# RESEARCH AND DEVELOPMENT CONSORTIA IN INNOVATION IN JAPAN: CASE STUDIES IN SUPERCONDUCTIVITY AND ENGINEERING CERAMICS

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*Thesis Summary - R&D Consortia in Innovation in Japan*
*Gerald Hane*

## 1.0 INTRODUCTION

The objective of this research project is to evaluate the roles of government promoted cooperative R&D projects in innovation in Japan. Over the decade of the 1980's, the international competitiveness of a nation's industries grew to become a prominent
concern in the United States as well as Europe. Product life-cycles were shortening, the links between technology-base research and commercial application were fusing, and requisite investment levels were increasing - all effects that were straining the resources of individual firms. In this environment, firms and nations were looking for new strategies to achieve and maintain cost and performance levels that were competitive internationally. One such strategy that became increasingly popular in the United States and Europe centered on the use of cooperative R&D, or research consortia.

More than just one policy option, however, research consortia received a high level of attention through the 1980's in the houses of policy in the United States, Europe, and Canada. In the United States, a number of successive commissions recommended that formal policies more actively encourage the promotion of R&D cooperation, as it was viewed as important to improving the nation's competitiveness. [1]

Much of the motivation for this interest in cooperative R&D appears to have been the perception that such collaborations have been a key element of the rapid industrial advance of certain industries in Japan. The research program directed toward Very Large -

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[1] The President's Commission on Industrial Competitiveness, for example, recommended the support of consortia noting that "cooperative vehicles for research and development have been used most effectively by other countries and are particularly useful as the cost of conducting R&D gets even higher." (President's Commission on Industrial Competitiveness, Global Competition. The New Reality, January 1985, Vol., 1); The Council on Competitiveness recommended that the government continue to facilitate cooperative R&D among industry, universities, and the government (Council on Competitiveness, Picking up the Pace: The Commercial Challenge to American Innovation, Washington: Council on
Competitiveness, 1988); The National Academy of Engineering called for the support of industry-wide consortia for the joint development of manufacturing or service delivery processes (National Academy of Engineering, The Technological Dimensions of International Competitiveness, Washington: National Research Council, 1988.)

Scale Integrated (VLSI) Circuits in the late-1970's and the subsequent growth and global market domination of the Japanese semiconductor industry in DRAMs is frequently pointed to as one striking example of the effectiveness of this strategy.

Soon after the completion of the VLSI project, the Japanese government launched its Fifth Generation Computer Project. This was a ten-year program to advance the state of artificial intelligence in Japan. As a response to this project, the European Community launched its own program, ESPRIT (European Strategic Program for Research and Development in Information Technologies), and at least partially as a response the Microelectronics and Computer Technology Corporation was established in the United States. This was followed by the passage of the Cooperative Research Act in October 1984.

However, the VLSI Project was just one of more than one hundred involving formal cooperative R&D associations, and one of more than several hundred cooperative R&D projects promoted by the government. A preliminary review of these projects shows that there are examples that can be quickly identified for which market evidence of success is much less clear. There are, for example, the cases of the C1 Chemical Project,[2] the Magnetohydrodynamic Power Project, the Electric Vehicle Project, the Stirling Engine Project, and a host of early computer projects.[3] Sigurdson has observed that of 18 national cooperative R&D projects that he inquired about, 10 should be classified as failures. [4] Thus although Japan does have a rich experience in cooperative R&D projects, the overall record appears, at a glance, to be rather mixed.

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[2] The problems of this chemical project are described by Masami Tanaka, "Japanese-style evaluation systems for R&D projects: The MITI experience," Research Policy, 18, 1989, pp.361-378.

[3] For a good description of the computer projects, see Marie Anchordoguy, Computers Inc.: Japan's challenge to IBM Cambridge, Mass: Council on East Asian Studies, Harvard University, 1989.

[4] Jon Sigurdson, Industry and State Partnership in Japan – The Very Large Integrated Circuits (VLSI) Project, Discussion Paper No. 168, Lund, Sweden: Research Policy Institute , University of Lund, 1986, p. 115.

To the extent that the VLSI experience was an exception, it will be a poor guide for general policy-making. Furthermore, to the extent that the positive and negative management and organizational experiences are not properly understood, the lessons and successes will be difficult to generalize. The analysis in this thesis is intended to assist in aligning our expectations about this type of activity with a more well informed understanding of likely outcomes.

In this thesis, I examined the roles of collaboration in R&D in innovation and investigated cases of collaborative R&D in Japan in two areas of materials science: superconductivity and engineering ceramics. I discussed the benefits and drawbacks of cooperative R&D generally, and developed a theory regarding cooperative R&D in Japan that was tested by the case studies. In this summary the theory and case studies will only be introduced and not described in detail. (An outline of the full dissertation is included in Appendix A.) Instead, the discussion will focus on the broader conclusions of the research project.

## 2.0 THE THEORETICAL FRAMEWORK

In the case studies that form the body of this thesis, I examined aspects of the operation of R&D consortia that, together, can be conceptualized as stages of an overall model. These aspects of consortia are formation, the setting of technical targets, organization, and the impact of the consortia activities. In addition, the industrial environment and established networks of cooperative and competitive relationships were also considered for their impact on the role of consortia. A summary of these issues is given in Figure 1.

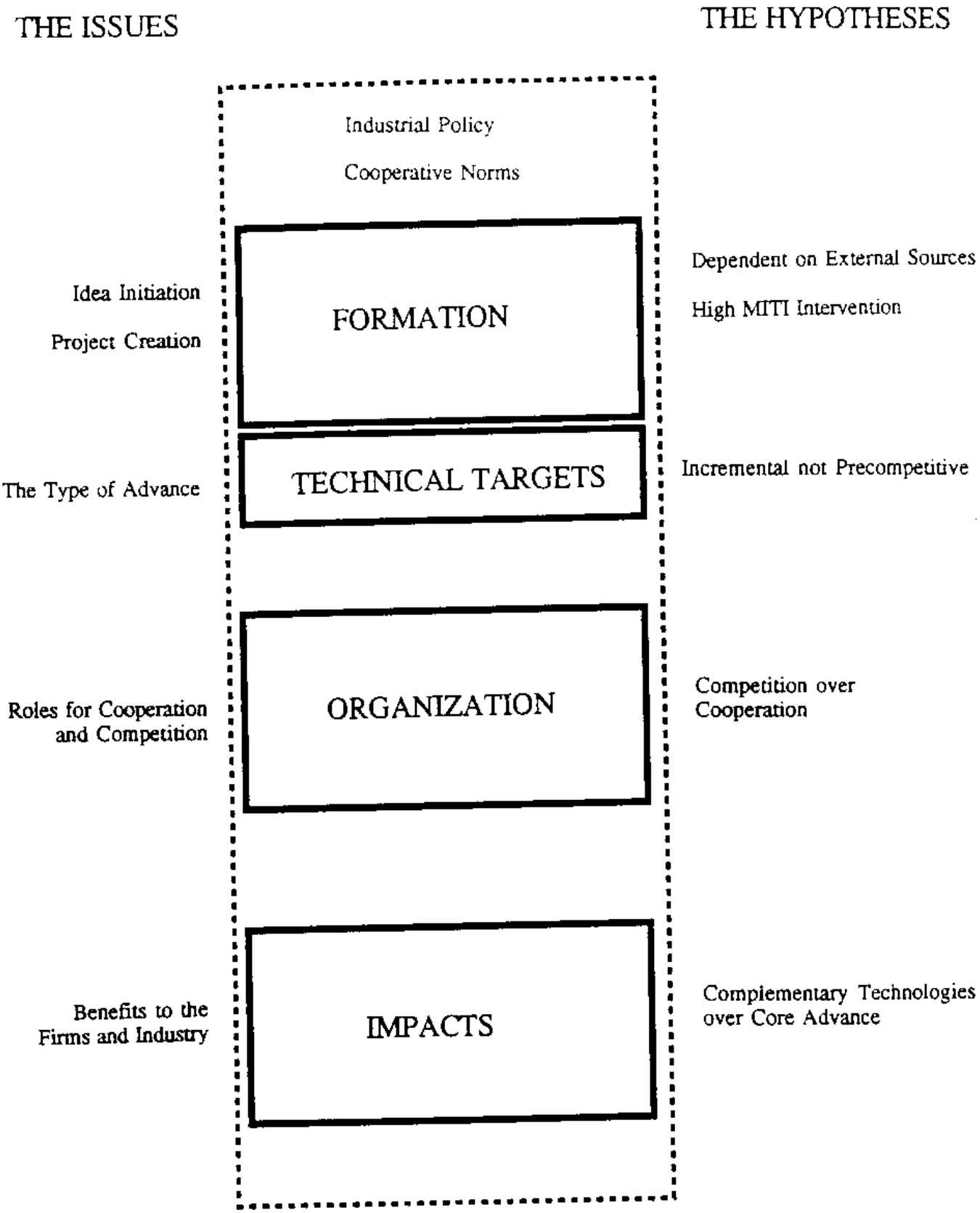


Figure 1. Conceptual Framework Outlining the Principal Issues and Hypotheses

*Thesis Summary - R&D Consortia in Innovation in Japan*
*Gerald Hane*

In formation, principal questions are how the ideas are created and molded, and how they are translated into consortia projects. The existing literature points to a MITI that is far from controlling, but the literature is vague on the precise roles taken by the bureaucracies and external organizations such as firms, universities and public laboratories. The hypothesis of this thesis is that institutional barriers to accumulating technical expertise in the bureaucracy, particularly MITI, will cause a clear reliance on external sources for ideas and technical judgments. However, as the ultimate goals of the projects involve achieving commercial success, the same philosophy and tools that MITI applies in its industrial policies are hypothesized to be important in innovation policy. MITI is thus hypothesized to be highly involved in tailoring participation in the projects.

Part of the exercise of formation is the setting of technical targets. Here the main question addressed is a technical one. It has become almost common wisdom in the United States that R&D consortia are best suited to precompetitive, generic research. This stage of research seems intuitively most amenable to cooperation between commercial competitors. But is this the case in Japan? Considering the catch-up nature of many R&D consortia projects in Japan and the emphasis on continual, process innovations in the industry generally, a very different model can be hypothesized to arise. The hypothesis of this thesis is that the principal technical targets of the consortia are not aimed at the generation of precompetitive advanced technologies, but at the continuous, incremental, iterative improvements that have proved successful for the nation's rapid industrial advance.

With the projects formed and the innovation goals established, the next issue treated is the organization and execution of the consortia to gain from cooperative advantages. However, are the consortia truly cooperative? If the firms are addressing iterative, process innovations to gain commercial advantage, as postulated above, then it would be just as likely that rather than cooperation as the dominant norm, it would be competition. The

hypothesis of this thesis is that it is competition, not cooperation that is the dominant mode of interaction between consortia leaders and the lever accelerating innovation.

Fourth is the broad issue of the impact of the consortia projects. What are the benefits to the firms and the industry? Do the projects result in significant advances in the core technologies? Recognizing that the impacts can be many, the hypothesis of this thesis is that more than simple core technology advance, the consortia take advantage of the complementary interests of the participants to develop a network of complementary assets. Through a diffusion of information to suppliers and users, the consortia are hypothesized to better match the incentives of the participants and accelerate innovative synergies.

Finally, there is the issue of the existing norms and traditions of cooperation and competition in the industry generally. What are the patterns of existing cooperative relationships and how might they determine the role to be filled by consortia? The hypothesis is that cooperation will reflect the competitive interests of the firms generally, but will be interests as defined by existing relationships and opportunities. *Keiretsu* are hypothesized to be more important when resources or markets are constrained, and the universities and public institutions are hypothesized to be important for the support of diversification and for *non-keiretsu* firms.

## 3.0 TECHNOLOGIES STUDIED

Case studies were taken from two areas of materials development, superconductivity and engineering ceramics. Areas of materials science were selected because they can illustrate both cross-cutting and applications-specific consortia. Materials such as superconductors and ceramics have a strong technology-base character, with the potential for use in a broad range of applications such as transportation, electricity generation, materials processing, and electronics. The development of these materials thus

provides incentives to firms in a variety of industries to collaborate in accelerating advances in material performance. As the materials are tailored to specific applications, a substantial amount of additional development is required to achieve specific performance and cost targets. In this process, the commercial viability of the technology becomes more apparent as does the incentive to appropriate value from the activity. Studying consortia targeted at systems and devices thus provides for a contrast with the more generic materials activities, illustrating how the differences in technologies pose different incentives, which drive different forms of consortia organization.

### Superconductors and Engineering Ceramics

Within superconductivity, cases studies are drawn from both the low temperature superconductivity industry and "high temperature" superconductivity. This allows for a contrast between an area of technology which had been developing over decades, and in which the primary barriers to application were engineering challenges, versus an area of technology which rose to international prominence suddenly, in which advances were occurring rapidly and in which established theories did not seem to apply: a contrast between incremental engineering advances and scientific breakthrough, and between the traditional policymaking process and policymaking in response to a major unexpected event in science.

Cases drawn from the low temperature superconductivity industry comprise systems that include the Japanese magnetic levitation train (known as the Linear Motor Car), the superconducting electricity generator, and the superconducting sensor (magnetoencephalograph); and devices that include Josephson Junctions, and the GOTO Quantum Flux Parametron. Cases in high temperature superconductivity include the International Superconductivity Technology Center (ISTEC), the Multi-Core Program, and the High Temperature Superconducting Electron Devices Project.

Case studies from another materials category are included to examine whether a technology area with different developmental needs and different market characteristics will lead to different patterns of inter-firm collaboration and government intervention. The area of fine ceramics is selected for an incremental comparison with superconductivity as it is a related group of materials which involves many of the same firms but nonetheless presents different technological and industrial characteristics which may affect R&D policy and the role of consortia.

The case studies are drawn from a sub-area of ceramics which has been the focus of government support in research and development: engineering ceramics. Engineering ceramics comprise components that can endure high temperature, corrosive, or highly abrasive environments. The other major sub-area, functional ceramics, comprises most applications to electronics and is a much larger commercial market, but was developed largely without direct government involvement in R&D. Because of the small direct role played by the government, functional ceramic materials are not included in this thesis.

In engineering ceramics, two types of programs are reviewed. One type is a technology-base materials development program aimed at developing ceramics for high temperature, harsh working environments. The other is a systems development program in which the goal, at least nominally, is the development of a prototype technology employing engineering ceramics. The systems prototype cases investigated in this report are gas turbines.

## 4.0 CONCLUSIONS

Understanding the role of government-promoted R&D consortia in innovation in Japan requires the evaluation of multiple influences, including those of the inherent processes of innovation, the technology, the market, the structure of the industry, and the practices of policy. Insights were developed in this dissertation regarding the process of program formation, the setting of technical goals, the organizational design, the impact of the activity, and general patterns of collaboration. These results are summarized below.

- *Formation*

In formation and in the execution of the projects, the cases show that MITT was neither simply the convener and facilitator, as pictured in some of the literature, nor was it the leader. Perhaps in an attempt to counteract early generalizations of MITE as a dominating influence, much of the recent literature assigns MITT a flag-waving, nurturing role of minimum power in influencing firms. However, the cases from this dissertation lead to a different conclusion. Although outside sources carry the technical leadership, MITT nonetheless leverages important power over the firms in project formation, with Mm's principal role in realizing a consortium being one of an *enforcer*.

Early leadership, the generation of ideas for research themes, and the drawing of a research plan are all activities that are largely executed outside of MITI headquarters by university professors, industrial proponents, and by the national laboratory staff. MITI then reflects the expertise of these external sources of technology policy by actively promoting the activity with the industry.

Once a project theme has been accepted by MITI, it then takes its main role in formation which is in enabling the activity with financial support and with the strongest firms that it can assemble. In the case of ISTEC, for example, MITI mobilized a number

of its offices to put pressure on many of the nation's leading firms to join. This pressure was very important in achieving the critical mass needed to enable the center's operation. In the case of the Engineering Ceramic Project, MITI worked to ensure the recruitment of the major ceramics manufacturers as well as strong firms with complementary expertise in processing and in knowledge about the end-use requirements.

Throughout the projects, MITI did not guide advance, its staff is simply too disadvantaged in relative expertise. MITI used its laboratories and university advisers to provide the technical transparency needed to allow firms to calibrate their relative progress and to spot free riders. The university advisers also provide a legitimacy to the overall direction of the activity, with their status and recognized knowledge of the field useful in mediating disputes between the participants.

In schematic form, the relationship of MITI to the firms, national laboratories, and universities can be viewed as shown in Figure 2. In promoting the project, MITI can leverage the strengths of any one of these groups, playing on their different roles to fill in for MITI's lack of expertise.

With strict controls on government funding by the Ministry of Finance, particularly on the general account budget, another important role for MITI and for each of the government agencies was in maneuvering funding for these projects. As seen in the case of high temperature superconductivity, the lack of flexibility from the Ministry of Finance and the lack of meaningful political salience on the part of supporting Diet members resulted in a year and a half lag before new funding was allocated from MITI or the Science and Technology Agency to pursue this field. Because of the lack of new funds from the Ministry of Finance, the bureaucracies had to turn to alternative strategies for funding. MITI responded by establishing ISTEC, which required an initial endowment from the participating firms, and the Science and Technology Agency responded with the Multi-Core Project, which was designed within existing STA research units and facilities.

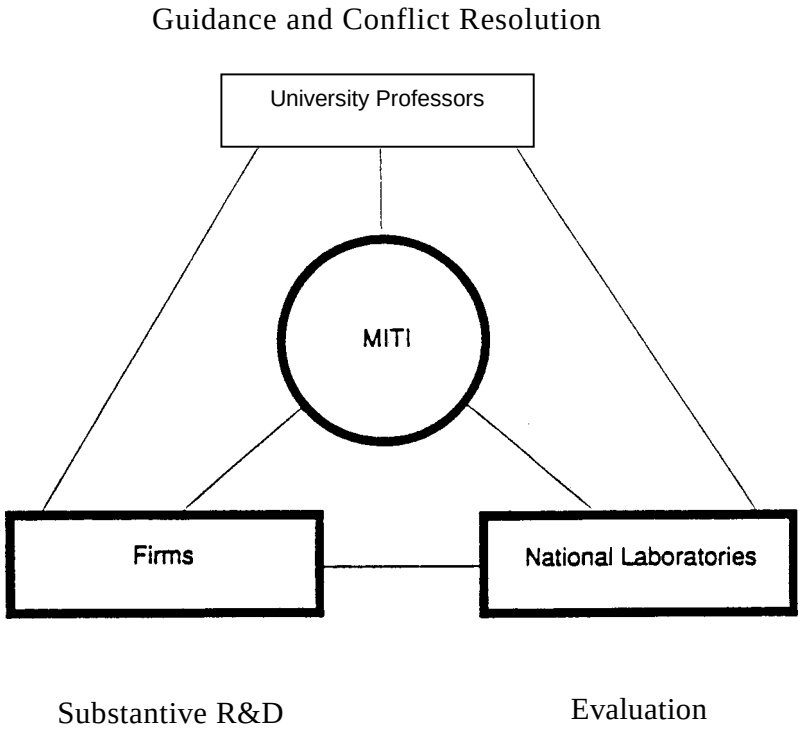


Figure 2. The Role of MITI as the Enforcer, Leveraging the Capabilities of the Various Participants

In the engineering ceramics cases, MITI had to draw from special tax funds from its energy tax accounts to continue the Engineering Ceramics Project and to initiate both the 300 kW and 100 kW Gas Turbine Projects. In tightening financial times, it seems that alternative financing will be an important function for the research supporting bureaucracies to fill as they try to promote additional areas of science and technology.

- *Technical Goals*

Regarding the technical goals, this review of cases leads to the conclusion that it is neither useful nor correct to view the technical goals as being 1 the generation of new knowledge in precompetitive areas of technology, nor as being 2) targeted at technologies that are extraordinarily advanced. In the cases of all of the systems and devices projects, as well as the more technology-base Engineering Ceramics Project, the goals were typically incremental advances over the state-of-the-art. These advances were small for projects initiated in the 1970's and early-1980's, but became bolder in the projects initiated in the late-1980's as the industries in general had caught up to the international standard.

More than the goal of generating new technologies and striking breakthroughs were the goals of 1) diffusing information about the state-of-the-art to the industry, 2) establishing certain standards of practice that would facilitate communication, 3) establishing data bases that would at a minimum help to eliminate blind alleys and contribute to the codification of knowledge that has a strong tacit character, 4) allowing time for the iteration of successive designs, and 5) co-opting the end-user or ultimate systems maker by lowering their risks through subsidization and incorporating these organizations into the development of the technology.

The first three points reflect some of the productive cooperative value that the collective and the firms attempt to draw out of the project. It is with regard to these early benefits of cooperation that Yutaka Kuwahara of Hitachi commented: "It is useless to have too much competition - it can double or triple the development costs. Sharing in government projects is very important, particularly when the industry is immature and has too many things it needs to exploit." [5]

[5] Marie Anchordoguy, The State and The Market: Industrial Policy Towards Japan's Computer Industry, Ph. Dissertation, 1986, p. 178.

The selection of technical goals reflects the realization by the collective body that the consortia are only vehicles for the firms, not ends. They are temporary and are not the units of eventual commercial appropriation, which will be undertaken by the participating firms. The emphasis is thus not placed on making the consortia appear successful through revolutionary advances, but to provide the time and resources for firms to take the technology through several generations of iteration for greater commercial attractiveness.

- *Organization*

The analysis of organization leads to the most important conclusion of this dissertation, which is that it is competition, not cooperation that is the key dynamic of government-promoted R&D consortia. The consortia have typically focused on a small set of the nation's strongest firms in a manner that is consistent with the government's long-standing industrial policy priority on rationalization. Evidence is seen in the systems and the devices projects covered here: three key firms in the Superconducting Generator, Josephson Junction, Parametron, 300 kW Gas Turbine, and 100 kW Gas Turbine Projects, and four in the Superconducting Sensor Project. Only in the case of the technology-base, science-oriented projects was this strategy not used. The basic philosophy is to prepare a few firms to lead the industry to international competitiveness in the area of technology.

In organization, competition between these key firms was used to speed development. This was reflected in consistent comments of the systems and device consortia participants. Although communication within one of the prototype development teams was good, communication across the teams was one of form more than of substance. Instead, the horizontal relationships were viewed as competitive with a continual ratcheting effect from consortia participation. Because the progress of each team was announced at least semi-annually by the firms and was periodically reviewed by the national laboratories, the extent of their measured progress becomes known both to their

sponsors and to the other project members. Free riding and a relative lack of progress therefore, have the potential of reflecting negatively on the participant by reducing the funds that are received and by damaging the reputation of the firm. The collective body attempts to leverage these competitive incentives to help promote the pace of development. Even in the project targeted at a controlled market, the linear motor car, three collaborators were used to leverage the same incentives for development, and to prevent dependency on a monopoly.

Referring back to some simple game theory, the Japanese organizations are seen to take a mixed strategy: a strategy that varies with the period of development. The collective body acts to move the firms toward collaboration in the early stages, in order to take advantage of the benefits of collective learning and diffusion mentioned earlier. In this stage, firms have incentives to share information to some degree because they typically lagged the international state-of-the-art and needed to accelerate catch-up. Establishing common evaluation and testing techniques to facilitate communication, particularly with suppliers and users, was frequently mentioned as an early benefit. However, the consortia then rather quickly move to an emphasis on raising the pay-offs in the competitive outcome, thus avoiding the stresses that can stem from cooperating on competing interests.

In the technology-base projects, however, this dynamic does not work as well. In these projects, the paradigm of technology development is not iteration in engineering knowledge focusing on prototypes, but on different aspects of materials processing and characterization. Thus the positive effect of intra-project competition evident in the systems and devices projects was not a consequence reported by the firms in the Engineering Ceramics Project. This has prompted some observers in the industry to comment that progress, particularly in the first half of the project, was rather haphazard.

In this project, there is some underlying desire to cooperate but no strategy to do so. In the case of the Engineering Ceramics Project, the failure to establish strategies for

exchanges in priority over time appears to have contributed to the distributed, uncoordinated nature of the research organization.

In all of the projects, however, collaborations between competitors are seen to occur only infrequently in the performance of the core research tasks. Competitor-collaborations were seen only in cases where 1) the regime of appropriability was highly uncertain, 2) it was dictated by the technology and the sponsor, or 3) it was a means for two weaker parties to catch-up with the leaders. Even in this latter case, however, cooperation was in a non-critical task. Cooperation between competitors is thus very much a specialized, not generalized, phenomenon.

The general lack of cooperation between competitors was strongly reflected in the general patent application data for both superconductivity and engineering ceramics. Virtually all of the cooperative patent submissions among competitors were explained by the intervention of the government or other sponsoring body.

The argument being made is that the primary mode of interaction of competing firms in consortia is competition, not cooperation. Positive cooperative outcomes occur in a manner that is consistent with the competitive priorities of the firms. It is not cooperation which overcomes competitive behavior, but cooperation which does not significantly conflict with competitive behavior. The primary modes of interaction between competing firms in the project are presented in Figure 3. Relations that are *procompetitive* among competitors and *coordinated* with suppliers and users describes the operative organization, a mode described here as *procompetitive coordination.*

The problem of technology transfer back to the home firm was addressed in one of three ways: to avoid it, embody it, or ignore i4. In the design of all of the consortia except for ISTEC, the projects attempted to avoid problems encountered in handing-off technologies from one organization to another by selecting firms for R&D that will be the

| | | Competitor A | |
|---|---|---|---|
| | | Compete | Cooperate |
| Competitor B | Compete | Superconducting Generator<br>Superconducting Sensor<br>Josephson Junction<br>HTS Electron Device<br>Parametron<br>Linear Motor Car<br>100 kW Gas Turbine<br>300 kW Gas Turbine<br>Engineering Ceramics | |
| | Cooperate | | ISTEC<br>100 kW Gas Turbine<br>Linear Motor Car<br>Cable mfgs. |

Figure 3. Modes of Interaction Between Competing Firms in the Consortia Projects Reviewed

same firms which will lead in commercial development. Internalizing the important developments avoids the inter-organizational transfer problems. When researchers must be dispatched, as in the cases of ISTEC, the Parametron, and the Superconducting Sensor Projects, virtually all will return to their home firms after two to three years, thus returning the explicit and tacit knowledge developed. Technology transfer is "embodied" in the movement of the researchers.

In the case of the parametron, the primary firm, Hitachi, used the project as a means of recruitment, hiring several of the project's freshly minted Ph.D.s. In the case of the Superconducting Sensor project, as in many of the Key Technology Center projects,

communication between the dispatched researchers and the home laboratory occurred frequently, even though it was formally prohibited by the system.

Finally, in the case of transfer from the national laboratories to the firms, it was a problem largely ignored. Because the themes were similar, there were occasions for the useful transfer of technology, as in the case of the Niobium materials for Josephson Junctions. However, the laboratories chose the research that they pursued largely on their own, and the occasions for transfer were more serendipitous than planned. Firm research was certainly not dependent on national laboratory advances. Their most direct interaction was in evaluation and testing. The transfer of technology from the national laboratories to the project firms was not a significant part of these projects.

The difficulty of meaningful transfer of technology among competitors in their core technologies is seen in the United States as well in the experiences of both MCC and Sematech. Mowery and Rosenberg have pointed out that although MCC was established to support pre-commercial, cooperative research, achieving strong commitment from the firms for personnel and in setting up mechanisms to transfer results from MCC proved extremely difficult. Thus, over time the consortia evolved so that it is now performing more proprietary research for its members.[6]

In the case of Sematech, the original plans targeted 1) R&D on advanced semiconductor techniques, 2) the testing and demonstration of the techniques on a pilot production line, and 3) the adaptation of these techniques to manufacturing? There was

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[6] David Mowery and Nathan Rosenberg, Technology and the Pursuit of Economic Growth.. Cambridge: Cambridge University Press, 1989, p. 270.

[7] Congressional Budget Office, The Benefits and Risks of Federal Funding for Sematech, Washington: Congressional Budget Office, September 1987, p. 41. George Cabot Lodge has noted that it was being predicted at the outset that Sematech would give the merchant semiconductor industry a one to one-and-a-half year lead time over the rest of the industry, notably their competitors from Japan. (George Cabot Lodge, Comparative Business Government Relations,, Englewood Cliffs: Prentice Hall, 1990, p.151.) Glenn Zorpette noted that by 1990, Sematech's officials were asserting that their main focus was not on precompetitive research in the core technology, but on the development of manufacturing methods, equipment, and materials for advanced semiconductors. (Glenn Zorpette, "Electronics consortia to impact products for generations," IEEE Spectrum, October 1990, p.50.) However Lewis Branscomb feels that this emphasis is misplaced , stating that IBM's

particular concern about the health of the merchant semiconductor industry, with a desire to diffuse state-of-the-art manufacturing and processing techniques to maintain a viable domestic industry.

However, by 1992, Sematech's officials were asserting that their main focus was not on advancing processes and manufacturing methods, but on supporting the upstream semiconductor equipment manufacturer industry. Enhancing the development of complementary assets and vertical diffusion of information became the more prominent benefits of the collaboration. The consortium seemed to be learning a lesson already well appreciated in Japan.

- *Impact*

Regarding the questions of impact, only one of the projects reviewed has been completed, with another soon to be completed. Therefore firm conclusions about the impact of the projects in superconductivity and engineering ceramics will have to wait a greater passage of time. However, comments about the more immediate hints of advance can be deduced from the case studies.

The first is that there was no evidence of seminal advances being made in the core technology or expected as a result of the project work. In the single case of a completed device project, involving Josephson Junctions, the project would have to be judged a failure. Although it assisted in bringing the Japanese firms to the frontier in their level of technology, important technical problems still remain as barriers to application. By the end of the project, there was little prospect for widespread use in the targeted application, superfast computers.

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intention in joining was not to advance transistor design or semiconductor process technology, but to assist manufacturing tool vendors to keep up with the demands of industry for rapid miniaturization (personal communication.)

With the exception of one case, the parametron, the ground-breaking work in all of the projects had been done overseas. Even in the case of the parametron, it was advances in related technology overseas that renewed a long dormant interest.

The cases in this dissertation, the general history of R&D consortia in Japan, and the experiences of consortia in the United States all point to the mistake of assuming that consortia are likely to be key to the core advance of an industry. Ralph Gomery has noted that, "While in the United States a cure for our problems is often automatically sought in more and better R&D, or the blame is put on too little R&D, the difficulties to date may well have more to do with manufacturing."[8] The search for industrial success through consortia seems to mirror a similar of misfocus in emphasis. Although there are contributions to be made by consortia, there is no evidence from the research in this thesis that the core technological advances are keys to industrial success.

Where the projects did provide value, as mentioned earlier, was in allowing firms the time for continuous iterations in the technology to improve performance and the ability to accumulate an important empirical knowledge base. The Linear Motor Car, MHD Generator, Electric Generator, Josephson Junction, Superconducting Sensor, 100 kW and 300 kW Ceramic Gas Turbine Projects were all designed to provide for innovation through continuous, iterative development.

The development of complementary assets also consistently emerged as a benefit of the projects. This was true for the suppliers of important processing and supporting equipment, such as high field magnets, high resolution electron microscopes, high magnetic field cable equipment, and hot isostatic presses for ceramics. It was also true for the suppliers of new materials, such as the chemicals and petroleum firms, in aiding the development of material specifications.

[8] Ralph Gomory, quoted in "A shifting world balance of R&D power," IEEE Spectrum, October 1990, p.82.

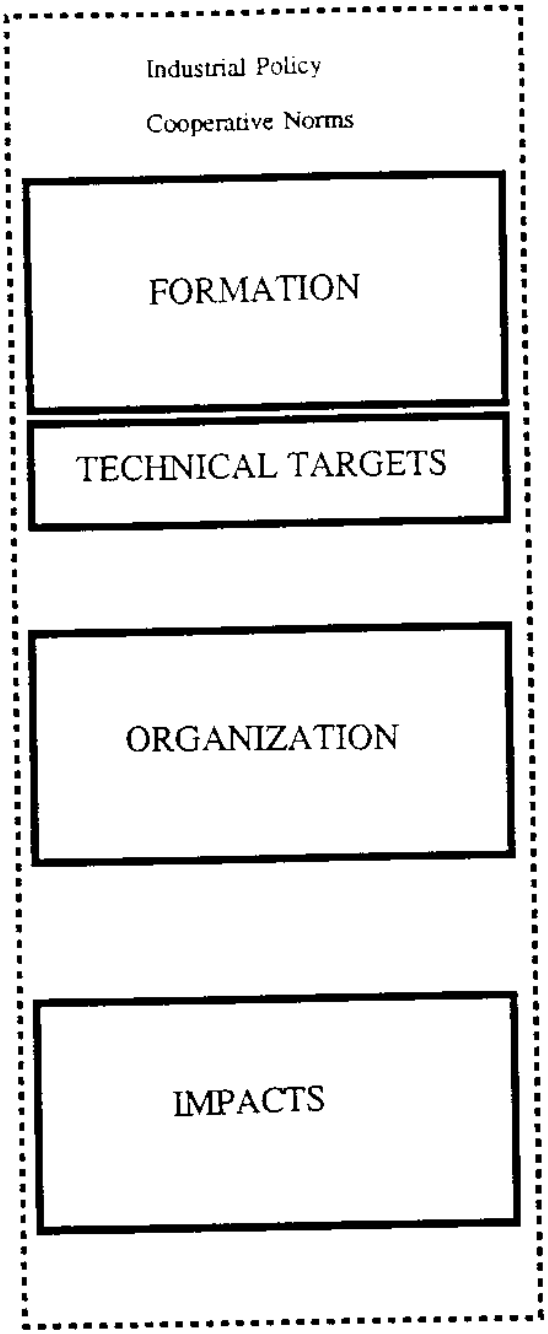
In the systems project cases, the systems developers received important aid in the prototype testing of technologies, such as the superconducting generators and the ceramic gas turbines, in which the pay-offs would otherwise be significantly distant to discourage their development. A targeted benefit in these cases is the co-optation of the users, such as the automobile firms and, in the case of the superconducting generator, the utilities.

The initiation of the national projects did appear to have some signaling effect to the industry generally, but this effect tended to be most important with firms diversifying into the field. In the case of engineering ceramics, firms in the cement and petroleum industry confirmed through interviews the general statistical data showing a response to signaling. Finally a difficult to measure but nonetheless important effect is that of industry stability because of the national projects. The long duration of the projects helps to insure the pace of development against major downswings from fluctuations in the market.

At the level of the firm, other benefits frequently cited by those interviewed were the training value of the project, the equipment and materials budget provided, the standardization of a vocabulary for the field and of testing and evaluation procedures, and the economizing on blind alleys. Participants also noted that there was significant in-house leverage afforded to research when it was associated with a national project. Researchers noted that obtaining budgets within the firm was typically a competitive exercise, particularly in the less research intensive firms from sectors such as cement and petroleum. The argument that a research area should receive corporate support because it would support participation in a national project could be used in the competition for funding priority within the firm, and facilitated the ability to get facilities and equipment. For most of these projects, the data collected have shown that the fraction of in-house activity accounted for by the national projects was usually significant *in the particular area of technology*.

*Thesis Summary - R&D Consortia in Innovation in Japan*
*Gerald Hane*

## THE FINDINGS




External Sources of Ideas

MITI as an "Enforcer"

Incremental Advance

Process Advance

Procompetitive Coordination

**Industry Level**
- Complementary Assets
- User Adoption
- Downstream Risk Reduction
- Early Diffusion
- Signaling to Perpheral Firms
- Bridging Market Cycles
- Spin-off Opportunities

**Firm Level**
- In-house Leverage
- Training
- Calibration of the State-of-the-Industry
- Evaluation and Testing
- Economizing on Blind Alleys

Figure 4. Outline of the Principal Themes and Findings

The conclusion of this dissertation regarding consortia formation, technical targeting, organization, and impact are summarized in Figure 4.

- *General Patterns of Collaboration*

In general patterns of inter-firm cooperation, the areas of superconductivity and engineering ceramics showed very different patterns, pointing to the importance of the technology, market and industrial structure in collaborations. Because of the limited market size but large technology scale of most of the traditional markets in superconductivity, the R&DR projects helped to support the development of market cartels, which pose high barriers to entry to other firms. In these cartels, the relationship between suppliers and users are fixed and are frequently entirely within their industrial grouping.

However, in the case of engineering ceramics, because the markets are multiple with many of a much smaller technical scale, the barriers to entry are lower. In addition, the electronics side of the market had developed largely without government support, and thus avoided a cartelized structure, and the earlier emergence of the engine ceramic developments by the firms without government intervention also allowed for greater variety in firm participation. As a consequence, user-supplier relationships are much more numerous than in the case of superconductivity and inter-firm collaboration occur largely outside of the industrial groupings.

The universities and the national laboratories appear to play an important training role for the industry, with the assistance of diversification into the field being an important contribution from their activities. The role of the universities was particularly notable in the case of high

temperature superconductivity, there they accounted for over half of the patent application collaborations involving all firms in this area of technology. The review of selected regional laboratories showed that in engineering ceramics, these labs were generally evenly split in their support of 1) small and medium firms, which these labs were set up to support, and 2) the nation's largest firms, which have the greater capacity to absorb new skills.

- *Final Observation*

The principal purpose of this dissertation was to analyze the execution of R&D consortia policy in Japan, and is therefore only implicitly comparative with other countries such as the United States. The dissertation describes a model that is very much influenced by the history of industrial policy in Japan. One must be cautious in drawing policy interpretations for applications in the United States and elsewhere as the policy interpretations are sensitive to context.

Nonetheless, there are characteristics that may point the useful functions of consortia generally. There are direct contributions to be made by consortia where there is a need to diffuse information to firms and establish standard routines to speed catch-up, where complementary assets are critical, where adoption of a technology by the user is important, or where large investment downstream by the systems developer is desired.

In the case of superconductivity, where the markets are limited, much of the industry's ability to sustain itself was based on government procurements and promotion. Thus, government intervention clearly had a promotional effect in maintaining the industry.

However, in superconductivity as in engineering ceramics, the primary commercial markets to develop have not come directly out of the government projects, but from the quicker movement of the industry. In the case of superconductivity, the largest commercial application, Magnetic Resonance Imaging, developed without any involvement of the government. The electronics ceramics industry grew to be very competitive internationally without direct guidance or assistance from the government. The structural ceramics markets excluding the gas turbine, such as ceramics for cutting tools, processing

components, and automotive and truck engine parts, are all markets that were also established before MITI had entered the field.

Given MITI's tendency to cartelize activity, however, the reactive nature of MITI's response may have proven to be a blessing more than a weakness. By waiting for firms to move first and by drawing heavily on firm expertise in the project selection and planning stages, MITI pre-empts itself from prematurely consolidating a technology area. Firms, without MITI, can enter fluidly, if the technology is amenable, and can respond flexibly to emerging markets. The slow step of MITI thus allows the industry to establish itself on its own, thereby taking advantage of the benefits of a flexible response. This characteristic has been noted as a key to success in other technology areas that are structurally less in need of government assistance such as the machine tool industry studied by Friedman.[9]

The paradigm advocated in this thesis is one of procompetitive coordination. It is a paradigm which emphasizes the importance of the competitive incentives, and of viewing collaboration from the network of influences on innovation, including those that stem from the technology, the market, the industrial structure, and the policy environment. Viewing collaborative R&D consortia in this way has led to a number of conclusions which are at substantial variance with other views offered in the literature.

In a discussion paper prepared for the National Academy of Engineering, one observer of Japan drew the following conclusion.

> "In Japan, where cooperative R&D has been a mainstay of public policy and private interaction, a number of design principles have emerged. Cooperation is viewed as appropriate where multiple individual efforts are "wasteful," in areas "generic" to the interests of all involved, and in "pre-commercial" contexts (i.e., likely to avoid open rivalry). The Japanese institutional paradigm has been, historically, to distribute a small sum of research funds throughout many performing sites, to enlist wide participation, share results periodically and avoid

[9] David Friedman, The Misunderstood Miracle, Ithaca: Cornell University Press, 1988.

> centralization. More recently, a trend has developed toward establishment of neutral central sites where research can be undertaken cooperatively.[10]"

The conclusions of this dissertation, however, draw a very different picture. The "design principles" are not avoidance of wasteful duplication in generic areas of non-rivalry. To the contrary, duplication is desired, frequently on systems and device research in which rivalry is deliberately leveraged. The observation that the projects do not commit large sums of funds is consistent with the case studies here, but this is on an absolute scale. These funds are usually significant for the particular target technologies. The projects typically do not enlist wide participation, but center around a small selected set of core firms, with other firms chosen as needed to provide the needed complementarities. The principal movement of information is vertical, not horizontal. Finally, regarding the trend toward establishing neutral sites, the operational evidence is that this is not happening, even in cases where it is legislated. Active cooperation between competitors does not appear easy to achieve, even in Japan.

Practices in Japan have developed well beyond the simple notions of collaborative consortia contributing to a common good. They are practices that have developed, not through sophisticated theoretical principles, but through years of empirical knowledge with the principal underlying objective of being internationally competitive. These are practices that reflect the understanding that although early cooperation can enhance diffusion, it is competition that speeds adoption. It is this "tacit knowledge" of consortia policy-making that this dissertation has attempted to provide some perspective on and which is in need of more thorough research.

[10] George Heaton, International R&D Cooperation. Lessons from the Intelligent Manufacturing Systems Proposal, Discussion Paper Number 2, Washington, D.C: The Manufacturing Forum, National Academy of Engineering, June 1991, p.28.