

# TECHNICAL RESEARCH REPORT

## Successful Industry-University Collaborations in Manufacturing Technology

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# Successful Industry-University Collaborations in Manufacturing Technology

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**Abstract** - Historically, many Japanese manufacturing companies have independently developed manufacturing technologies such as advanced processes and equipment, methods of analyzing manufacturing phenomena, and production management and quality control systems, which maintain the competitiveness of product development and production. Most of these companies are beginning to recognize the importance of collaborating with universities, where advanced technologies and methodologies are researched, as a way to adapt to the short lead-time requirements for research and development in manufacturing technology. Because of the many challenges to the success of joint research, the anticipated results are not always obtained. In this paper, key factors for the success of industry-university collaboration in the manufacturing technology field are discussed by demonstrating actual successful cases carried out by Toshiba and the University of Maryland.

## I. INTRODUCTION

In Japan's high-growth era, many Japanese manufacturing industries introduced technologies for product development from advanced companies in Europe and the U.S. [1]. These industries efficiently realized and produced new products by developing manufacturing technologies such as advanced manufacturing processes and equipment, methods of analyzing manufacturing phenomena, production management and quality control systems. The companies grew as a result.

Historically, these technologies have been developed independently. Japanese companies believed manufacturing technologies were one of Japan's strengths, and that by developing them on their own they would maintain product development and production competitiveness.

However, today most of these companies are beginning to recognize the importance of collaborating with universities that research advanced technologies and methodologies as a way to adapt to the short lead-time R & D requirements in this area.

Because of many challenges to the success of joint research, the anticipated results are not always obtained. One challenge is the difficulty of finding appropriate researchers or laboratories within a university. Another is defining suitable research targets. Many manufacturing companies are not sufficiently taking advantage of the expertise and knowledge of university researchers to assist in determining suitable themes for joint research. Instead, joint research themes tend to be determined from ideas conceived by manufacturing engineers. A third challenge involves the difficulty of obtaining practical research results. University researchers are experts in model and algorithm development, but typically do not understand the details of industrial manufacturing technology. Therefore the models and algorithms they develop do not encompass all the necessary factors needed for the results to be readily useful in a manufacturing environment. As a result, the manufacturing company often needs to spend additional effort modifying the research results before they can be used.

Many research studies regarding industry-university collaboration were reported in Japan from

various viewpoints, including the role of the university, TLO (Technology License Organization), entrepreneurship, contract, and intellectual property [2]-[5]. However, concrete management approaches for the industry-university collaboration from the viewpoint of manufacturing technologies management were not discussed enough in these research studies.

In this paper, three key features for success of industry-university cooperation in manufacturing technology are discussed by demonstrating actual successful cases carried out by the Corporate Manufacturing Engineering Center (CMC) of Toshiba Corporation (Toshiba) and the Institute for Systems Research (ISR) of the University of Maryland (UMD). The features are:

- (1) The way the interdisciplinary organization of the ISR within the University facilitates finding appropriate researchers;
- (2) How concepts and goals are clarified to define effective themes for joint research; and
- (3) The strong and continuous communications between manufacturing engineers and researchers

## II. HOW ISR'S INTERDISCIPLINARY ORGANIZATION WITHIN THE UNIVERSITY FACILITATES FINDING APPROPRIATE RESEARCHERS

When they search for suitable universities for joint research, manufacturing companies typically contact people they know from previous or pre-existing relationships or investigate information found in university-published papers, reports or web pages. Once a potential university partner is identified, it is very important for the manufacturer to be able to connect with the appropriate researchers. Dialogue and negotiation are needed to establish crucial time and result parameters that will benefit the company. However, companies typically find it difficult to meet the appropriate researchers or visit their laboratories.

In this section, ISR's interdisciplinary organization is presented as a way to facilitate finding appropriate researchers. We will demonstrate ISR's activities, beginning with its initial contact with Toshiba.

### A. Interdisciplinary organization of ISR

ISR began in 1985 as a National Science Foundation Engineering Research Center [6]. ISR completed its full funding cycle (11 years), gained university institute status along the way, and is now fully self-supporting. ISR's unique systems engineering environment of interdisciplinary research is composed of researchers from five colleges and 11 units across campus, allowing ISR to bring together a wide variety of teams that can address the needs of companies.

ISR's industry partnership strategy seeks mutual benefit and work on topics of strategic priority to both parties. ISR presently works with about 35 companies on a variety of topics. However, it emphasizes deeper and broader partnerships with a select set of companies well aligned with ISR to benefit from highly cross-disciplinary, system-oriented R & D.

ISR supports this strategy by employing a process of 1) understanding the customer [What are the customer's needs, interests and organization? What do both faculty and the company want? Where are the collaboration opportunities?]; 2) getting the right people together to define the partnership and collaboration opportunities, including costs; and 3) selecting the best business vehicle to implement the partnership.

In addition to this process, ISR's structural aspects help industrial partnerships to become established. A critical component is to have a staff position dedicated to building relationships, as

other have also observed [7]-[9]. This staff member catalyzes, facilitates and integrates all the necessary elements and works to understand the needs of companies. In collaboration with ISR's Director, the staff member identifies the most appropriate ISR researchers across the campus as candidates for collaboration. This is a welcome source of coordination for both companies and the faculty, assisting to create partnerships on topics of mutual interest. The staff member provides a "one stop shopping" service for both the company and the faculty and works across technical, legal, and business domains. The staff member involves the appropriate faculty; university administration and legal staff; and industry technical staff and management as needed in order to help form and maintain the partnership. Figure 1 pictorially shows these relationships and interactions.

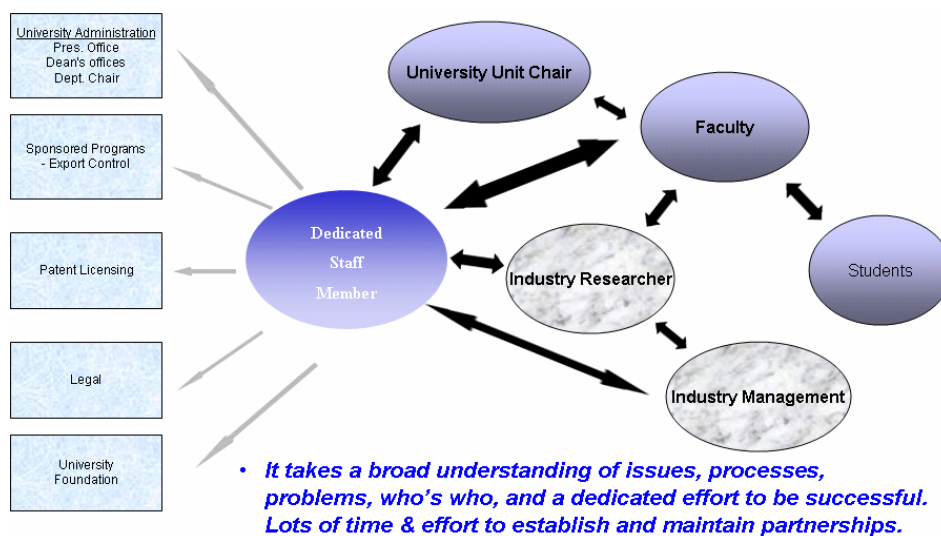


Figure 1

#### B. Application to initial contact from Toshiba CM C

Toshiba CM C serves a group of business and product units in the company. Recognizing that Toshiba is a technology-centric, hardware-intensive culture, CM C made a strategic decision to understand and adopt more information-centric approaches to technology development and particularly to manufacturing systems. To broaden its perspective in information and systems areas, CM C sought external partners, particularly university research groups with insight into systems-aided manufacturing systems.

Toshiba CM C contacted the University of Maryland in the summer of 2000 through a pre-existing relationship (a CM C leader had been a student of University of Maryland President C D .M ote).

From this initial contact, ISR was clearly identified as a repository for cross-disciplinary systems research and engineering skills and their application to manufacturing [10]. CM C decided to hold multi-day meetings with ISR for discussions of the salient concepts, scope, and research expertise needed to formulate and implement key components of its strategy. ISR's dedicated staff member gathered faculty whose research encompassed areas such as operations research, optimization, modeling and simulation, sensing and control, and software engineering. These faculty had experience in applying their research to electronics manufacturing, manufacturing logistics, control systems, and chemical engineering. This interaction was a superb opportunity to think about and evolve a larger picture in significant depth, stimulating enthusiasm on both sides along with an appreciation of the individuals involved.

Table 1 shows the summary of the technology management approaches that are indicated in this

section.

Table 1 :A pproaches and applications forfinding appropriate researchers or laboratories in universities

Challenges to collaborations	Approaches for overcoming the issues	Applications at CMC and ISR
Difficulty in finding appropriate researchers or laboratories in universities	Interdisciplinary organization of units within the university	ISR dedicated staff member catalyzes and facilitates partnership  CMC meets with researchers from different disciplines within the university

### III. CLARIFYING THE CONCEPT AND GOALS TO DEFINE THE THEMES OF JOINT RESEARCH

The second feature of successful industry-university collaborations is to clarify the concept and goals and define joint research themes. Again, we will describe the actual activities of Toshiba CMC and UM d's ISR .We begin by discussing the needs of manufacturing industries.

Because manufacturing technology is a field of process innovation, it should use various technologies and approaches to solve issues in product development and production. However, manufacturing industries tend to determine joint research themes based on ideas conceived solely by manufacturing engineers. Because the main mission of manufacturing engineers involves developing and producing high-quality products at a low cost and with high productivity, they tend to think about important processes, approaches, systems and equipment which could improve manufacturability or product performance, reduce cost, or provide some combination of these factors. This independent approach of defining joint research themes based solely upon the manufacturing engineer's perspective does not bring the greatest benefit to the company.

Industry-university cooperation allows both sides to share knowledge and experience. For the partnership to be successful, it is important at the outset to jointly define projects that both meet the needs of the company and are intellectually stimulating to faculty [11].

#### A. Clarifying the concept to define joint research project candidates

Toshiba CMC found that clarifying its manufacturing technology concepts was essential in stimulating ideas from university researchers.

To begin discussions, Toshiba CMC introduced their new "Digital Manufacturing (DM 'g)" manufacturing technology concept- a methodology that uses explicit knowledge and information technology (IT) to minimize losses of quality, cost and lead time in product development and production [12]. In the DM 'g framework, six subject frames are defined to efficiently apply technologies and methods to actual activities.

Figure 2 shows where the six subject frames are applied along the two axes to represent product development and production work flow. Each subject frame connects sequential processes along the two axes with digital data and information. After introducing this concept and its framework to ISR faculty, Toshiba CMC explained the technologies and systems of each subject frame currently in development.

After extensive discussion, ISR faculty proposed a revised DM 'g fram ew ork (Figure 3) and useful technology based on their research, including web applications, decision-making tools (DM T) and visualization tools.

This resulted in Toshiba CM C proposing some candidates for joint research that would fit the proposals and ideas generated by the ISR faculty.

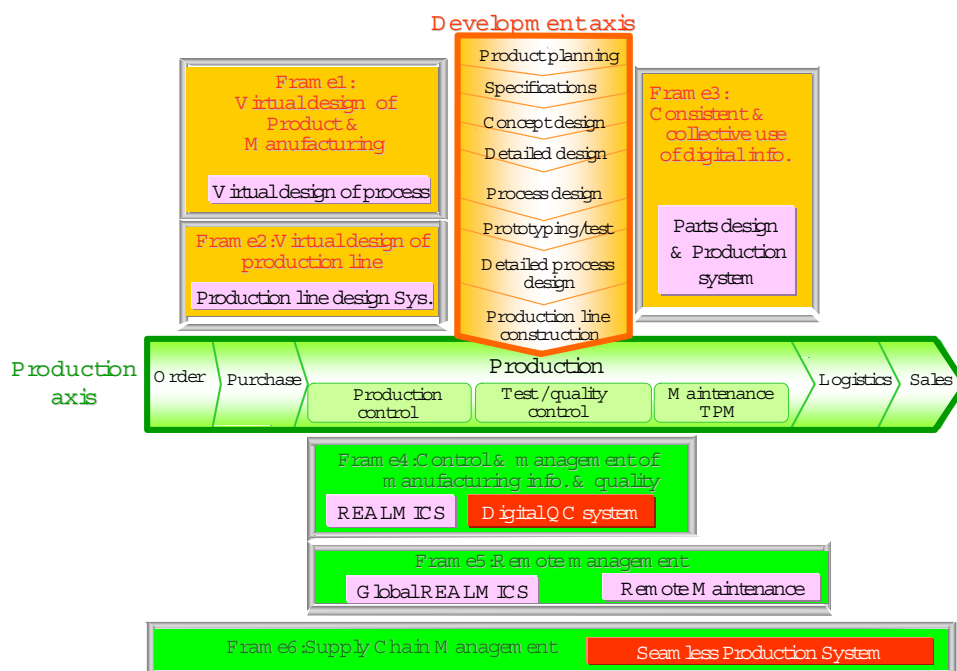


Figure 2: Framework of Digital Manufacturing

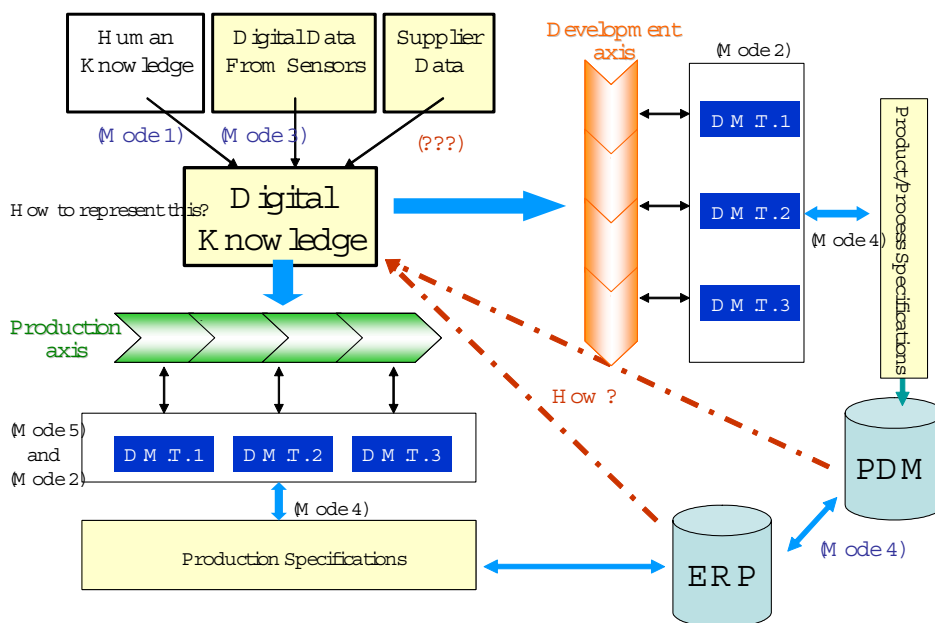


Figure 3: Revised Framework of Digital Manufacturing

B. Clarifying the goals to determine concrete themes for joint research

Agreeing on goals is another important step in determining a joint research theme. It is especially crucial that issues important to the manufacturing company are clarified at this stage. Here we describe a successful method Toshiba CM C and ISR used to determine the joint research theme of a "seamless production system," which is one of the DM 'g subject frames described above. It realizes the seamless transfer of data and information from planning and sales to production as shown in Figure 4. Toshiba CM C manufacturing engineers determined the items needed for this system based on the ISR ideas and proposals generated during the DM 'g concept clarification meeting. They recognized that one requirement was useful tools for solving complicated decisions and defined creating useful DM T as a goal for a joint research project. They analyzed where DM T would be required in the seamless production system and designed the basic logic of DM T. This step helped the ISR researchers consider how their technologies and methods applied to the targets of the joint research candidate project.

Finally, CM C and ISR agreed to jointly research the DM T identified as "Advanced Available To Promise (A-ATP)" [13, 14]. The second year follow-on project was titled "Production Capability Planning (PCP)" [15] and the year three project was "Production Loading" [16]. All three have produced useful results for Toshiba CM C.

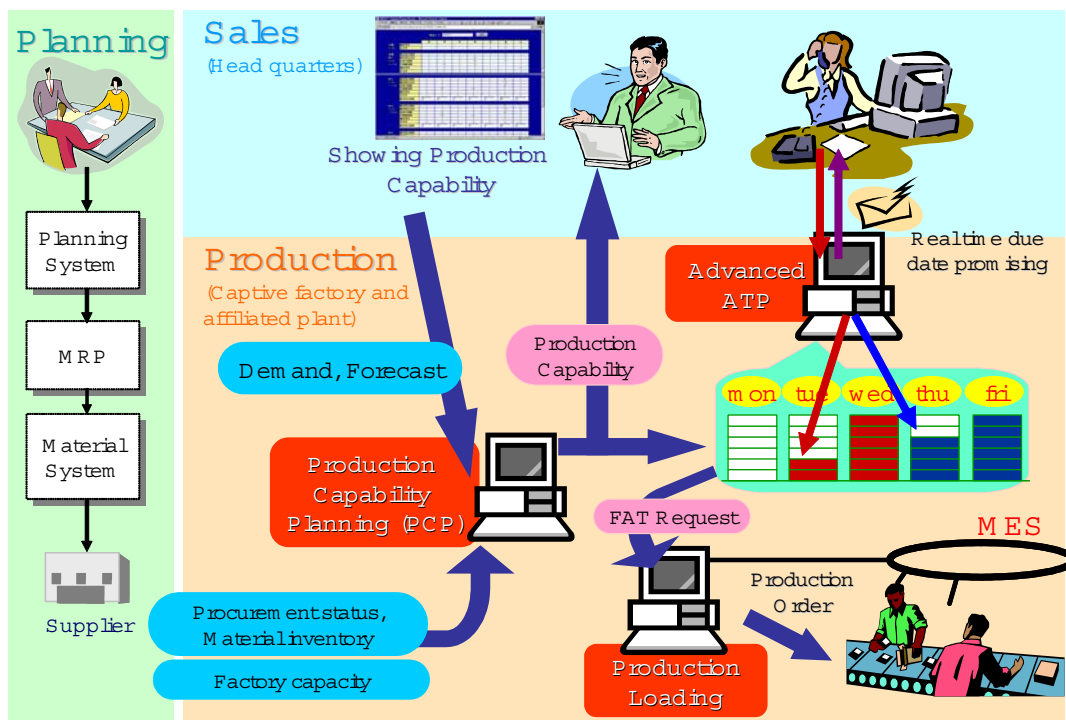


Figure 4: Decision Making Tools for Seamless Production

Table 2 :A pproaches and applications for defining suitable research targets

Challenges to collaborations	Approaches for overcoming the issues	Applications at CMC and ISR
Defining suitable research targets	Clarifying the concept and goals to define the themes of joint research	<p>CMC introduces the Digital Manufacturing concept and stimulates feedback from faculty which allows CMC to propose candidate joint research themes</p> <p>Clarification of the joint research goals was achieved through the Seamless Production System theme, a component of the Digital Manufacturing framework.</p>

#### IV. STRONG AND CONTINUOUS COMMUNICATIONS BETWEEN MANUFACTURING ENGINEERS AND RESEARCHERS

University researchers typically develop models and algorithms that describe detailed fundamental phenomena and methods in addition to specific applications. Generalized phenomena and methods are useful for widely applying the results of the work. However, the models and algorithms of many joint research activities are difficult to use directly in actual manufacturing activities because university researchers typically do not understand all the necessary details of industrial manufacturing technology. This creates a need for significant improvement of the research results at manufacturing companies prior to utilization.

Strong and continuous communications between industrial manufacturing engineers and university researchers is necessary to overcome this problem. Manufacturing engineers know the actual complexity and details of manufacturing activities, and they can describe these to faculty so the joint research can encompass these factors as they develop their models and algorithms.

In this section we show management approaches for developing an environment where manufacturing engineers of the company and university researchers can communicate strongly and continuously. One of these approaches involves building relationships by making a partnership contract. The other approach includes sending manufacturing engineers to university laboratories for face-to-face communications with university researchers [7].

As described in sections 2 B. and 3 A., several extended meetings and discussions were held between Toshiba CMC staff and ISR faculty and administration to identify specific opportunities for joint collaboration. Following the ISR process for forming partnerships described in section 2 A., it was then appropriate to select the best business vehicle to implement the partnership.

ISR proposed, and Toshiba CMC agreed, to partner with ISR as a Sustaining Member in ISR's Industrial Affiliates Program. This vehicle puts a strong business agreement in place. The agreement defines the terms and conditions of membership, the annual dues amount, and describes the process and rights for publications and intellectual property resulting from the joint research. This took considerable time to complete, but through a dedicated effort, plus flexibility from both Toshiba and the university (working within their own constraints), plus reasonableness and fairness



during the business agreement negotiations, we were able to successfully accomplish this task.

A portion of the membership dues are allocated to the specific joint research projects. A plan was created to identify two to three key areas per year for collaborative research and to send Toshiba manufacturing engineers to work in ISR research groups for periods of 6-12 months in each of these areas.

Two Visiting Scientist Toshiba engineers are working in ISR at most times. These Visiting Scientists maintain regular contact with their Toshiba CMC management, while working as full and valued members of their respective ISR faculty research groups. The Visiting Scientist vehicle provides daily opportunities for continuous and strong communication, allowing the industrial manufacturing engineer to fully describe the key elements of manufacturing activities so the faculty can incorporate these items into the research project. It also provides an environment to understand each other better, which leads to identifying additional research projects that address real-world issues and are intellectually stimulating to university researchers.

Technology transfer is a continual process. The active engagement and hosting of Visiting Scientists at ISR increases the probability of developing useful research results, provides a strong vehicle to ensure the use of the research results in Toshiba applications, and supports more rapid technology transfer.

Table 3 :Approaches and applications for obtaining practical research results

Challenges to collaborations	Approaches for overcoming the issues	Applications at CMC and ISR
Difficulty of obtaining practical research results	Strong and continuous communications between manufacturing engineers and researchers	Environment developed where CMC engineers and ISR researchers can have continual face-to-face interactions (Visiting Scientist Program and contract)

## 5.SUMMARY & CONCLUSION

This paper focused on the issue that industry-university collaborations do not always obtain the anticipated results because of the many challenges to success. Successful industry-university collaborations between Toshiba and the University of Maryland were demonstrated by adopting three key features: interdisciplinary organization of ISR within the University for finding appropriate researchers, clarifying the concept and goals to define effective themes for joint research, and strong and continuous communication between manufacturing engineers and researchers.

In the first feature, the interdisciplinary organization of ISR within the University for finding appropriate researchers was described. The existence of the ISR dedicated staff member did much to catalyze and facilitate the partnership. It was especially helpful for the manufacturing company to meet with the best researchers from several different disciplines within the University.

The second feature, clarifying the concept and goals to define effective themes for joint research, had two steps. The first step was clarifying the concept as a strategy of the manufacturing company for stimulating ideas from university researchers. Toshiba CMC succeeded in triggering the

creativity of ISR faculty by introducing the concept of "Digital manufacturing" as their new strategy for manufacturing technologies. CM C obtained several useful ideas which led to the generation of the candidates for joint research. The second step was to clarify the joint research targets, to help the university researchers consider how their technologies and methods could be applied to these goals. The successful application of this method was demonstrated through the theme of a "seamless production system," a component in the digital manufacturing framework. Toshiba CM C and ISR determined appropriate themes for joint research projects by adopting this feature.

The third feature emphasized strong and continuous communications between manufacturing engineers and researchers. Developing an environment where manufacturing engineers and university researchers could hold face-to-face communications was accomplished through developing a partnership contract and allowing manufacturing engineers to work daily in ISR research groups for extended periods of time.

Strong and continuous communications helped overcome the issue that the results of many joint research projects are difficult to use directly in actual manufacturing activities. This approach allowed industrial manufacturing engineers to fully describe the key elements of manufacturing activities, so the faculty could incorporate these items into the research projects. The output was the application of the joint research results into Toshiba actual manufacturing systems in a short period of time.

It is not easy to realize successes in industry-university collaborations because of the differences in the purposes of universities and manufacturing companies. The greatest benefit can be achieved through integrating advanced technologies developed in universities with the large variety of technologies in a manufacturing system. The features presented in this paper are useful technology management methods that help achieve successful partnerships.

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