CLRC

Technical Report
DL-TR-97-001

Infrastructure and Technology Transfer Programmes for Microtechnology in the UK

D W L Tolfree

Published in the Proceedings of the Conference on the Commercialisation of Microsystems '96'
Kona, Hawaii, October 6-11 1996

April,1997

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ISSN 1362-0223

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voted best paper at the conference on

Commercialisation of Microsystems '96.

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Extracted for the Proceedings of the Conference on the Commercialisation of Microsystems '96'

Sponsored by the US Engineering Foundation and Semiconductor Equipment and Materials International

Commercialization of Microsystems '96

Edited by

Dr. Steven Walsh

Kona, Hawaii
October 6 - 11, 1996

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(**Denotes papers that received "best paper" votes

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Infrastructure and Technology Transfer Programmes for Microtechnology in the UK

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Abstract

The national and European programmes relevant to the development and commercial exploitation of microtechnology are described with an emphasis on mechanisms for technology transfer to SMEs.

1. Introduction

Important factors in developing exploitation and commercialisation strategies for microtechnology are a) infrastructure and mechanisms to facilitate technology transfer between the science base and industry b) the identification of key centres with facilities, expertise and equipment c) funding routes for R&D, and d) markets for products. The actual selling of the end product or service ultimately determines commercial success.

While the economic importance of microtechnology is widely acknowledged, the establishment of design and process methodologies are crucial to the manufacture of acceptable products. The ability to mass-produce microstructures inexpensively and assemble them into useful microsystems is an essential pre-requisite for commercialisation. Applications for microproducts exist in many market sectors. These include automotive and aerospace, chemicals, textiles, medical instrumentation, and communications. The growth of markets will depend on a well-established technological and supply base.

During the last few years the UK Government has implemented the objectives of its White Paper on Science, Engineering and Technology, published in 1993 (1). These included changes in the infrastructure for funding R&D, mechanisms for technology transfer between the Science Base and Industry and programmes to enhance the process of competitiveness and wealth creation.

The main thrust of the White Paper was aimed at creating a culture of partnership and co-operation between companies and universities to expedite the release of knowledge and expertise from the latter, particularly to small and medium size companies (SMEs).

Many of the national programmes compliment those set out in the Fourth Framework Programme for R&D of the European Commission. The latter provide funding support for research projects that will stimulate collaborative links across the European Union (EU) in fields such as industrial materials, information technologies and biotechnology.

2. Infrastructure

A simplified organogram of the new structure for research funding in the UK is shown in figure 1. An emphasis on exploiting the Science Base for wealth creation, the main theme of the 1993 Government White Paper, 'Realising Our Potential', produced a restructuring of the Office of Science and Technology (OST) and the Research Councils. The latter are now required to contribute to the wealth creation process through meeting the needs of all users of research facilities, both academic and industrial. Innovation, the diffusion of knowledge and technology to industry and competitiveness are three key elements in the forward strategy.

The Office of Science and Technology was established in 1992 in the UK Government Cabinet Office. It is now part of the Department of Trade and Industry (DTI) and provides a focus for the development of Government policy on science and technology, both nationally and internationally. The OST has responsibility for the allocation of grants to the Research Councils and for implementing the policies set out in the White Paper. The grant is provided by Government from the science vote (the Government's science budget.

In 1995 a new Council for the Central Laboratory for the Research Councils was to incorporate the two national laboratories at Daresbury, near Warrington and the Rutherford Appleton Laboratory near Oxford. They receive the funding service level agreements with the other Research Councils.

3. The Central Laboratory of the Research Councils

The Central Laboratory of the Research Councils is comprised mainly of the two national laboratories located at the Rutherford Appleton Laboratory (RAL), Oxfordshire, and the Daresbury Laboratory (DL), Cheshire, in the UK. The work of the Laboratory is summarised in figure 2

3.1 Central Microstructure Facility CMF)

The CMF is located at RAL and is the national centre of R&D in microstructure and nanostructure fabrication. It has advanced equipment for CAD design tools, optical and X-ray masks, layer processing and resist development. which includes excimer laser ablation, 100keV electron beam writers and deep reactive ion beam etching, electrodeposition and an infrastructure dedicated to providing access to its facilities by academic institutions and industry.

Extensive facilities exist for X-ray lithography and related process technology at the 2 GeV national synchrotron radiation source at Daresbury.(2). Use is made of the LIGA technique for the realisation of precision mechanical microstructures. The Daresbury synchrotron is a designated European Large Scale Facility and was recently a partner in a European network for 'Microfabrication using Synchrotron Radiation', co-ordinated by the Institute for Microtechnology at Mainz in Germany.

3.2 The LIGA CLUB

In 1995, an industry 'LIGA Club' was formed to provide cost effective access to users for prototype microstructure design (3). Fees are used to fund the development of individual members projects under confidentiality agreements. A leading North West Company, Oxley Developments an SME, currently Chairs the Club's Steering Committee. University-industry groups are also encouraged to join as consortia members. The 'Club' concept was modelled on Clubs formed in other subject areas. Projects involving LIGA can also be funded through other routes as shown in figure 3

Other Government- funded programmes exist to provide funding routes for projects, these include LINK, the Teaching Company Scheme, and Foresight., some of which are described below.

4. Programmes and New Initiatives

4.1 Technology Foresight

Two broad aims were to forge new working relationships between scientists and industrialists and to inform decisions on the balance and direction of publicly funded R&D. The programme seeks to introduce a Foresight culture into industry. It aims to bring together industrialists and scientists to identify opportunities in markets and technologies likely to emerge during the next 10-20 years, together with the investments and actions needed to exploit them.

A large scale DELPHI survey was carried out, followed by a consultation exercise through 60 regional workshops, conferences and other events. The Programme was driven by 16 sector panels. A panel of experts reported back the results to Government and will inform decisions on future spending priorities. Microfabrication and microengineering were seen as enabling technologies for a wide range of industries.

4.2 Pilot Faraday Programme

The White paper set out a mechanism for improving technology transfer between industry and academia. It was based on a set of Faraday Principles which were derived from the much admired Fraunhofer Institutes in Germany. These seek to promote the flow of industrial technology and skilled people between the science and engineering base and industry, to strengthen partnerships between industrially orientated research organisations and the science and engineering base, to support core research underpinning product and process development, to enhance the relevance of post-graduate education and training for careers in industry.

Initially, funding was provided in 1995 by the Department of Trade and Industry and North West Companies to set up a two year pilot Regional Faraday Network in the North West of England. The North West is distinct and compact with a concentration of Higher Education Institutions (HEIs), Industrial Research Organisations (RTOs), and many strong sectors of industry.

The North West of England has a tradition and significant resource consisting of knowledge, innovation and skills related to manufacturing. A number of scientific and research networks already existed in the region so a basic infrastructure for Faraday networks was available. The objective was to demonstrate that such a structure was an effective way to improve the competitiveness of the region's key industries through exploitation of science and technology. These include chemicals, food, pharmaceuticals, aerospace, electronics, nuclear engineering, mechanical and electrical engineering.

A number of Faraday projects were identified which satisfied the principles outlined above. These involved the use micro-engineering and surface engineering technologies.

4.3 Faraday Partnerships

A new initiative will be launched by the Department of Trade and Industry and the Engineering and Science Research Council to develop Faraday Partnerships. Pump priming funding for up to three years will be offered to such partnerships which are likely to involve groups of universities, intermediate research and technology RTOs and companies.

The programme will be used to connect academia with SMEs, identifying clusters of SMEs as technology providers, users and suppliers of equipment and services. Faraday partnerships could be a vehicle for driving new microfabrication technologies into SMEs through projects. Access to facilities and expertise will be made available to companies within the partnerships.

4.4 Programmes for SMEs

Public sector financial support for technological innovation in the SME sector is available through a number of programmes - some have a local or regional focus, some a national focus and some a European focus. Most programmes provide subsidised support services or award grants, others involve collaborative projects which can access larger Government programmes.

A mutli-million pound programme of grants is available over the next three years for companies who propose innovative projects which will result in new products and processes. Business advice is available through a Business Links Network, operated at regional levels. Innovation for SMEs is also encouraged through a network of Regional Innovation Groups and Technology Centres.

Various initiatives are aimed at making SMEs aware of the opportunities and facilities available for the design and development of new products. Lack of awareness is seen as a barrier to the exploitation of new technology. For example, a recent marketing survey carried out in the North West of England showed that there was a complete lack of awareness by SMEs of the exciting developments taking place in micromechanics. The survey, based on a relatively small sample of companies, showed those product areas where microproducts were thought to most likely needed (figure 4). It is intended to target companies in these areas in the future.

Most SMEs have an interest in what is available now or in the short term rather than the longer term; they are not generally interested in R&D. A new strategy is needed to engage this important sector of industry.

5. SME Success in Microengineering

There are an increasing number of SMEs becoming interested in the manufacture of microengineered products, additional to those involved in silicon devices such as sensors and fluidic systems. This sector of industry, however, is slow to develop a significant industrial force.

Oxley Developments Ltd, a North West company and leading member of the LIGA Club is an example of an SME who has been successful in developing a microengineering capability and market penetration. The Company is currently working with the CMF through the Club and participates in European and Faraday projects.

The Company has recently completed the development of a passive optical switch for fibre optic communication channels. This is illustrated in figure 5 . The was carried out and supported as part of a Teaching Company Scheme between Lancaster University and the Company, using the Synchrotron Radiation and the LIGA facilities at Daresbury.

6. UK Micro engineering Common Interest Group (MCIG)

The MCIG was set up in 1993 with DTI support to promote and catalyse developments in the UK in micro-engineering. It sponsors seminars and meetings and acts as a co-ordinator for national microengineering activities in the UK.

The MCIG is associated with NEXUS (European Network of Excellence in Multifunctional Microsystems). Over 55 companies and 20 universities in the UK have been identified as being involved in micro-engineering, mainly in micro-electronics, with silicon as the base material.

7. European Networks

The three networks outlined below, although dissimilar, have the same objective to help make European industry more competitive in microproducts. The first brings together research centres associated with synchrotron radiation sources with interests in developing microfabrication technologies. The second creates a network of centres interested in a wide range of process technologies, while the third is a co-ordination network for microsystems technology.

7.1 Network For Microfabrication with Synchrotron Radiation

A network for 'Microfabrication Using Synchrotron Radiation' was established in 1994 under the Human Capital and Mobility Programme of the European Union. It was initiated and co-ordinated by the Institute of Microtechnology at Mainz, in Germany (4). Ten European countries participated, including all those with synchrotron sources with collaborations between 16 research institutions. (Figure 6). The project brought together European researchers and technologists to develop the process technologies needed for product design and enabled knowledge and expertise to be distributed around Europe.

The work of the Network was concluded in 1996. Plans are being made for more such networks to take the technology towards industrial and commercial exploitation.

7.2 Europractice

Microsystems is designated a key area in the European Programme for R&D in Information Technology (ESPRIT), part of the European 4th Framework Programme for R&D.

The first task of the programme is the provision of academic support and industrially orientated basic services for components and microsystems. This task is covered by a project known as Europractice. It was set up as a four year project to create a network of manufacturing centres and technology providers in four EU countries. The countries are Germany, France, Great Britain and Holland. Each has a manufacturing cluster which cover a range of technologies (Table 1). The programme aims to bring together interdisciplinary skills and complementary technologies and make them available to a wide variety of users, particularly small companies whose resources are limited.

The aims and objectives of the Europractice Programme was described by Dirk Beernaert of the CEC in MST news (5), extracts of which are summarised below.

The project objectives are to transfer expertise from research to industry, to create services which can supply microsystems technology to users covering design, microengineering processes, simulation manufacturing testing and assembly, to explore ways of lowering the entry cost and risks associated with the design and manufacture of microsystems.

The objectives will be achieved by facilitating access to components, subsystems and microsystems technologies and relevant know-how for enterprises in all industrial sectors, promoting the application of technologies which can lead to substantial improvements in industrial competitiveness, enhancing the capacity of European industry and acadèmia to train engineers in the area of components, sub- systems and microsystems

The above aims and objectives will be implemented through European service centres delivering basic services, cost effective access to technology through consultancy, software tools, training design support and low volume production runs. The adoption of common standards and processes will be encouraged.

The challenge is to disseminate microtechnology into industry both to the large companies and small companies in the supply chain.

The Cluster in the UK is a consortium led by the Hirst Division of GEC Marconi Materials Technology (GMMT) and co-ordinated by Smith System Engineering Ltd. It consists of the Research Councils Central Laboratory (Rutherford Appleton and Daresbury), which covers all the process technologies, including LIGA using synchrotron radiation and laser oblation, the Central Research Laboratory of Thorn EMI, which carries out rapid prototyping, TWI which is a specialist in materials technology and packaging and Epigem, an SME which specialises in the design of advanced polymer components for optical systems

7.3 European Network of Excellence in Multifunctional Microsystems (NEXUS)

NEXUS was set up in 1992 to bring together expertise, research and development centres in Microsystems technology (MST). It currently has a renewed contract with the European Commission to continue its activities as NEXUS II. These include the strategic assessment of MST world-wide , the formation of industrial links to small companies, research co-ordination, training and education, public relations and developing a communications infrastructure. In order to implement its objective to identify and establish core industrial applications it has set up four 'User Supply Clubs'. These will establish links between MST technology suppliers and manufacturers, users and organisations involved in the fields of medical, bio-medical, and environmental monitoring, automotive and aerospace, instrumentation and process control and peripherals and multimedia. Members of the Clubs will link to other European initiatives like Europractice.

7. Conclusions

The infrastructure and national initiatives described above provide a framework for supporting microtechnological development from both the public and private sector. As microfabrication technology advances into real industrial applications, there is a need to establish a manufacturing methodology, a supply base and a supporting research and development infrastructure. Microcomponents which will have to engineered into working microsystems. This will provide a much needed stimulus for the development of microengineering technologies. It is expected that these technologies will make a paradigm shift in future manufacturing.

Market surveys indicate growing markets for microproducts which will provide opportunities for the SME sector. Investment in R&D and market analysis currently lacking in many European countries is urgently needed. Both the European Union and national Governments have targeted SMEs for support as they are the most likely source of future job creation.

Clearly, a strategy for research and development, manufacturing and market exploitation within the new infrastructure needs to be established for the SME sector if it is to become competitive in the emerging global markets for microengineered products.

8. References

1. Realising our Potential - A Strategy for Science, Engineering and Technology Cm2250 HMSO 1993

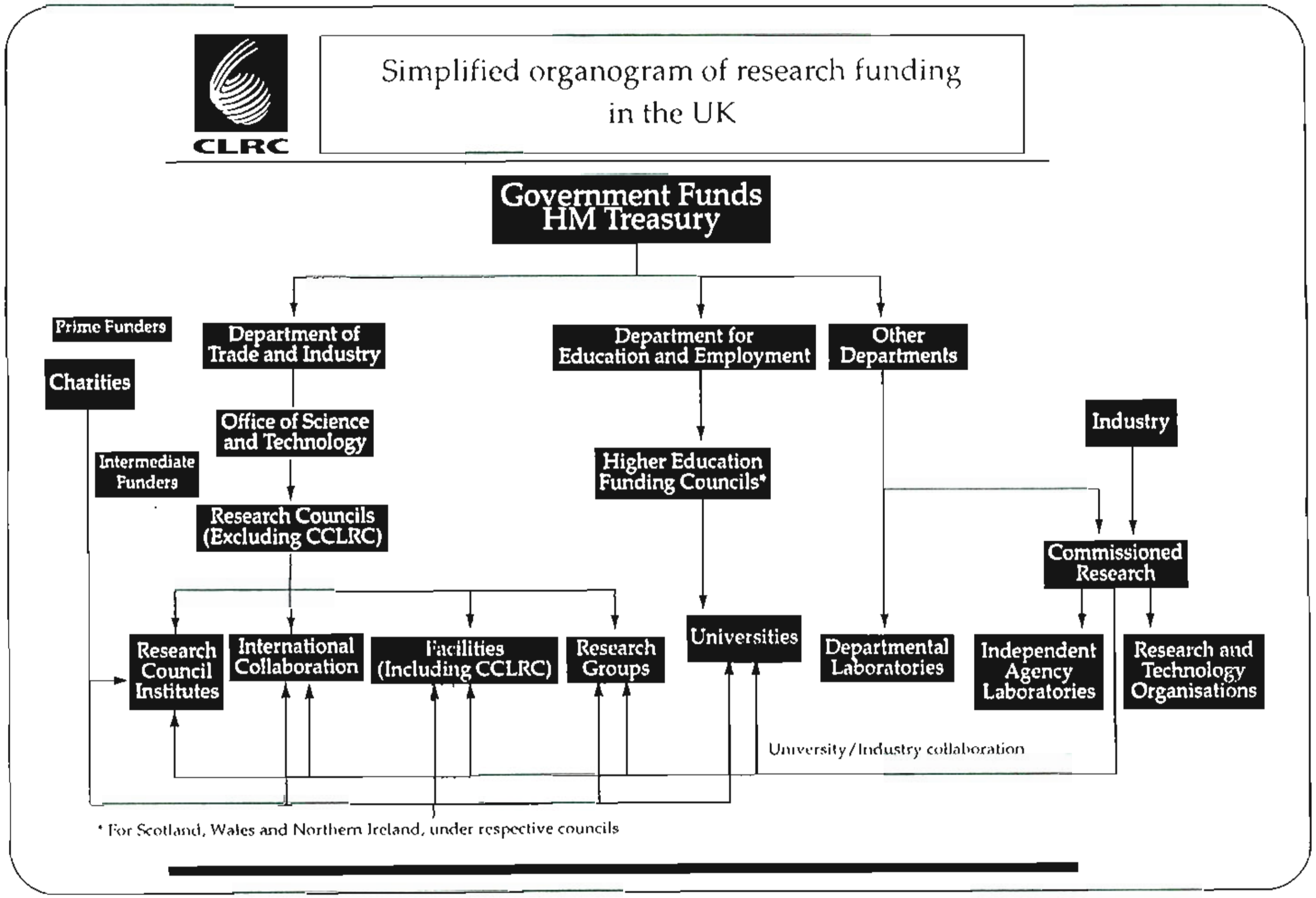
2. Microfabrication Using X-Rays from Synchrotron Radiation Sources IOP . D W L Tolfree, X-ray Science, Issue 3 Autumn 1994

3. LIGA Club Brochure, D W L Tolfree, (CCLRC 1996)

4 Hesch, K Weiel, R 1996, Microfabrication with Synchrotron Radiation, EC HCM Programme (1994-1998)

5. D Beernaert, MST news No 14 1995 pp 2-10

Figure Captions



CLRC
Simplified organogram of research funding in the UK
Government Funds HM Treasury
Prime Funders
Charities
Department of Trade and Industry
Department for Education and Employment
Other Departments
Industry
Office of Science and Technology
Intermediate Funders
Higher Education Funding Councils*
Research Councils (Excluding CCLRC)
Commissioned Research
Research Council Institutes
International Collaboration
Facilities (Including CCLRC)
Research Groups
Universities
Departmental Laboratories
Independent Agency Laboratories
Research and Technology Organisations
University/Industry collaboration
* For Scotland, Wales and Northern Ireland, under respective councils

Fig.1

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Daresbury Laboratory

SRS: The Synchrotron Radiation Source: the UK's brightest photon source, producing light from infrared to X-ray wavelengths.

Theory and Computational Science: operating advanced computers, including parallel computers, as national facilities.

Databases: the laboratory is host to the Chemical Database Service and to SEQNET, a molecular biology computing service.

Nuclear Physics: the Nuclear Physics Support Group helps UK experimenters plan their work on facilities around the world.

Other facilities include the Research **Unit for Surfaces, Transforms and Interfaces,** and the **Medium Energy Ion Sources.**

X-ray Lithography and **LIGA** for the microfabrication of precision components.

Rutherford Appleton Laboratory

ISIS: the world's most powerful source of pulsed neutrons and muons.

Central Laser Facility: one of the world's leading centres for high-power laser research. Operates the Vulcan and Titania high-power lasers.

Particle Physics: the laboratory supports work at the international laboratory CERN and co-ordinates experimental particle physics throughout the UK.

Space: advanced facilities for design, construction and testing of instruments for space missions are provided, with other activities covering data collection, processing, analysis and remote sensing.

Central Microstructure Facility: provides over a hundred instruments for the design and manufacture of tiny micro-engineered structures.

Computing: offers a range of high-performance computing facilities, including supercomputers.

Fig.2

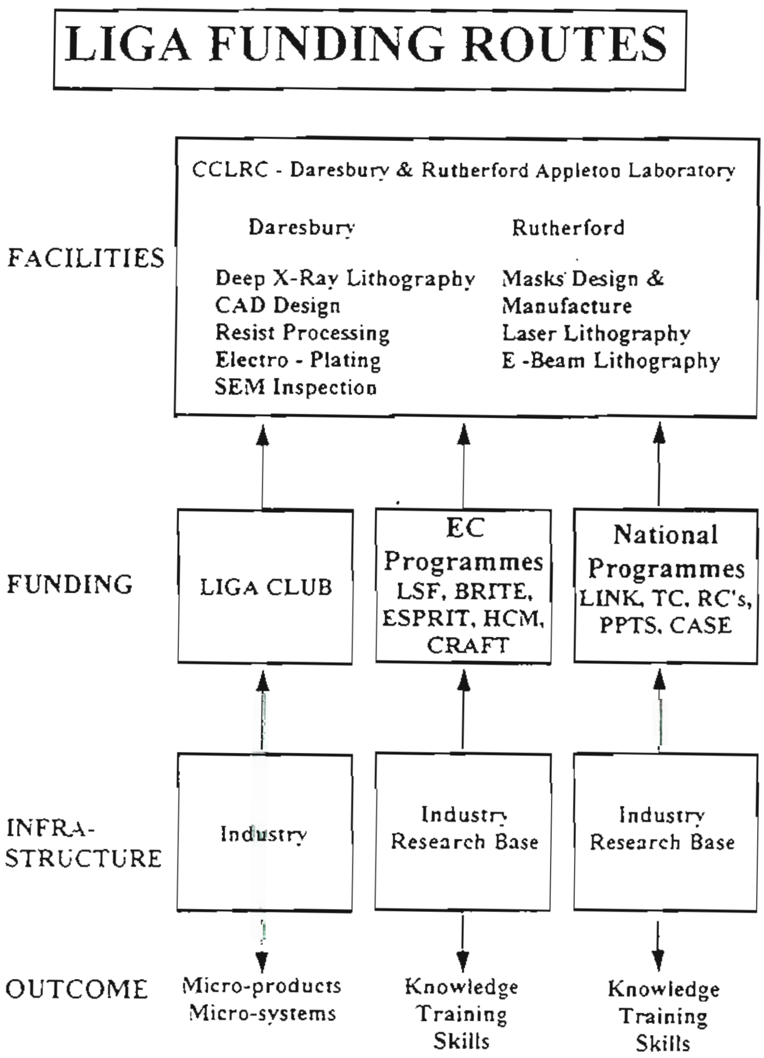
LIGA FUNDING ROUTES
FACILITIES
CCLRC - Daresbury & Rutherford Appleton Laboratory
Daresbury
Deep X-Ray Lithography
CAD Design
Resist Processing
Electro - Plating
SEM Inspection
Rutherford
Masks Design &
Manufacture
Laser Lithography
E -Beam Lithography
FUNDING
LIGA CLUB
EC Programmes LSF, BRITE, ESPRIT, HCM, CRAFT
National Programmes LINK, TC, RC's, PPTS, CASE
INFRA-STRUCTURE
Industry
Industry Research Base
Industry Research Base
OUTCOME
Micro-products Micro-systems
Knowledge Training Skills
Knowledge Training Skills

Fig.3

UK COMPANIES vs PRODUCT AREAS

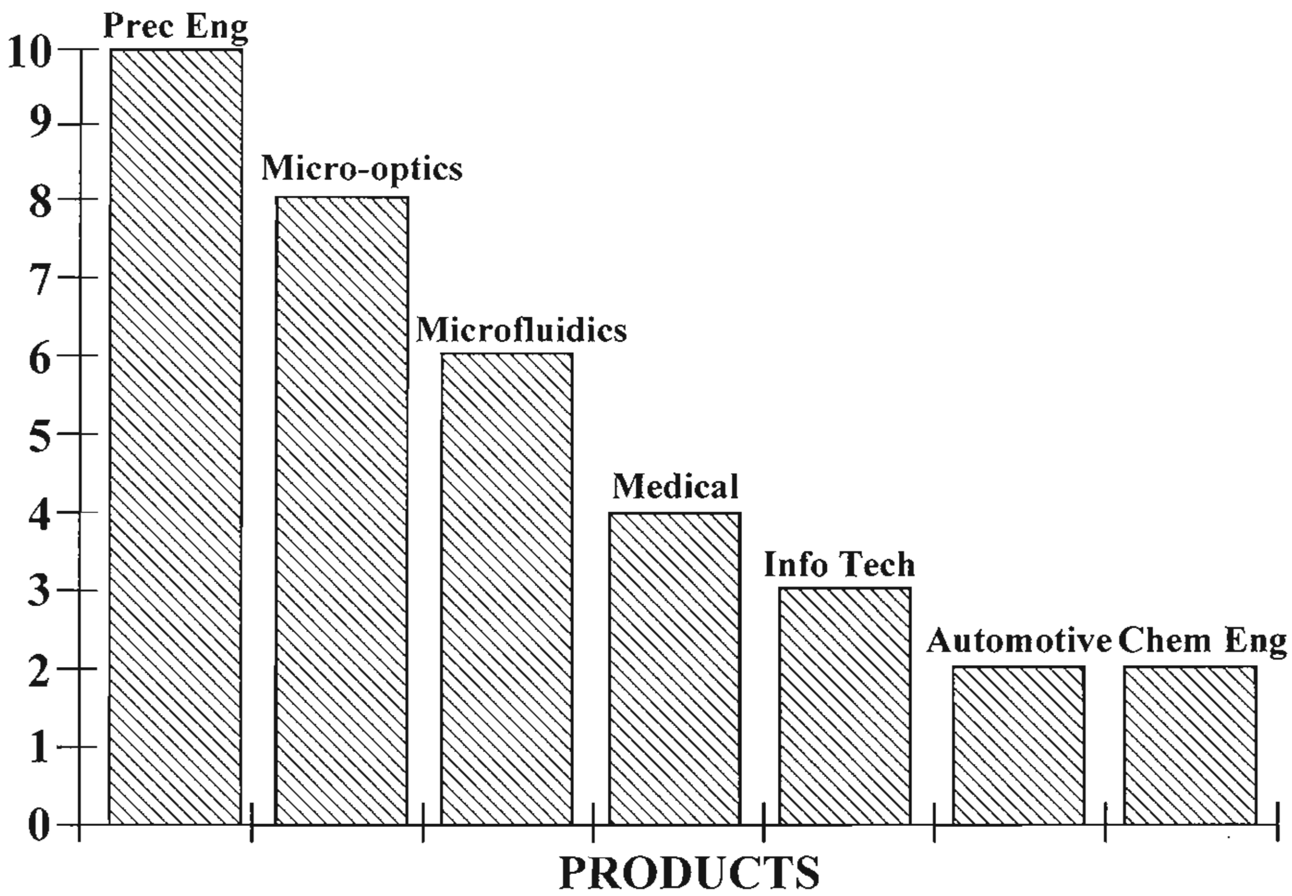

Fig.4.

93/409/18

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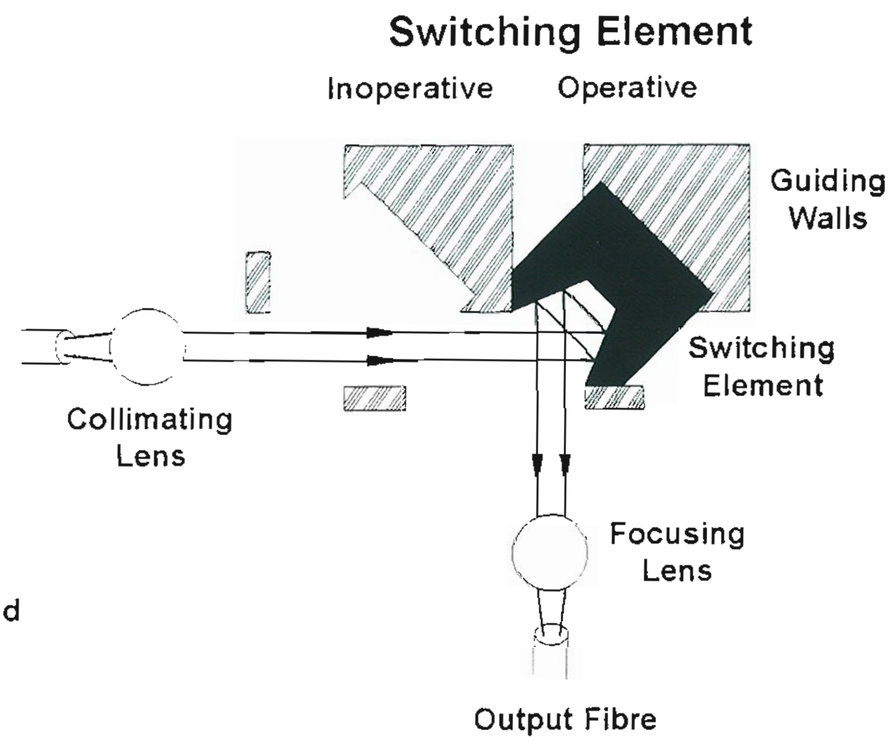
SWITCH DESIGN



Bulk Optics

Lenses collimate and focus light signal

Mirrored switching elements redirect signal

f:\pm5\sf5\023.pm5

OXLEY

Fig.5

EUROPEAN NETWORK PARTNERS IN MICROFABRICATION

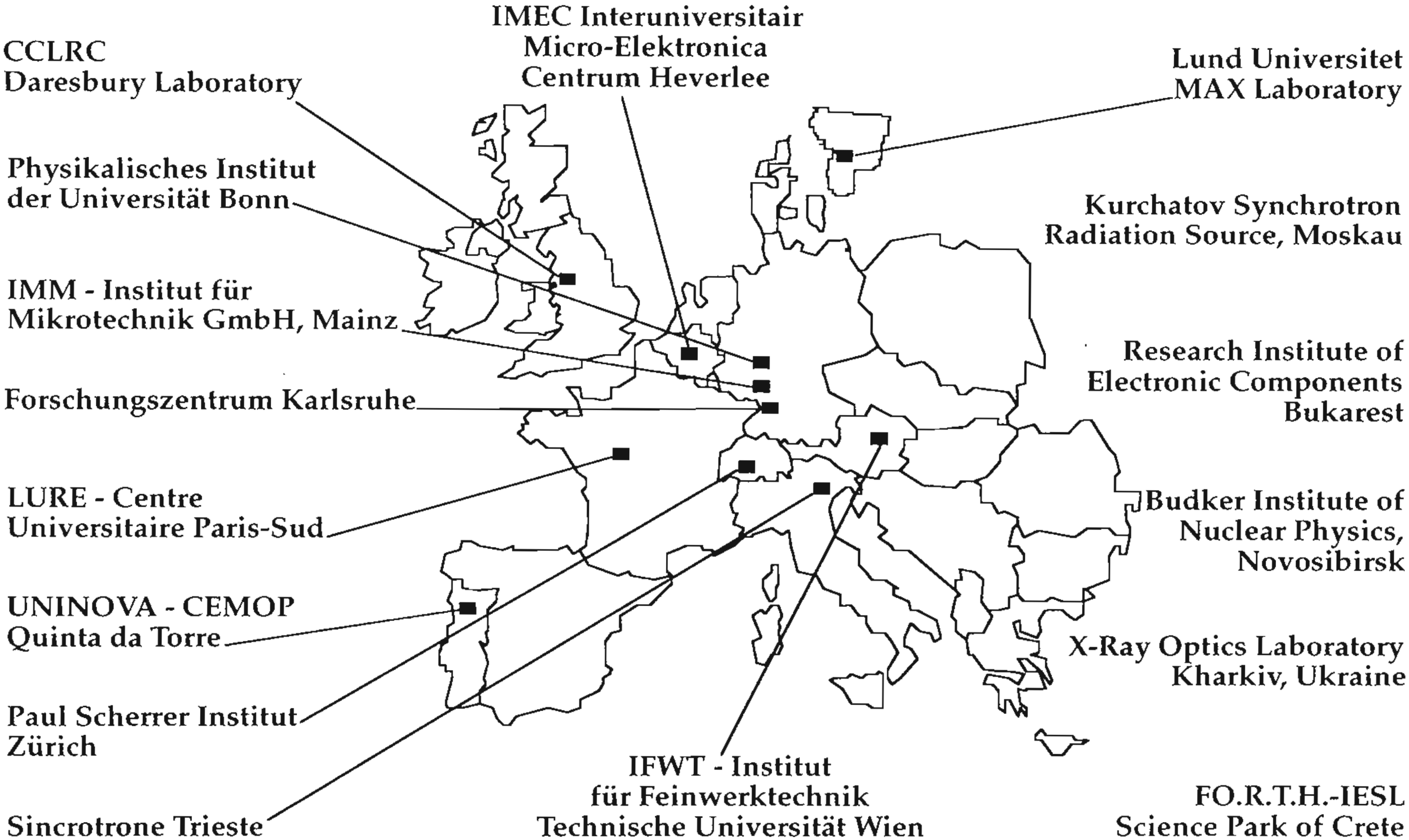


Fig. 6

Technologies on offer in EUROPRACTICE

PARTNER / TECHNOLOGY	Manufacturing Cluster 1: Bosch HL Planer, Fhg ISIT, GMA, FHG IMS Microparts	Manufacturing Cluster 2: Sagem, Sextant, LAAS CNRS, CEA-LETI	Manufacturing Cluster 3: GMMT, TWI, RAL, Epigem, CRL	Manufacturing Cluster 4: CSEM, Twente-Microproducts, Holland Signaal
Surface micromachining silicon	●	●	●	●
Bulk micromachining on silicon	●	●	●	●
Micromachining on quartz		●	●	●
Laser trimming/ablation/drilling	●		●	●
Electroforming	●		●	●
LIGA	●		●	
Laser Excimer			●	
Micromoulding	●		●	
Electroplating	●		●	●
Polymer materials	●		●	
GaAs components			●	
ASIC design	●	●	●	●
Silicon on insulator		●	●	
Chip and Wire Assembly	●	●	●	●
Flip chip/Solder bump	●		●	●
Multi chip module	●	●	●	●
Anodic Bonding/Silicon bonding	●	●	●	●
Biosensitive Layers	●		●	●
Magnetic Layers	●		●	●
Piezo resistive layers				

THE COMMERCIALIZATION OF MICROSYSTEMS

1994-1996

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The first Commercialization of Microsystems conference was held on September 11-16, 1994 in Banff, Canada. The success of this conference, the "Banff" conference as it is now commonly referred to, has led to this second conference on the commercialization of microsystems. The first conference provided information concerning infrastructure, government policies, case studies, and, more importantly, a forum for meaningful informal discussions on marketing, technology management and transfer, incubation, and a host of other topics that are not normally the subject of discussion and/or debate at a traditional technical conference. For your reference, I have included the white paper, the program, and the attendee list from the Banff conference with the handout materials.

In the two years since the Banff conference considerable progress has been made in the advancement of the miniaturization fabrication technologies and new areas for applications and research have developed around the world. The number of technical conferences has increased dramatically and many more companies are now aware of the potential of the miniaturization technologies. Commercial products developed or purchased by large companies, products developed by MEMS (microelectromechanical systems) companies, and commercialization infrastructure support have all increased or expanded over the past two years. Micro cars and helicopters have been "driven" and "flown" and new possibilities for the technology have emerged in card and game companies, car passenger safety, environmental remediation, chemical processing, and, **yes, even the toy industries.**

The miniaturization fabrication technologies are bridging the gap from mini-micro-nano in field size, depth and/or aspect ratio, and in working materials. New replication technology allows for the economical manufacture of parts in a wide variety of materials. New research thrusts are allowing for the fabrication of true 3-D surfaces. The miniaturization technologies have the potential of becoming the most value-added and pervasive technologies of our time. These enabling technologies, not unlike the microelectronics industry, could affect virtually every industry - "Smaller, lighter, more functional and less expensive consumer products, industrial machines, instruments ... possibilities limited only by man's imagination" is a phrase that we use at the IfM (Institute for Micromanufacturing) that sums up our assessment of the technology, hopefully, this second commercialization conference will explore the possibilities and will continue the enthusiasm and excitement generated by its predecessor.

THE COMMERCIALIZATION OF MICROSYSTEMS '94

White Paper from the Banff Conference, 11-16 December 1994

Draft sent to conference attendees on 15 November 1995

5 January 1996

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Abstract

This Engineering Foundation conference focused on the challenges and opportunities faced by firms attempting to commercialize Micro Electro Mechanical Systems (MEMS) based devices. The conference targeted research directors, design engineers, commercial development managers, and professionals struggling with the challenges of bringing these devices to commercial viability. The conference provided information concerning ongoing infrastructure activities, government policies, and individual firm case studies. This information provided the foundation for many fruitful discussions. Many insights were developed during the analysis and discussion of the presented material. The conference facilitated the generation of new ideas to aid in the commercialization of MEMS and microtechnology based products.

Examples of the insights and suggestions which were generated at the conference included the following items:

- The need for the development of an industry association.
- The development of "easy" access policies to disseminate information from national labs.
- The development of a newsletter to promote HARM (high aspect ratio MEMS) technologies such as LIGA (German acronym for deep x-ray micromachining).
- Defining immediate infrastructure needs versus long-term industry infrastructure needs.
- The need for a program similar to SBIR (Small Business Innovation Research) specifically for MEMS.
- The identification of significant roadblocks for current promising technologies.
- The development of a populist article in a magazine like "Time".
- The next conference should spend more time on policy, market strategies, and capital investment.

The conference was attended by many of the leaders in MEMS research and in the commercialization of MEMS. Representatives of large companies (IBM, Texas Instruments,

Tektronix, Ford Motor Company, etc.), MEMS specific companies (Microparts, Lucas Novasensor, Analog Devices, Redwood Microsystems, etc.), and relatively new start-up companies (Integrated Technologies for Medicine, etc.), government, and researchers from the U.S., Canada, Germany, Japan and Switzerland all contributed to the commercialization conference.

BACKGROUND

The number of MEMS based applications is increasing at a rapid pace, however, the market has been relatively slow to accept many of these products. One of the biggest problems shared by many of the individuals at the 1994 conference was how to commercialize the many products developed with MEMS technologies and how to increase the market pull. The lack of some of the enabling technologies, such as packaging, were also of importance.

The conference brought together professionals from all over the world who are currently intimately involved in the MEMS commercialization process. Many important problems and opportunities were discussed. The conference featured sessions concerning such topics as the state of current worldwide infrastructure for MEMS, differing government policies, and individual corporate commercialization case studies. Discussions at the sessions helped clarify the state of the MEMS commercialization process and identify strategies which will be helpful in the future.

Individuals from various government organizations and government sponsored agencies reviewed the policies of the major manufacturing countries. The technological and commercial policies of the United States, the United Kingdom, Japan, Germany, and Switzerland were reviewed. National laboratories such as Battelle and centers of excellence from around the world sent representatives to discuss their corporate interaction policies. A great number of corporate commercialization processes were reviewed. Large corporate efforts were reviewed from companies such as Analog, Perkin Elmer, Texas Instruments, Ford, and Lucas NovaSensor. Smaller entrepreneurial efforts were reviewed such as Microtech Associates, Redwood Microsystems, Interactive Technologies for Medicine Inc., and Intellisense.

GOVERNMENT POLICY

Alternative government policies of the United Kingdom, US, Japan, Germany, Switzerland, and others were discussed. Various governments have supported the development of MEMS. The support came in many different ways. Government support activities ranged from limited interaction to explicit help in focusing on emergent technological issues. Certain countries have policies designed to give financial, technological, and scientific aid in support of specific technological, commercial, and infrastructure issues. The interest of various governments to facilitate MEMS activities depended on such things as the available government resources and perceived value of MEMS technologies to the individual countries.

The following four examples give some of the highlights from the discussions on Government activities.

In the US

ARPA (Advanced Research Projects Agency) has been active in promoting not only the design, use, and systemization of MEMS devices, but also in aiding the creation of MEMS technology infrastructure. The presentation by ARPA emphasized how MEMS manufacturing technologies have gone from "laboratory curiosities" to commercially viable products. It began with an historical review and focused on the part played by the corporate pioneers of MEMS technologies such as Analog Devices. The current BAA (Broad Agency Announcement) proposals were discussed.

- ARPA's BAA proposals are focused on four issues: manufacturing technologies, systems development and demonstration, infrastructure activities, and new application domains. This is well in keeping with ARPA goals of bringing the value of their sponsored research to the end user.
- US CRADA (Cooperative Research and Development Agency) grants were discussed as a possible way to open the door to national laboratories for firms of all sizes without undue administrative effort. These grants allow US firms to make use of the facilities in national laboratories for a fraction of the normal cost.
- The ARPA infrastructure proposal process and aims were briefly discussed. The review of ARPA efforts focused on establishing natural infrastructure for MEMS. Programs such as the MCNC (Microelectronics Center of North Carolina) MUMPS program, and the MEMS program at Analog Devices were presented in detail.

In Germany

The funding process of the German Microsystems Program was discussed. The Federal Ministry of Research and Technology has identified four areas of emphasis. During the five year span from 1994 to 1999, funding will be focused in industrial cooperative projects, scientific pre-projects, exchange of scientists, and diffusion and technology funding.

- Examples of technological activities such as the airbag sensor were provided.
- Efforts concerning LIGA and LIGA-like technologies were discussed.
- Examples of government - industry interaction activities were discussed such as: Microparts, KfK, iMM, and others.

The German program on Microsystem Technologies includes manufacturing processes, interconnection and packaging, simulation and design tools, testing, and also a wide range of applications such as automotive, medical, environmental, energy management, sensors and actuators, etc. Special emphasis has been placed on pushing the technologies from the research stage into commercial use. International cooperation is also a key issue of the program.

In Japan

In Japan, the Ministry of International Trade and Industry (MITI) and other government agencies shepherd the research effort in microsystems technologies. Most of this support flows through the ISFT (Industrial Science and Technology Frontier Program) Micromachine Technology Center. The Japanese effort is ending the first phase of a two phase program in 1995. During the second phase of this two phase program, the government plans to spend approximately 15 billion yen over the next 5 years. The targets of the first phase were issues such as miniaturized device technology and evaluation technology.

The ISTF project is a three phase, three tier effort. University research forms the foundation with a concentration on micro science and technology. These forums are also expected to generate new ideas and applications. University research is also expected to support materials microfabrication and measurement efforts. National research labs focus on materials, micro fabrication and measurement projects, as well as supporting university and ISTF industry projects. Finally, many firms are directly working on the ISTF projects, focusing on micro devices and components and systems integration. These activities are also designed to support the efforts of the national research labs. There are over 25 Micromachine Center contributing members. Most are Japanese corporations, but at least two firms are from the US and one is from Australia.

In the UK

The United Kingdom has a loose association of individuals from national labs, industry (approximately 45 firms), and universities (16), as well as government policy makers who have developed a Microengineering Common Interest Group (MCIG) with 55 members and a LIGA group with 40 members. Formal presentation of the LIGA activities to the Government Science Minister occurred in 1992. The LIGA group was emphasized, and government support has continued.

The LIGA group in the UK is a combination of small and large firms that take advantage of the resources and technology of all member universities. Funding can be secured through a number of sources and a variety of outcomes can be obtained. Current members have goals that vary from the acquisition of microparts and microsystems to the often more important goals of acquiring knowledge, skills, and training in MEMS technologies. The aims of the LIGA group are to centralize the LIGA effort, disseminate knowledge, market UK technology and promote European collaboration.

In Switzerland

Swiss industry has over 150 years tradition in microtechnology with the watchmaking and machine tool industry. Switzerland produces more that 50 percent in value of the world's watch market (15 percent in quantities). A peculiarity of the Swiss industry is the size of the companies; over 99 percent have less than 1000 employees and over 95 percent have less than 50 employees.

Microtechnology has been declared a priority in the government's research policy for over 20 years. A high level of expertise exists in Swiss university institutes and R&D centers.

A new Priority Program, called MINAST (Micro and Nano Systems), will start in 1996 for four years with public funding of around 60 Million Swiss Francs and private participation of the same order coming from around 100 Swiss companies, mostly small to medium businesses.

CORPORATE CASE STUDIES

A large number of companies made presentations about their attempts to commercialize MEMS based products. Many participants thought these sessions were extremely useful. Some excerpts from two of the case studies are included below. The first is a small company, Lucas NovaSensor, and the second is a large company, Texas Instruments.

Lucas NovaSensor

The Lucas NovaSensor story was primarily the story of a small Silicon Valley micromachining company called NovaSensor which was sold to Lucas in 1990. It was heartening to hear how a start-up company in 1985 became sufficiently profitable to be acquired by a large company only five years later. Some of the insights are included below.

- Large companies have a tendency to buy out founders, freeze innovation, and convert it into real products.
- It is very important to encourage experimentation.
- The only factor keeping a start-up company on course through the good and bad times is the founder's desire for large financial return.
- Do not be surprised to have your future hanging on a large, troublesome order that is being delivered to Fedex at 5:55 p.m. for the next day's production.
- If they were to do it again, they would split resources 50-50 between product R&D and manufacturing R&D.

Texas Instruments - Digital Micromirror Display Technology

While many innovative products come out of small firms like NovaSensor, large firms account for many of the new ideas and products as well. The development of Digital Mirror Display (DMD) technology at Texas Instruments is an example of MEMS-based innovation and commercialization at a large firm. It is clear that the problems encountered at larger firms can be dramatically different from the problems at larger firms. Some of the insights about the differences and similarities between large firms and small firms are listed below.

- It took 13 years for DMD technology to get out of the R&D lab. Smaller firms will generally need to commercialize a technology much sooner to stay alive.
- People involved had to show the soundness of the project. This was accomplished by obtaining external funding through ARPA and other avenues. This is likely to be true of large and small firms.
- Had to convince management that a substantial market existed for the technology. In a small firm, the potential market exists mostly in the mind of the founder.
- Management had a large number of investment options. Management had to be convinced that the DMD project was relatively more attractive than other projects. At small firms all the eggs are usually in one basket. It is do or die.
- To commercialize the technology, they worked with "partners" who were industry and market leaders. A thorough understanding of the market is critical for large or small firms.
- They developed a subsystem approach which provided display "solutions" not just DMD components.
- They worked with related display component manufactures to insure a superior product.

CONCLUDING COMMENTS

Although the presentations were informative, much of the "value added" at the conference came from the working group discussions and informal discussions. Many problems, ideas, and suggestions were discussed and some of the more important issues are listed below. The list is obviously not complete but hopefully is indicative of what transpired at the conference.

- Packaging MEMS devices is difficult. Many thought an excellent topic for an

ARPA project was the development of generic packaging technology with attention to die separation. Perhaps there is a market opportunity here.

- There were not many MEMS device purchasers participating in the conference. Many thought that the inclusion of the customer would be an excellent addition. One possible way to bring supplier and customers together was to have an "expo". Another idea was to invite customers to the technical program, but run it in conjunction with sessions where the basic technologies were explained.
- There is need for more innovative design tools. Three suggested needs include CAD systems which can be used to design macro models for system integration, CAD tools for simulation of devices and processes, and CAD design aids for masks and other steps in the process.
- Access to design facilities and/or fabrication facilities is still very difficult. A methodology must be developed for this type of information to be communicated. Information access is the key to this dilemma
- One issue of concern was how to expand the potential customer base. One suggestion was to make the general public more aware of the value of microsystems. The idea was to get some play in the popular press by developing articles for publications like Time and Newsweek.
- Another issue of importance is access to national labs. Most national labs prefer to work on larger projects with perceived large payoffs. Many large firms gain access because they are working on large projects and can dedicate manpower to long term projects. Many small firms have trouble gaining access because they often have smaller, more idiosyncratic problems that must be solved. Small firms often cannot afford to dedicate manpower to projects with longer term horizons. New, low bureaucracy CRADA's will help the small firms by making the process much less complicated.
- Many thought a trade association would be a valuable contribution. A trade association was perceived to have many possible benefits. A trade association would facilitate information dissemination, would stimulate university research relevant to the commercialization of microsystems, would help give the MEMS related products an identity, and would serve as a voice to other organizations.
- There was much discussion about how to build the infrastructure for MEMS technologies. Many thought that the further development of "technology centers" was one of the necessary steps. Two possible technology centers were identified as being at universities and national labs. The perceived key was to encourage firms to go beyond the "proof of concept" stage.
- US CRADA grants were discussed as a possible way to help improve the infrastructure. These grants could open the doors of national laboratories to firms of all sizes without undue administrative efforts. These grants allow US firms to

make use of the facilities in national laboratories for a fraction of the normal cost.

- Another possible way to help build the infrastructure is an SBIR like program, specifically for MEMS. This would facilitate the development of MEMS technologies.
- Many perceived a problem getting from the development stage to the production stage. One suggestion was a government sponsored program for "working capital loans". Some firms get to the point where they have a working prototype but cannot enter production for lack of funds. Obviously this program would be primarily for small businesses. Another promising concept was the development of an organization or structure to consult with and link innovators and capital venture.

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The Engineering Foundation announces the second conference dedicated to the commercialization of miniaturized systems and the strategic management of the miniaturization technologies. The commercialization process is by its nature a multi-disciplinary task and its strategic development demands professional interaction. The 1994 conference owed much of its success to the participation of professionals from many fields.

The target audience for this "Gordon style" conference are professionals involved in the transfer of MEMS technologies to the marketplace. These include professionals from corporations involved in MEMS manufacturing, as well as corporations involved in developing materials and equipment for MEMS based manufacturing. Research directors, product champions, business managers, commercial development managers, marketing managers, manufacturing managers, design and process engineers, directors of MEMS commercialization centers, entrepreneurs, and government publicists are invited to attend.

Topics in this years conference include, but are not limited to, infrastructure needs, entrepreneurship, deriving competitive advantage through MEMS technologies, market analysis, government support activities, technology development and transfer, and company case histories

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