The Use of R&D Consortia as Market Barriers: Case Studies of Consortia in the United States, Japan, and Western Europe

Jeffrey A. Hart

There are strong temptations to use research and development (R&D) consortia as barriers to trade and investment. The cases discussed here, the VLSI Project in Japan, Sematech in the United States, the Joint European Submicron Silicon Initiative (JESSI), the European Eureka EU95 program, the European Vision 1250 program, and NHK Engineering Services in Japan are all in the field of high technology electronics. Electronics has been made a priority for public research and development efforts because the governments of advanced industrial countries believe that competitiveness in high technology electronics is important for both national security and overall economic competitiveness. R&D consortia are used by governments and the European Community to pool the risks of the development of new technologies. Access to full membership in these R&D consortia in all three regions is limited, as a rule, to firms owned and headquartered in the region. Access to the technology created is limited in a variety of ways, the most important of which is the inability to work with the technologies themselves at an early stage, which is a major disadvantage in high technology industries. © 1993 John Wiley & Sons, Inc.

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Jeffrey A. Hart is a Professor in the Department of Political Science, Indiana University, Bloomington, IN 47405.

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INTRODUCTION

Increased competition among the advanced industrial countries in high technology industries has resulted in a number of efforts on the part of individual countries and groups of countries to create at least temporary competitive advantages by authorizing the formation of research and development (R&D) consortia. R&D consortia are used ostensibly to reduce the risks to individual businesses of developing new technologies. In most R&D consortia, public funding is combined with contributions from the business members of each consortium to fund a set of research projects which are "precompetitive"—that is, research is supposed to focus on underlying or generic technologies and not on products that are ready for commercialization. Members of consortia apply the successful technological results from consortia research efforts to the production and commercialization of marketable products. Full members usually get more timely or cheaper access to consortia technologies than others.[1]

Limiting R&D consortia to "precompetitive" research ostensibly avoids two major problems: (1) getting firms who are competitors in the marketplace to cooperate with one another, and (2) minimizing the possibility that members of the consortia will collude with one another in the market for final products. It is not always easy to get firms to agree to join a consortium, and once they have joined, it is not always possible to get them to assign sufficient resources to the consortium's research efforts. Sometimes a firm will quit a consortium in midstream, especially if it believes its own research efforts are more advanced than those of the consortium. Thus, a successful consortium requires incentives for firms to join, to contribute adequately, and to remain in the consortium from start to finish. One such incentive offered to prospective members is limited immunity from prosecution under local antitrust laws. This sort of guarantee is much easier to justify if the work involved is strictly "precompetitive." But sometimes the incentives to join and remain in R&D consortia degenerate into guarantees to members that they will be

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[1]There is not much published on R&D consortia, but see Congressional Budget Office (July 1990) *Using R&D Consortia for Commercial Innovation: SEMATECH, X-Ray Lithography, and High-Resolutions Systems*, Washington, DC; Sandholtz, Wayne (1992) *High Tech Europe*, Berkeley, CA: University of California Press; Fong, Glenn (April 1992) "State Strength, Industrial Structure, and Industrial Policy: American and Japanese Experiences in Microelectronics," *Comparative Politics*, 22; and Häusler, Jürgen, Hohn, Hans-Willy, and Lütz, Susanne (September 5–7, 1991) "The Architecture of an R&D Collaboration," paper prepared for the Workshop on Games in Hierarchies and networks, Max Planck Institut für Gesellschaftsforschung, Cologne.

able to dominate collectively a future local market without fear of external competition or the application of antitrust laws.

As international competition increases, it becomes tempting to use R&D consortia for technologies which are much closer to commercialization—and therefore not genuinely "precompetitive"—and to use them as a guarantee for local market domination. The temptation to do this springs not just from greater international competition, but also from the effort of public authorities to justify the expenditure of public revenues in the funding of R&D consortia. The business members of a consortium may come to see that they have bleak future prospects in the market if the consortium's efforts fail to produce near-term commercial results. The public rationale then shifts from one of pooling risks of technology development to creating incentives for local investment and production (i.e., job creation). This, in short, is how R&D consortia can turn into barriers to market access.

The cases discussed here are all in high technology electronics. The first three consortia were created for developing advanced semiconductor production equipment; the second three were for developing technologies for high definition television (HDTV). HDTV is important for the advanced industrial economies because many of its underlying technologies, especially integrated circuits and advanced displays, are considered to be critical for the future of computers and telecommunications equipment.[2]

The cases to be examined here are: (1) the VLSI Project in Japan; (2) Sematech in the United States; (3) the Joint European Submicron Silicon Initiative (JESSI); (4) the EU95 program in Europe; (5) the Vision 1250 program in Europe; and (6) NHK Engineering Services in Japan. These cases were selected because they provide clear examples of the use of R&D consortia to limit market access, even if this may not have been the intention of their founders.

THE VLSI PROJECT

In the mid-1970s, the Japanese expected IBM to come out with a new generation of computers by the end of the decade, based on very-

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[2]See Hart, Jeffrey (Summer 1991) "Consumer Electronics," in Bjorn Wellenius, Arnold Miller, Carl Dahlman, and Darius Mans (eds.), *Electronics Industry Development*, Washington, DC: The World Bank, forthcoming; Hart, Jeffrey "The Consumer Electronics Industry in the United States: Its Decline and Future Revival," *Business in the Contemporary World*, 3: 46–54; and Hart, Jeffrey and Tyson, Laura (Summer 1989) "Responding to the Challenge of HDTV," *California Management Review*, 31: 132–124.

large-scale-integrated (VLSI) circuits. The government was authorized accordingly to make sure that Japanese firms developed VLSI components at least as rapidly as U.S. semiconductor firms. In 1975, NTT formed a VLSI group with Hitachi, Fujitsu, and NEC at a cost of 20 billion yen to assure that VLSI devices would be available for the Japanese telecommunications system. Shortly after, MITI proposed consolidation of the NTT effort with its own research at the Electro-Technical Laboratory. Initially NTT was opposed, but on July 15, 1975, NTT and MITI agreed to establish a joint program.

The VLSI Project began in March 1976 and extended to 1979. The government contributed 20 billion yen to the project, and the private firms contributed 43 billion yen (for a total of approximately $300 million). Oki was excluded at first because it was not strong enough technologically, in MITI's view, to produce the required results. A VLSI Technology Research Association was organized, and a laboratory was set up in a wing of the NEC central lab in Kawasaki. Advanced manufacturing and testing equipment was purchased from the United States. Most of the early effort was focused on reverse engineering the American equipment and then improving it. The new equipment was tested initially by manufacturing 64-thousand-bit (64K) dynamic random access memory (DRAM) devices, although the real test of VLSI capability would be in building 256K DRAMs.

The VLSI Project focused on wafer fabrication technology. The firms had spent much of their research money in the early 1970s on developing equipment for automating the assembly of integrated circuits. While these funds allowed the firms to catch up with U.S. firms in the production of LSI circuits, and later helped them to lengthen their lead in VLSI circuits, further investments in automated assembly needed to be supplemented with basic research on VLSI process technology if the Japanese firms were to catch up or overtake U.S. firms in the next generation of devices. This was the lesson they had learned from their failures in the computer competition.

The VLSI Project was successful in speeding the development of state-of-the-art memory circuits, but more importantly it put Japan on the leading edge of process technology. Japanese firms were the first to ship both 64K DRAMs (in 1978) and 256K DRAMs (in 1982).[3]

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[3]The early lead in 64K DRAMs was not based on superior product technology. See Borrus, Michael (1988) *Competing for Control*, Cambridge, MA: Ballinger, 144: "Japanese firms, chose, essentially, a straightforward scale-up to 64K of their 16K DRAM, based on U.S. merchant Mostek's industry-standard 16K design. They accomplished this though incremental improvement of older photolithographic techniques—proximity aligners, which few U.S. firms believed capable of reaching the 2–3-micron design rules of the 64K device."

Toshiba was the first firm in the world to ship 1-megabit DRAMs (in 1985). NTT helped to promote the production of advanced integrated circuits by transferring its designs for DRAMs and other circuits to the firms and by purchasing devices for use in the telecommunications system.[4] Prior to 1978, Japan had a trade deficit in integrated circuits. In 1978, the deficit became a surplus and grew rapidly until 1984, when it peaked at around 550 billion yen.[5]

The main benefit to the firms of the VLSI Project was the pooling of research efforts in wafer fabrication, and the subsequent freeing of resources for investments in plant and equipment. MITI's involvement in the VLSI Project meant that the Japanese government was committed to helping the firms obtain a preeminent global position in the production of integrated circuits. Japanese firms, accordingly, made very large investments in plant and equipment between 1978 and 1987. Japanese firms invested an average of 40 percent of sales in research and capital equipment during the early and middle 1980s. These investments increased from less than $500 million in 1976 to over $4 billion in 1984.[6]

The VLSI Project was such an enormous success that it was widely copied. Two more recent R&D consortia in semiconductors were responses to the success of the VLSI Project: Sematech in the United States and JESSI in Europe.

SEMATECH

The success of the VLSI Project threatened the dominance of the U.S. semiconductor industry to such an extent that the Department of Defense became concerned about its increased dependency on imports of Japanese semiconductors in the early 1980s. A Defense Science Board Task Force on Semiconductor Dependency was convened in mid-February 1986 to assess the "impact on U.S. national security

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[4]The importance of NTT is underlined in Borrus, Michael, Tyson, Laura D'Andrea, and Zysman, John (1984) *Creating Advantage: How Government Policies Shape High Technology Trade* Berkeley CA: Berkeley Roundtable on the International Economy, 68–70. For an interesting account of the limits to cooperation among Japanese semiconductor firms, see Fong, Glenn R. (August 30–September 2, 1984) "State Capacity, Industrial Structure and Industrial Policy: American and Japanese Experiences in Microelectronics," paper delivered at the annual meeting of the American Political Science Association, Washington, DC.

[5]Ministry of Finance Statistics (1989) as cited in *Japanese Electronics Almanac*, Tokyo: Dempa, 305.

[6]Howell, Thomas R., Noellert, William A., MacLaughlin, Janet H., and Wolff, Alan William (1988) *The Microelectronics Race: The Impact of Government Policy on International Competition*, Boulder, CO: Westview, 37.

if any leading edge of technologies are no longer in this country." The Department of Defense decided, on the basis of Task Force reports, to support a new effort in bolstering U.S. technology: *Sematech*—short for Semiconductor Manufacturing Technology. Sematech was originally proposed by Charles Sporck, president and CEO of National Semiconductor and was to be jointly funded by members of the Semiconductor Industry Association (SIA) and the Department of Defense. The Defense Science Board recommended that the Department of Defense provide $200 million per year over the 1987–92 period, but the actual level of governmental funding ended up being only around $100 million annually.[7]

Sematech had 13 industry members: IBM, AT&T, Harris, Micron Technology, Rockwell, Texas Instruments, Motorola, AMD, Intel, LSI Logic, Hewlett-Packard, Digital Equipment Corporation, and National Semiconductor. The Department of Defense was the fourteenth member of the consortium, and it was represented at consortium board meeting by the Defense Advanced Research Projects Agency (DARPA). Sematech's charter allowed only 100% U.S.-owned firms to be members. All the large merchant semiconductor firms plus four large computer manufacturers—IBM, AT&T, Digital Equipment Corporation, and Hewlett-Packard—were represented in Sematech's core. The purpose of Sematech was to put U.S. firms back on the technological frontier in the area of semiconductor manufacturing. Its goal was to produce circuits with smaller and smaller linewidths in three stages: 0.7 microns, 0.5 microns, and 0.35 microns. Sematech worked only with U.S.-owned semiconductor manufacturing equipment producers through a separate organization called SEMI/Sematech in pursuit of this goal.[8]

Sematech had to be registered with and monitored by the Department of Justice under the National Cooperative Research Act of 1984, so that it did not violate antitrust laws. DARPA administered the Sematech effort with a light hand, hoping not to introduce the complication of military requirements into the primary goal of restoring the domestic semiconductor manufacturing industry to economic health. Although there have been some disputes between the companies and DARPA over the goals and objectives of the program, increased competition from Japan created a higher level of solidarity

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[7]Bairstow, Jeffrey (May 1987) "Can the U.S. Semiconductor Industry Be Saved?" *High Technology*, 34; Sanger, David E. (March 5, 1987) "Chip Makers in Accord on Plan for Consortium," *New York Times*, 29; and (December 21, 1987) "Conferees OK $100M for Sematech," *Electronic News*, 1.

[8]Presentation by Sanford Kane at a meeting on the U.S. Semiconductor Industry at Stanford University, October 21, 1988.

between government and industry than had existed for previous U.S. R&D programs.[9]

IBM and AT&T were particularly instrumental in getting Sematech off the ground. An IBM executive, Sanford Kane, was the chairman of the executive committee of Sematech. Another IBMer, Paul Castrucci, was chief operating office (COO) of the venture, until his resignation in April 1989. IBM licensed its 4-megabit DRAMs for production at the Sematech facility in Austin, Texas. Similarly, AT&T licensed a 64K SRAM to Sematech and donated its own proprietary 0.7-micron CMOS production process for use in the early stages of the project.[10]

The Chief Executive Officer of Sematech from 1987 until his death in June 1990 was Robert Noyce, former CEO of Intel and one of the founding fathers of Silicon Valley. Noyce became a firm advocate of the use of R&D consortia to deal with competitive challenges from abroad. Opponents of industrial policy challenged the necessity for R&D consortia, and criticized Sematech for its high costs and its potentially anticompetitive effects. Sematech was also criticized for being slow in recognizing the need to reverse the rapid decline of the U.S. semiconductor production equipment industry.[11] Supporters of industrial policy defended R&D consortia as a necessary response to the increasing competitiveness of both Japan and Western Europe in advanced electronics.[12] Some advocates of R&D consortia argued that industry cooperation should be extended beyond R&D to joint production, which would require further modification of antitrust laws.[13]

The charter for Sematech forbids membership for firms which are not 100% U.S.-owned. Only U.S.-owned equipment manufacturers may contract with Sematech for supply of next-generation production equipment. Partial funding of Sematech by the Department of Defense is partly responsible for these rules, but one could also argue

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[9]Interview materials.

[10]Santo, Brian and Rappleya, Warren (February 1, 1988) "Sematech Front End: 4-MB DRAM, 64K SRAM Recipes Will Be Donated to Consortium," *Electronic News*, 1.

[11]See Stowsky, Jay (1989) "Weak Links, Strong Bonds: U.S.–Japanese Competition in Semiconductor Production Equipment," in Chalmers Johnson, Laura D'Andrea Tyson, and John Zysman (eds.), *Politics and Productivity: The Real Story of Why Japan Works*, Cambridge: MA Ballinger; *Using R&D Consortia for Commercial Innovation: Sematech, X-Ray Lithography and High-Resolution Systems* (July 1990) Washington, DC: Congressional Budget Office; and Barfield, Claude (September 19, 1989) statement before the Subcommittee on Science, Research, and Technology, *The Government Role in Joint Production Ventures* Washington, DC: United States Government Printing Office, 63.

[12]See Dertouzos, Lester, and Solow, *Made in America*, 140.

[13]See Jorde, Thomas and Teece, David (Spring 1989) "Competition and Cooperation: Striking the Right Balance," *California Management Review*, 32: 25–37.

that Sematech is partially a response to exclusive Japanese R&D consortia like the VLSI Program or European R&D consortia like JESSI (the Joint European Submicron Silicon Initiative, under the Eureka umbrella).[14]

JESSI

In 1983, Siemens decided to make major new investments in the production of standard MOS memory devices, and especially in DRAMs. When Karlheinz Kaske became head of Siemens in 1981, he brought with him a firm belief that dependence of Siemen's competitors for the supply of key components, such as DRAMs, was not in the firm's long-term interests. Apparently, Siemens had had some difficulties in bringing new telecommunications products to the market when Japanese firms refused to sell their newest chips. According to Jürgen H. Knorr, head of Siemen's semiconductor unit: "We were being manipulated."[15]

The Mega Project would develop new integrated circuits in three phases: (1) 1-megabit DRAMs at 1.2-micron line-widths; (2) 4-megabit DRAMs at 0.7-micron line-widths; and (3) devices with 0.3-micron line-widths. The initial investment allocated for this project was 1.4 billion marks. The 1-megabit DRAM was to be developed at a Siemens facility in Regensburg, and the firm hoped to bring the chip to market by 1986. But it encountered a number of problems early on which pushed it in the direction of international collaboration.

In October 1984, Siemens and Philips agreed to work together on the Mega Project. A long-range R&D agreement had been signed in 1982 to develop submicron technology, CAD, speech recognition, and new materials. The earlier agreement was to involve about 50 scientists from the two firms and only $3.7 million in funding. In 1984, the funding was increased to around $500 million with an additional $170 million to come from the Dutch and German governments. The two firms would work together to develop two submicron CMOS circuits by the end of 1988: a 1-megabit static RAM (SRAM) and a 4-megabit DRAM.

After continuing to have problems designing and manufacturing its 1-megabit DRAMs, Siemens turned to Toshiba in July 1985 to supply the production equipment and circuit designs for these chips. This enabled the firm to begin commercial production of the devices in January 1987. The Toshiba production technology for 1-megabit

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[14]On this question, see Flamm, Kenneth "Semiconductors," in Hufbauer, *Europe 1992*.

[15]Quoted here from "Siemens: A Plodding Giant Starts to Pick Up Speed," (February 20, 1989) *Business Week*, 136.

DRAMs used 5-inch silicon wafers. The Siemens engineers wanted to use 6-inch wafers instead and purchased the wrong kind of alignment equipment in the United States, which had to be scrapped. This put the 1-megabit production badly off schedule, even with the purchase of the technology from Toshiba.

Siemens sold 1.5 million units in 1987, when the total demand in Europe for that year was 10 million units. Siemens' customers, including German computer firms like Nixdorf, were very unhappy with this performance. Without the agreement with Toshiba, Siemens would have been even later in delivering its 1-megabit DRAMs. In 1988, Siemens sold around 3.5 million units at around $60 per unit. But neither the Dutch nor the German government was particularly happy about the fact that it had helped to subsidize the purchase of Japanese technology.[16]

Siemens was behind IBM and several Japanese firms in bringing its 4-megabit DRAMs to market, but the lead of Siemens' competitors had decreased. By the end of the Mega Project, Siemens and Philips were widely recognized as being ahead of Japan and the United States in the development of X-ray lithography equipment and other technologies necessary for achieving submicron linewidths. The final cost of the Mega Project was around 4 billion marks: 1.5 billion marks for research and 2.5 billion marks for fabrication facilities. The firms provided all of the funding for the latter. Of the total for research, 403 million marks came from the two governments: 243 million from the German government and 160 million from the Dutch government.[17]

In 1986, Siemens, Philips, and Thomson began discussions of a follow-on to the Mega Project later to be called the Joint European Semiconductor Silicon (JESSI) project. The initial proposals called for an eight-year program budgeted at 3 to 4 billion marks to develop and design manufacturing technologies for the next generation of integrated circuits. As in the Mega Project, a large proportion of the total budget would come directly from the Dutch and German governments.

There was a lot of pressure from the French government and Thomson for SGS-Thomson's participation in JESSI.[18] Siemens and Philips were not too eager to include SGS-Thomson at this point because of Thomson's failure earlier to invest in the Mega Project.

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[16]Interview materials.

[17]Ziegler, J. Nicholas (December 12, 1987) "The Hare and the Tortoise Revisited: Political Strategies for Technological Advance in the French and West German Semiconductor Industries," unpublished manuscript, Department of Government, Harvard University, 35.

[18]The merger of Thomson's semiconductor operations with those of SGS in 1987 made SGS-Thomson, with sales of $859 million dollars in 1987, the second largest European semiconductor firm, behind Philips ($1.6 billion), but ahead of Siemens ($657 million).

The Siemens representative, Hermann Franz, said that "Philips and Siemens will develop the technology itself. But SGS-Thomson could be associated with work on design and equipment."[19] The French, however, insisted that the French firm should have equal status with Siemens and Philips.

In June 1988, the Dutch government announced that it would renew its subsidies for Philips' participation in the Mega Project and JESSI. In November, the European Community began to consider funding of JESSI. When Karlheinz Kaske was asked on November 17 if he thought EC funding of JESSI was essential, he said it was. Kaske indicated that there would probably also be a role for Plessey in JESSI if the GEC-Siemens acquisition was approved. In January 1989, Plessey officially joined the project. In April 1989, Heinz Dürr of the AEG subsidiary of Daimler announced that Daimler would like to participate in JESSI. Thus, the Mega Project had spawned a much broader European effort to develop leading-edge semiconductor technologies within JESSI.

By the end of the 1980s, JESSI was widely recognized as a world leader in the development of the next generation of semiconductor manufacturing equipment. JESSI was particularly strong in the area of x-ray lithography. Both Japan and the United States were weak in this area. IBM began to petition JESSI for access to its research on x-ray lithography, while continuing to support joint research on semiconductor manufacturing in the United States. Eureka and the European Commission are unlikely to exclude firms like IBM, who have a major European manufacturing and R&D presence, from participation in European projects like JESSI—even though they might like to do so. However, there seems to be less restraint when it comes to excluding smaller American concerns and Japanese multinationals. A case in point is the recent expulsion of International Computers Limited (ICL) from several EC joint research projects after it was purchased by Fujitsu. ICL was also expelled from the European Information Technology Roundtable, a private industry association, after the purchase.[20]

EUREKA EU95

The Eureka EU95 program was launched in June 1986, at the initiative of French President François Mitterrand, in response to Japa-

[19]Quoted here from de Jonquieres, Guy (April 5, 1988) "European Chips Plan Clouded by Siemens, SGS-Thomson Dispute," *Financial Times*, 1.

[20]See Tyson, Laura (1992) *Who's Bashing Whom?* Washington, DC: Institute for International Economics, 6.

nese proposals for a new world standard for HDTV at a plenary meeting of the CCIR (the Consultative Commission on International Radio) in Dubrovnik, Yugoslavia, in May 1986. EU95 was one of the first research programs announced under the Eureka rubric.[21] The heads of state of the members of the European Community decided at their summit conference in Rhodes in December 1988 to make EU95 and HDTV a high priority issue in Europe. In April 1989, the EC Council of Ministers adopted a decision on HDTV, which outlined a comprehensive strategy for the launch of HDTV service in Europe starting in 1992.[22] EU95 itself was renewed and expanded in 1990 when its first phase ended. In short, Europe is betting a lot on the success of EU95.

The participants in EU95 are listed in Table 1. All of them are European entities—either private businesses, public broadcasters, publicly funded research institutes, or business associations. Non-European entities are permitted to join EU95 and other European R&D consortia only on a case-by-case basis. "In making decisions on such cases, the Community has emphasized two criteria—the kind and extent of investment by foreign firms in European facilities, and the issue of reciprocity."[23]

The initial funding for the program was to have been 190 million ECU for the first four years, from a mixtures of public and private sources. The actual expenditure for the first phase of the program, ending in December 1989, was 270 million ECU (approximately $350 million). The second phase began in 1990 and was budgeted at 350 million ECU (around $500 million) for three years.

The most important participants from the beginning were Thomson, Philips, and BTS (a joint venture for advanced television technology created by Bosch and Philips in 1986). Peter Bögels of Philips

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[21]Eureka began in July 1985 with the membership of 19 European nations as a way of pooling research efforts across Europe. Eureka was seen as a less bureaucratic alternative to the mechanisms established by the European Commission to conduct joint European research in high technology. It was also, to some degree, a response to inducements from the Reagan Administration to involve Europeans in research for the Strategic Defense Initiative

[22]This decision is labeled 89/337/EEC in European Community documentation. It states five objectives: (1) making sure that European industry develops all the technology needed for HDTV services; (2) promoting the adoption of 1250/50 as a global standard; (3) promoting the widespread use of 1250/50 globally; (4) promoting the introduction of HDTV services in Europe as soon as possible after 1992; and (5) making every effort to ensure that the European film and production industry occupy a competitive position in the HDTV world market. For commentary, see Watson-Brown, Adam (November/December 1989) "Hype, Hope & Clarity," *Television: Journal of the Royal Television Society*, 312–315.

[23]D'Andrea Tyson, Laura (1992) *Who's Bashing Whom?* Chapter 6. Tyson goes on to say that IBM qualifies for membership in certain ESPRIT consortia, but not for JESSI because of the exclusion of European firms from SEMATECH. See the discussion of these consortia in the concluding section below.

Table 1. Participants in the Eureka EU95 Consortium

Country	Company	Type of Participation
Austria	Oesterreichische Philips Industrie GmbH	A
	Video Werk (Philips affil.)	A
Belgium	NV. Philips Industrie	A
	Barco Industries	B
France	Thomson S.A.	A
	Océanic S.A. (subsid. of Nokia)	A
	Affiliated companies of Philips	A
	Angéieux	B
	CCETT (TDF & France Telecom)	B
	EUTELSAT	B
	SEDAGS	B
	SFP	B
Finland	Nokia Corporation	A
	Radio-ja Telvisiotekniikan Tutkimus Oy	A
	Salory Oy	A
Germany	Robert Bosch GmbH	A
	Broadcast Television systems (Bosch-Philips joint venture)	A
	Nokia affiliates	A
	Thomson affiliates	A
	Philips affiliates	A
	BASF	B
	FTZ (Deutsch Bundespost Research Center)	B
	Fuba	B
	Grundig AG	B
	Heimann GmbH	B
	Heinrich-Hertz Institut	B
	Intermetall (ITT affiliate)	B
	IRT	B
	Rohde and Schwartz	B
	Schneider	
	Siemens AG, Bereich Halbleiter	B
	Studio Hamburg Atelier	B
	Technische Universität Braunschweig	B
	Universität Dortmund	B
Italy	Consorzio per lo Sviluppo della Televisione ad Alta definizione Europea	A
	Videocolor (Thomson affil.)	A
	Philips S.p.A	A
	RAI	B
	Seleco	B
	Selenia Spazio	B
	Telettra	B
	SGS Thomson	B

(continued)

Table 1. (Continued)

Country	Company	Type of Participation
The Netherlands	N.V. Philips	A
	BTS affiliate	A
	P.D. Magnetics (Philips affil.)	A
	Nederlands Omroepproduktie Bedrijf	B
Spain	Philips Ibérica S.A.E.	A
	Television Española	B
Sweden	Luxor AB (Nokia affiliate)	A
Switzerland	Gretag	B
	Kudelski	B
United Kingdom	Ferguson (Thomson affil.)	A
	Philips affiliates	A
	Applied Video Systems	B
	BBC	B
	British Telecom	B
	Colour Film Services, Ltd.	B
	NTL	B
	ITV Association	B
	Laser Creations	B
	Quantel	B
	Rank Cintel	B

Source: *HDTV Report* (March 1991), p. 12, a publication of the Eureka EU95 Directorate.

has been the head of the EU95 Directorate in Brighton, England since 1986. Thomson directs the program's activities in France. BTS directs the program's activities in Germany. Nokia, a Finnish firm, was added to the inner circle of program directors in October 1989. In May 1990, Philips and Thomson announced that they were planning to spend 20 billion francs (around $4 billion) on the development of HDTV products over a five-year period, but this was to be a Franco–Dutch effort and not strictly part of the Eureka initiative.[24]

The purpose of EU95 was to develop technologies and prototype equipment for the processing of high-definition video images and stereo sound. From the very beginning, EU95 focused on the develop-

[24]Philips plans to invest 11 billion francs, Thomson 9 billion. See Office of Technology Assessment, (June 1990) *The Big Picture: HDTV and High-Resolution Systems*, Washington, DC: U.S. Government Printing Office, 32–34; Samuel, Patrick (1990), "High-Definition Television: A Major Stake for Europe," in John F. Rice (ed.), *HDTV: The Politics, Policies, and Economics of Tomorrow's Television*, New York: Union Square Press; and Sweet, William (March 1991) "Future of Electronics Companies at Stake in Development of New TV Systems," *Physics Today*, 44: 57–61.

ment of a high definition version of a direct-broadcast-satellite (DBS) transmission system called MAC (multiplexed analog components), which came to be called HD-MAC. HD-MAC video images have 1250 lines per frame (double the 625 lines of PAL and SECAM, the current standards in Europe), an aspect or width-to-height radio of 16:9 (the aspect ratio of PAL and SECAM is 4:3), and scanning is progressive or noninterlaced (the current standards are interlaced) at 50 frames per second.[25] Nevertheless, HD-MAC signals are backward compatible with MAC receivers, so people who purchased MAC sets will still be able to view images produced for HD-MAC receivers.

MAC was developed originally by the Independent Broadcast Authority (IBA) in England. MAC signals are suited to satellite delivery because they are analog and fit nicely within the band-width limits of existing satellite transponders. The multiplexing aspect of MAC signals improves the ability of MAC receivers to compensate for errors introduced in transmission. One cannot receive MAC signals on existing PAL and SECAM sets, however, and direct reception in homes is impossible without the use of higher power satellites at the transmission end, and of a satellite dish and decoder at the reception end.

MAC was designed to be consistent with an international standard, CCIR 601, negotiated in 1982 at the CCIR plenary. One version of MAC, C-MAC/Packet, was adopted as a European standard by the European Broadcasting Union (EBU) in 1982. D2-MAC/Packet was adopted as an EBU standard in April 1985. Distinctive variants of the MAC standard (B-MAC, C-MAC, D-MAC, and D2-MAC) were adopted for use by public broadcasters in Britain, France, Germany, and The Netherlands, but few MAC receivers were sold initially and there were problems with the launching of DBS satellites.[26] Nevertheless, unlike PAL and SECAM (the preexisting color TV standards in Europe), MAC was designed in such a way as to make it relatively easy to upgrade signals to higher resolutions without losing backward compatibility. This made it possible for Europeans to envision a gradual evolution from PAL and SECAM, to MAC, to enhanced MAC

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[25] "HD-MAC" is frequently used synonymously with "1250/50" in discussion of the European HDTV standard, because HD-MAC which is a transmission and reception standard, requires a studio or production format of 1250 lines per frame and 50 frames per second. To be more accurate, however, one should note that the 1250/50 production format may produce digital signals that have not been encoded by HD-MAC encoding methods. The reader should keep this distinction in mind, especially in the section on the case of HDTV Fine Arts Production below.

[26] See Watson-Brown, Adam (January 1988) "Towards the Triumph of the Matt Black Box," *Intermedia*, 16: 21–24.

(with wide-screen capability and better sound), and finally to HD-MAC.[27]

The EU95 consortium was successful in developing prototype HD-MAC cameras, video recorders, and transmission equipment only two years after its formation. It successfully demonstrated HD-MAC equipment first at the International Broadcasting Conference (IBC) in Brighton, England in October 1988, then at the Funkausstellung in Berlin in August 1989, and then again at the National Association of Broadcasters meeting in Las Vegas in May 1991.

The technical success of the EU95 consortium should be juxtaposed with the so far limited success of MAC itself in penetrating European TV markets. MAC has been challenged by a group of private broadcasters who have committed themselves to prolonging the life of the PAL standard by moving to enhanced versions of PAL—PALplus and wide PAL.[28] Rupert Murdoch's Sky Television, for example, was able to win important increases in European audience shares by directly delivering PAL signals to homes and cable operators via privately owned medium-power communications satellites, as opposed to the high-power communications satellites owned and operated by the public telecommunications agencies of Europe. All the publicly owned satellites had been committed to broadcasting MAC signals. Besides the problems connected with launching the high-power satellites, manufacturers had problems producing enough MAC receivers because of shortages of key components.

Not only did Murdoch steal a march on the PTTs and the public broadcasters by broadcasting in PAL, he also provided more international programming, mainly from Britain and the United States, to Europeans than the public broadcasters had been willing to provide. Thus, many Europeans bought satellite dishes or subscribed to cable services offering the Sky channels in order to get access to greater variety in programming.[29]

When Sky Television merged with British Satellite Broadcasting (BSB) at the end of 1990, the new company, British Sky Broadcast-

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[27]See Jurgen, Ronald K. (October 1991) "Chasing Japan in the HDTV Race," *IEEE Spectrum*, 28; Watson-Brown, Adam (April 1987) "The Campaign for High Definition Television: A Case Study in Triad Power," *Euro-Asia Business Review*, 6: 3–11.

[28]PALplus is an improved definition version of PAL which makes the image clearer by correcting errors introduced in transmission of PAL signals. WidePAL is an enhanced definition version of PAL which makes the image wider by moving from the current 4:3 aspect ratio to the 16:9 aspect ratio of HDTV, but without great increases in picture resolution.

[29]I am indebted to Adam Watson-Brown and Hans Kleinsteuber for explaining these details to me. See also Cawson, Alan (September 1990) "The Politics of Consumer Electronics: The British and European Industry in the 1970s and 1980s," rough draft of a unit produced for the Open University Social Sciences course Running the Country, University of Sussex.

ing, announced that it would continue to broadcast in PAL and would drop BSB's former plans to convert its signals to MAC. Since that time, Murdoch, together with his European allies, has argued against efforts of the European Community to require all high-powered satellite broadcasters to adopt the MAC standard. The counter argument of MAC supporters has always been that PAL is incapable of being upgraded to high definition, and that failure to enforce uniformity of broadcast standards will confuse consumers and disrupt the future market for HD-MAC products. In essence, the argument is about whether the already rather large investments in developing HD-MAC technologies should be written off. Predictably, those who have made the investments say no.[30]

VISION 1250

Vision 1250 is a tangible embodiment of the continued commitment of European governments, manufacturers, public broadcasters, and other interests in holding together the coalition that was behind the formation of EU95. It was founded in Strasbourg on July 11, 1990, as one of the first European Economic Interest Groups (EEIGs) made possible by new European business laws that passed in the wake of the Single European Act of 1987.[31]

The business founders of Vision 1250 are the same as the principal actors in EU95: Thomson, Philips, BTS, and Nokia. Other participants in Vision 1250 include a number of firms that were not in EU95, and particularly, broadcasters and satellite telecommunications service providers (see Table 2). All the members of Vision 1250 are European, consistent with the laws authorizing the formation of EEIGs.

The purpose of Vision 1250 is to prepare the ground for the introduction of HD-MAC services in 1992 and, in particular, to help those who want to produce video programs in the 1250/50 format to do it successfully. Vision 1250 is providing a variety of services, but the most expensive involves the establishment of mobile television studios in large trucks with HD-MAC cameras, video recorders, editing

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[30]Interview materials; Hart, Jeffrey and Thomas, John (February 1992) "Corporatism for Competitiveness? Tracing Policy Networks in the New European Community," unpublished manuscript, Indiana University, Bloomington, IN.

[31]For discussion of the Single European Act, see Hufbauer, Gary Clyde (1990) "An Overview," in Gary Clyde Hufbauer (ed.), *Europe 1992: An American Perspective*, Washington, DC: Brookings; and Moravcsik, Andrew (1991) "Negotiating the Single European Act," in Robert Keohane and Stanley Hoffman (eds.), *The New European Community: Decisionmaking and Institutional Change*, Boulder, CO: Westview Press.

Table 2. Participants in Vision 1250

Type of Member	Member	Country
Founding members		
Industry	Thomson	France
	Philips	The Netherlands
	Nokia	Finland
	BTS	Germany
	Laser Creations	United Kingdom
EBU members (broadcasters)	BBC	United Kingdom
	RAI	Italy
	ORTF	France
	Antenne 2	France
	FR3	France
	Canal Plus	France
	TDF	France
Independent broadcasters	BSB	United Kingdom
	Thames TV	United Kingdom
	BHDTV	France
	Unitel	Germany
	SFP	France
Transmission	France Telecom	France
	Deutsche Bundespost	Germany
	Retevision	United Kingdom
Newer members or applicants		
Industry	Seleco	Italy
	Telettra	Italy
EBU members	Danmarks Radio	Denmark
	Elliniki Roadiofonia Tileorasi	Greece
	Radiotelevision Española	Spain
	Radiotelevisao Portuguesa	Portugal
	RTBF	Belgium
	ARD	Germany
Independents	HD Synergetic	France
	RTL Productions	Luxembourg
	Teti Televisive	Italy
	Metropolitan	Germany

Source: Same as Table 1, p. 2.

equipment, and transmission equipment. Vision 1250 supported the use of these units in the HD-MAC coverage of the 1992 Olympics in Barcelona, as well as of a series of sporting and cultural events.

There have not been many requests from non-European entities for the services of Vision 1250, but one case with which I am familiar suggests that both EU95 and Vision 1250 may have a tendency to discriminate against non-Europeans. The case involves the effort of an American named Dale Cripps, through a firm called HDTV Fine Arts Production, to deliver HDTV signals of the Salzburg Festival's Mozart performances to live audiences at European theaters. Mr. Cripps was unable to obtain services from Vision 1250 directly because he and his firm were not European, so he had to ask his Austrian partner, the public television broadcaster ORF, to join Vision 1250 at a cost of $75,000. In addition, Mr. Cripps was strongly urged by the EU95 directorate to use European HD-MAC equipment instead of Japanese Hi-Vision and MUSE equipment in delivering his signals within Europe even though the Japanese equipment was more rapidly available and cheaper. That the venture eventually failed was due to other factors, but Cripps' dealings with EU95 and Vision 1250 added some important constraints to Cripps' business strategies that probably contributed to that failure.[32]

NHK AND HI-VISION

NHK (Nippon Hoso Kyokai or the Japan Broadcasting Corporation) is Japan's public broadcaster funded almost entirely out of user fees. Each Japanese household with a television receiver pays a monthly fee to NHK on a "voluntary" basis.[33] However, NHK spends about 17% of its total budget collecting these fees, and around 90% of the households with TVs actually pay the fees.[34] NHK has operated a research laboratory since 1930 called NHK Science and Technical Research Laboratories. NHK Labs have been responsible for all of the key technologies behind Japan's decision to adopt an HDTV standard called MUSE (Multiple Sub-Nyquist Encoding) or, more popularly, Hi-Vision. It has been estimated that NHK and the Japanese electronics manufacturers spent as much as $500 million dollars between 1970 and 1980 on the development of Hi-Vision technologies.[35] NHK licenses these technologies to manufacturers, because it is enjoined from producing its own television equipment under the laws that established it.

The Joint Research and Coordination Division of NHK Science and Technical Research Laboratories works with other organizations, including private firms, on cooperative R&D projects. For example, in 1984, after the internal Japanese decision to adopt the Hi-

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[32]Interview materials.

[33]Subscribers without satellite dishes pay 2000 yen per month, those with dishes pay 3000.

[34]Interviews in Japan, Fall 1989.

[35]Choy, Jon (January 13, 1989) "Developing Advanced Television" *JEI Report* (Washington, DC: Japan Economic Institute), No. 2a.

Vision standard, with its 1125 scanning lines, interlaced at 60 frames per second,[36] NHK began to work on a contract basis with major Japanese equipment manufacturers to produce prototype Hi-Vision decoders and video recorders. The contracts provide for each manufacturer to develop its own equipment and for NHK to retain patent rights for the basic technology. A research consortium of several firms was created to design LSI chips for Hi-Vision decoders.[37] This cooperative research and development became so extensive that NHK decided to form a subsidiary to manage it and to diffuse the technologies it produced.

NHK ENGINEERING SERVICES

NHK Engineering Services, Inc. (NHK-ES), founded in 1986, is formally a subsidiary of NHK, which NHK says is a vehicle for technology transfers to any interested manufacturer. However, in fact, NHK-ES has acted as an R&D consortium. All the major consumer electronics manufacturers are "associates" of NHK-ES, and pay hefty membership fees. In exchange for the fees, part of which is used to fund further research on Hi-Vision, the members are permitted to have early access to the research results of NHK programs and may be accorded some preferential treatment in the licensing of NHK's patented technologies. NHK holds the patents for all the basic circuit designs for Hi-Vision and for the new HARP tubes needed for Hi-Vision cameras. It also holds the patents on Hi-Vision video recording technologies. NHK-ES provides an annual "open house" at NHK Labs, periodic briefings, and a newsletter service for all members. These services provide early information about new research directions. Anyone who wants to compete in the Hi-Vision final equipment market clearly must be an associate of NHK-ES.

All the major Japanese manufacturers of television equipment have chosen to become associates of NHK-ES: Sony, Matsushita, Toshiba, Hitachi, NEC, Sharp, Sanyo, and Mitsubishi. One small firm, Ikegami, a producer of high-end television production equipment and high-resolution displays, also belongs. There were ten busi-

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[36] Hi-Vision, 1125/60, and MUSE are used interchangeably in some contexts to refer to the Japanese HDTV standard. To be somewhat more accurate, 1125/60 refers to a production or studio format, while MUSE or Hi-vision refers to compatible transmission and reception standards. It is possible to produce uncompressed digital signals in the 1125/60 format without using the compression techniques inherent in MUSE and Hi-Vision encoding.

[37] Interview with Toshiro Ozawa and Susumu Suzuki of Sony Corporation conducted by Jean Kumagai, a *Physics Today* staffer in August 1990, and reported in (April 1991) *Physics Today*, 93.

ness associates of NHK-ES as of the Fall of 1989, all Japanese. The only American firm that has joined since then is the Japanese subsidiary of Texas Instruments. But because the Japanese members of the subsidiary worked closely with NHK on the development of LSI (large-scale integrated) circuits for Hi-Vision equipment, those firms have access to all the LSI devices they created for NHK, while Texas Instruments only has access to the "transistor-level" circuitry. An attempt was made by one other American firm to join—National Semiconductor, but that firm decided not to join when it was asked to pay a fee of $150,000 prior to being allowed to see any detailed information about the technologies being licensed by NHK-ES, including the transistor-level circuit designs.[38]

This illustrates an important problem with R&D consortia. Once formed, the consortium has to ensure members that they will receive significant benefits from membership and that new members will not be able to benefit from discoveries to which they have not contributed. This is likely to reinforce any existing tendencies to create barriers to new entry into the consortium.

Another more recent incident demonstrates the difficulty of eliminating barriers of access to the services of R&D consortia like NHK-ES. The English-language version of the brochure explaining NHK-ES to potential members, as of August 1991, was apparently much vaguer and briefer than the Japanese version. Vital information about the services available, the nature of NHK patents, and the fee structures of NHK-ES membership were missing in the English version. When NHK officials were made aware of this fact, they quickly retranslated and reissued the brochure. Apparently, some lower-level official thought it was a good idea to drop certain items from the translated brochure.[39]

NHK-ES took pains to exhibit its technologies at the annual meeting of the National Association of Broadcasters in Las Vegas in 1991, and to provide information about both NHK and NHK-ES to participants. I received a letter from Junichi Ishida, vice president of NHK-ES, dated October 30, 1991, in which Mr. Ishida insists that NHK "is ready to transfer technologies in its possession to every company in and outside Japan under the fair conditions and fees (consideration), without any discrimination between Japanese and foreign companies." However, regardless of the good intentions of key members

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[38]Correspondence and interview materials.

[39]I learned of this incident in a telephone conversation in September 1991 with Greg Noble, who is a political scientist and a Japan specialist at the University of California at Berkeley. Noble visited Japan in August 1991 to conduct interviews with officials at NHK, MITI, and the Ministry of Posts and Telecommunications about HDTV standards issues.

of any R&D consortium, the practical effects will often be exclusionary. It is tempting and often easy to use them for such purposes.[40]

It is possible, of course, to participate in Hi-Vision markets without being a member of NHK-ES. For example, semiconductor firms that innovate new ways of implementing NHK's Hi-Vision circuit designs in VLSI circuitry may develop these designs for final equipment producers who have licensed the patents for Hi-Vision circuits. Also, anyone may produce Hi-Vision video programs, and a number of American and European programmers have done so. Because NHK is a broadcaster and not an equipment producer, it has a strong interest in maximizing the range and breadth of equipment and programming compatible with the Hi-Vision standard. But NHK is not the only agency with a stake in HDTV in Japan, and it has itself participated in actions which have had access-limiting effects.

CONCLUSIONS

The main explicit purpose behind the formation of an R&D consortia is usually to strengthen the position of national or regional firms in important technologies. R&D consortia can reduce the technological and financial risks of individual firms by allowing them to pool their R&D resources, and by allowing public agencies to partially fund private R&D activities. But R&D consortia also create expectations about and opportunities for erecting barriers that would perhaps not otherwise exist.

Because of the need to provide immunity from antitrust enforcement and sometimes public funding to supplement private contributions, which arises from the natural tendency of competing firms to distrust each other and therefore to do their own research, there is almost always strong pressure on R&D consortia to exclude firms from outside the region. This pressure can be resisted in specific cases, and arrangements can be made to allow nonparticipants access to the technologies created by consortia. Nevertheless, there will always be some disadvantage inherent in being removed from direct participation in the innovation process, a disadvantage particularly important in fast-moving high-technology industries like the advanced electronics industries.

There needs to be recognition of the value to the citizens of the competing regions of the existence of R&D consortia. They may produce important positive externalities because of the public goods nature of advances in technology. Electronics technologies in partic-

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[40] The letter is reproduced in the Appendix to this article.

ular are subject to virtuous cycles created when lower production costs lead to higher revealed demand and then further reductions in production costs. R&D consortia may help to increase competition across regions, and thereby lower prices to consumers. They may help to produce a more stable and orderly market, less subject to protectionist pressures, because they help to calm fears of being left behind in important technologies.

In the end, however, there is a need to begin formulating international rules about R&D consortia, just as has been done in the past for other potential sources of barriers to markets, because of the strong temptations to use R&D consortia to limit access. The *sine qua non* of such rules is transparency. One cannot object to R&D consortia or ask for compensatory measures unless one know that they exist. More importantly, the rules of access and technology transfer for R&D consortia need to be more readily available to all trading firms and nations. Thus, it seems reasonable to propose some sort of global registry for R&D consortia, at a minimum, and multilateral rules for access to R&D consortia, at a maximum.

The initial steps toward such a regime have already been taken. As mentioned above, there is already an informal regime of reciprocity between Europe and the United States on participation in each other's R&D consortia. It is quite likely that reciprocal access can be negotiated between the United States and Japan and between Europe and Japan in some areas. Something of the sort has been worked out for those U.S. semiconductor manufacturers interested in designing new chips for the Japanese HDTV standard. These sorts of bilateral and managed trade solutions have all the shortcomings of bilateralism and managed trade in other areas. They further undermine the norm of nondiscrimination inherent in the GATT.

So a modest firm step toward multilateral arrangements would be to start preparing for multilateral negotiations on trade-related research and development measures (TRR&DMs?). This may not seem like practical advice when much simpler problems are being ignored or made worse at the Uruguay round. However, if we are not to see countless repetitions of the problems of firms like National Semiconductor and HDTV Fine Arts in the coming years, and the increased international tensions that go with them, then we must act in this way.

APPENDIX

Dear Professor Hart:

I am writing this letter, since I heard from Mr. Nishizawa, Deputy Director General of NHK Science and Technical Research Labs., of your group studies on High Definition Television in Japan. He met with Professor Noble of the University of California, Berkeley this summer, and one of the subjects at that time was opaqueness of NHK Engineering Services Inc. that is also mentioned in your report.

Here, I would like to make clear the position on which NHK and NHK-ES stand. NHK-ES is authorized by NHK to carry out, on behalf of NHK, technology transfer. NHK is ready to transfer technologies in its possession to every company in and outside Japan under fair conditions and fees (consideration), without any discrimination between Japanese and foreign companies.

NHK-ES has a membership system, but the members only receive a regular publications from NHK-ES and the option to join seminars held by NHK-ES at a reduced fee. The right to get technology transfer has no connection with the membership participation.

We at NHK-ES think technical cooperation with U.S. companies is very important in promoting the development of American and Japanese broadcast industries and in eliminating economic conflict between the U.S. and Japan. That was our intention at the NHK Open House demonstration at the '91 NAB show. Therefore, the point described in the conclusion of your report reflects our sentiments.

I also heard from Mr. Nishizawa. Mr. Noble phoned you that NHK-ES had a booth at '91 NAB show and appealed NHK-ES's position to the American public, and your feeling of wariness regarding NHK-ES seems to have somewhat dissipated.

I thank you very much for your understanding of NHK-ES's position. I would appreciate it very much if you could suggest how and where to promote NHK-ES public relations in the U.S.

Junichi Ishida
Vice President
NHK Engineering Services, Inc.
cc: Professor G. Noble
Mr. T. Nishizawa