WORKSHOP ON CHANGING BUSINESS STRATEGIES FOR R&D AND THEIR IMPLICATIONS FOR SCIENCE AND TECHNOLOGY POLICY

RAPPORTEUR'S SUMMARY[1]

Background

1. The Workshop on Changing Business Strategies for R&D and their Implications for Science and Technology Policy, co-sponsored by the OECD, the European Industrial Research Management Association (EIRMA), and the French Ministry of Research, was held in Paris on 22 October 2001. John Barber of the U.K. Department of Trade and Industry served as Chairman of the Workshop. Henry Chesbrough, from the Harvard Business School, served as Workshop Rapporteur. The Workshop provided a forum for more than 100 business R&D executives and science and technology (S&T) policy makers to discuss the ways in which firms are reorganising their R&D programmes to improve their innovative capabilities. It also served as a forum for exploring ways in which public policy might best respond to these changes. Participants addressed issues related to: *i*) the reorganisation of firms' internal R&D programmes, *ii*) the increasing externalisation of R&D activity by businesses; *iii*) globalisation of business R&D, and *iv*) implications for S&T policy.

2. The motivation for organising the Workshop was the growing perception of important shifts in the ways firms are organising, implementing, and managing R&D activities. These shifts are most evident at the firm level, where they have been documented in case studies of individual firms, but they are beginning to manifest themselves in more aggregated statistics. The Issues Paper prepared for the Workshop identified several important trends, the most salient of which include:[2]

– *Rapidly growing business investments in R&D*. Business enterprise expenditures on R&D (BERD) rose 25% in real terms across the OECD from 1993 to 1998, to reach an estimated US$ 345 billion in 1998.[3] This growth appears to have been driven primarily by knowledge-

1 . This document was prepared by the Workshop Rapporteur, Henry Chesbrough, of the Harvard Business School.

2 . Unless otherwise indicated, the data cited in this paper derive from the OECD Main Science and Technology Indicators database.

3 . These changes vary across countries and across sectors. Australia, Italy, and the UK experienced a decline in BERD, while BERD remained unchanged as a whole for the European Union. Finland, Japan, Sweden and the United States saw increases in BERD.

intensive manufacturing and service sectors (*e.g*., information and communications technology, biotechnology) and occurred despite a stagnation in government financing of R&D. Hence, the portion of R&D investment financed by industry rose from an estimated 58% in 1990 to 63% in 1998, while the government share declined from 38% to 30%.

- *Rising levels of collaboration.* A variety of indicators show increases in collaborative R&D activities in the 1990s. The share of business funding of university research, the amount of R&D contracted to outside organisations, the numbers of acquisitions of small firms, and the number and size of corporate venture capital funds[4] all showed growth in many OECD countries. These statistics suggest that firms are increasingly looking outside their corporate boundaries for new technology.

- *Growing importance of venture capital financing*. Many OECD countries saw their venture capital (VC) markets grow 30% or more between 1995 and 1998, a factor that has contributed to the growing share R&D conducted by small and medium-sized enterprises (SMEs). The downturn in venture capital (VC) markets in 2001 slowed rates of new firm formation and initial public offerings, but VC remains at historical high levels, suggesting that VC will remain an important part of the R&D landscape going forward.

3. These trends suggest that a new division of labour is emerging in the funding and conduct of business R&D, with implications for the structure of national innovation systems and for public policy. Growth in business R&D expenditures, for example, suggests that governments will need to find ways to better leverage their comparatively smaller R&D investments. Increasing collaboration creates a broader, more diffuse target for government policies, possibly requiring changes in the individual instruments used to support business innovation (*e.g*., direct financing of R&D, tax incentives for R&D) and the balance among them. It might also heighten the importance of other policies in stimulating innovation, such as policies related to intellectual property rights or support for SMEs. The growing importance of venture capital financing may also make R&D investments more susceptible to the business cycle and heighten government's role as a stabilising force.

4. This document summarises the results of the Workshop, drawing from the formal presentations and the general discussion among participants. It synthesises the key themes that emerged from presentations by business executives on the new strategies firms are adopting for their R&D programs, and it discusses the implications of these changes on industrial innovation and on S&T policy. Because most of the Workshop focused primarily on changing business R&D strategies, rather than on S&T policy, the policy issues identified herein represent areas for further investigation and discussion by the OECD and other organisations rather than firm policy conclusions. Annex 1 contains summaries of the individual presentations made during the Workshop. Annex 2 includes two case studies presented at the Workshop by Henry Chesbrough to illustrate the changing R&D strategies of two specific firms, IBM and Intel.

Overview of Workshop Findings

5. The Workshop presentations reinforced the notion that a new division of labour is emerging in the funding, conduct, and focus of business R&D. Firms appear to be turning to a more open model of

4 . The term *corporate venture capital* refers to venture capital funds operated by firms whose primary business activity is in fields other than financial investment. These include a wide range of firms such as France Telecom, Hitachi, and IBM. The number of firms operating corporate venture capital funds also jumped from 49 in 1996 to approximately 350 in 2000.

innovation that makes more extensive use of research results that originate outside their boundaries. Among the more notable elements of this transition that emerged from the Workshop:

– Leading firms are increasingly charting the course of internal research by monitoring external activities and targeting internal research to fill the gaps or to create integration mechanisms that build upon the external research activity.

– Many firms actively fund external R&D through direct financial support (R&D contracts, grants, etc.) or by providing venture capital financing to start-up firms. These techniques allow them access to a broad portfolio of innovative projects without having to develop the necessary competencies internally.

– Managers are considering multiple paths for deriving value from internal R&D, whether by using R&D results in new products and services, spinning off companies that can pursue the technology in a new and different business model, or licensing a technology to other companies.

6. Participants generally agreed that governments had an important role to play in supporting innovation in this new environment. Financing of business R&D will remain important, but governments will also need to work with the private sector to ensure that the overall economic and regulatory environment supports innovative activities in a growing number of organisations. The discussion suggested the following:

– Government support for basic, or fundamental, research may become even more important as industries become more knowledge-intensive, competition intensifies and firms face continuing challenges in appropriating the returns from their investments in R&D.

– Government S&T policy may be more effective if, instead of supporting individual firms, it attempts to cultivate the soil in which innovative firms can grow, encourages diverse approaches to scientific and technological challenges, and acts to counter-balance market forces.

– Policy will need to increasingly address issues associated with intellectual property rights, the licensing of results from publicly funded research, development of human resources and promotion of entrepreneurship. The direct effects of such policies may be harder to measure because they will be more diffuse, making evaluation ever more challenging.

Changing Business Strategies for R&D

The old paradigm

7. Henry Chesbrough suggested that the best way to appreciate the ongoing changes in business R&D strategies is to compare them with those that previously dominated leading research organisations. He characterised leading laboratories of the 1980s as fundamentally closed, in that internal research investigations were launched within corporate research laboratories, evaluated and screened internally, and then selectively transferred into development divisions, where they were incorporated into new products and services to be sold through internal channels of distribution. This paradigm was based on two underlying assumptions:

- Firms could anticipate the important technologies that would be needed to advance their businesses.

- Most of the best people in the field worked for their firm.

These assumptions led managers to undertake long term research investigations because they believed that their staff could identify the areas where investigation would be needed and because they felt that they possessed, or could readily attract, the researchers needed to complete the R&D.[5] This paradigm was based on a linear model of innovation and the assumption that most technologies have strong first-mover advantages. Companies felt that the more they spent on internal R&D, the greater their future payoffs would be.

8. As Professor Chesbrough noted, this paradigm worked very well for most of the 20th century. It led to numerous technological breakthroughs, and it fostered a virtuous circle for R&D: fundamental breakthroughs in the lab enabled new products, services, and features to be brought to market place; these offerings boosted sales and profits for the company, which in turn financed new R&D that could start the cycle over again.

Changing environment for business R&D

9. As several Workshop participants highlighted, however, the environment in which firms conduct R&D is changing. Three factors that were identified in presentations were.

- *Shortening time to market*. Several speakers described how increasing competition is forcing them to shorten time-to-market for new products and services. Attempts to speed up the innovation process have altered business R&D processes. Christian Grégoire, for example, reported that the need to introduce new products and services rapidly into the market place has required Alcatel to more frequently act an assembler of component technologies developed by outside companies, rather than to develop component technologies itself.

- *Expanding technological competencies*. Other speakers noted that individual firms can no longer maintain in-house all the competencies needed to innovate; hence, they must look to external sources of knowledge and technologies. According to Pierre-Yves Saintoyant, Microsoft's support of university research serves as a means of expanding the external pool of knowledge from which it and other software firms can draw.

- *Globalisation*. Global restructuring of business is also influencing innovation patterns by deepening the specialisation of individual firms and regions and strengthening the interdependence of firms. Kazuya Matsumoto stated that Canon now looks to its French research operations for new technologies and often deploys them first in its European business before launching them in Japan or elsewhere in the world.

10. Henry Chesbrough outlined additional factors that further undermined the old paradigm for business R&D. Factors such as *i)* increasing mobility of skilled workers; *ii)* growing capabilities of university research; *iii)* more diffuse distribution of knowledge; *iv)* erosion of dominant market positions of many large firms; and *v)* enormous increases in venture capital have compromised the ability of companies with significant internal R&D investments to appropriate the returns on those investments.

5 There are other reasons beyond these beliefs for companies undertaking internal research, including the increasing ability of firms to co-ordinate with complex and tacit information.

Firms' discoveries are increasingly at risk of diffusing out of the company, Professor Chesbrough stated, with little or no compensation to the company. For example, skilled researchers can more easily create new companies that make use of knowledge learned in research conducted at other firms. Not only does the firm that conducted the original research fail to capture the returns of its investments, hence breaking the virtuous circle, but also the start-up firm is generally less likely than the parent firm to invest heavily in basic research.[6]

Toward a new paradigm for business R&D

11. In response to this changing environment, firms have begun to adopt new strategies for their R&D. These changes attempt to increase the returns from their own R&D investments and to make greater use of R&D conducted elsewhere. Leading firms appear to be charting the course of their internal research by carefully monitoring what external activities are already underway, and then target internal research at either filling in missing gaps, or creating integration mechanisms that build upon the external research activity. Managers are considering multiple paths to market for the project, from internal deployment within current products, to spinning off companies that can focus on pursuing the technology in a new and different business model, to licensing a technology to another company with an already established business model. Globalisation of R&D has also become more prominent as firms seek out centres of scientific and technological excellence around the world and as supply chains become more internationalised.

Linking business R&D to business strategy

12. Several speakers provided evidence that business R&D investments are no longer made in a support role that is only indirectly linked to business objectives, but are increasingly driven by business strategy. Firms actively seek to demonstrate financial returns on their R&D investments, and the R&D projects firms choose to pursue are increasingly linked to the development of new products, processes, and services. Andrew Dearing reported on the results of a recent survey of EIRMA members (large R&D-conducting firms) that showed a significant increase in R&D that is linked to the development of new businesses. Takuo Takashita described how Mitsubishi Materials created eight separate companies within its corporate structure and more closely linkrd R&D to product development and customer needs in each company. Even in firms with a growing commitment to fundamental (or basic) research, attempts are made to capture the near-term value of inventions. Pierre-Yves Saintoyant claimed that virtually all of Microsoft's new products incorporate technology developed by Microsoft Research, even though the lab is not charged specifically with generating near-term results, but with ensuring the future of the firm.

Acquiring technology from external sources

13. Many speakers highlighted the growing number and kind of relationships their firms are entering into with other firms (both large and small), universities and government laboratories to pursue their R&D

6 One illustration of the effort of the broken circle is Xerox Corporation's experience in the 1980s and 1990s. While the company did succeed in creating numerous technologies that improved its copiers, it created other technologies that were more valuable in other businesses, such as computers and networking. It intentionally spun off 30 companies from its research from 1979 through 1998, and while many of these companies failed, 10 of them were either sold at a large profit, or became public companies themselves. The market value of these firms was over $40 billion as of June, 2000, compared to less than $15 billion for Xerox. While a great deal of value was created, little of that value accrued to the Xerox shareholders, and little reinvestment in further research was therefore possible.

objectives. This process was illustrated by Brian White-Guay, who stated that Merck researchers are now charged not only with generating new internal research but also with accessing external research discoveries. The goal is to create virtual labs that combine both internal and external research. In addition, Merck launched a corporate venture capital fund that invested more than $1.5 billion in life sciences firms in the first half of 2001. It also engaged in M&As valued at $27 billion. As a result, more than one-third of Merck's drug sales now come from externally developed products. Over half the new chemical entities in active development in the pharmaceutical industry in 2001 were estimated to come from external sources.

14. Externalisation of R&D does not appear to be limited to the pharmaceuticals sector. As Klaus Mayer described, it is part of the extensive division of labour in R&D in the automotive industry, in which medium-sized companies like AVL-List aggregate and co-ordinate the work of a network of sub-contractors in large vehicle programs for leading automotive manufacturers. Externalisation is abundantly evident in the ICT sector. Speakers from Alcatel, Intel, and Microsoft reported extensive use of M&As and corporate venture capital investments to identify new strategic opportunities, extend the market penetration of standards they have championed, access external technology, and transfer new technology into their own operations. Tim Keating noted that the slowdown in the ICT sector had forced significant reductions in the number of investments made by Intel Capital in 2001. Nevertheless, Intel has investments in over 500 firms and remains committed to corporate venture capital as a means of identifying important trends in markets and technologies. Pierre-Yves Saintoyant reported that Microsoft devotes 20% of its growing research budget to university research, a share equal to approximately $75 million in 2001. Interestingly, increasing engagement of external sources of knowledge has occurred at Intel and Microsoft even as these firms have built and expanded new internal research organisations.

15. By monitoring external R&D efforts firms can identify important technologies that are not being developed internally in a timely fashion. Companies then seek to license-in missing technologies for their own businesses or acquire companies that have developed technologies and products of immediate interest for the company. Of course, patterns differ across industry sectors. Takuo Takeshita of Mitsubishi Materials Corp. – a firm that operates in several different product markets – reported that innovation aimed at strengthening existing business areas tends to entail greater collaboration with customers, whereas innovation aimed at developing new businesses entails greater collaboration with universities. In markets that are growing more slowly, such as for cement, cost reduction is a key driver of R&D strategies. Mitsubishi Materials participates in a large number of joint ventures to pool its R&D resources with other firms and share to costs of R&D.

Externalising internal technologies

16. Henry Chesbrough observed that firms are also seeking ways to benefit financially from R&D results that they have produced but that do not fit into their business plans or match their competencies. Rather than thwarting the processes of diffusion, Professor Chesbrough sees leading firms developing processes to leverage and profit from them, such as through spin-offs and licensing. Spin-offs and start-ups are seen as a means of conducting experiments with technologies that may reveal new technical possibilities and/or new market opportunities. They may become sources of new technology for the larger firm's current businesses.

17. As suggested by many speakers, intellectual property (IP) takes on a different aspect in this perspective. Companies traditionally relegated the management of their IP to the in-house legal counsel, or they contracted with an external legal advisor to decide whether and when to patent a technology, and when and how to enforce a patent. The involvement of R&D management has typically been to ensure that IP policy maintains open access and design freedom for internal R&D efforts. R&D managers do not want to be blocked by some other company's IP. They care little, though, about how much money the company

might make from enforcing its IP. In a more open innovation system, IP becomes a tool for accessing external technology that might be vital to advancing one's own business, and it becomes a marketing channel for capturing further value from IP that might not be fully utilised internally. Instead of constraining IP to be used solely within the firm, firms aggressively market technology to their competitors – and then charge them licensing fees to do so. This process forces competition between internal and external development activities – and forces R&D managers to justify the additional value added of internal activities.

Globalisation of R&D

18. Workshop presentations highlighted the fact that firms are increasingly globalising their R&D operations. Microsoft has research centres in China and Europe, in addition to its main centre in the United States. Intel, as a result of its corporate venture capital investments, now has R&D activities in 15 countries. Canon has research centres in Australia, China, France, Japan, the United States, and the United Kingdom. Even a smaller firm, such as AVL-List, operates in more than a dozen countries. While proximity to markets is a consideration in locating R&D facilities, speakers suggested that access to local scientific and technological expertise is increasingly important. Intel's investments, for example, have been based on acquiring technological capabilities. Canon's research centre in France was specifically located near a centre of expertise in digital imaging and network technology. Such investments underscore the importance of strong science and technology bases to attract foreign investment in local R&D.

19. Jacques Serris, from the French Ministry of Research, highlighted the benefits of this globalisation of R&D, noting that it can diminish economic autarky, increase economic interdependence among nations, and bring new technological capabilities to a region. Takuo Takeshita reported that Mitsubishi Materials found pockets of excellence in rural China that provided far better capabilities than were anticipated. As a result, Mitsubishi Materials has transferred more of its technology to the partners, boosting the partners' abilities going forward. Much of the technology developed in foreign-owned labs is exploited in local markets. As described by Kazuya Matsumoto, Canon's strategy allows its foreign research labs to pursue R&D in support of local market needs and to deploy research results first in local products. Canon found it best to specialise the technology research efforts of each regional centre according to the capabilities of human capital found within each region. In turn, much of the research output is most valuable within that same region, creating a tighter loop between the discovery of new technology and its initial application in that same market. Microsoft's research labs also have competencies that are linked to local needs; its China lab, for example, specialises in speech and character recognition.

20. Speakers emphasised the need for robust information infrastructures to support globalisation. Mitsubishi Materials, for example, found that its partnership in China required intensive information sharing between partners in order to make the decentralised R&D system effective. AVL-List makes extensive use of electronic collaboration tools to manage its far-flung R&D operations. These include tools for engineering data management, application sharing, project management, and tele-conferencing. The private and public sectors typically share responsibilities for ensuring basic infrastructure over which such applications run.

Implications for S&T Policy

21. Although the primary focus of the Workshop was on better delineating the changing patterns of business R&D, the implications of these changes on government policy were discussed, and participants introduced a number of ideas for governments to consider as they develop policies to better encourage and support business innovation. Overall they overall suggest that promising policy measures will be more

indirect, seeking to improve the conditions for knowledge generation, diffusion, and utilisation in the business sector. The emphasis will need to be on not only R&D policies, but also on policies related to intellectual property, human resources, and entrepreneurship.

Support to basic research is increasingly important

22. Workshop participants agreed that growing investments in industry-financed R&D do not weaken the need for government support to R&D, especially as industry becomes more knowledge-intensive and firms draw more frequently from the public knowledge base (*i.e.,* from research conducted in universities and government labs) in their innovation efforts. Indeed, changing business R&D strategies may actually heighten the need for government to finance basic research.

23. As became clear in the Workshop discussions, few firms can afford to finance fundamental (basic) research in the current competitive environment. Not only are firms R&D resources strained in an attempt to get quickly to market, but numerous competitors stand ready to capitalise on advances in science and technology. Andrew Dearing's survey results reveal that businesses have scaled back their investments in more fundamental, long-term research even as their overall R&D portfolios have expanded. They now think about their R&D investments in terms of the contribution to new business development. The Issues Paper prepared for the Workshop provided further evidence of this trend: OECD statistics that show that that between 1991 and 1998, the share of BERD allocated to basic research fell from 6.8% to 5.5% in Japan and from 6.8% to 5.1% in the Unites States. It stagnated in several of the larger European countries for which time-series data is available.[7]

24. Workshop presentations indicate that basic research remains an important element of the R&D portfolio of some large firms. Both Microsoft and Merck reported growing investments in basic research because such investigations are seen as supporting their overall business objectives. As Guy Haemers, of Bekaert SA, pointed out, academic research is like an ore that requires substantial refining before it becomes something of real value. Similarly, start-up firms, he claimed, tend to focus on individual technologies ("monotechnologies") that must often be integrated with other technologies into systems in order to deliver value. This suggests that the internal research efforts of large companies will continue to be necessary to refine academic discoveries and integrate the narrow technologies of start-ups into broad system-level products and services.

25. Nevertheless, if the diffusion of research results has become more widespread due to the factors outlined above, and if companies in many industries struggle to appropriate returns from their research investments, then there are serious implications for both firms and for S&T policy. For firms, there is the question of how they can best advance their technologies in their current businesses – and how they can establish themselves in new businesses – if they do not undertake significant basic research investments themselves. To what extent can they outsource the research function? For government, the challenge is one of maintaining and developing further the knowledge and experimentation necessary to fuel continued innovation.

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7 . These data use the definition of basic research outlined in the 1993 Frascati Manual, which defines basic research as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts without any particular application or use in view." The results of basic research are not generally sold but published in scientific journals. The research may be oriented toward some broad fields of general interest, forming the background to the solution of current or future problems.

26. The strength of the diffusion mechanisms and the resulting breakdown in the virtuous circle mean that industry can no longer be expected to underwrite the bulk of the costs of early stage research. Alcatel's R&D strategy, which is aimed at developing new products by recombining existing technologies rather than at generating fundamental new discoveries, illustrates this pattern. The seed corn that will create the innovations of twenty years hence will have to be provided elsewhere in the society, and will most likely have to be financed by government. As Paulo Annunziato from Confindustria stated, governments will need to finance such work in a way that promotes quality science, an objective few could disagree with, but that may require changes in the ways governments award R&D funding.

Other elements of successful S&T policy

27. Beyond support for basic (or fundamental) research, Workshop participants suggested other ways in which government S&T policy might be strengthened:

- *Feeding the fish, not the sharks*. Instead of directly targeting specific firms to serve as the engines of innovation, government policy may do better to develop and cultivate the soil in which innovative firms can grow. As noted by Mr. Serris, from the French Ministry of Research, government S&T policy cannot focus exclusively on large firms, which are increasingly mobile; rather it may be more effective to support numerous smaller firms that develop particular scientific competencies and become attractive targets for multinational investment. Multinationals bring with them additional technology as well as jobs. Some speakers identified centres of excellence and technology/business incubators as key steps in creating localised expertise that will attract multinational investment.

- *Encouraging diversity*. Related to the above, several speakers indicated that the interplay between science and technology encourages policies that stimulate experimentation by firms and that increase the amount of recombination of new and existing ideas. Policy must enrich the soil for companies to conduct experiments, take risks, and attempt new combinations of knowledge. This suggests that policy should actively seek to incorporate participation from start-ups and other SMEs in the conduct of research. Paolo Annunziato of Confindustria supported this approach by noting that SMEs provides greater competition for larger, more established firms and can increase incentives for large firms to innovate. According to Workshop participants, policy should also ensure that SMEs have access to the results of publicly funded research investigations. One speaker cautioned policy makers against concentrating resources in too small a number of large-scale projects at the expense of potentially more numerous, smaller scale efforts.

- *Acting counter-cyclically*. Several participants proposed that governments act counter-cyclically to compensate for economic downturns that stifle business investments in R&D. Élie Cohen pointed out that increases in venture capital financing for start-up companies, combined with increasing use of mergers and acquisitions and corporate venture capital among large firms, has made business R&D more sensitive to stock market fluctuations. As market values of firms decline, venture capital firms curtail new investments and large firms become unable to use their elevated stock price to acquire other firms. The downturn in the ICT sector, he noted, had turned the predators into the prey. Publicly financed R&D becomes relatively more important in such an environment, especially in helping R&D-conducting organisations in the public and private sectors maintain their R&D capabilities for future use. Evidence from the Spanish electronics industry suggests that during economic downturns, business R&D becomes more dependent on public funding and research positions in universities and public research organisations become more attractive.[8] As Jeanne Seyvet of the French Ministry of Industry rightly noted, governments need to ensure that they do not contribute to the creation of bubble economies by amplifying business and investment cycles.

Other policy areas

28. The Workshop discussions emphasised that changing business strategies for R&D will require consideration of policy responses in areas other than R&D policy. As stated by Takayuki Matsuo, Director for Science, Technology and Industry at the OECD, the R&D process is becoming more open, requiring a heightened degree of co-operation between government and industry. This implies a stronger role for governments as rule-maker, referee, and facilitator of innovation. Promising policy measures that were suggested by Workshop participants tend to be more indirect, seeking to improve the conditions for knowledge generation and diffusion, intellectual property protection, SME formation.

Intellectual property rights.

29. Jeanne Seyvet from the French Ministry of Industry remarked that formerly technical issues such as intellectual property protection have risen to primary importance in government policy making. IPR is becoming a more important mechanism than in the past for diffusing technology. As firms attempt to acquire technology developed by other R&D organisations and make businesses out of licensing their own IPR, issues of the scope and length of patent protection become more significant (even though the sums concerned are still small by comparison with more mainstream business activities). Policy makers must remain concerned with the trade-off between protecting rights to inventions and encouraging their diffusion, but recent shifts in the R&D strategies of private firms suggest that markets can play a more important role in promoting diffusion than perhaps in the past. As companies look to make greater use of IP outside of their own businesses, the supply of knowledge available in the market is likely to increase. Thus, governments should clarify the ownership of IP and provide the institutional and legal support for their purchase and exchange.

30. A further and more nettlesome issue that arose in the discussions is whether and how the government should assign IP rights to the results of research that it funds itself. In the United States, for example, the Bayh-Dole Act of 1980 allows universities that conduct research with government funds to retain the rights to patents resulting from that research. The implications of this and related legislation on innovation and economic performance in the United States are hotly debated – but are critically important. If in the future industry is going to rely increasingly on government-sponsored research for its seed corn, then issues related to IPR become critical policy levers that can enable or thwart the advance of a country's innovation system. Effective solutions will require careful crafting of policy to ensure that scientific and technical advances can be brought to the market place without unduly limiting the diffusion of knowledge or undermining nature of public research. Kazuya Matsumoto indicated that particular aspects of IP rules in France preclude Canon from entering into certain types of R&D partnerships with French public research organisations, illustrating the kinds of issues that must be addressed.

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8 . This statement is based on the results of a survey of Spanish electronics firms conducted by Paloma Sanchez of the Autonomous University of Madrid and Jesús Banegas of the Asociación Nacional de Industrias Electrónicas y de Telecomunicaciones (ANIEL) that was made available at the Workshop.

Developing human resources.

31. Workshop speakers and participants all highlighted the importance of human resources – skilled scientists and engineers in particular – in advancing business R&D. Developing and maintaining a skilled labour force requires governments to ensure high quality education at the primary, secondary, and university levels. As populations age, and as the useful lifetime of training shortens, policy will also need to address education and life long learning after graduation as well. Related to the issue of creating a skilled workforce is the issue of facilitating the mobility of S&T workers. Pensions, benefits, health care, and other aspects of compensation today are typically tied to employment, which effectively constrains mobility. Making these elements portable, or severing their tie to a specific employer, might enhance mobility and enable workers to seek out the best opportunities to utilise their skills.

Promoting entrepreneurship.

32. New firms appear to be an effective means of developing new technologies and introducing them to the market place. While policies to encourage commercialisation of public research results are one way to promote start-up firms, Workshop participants discussed a broader range of policy initiatives that could help stimulate entrepreneurship. Several speakers highlighted the importance of effective capital markets for financing start-ups and supporting the growth of SMEs. This is a deep and wide-ranging topic in itself; it includes issues of bankruptcy law and the extent of personal liability, the ability to issue stock to investors and employees, treatment of stock options (*e.g.*, when these are taxable events), the treatment of capital gains on equity investments, regulatory requirements for listing stocks on public exchanges, and the depth and rigor of financial reporting requirements. Tim Keating cited international differences in the treatment of stock options as a complicating issue in Intel's foreign investments. Although the firm would like to offer similar benefits to employees based in different regions, it has found that differences in tax law force changes in the nature of the programmes and their attractiveness to employees. Guy Haemers suggested the need for ways to account for intangible assets (*e.g.* investments in intellectual property, R&D, worker training) on corporate balance sheets, much as goodwill is included today. Doing so, he suggested, would allow companies to better account for their intellectual assets and attract investor interest.

Mobilising support

33. Another unanswered issue is how to build and sustain political support for government S&T and innovation programmes, especially as they shift from supporting individual firms to creating an environment that is more conducive to innovation. A key virtue of direct incentives is that the beneficiaries of this policy know who they are and can mobilise support for incentives-based policies. The policies noted above are far more indirect, and the ultimate beneficiaries of those policies will be harder to identify specifically. Mobilising support for indirect policies could prove to be difficult. As noted by John Barber of the United Kingdom's Department of Trade and Industry, governments will also need to develop new metrics for assessing policy outcomes in this environment. Without a clear understanding of industry practices, governments are likely to measure the wrong outcomes, causing their evaluation of policy initiatives to be surprising and disappointing. This in turn would make it harder to improve and to gain support for future policy.

Looking ahead

34. As a one-day event, the Workshop could not fully explore the changing strategies for business R&D in all countries and all industries. Nor could it reach definitive conclusions regarding ways in which S&T policy can best support emerging models of business R&D. Rather, the value of the Workshop was in

validating initial hypotheses outlined in the Issues paper about business R&D practices and identifying future areas of inquiry related to policy. Additional work will be needed to further investigate these themes. An ongoing OECD project on Emerging Patterns of Public and Private Investment in R&D will attempt to deepen the understanding of business R&D, looking more closely at variations across countries and industry sectors and examining R&D patterns in representative firms. Other work will be needed to better evaluate the efficacy of different instruments of government support for business R&D. Research is also needed on the changing role of IPRs in stimulating innovation and business R&D investments, as well as on issues of licensing the results of publicly funded research. The results of such analysis will enable policy makers to better address the range of issues raised in the Workshop and develop more effective S&T policy.

ANNEX 1: SUMMARY OF WORKSHOP PRESENTATIONS

1. The majority of the Workshop presentations were submitted to the OECD and made available to Workshop participants in viewgraph form only. In order to provide a more complete record of the remarks made by each speaker, the following set of summaries was prepared by the Workshop Rapporteur. The summaries are not transcripts of the presentations, but brief recapitulations of the remarks made by each speaker, highlighting the key themes of the talk. They are organised below according to the Workshop agenda. Much of the material contained in the summaries was abstracted into earlier portions of this document to support particular summary points.

Opening Remarks

John Barber, Workshop Chair

2. The Workshop Chair, John Barber, opened the conference, noting its importance and timeliness. He stated that governments needed to understand what companies are actually doing in their R&D activities. In the absence of such understanding, government policies are likely to be mis-specified, and are likely to be ineffective as a result – or worse. Equally, without a clear understanding of industry practices, governments are likely to measure the wrong outcomes, causing their evaluation of policy initiatives to be surprising and disappointing. This in turn would make it harder to improve future policy.

Jacques Serris, French Ministry of Research

3. Mr. Serris from the French Ministry of Research reminded attendees of their location in Paris' 5th arrondissement, among the streets of Descartes, Laplace, LaGrange, and other seminal thinkers. “We are the heirs of past development, even as we must look into the future of our development.” He shared the experience of the Ministry in expanding the scope of its policies beyond the traditional participation of industry, government and academia. Today, the Ministry actively solicits input from venture capitalists, incubators, and SMEs in its planning processes. Government’s role shifts from one of promoting autarky in technological development to one of facilitating increased technological exchange. Instead of fearing international economic competition, the Ministry sees this intensified exchange culminating in increased economic interdependence.

Takayuki Matsuo, OECD

4. Takayuki Matsuo, Director for Science, Technology and Industry, connected the issue of S&T policy to the role of knowledge creation in generating growth. “Business R&D has become more open,” he said, “with other firms, with government, and with universities.” He noted greater diversity in the kinds of organisations performing R&D and financing innovation activity. These new actors influence the creation of knowledge and the focused application of that knowledge. Innovation needs to be approached as a

complex process, not a linear one, he noted, and he offered hope that the Workshop itself could serve as a model for future co-operation between industry and government policy makers.

Session 1 - An Overview of Key Trends in R&D

5. This session provided a brief introduction to the issues to be explored in the Workshop. In addition to establishing a common framework for subsequent discussions, speakers reviewed key trends in business strategies for managing and investing in R&D and highlighted particular issues of interest to the S&T policy community.

Andrew Dearing, EIRMA

6. Andrew Dearing, Secretary-General of the European Industrial Research Management Association (EIRMA), reviewed a number of important trends in EIRMA member firms and in their counterparts in the United States and Japan. The most salient trend Mr. Dearing reported was that business R&D investments were no longer made in a support role that is only indirectly linked to business objectives. Instead, business R&D was now driven directly by business strategy. This shift was most clearly seen in the "Sea Change" index of EIRMA and its counterparts in the United States and Japan. Business firms that were surveyed reported a marked decline in basic research and a concomitant increase in R&D directed to new businesses. Other statistics in the index similarly reflected a greater external orientation by EIRMA member firms away from their earlier, more internal orientation. Mr. Dearing found that firms had also changed the character of their relations with universities. "The value of university research today is seen much more in terms of excellence than inexpensive labour," he said. EIRMA's member firms now approach R&D in a network, not within a central research laboratory. Universities are clearly an important part of that network. This had implications for intellectual property (IP) policy as well, since these policies conditioned the ability of parties to co-ordinate within the network.

7. Mr. Dearing sounded a cautionary note regarding the social pressures that were likely to impinge on firms' R&D strategies. He identified four particular pressures: *i)* anti-globalisation sentiment, *ii)* denial of IP protection in crises such as AIDS, *iii)* open source alternatives such as Linux, and *iv)* pollution. These external forces are likely to interact with businesses' R&D networks, in ways that are hard to foresee at present but cannot be ignored in thinking about the future.

Élie Cohen, University of Paris-Dauphine

8. Professor Élie Cohen of the University of Paris-Dauphine, outlined further trends underlying businesses' R&D strategies. His perspective was informed by his own experience organising an incubator. Professor Cohen pointed out the need to separate cyclical trends tied to the business cycle from deeper secular trends. VCs were clearly bringing new capital into the innovation process, although the level of this new capital will fluctuate with the business cycle. Relations between companies and universities were taking on a new character, leading to new goods, new ideas, and new practices.

9. Professor Cohen pointed out that these new trends came at some cost. The very recent past, for example, had created a market value crisis for many technology companies. As market values plummet, access to capital is diminished by public companies, and private VCs curtail their funding of new business plans. This effectively diverts capital from the innovation system to other parts of the economy, and raises the issue of how the innovation system is going to finance itself going forward. Firms that formerly leveraged their high prices to acquire other firms are now themselves in serious trouble. "These acquirers are no longer predators; now they are the prey," he observed.

10. In the telecommunications sector, governments have had a direct role in diminishing access to capital. The GSM license award auctions resulted in payments so high that telecommunications companies who won these awards found their financing became a direct cause of losses – putting further innovation at risk in that sector. It is for this reason, Professor Cohen pointed out, that the French government recently elected to cancel the most recent round of auctions, to enable telecommunications firms to continue to invest in innovation. Finally, Professor Cohen also took note of the social forces that could undermine business R&D strategies, if left unaddressed.

11. Despite these cautions, Professor Cohen felt that this New Deal in business R&D was not a long-term threat to the innovation system. Companies clearly needed to think beyond the short term in forming their R&D strategies, and new business plans could not proceed on the basis of bubble valuations. Companies also will need access to knowledge from public sources, as well as private sources. The larger public must be engaged in the innovation process, to preserve the social legitimacy of the new innovation system, and avoid its derailment by excluded social forces.

Session 2 - Toward a New Model of Business R&D

12. This session focused on the reorganisation of R&D within firms. Speakers presented different approaches being taken to enhance the contribution of internal R&D activities to firms' business strategies. Topics be discussed included: drivers of recent increases in business funding of R&D and likely trends for the future; changes in the balance between near-term needs of product divisions and longer-term technology development programmes; and shifts in the scope of R&D activities and the fields of science and technology that receive attention within the business sector.

Christian Grégoire, Alcatel

13. Mr. Christian Grégoire, Vice President and Director of Research and Innovation at Alcatel outlined significant shifts in the roles that various participants play in the innovation process. He noted that start-ups and SMEs are a growing source of innovation, while government and military sources are declining. The traditional linear model of research to development to market is also giving way to a more cyclical and iterative model of R&D that cycles between the developer and the customer, and utilises research and development activities inside and outside the firm. Importantly, Alcatel finds that its processes need to incorporate its new innovations into complex systems, which has forced it to think about research more as a process of recombining existing technologies and less as a process of generating new fundamental discoveries.

14. External collaborations are also an increasingly important element of innovation at Alcatel. The Internet 2 project illustrated the extensive external collaboration underway to launch a higher speed, higher capacity Internet that would contain open standards that many types of suppliers could utilise. Some of these suppliers were likely to be *de novo* start-up firms in this architecture. These collaborations require the development of standards to co-ordinate the actions of independent parties, and this process has itself changed from a reactive one that codified the state of affairs on the ground to a pro-active one that enabled and directed new innovative activities.

15. While the role of government needs to change, in light of these many shifts in business R&D strategy, Mr. Grégoire articulated three areas where government initiative was warranted:

- Initiating change to bring numerous Government functions into an Internet-based environment, such as by providing Web-enabled access to Government information.

- Regulatory reforms to maintain or restore incentives for further telecommunications investments. Unbundling the local loop and parity between regulation of cable modem and DSL were mentioned.

- Benchmark policies and track their outcomes for items such as end user prices and service levels.

Brian White-Guay, Merck & Company

16. Mr. Brian White-Guay, from Merck Research Laboratories, spoke of the research environment facing pharmaceutical manufacturers such as Merck. The average cost of inventing new chemical entities (NCEs) rose to USD 600 million in 2000, with the average time to earn regulatory approval remaining at about 10 years during the past decade. Other economic forces include *i)* the increased use of managed care and other cost-related government regulation, and *ii)* the expiration of patent protection for drugs with current revenues of USD 31 billion before 2005. These factors seriously constrain R&D in the pharmaceutical sector.

17. In this environment, Merck and other large pharmaceutical companies must seek out new blockbuster drugs that can earn sufficient profits to justify the lengthy and risky investments needed to create and market new compounds. While Merck in the past has emphasised internal drug discovery and development, it recently established initiatives to expand its external linkages. These include mergers and acquisitions, strategic alliances, corporate venture capital investments, and partnerships with public entities. As a result, Merck is charging its researchers with the task not only of generating new internal research, but also of accessing external research discoveries to become “a virtual lab” that combines both internal and external research. The latter branch has become particularly important in the biotechnology side of pharmaceutical drug development, with over half of NCEs in active development in the industry in 2001 estimated to come from external sources (Source: CMR International, UK), and more than a third of Merck’s drug sales coming from external sources.

18. The pharmaceutical industry is also active in other dimensions of external technology acquisition. It remains actively engaged in mergers and acquisitions, with more than USD 27 billion of deals closed in the first half of 2001. Corporate venture capital (CVC) remains active in the industry as well, with 121 investments made in the pharmaceuticals industry in the first half of 2001, with a value of USD 1.5 billion. This runs against the tide of many companies abandoning CVC in many other sectors of the economy. Finally, Merck has entered into public-private partnerships with governments and non-governmental organisations to promote greater health, including partnerships in tuberculosis, malaria, and AIDS/HIV.

Takuo Takeshita, Mitsubishi Materials

19. Mr. Takuo Takeshita of Mitsubishi Materials Corp. (MMC) indicated that MMC’s situation was typical of most companies in the material sector. He stated that the materials sector had to adopt innovation practices that took account of the rapid diffusion of information technology in that sector. This diffusion rate has accelerated as a result of the spread of information and communications technology (ICT) around the globe. ICT facilitates collaboration with foreign partners and overseas laboratory and development facilities. Evidence of the rapidity and thoroughness of this diffusion was offered through Mr. Takeshita’s

visit to a factory in rural China, which had already received ISO 4001 certification for environmental sensitivity in its processes. In MMC's case, this global impact of ICT creates expanded markets for MMC's products, even as it transforms the processes MMC itself uses to create these products.

20. MMC regards materials as the basis for the ICT sector, which supports the mass production sector, the consumer sector, and social systems products. However, MMC has made significant changes in its R&D systems, as have most players in this sector. On the one hand, MMC has had to focus on specific core businesses to a far greater extent than in the past. This has led to greater separation between family companies, and greater autonomy and responsibility for each company. MMC itself has created eight companies within its structure, and given each company greater authority and autonomy for its operations. On the other hand, MMC is witnessing great promise for further advances in semiconductor wafer technology, as well as nanotechnology, an area that is receiving attention from government initiatives in the United States, Europe, and Japan.

21. Mr. Takeshita also returned to the theme of social forces that was raised in the first panel session, in particular the theme of the environment. In MMC, the social imperative is being pursued as a business initiative. MMC has developed an extensive recycling business for home appliances for example, which leverages its competence in smelting.

Session 3 – Networks of Knowledge Creation and Acquisition

22. This session highlighted trends in the external acquisition of scientific and technological knowledge. It considered the roles of university-based research and new technology-based firms in the R&D strategies of large firms. It identified different mechanisms that firms are using to acquire complementary R&D capabilities, such as contracting, outsourcing, licensing, corporate venture capital investments, mergers and acquisitions, and strategic alliances. It examined how these activities complement the internal R&D activities of large firms and their implications for the division of labour in business R&D.

Pierre-Yves Saintoyant, Microsoft Research

23. Pierre-Yves Saintoyant, Director of University Relations for Microsoft Research (MSR) noted that Microsoft is a company that operated throughout its early years without an internal laboratory for basic research. As of 1990, the company had reached the USD 1 billion mark in sales, without any internal research. In 1991, however, the company founded an internal research division, which has grown to over 600 people, active in over 40 research areas of interest to Microsoft. The company currently maintains five lab facilities, located in Redmond, WA; Cambridge, UK; San Francisco, CA; Beijing, People's Republic of China; and Mountain View, CA.

24. As one of the younger companies represented at the Workshop, Microsoft reflects a relatively new approach to R&D, unencumbered by earlier commitments and initiatives. Surprisingly, much of the focus of MSR remains very traditional, in that it takes a long-term view, "to ensure that Microsoft products have a future." Near-term products are not a primary focus, although is job includes "watching out in case we do something that is useful in the short-term." The research organisation is not under any orders to do specific projects from Microsoft's product groups. This is not to say that Microsoft Research has not affected Microsoft products. Mr. Saintoyant claimed that virtually all Microsoft products shipping today use technology from Microsoft Research.

25. Also traditional is Microsoft's evaluation of its research staff. Mr. Saintoyant produced statistics on the high percentage of publications that Microsoft researchers had contributed to in leading areas of computing. Microsoft has also played a leading role in the computing scientific community in technical committees and associations. This active external involvement of research scientists does not result from insufficient oversight on the part of Microsoft management. Mr. Saintoyant explained that, "no matter how many people there are working within Microsoft Research, there will always be more people outside – so you have to be open in how you work. Research cannot be carried out in isolation." In keeping with this philosophy, Microsoft Research devotes 20% of its budget to fund research conducted in universities, through lab grants, research grants, fellowships, etc. This will amount to USD 75 million in 2001. This open approach will figure prominently in Microsoft's pursuit of its .Net initiative, as it is funding the creation of tools and programming languages that connect .Net to traditional academic repositories, such as the Unix programming environment.

Tim Keating, Intel Capital

26. Mr. Tim Keating, Director of Intel Capital, presented a complementary perspective to that of Mr. Saintoyant, the perspective of corporate venture capital (CVC) as an element of a company's R&D strategy. Mr. Keating reminded the audience of the terrible returns currently being realised in the private equity markets, and of the resulting retreat that most corporations have made from CVC. Intel itself has had to reduce its CVC staff, and has reduced the number of investments it has made in 2001 by 40 to 50% relative to the prior year. Mr. Keating noted that Intel's portfolio value has declined 60% from last year, and that Intel now has 500 companies with a book value of USD 2 billion in its portfolio.

27. However, Intel remains committed to using CVC as a tool to help grow Intel's own business as "the building block supplier to the Internet economy." Intel Capital continues to employ 300 people in 15 countries, and perhaps 40 to 50% of its investments will be made outside the United States in 2001. Intel's CVC efforts serve as "eyes and ears" to help Intel identify potentially important new trends in its markets and technologies. Through its investments, Intel can get out in front of emerging industry trends.

28. However, to do this successfully, Intel has found it important to leverage its technical strengths, not simply invest its money. Other companies in the industry that embarked on CVC for primarily financial gains, such as SAP Ventures, have since abandoned the efforts. Intel continues to work closely with the venture community in identifying promising investment opportunities and has found that so-called angel investors are key players in the early stages of financing new companies.

Paolo Annunziato, Confindustria

29. Mr. Paolo Annunziato, Director for Innovation, Research and Net Economy for Confindustria in Italy, gave the final presentation in this session. He presented a cautionary view of the Italian innovation system, which appears to be mired in a vicious cycle of low business R&D investment, which is generating weak market positions for Italian firms in the leading sectors of innovation, such as ICT and the life sciences. This inhibits further R&D investment to improve the position of these Italian firms. Mr. Annunziato's data show that this pattern has persisted for over a decade, and in the absence of some effective policy interventions, will likely persist into the foreseeable future as well.

30. Mr. Annunziato adduced many probable causes for this state of affairs. Italy provides only a low level of public funding for research and lacks a long-term policy towards S&T. What programmes exist suffer from a lack of selectivity, often funding low quality research in public and university laboratories.

Italy also suffers from a highly rigid labour market, a relatively small domestic market, and low levels of product market rivalry within its domestic market.

31. Mr. Annunziato identified two areas where new policy initiatives might profitably boost the country's innovative capabilities. The first was an increased focus on SMEs, to promote greater rivalry with larger Italian firms and to strengthen SMEs' interactions with the university sector. The second was to elevate the role of science and the need for excellence within the Italian university sector. "What is key is excellence in university science. Mediocre science is definitely not useful for Italy," he concluded.

Afternoon Keynote Address – Mrs. Jeanne Seyvet, French Ministry of Industry

32. Mrs. Seyvet is the Director-General of Industry, Information Technology, and Post (DiGITIP). She echoed the need first articulated by Workshop chair John Barber that government must adapt to changing R&D structures. She saw the changes in business R&D strategies as linked to the global restructuring of business. This restructuring has offsetting impacts. On the one hand, it deepens diversification and interdependence, through deeper specialisation. On the other hand, it intensifies national competition, and risks rewarding policies of the lowest common denominator.

33. These tensions are being played out, she observed, in policy areas that were considered only technical issues ten years ago. The international mobility of researchers is one area where policy is now an important political question. The treatment of intellectual property is another. The state's role in promoting and protecting IP is now a driver of long-term growth.

34. There remains an important role for government policy, she concluded. In some cases, the state might act counter-cyclically to offset downturns in the economy that might otherwise damage long-term R&D investment. Specific measures were likely needed to address particular sectors. She felt that governments may have encouraged venture capital too much in the recent bubble and wondered if the pattern was not repeating now in the biotechnology area. "Can we avoid amplifying the cycles again?" she asked. On the other hand, in the recent UMTS auctions, the government has decided to modify the payment criteria within France, to offset the downturn in that sector. Finally, with the bankruptcy of Moulinex, she argued that, while the company had to be allowed to fail, the government had to mitigate the consequences of that failure in that region within France.

Session 4 – Globalisation of Business R&D

35. This session examined trends towards increased globalisation of business R&D. Discussions focused on the motivations for firms to establish R&D facilities in foreign countries, the barriers they face in doing so, and the effects of such globalisation upon international transfers of technology. The discussion was also to consider the relationship between globalisation of R&D and international financing of innovation (*e.g.* venture capital funding).

Kazuya Matsumoto, Canon Research France

36. Mr. Kazuya Matsumoto, President and Managing Director of Canon Research, France, described Canon's strategy for globalising R&D. Canon began its research operations in Rennes, France in 1990. Today it has 70 scientists at the centre, which is focused on digital imaging and networks. Interestingly, only three of the 70 staff members are from Canon's world headquarters in Tokyo.

37. Until 1999, Canon’s strategy for its French centre was to use its people to advance technology that would be taken up by world-wide product groups in Canon's Tokyo headquarters. Engineers in Tokyo would then create products that embodied the innovative technology. This model of “indirect contribution” to Canon’s strategy suffered from many defects. First, it took Canon a long time to identify, transfer, and incorporate technologies from the French centre into its products. Second, there were instances of hoarding, in which the ineffective use of technology from the French centre resulted in a build-up of unused technologies – even when those technologies were potentially important. Third, the research effort suffered from a lack of business direction over where to focus its future research investigations, since they were quite far from the business units. Finally, individual researchers felt frustrated by the lack of impact they were having on Canon’s businesses.

38. In response to these problems, Canon shifted its R&D strategy for the French centre in 2000. The centre continues to co-ordinate with Tokyo on long term R&D investments, but now has an additional ability to work with Canon’s European operations to fund shorter-term technology developments targeted specifically for the European market. This has shortened the time to get technology from the centre to market, it has improved the direction given to the centre for focusing future research initiatives, and it has given Canon France researchers the satisfaction of seeing their work instantiated in new products.

39. Canon’s experience in France is a microcosm of its strategy around the world. Canon now maintains research centres in Australia, China, France, Japan, the United States, and the United Kingdom. These centres exploit the scientific excellence of researchers in each country and give Canon the ability to create interaction between its scientific centres and its business operations in those countries. This interaction can come in a variety of forms, from standards to research consortia, national projects, alliances, and more informal sharing of market and technical information. This complements and extends the research being conducted at Canon’s Japan headquarters. It does occasionally raise interesting policy issues, such as the recent French government initiative on IP rights in collaborative research programmes, which appears to jeopardise Canon’s international IP rights and may become a barrier for Canon’s ability to participate in collaborative research with French institutes and universities.

Klaus Mayer, AVL List

40. Mr. Klaus Mayer, Vice President of Market Development, AVL Austria, presented AVL’s innovation strategy in the automotive sector. AVL seeks to integrate the discoveries of academic research in basic scientific domains with industrial research that converts science into technology and eventually into products. University research on its own is too basic to be of direct use to AVL. Industry must develop co-operation mechanisms such as “oriented basic research” to enable industry to build on the discoveries of universities and apply them to industrial problems. This co-operation sits at the base of an elaborate network of innovation excellence in the automotive industry, which spans multiple suppliers and includes the vehicle manufacturers and ultimately the end customer.

41. This network is being forced to contend with a number of pressures on the automotive industry. The time to market for new vehicles has shortened dramatically. Quality requirements have increased. Costs are under great pressure, and manufacturing is globalising. This has caused the network to split its traditional value chains, to focus internal activities on areas of real competence, and utilise outsourcing more aggressively to provide the other requisite parts of the chain. A more open perspective is needed, to manage this network of fragmented value chains.

42. In addition to a more open perspective, however, AVL has found it vital to systematise many elements of its development processes so that the firm can work effectively with outside partners, often located remotely from AVL. ICT is used extensively to document these processes and to depict the high

degree of interaction involved in engine development: between the management of the project, the standards used to implement the project, and the quality, regulatory, and environmental requirements that engines must meet.

43. Mr. Mayer felt that the ICT department was a critical player in AVL's ability to work effectively in its product development network. It has been able to impose its ICT tools upon its own suppliers, but it cannot impose these upon its customers, who have their own elaborated IT systems requirements. Instead, AVL seeks to map its ICT onto the requirements of its customers and has found that the Web has been useful in facilitating this "e-collaboration" process. However, these systems do not design out the people in the process; rather they enable staff to work more productively and more creatively, by having the latest and most reliable data in hand, as they create new products.

Session 5 – Strengthening Science and Technology Policy

44. Session 5 explored ways in which government policy can adapt to changing business R&D strategies to more effectively support innovation. It provided an opportunity for business executives and government officials to present their views on the kinds of S&T policies that are needed to stimulate industrial innovation and to remove barriers that prevent successful collaboration between the public and private sectors. It also provided a forum for discussing other innovation-oriented policies, such as programmes to support R&D in small business and licensing of public research.

Guy Haemers, Bekaert

45. Mr. Guy Haemers, Corporate Vice President of Bekaert SA in Belgium, opened the session by observing that it was strange for an entrepreneur and industrialist to talk about policy issues. He then proceeded to belie this statement by presenting an insightful perspective on S&T policy. He noted that the role of entrepreneurs and SMEs had indeed increased, but that this should be kept in perspective. Start-ups do "mono-products and technologies" that typically get absorbed later on into larger companies. These players do have an important impact, but it arises from focusing companies on activities where they can provide comparative advantages above and beyond those offered by the start-up firms.

46. Mr. Haemers felt that patents and licenses, while important, were often overstated in their role in science and technology. "Only 7% of patents are actually used effectively," he stated. "There is much more knowledge that exists in our society, than is used today." Other areas of policy are of at least equal importance, but have received much less attention. He called attention to policies towards the treatment of intangibles on the balance sheet, such as is done with "goodwill,", and argued that getting this right was more important than providing new direct incentives for further R&D investment.

47. Mr. Haemers felt that university research, while important, was akin to an ore: it needs refinement before it becomes useful. He viewed government and society as determining the direction of technology development (and it is here that societal needs become incorporated into the innovation process), while science and industry determine the rate of speed of that development. He supported a cyclical model of new science leading to new business leading to further new science, but suggested that an intermediate step be interposed in the cycle: new combinations of existing knowledge that (along with new knowledge) lead to new business. Universities, in turn, were at risk of deepening their specialisation too much, and most important new knowledge would likely arise from multi-disciplinary research at the boundaries between academic disciplines. He warned business managers to be clear on the objectives of their university partners: "Does the university understand my strategy, or are they looking for money to keep some Ph.D.s busy?"

48. Likewise, he suggested, government policy would have to be multi-disciplinary, in the sense of co-ordinating and integrating activities from industry, academia, and government. Given the number and diversity of players in this complex system, government policy must be formed with three principles in mind: *i)* streamline policies wherever possible, *ii)* maintain consistency across policies over time, and *iii)* flexibility. He offered a case study of the Finnish agency, Tekes, as an example of appropriate and effective government policy in a complex, globalised context.[9] This case study was well received by the audience, some of whom made additional reference to it later on.

Jacques Serris, French Ministry of Research

49. Mr. Jacques Serris, Deputy Director of Technology for the French Ministry of Research, challenged the audience to consider how business R&D can grow without increased government spending. He felt that French policy had shifted from focusing solely on large companies at the top of the food chain (sharks) towards addressing many other companies lower down in the food chain (fish), such as start-ups and SMEs. Mr. Serris pointed out that the sharks were becoming global entities that would swim to wherever the fishing was best. Government policy, therefore, needs to spawn conditions where the fish could abound, thus retaining the sharks. Government can also support the food chain as a large user in its own right, in its military, health, transportation, environment and other ministries.

50. An area of new potential for governments is in their management and control of databases of electronic information. Just as one could judge the degree of economic development of a society in the 1950s through its use of oil, so one could judge the degree of development through the use of databases today. As more people make use of this information, the need for managing it will grow. Questions of access to the data will contend with protections for personal privacy. Government can play a vital role in creating the ground rules for how these databases will be used in future.

Concluding Session

Henry Chesbrough, Workshop Rapporteur

51. Henry Chesbrough, a professor at Harvard Business School, offered summary remarks that framed the previous presentations in a paradigm for managing firms' R&D that he referred to as "Open Innovation."[10] Professor Chesbrough began by positing an earlier paradigm that informed the design of many leading research organisations, such as Bell Labs, DuPont, Xerox PARC, IBM's Watson laboratory, or GE's laboratory. This paradigm was fundamentally closed in that internal research investigations were launched within the lab, evaluated and screened internally, and then selectively transferred into development, culminating in new products and services to be sold through internal channels of distribution. Projects only enter at the beginning, and only exit at the end of the process.

52. Professor Chesbrough noted that this paradigm arguably worked very well for most of the 20th century. It led to the realisation of numerous breakthrough technologies, and it fostered a virtuous circle for R&D: fundamental breakthroughs in the lab enabled new products and features to be brought to market,

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9 . Tekes provides funding and expert services for R&D projects and promotes national and international networking.

10. Readers interested in a more extended treatment of these ideas should note that a forthcoming book, *Open Innovation*, from Harvard Business School Publishing in 2002, will elaborate on the ideas presented here.

leading to increased sales and profits in the company’s business. These profits allowed companies to reinvest in new R&D, generating new breakthroughs, which re-started the cycle. Companies felt that the more they spent on internal R&D, the greater their future payoffs would be. Professor Chesbrough noted that this belief continues in some sectors of the economy even today, as evidenced by the life sciences sector.

53. In Professor Chesbrough's view, the demise of this paradigm has arisen as a result of important changes in the external environment, including the increasing mobility of skilled workers, growing university research, more diffuse distribution of knowledge, erosion of firms' dominant positions, and increased venture capital. These changes compromise the ability of companies with significant internal R&D investments to appropriate the returns on those investments. When companies invest in long term R&D, many of those discoveries are at risk of diffusing out of the company that funded the research, with no compensation to the company. Thus, the virtuous circle is broken, in that the originating firm cannot reinvest in R&D to create the next round of breakthroughs, and the successful spin-off firm does not make up the difference. Professor Chesbrough illustrated this broken cycle with the example of Xerox Corp, which spun-off 30 companies between 1979 and 1998. These firms have a market capitalisation greater than Xerox's, but Xerox appropriated little of the financial or technical benefit. Similarly, research by IBM and AT&T into semiconductors developed considerable knowledge that was harnessed by other firms, including Motorola, Toshiba, Texas Instruments, and Mitsubishi.

54. In the emerging paradigm of open innovation, Professor Chesbrough posited, firms must recognise that most research occurs outside their firm, and they should target internal research to filling in gaps or integrating external results. Firms should actively acquire externally generated technology through licenses, mergers and acquisitions, spin-ins, and collaborative R&D. Firms will also need to consider multiple paths to market for internal research, whether through internal development of new or improved products and services, spin-offs, or licensing results to other firms. IBM has become extremely active in licensing technology for use by other companies, generating significant revenue streams. It has also begun selling component technologies to its competitors in the PC business, earning a handsome profit in the process. Intel Capital has taken a different approach. With limited internal research capability, Intel has developed small "lablets" to encourage research partnerships with universities. It also actively invests in start-up firms that offer products that may boost demand for Intel products. Both of these cases are examined in greater detail in Annex B.

55. Professor Chesbrough postulated that such changes have implications for many areas of government policy. He suggested that R&D policies would have to cultivate the soil in which innovative ideas can grow by financing the seed corn that lead to new breakthroughs. Efforts will need to be made to ensure such funding supports quality science, and that it actively incorporates participation from start-ups and SMEs. Policies to strengthen the supply of skilled labour, to develop effective capital markets, and to develop IP regimes that balance the need to stimulate innovation and diffusion. Additional efforts will be needed to develop sound policies for licensing IPR from government funded research. A particular challenge will be ensuring and sustaining political support for innovation programmes that may be indirect and diffuse. Who will champion them if their effects cannot be easily and directly measured?

ANNEX 2

COMPANY CASE STUDIES

56. Two companies mentioned in the presentation by Workshop Rapporteur Henry Chesbrough illustrate the diverse range of ways firms are opening their R&D systems. These changes, detailed below, enable the firms to make better use of technology developed internally – even if it cannot be used in their own products – and to take advantage of technology developed by other organisations that is directly relevant to their corporate strategies.

IBM

57. IBM has historically been a deeply vertically integrated company. Its approach to R&D in its mainframe computer business was a paradigmatic example of a closed innovation mindset. Today, however, IBM has evolved a rather different R&D strategy. It continues to invest in internal basic research activities, with an estimated 3000 researchers in labs around the world. However, IBM now makes aggressive use of external technology developments in its business strategy. This is most clearly seen in its approach to Internet software languages, such as Java and Linux. Both originated outside of IBM's own labs, yet IBM is perhaps the company most actively propelling these technologies forward.

58. IBM has also opened up other channels to market for technologies originating in its own labs. IBM's Technology Division is charged with developing advanced technology components. In the semiconductor area for example, IBM's copper interconnect technology has been widely licensed to most of IBM's competitors in the semiconductor industry. This is not altruism on IBM's part: firm managers calculated that they would make more money sooner by enabling their semiconductor competitors to use the technology, than they would be restricting their use, and hoping to gain share in the semiconductor space by restricting the technology to its own products. In aggregate, IBM reported receiving $1.7 billion in royalties from its IP in 2000. That figure compares with an investment of approximately $600 million in its basic research that year.

59. In the disk drive industry, IBM sells disk drives to rival storage competitors such as EMC. IBM's Technology Division even sells disk drive heads and media to rival disk drive manufacturers. As a result, IBM's share of disk drive components is greater than its share of disk drives, and IBM's share of disk drives exceeds that of its systems. IBM's position allows it to be the first to develop new head and disk technologies, to be the first to build new production capacity to build these new technologies, and to be the most profitable player in the disk drive market, with much of the profits realised in the capital intensive, upstream components business.

60. At the other end of the value chain, IBM's Global Services division assists IBM clients in making their ICT infrastructure work to the client's requirements. This means that IBM will figure out how to get *anyone's* products to work together, regardless of what vendor makes the product. So IBM Global Services makes IBM mainframes tie to Sun servers, to Dell Web servers, to Unix or Windows or even McIntosh operating systems, Oracle or SAP databases, etc. This has caused IBM to realise that, as capable as IBM is, no single company can meet all of a large client's ICT needs. IBM need not do everything to be able to add value. Instead, it does a great deal in certain parts of the value chain internally, but actively partners with external parties in other parts of the chain. In the recent past, IBM's Technology Division, and IBM Global Services, have been the two fastest growing parts of the entire company.

INTEL

61. Intel's R&D strategy differs markedly from that of IBM and points out a different approach for firms operating in a regime of rapid technology diffusion. Intel eschews large internal research programs. Intel's researchers have neither been significant contributors to scientific journals, nor have they been awarded many patents (especially considering Intel's size in semiconductors). The experience of Intel's founders (Gordon Moore, Robert Noyce, and Andrew Grove) showed them the difficulty of transferring research into production and the likelihood of research results diffusing out of the firm. They concluded that they had to advance their technologies in a different way. For many years, they insisted on developing new technologies on the same equipment in the same production environment as was being used for making the current products. This was a highly incremental approach and essentially forfeited the opportunity to create a fundamental breakthrough technology in a laboratory setting. Intel was effective, however, at recombining existing technologies to create new types of products, such as DRAMs (their initial product), EPROMs (which started from analysing the causes of defects in DRAMs), and the biggest of all, microprocessors (which started as a lower cost way to meet the requirements of a third-tier Japanese calculator manufacturer).

62. As Intel grew in size, and as IBM and AT&T began to withdraw from funding leading edge semiconductor research, Intel adjusted its approach to create internal labs that were focused on leveraging external research, primarily at universities and at SEMATECH, the consortium of major semiconductor manufacturing companies. By 1996, Intel was spending $100 million annually in equipment grants and donations to fifteen select universities in the United States. It has since expanded this program to include elite universities overseas as well. This active funding positioned Intel to solicit research proposals from leading university researchers and to fund those it considered most promising. Once funded, Intel's internal scientists maintained contact to track progress and determine if and when an academic project was ready to be transferred to internal development within Intel. The decision to transfer often included offers of

temporary consulting employment to university faculty involved and selective hiring of graduate students who were involved in the research.

63. Through such investments, Intel is not simply creating an intellectual commons for other firms to enjoy. For one, Intel’s funding does not cover the full cost of the research. The universities provide faculty and graduate students’ salaries, benefits, and infrastructure, as well as most equipment. For another, Intel is actively following its donations so that it likely is among the first to learn of a new breakthrough. And because its own research staff is involved from the outset, Intel is likely to transfer successful breakthroughs as fast or faster than anyone else. Indeed, what is interesting about Intel’s R&D strategy is that Intel does not need to own the intellectual property in order to profit from it.

64. Intel also makes extensive use of corporate venture capital (CVC) as a tool to promote Intel’s businesses. While CVC has gone through cycles in the past 30 years, Intel has developed a different rationale for its program. Past cycles of CVC sought to identify new sources of diversification for corporations, to help them enter new, unrelated businesses. Intel instead uses CVC to stimulate the growth of markets for its current businesses. Intel’s investments in this area go back a number of years, and were initially focused on shoring up smaller suppliers to increase their financial strength so that they could support Intel. Starting in the mid-1990s, Intel realised that its control over the Pentium architecture gave it the ability to influence the ecosystem of companies that build complementary products to the Pentium microprocessor. Intel also realised that its own ability to grow further would depend in part on the success of these so-called *complementors*. If they succeeded with their offerings, Intel would likely see an increase in demand for its own products. Intel therefore invested in the ecosystem to accelerate its own rate of growth in its markets.

65. Intel hit upon this strategy at a fortuitous time, as the equity markets surged not long after Intel began to aggressively execute its CVC strategy. Intel’s investments rose from under $50 million in 1994 to over $1.3 billion in 2000. This level of investment declined substantially in 2001, to perhaps 50% or less of 2000 levels. Financial returns from Intel’s investments were also attractive up through 2000, but fell significantly in 2001. However, as noted above, it is a mistake to evaluate the Intel CVC program solely on its financial performance. What’s missing in such a calculation is how much more Intel has grown as a result of making these investments. This is a difficult item to measure, since one cannot observe the counterfactual case of what Intel’s revenues would have been had they eschewed CVC. One cannot even use competitors such as Advanced Micro Devices (AMD) and examine their growth as a baseline because AMD’s product sales also may have benefited from Intel’s CVC investments in the ecosystem.

66. Indeed, this suggests one of the limits of Intel’s approach to CVC: one must have a very strong market position to invest in growing the surrounding market, lest one merely create growth for competitors. Intel's most direct competitor, AMD, does not conducting CVC investments, most likely because it cannot ensure that it will appropriate enough of the market growth from such investments to justify them.