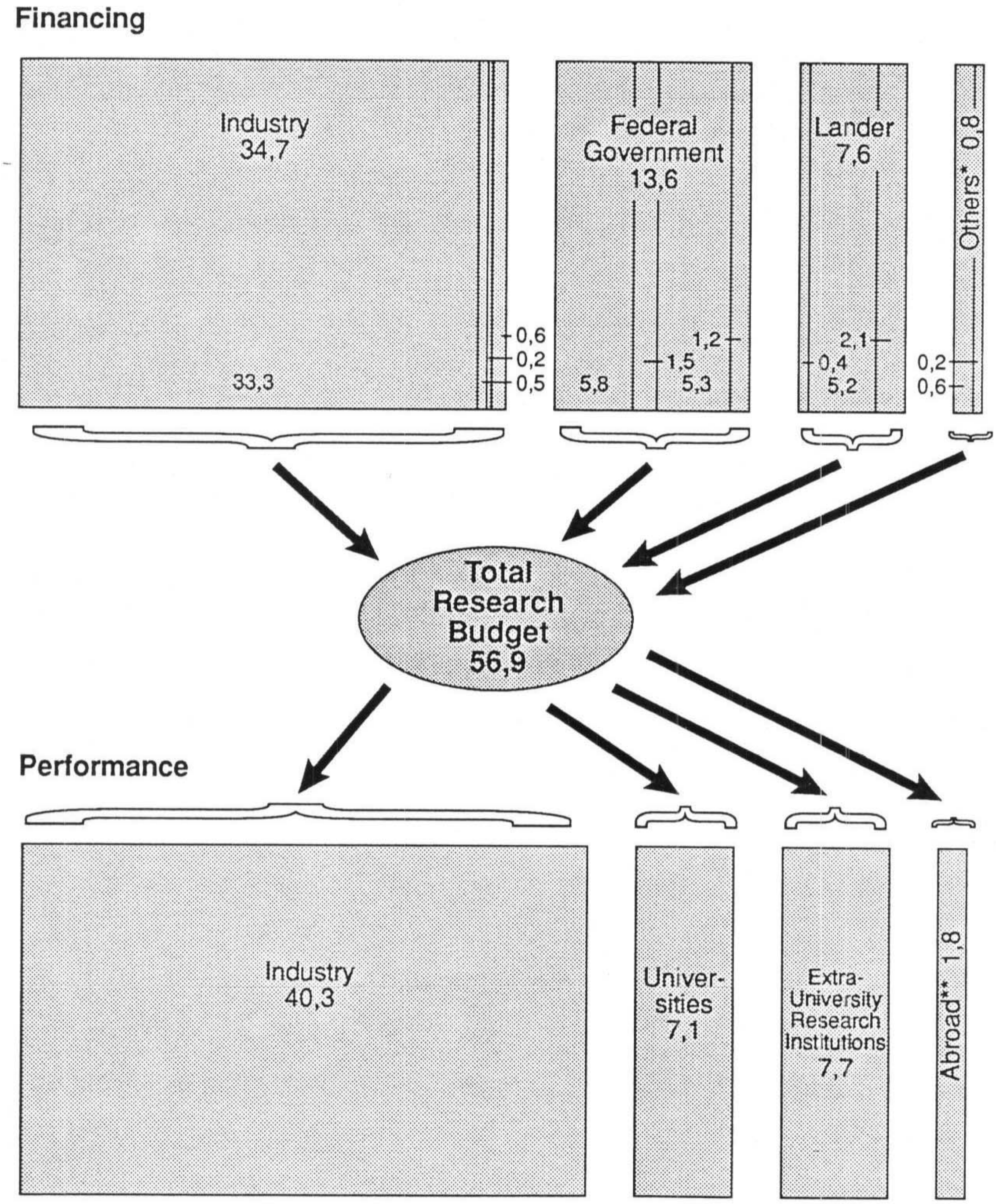
Total Research Budget of Federal Republic of Germany, 1987 in DMbn (estimated)

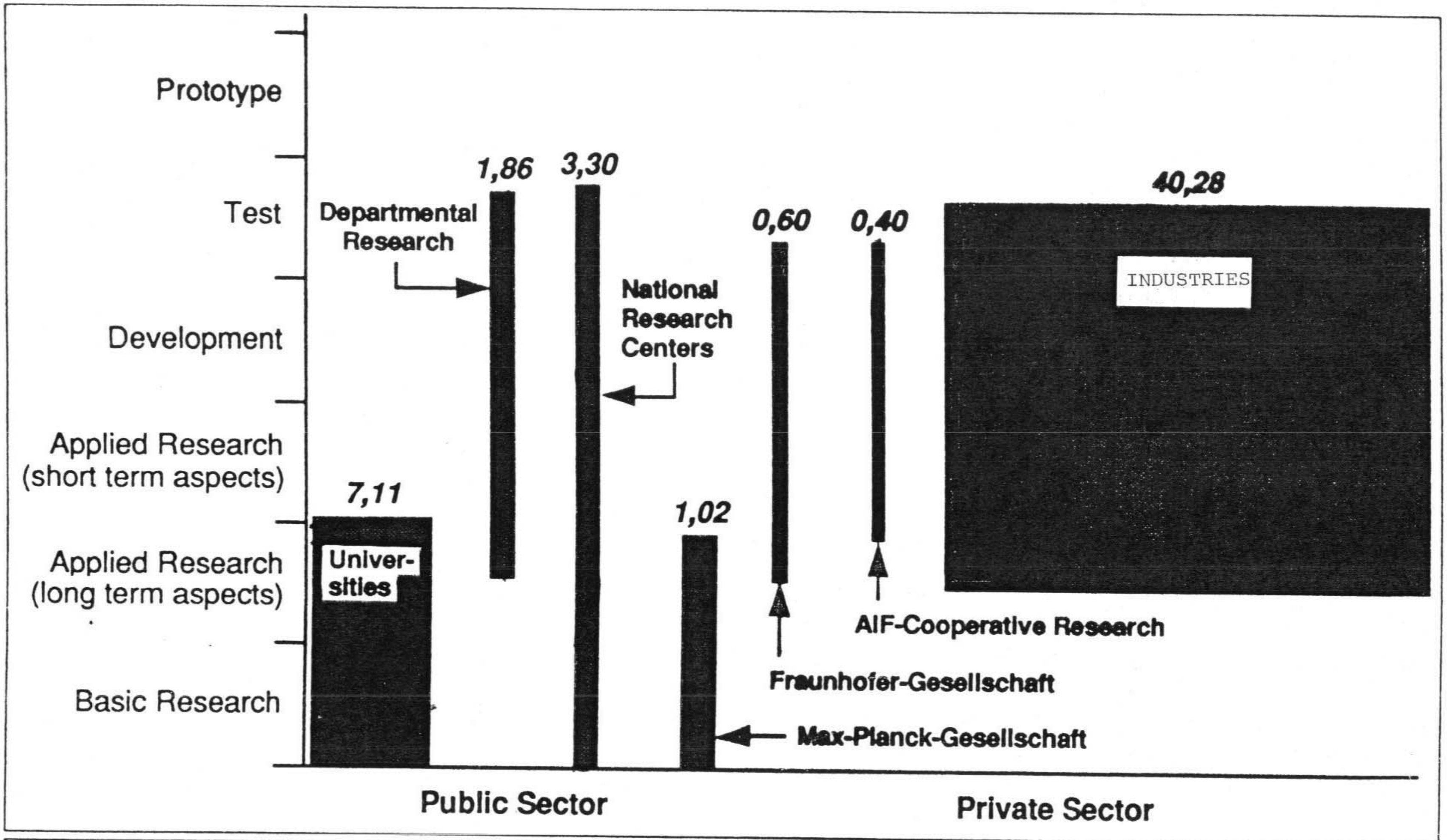


*Own resources of private non-profit-making institutions and abroad
**Including international organizations

Discrepancies in the total are due to rounding

Source: Federal Ministry for Research and Technology, Report of the Federal Government on Research 1988.

Figure A



The System of Research Institutions
in the Federal Republic of Germany 1987
(Expenditures in Billions DM)

22.05.89

Figure B

The Fraunhofer-Gesellschaft at a Glance

1989

664 Million DM Budget

(including 60 Million DM for premises and basic equipment)

88 % Contract Research

hereof 70 % funding by contracts and projects

(approx. 50 % from industry, 50 % from the public sector)

30 % basic funding by the Federal Government

12 % Defense Research

4020 Permanent Staff

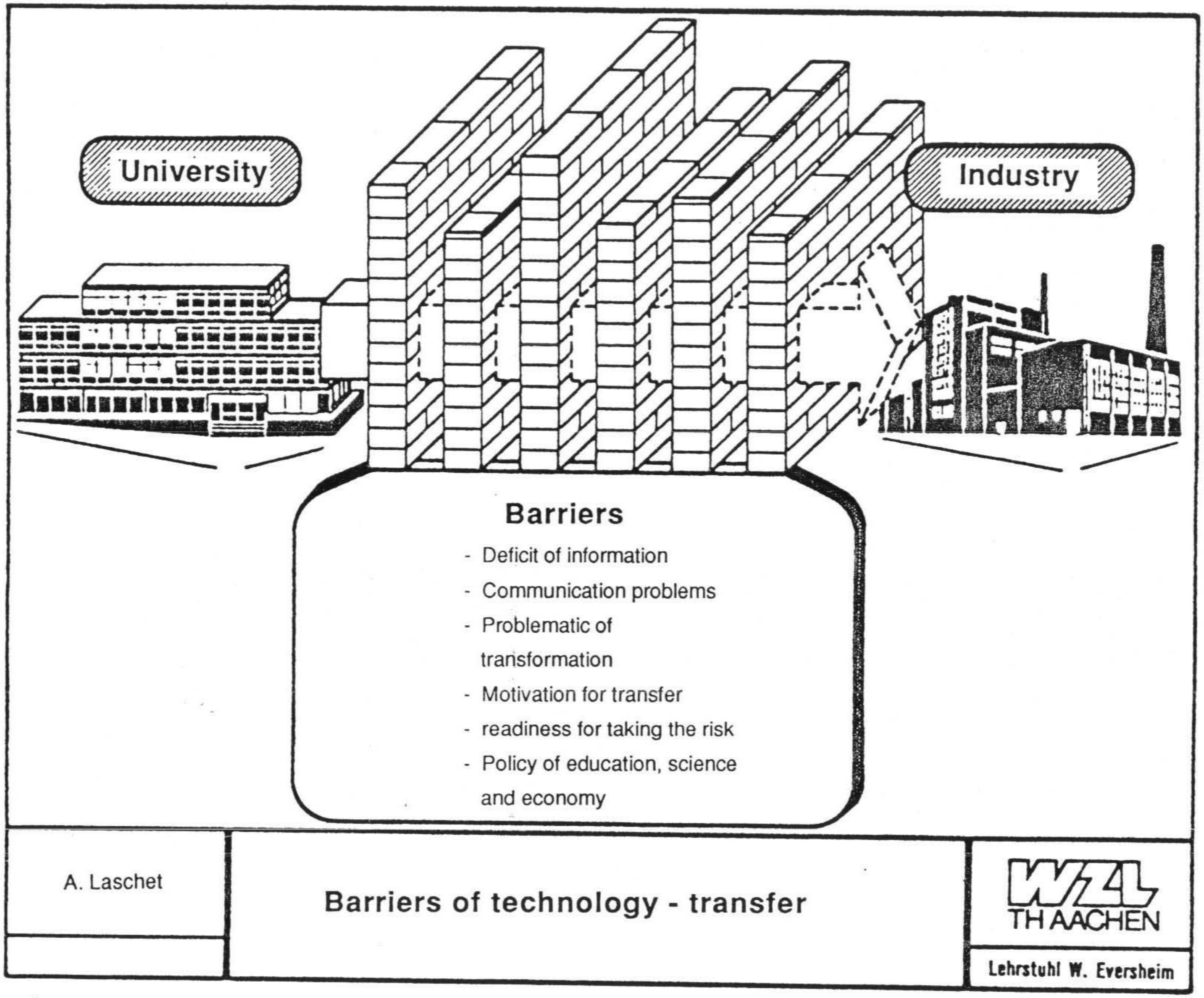
1950 Additional Temporary Staff

36 Research Institutions *

**32 Research Institutes, 2 External Scientific Groups, 1 Patent Office, 1 Technical Information Center*

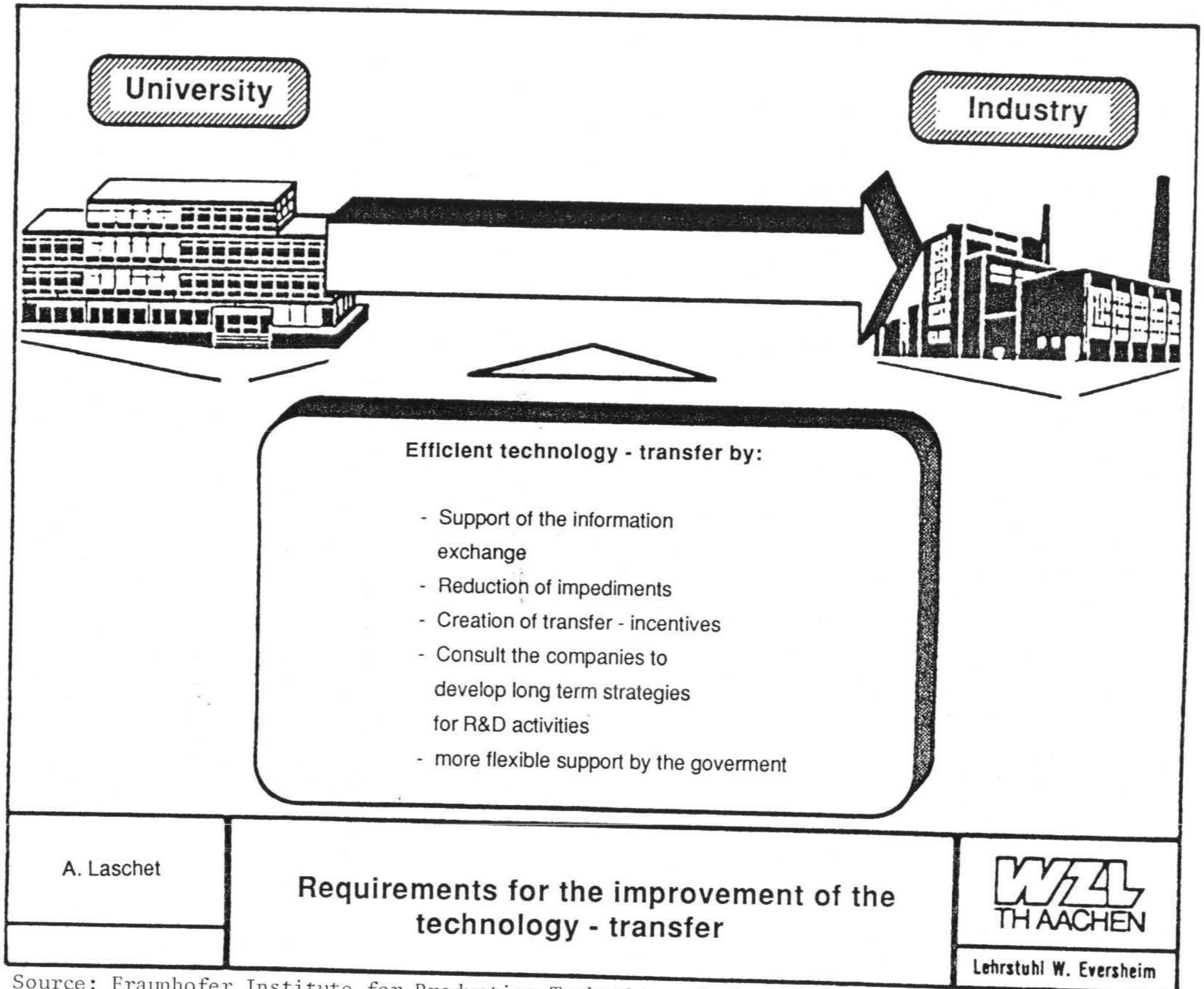
R,2/90E

Figure C



Source: Fraunhofer Institute for Production Technology, Aachen

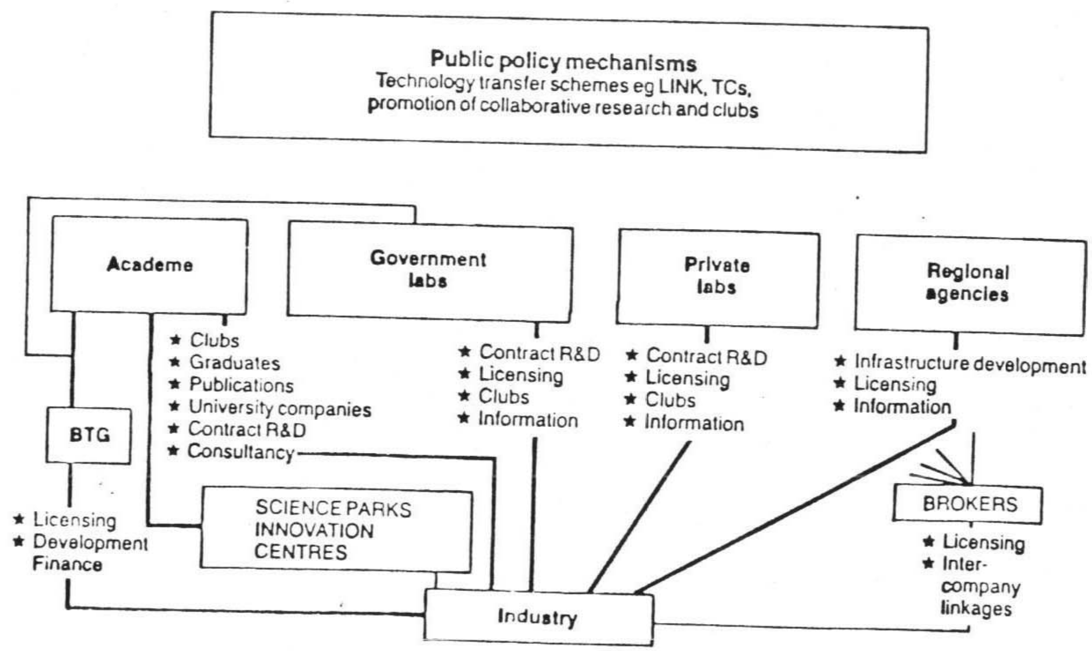
Figure D



Source: Fraunhofer Institute for Production Technology, Aachen

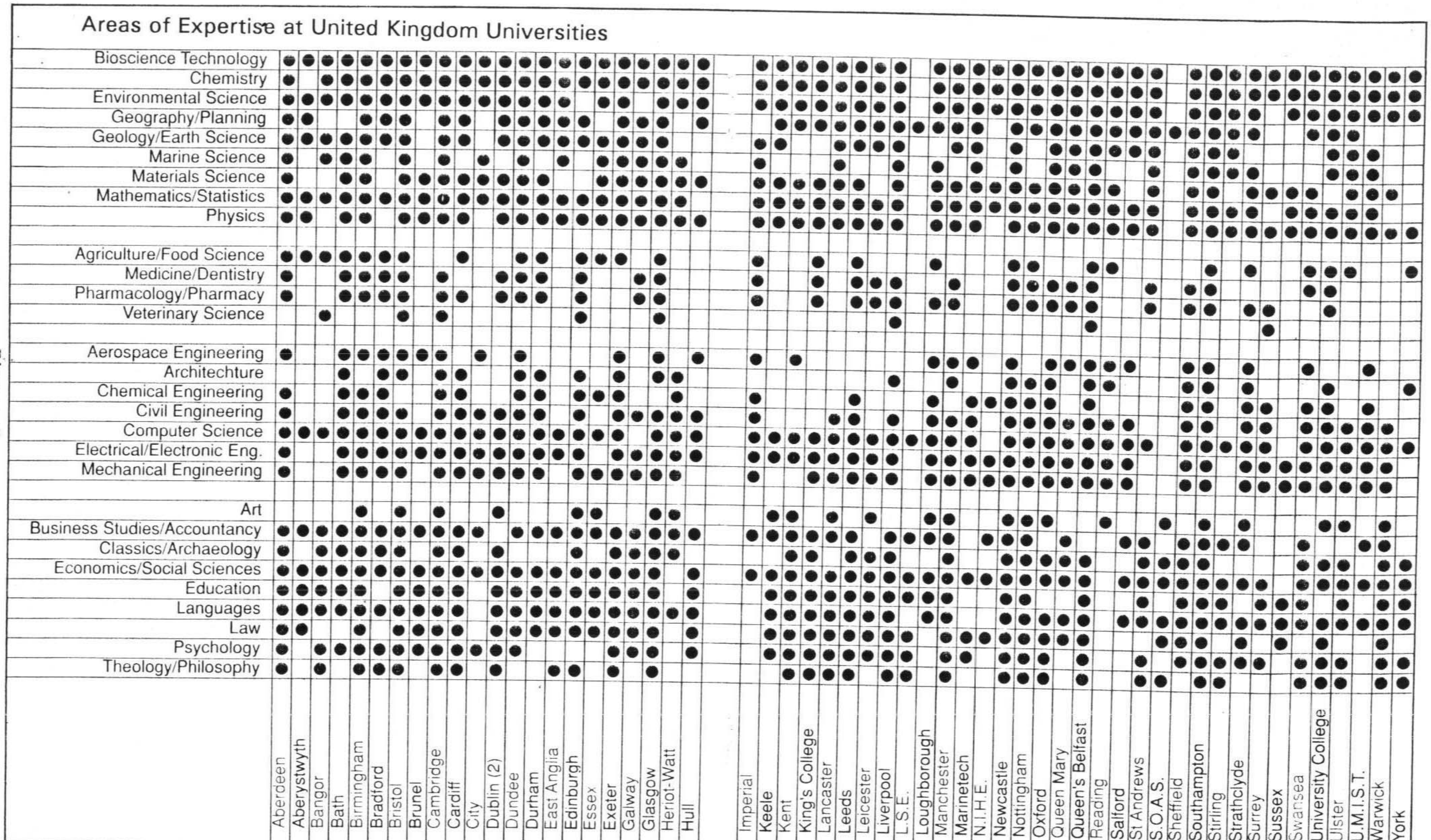
Figure E

Figure F **Major UK technology transfer agencies**



Source: NEDC, 1989, p.26

Figure F



Source: Directory of Industrial Liaison Offices.

Figure G

Nimtech
The North West Technology Centre

U.K. REGIONAL TECHNOLOGY CENTRES

1. SCOTLAND
   Technology Training Partnership
   Scotland Ltd.

2. NORTH EAST
   RTC North
   HESIN

3. NORTH WEST
   NIMTECH

4. YORKSHIRE & HUMBERSIDE
   Yorkshire & Humberside Regional Technology Network
   Yorkshire Electricity Board

5. EAST MIDLANDS
   East Midlands RTC
   Leicester Polytechnic

6. WEST MIDLANDS
   West Midlands Technology Transfer Centre
   Aston Science Park

7. COVENTRY
   RTC Coventry Consortium
   The University Of Warwick

8. THAMES VALLEY
   Thames Valley Technology Centre
   Fulmer Research

9. SOUTH EAST
   Technology Transfer South
   East Sussex County Planning

10. LONDON
    L-TECH
    London Enterprise Agency

11. WEST OF ENGLAND
    West Of England Technology Centre
    Engineering Employers Federation

12. WALES
    Wales Technology Centre
    WDA (Welsh Development Agency)

13. EASTERN REGION
    Eastern Region Technology Centre

14. DEVON & CORNWALL
    South West Technology Network
    Devon & Cornwall Development Co.

Figure H