Title: Japan’s Intelligent Manufacturing Systems Initiative and the Politics of International Technology Collaboration

By: Gregory P. Corning

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Abstract:

Discusses Japan’s Intelligent Manufacturing Systems (IMS) initiative, an international research program in manufacturing technology with the goal of developing a next-generation production system to maximize efficiency by integrating the entire range of business activity from order-booking through design, manufacture and distribution. Examines the role of techno-nationalism, foreign pressure, and scientific and technical factors in motivating Japan’s original IMS proposal. Examines the framework of the IMS program emerging from negotiations between Japan, the U.S. and the European Union. Examines the experience of Japanese and foreign firms in IMS. Evaluates IMS as a potential model for large-scale, industrial R&D collaboration. Argues that future interest in the model will be determined by whether it generates sufficient research results over the next ten years that firms can justify the overhead of organizing research collaboration on a global scale.

Keywords: manufacturing; research and development; Intelligent Manufacturing Systems; collaboration

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Japan’s Intelligent Manufacturing Systems Initiative and the Politics of International Technology Collaboration

by

Gregory P. Corning
Assistant Professor
Department of Political Science
Santa Clara University

Visiting Lecturer
The University of Texas at Austin
Academic Year 1996-97

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IC² Institute
The University of Texas at Austin
2815 San Gabriel
Austin, TX 78705

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In October 1989, a committee of Japanese academics and corporate executives sponsored by MITI proposed an international research program in manufacturing technology called the Intelligent Manufacturing Systems (IMS) Initiative. Under the leadership of Dr. Hiroyuki Yoshikawa of Tokyo University, the so-called Yoshikawa kondankai proposed a leap beyond computer-integrated manufacturing to research on a next-generation production system that would maximize efficiency by integrating the entire range of business activity from order-booking through design, manufacture, and distribution.

At first, the IMS proposal received a cold reception from the United States government and the Commission of the European Communities which perceived the program as an attempt to access western capabilities in software and systems integration. Washington and Brussels were particularly disturbed by the vague terms of the proposal and the fact that Japan had directly approached foreign firms and universities about their participation. Arguing that western interests were not sufficiently represented in the evolving framework of the program, both Washington and Brussels asked MITI to place a moratorium on IMS in the spring of 1990. Two years of negotiations followed before the parties agreed to a feasibility study that would develop modalities for international collaboration and then evaluate those modalities in test-case consortia.

The IMS framework evolved significantly over the years from 1990 to 1994. What began as a MITI-sponsored initiative incorporating international participation in planning and evaluation became a “fully-international” program with management and funding responsibilities shared among Australia, Canada, the EU/EFTE, Japan, and the United States. IMS represents a departure from previous international research programs in applying the industry-led model of collaboration from Europe’s ESPRIT and EUREKA programs on a global scale. Establishing the basic parameters for the program, the IMS member regions agreed on technical themes, guidelines for protection of intellectual property rights, and the requirement that each consortium must have partners from at least three of the five IMS regions. Working within these broad parameters, firms are able to develop their own research proposals.

This paper is organized into three main sections. The first section examines the role of techno-nationalism, foreign pressure, and scientific and technical factors in motivating Japan’s original IMS proposal. The history of this formative stage of IMS suggests a major role for both technological complimentarities and foreign pressure but a much less important role for techno-nationalism. The second section examines briefly the framework of the IMS program that emerged from negotiations amongst Japan, the United States, and the European Union between 1990 and 1993.

The third section of the paper uses the six test-case consortia of the feasibility study, which ran from March 1993 to March 1994, as a window through which to examine the experience of Japanese and foreign firms in IMS. Although the survey nature of much of the test-case research did not provide a real test of crucial aspects of the IMS framework, such as provisions for the protection of intellectual property rights, the test-cases generated sufficient enthusiasm that the IMS International Steering Committee recommended the launch of a ten-year, full-scale program. Perhaps, the clearest validation of IMS, to date, is the fact that a number of European and American firms have decided to take part in the full-scale program. Members of the seven consortia approved for the full-scale IMS program as of early 1997 include firms like General Motors, IBM, Mercedes-Benz, Nokia, Pirelli, and Rockwell.

After examining the transition to the full-scale IMS program which began in May 1995, the paper closes by evaluating IMS as a potential model for large-scale, industrial R&D collaboration. The Japanese experience in proposing IMS, like the American failure to attract international funding for the Superconducting Supercollider, illustrates the growing recognition that governments expect to have some input in the planning of any international project that they might be asked to subsidize. For this reason, the decentralized management and funding structure developed in IMS seems to provide a likely model for large-scale, industrial research collaboration. The key issue in determining future interest in this model, however, is whether IMS generates sufficient research results over the next ten years that firms can justify the overhead of organizing research collaboration on a global scale.
I. Forces Driving the Internationalization of the IMS Program

Techno-Nationalism

The IMS proposal was perceived by many in the west as simply the latest Japanese effort to access and indigenize superior foreign technologies. Indeed, the more polished presentation of IMS than earlier programs led many to see it as the most sophisticated and, therefore, most insidious example yet of Japanese techno-nationalism. According to one foreign official who attended the initial IMS briefing in January 1990, MITI had clearly learned from the experience of the Human Frontier Science Program. IMS brochures were written in clear English and offered concrete examples of the potential benefits to foreign participants. Also, by avoiding the involvement with other ministries that had delayed the launch of the HFSP, MITI would be able to move more swiftly to accomplish its goals.2

The IMS proposal was labeled a “Trojan Horse” by those who saw Japan’s offer to “share its pre-eminent manufacturing technology” as a thinly guised attempt to access western capabilities in software and systems integration.3 Western suspicions concerning the motivations underlying IMS were based on three broad concerns: (1) the fact that Japan made direct contacts with not only government agencies but private organizations, (2) the terms of collaboration initially proposed by Japan, and (3) the relative national positions of Japan, the United States, and the European Union in key manufacturing technologies.

Initial Contacts

Government officials in the United States and Europe were angered by the fact that Japan made initial overtures concerning IMS to a mix of private and public organizations rather than through government channels alone. George Heaton notes conflicting reports as to which parts of the U.S. government were actually contacted regarding IMS and how they might have responded.4 According to Dr. Yuji Furukawa, who made the first contacts about IMS, the goal of initial discussions was to gauge the interest in collaboration of American and European engineers who would best be able to understand the goals of the program.5

In November 1989, Furukawa visited the National Academy of Sciences, the Society of Manufacturing Engineers, and the former National Bureau of Standards in the United States before moving on to Europe where he met with officials from Directorate-General XIII of the Commission of the European Communities, and the U.K. Department of Trade and Industry among others. Furukawa explains these meetings as unofficial contacts because IMS was at that time only a draft proposal without any official endorsement or commitment of financial support from MITI. In fact, Furukawa received no travel subsidy from MITI and was forced to arrange funds through the Japan Machine Tool Builders Association.

During this trip, Furukawa proposed that the Society of Manufacturing Engineers (SME) become the point of contact in the United States for any future IMS program. As head of the Japan chapter of SME at the time, Furukawa explains the decision as a natural outgrowth of personal contacts and SME interest rather than as part of a deliberate strategy to marginalize the potential role of the U.S. government. While the academic origins of the IMS program give some credence to this interpretation of events, there is reason to believe that MITI’s role was larger than Furukawa suggests. According to one MITI official, “we knew that the Department of Commerce was not highly respected by industry so we also approached firms and industry associations directly.”6

Government officials in both the United States and Europe rejected the notion that the discussions on IMS were informal contacts. Deborah Wince-Smith, then assistant secretary for technology policy at the Department of Commerce, requested that MITI not approach the private sector directly. The U.S. government insisted that any discussion of large-scale collaborative programs take place within the framework of the U.S.-Japan Science and Technology Agreement. MITI countered that IMS was envisioned as a multilateral program and so did not fit within the bilateral framework of the Science and Technology Agreement.7 Directorate General XIII argued more
cogently that any international program involving public funds was de facto a government program and must therefore involve some supervisory role for governments. To underscore this position, both Washington and Brussels insisted that firms which had already agreed to take part in IMS withdraw from the program until a more appropriate framework for collaboration had been developed.

Terms of Collaboration

Four drafts of the IMS proposal appeared between November 1989 and May 1990. The “Version 1” proposal brought by Professor Furukawa to the United States in November 1989 set out potential research themes but did not lay out a framework for IMS. The “Version 2” proposal was distributed in January 1990 to coincide with meetings that formally introduced the IMS Program to Japanese industry and officials from foreign embassies. Still vague on major aspects of project organization, the Version 2 proposal stated that the final design of the program should be left to an international committee. Yet, the proposal did not specify the location of the main administration office for the program, raising fears that a central office located in Tokyo would give Japan control over an immense storehouse of knowledge. These fears seemed to be confirmed in April with the establishment of the IMS Promotion Center in Tokyo, funded on a fifty-fifty basis by MITI and industry. Together with a “Version 3” proposal, the IMS Center issued an international call for research proposals and scheduled the official launch of the program for September 1990.

These events created the distinct impression among foreign governments that Japan was trying to present the terms of IMS as a fait accompli. As George Heaton notes, “the program seemed to be developing altogether too rapidly, with non-Japanese interests under-represented, and basic control aspects--over funding and intellectual property--ill-defined.” Based on these concerns, Washington and Brussels asked MITI to place a moratorium on the program until government-level consultations had taken place.

In preparation for a trilateral meeting in Brussels during May, the IMS Center distributed “Version 4” which presented a more detailed proposal on project organization and the first draft of guidelines on intellectual property rights. Beginning with the disclaimer that it represented only “a basis for discussion” with the United States and the European Union, Version 4 proposed the creation of a management committee with members drawn from government, industry and academia and a technical evaluation committee with members drawn chiefly from academia. Version 4 also proposed that a joint research center, which would serve as the hub of research activities, should be located in the United States or the European Union. This particular proposal was premised on the logic that some part of the research results would be in the form of tacit know-how not easily transferred, and so a greater share of benefits would accrue to the host country than to Japan. Although the European Union pushed to drop the idea of a central research facility in later discussions, Japan's proposal to locate the lab overseas reflects the efforts in IMS planning to respond to foreign pressure and criticism that Japan had to contribute more to international science and technology.

In addition to reservations over project organization, there were specific foreign concerns regarding funding and protection of intellectual property rights. Both the United States and European Union balked at the notion of Japan providing 60% of IMS funding. Although both had been pushing for greater Japanese government funding of science and technology research, the idea was more unsettling in practice than theory. Feeling that balanced benefits were most likely to be achieved between partners of equal weight, the EU called for decentralized consortia with each participant being financed from within its respective region. The United States shared these concerns over funding arguing that each partner should bring technology and not simply money to the project. In addition to the shared preference for a program of equal partners, both Washington and Brussels worried that pooling of funds would further complicate the challenge of designing intellectual property guidelines for such a large-scale, multicultural collaboration.

The IPR guidelines proposed in Version 4 were a second major source of concern for foreign governments. Suggestive of the academic origins of the IMS proposal and MITI's deliberate efforts to keep a low profile, the IPR guidelines were drafted by Professor Furukawa, an engineer, rather than by lawyers. American and European officials were disturbed by the lack of explicit protection mechanisms for both background and foreground
information, and by terms that encouraged as wide application as possible of research results. Version 4 proposed, for example, that academic and public research institutions should transfer ownership of intellectual property resulting from IMS research to an international IMS Organization in order to maximize potential access to the data. As IMS had been promoted with the idea of Japanese firms sharing their hardware expertise, these firms were also very concerned by the vague nature of the guidelines. Expressing the fears of Japanese firms, Tetsuya Oishi of Toyo Engineering stated that "our ability to offer production technology is contingent on the establishment of a system to protect IPR. If that occurs, interest in IMS will expand."14

Another major area of concern for both foreign and Japanese firms was the emphasis placed in Version 4 on Professor Yoshikawa’s ideas about the need for systematization of manufacturing knowledge. Declaring that production technology should be the “common property of mankind,” Version 4 called for the integration and systematization of production technology for the shared use of the industrialized world.15 The concern of American and European officials was that systematization of manufacturing knowledge would simply make foreign technologies easier for Japan to access and indigenize. Yet, it is important to recognize the divergent views within Japan itself regarding systematization. The idea has its roots in academia and although endorsed by MITI has neither been understood nor supported by Japanese industry.

Knowledge systematization lies at the heart of Professor Yoshikawa’s vision of the manufacturing industry of the twenty-first century. In this context, however, the idea is more an academic theory of paradigm change than a pragmatic strategy of technology indigenization. Ascending to the presidency of Tokyo University, Yoshikawa has emerged as one of Japan’s visionary thinkers. Yet, his notion of knowledge systematization has received a less than enthusiastic reception among corporate executives. In the words of one Toshiba executive, Yoshikawa’s theories have a “dream-like” quality.16 In short, the fact that knowledge systematization has become only a minor part of the full-scale IMS program has less to do with foreign efforts to purge techno-nationalistic elements of the Version 4 proposal than with a sheer lack of corporate interest, among even Japanese firms, in the systematization of manufacturing knowledge.

Relative Technological Position

American and European opponents of the IMS proposal did not accept Japanese claims of leadership in computer-integrated manufacturing (CIM). Mark Lieberman, then deputy assistant secretary for technology policy at the Department of Commerce, said the original IMS proposal would not have produced a “balanced, symmetrical, win-win situation,” and that "most of the benefits would have flowed in a direction which our companies are not very comfortable with."17 Fred Nichols of the National Coalition for Advanced Manufacturing argued that American university research driven by NASA and DoD requirements was more sophisticated than Japanese research in areas like visual simulation, artificial intelligence and sensor technology that are crucial to CIM.18

One of the earliest and most vocal European critics of the IMS proposal was CECIMO, an association of machine tool builders, which complained to the European Commission that the program would simply transfer know-how from European firms to their Japanese competitors.19 One of the major European fears was that Japan would gain access to western advances in computer-integrated manufacturing and then flood European markets with standardized parts. In July 1990, the European Commission circulated a draft report comparing European and Japanese manufacturing capabilities. The report acknowledged that Japan led in the rapid conversion of designs into manufactured products but attributed this advantage to cultural factors that could not be readily reproduced in the west. The report also suggested that Japanese claims of superiority in many areas of computer-integrated manufacturing were based on the mistaken belief that European technologies licensed through U.S. distributors were actually American technologies.20

In addition to suspicions that IMS was an effort to access superior western technologies, there was concern that IMS was an attempt to impose Japanese factory automation standards on the rest of the world, and so reinforce the dominant market positions held by Japanese makers of machine tools, robots, and programmable controllers.21 Thus, paradoxically, IMS was seen as both an effort to steal the technologies of western firms and as an attempt to impose more advanced Japanese standards on those same firms. One clearly mistaken fear, in view of the proposed
budget for IMS, was that European firms had no choice but to join the program because the amount of money the Japanese were willing to spend would end up wiping out other CIM efforts anyway.22

The IMS proposal generated a number of suspicions in the United States and European Union about Japanese motivations. Although some of these suspicions were groundless or ascribed contradictory motives to Japan, the proposal itself was vague enough on key issues such as protection of intellectual property rights to raise several legitimate concerns. The fact that Japan directly approached firms and universities rather than first working with government officials lends credence to the techno-nationalist interpretation of IMS. Undermining this argument, however, is the fact that the initial proposal also left important details of project organization to be decided by an international committee. In this sense, the real threat in the IMS proposal was ambiguity rather than a clear strategy of technology indigenization.

Foreign Pressure

Foreign pressure played an important part in both motivating and shaping the IMS program. The role of foreign pressure as a catalyst for IMS is evident both in American diplomatic initiatives to promote collaboration in manufacturing technology, and the consistent reference to trade friction and criticisms of “free riding” in both official and unofficial Japanese discussions of the program. The role of foreign pressure is even clearer in shaping the ultimate form of the IMS program. MITI initially hoped for IMS to begin in the autumn of 1990. Yet, American and European insistence on reshaping the proposal and conducting a feasibility study resulted in protracted negotiations that delayed the launch of the full-scale program until May 1995.

Foreign Pressure as Catalyst

The United States had actively sought to establish linkages with Japan in manufacturing technology prior to IMS. In 1986, the National Science Foundation approached the Japan Society for the Promotion of Science (JSPS) about establishing a project to encourage bilateral collaboration in manufacturing research. Teams of academics and corporate executives from both countries met during 1988 and 1990 to discuss themes and management structures for collaboration. At the 1988 meeting, both nations agreed that sensor, control, and computer integration technologies were strong candidates for joint-research and decided to develop joint programs to address these areas.25 Thus, the NSF initiative served as a catalyst for bilateral collaboration three years before the IMS proposal.

The second application of foreign pressure to open the Japanese manufacturing industry came during 1988 with negotiations on the revision of the U.S.-Japan Science and Technology Agreement. Manufacturing technology was one of seven fields designated in the agreement as a priority area for development of collaborative projects. It is important to note, however, that Japan rather than the United States first tabled the idea of a five-year joint project in manufacturing during these negotiations.24 Although technological complementarity was a major factor driving Japanese interest in collaboration in manufacturing technology, as will be discussed later in the paper, the weight of foreign pressure in motivating IMS is reflected in all Japanese discussions of the program.

In both official and unofficial Japanese discussions of IMS, there is consistent emphasis placed on the need for Japan to ease trade frictions with the west and make contributions to international science and technology commensurate with its economic strength. The final report of the Yoshikawa kondankai, which makes the first official mention of plans for IMS, cites trade frictions and the need for greater international contribution before discussing the technological forces motivating a collaborative research program.25 The fashion in which IMS was presented to the international community also suggests an effort to maximize the public relations value of the program. Architects of the IMS proposal described the program as a sharing of torn no ko, literally translated as “tiger cub,” or Japan’s most treasured technology.26 Aspects of the proposed program structure also made concessions to techno-globalism not dictated by economic or technological necessity. Japan suggested, for example, that the main IMS research facility be located in either the United States or Europe.
The role of foreign pressure in motivating IMS was also not lost on the Japanese press. In its comprehensive coverage of the early stages of the program, the *Nikkei Sangyō Shim bun* consistently mentions the role of foreign pressure, on one occasion stating that “IMS is more to reduce trade friction than to increase Japan’s international contribution.” Yet, perhaps, the most cynical testimony to the role of foreign pressure in explaining the motivations behind IMS comes from a Hitachi executive, who while maintaining the technological importance of the program to his firm, recalled that “MITI cared less about the substance of the program than the fact that it was international.”

**Foreign Pressure in Shaping the IMS Program**

Both the United States and the European Union played a major role in shaping the ultimate form of the IMS Program. In April 1990, Washington and Brussels each asked MITI to stop making direct contact with firms and industry associations until government officials had agreed to a framework for further discussions. The following month representatives from MITI, the U.S. Department of Commerce, and Directorate-General XIII of the European Commission met in Brussels and agreed to suspend the original MITI proposal. They also agreed that the decision to proceed with IMS could only be made after all three parties reached consensus on modalities for collaboration, research themes, intellectual property rights provisions, and funding arrangements.

A follow-on to the Brussels meeting was scheduled for July 1990 but later postponed as government-industry consultations continued in the U.S. and Europe. By late summer, the Department of Commerce had drafted a counter-proposal based on the results of two IMS workshops organized to canvass the views of industry. In addition to specifying areas of potential collaboration, the counter-proposal stated that each party should have equal voting rights and control over the composition of financial and other regional contributions. In the same month, the European Union issued its counter-proposal for a “Future Generation Manufacturing System.” The European counter-proposal agreed that consortia should be organized on a decentralized basis with each participant financed from within its own region. The Europeans also called for a feasibility study to work out appropriate modalities for collaboration and provisions for the protection of intellectual property rights.

The American and European counter-proposals formed the basis of discussions at a second tripartite meeting held in Tokyo in November 1990 which was also attended by observers from Australia, Canada, and the European Free Trade Association. At this meeting, the American, European, and Japanese delegations agreed to conduct an IMS feasibility study. After a year of further consultations with industry, Australia, Canada, Japan, the United States, and a combined EU/EFTA delegation adopted “Terms of Reference” establishing the parameters of the feasibility study. The terms of reference divided the feasibility study into approximately one year of committee work to establish the modalities of collaboration and a second year of trial consortia to test these modalities.

Foreign pressure played a crucial part in motivating and shaping the IMS program. The catalytic role of foreign pressure can be seen in American diplomatic initiatives to build collaboration in manufacturing and the consistent mention of the need to reduce trade frictions in Japanese discussions of IMS. The role of foreign pressure is even clearer in the aggressive American and European efforts to reshape the program to better meet their own preferences.

**Scientific and Technological Factors**

Underlying foreign interest in reshaping the IMS program were opportunities to advance manufacturing technology through the pooling of financial resources and the matching of complementary national capabilities. The Version 4 proposal cites six trends that it claims challenge the foundation of the manufacturing industry in every industrialized society: (1) the diversification of consumer needs, (2) the globalization of manufacturing, (3) the appearance of isolated islands of manufacturing, (4) the hollowing out of industry, (5) the changing labor environment, and (6) the insufficient systematization of existing technology. The first three trends reflect the short-term concerns of firms while the latter three reflect broader societal and academic concerns.
The heart of corporate interest in IMS, discussed in more detail later with reference to the test-case consortia, is responding to the short-term challenges posed by the diversification of consumer needs and globalization. At the factory level, firms confront the challenge of designing “variable-kind variable-lot” production systems which can respond quickly to custom orders and changing demand conditions. In the longer-term, IMS envisions a shift from the present make-to-stock and sell-from-stock practices to manufacturing only the products wanted in only the quantities wanted. On the management level, firms face new technological challenges as they attempt to coordinate the entire range of corporate activity from research to delivery on a global basis. A major goal of IMS is to develop technologies that would connect these pockets of automation in a seamless thread.

In addition to these corporate concerns, the Version 4 proposal also cites broader societal challenges common to the advanced industrial economies. The first challenge is the hollowing out of local manufacturing capabilities as firms transfer production abroad in search of cheaper labor. As one of the main architects of the Version 4 proposal, Professor Furukawa suggests that fear of the hollowing out of the Japanese manufacturing sector during the late 1980s was one of the most important factors driving the IMS proposal. The second challenge is bolstering the deteriorating image of the manufacturing sector as students, and even trained engineers, seek employment in sectors offering higher wages. The proposal also cites the need for increased systematization of knowledge reflecting Professor Yoshikawa’s belief that manufacturing is on the verge of becoming an academic science that can be systematized in a unified data base to facilitate technology transfer.

Both the United States and European Union agreed that the trends identified in the Version 4 proposal represent common challenges to the manufacturing industries of the advanced industrialized nations. As a result, subsequent IMS planning documents drafted by international committee cite these same trends as well as the additional challenge posed by the need for the manufacturing industry to preserve natural resources and the environment. The idea of using IMS to address the environmental impact of manufacturing was suggested initially by the European Union. Although this dimension of the program has played an important public relations role in providing a concise explanation of IMS to those outside the manufacturing community, research on environmental themes has not, to date, generated significant interest among firms.

On the whole, there was broad international agreement on the challenges confronting the manufacturing sector but uncertainty in Washington and Brussels as to whether IMS would be an effective means to address those challenges. Version 4 argued that IMS would not only eliminate redundant R&D investment by unifying standardization efforts but would develop better technology by leveraging national strengths through international collaboration. The proposal suggested that IMS could combine Japanese expertise in hardware, such as machine tools and robotics, with American expertise in software and network technology, and European expertise in precision machinery. This idea met with cautious reactions from Japanese industry as well as foreign firms and governments uncertain about how to achieve balanced exchange.

Japanese Industry and the IMS Proposal

The strongest base of support for IMS came from firms that had taken an active role in the Yoshikawa kondankai during the summer of 1989. Among these firms were major electrical equipment makers like Hitachi and Toshiba as well as construction firms like Shimizu and Kajima. The IMS proposal was announced to Japan’s manufacturing industry at a January 1990 forum attended by over 130 members of the International Robot and Factory Automation Center (IROFA) and the Japan Industrial Robot Association (JIRA). By April 1990, an IMS Promotion Center had been established within IROFA. While the latter is an industry association funded entirely by firms, the former is a tokushu hojin or special legal entity funded on a fifty-fifty basis by MITI and membership dues from firms. The IMS Center included sixty-seven manufacturing firms as core members and seventeen firms, including banks and trading companies, as supporting members.

The fact that over eighty firms had signed on to support IMS in under four months would suggest that the program had strong support within industry. Yet, even several core members harbored serious reservations about IMS. Seiuemon Inaba, then president of Fanuc, declared that his company might provide basic technology in an
IMS program but would not share existing know-how. Yutaka Matsumura, then managing director of Hitachi's wholly-owned subsidiary Hitachi-Seiki, stated that many firms opposed the IMS project, especially the high membership fee of one million yen per month. He explained that the main reason his firm was taking part in IMS was to gain a better sense of the technological direction being taken by the larger firms in the program.

According to sources both within and outside the program, MITI's "power of persuasion" had a major influence on the rapid speed with which members were recruited. Almost all of the firms that joined the IMS Center fall under the regulatory net of MITI's Machinery and Information Industries Bureau. Although these electronics and machinery manufacturers, especially those with global operations, would have the most to gain from participation in IMS, such participation does not necessarily equate with genuine commitment to the program. The actual degree of participation in IMS research activities provides a better gauge of industry interest.

Prior to the start of the international feasibility study, the IMS Center began a domestic feasibility study in February 1991. The core members were divided into five research groups, each under a prime contractor, working on themes including intelligent machines and information integration. From these discussions, plans emerged for eighteen test-case consortia, two of which would later become test-cases in the international feasibility study. The domestic study was organized both to prepare candidate consortia for an international program and to retain momentum until the international IMS program began. Certain firms were dismayed by the delay in beginning the international program and wanted some return on their membership dues in the meantime. The domestic study also laid the groundwork for a potential national project if the United States and European Union decided ultimately to reject the Japanese proposal.

All core members of the IMS Center took part in at least one of the test-case consortia of the domestic feasibility study. Among these firms, some were more active than others. Canon, Kubota, Honda Engineering, Mitsubishi Materials, and Yamatake-Honeywell all participated in at least three consortia while more than twenty firms including Matsushita, Nippondenso, and Sharp took part in two test-cases. Some of these consortia reported early successes. For example, Hitachi announced development of a computerized order-taking system linked to a computer-aided design system and flexible robot production system that would be capable of handling changes in production plans according to market trends. Hitachi introduced the system into one of its home appliance factories in 1992. Although two-thirds of the test-case projects disbanded, six had moved on to become consortia in the full-scale, international IMS program as of early 1997.

International Response to the IMS Proposal

The international response to the Version 4 proposal suggests that despite serious reservations regarding the exact terms of collaboration both foreign firms and governments saw potential for meaningful technological exchange. Thus, the clearest indications that scientific and technological factors played an important role in the launching of IMS lay not in Japanese pronouncements but in the initial interest shown by foreign firms, and the efforts made by foreign governments to build on the proposal rather than dismiss it as simply an effort to access western technologies.

In response to the initial call for research proposals in April 1990, the IMS Promotion Center received almost one hundred submissions with sixty-eight coming from Japan, fourteen from the United States, twelve from Europe, and one from Australia. Of these proposals, fifty-six came from firms and thirty-nine from public research institutes. In the United States, United Technologies played a leading role in the formation of an ad hoc industry group whose members included Digital Equipment Corporation, General Motors, Rockwell, and TRW. The ad hoc group met several times during 1990 to discuss American interests in IMS and dispatched representatives to consult with Japanese firms like Fanuc and Toyo Engineering about potential areas of collaboration. It was also the ad hoc group that asked the U.S. government to take a leadership role in the negotiation of an effective framework for protection of intellectual property rights.

Of the firms that formed the ad hoc industry group, some have gone on to take part in IMS while others have not. Digital Equipment, TRW, and General Motors did not take part in the IMS feasibility study although General
Motors has since become involved in one of the consortia of the full-scale program. The interest of the American private-sector in IMS has also spread beyond the original members of the ad hoc group. Firms like Honeywell, Kodak, and Caterpillar have also contributed to plans for consortia in the full-scale program. From the start of the IMS program, however, United Technologies and the Alien-Bradley division of Rockwell have been the most active American firms. Executives from each firm have served on IMS committees and both firms assumed the role of regional coordinator in feasibility study test-cases.

Both United Technologies and Alien-Bradley saw a chance to gain insights into emerging standards through participation in IMS. According to Stan Krueger, who served as president of United Technologies Japan, "the risks of participation in IMS are quite low so why wouldn't you at least try? The only people who will lose are those who do not play." James Christensen explained Alien-Bradley's approach to IMS as follows:

We join IMS principally to augment our understanding of the direction that the market will follow in the next century. As world leaders in standardization for industrial process and measurement control, we need to understand the types of standards which will be required in the next century...Allen-Bradley's advantage consists not in proprietary information development in IMS, but in our ability to deliver products and services into this evolving market.

While individual American and European firms may have seen the potential for important technological complementarity in the Version 4 proposal, government officials were more concerned about protecting the broader national interest and the vitality of national manufacturing industries. In addition to reservations over specific terms of collaboration discussed earlier, Washington and Brussels were concerned about how much useful technology the participating Japanese companies would have to offer. Although several major firms like Hitachi, Toshiba, and Toyota were charter members of the IMS Center, other major manufacturers like Matsushita and Sony were much slower to join the program. Despite such concerns, however, the United States and European Union worked to reshape the IMS proposal into a framework closer to that of ESPRIT and EUREKA. These efforts suggest that reservations about IMS concerned the terms of collaboration rather than the lack of potential for mutually-beneficial collaboration.

Although there was no history of Japan-EU collaboration in manufacturing technology prior to IMS, serious discussion of U.S.-Japan research collaboration in this area predates the IMS program by four years. In 1986, the National Science Foundation and the Japan Society for the Promotion of Science (JSPS) opened talks which produced a 1988 agreement to develop joint programs in product realization and intelligent manufacturing control--two concepts at the core of IMS. The former focuses on streamlining the process of taking a concept from innovation to saleable product through more effective integration of planning and technology. The latter centers on the design of a fully automated factory that would be capable of controlling, rather than simply responding to, the manufacturing environment. With substantial crossover in both technical themes and the personnel involved on the Japanese side, the IMS proposal is in many ways an outgrowth of the NFS-JSPS discussions.

The United States and the European Union were not the only ones to see potential technological benefits in IMS. Although Japan initially proposed IMS as a tri-polar collaboration with the United States and European Union, several other nations including Australia, Canada, Korea, and the European Free Trade Association (EFTA) countries expressed interest in joining IMS. For these countries, with their smaller manufacturing industries, the potential benefits of participation in IMS far outweighed the risks. In the case of Canada, for example, Michael Wilson, then minister for industry, explained that partnerships like IMS are "just as important to Canada as technology is in creating a wedge for greater penetration of foreign markets...for Canadian companies the question of learning and adopting these techniques is literally one of survival." Yet, decisions about which countries outside the triad should be allowed to take part in IMS reflect political as well as technological considerations. According to one Japanese source, the United States pushed to broaden membership beyond the triad in order to weaken the voice of Japan in managing the program. The least controversial membership decisions involved Canada and EFTA which appeared as natural extensions of the United States and European Union, respectively. In fact, the EU and EFTA subsequently combined resources to form one
regional European secretariat. Much more controversial was the decision to allow Australia but not South Korea to participate in IMS.

Although not regarded as a major manufacturing nation, Australia gained admittance to IMS largely because of its status as a G-7 nation. The exclusion of South Korea from IMS has been perceived by some western firms and journalists as an effort by Japan to keep a major backyard competitor at bay. Yet, according to Kenzo Inagaki, former director of MITI's industrial machinery division, Korea was not technologically advanced enough to participate in IMS. Despite the fact that Korean conglomerates like Hyundai and Samsung made major strides in exports of automobiles and electronics beginning in the mid-1980s, Korea did not fit the profile of "advanced industrial nation" met by other IMS members. Korea is not a member of the OECD and at the time was yet to join the World Intellectual Property Organization (WIPO). Although Korea may have a more dynamic manufacturing sector than Australia, the International Steering Committee did not believe that the country met the membership criteria for IMS.

Relative Importance of Factors Driving the IMS Proposal

The role of techno-nationalism in MITI's support of the IMS program is not clear-cut. Although Japan's first proposal stated that research themes and projects should be selected by an international committee, the proposal was sufficiently vague on key issues such as protection of intellectual property rights to raise legitimate suspicions among foreign governments. Most disturbing to Washington and Brussels was the fact that MITI approached firms and universities directly rather than first gaining approval through official channels.

Much more important than techno-nationalism was the role of foreign pressure. American interest in collaboration with Japan on manufacturing technology predates IMS by several years. This American interest is apparent in both NSF efforts to establish collaboration and the renegotiation of the Science and Technology Agreement. Moreover, Japan's initial IMS proposal made several concessions to techno-globalism much better explained by foreign pressure than technological imperatives. Much of the American interest in greater collaboration in research on manufacturing was due, of course, to technological complementarity in Japanese and American capabilities. Thus, Japan's IMS proposal was more than a public relations gesture. For Professor Yoshikawa it was about accelerating the transition to a new paradigm in manufacturing while for MITI it was about leveraging complementary foreign capabilities. The following section moves from the forces motivating Japan's IMS proposal to an overview of the IMS framework that emerged from international discussions during 1992-93.
### Table 1
Relative Importance Of Factors Driving Internationalization Of The IMS Program

<table>
<thead>
<tr>
<th>Techno-Nationalism</th>
<th>Moderate Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The initial Japanese proposal reflects a clear interest in accessing superior western capabilities in software and systems integration.</td>
<td></td>
</tr>
<tr>
<td>• Yet, the proposed terms of collaboration did not maximize the potential for indigenization of these technologies. The IMS proposal left the details of project organization and IPR to be decided by international committee.</td>
<td></td>
</tr>
<tr>
<td>• Nevertheless, Japan's direct recruitment of firms suggest that Japan had hope to present the program to foreign governments as a fait accompli.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foreign Pressure</th>
<th>Major Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Foreign pressure played a major role in motivating and shaping IMS.</td>
<td></td>
</tr>
<tr>
<td>• The NSF first sought to establish collaboration in manufacturing tech in 1986.</td>
<td></td>
</tr>
<tr>
<td>• Manufacturing technology was designated a priority area for collaboration in the 1988 revision of the US-Japan Science &amp; Technology Agreement.</td>
<td></td>
</tr>
<tr>
<td>• The goal of easing trade frictions is clear in IMS planning documents and Japanese press coverage of the program.</td>
<td></td>
</tr>
<tr>
<td>• Japan's initial IMS proposal made key concessions to techno-globalism not dictated by technological or economic necessity.</td>
<td></td>
</tr>
<tr>
<td>• After asking Japan to retract its initial proposal, the US and EU renegotiated the terms of collaboration</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scientific &amp; Technological Factors</th>
<th>Major Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>• International agreement on common challenge posed by diversification of consumer needs and globalization of manufacturing etc.</td>
<td></td>
</tr>
<tr>
<td>• Int'l agreement on opportunity to leverage complementary capabilities of partners e.g. Japanese hardware, US software, EU precision machinery etc.</td>
<td></td>
</tr>
<tr>
<td>• Indicators of technological complementarity including crossover in research themes with NSF-JSPS program and formation in US of the ad hoc industry group.</td>
<td></td>
</tr>
</tbody>
</table>

### II. IMS as a Framework for International Collaboration

The framework of the IMS program evolved significantly over the years 1990 to 1993. What began as a MITI-sponsored initiative incorporating international participation in planning and evaluation became a fully-fledged international program with a decentralized management and funding structure. IMS is not simply a departure from earlier MITI research programs but a unique experiment in international R&D collaboration that applies elements of Europe's ESPRIT and EUREKA programs on a global scale. In other words, firms and universities have the freedom to develop their own consortia within the broad parameters of the IMS framework which establishes eligible technical themes, regional membership requirements, and guidelines for protection of intellectual property rights. Yet, unlike ESPRIT and EUREKA which were designed to strengthen the competitiveness of European firms vis-a-vis American and Japanese competitors, each IMS consortia must have partners from at least three of the IMS regions.
Developing the IMS framework required overcoming suspicions of Japanese motives in proposing the program, as well as different regional research interests and attitudes regarding government support of industrial research programs. This section presents a brief overview of the structure of the IMS organization and the modalities developed to manage international collaboration.5

Management Structure

The feasibility study was governed by an International Steering Committee (ISC) which met six times over the two-year period from February 1992 to January 1994. The committee was composed of thirty members: five each from Australia, Canada, Japan, and the United States, and ten from the combined EU/EFTA delegation. The majority of ISC members were corporate executives, at the vice-presidential level or above, from major firms like ICI, Daimler-Benz, Motorola, Rockwell, Toshiba, and Toyota.

Working under the ISC were the International Technical Committee (ITC) and the International Intellectual Property Rights Committee (IIPRC). The thirty members of the ITC recommended technical themes for the feasibility study and developed criteria for selecting and evaluating test-case proposals. The eighteen members of the IIPRC developed guidelines for the creation, protection, and equitable dissemination of intellectual property rights discussed later in this section. Both of these committees also met six times with additional meetings held by interim task forces.

The third leg of the management structure was formed by regional secretariats including: MITI, the EU’s Directorate-General XIII (later Directorate-General III), the U.S. Department of Commerce, Canada’s Department of Industry, and Australia’s Department of Industry, Technology and Regional Development. The secretariats disseminated program information, circulated expressions of interest among potential partners, and organized the various committee meetings. The work of the regional secretariats was supported by private organizations including: the IMS Promotion Center in Japan; the Coalition for Intelligent Manufacturing Systems (CIMS) in the United States; the IMS Ad Hoc Group in the European Union; an Industrial Advisory Council in Canada; and Australia’s Industry Research and Development Board.

The basic modalities of the IMS program were established during the first two meetings of the ISC. The committee agreed that each test-case should have partners from at least three of the five regions, and that prospective partners must show how contributions to, and benefits from, each consortium would be equitable and balanced. The ISC further agreed that test-case consortia should have significant industrial participation, and that the set of test-cases should address as many phases of the innovation process as possible. The committee stipulated, however, that projects using government funds should involve only pre-competitive research.

To assist potential applicants in submitting proposals, the ITC identified six general areas as technical themes for the feasibility study: enterprise integration, global manufacturing, system component technologies, clean manufacturing, advanced materials processing, and human and organizational issues. In addition to establishing technical themes, the ITC also developed criteria for the mid-term and final assessments of the test-cases. Discussion on IMS had advanced sufficiently by 1992 that the main problems confronting the ISC and ITC in organizing the feasibility study were logistical rather than substantive ones. Yet, the management of intellectual property rights raised many complex questions, many of which would remain unresolved even after the feasibility study.

Intellectual Property Rights and IMS

The IMS program divides IPR into two categories: (1) background rights existing prior to the commencement of an IMS consortium, and (2) foreground rights created during IMS research. With the intent that firms do not use their background rights to block partners from using foreground intellectual property generated in an IMS consortium, IMS guidelines require that background rights be licensed on normal commercial terms when those rights are necessary for the commercial exploitation of foreground intellectual property. The guidelines further propose that
foreground intellectual property should be owned by the party or parties generating it and licensed on a royalty-free basis for R&D and commercial exploitation to other partners in the same project.

The IMS rules on IPR represent a departure from those in other MITI industrial programs in that the Japanese government acquires no ownership of intellectual property through its provision of funding. The rules also break new ground on a more general level with provisions allowing licensing to third parties, and disclosure requirements that aim to eliminate obstacles to participation in IMS. To encourage the diffusion of IMS results, a joint owner of intellectual property developed in an IMS consortium may license it to third parties without the consent of, and without accounting to, co-owners unless otherwise agreed. To reduce concerns about potential conflicts in enforcing IPR provisions, IMS also requires that all parties provide advance notice to partners of government requirements that might impact their compliance with these provisions. Furthermore, to reduce worries that IPR expressly licensed to one entity may be transferred to an affiliate of that entity, thereby helping a competitor, the IMS rules also require partners to disclose, at the beginning of the project, all participating affiliates.

Testing the IMS Framework

The goal of the second stage of the feasibility study was to test the IMS framework in three test-cases that would shed greater light on the costs and benefits of organizing R&D collaboration on a global scale. Applicants were required to submit consortium cooperation and IPR agreements. After regional evaluations, eleven proposals were submitted for consideration by the ISC. Of these proposals, six were selected as test-case projects. The experience of major corporate partners in each of these projects is examined more closely in the following section.

III. Corporate Experience in the IMS

Test-Case Consortia

This section uses the six test-case consortia of the international feasibility study as a window through which to examine the experience of leading American, European, and Japanese firms in IMS. A survey of all participants in the IMS feasibility study, conducted by the International Technical Committee, suggests that the test-case partners were, on the whole, able to identify projects requiring international collaboration, and overcome any cultural differences in managing consortia with "equitable and balanced" regional contributions (Table 2). The final report of the IMS International Steering Committee issued in January 1994 summarizes the results of the feasibility study as follows:

The feasibility study clearly demonstrated that the guiding principles embodied in the Terms of Reference were workable and necessary, and that the IMS framework enhanced global manufacturing cooperation. It facilitated establishment of relationships amongst large companies, small companies, academic and research institutions, and public authorities on a world-wide scale. It provided a structure for sharing intellectual property in international consortia, and allowed this structure to be thoroughly tested.

International collaboration provided added value which outweighed additional overheads incurred through collaboration on this scale.

In order to put these claims in perspective, this section takes a closer look at the organization and accomplishments of each test-case, and the experiences of corporate partners from different regions. Rather than duplicating the broad survey approach of the ITC evaluation, this section contrasts the interests and experiences of a smaller group of firms from different industrial sectors that took an active part in the test-case consortia. It examines the motivations of these firms for joining IMS and how the program fits with their broader R&D strategies. Of the six test-case consortia, three disbanded following the feasibility study while the three others went on to become consortia in the full-scale program. This section begins with an overview of the former group and their reasons for disbanding, and then moves on to the experiences of the latter group and the factors driving their decisions to make a longer-term commitment in the full-scale IMS program.
Table 2  
IMS Partner Survey

<table>
<thead>
<tr>
<th>Survey Questions</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consortium Formation and Organization</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Did you readily recognize a problem which required international collaboration?</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>• Did the consortium build on existing links?</td>
<td>58</td>
<td>42</td>
</tr>
<tr>
<td>• Were there difficulties in convincing partners with “tech advantage” to share their expertise?</td>
<td>34</td>
<td>66</td>
</tr>
<tr>
<td>• Were these difficulties resolved?</td>
<td>7</td>
<td>93</td>
</tr>
<tr>
<td>• Was funding a problem in forming consortia?</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>• Due to difference in regional funding mechanisms?</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>• Should there be a limit on the number of partners?</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>• Regionally?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Inter-regionally?</td>
<td>46</td>
<td>54</td>
</tr>
<tr>
<td>• Were IMS secretariats helpful in formation of consortia?</td>
<td>73</td>
<td>27</td>
</tr>
<tr>
<td>• Was the exchange of interested parties lists useful?</td>
<td>67</td>
<td>33</td>
</tr>
<tr>
<td>• Was requiring collaboration between at least three regions necessary?</td>
<td>87</td>
<td>13</td>
</tr>
<tr>
<td>• Did regional cultures have an inhibiting influence on your consortium?</td>
<td>28</td>
<td>72</td>
</tr>
<tr>
<td><strong>Technical and IPR Agreement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Difficulties in reaching agreement on project goals?</td>
<td>37</td>
<td>63</td>
</tr>
<tr>
<td>• Did you readily define work packages?</td>
<td>84</td>
<td>16</td>
</tr>
<tr>
<td>• Was there difficulty in arriving at a common, coherent statement of work?</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>• Was it difficult to agree on timing/content of deliverables?</td>
<td>21</td>
<td>79</td>
</tr>
<tr>
<td>• Were there impediments to arriving at an IPR agreement?</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>• Were there difficulties encountered in achieving “equitable and balanced” contributions?</td>
<td>32</td>
<td>68</td>
</tr>
<tr>
<td>• Regionally?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Inter-regionally?</td>
<td>53</td>
<td>47</td>
</tr>
</tbody>
</table>

*Data from ITC Survey of all Test-Case Partners  

The Disbanded Test-Cases

Three of the six IMS test-case consortia decided to disband following the feasibility study. Although each test-case disbanded for slightly different reasons, money was a factor in each decision. In the clean manufacturing test-case, the Japanese coordinating partner thought potential results too long-term. In the rapid product development test-case, the American coordinating partner found the overhead costs of supporting academic partners as too high to justify continuing with the project. Finally, the global concurrent engineering test-case was essentially an academic survey lacking active industrial partners willing to apply the survey results in a full-scale consortium. Yet, the decision to disband made by these particular test-cases does not rule out future consortia in these same areas. A
different group of firms and universities has, for example, received ISC approval to assemble a second rapid product
development consortium in the full-scale program.

1) The Clean Manufacturing Test-Case

The proposal for the clean manufacturing consortium begins with the now commonplace observation that
environmental issues are best addressed on a global scale. It argues further that the IMS program would provide an
ideal platform for industrial coordination of such an international effort. The initiative for the consortium came
from British chemical giant ICI. Under the full-time direction of four ICI managers, the clean manufacturing
consortium involved collaboration between twelve firms and research institutes from Canada, Europe, Japan, and
the United States (Table 3).

Table 3
Clean Manufacturing Test-Case Partners

<table>
<thead>
<tr>
<th>Country</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Atitibi-Price</td>
</tr>
<tr>
<td>EU/EFTA</td>
<td>ICI, Foster Wheeler Italiana, John Brown Engineers, Marex Technology, Finnish Forest Industries Federation, VTT, Finnish Pulp and Paper Institute</td>
</tr>
<tr>
<td>Japan</td>
<td>Toyo Engineering, Teijin, Tokyo Institute of Technology</td>
</tr>
<tr>
<td>United States</td>
<td>DuPont</td>
</tr>
</tbody>
</table>

With the expectation that some funding would be available to each member from its national government, the
partners planned a total consortium effort of approximately twenty person-years plus associated fixed costs.
Although the American and Canadian partners did not receive any government subsidy, they elected to continue
with the project at a reduced level. Reflecting both European leadership and dramatically reduced Canadian
participation, regional resource contributions for the completed project broke down as follows: the European Union
33%, EFTA 12%, Japan 27%, the United States 26%, and Canada 2%.5 6

At the inaugural partner meeting, a number of workshop sessions and prioritization votes were used to identify
thirteen study topics. The basic objective of these research themes was to assess promising generic technologies for
cleaner manufacturing and the current engineering and economic constraints on development and application of
such technologies in the chemical, pulp, and paper industries. The data collected for the test-case drew on the
practical knowledge of over four thousand engineers, scientists, and managers working in the process industries.

Technical and Management Results

The consortium identified three main barriers to the adoption of clean manufacturing in the process industries: (1)
lack of information on the practical use of available technologies, (2) uncertainty of financial returns on investment,
and (3) uncertainty regarding national legislative environments. A unifying finding of the consortium studies was
that there are very few fundamental scientific barriers to clean manufacturing. The major barrier is an
overwhelming lack of information on the cost, efficacy, and scalability of available technologies. The
information which does exist is at a fundamental level based on lab experiments and trials. Massive investment in
R&D and demonstration is still required before firms will be prepared to take the risks of implementing candidate
technologies on an industrial scale. The consortium concluded that international collaboration could help speed the
adoption of clean manufacturing by reducing the costs and risks of moving technologies from the lab stage to pilot-
plant testing, and providing better networks of information on the evolution of environmental legislation.
On the management level, ICI used the consortium as a test of software-based project control procedures requiring regular input from all partners on costs and technical progress in work tasks. The team concluded that these procedures, while more commonly used on capital projects, were an effective tool for management of collaborative R&D projects. On a more general level, collaboration through the IMS framework resulted in both “cross fertilization” between industrial sectors and the development of common interest groups across regions. In bringing together chemical firms with pulp and paper firms, the test-case opened up new opportunities for technology transfer such as the sharing of ultra-filtration techniques with the pulp and paper industry where this technology had not been previously considered. The international network of contacts generated through the IMS framework also created potentially self-sustaining collaboration between different regions. In the area of water management, for example, inter-regional meetings continued beyond the end of the test-case.

The Decision to Disband

The final test-case report states that clean manufacturing is “fundamental to the long term creation of wealth in the process sectors and for short and medium term competitive advantage.” The decision to disband the consortium suggests, however, that not all participants were convinced that this is really the case. The ICI management team was pleased with the work done in the test-case and was prepared to continue the project if it had received financial support from the European Commission. Although the IMS consortium disbanded, the research of the clean manufacturing test-case formed the basis for discussions of the European SUSTECH initiative launched in April 1994. Organized with the assistance of the European Chemical Industry Council, the SUSTECH program supports the development of environmental management technologies to ensure the long-term sustainability of Europe’s processing industries. European chemical firms felt regional collaboration more appropriate than the inter-regional and inter-sectoral collaboration in IMS.

In Japan, the test-case had attracted only two firms. A staff of ten managers and researchers from Toyo Engineering had worked on the test-case, three of them full-time. Yet, upper management at Toyo thought potential results too long-term to justify continued participation in the project. Meanwhile, Teijin withdrew altogether from membership in Japan’s IMS Promotion Center following the completion of the test-case. As a maker of fiber and chemical products, Teijin was one of the few firms outside the jurisdiction of the Machine and Information Industries Bureau to take part in IMS. Teijin felt it had little to gain from collaboration with manufacturers of machine products and had joined the clean manufacturing test-case primarily because of the participation of ICI and DuPont.

2) The Rapid Product Development Test-Case

After a meeting in October 1992 to discuss potential collaborative opportunities in the IMS feasibility study, Daimler-Benz, United Technologies, and Pratt & Whitney-Canada agreed to submit an IMS proposal on the general theme of rapid product development with a focus on rapid prototyping and measurement technologies. The project had four major technical objectives: (1) conduct a worldwide assessment of rapid prototyping, 3D measurement systems, and conversion technologies for product development; (2) map product development cycles comparing conventional manufacturing methods to those that employ rapid prototyping techniques; (3) determine organizational and management issues associated with integrating rapid prototyping into the product development cycle; and (4) identify guidelines for the manipulation of measurement data for comparison to CAD models that are necessary for long-term industrial standardization. The project involved twenty-two partners from four IMS regions (Table 4).
Table 4
Rapid Product Development Test-Case Partners

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>HPM Industries, Queensland Manufacturing Institute, Swinburne University of Technology</td>
</tr>
<tr>
<td>Canada</td>
<td>Pratt &amp; Whitney, Cercast, Ecole Polytechnique, McMaster University, National Research Council, University of Western Ontario</td>
</tr>
<tr>
<td>European Union</td>
<td>Daimler-Benz, Mercedes-Benz, IPA Fraunhofer Institute, University of Karlsruhe</td>
</tr>
<tr>
<td>United States</td>
<td>United Technologies Research Center, Carnegie Mellon, MIT, Pratt &amp; Whitney, Purdue, Rensselaer, Sandia National Lab, University of Texas</td>
</tr>
</tbody>
</table>

Technical and Management Results

The assessment of rapid prototyping technologies resulted in the fabrication of forty common test parts by thirteen firms from all over the world. The test-case produced several public domain reports identifying the comparative cost, training, system capability, and processing time required to fabricate test parts as well as proprietary reports comparing qualities such as dimensional accuracy and surface finish. One of the main contributions of the test-case was the identification of opportunities to apply these technologies in areas like design verification and the conversion of prototypes into materials for performance and testing. In the area of measurement technology, a variety of contact and non-contact systems were used to measure the common test parts and to create new CAD databases from the measured data.61

The test-case created new relationships within and between regions and even within companies themselves. At the intra-firm level, for example, the consortium resulted in a first-time coordination of rapid prototyping activities in Daimler-Benz. At the intra-regional level, United Technologies, Daimler-Benz, and Pratt & Whitney each made substantial collaborative agreements with regional universities that they had not worked with prior to the program. On the inter-regional level, the test-case created new relationships between Daimler-Benz and Canada's National Research Council as well as several agreements between U.S. partners and the Canadian firm Cercast. In addition to two major partner meetings, site visits and multimedia conferencing, the consortium held a three day conference in Stuttgart in February 1994 that served as the primary vehicle for technology transfer among partners.62

On a managerial level, the consortium encountered a number of problems in partner selection and commitment. Much less assistance was received from regional secretariats than anticipated in matchmaking between potential partners. The short lead-time for proposal preparation also made it impossible to recruit Japanese partners despite serious efforts by both United Technologies and Daimler Benz. Schedule slippage early in the test-case resulting from the withdrawal of the initial Australian coordinating partner, Moldflow, also suggested the need for more formal contractual agreements on partner commitment.63 Added to these problems in launching the consortium were problems in managing the test-case itself. The coordinating partners feel that there were too many members for the structure adopted and that a better methodology had to be developed for managing a consortium of twenty-two partners. They estimate that almost two person-years were spent on administrative and coordination activities in each region. Far more than estimated at the outset of the test-case, this figure represents over 25% of the twenty-four person-years of effort expended in the program.64

The Decision to Disband

The rapid product development consortium was one of the more highly praised of the six test-cases. According to the International Technical Committee, the project demonstrated an “extraordinary level of activity and research...
quality" with more accomplished through international collaboration than would have been possible otherwise.\textsuperscript{65} Yet, despite this favorable evaluation, the coordinating partners decided against developing a proposal for the full-scale IMS program. For United Technologies, the decision was a financial one.

While partners from Australia, Canada, and Europe all received some subsidies from their national governments, United Technologies received no government support. In addition to absorbing the higher than anticipated management and coordination costs, United Technologies ended up subsidizing the participation of American universities. According to Richard Aubin, the involvement of United Technologies was in many respects a give-away. Although the firm learned a great deal from the project, it also paid a lot for this knowledge. Without partial subsidy from the U.S. government and a clearer tie-in with the needs of UTC working divisions like Otis and Pratt & Whitney, the firm could not justify further participation in the consortium.\textsuperscript{66}

3) The Global Concurrent Engineering Test-Case

The term “concurrent engineering” was coined in a 1988 Institute for Defense Analysis report to describe a new approach to product development being implemented by certain U.S. defense contractors. Also known by names such as “simultaneous engineering” and “life-cycle engineering,” concurrent engineering describes a systematic approach to product development in which the units of the traditional sequential design process are reorganized into collaborative, multidisciplinary teams. These cross-functional project teams apply a variety of product and process information management tools that incorporate manufacturability, user requirements, and product life-cycle issues, from conception through disposal, into the design of products.

The Global Concurrent Engineering (GCE) test-case developed and administered a survey instrument on GCE practices in an international sample of firms in industries including automobiles, aerospace, electronics, and telecommunications. The survey data was then modeled to provide a basis for testing GCE concepts and allowing member firms to benchmark their existing practices. According to Andrew Young, then at Northern Telecom, the project was based on personal contacts rather than any real knowledge of, or driving interest in IMS. Driven by academia more than industry, the consortium was formed under the leadership of Peter O’Grady at North Carolina State University and gradually expanded to include colleagues at California Polytechnic, Carleton University in Canada, and De Montfort University in England. These four universities with the support of Northern Telecom conducted the survey research while the participation of other partners listed in Table 5 was mostly limited to supplying data. As the table suggests, project management decided against recruiting Japanese participants feeling that language and cultural barriers might prove too great an obstacle in the short time allowed for the feasibility study.\textsuperscript{67}

| Table 5 |
| Global Concurrent Engineering Test-Case Partners |

<table>
<thead>
<tr>
<th>Canada</th>
<th>Northern Telecom, Carleton University</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU/EFTA</td>
<td>Syntax Factory Automation, De Montfort University, Transfer Technology PLC, Nokia, VTT</td>
</tr>
<tr>
<td>United States</td>
<td>North Carolina State University, California Polytechnic, Aeroglide Corporation, Airtech Corporation, Exide Electronics, JC Steele &amp; Sons, Jacumin Engineering, Prodelin Corporation</td>
</tr>
</tbody>
</table>
Technical and Management Results

The GCE test-case was designed to examine concurrent engineering practices at three different levels in the firm. A survey of corporate strategies and practices regarding GCE was conducted by a team from the Department of Mechanical Engineering at De Montfort University in England. A second set of data examining the operation of specific product development teams and their relationship with higher levels of management was conducted by a team from the School of Business at Carleton University in Canada. A third set of data focusing on intra-team issues was collected and analyzed by teams at Carleton and California Polytechnic University.

The total study sample included sixty-two concurrent engineering project teams from twenty-two firms in seven countries. Fourteen firms provided information on more than one project team with many providing information on more than three teams. Among the companies who provided more than one project team to the sample were: Northern Telecom, Pratt & Whitney, and Paramax in Canada; Alcatel Network Systems, Caterpillar, DuPont, Ford, and Unisys in the United States; Amchem, Ford, Nokia, Odense Steel Shipyards, and Syntax Factory Automation in Europe.

The survey data suggested several ideas which may be of value to firms considering the implementation of GCE strategies. One of the main conclusions is that GCE is an organizational strategy and not simply a “tools based” product development strategy. As a result, GCE strategies often require significant changes in the work methods of both managers and engineers, particularly in functionally specialized bureaucratic organizations. Moreover, there is a long learning curve in GCE with more than three years of high-level commitment usually necessary before firms really begin to benefit.

The Decision to Disband

The GCE test-case was successful in meeting its objective of creating public domain knowledge that increased understanding of state-of-the-art manufacturing practice. Yet, the test-case was an academic survey, with results presented in the form of business school studies, rather than an industry-led consortium laying the groundwork for an actual research project in global concurrent engineering. Without coordinating partners from industry interested in building on the results of the test-case, the project was destined to end with the analysis of the survey results.

Test-Cases that Became Full-Scale Consortia

Three of the test-cases decided to submit applications to become consortia in the full-scale IMS program, and subsequently received “fast-track” approval from the International Steering Committee. In two cases, partners left the consortium after the feasibility study while other new partners joined. In the “Globeman” consortium, for example, British Aerospace left while IBM, Mitsui Shipbuilding, and AT&T Europe among others joined. In contrast to the disbanded test-cases, each of these three consortia is industry-led, focuses on core issues such as enterprise management or development of a next-generation production system, and promises some short-run, commercial payoff. The level of partner commitment varies within each consortium with those partners who have been most proactive in shaping research plans and management rules finding the project most rewarding.

1) The Globeman Consortium

The Global Manufacturing or “Globeman” consortium represents the merger of a test-case in the Japanese domestic feasibility study and a research proposal submitted by a group of European firms. In December 1992, the Japanese partners led by Toyo Engineering prepared a proposal based around the concept of virtual manufacturing—the use of software tools to model and design manufacturing systems. At the same time, British Aerospace working with industrial and academic partners from the EU and EFTA developed a proposal focusing on global manufacturing management. After consolidating the two proposals into one project, which identified virtual modeling techniques
as the key tool for realizing efficient global management, the Japanese and European groups recruited partners from the United States, Canada, and Australia (Table 6).

The experience of the European partners in ESPRIT suggested that three to six months was required for familiarization of partners and so the objective of the test-case consortium was limited to establishing user requirements and the technologies necessary for meeting those requirements. In order to establish these requirements, the academic partners developed a set of methodologies for the collection and analysis of data provided by the industrial partners. Firms were organized into four "domains" according to manufacturing volume. The one-off manufacturing domain was led by England’s BICC Cables; the semi-continuous/continuous manufacturing domain by Toyota; the small-batch processing domain by the Finnish engineering and paper products firm Ahlstrom; and the large-batch processing domain by the French telecommunications firm Alcatel.

Table 6
Globeman Test-Case Partners

<table>
<thead>
<tr>
<th>Australia</th>
<th>CSIRO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;BHP, Farley Cutting, Moldflow, Telecom Australia, Griffith University</td>
</tr>
<tr>
<td>Canada</td>
<td>Spar Aerospace, University of Toronto</td>
</tr>
<tr>
<td></td>
<td>&quot;Spar Aerospace, &quot;Dofasco</td>
</tr>
<tr>
<td>EU/EFTA</td>
<td>British Aerospace, Alcatel, BICC, Fraunhofer Institute, Grai Group, IWF, Pirelli, Ahlstrom, Helsinki University of Technology, Partek, Sintef, VTT &quot;British Aerospace, Alcatel, &quot;AT&amp;T, Intracom, Nokia, Odense</td>
</tr>
<tr>
<td>Japan</td>
<td>Toyo Engineering, ETL, IBM Japan, Kyoto University, Mazda, Ricoh, Takenaka, Tokyo University, Toyota, Yokogawa Electric</td>
</tr>
<tr>
<td></td>
<td>&quot;Daikin, Mitsui Shipbuilding, Omron, Toyoda Machine Works</td>
</tr>
<tr>
<td>United States</td>
<td>Carnegie Mellon, Newport News Shipbuilding, University of Virginia</td>
</tr>
<tr>
<td></td>
<td>&quot;IBM, Kamyr, Pyropower, Deneb Robotics</td>
</tr>
</tbody>
</table>

'Left consortium after the feasibility study
"Joined consortium after the feasibility study

Data was collected across the strategic, tactical, and operational management levels for each domain group by company. The data was then organized into "as is" and "to be" matrices which allowed the determination of user requirements within domain, across domain, across regions and between enterprises. The intent of this approach was to bring together industries and regions which would not normally collaborate but might learn from each other in confronting common managerial and technical challenges.

Technical and Management Results

The major result of the test-case was the decision to continue with the consortium and the identification of nine major topics for future research including: enterprise modeling, logistics management, life-cycle support, and information infrastructure. Although some consortium members, including the Canadian partners, thought that it was unnecessary to use a methodology to determine research topics, the majority of members believed a formal methodological approach was necessary for determining the common needs of a group as diverse as the Globeman partners. Nevertheless, several problems emerged in using the methodology to gather data. Some partners had difficulty understanding certain concepts and processing methods for data, and confidentiality issues prevented the general collection of quantitative data making the evaluation of needs more difficult and less precise. Even with
these problems, however, several partners found the methodology a useful tool to analyze company priorities and to extract data from various strategic documents scattered throughout their own companies.\textsuperscript{71}

On the management level, one of the major problems experienced in the test-case was associated with differences in funding mechanisms across regions. In addition to differences in the fiscal years of participating regions, funding for the pilot phase was approved in different regions at different times. This created problems with some partners wishing to press forward and others holding back awaiting funding. Lack of government subsidies also proved a barrier to recruitment of partners in the United States. Finally, several participants felt strongly that small and medium-sized enterprises lacked the resources needed to take part in Globeman.

The final report of the test-case, which was drafted mostly by European partners, also notes difficulties arising from cultural differences with Japanese partners. The report cites consensus-style decision-making among Japanese partners as the cause of sometimes lengthy delays, and the tendency of the Japanese partners to present views through a single spokesperson as creating the perception that not all of them were contributing equally to the work of the consortium.\textsuperscript{72}

The Decision to Continue

Of the three test-cases that have continued on to the full-scale program, the Globeman consortium has experienced the greatest changes in membership. These changes have been most dramatic in the European region where British Aerospace, the principal coordinating partner for the test-case, and Alcatel, the leader of the large-batch processing domain, both decided to leave the consortium. Offsetting these changes, however, AT&T Europe and the Finnish electronics firm Nokia have joined Globeman. There have been no major firms dropping out in other regions but several deciding to join the consortium including: IBM, Mitsui Shipbuilding, Omron, and Telecom Australia.

British Aerospace and Alcatel were unwilling to comment on their reasons for leaving Globeman but other firms see the consortium as an important opportunity to help shape the changes that will revolutionize manufacturing in the early decades of the next century. Although it could not justify continuing with the clean manufacturing consortium, Toyo Engineering is continuing as Japanese regional coordinator in Globeman. Established in the mid-1980s in response to the global downturn in Toyo’s primary business of plant engineering, the factory automation division does most of its business in Asia at present. With a staff of over ten professionals working on the project, Toyo sees Globeman as a means to learn more about both the technological state-of-the art and the broader international market.\textsuperscript{73}

The world’s second largest maker of industrial instruments, Yokogawa Electric echoes many of these same sentiments. A total of thirteen engineers and managers from Yokogawa worked on Globeman, four of them on a full-time basis. While Yokogawa sees virtual manufacturing as a crucial tool in the longer-term, its shorter-term interests in Globeman are research on total quality management and life-cycle support. Although somewhat disappointed by the lack of exchange between domains during the test-case, Yokogawa had no hesitations in continuing as a member of Globeman.

One of Yokogawa’s major concerns was the conceptual gap between Japanese and western partners regarding the objectives of the consortium. Most of the Japanese participants are researchers interested in hardware issues while the western participants tend to be managers more interested in global management issues. Thus, Yokogawa sees a slight divergence in research interests that was papered over in the final report on the test-case. On a more optimistic note, however, Yokogawa senses that a revision of guidelines on mandatory disclosure of background intellectual property has mitigated concerns of some of the largest Globeman partners like IBM and Toyota and might encourage their more active participation in the program.\textsuperscript{74}

On the American side, Newport News Shipbuilding is also encouraged by the revision of the IPR guidelines. The firm sees Globeman as providing a solid legal foundation for working with international partners. NNS considers IMS as “wholly consistent” with its corporate globalization strategy. Globeman provides NNS with a world-class partnership to address issues in its manufacturing processes and leverages heavy involvement in the
Continuous Acquisition and Life-Cycle Support Program (CALS). According to Bill Georges, who coordinates NNS participation in Globeman, one could say "that the Globeman project is a proof of concept for integration of CALS, STEP and other technical infrastructure concepts in an international "virtual" electronic business environment."75

2) The Holonic Manufacturing Systems Consortium

The Holonic Manufacturing Systems (HMS) test-case investigated architectures for highly decentralized manufacturing systems built from a modular core of standardized, autonomous, cooperative, and intelligent elements termed "holons." In contrast to existing computer-integrated manufacturing approaches, HMS are not based on a rigid, centralized hierarchy and so would provide greater flexibility in high-volume high-variability manufacturing. The main objectives of the test-case were to define: (1) user requirements for next-generation manufacturing systems, (2) the major weaknesses of existing systems, and (3) test-beds for the benchmarking, validation, regression testing, and measurement of the attributes of HMS. According to consortium organizers, large-scale international collaboration offers both a global perspective on user requirements and the broad range of skills necessary to develop the software and hardware for HMS.

A total of thirty-one partners drawn from each of the five IMS regions participated in the test-case (Table 7). The consortium included a mix of large and small firms, both users and vendors, specializing in discrete, continuous, and batch processing applications. The principal coordinating partner was Allen-Bradley from the United States. A division of Rockwell with annual sales over $2 billion, Allen-Bradley supplies automation control products to a variety of manufacturing and process industries. The test-case was coordinated in Japan by Hitachi, the country's largest electric machinery manufacturer, and in Europe by Softing GmbH a small German vendor of software tools. Rounding out the list of coordinating partners was Canada's Queens University and Australia's Broken Hill Proprietary Company, a diversified natural resource firm with annual sales over $18 billion.

Table 7
Holonic Manufacturing Test-Case Partners

| Australia                             | Broken Hill Proprietary Co. (BHP), Commonwealth Scientific and Industrial Organization, Royal Melbourne Institute of Technology  
"Holden's Engine Co., Cooperative Research Center for Robust and Adaptive Systems |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Canada                               | Alberta Research Council, Basic Technologies Corp., Queens University, University of Calgary  
"Basic Technologies Corp., "Simon Fraser University |
| EU/EFTA                              | Aitec Automation, Fraunhofer Institute, University of Hanover, Keele University, Catholic University Leuven, Nestec York, Nestle, Softing, Technologia Grupo INI (TGI), Teniker Research Association, VTT  
"Aitec Automation, Nestec York, Nestle  
"AEG Schneider Automation, Ansyak, Bachmann, BT Systems, Mercedes Benz |
| Japan                                | Fanuc, Hitachi, Keio University, Kobe University, Toshiba, Yaskawa Electric |
| United States                        | Allen-Bradley/Rockwell, Carnegie-Mellon, UC Berkeley, University of Connecticut, University of Illinois, United Technologies  
"UC Berkeley, University of Illinois, "Nat'l Center for Manufacturing Sciences |

*Left consortium after feasibility study  
**Joined consortium after feasibility study
In addition to work-package and regional meetings, the HMS test-case held four plenary sessions with an average attendance of over fifty people. Yet, the planned commitment of forty-four person years decreased to thirty-four person years due to funding limitations in Europe and the United States. This total effort of thirty-four person years was distributed across regions as follows: Australia (4.3), Canada (3.5), Europe (12.8), Japan (8.3), and the United States (5.3). The total test-case budget reached $4.3 million with matching funds of over $1 million provided by the EU/EFTA and over $500,000 by MITI. The regional budget for the United States of roughly $650,000 was funded entirely by the U.S. partners.

Technical and Management Results

The test-case cites validation of the feasibility and desirability of a full-scale HMS consortium as its main result. The main technical results were identification of user requirements, definition of an initial architecture of a holonic system, and the creation of guidelines for future standardization efforts. In the full-scale program, the consortium hopes to build on this work by developing generic aspects of holonic technologies such as systems design, and then developing demonstrations of HMS in specific applications such as machining, fixturing, and handling.

On the management level, the consortium disagreed strongly with elements of the IMS guidelines on intellectual property, in particular, the compulsory licensing of undeclared background information. Although it generated friction with the International Steering Committee, the consortium pushed for changes in the treatment of foreground and background information. The compromise reached with the IMS organization still prevents partners from blocking access to background intellectual property, which might be necessary to exploit foreground created in the HMS consortium, but prevents partners from "going on fishing expeditions." Reflecting both a diversity of research interests and concerns over management efficiency, the partners also decided that the full-scale consortium should be organized as a number of projects, each with its own work plan, rather than as a single project with a high number of work packages as was the case in the feasibility study. The partners found the consortium too large to adopt the sequential organization of work packages used in ESPRIT. Thus, research projects are arranged around areas of interest with partners anticipating a significant degree of parallelism and exchange among projects.

Reporting overhead of approximately 10-15%, the consortium considers that face-to-face meetings between researchers, although expensive, were still indispensable in the early phases of the project. Despite the large number of regions involved, the HMS consortium did not find language to be an insurmountable barrier in such meetings. The working language of the consortium is English but time is set aside during all meetings for regional groups to caucus and confirm understanding of the proceedings.

The Decision to Continue

Although it is the principal coordinating partner, Allen-Bradley describes its manpower and financial commitment to HMS as "relatively modest." The firm's major interest in the consortium is work on system architecture and engineering that might lead to the development of new standards. Allen-Bradley will be working most closely with other vendors of automated systems such as Hitachi and Toshiba with whom there is a sufficient difference in product lines that R&D collaboration is still possible. Despite efforts to recruit more American partners, Allen-Bradley has found that many American firms are still relatively inexperienced in dealing with international consortia and still suffer from a "not invented here" syndrome.

On the Japanese side, the test-case was coordinated by Hitachi where a total of seven managers and researchers worked on HMS, two of them on a full-time basis. Hitachi initially had doubts about IMS, especially about the scale of the program, when it was first proposed in 1990 but is pleased with the way in which the HMS consortium has developed. It sees the consortium as providing a number of secondary benefits such as the opportunity to gain experience in international collaboration and to strengthen links with major university labs. Yet, Hitachi feels that HMS is most important because it opens a totally new area of research. Rather than simply expanding existing ideas, HMS research represents a more dramatic leap toward a next-generation manufacturing paradigm. According
to Dr. Yoshio Matsumoto, senior chief researcher at Hitachi's Production Engineering Lab, his firm spends more of its own funds on HMS than it receives from MITI as a subsidy. Although Hitachi participates in most large-scale projects as a matter of policy, Matsumoto states that Hitachi would still take part in HMS if it were receiving no subsidy from MITI at all.80

3) The GNOSIS Consortium

With its roots in Professor Yoshikawa's theories of paradigm change in manufacturing, the research agenda of the knowledge systematization or "GNOSIS" consortium comes closest to the original vision for the IMS program. Yet, the consortium is marked by a disparity between Yoshikawa's vision of long-term change and the shorter-term interests of industrial partners. The long-term objective of GNOSIS is to move the manufacturing industry into a "post-mass-production paradigm" by systematizing design and manufacturing knowledge into a form that supports the production of "soft machinery," characterized by properties such as flexibility and reconfigurability, that would reduce both resource utilization and waste elimination.81 The post-mass-production paradigm describes a world in which multi-functional and adaptable "soft factories" produce modular and reconfigurable "soft products." The key to making soft products viable, in this view, is to extend the life of each modular component "indefinitely" without breaking the pace of progress in the functions that form the system. Thus, the transition to the post-mass-production paradigm would represent a revolutionary leap beyond small-batch customized production to a manufacturing industry that grows based on the demand for renewal and maintenance.82

Although some academic partners are interested in exploring the notion of paradigm change, many corporate partners have difficulty even understanding some of the theory underlying GNOSIS. According to one executive whose firm is taking part in the consortium, "the idea of an eternal, soft product is stupid."83 Nevertheless, these same firms are interested in the shorter-range applications of modular design and virtual factory software tools. The GNOSIS test-case included thirty-one partners from four regions led by Mitsubishi Electric (Table 8). The partners expended a total of forty-eight person-years of effort on the GNOSIS test-case with meeting costs reaching over $900,000.84

Table 8
Gnosis Test-Case Partners

<table>
<thead>
<tr>
<th>Canada</th>
<th>Alberta Research Council, University of Calgary</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU/EFTA</td>
<td>ADEPA, Telemecanique, ARM, IBM France, ITMI, Man Roland, Brose, BICC, FAST-LLP, IPA Fraunhofer Institute, Cambridge University, Asea Brown Bovari, Tehdasmali Oy, Synergy Center, FIMET, VTT, Tampere University, Swiss Federal Institute of Technology</td>
</tr>
<tr>
<td>Japan</td>
<td>Mitsubishi Electric, Nissan, Fuji-Xerox, Kajima Construction, Shimizu Construction, University of Tokyo, Tokyo Institute of Technology, Kyushu Institute of Technology</td>
</tr>
<tr>
<td>United States</td>
<td>Deneb Robotics, *Deneb Robotics *</td>
</tr>
</tbody>
</table>

*Left consortium after the feasibility study
**Joined consortium after the feasibility study

The consortium conducted work on five themes including configuration management systems, configurable production systems, and soft machinery. In each theme, partners issued tools or models to groups of other partners
to apply to their own businesses, thus generating new data for the refinement of these tools. The configuration management systems theme involved fifteen partners researching the application of software management tools to distributed manufacturing of products. The configurable production systems theme involved ten partners researching intelligent systems that can respond rapidly to external changes by reconfiguring resources, processes, and products. Finally, the soft machinery theme involved twelve partners researching functionally redundant design and product re-cycling.

Technical and Management Results

The configurable production systems theme featured one of the higher levels of corporate participation, much of it based around the use of QUEST factory simulation tools from Deneb Robotics. Asea Brown Bovari, Deneb, Tehdasmallit, and VTT developed a virtual manufacturing environment for industrial production lines and tested it with product models and data from ABB for real-time production control. Meanwhile, Deneb, VTT, and Shimizu specified a virtual construction environment with data from Shimizu. In the soft machinery research theme, several firms applied the University of Tokyo’s SYSFUND design tool to their own domains. Shimizu used it to characterize the dependencies between building functions and structures while Fuji-Xerox applied the tool to design of a next-generation “soft- copier” featuring multiple functions and autonomous control. In addition to evaluating SYSFUND, Nissan worked on modularized auto design that would facilitate repair and recycling.

The QUEST and SYSFUND design tools were only two of over thirty tools identified by the consortium as potentially exchangeable among partners. Firms found, however, that the resources required to effectively use such tools can be very high, and that it is often best to focus on the exchange of only a few tools. In short, partners must consider the costs of technology transfer for both donor and recipient rather than simply the potential for technology transfer itself.

The Decision to Continue

According to a survey conducted at the end of the test-case, partners found the main benefits of the consortium to be learning on technological rather than management or cross-cultural issues. They believed that the test-case was most useful in creating new relationships with potential collaborators and as a means to evaluate the state-of-the-art. Over ninety percent of the partners saw links created during the test-case as durable within a full-scale GNOSIS program or in other possible collaborations. The generality of the survey tends to mask, however, the varying level of commitment to GNOSIS amongst various partners. Such differences are illustrated in the different approaches to the consortium among Mitsubishi Electric, Nissan, and Shimizu Construction.

The third largest of Japan’s comprehensive electric machinery makers, Mitsubishi Electric (MELCO) served as principal coordinating partner for GNOSIS. Dr. Eiichi Ohno, managing director of headquarters R&D at Mitsubishi Electric, has been a strong proponent of the IMS program since it was first proposed and served as a member of the ITC during the feasibility study. With his support, MELCO became the driving force in setting up the domestic and later international GNOSIS test-case. According to Dr. Niall Murtagh of the IMS Planning Group at MELCO, the benefits of the test-case are somewhat difficult to specify. In the long-run, GNOSIS is related to almost everything but in the short-run software tools for virtual manufacturing will be the most tangible result of the consortium’s research. Murtagh also cites the opportunity to make personal relationships across disciplines and industries as a highly valuable aspect of the test-case. Despite the presence of some free-riders in the test-case, MELCO feels strongly that the overhead costs of participation in GNOSIS are worthwhile.

Nissan has assumed a more cautious approach to IMS deciding to participate in GNOSIS on a “limited basis.” The senior researcher at Nissan’s Opama lab decided to submit a research proposal for GNOSIS after being invited to join the test-case by Professor Tomiyama of his alma mater Tokyo University. Despite some difficulty in convincing upper management as to the benefits of joining GNOSIS, participation in the test-case was eventually approved. According to Kenichi Yoshida, who oversaw participation in GNOSIS during 1994-95, Nissan
For the full-scale program, Yoshida developed proposals on both traffic flow and air quality simulation techniques. While the research on traffic flow has no direct connection to manufacturing and would be best characterized as part of Nissan’s “public outreach” activities, the work on air quality simulation has a direct tie-in to ongoing research on electric cars. Reflecting the still cautious approach to IMS, however, neither proposal generates any significant IPR concerns. A total of seven Nissan managers and researchers work on GNOSIS, three of them spending at least 50% of their time on the consortium. Although Nissan felt no pressure from MITI to join IMS, according to Yoshida, the company would probably not have joined without the MITI subsidy.

In contrast to Nissan, Shimizu Construction has been active in IMS since the inception of the program. In addition to drafting part of the final report of the Yoshikawa kondankai, Shimizu joined four test-cases in the Japanese domestic feasibility study. Consistently ranking as one of Japan’s top three construction firms, Shimizu has also emerged as one of the foremost global engineering firms with sales in many years surpassing those of competitors like Bechtel. Out of roughly one hundred and thirty professionals assigned to Shimizu’s FA/CIM business, ten researchers and managers worked on GNOSIS, four of them on a full-time basis. According to Yuichi Tanioka, who oversees Shimizu’s involvement in IMS, the construction industry lags behind the manufacturing industry in development of robotics and automation. Thus, participation in IMS serves to bolster Shimizu’s core research in construction technology as well the research of its engineering division on computer-integrated manufacturing.

IV. Preliminary Evaluation and Implications of the IMS Program

After a gestation period of five years, the full-scale IMS program was launched in April 1995. A full assessment of IMS must wait until after 2005 when the program is scheduled to end. Yet, the experience of the feasibility study and initial years of the full-scale program suggest the potential value of the IMS framework as well as more general lessons on the organization of large-scale, industrial research collaboration. This paper closes by examining the lessons learned during the feasibility study, the expansion of IMS during its first two years, and the applicability of IMS as model for future research collaboration.

Lessons of the IMS Feasibility Study

In the International Steering Committee’s final report on the feasibility study, Australia, Canada, the EU/EFTA, Japan, and the United States agree that IMS serves as a “catalytic facilitator for global manufacturing cooperation” that enhances standardization efforts, and dissemination of information on developments in manufacturing technology, by bringing together large and small firms, universities, and public authorities in global consortia. Based on the results of the test-case consortia, the ISC concluded that international collaboration through the IMS framework “provided added value which outweighed additional overheads incurred through collaborating on a global scale.” Making only minor revisions in the terms of reference that governed the feasibility study, such as a streamlining of the IMS committee structure, the ISC recommended the launch of a ten-year, full-scale IMS program.

Yet, the ISC’s enthusiastic endorsement of the IMS program must be viewed in context. After spending significant time and energy on the development of the program, the members of the ISC had an interest in seeing the feasibility study judged a success. More importantly, as the ISC itself acknowledges, the survey nature of much of the test-case research did not provide a real test of crucial aspects of research collaboration such as provisions for the protection of intellectual property rights. The IPR provisions deal, for example, with methods of determining substantive rights but do not provide a method of dispute resolution. They also fail to address the issue of
applicable law. If there is no explicit mechanism to resolve disputes, and negotiations fail to produce a resolution, the issue of applicable law becomes critical because these laws vary from country to country.91

In short, there are limits to what any feasibility study can actually demonstrate. As an executive at one American partner wryly noted, "having a nice honeymoon is no guarantee that your marriage is going to work."92 Nevertheless, the International Steering Committee's recommendation for a full-scale program was by no means a foregone conclusion. This was a consensus rather than majority decision reached by an industry-led committee of thirty representatives from Australia, Canada, the EU/EFTA, Japan, and the United States. The mere fact that consensus could be reached among a group such as this suggests that industry sees potential in the program. Although some Japanese firms may see participation in IMS as a way to reaffirm the "internationalization" of the Japanese economy, the program holds no such public relations value for foreign firms. As the disbanded test-case consortia suggest, not all firms will view participation in IMS as an appropriate or efficient part of their R&D strategies. Yet, the fact that several American and European corporations have chosen to take part in the full-scale program suggests that IMS can be a useful supplement to in-house research activities.

Expansion of IMS (1995-97)

The IMS program has grown substantially in its first two years. As of Spring 1997, a total of seven consortia have been endorsed by the IMS Steering Committee and are currently underway. Five consortia are currently in the final stage of the endorsement process while abstracts have been endorsed for four additional proposals (Table 9). A further nine proposals are in the outline stage and currently seeking a balance of regional partners so that work-plans can be developed and full proposals finalized. American and European firms are playing an important part in expanding IMS.

American firms have taken a leading role in developing two IMS proposals. The first involves a series of IMS consortia planned under the umbrella of the already endorsed Next Generation Manufacturing Systems (NGMS) program. Serving as the international coordinating partner of the NGMS program is the Consortium for Advanced Manufacturing International (CAM-I) based in Arlington, Texas.93 Founded in the early 1970s to develop pre-standards in the field of numerical tool control, CAM-I is a member-supported, international consortium of approximately fifty firms conducting research on management and technical themes related to manufacturing. CAM-I became involved in IMS because of the close fit in the research objectives of the two programs and the participation of CAM-I board members from Japan and Europe on IMS planning committees. CAM-I proposed the NGMS-IMS program as a way to allow more firms to participate in CAM-I research without the obligation of becoming a CAM-I member. The NGMS-IMS is a hybrid program in the sense that it is managed by CAM-I as part of, and under the rules of, IMS.
The NGMS program plans to organize between four and six consortia over the ten years of the IMS project on topics including control systems, integrated operations, and enterprise dynamics. The first consortium deals with description, modeling, and simulation of next generation manufacturing systems. The consortium is testing the cost, flexibility, robustness, and scalability of various NGMS approaches developed in different regions: the fractal factory (Europe), biological manufacturing systems (Japan), and agile manufacturing (United States). This first consortium includes over twenty corporate partners (Table 10).

The International Supply Chain Integration Project (ISCI) is a second US proposal still in the outline stage as of early 1997. The proposal brings together General Motors, Ford, Toyota of America, and BMW of America, as well as four US universities in work on upgrading the performance and quality capabilities of parts and components suppliers in the auto industry. In addition to collaboration between US auto makers and the US affiliates of major Japanese and European competitors, ISCI is the first IMS proposal to be submitted to the National Science...
Foundation for funding to support work by American partners. The ISCI complements ongoing collaboration on supply chain issues among America’s Big Three auto makers in the Automotive Industry Action Group.

IMS as a Model for Future Research Collaboration

IMS is the first program to organize large-scale industrial research collaboration on a global basis. Although the initial IMS proposal would not have generated so much skepticism had it come from the United States or Europe, it seems likely that governments would still have insisted on some role in the development and management of the program. The Japanese experience in IMS and the American failure to win Japanese sponsorship of the Superconducting Supercollider have produced growing recognition that foreign governments expect to be involved in the planning of any international projects they might be asked to subsidize. For this reason, it also seems likely that any large-scale industrial collaborations organized in the future would be managed with a decentralized committee structure similar to that in IMS.

Of course, the key issue determining the future applicability of the IMS model is whether the program generates sufficient research results that firms can justify the overhead of organizing research collaboration on such a large-scale. One of the major challenges confronting each IMS consortium will be learning to coordinate collaborations among sub-groups of partners while exploiting the global test-bed provided by broader consortium membership. There is a widely held expectation that the overhead cost of coordinating such activities in the full-scale program will be lower than during the feasibility study due to improvements in the infrastructure for electronic communication. During the test-cases, for example, the majority of Japanese partners did not yet have electronic mail.

The ultimate arbiters of the success of IMS will be the corporations driving the IMS research agenda and the governments subsidizing the IMS management structure. Although the ability of IMS to produce and disseminate tangible research results remains the real test of success, the program has been carefully structured to reflect the preferences of both of the above constituencies. First, the leadership role played by industry makes IMS less susceptible to the criticism that the program is simply another instance of bureaucratic cooperation. Many scientists believe, for example, that bodies such as the OECD Megascience Forum are not as much about scientific cooperation as they are about bureaucratic cooperation. In this view, governments enter many international science projects for budgetary reasons and only use scientific merit as a post-hoc justification. Second, the program’s focus on manufacturing cuts across numerous sectors including automobiles, industrial machinery, and consumer electronics. In doing so, IMS has successfully diffused the common criticism that industrial technology programs tend to “pick winners.”
Endnotes

1. IMS is most frequently compared to ESPRIT but it resembles EUREKA in two important respects. First, IMS is like EUREKA in that it is an ad hoc inter-governmental bargain whereas ESPRIT took shape around existing regional organizations. Second, IMS has a distributed funding structure like EUREKA. Funds do not come from a central pool as in ESPRIT.


3. *Nikkei Sangyō Shimbun* 4/16/91, p. 3.


5. Personal interview with Professor Yuji Furukawa, Dean, Faculty of Engineering, Tokyo Metropolitan University, 6/27/95.

6. Off-the-record interview

7. Personal interview with Mr. Katsuhiko Umehara, Director, General Planning & Coordination Division, NEDO, 3/30/95.

8. Personal interview with Mr. Hideyuki Hayashi, Senior Executive Director, IMS Promotion Center, 4/3/95.

9. Both the IMS Promotion Center and U.S. Department of Commerce were unable to find copies of the Version 1-3 proposals. As a result, discussion of the content and timing of these proposals has been cobbled together from a number of interviews.


13. Personal interview with Mr. Hideyuki Hayashi, 4/3/95.


15. IMS Promotion Center (May 1990), p. 6.


27. For mention of foreign pressure see *Nikkei Sangyō Shimbun* 1/23/93, p. 4 and 4/16/91, p. 2. For the statement that reducing trade friction is a more important motivation than international contribution see *Nikkei Sangyō Shimbun* 8/24/92, p. 5.


32. IMS Promotion Center (1990), pp. 3-4.

33. Personal interview with Professor Yuji Furukawa, 6/27/95.

34. Personal interview with Mr. Hideyuki Hayashi, 4/3/95. For more background on environmental issues and IMS see *Kikai Shinkō* [Promotion of the Machine Industry] (November 1993), p. 15.


36. Personal interview with Mr. Takayoshi Ozaki, Deputy Director, Industrial Machinery Division, Machinery and Information Industries Bureau, MITI, 3/6/95.


40. *Nikkei Sangyō Shimbun* 4/16/91, p. 5.

41. Personal interview with Mr. Hideyuki Hayashi, 4/3/95.

42. IMS Promotion Center, “Outline of IMS Domestic Feasibility Study Projects 1993,” (photocopy).

43. *Nikkei Sangyō Shimbun* 2/19/91, p. 5.
44. Nature 6/14/90, p. 563.

45. Nikkei Sangyō Shimbun 10/17/91, p. 11.


51. Off-the-record interview


59. Telephone interview with Dr. D Boland, Manager, ICI Engineering Technology, 2/22/95.

60. Personal interview with Mr. Tetsuya Oishi, Manager IMS Research Department and Mr. Tetsu Shimatani, Environmental Engineering Business Division, Toyo Engineering, 4/28/95.


63. Telephone interview with Mr. Richard Aubin, United Technologies Research Center, 2/7/95.


66. Telephone interview with Richard Aubin, 2/7/95.

67. Telephone interview with Mr. Andrew Young, formerly of Northern Telecom, 3/8/95.
68. Linda K. Moffat and Donald Gerwin, "Concurrent Engineering Project Teams: An Examination of Critical Test Factors," (Report prepared for the IMS GCE Test-Case, School of Business and Department of Systems and Computer Engineering, Carleton University, April 1994), p. 11.


70. Membership in each consortium was still somewhat fluid as of early 1996 as research plans evolved and recruitment of new members continued. The membership data in this section is from July 1995.


73. Personal interview with Mr. Tetsuya Oishi, Manager IMS Research Department, Toyo Engineering, 4/28/95.

74. Personal interview with Mr. Yoji Takeuchi, General Manager Government and Industry Relations, and Mr. Michiaki Yamagata, General Manager Corporate R&D, Yokogawa Electric, 6/13/95.

75. Letter from Mr. Bill Georges, Program Coordinator IMS-GM21, Newport News Shipbuilding, 3/19/96.


78. Telephone interview with Dr. James Christensen, Senior Principal Engineer, Allen-Bradley Industrial Automation, 3/22/96.

79. Telephone interview with Dr. James Christensen, 3/22/96.

80. Personal interview with Dr. Yoshio Matsumoto, Senior Chief Researcher, Production Engineering Lab, Hitachi, 5/18/95.


83. Off-the-record-interview


86. Personal interview with Dr. Niall Murtagh, IMS Planning Group, Mitsubishi Electric, 5/4/95.

87. Personal interview with Mr. Kenichi Yoshida, Manager CAE Section, Engineering Systems Center, Nissan, 6/27/95.

88. Personal interview with Mr. Yuichi Tanioka, Manager Planning Department, and Mr. Kobun Araki, Manager Engineering Division, Shimizu Corporation, 6/6/95.


92. Telephone interview with Dr. Odo Struger, Vice President for Technology Development, Allen-Bradley, 2/16/95.

