A Report on the NSF-EDRC Study of Product Design Processes in Selected Japanese Companies

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1. Introduction

The primary motivation for this study of Japanese companies was to understand three basic aspects of their design process:

a) organization of the current process,
b) expectations and approaches for changes to the process, and
c) role of research in enhancing industrial practice.

Given these objectives, we collected data using a questionnaire and an on site interview with company personnel. The questionnaire was sent in advance of our trip to allow the companies to prepare written and verbal accounts in answering the questions. The questionnaire elaborates the three aspects of study given above. The questionnaire also covers the role computers and computation in the current and future design process (see Section 2).

As questionnaires and interviews by themselves could not provide complete answers, the companies provided us with other sources such as reports and company documents. To enable the readers of this report to interpret our results based on the amount of data available from each company, the data collection and data sources are give in Section 2. Further, this data will allow the reader to understand the scope of the results in terms of general trends.

Besides the direct study of the selected companies, we also visited individuals at Mitsubishi Research Institute. MRI consults and conducts studies in process re-engineering in manufacturing industries. MRI gave us details of a case study of process change and implementation to enhance concurrent engineering in an electrical equipment manufacturer. This case study is interesting from the point of managing changes in design and manufacturing processes and environments.

General Trends in Japanese Industry. There are some general trends that seem to drive change in the in Japanese Industry .

Globalization: One of the primary motivation in all of these companies is the change in world economic conditions that has rendered their traditional markets (Japan, the U.S. and Europe) essentially stagnating or declining. In responding to this change, Japanese industries are experimenting with a number of globalization plans. These plans vary from changing their own organization from a monolithic Japanese corporation into a multi-cultural organization (Mitsubishi Kasei) to creating a decentralized market-based product development and innovation structure (Sony). Each of these strategies is based on specific conditions in the industry as well as the history of the industry and the company.

Changing work conditions: Changes in the social conditions in Japan have created labor shortages in certain areas of skilled and unskilled work. To deal with the changing conditions and social preference of Japanese workers, companies are motivated to eliminate working conditions that are characterized by the three K's:

- Kitsui - Hard conditions,
- Kitanai - Dirty conditions, and
- Kiken - Dangerous conditions.

Hard conditions include night shifts and other physically demanding work environments.

Internal evaluation of the design process: In response to the need to continually improve the design process, different industries and companies are instituting procedures for internal evaluation of the design processes. A few companies have even created new departments for this purpose. Although the methods to improve the process and the current state of implementation vary, the self reflective nature of the evaluation process is crucial to continuous improvement.

Information technology - An integrated view: The importance of design evaluation, capture, and access of earlier design work has been identified to be critical for both internal evaluation of design processes. In the industries visited, the sophistication in the use of computers varied. Japanese companies seem to understand that their competitive edge arises from organizational structures that allow design information to be shared and preserved. Their goal is to introduce computers without destroying the existing organizational advantage based on exchange of information between people. The problem of information integration is viewed as an internal development problem where the pieces for the integration will consist of commercial tools, pubic domain off-the shelf tools, and in-house tools. While the importance of information technology is acknowledged, we did not perceive a coherent strategy across different companies and industries. Of the companies we visited, the chemical industry appears the most farsighted.

Reduction in design to market time for flexible response: Design to market time in consumer products versus non-consumer products varies and have different levels of pressure from market conditions. However, the goal of minimizing lead time is interpreted as getting to the market before any competitors and also having the flexibility to change the product mix and meet consumer demands as quickly as possible. For example, many automobile industries are keeping their models longer while continuing to reduce lead time.

These general trends identified here seem to form the current strategic goals of Japanese industry. However, a recent report on the re-organization of the Japanese auto industry notes that the walls between "keiretsu" parts suppliers and the large companies must be broken down even further. These changes reflect a long term objective of continual re-structuring across industry to minimize shocks from changing market conditions. These tends will help in understanding the specific cases discussed below.

2. Data Collection and Sources for the Study

The basic processes of data collection, questionnaires and interviews, were identified in the introduction. Due to varying levels of detail in the responses to the questionnaire, data from other sources were required to create a coherent picture. The response was spotty in the written format because it was construed as too detailed by some and not by others[1]. The questionnaire is included in Appendix A.

The interviews were conducted on-site with the questionnaire as basis for discussion. The duration of these interviews varied from a morning session to two working days. Some of the companies provided us with extensive written answers to the questions while others felt that they were too detailed to be answered across their product lines. However, during these on-site interviews, we asked the same questions and elaborated them to the extent the information was made available. The amount of data collected varied from company to company. While general trends were identifiable as discussed in the introduction, the implementation of the underlying plans varied from industry to industry. Table 1 identifies the sources of data for each of the companies visited.

Source Company	Questionnaire	Interviews (authors notes)	Company Literature
Sony Corporation	not-completed	yes(1day)	yes
Mitsubishi Kasei Chemicals	answered through a prepared folder	yes (2 days)	yes
Toyo Engineering	completed	yes (2 days)	yes
Honda Engineering	found it too detailed	yes (.5 days)	yes
Mitsubishi Research Institute	none	yes (.5 days)	yes
NEC	none	yes (.5 days)	no
Fujitsu	none	yes (.5 days)	no

Table 1. Sources of Data

1 The questionnaire was create by distributing and inviting comments from a number of EDRC industrial affiliates. Some of them felt that the questions were not detailed enough. Only a few of them answered the questionnaire with respect to their companies for us. Because of lack of data we cannot compare the finding from the Japanese Industry with respect to the U.S. companies.

3. Summary of Findings for each Company

Chemical Industry: Mitsubishi Kasei Chemical (MKC); Misushima, Osaka

Background: Mitsubishi Kasei is the twelfth largest chemical company in the world. Their objective over the next 10 years is to become the 3rd largest chemical company in the world. They produce commodity chemicals, functional chemicals, soy milk, magnetic and optical disks for the computer and consumer electronics industries, and other photo-sensitive chemicals and films for photographic products. All commodity chemicals are consumed internally by the company to create value added products.

The planning and co-ordination department is responsible for process evaluation for strategic planning and for developing long terms plans for the corporation. The trend toward globalization, information integration, improvement in working conditions to eliminate the three K's, and the need for flexible design and production of functional chemicals drive the overall strategy of planning. This strategy is also based on the decision that no new plants for commodity chemicals will be designed or installed for the next 15-20 years. Further, by better maintenance and incremental modifications, the life of the existing chemical plants can be extended far beyond predicted design life.

Current design process: The current design process in MKC is directed from the marketing department which identifies potential functional chemicals. Once the functional characteristics of the chemical have been identified the problem is given to a product manager with a team of a chemists and process plant engineers. Alternate chemical formulations and processes are created and evaluated. Once the conceptual design stage is competed, the detailed design is left to junior engineers. Various types of analysis tools and simulators are used in the detailed design stage. A detailed diagram of the process is shown in Figure 1. MKC expects that functional chemicals will have a design to product cycle of no more than three years. Most functional chemicals are expected to be produced using batch processes. Hence MKC is in the process of evaluating and installing MILOX, a flexible pipeless batch production system for chemicals from Toyo Engineering Corporation.

The role of computers is dispersed and is limited to simulation tools. Training facilities for plant operators are currently being deployed using the simulators to create plant operating conditions. A separate computer-based training center is being installed and used in the training process. The company is planning to develop a completely integrated information environment that includes plant design information as well as operation and maintenance information. The objective is to make the information available as easily and quickly as possible.

Expected changes in the next 10 years: The primary strategy for change arises from the decision to create a global corporation. Towards this effort, MKC is expected to hire over 1000 foreign engineers and to change the language of communication to English. Further, this change will allow MKC to change from being a Japanese-based homogenous company to a multi-national company. However, such a change could potentially break down the traditional Japanese organization that currently allows informal information exchange and integration. Further, the notion of life-time employment and expectations from the employees to commit to life-time emp-

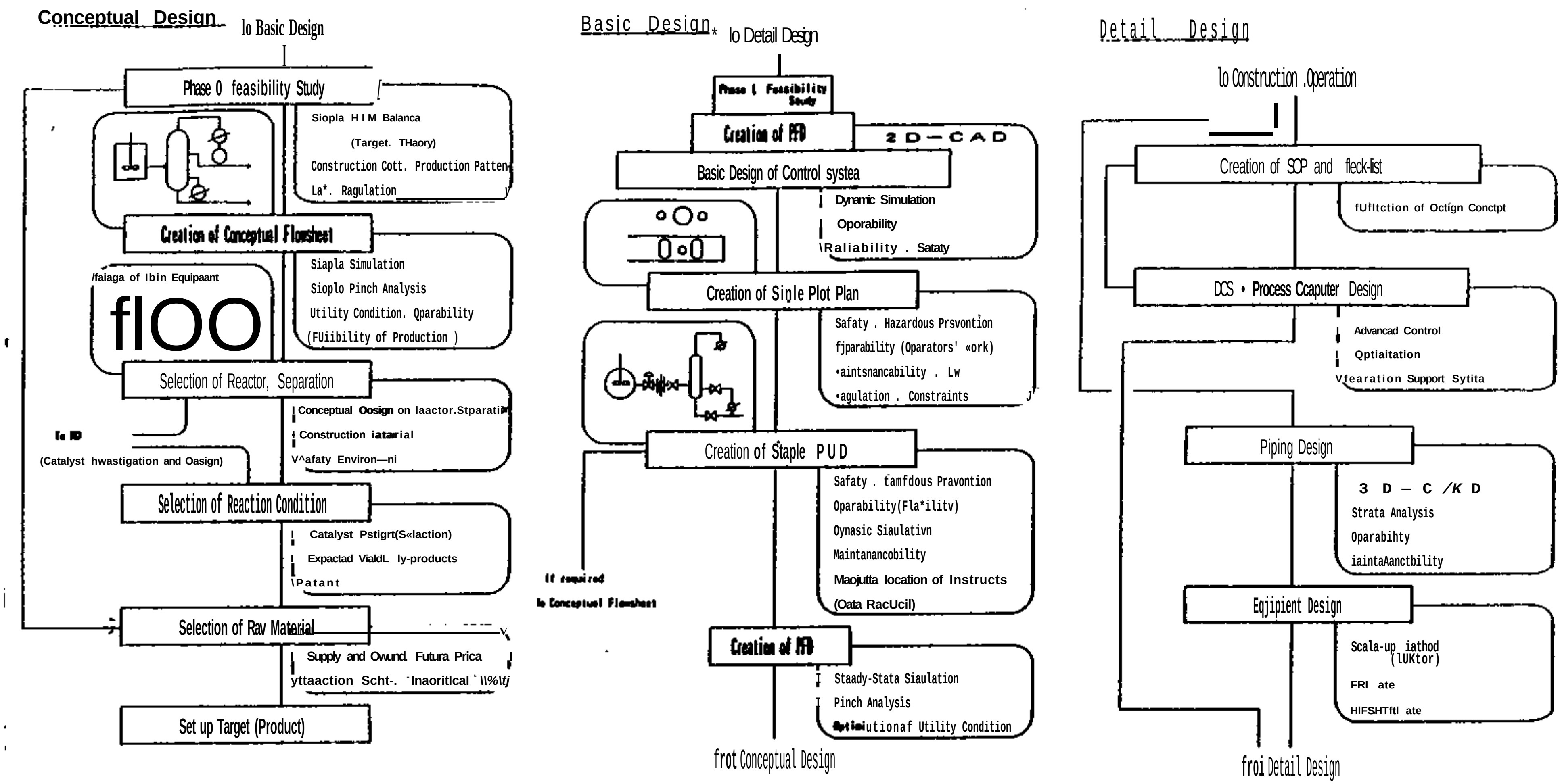

Figure 1: Mitsubishi Kasei Design Process

loyment may not be realizable in the new global company. A generational change in the attitude of workers as well as a shortage of chemical engineers in Japan will require that the process use as little labor as possible while also minimizing the information losses due to changes in the organizational setting. These factors form the basis for planning for the next generation design process at MKC.

The strategy for information systems development is to prevent information loss and to allow multiple use of information in the design and operation of chemical plants through multiple functional tasks. This strategy is depicted in Figure 2 at the level of system block diagram. The software pieces that are used in creating these task-based environments are drawn from a number of sources including commercial and non-commercial sources. The figure does not convey the richness of the environment envisioned by the MKC planners. They view the system not as just a collection of simulation and expert system tools but as the identification of the nature of engineering work.

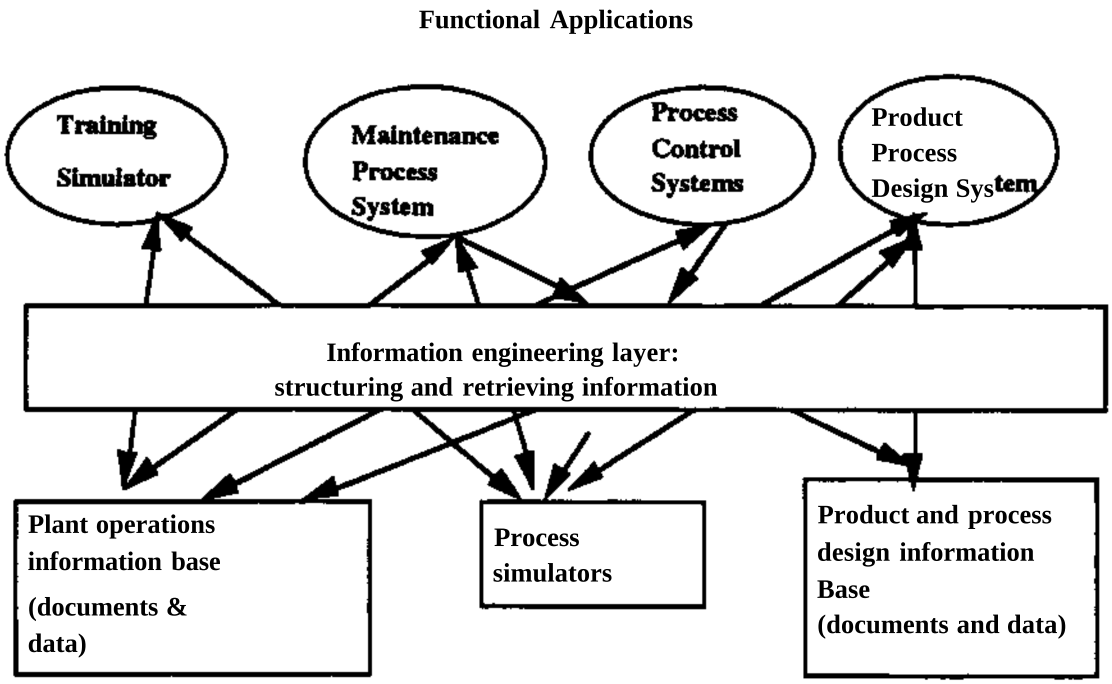

Figure 2. Integration of Information for Supporting Multiple Functions

In their internal studies, MKC has found that over 220,000 person/hours per year can be saved with better support for desk work; organizing, accessing, and documenting information (Figure 3). This problem is complicated by the fact that all information on previous designs is available only in Japanese. All future development is being performed in English. So that prior information is not lost, MKC is creating English abstracts of this information while also introducing a system in Japanese for indexing and retrieving prior information in documents. They are working with a

Japanese company for very fast access of information in Japanese[2]. The reporting procedure is being changed so that all technical documents will have computer readable text as its summary page while the rest of the pages may be hand written and available as bit map.

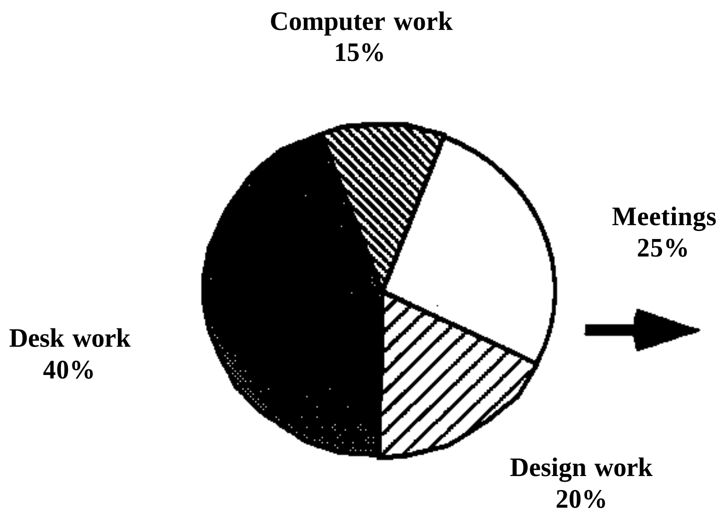

Figure 3. Work Distribution of MKC Engineers & Managers in Production and R&D

Role of Research in Company Practice

External research: MKC interacts with MITI at the national level and with some universities at an individual level. MKC has collaborated at the national level with generic technologies such as coal gassification. They see the role of university and other research centers to be in the area of creating algorithms for design, simulators and other computational tools for analysis and design. It is their policy and feeling that they should be responsible for the integration of different systems in the context engineering work.

Internal research: MKC has purchased and developed the process they are currently using in their operations. They develop most of the processes and perform chemicals research, especially in the area of functional chemicals, internally. The value-added nature of functional chemicals provides them with access to specialized markets. Currently they consume their production of commodity chemicals internally. Further given that they have decided to extend the life of their commodity chemical plants, their research and development is directed toward improving the maintenance through the use of customized simulation models using existing computational technologies such as process simulators (e.g. ASPEN and SPEEDUP). They are in the process of creating an integrated information system that provides a common substrate for supporting different functions such as maintenance, training,

[2] The retrieval system is based on turning every Japanese character into specific signals and using the signals in the matching process. We were not given details for proprietary reasons other than it can search 80 gigabytes of information with an acceptable response time.

design, and process control. They are performing controlled studies of training requirements, developing the environment using model based representation, optimization and control of the plant operations and equipment.

In summary, MKC identified a short list of current research and development projects that contribute to the overall strategic goal of an integrated information system as well reducing the three K's in working conditions. This list includes:

- Power plant simulation to manage captive plants to reduce the cost of electrical power
- Heat recovery in a broader sense includes utility optimization
- Flexible batch processes
- Total site optimization project
- Polymer simulation processes
- Training simulator (using G2 an expert system shell and SPEEDUP) for design
- Project on inventory control.
- Scheduling of batch processes
- Research into creating tools for conceptual design by piecing together simulation ad other approaches
- Capture and access to history of design.

Process Plant Design and Construction: Toyo Engineering Company; Tokyo

Background: Toyo Engineering is one of the largest chemical plant design and construction companies in Japan. It has three divisions: Process Plant, Industrial Systems, and Nuclear and Power Operations. The information gathered and presented is for the Process Plant Division.

Current design process: Toyo is a design and build company. Most domestic projects are turn key projects that include construction and initial operations assistance. Some of the foreign projects are "Free on Board" projects that include engineering and procurement services. Feedback from each of these projects is gathered from the customers to improve subsequent designs. Toyo uses two organizational processes within the process plant division as shown in Figure 4.

The company uses a matrix organization. The vertical axis of the matrix is the project teams and the horizontal axis is the areas of expertise as represented by different design departments. An engineer from a design department is nominated as a project member for a specific project. Project members can use the expertise within their own departments while on a project. Technicians and junior engineers from any design department are shared resources for the whole design organization and hence are distributed across projects depending on the needs of individual projects. The strength of the project team and the design team varies by project type. For example, in the case of big turn key projects, the vertical organization of the matrix is dense while in the case of several similar medium size projects, the horizontal organization is stronger because of multiple assignment of tasks across projects. The design organization has remained the same for 20 years.

Toyo, as a company designing and constructing plants for a global market, has different types of supplier relationships. They are licenser, contractor, contractor-subcontractor, and contractor-vendor. In the first two cases the relationship is based on providing the design procedure according to which the design will be constructed. The results are fed back to the originator of the design procedure. In the contractor-vendor case, especially with domestic customers, very close relationships with equipment manufacturers have been established whereby design information is provided at the earliest stages to the vender to increase their participation in and concurrency of the design process.

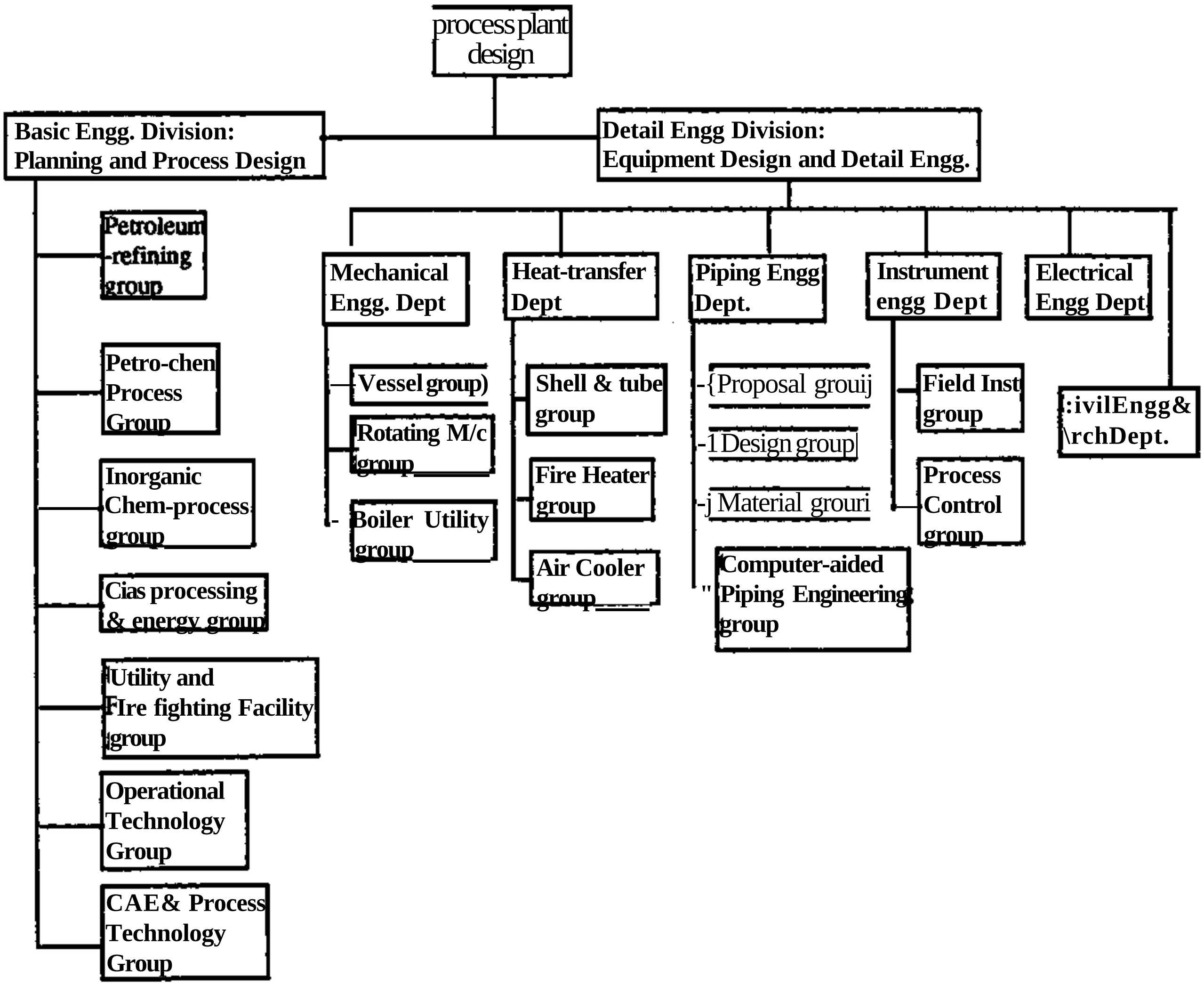

Figure 4. Departmental Organization of **the** Toyo Process **Plant Design Division**

Design activities in Toyo are structured by stages and design documents. A typical process for engineering documents by stages are shown in Figure 5. The results of the design are summarized in design documents. Toyo has a total of nine type of standardized documents for process engineering and 39 types of documents for complete plant design engineering

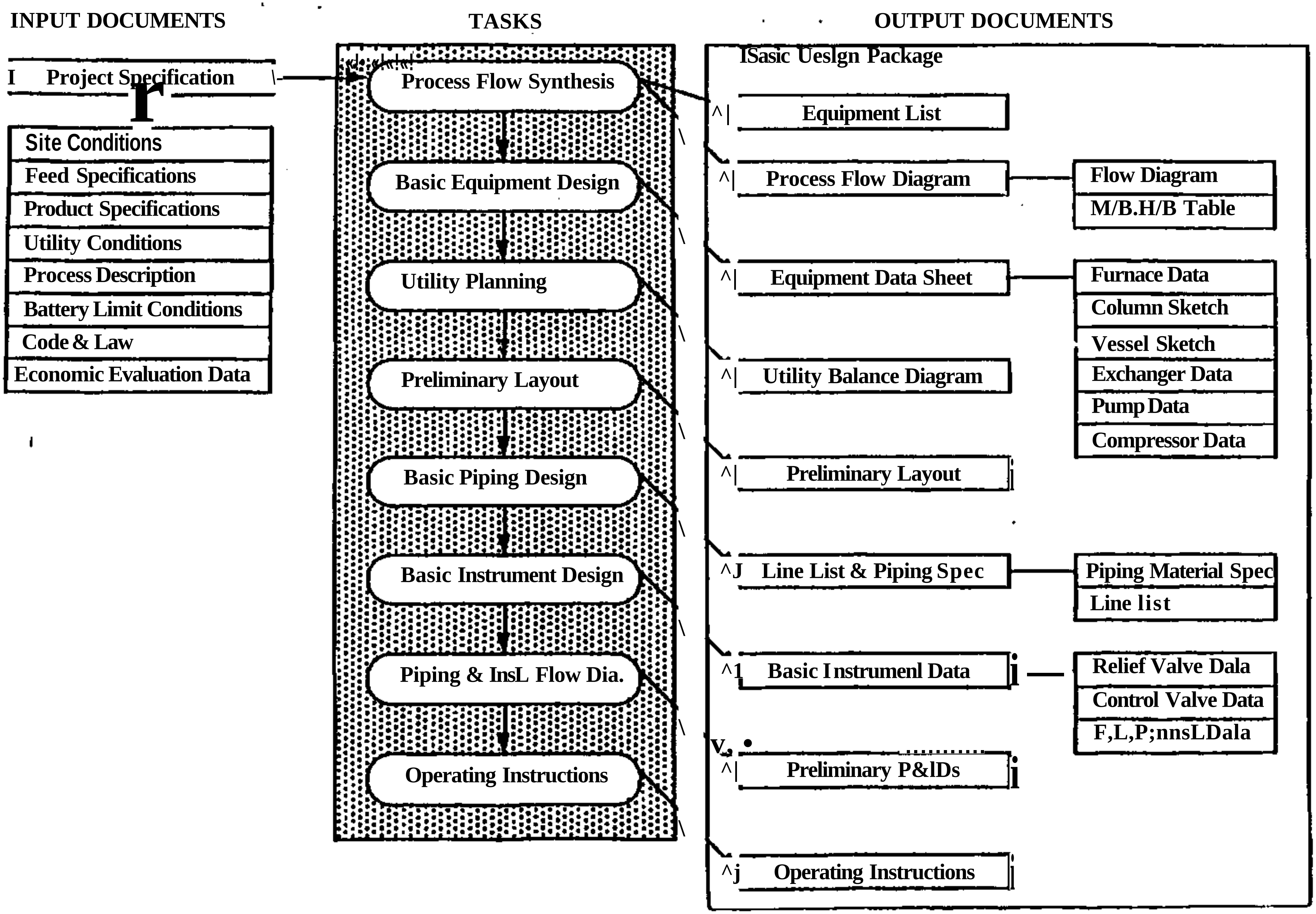

Figure 5: Design Stages and Document Flow for Toyo Engineering

Computational support: Toyo has an overall structure for its computing system for design and construction. Figure 6 provides the schematic of their system. Over time, the role of computational support has changed. The history of utilization is as follows:

- fast calculation tools ('60s)
- complex engineering calculations for analysis and simulation ('70s)
- production tools for uniform and high quality documents ('70s and '80s)
- standard procedures for design ('80s)
- shared databases ('90s)
- design decision support and communication ('90s)

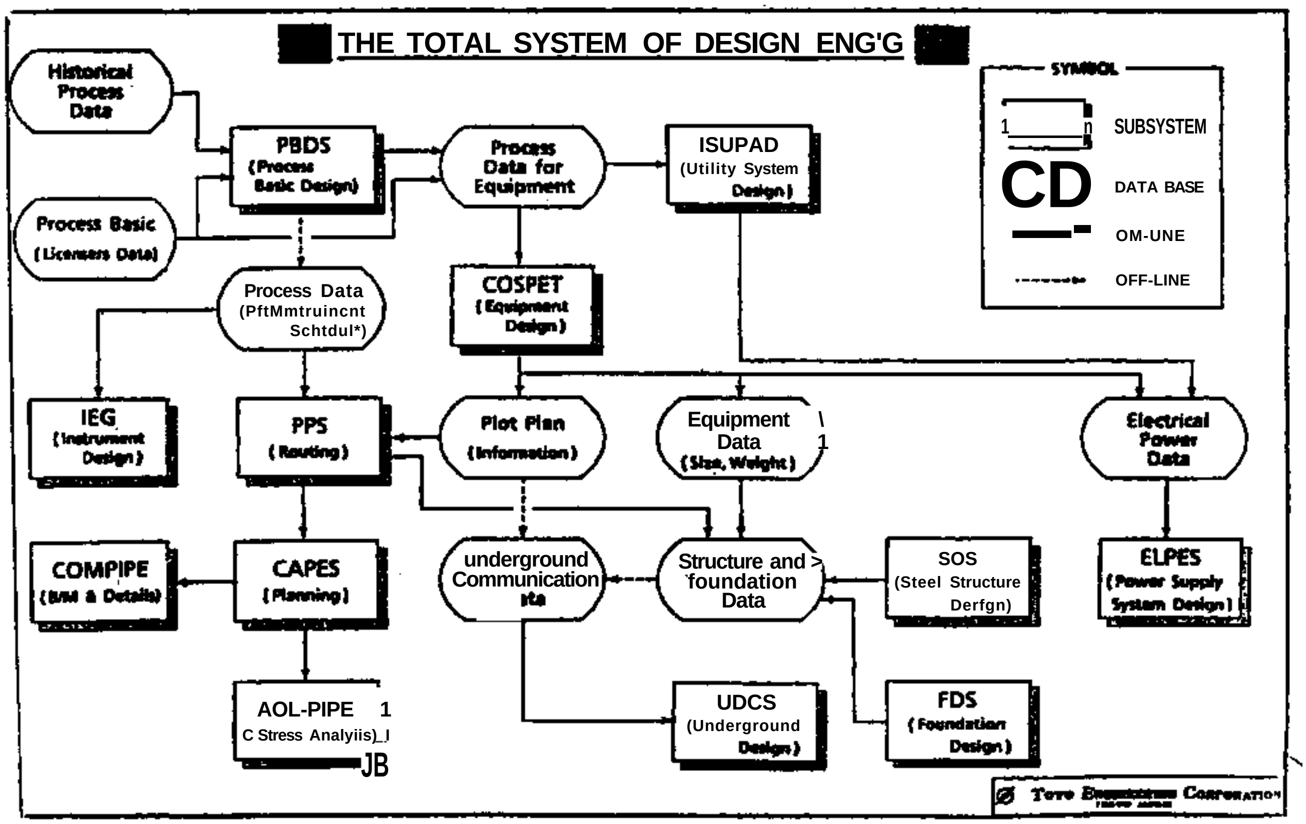

Figure 6: Total Design System for Toyo Engineering

The benefits Toyo sees from computerization are accuracy and uniform quality while they see cost, lack of flexibility, and the lack of ability to develop engineering insight in junior engineers as drawbacks. Computers are being used for some error checking functions for maintaining uniform quality.

Expected change in the next 5 years: Toyo expects the biggest change to be in the intensity of computer use in every stage of the design process. They also expect the use of dynamic simulation in addition to the currently extensive use of steady-state simulation. In addition to these changes, Toyo expects changes in their organization. Toyo also expects to use more engineers from other countries on a contract basis.

In terms of research impact on practice, the following critical areas are expected to make significant impact:

1. Integrated computer-aided engineering and project execution system
   - project data models for the total life cycle of process plants
   - plant CIM (integrating design into operation and maintenance)
   - on-line knowledge based support for design decision

2. Environmentally safe process plants
   - practical application of pinch technology for efficient energy utilization
   - low cost and high efficiency waste treatment process
   - precision machinery washing system without freon fluids

3. Flexible batch plants for the medical and food industries (e.g., AGV reactor system and the MILOX pipeless reactor system)

4. Improvement of the process for licensing products such as urea, polystyrene, methanol, and ammonia

The areas above are critical for changing the process of designing and constructing process plants.

Role of Research in Company Practice

External research: Some research projects have been conducted with Engineering Advancement Association, an industry wide organization under the auspices of MITI. New material development and catalyst development are sometimes done with engineering companies from other sectors of the industry.

The role of engineering research centers were seen to be critical in the following areas:

- applying new computer science techniques to improve design practice in the areas of design knowledge accumulation and retrieval
- uncovering the processes of individual and group design
- application of common design practice from one field to another

Internal research: Internal research is directly related to company goals. All research projects are evaluated by a steering committee chaired by the president of the company. Toyo is not involved in any fundamental research. Because most projects are development projects, the customers who will operate the process plants are involved in the process. Customer needs and operating data provide the basis for creating the next set of research plans. While some research is conducted with outside parties, almost all research and development in computer engineering and project execution is performed internally. Research at Toyo is directly related to the needs of the company. Toyo has two separate promotion structures for technical experts and researchers. People nominated to be technical experts in their area of specialization are also allocated a personal research budget for exploration above and beyond the research budget for assigned projects.

Electronics: Sony Corporation; Tokyo

Background: Sony Corporation is a unique electronics corporation even among Japanese companies. It is a personal electronics and entertainment company. The primary products of Sony are electronic products for individual consumers and professional products for the broadcast industry. The company made its mark with the introduction of the pocket transistor radio and has continued to produce consumer electronics and personnel electronics products. Most of its successes have been in developing innovations and converting them into usable, miniaturized products or, in the case of Trinitron TV tubes, perfecting an existing innovation with the promise of being superior to existing products. As a company, Sony has been adventuresome. It has an organizational structure very different from other Japanese companies.

For products in the visual documentation arena, the goal of the company is to replace or capture the photographic film market with electronic devices that can provide the same level of picture quality. Based on this strategic objective, the logic of the products developed by Sony can be traced.

Current design process: The design process used at Sony depends on whether the product is a consumer product, such as the Walkman, or a non-consumer product for the telecommunications industry, such as professional video cameras or editing and enhancing equipment. We will examine each of these product categories individually.

Consumer products: Consumer products have been the mainstay of Sony's business. As has been described in Sony's own literature, the conception and creation of the earliest successful consumer products such as the transistor radio and Trinitron television were conceived, designed, and produced by the founders of the company. To this day most of the consumer products are still conceived at the topmost levels of company. The process of designing these products is organized around small groups of designers who are responsible for a product or product model through its life-cycle. For example, a different group is responsible for each model type sold in the television market. The group for each model consists of two electrical engineers, one mechanical engineer and one industrial designer. The groups of designers are chosen for their social compatibility, expertise, and sense of ownership of the product.

Another important aspect of the design process is its integration with manufacturing. The prototyping and evaluations cycles are short and each cycle increases in scale. Most consumer products go through two cycles of prototyping before release. For example in the case of Handycam, the first cycle consisted of a small batch of 30 to 50 first die prototypes within two to three months of the product design. These prototypes are used and critiqued by Sony's founder, Akio Morita, and his group of directors. In the first cycle the primary objective is to evaluate the product function and performance. After 12 to 15 months, about 300 second prototypes are distributed on a wider scale within the company. In manufacturing the second prototype, the stability of the manufacturing process for mass production has been tested. The third release is the initial product in the market for that class of electronic devices. For example, the Walkman is a re-incarnation of a personal tape player that Sony attempted to create from its experience with pocket transistors. Sony' s innovation is in continual miniaturization and perfection of devices, not

necessarily invented by them, that can deliver audio-visual recording, access to entertainment, and personal family records in a shirt pocket.

With over 400 models of TV and numerous models of other consumer electronic goods, Sony manages its part information and drawings in a single centralized data base. There are over 300,000 parts in the data base. Maximization of parts re-use is encouraged through access to the data base.

Non-Consumer products: The theme of audio-visual equipment continues in non-consumer goods as well. Here the emphasis is on the producers of audio-visual end products and commercial users of audio-visual equipment. The market is relatively small and very competitive. The approach taken for the design process is one where the consumers are part of the design team. The product specification in terms of output and performance is articulated by the customer while the Sony design team brings its expertise in creating these devices. HDTV was developed by Sony in conjunction with NHK , the Japanese Broadcasting Company. Sony has created a demonstration theater where HDTV images are projected instead of photographic film images. Sony also uses a team-based approach in non-consumer product design and manufacture.

Another segment of the professional market is the bulk consumer of communication networks such as a newspaper company and corporate offices that need rapid transmission of images and other forms of information. The objective in this market is to create devices that permit transmission of single still frame images using video cameras as printing devices in remote locations.

Computational support: Computation support in Sony is organized and implemented by the Engineering Services Department and the Design Innovation Department. Currently the parts information is stored in a centralized data base for all products. The audio systems division has an internally developed system for electrical design (SIED - Sony Integrated Electrical Design System). For drafting and drawing, they use commercial software such CALMA and CADAM. Earlier experience with 3-D systems led to the belief that they are inadequate for design tasks. Efforts to use 3-D modeling have been abandoned. The broadcast digital/analog Video Tape recorder division uses systems such as IDEAS, CATIA and WISDOM systems for manufacturing. Most of the designers use 2-D models.

Expectations for the next 5-10 years: The aging of the founders of Sony and the need felt for globalization has left Sony in an interesting situation. Due to the structure and nature of its design teams, Sony has done all its research and development in Japan. Sony can shift production to other countries as soon as the product stabilizes in the market with several competitors offering similar products. However, this aspect of Sony is changing. For example in the TV product line, in addition to two facilities in Osaka, Sony has established three facilities in Europe and two in Asia. Sony's expectations are that it will recreate its model of operations for designing and manufacturing around the world. Clearly the target products for globalization are Sony's customary product markets, such as television, where the basic technology is well established and requires only incremental innovation to keep their products differentiated from the rest.

To manage the change and to improve innovation within the company, Sony has created a Design Innovation Department. This department's role is to create methods

and measures to evaluate the product processes, information systems design, and identify communication issues. However, it was unclear in our discussions how they planned to evaluate different processes and compare the stylistic aspects in the design process. As a starting point, they are conducting studies of their design process by creating flow charts of the process to identify bottlenecks and to correct them incrementally. The data collected will allow them to plan for controlling events that arise in the design manufacturing process. Prototyping, a critical but time consuming process, is one target for improvement. Sony would like move toward rapid prototyping so they could have a few working models within two months. They are also looking at methods for visual and functional computer prototyping to speed up the process. The description of the Handycam design process provides a bench-mark for improvement. The task of evaluation and transfer of experience across products was seen as difficult task to tackle.

Role of Research in the Company

External research: Little of Sony's research is conducted outside the company. However, they are working with and monitoring the research in some U.S. universities especially in the areas of computational software for manufacturing simulation, prototyping.

Internal research: Most of Sony's R&D is done internally. The money allocated for R&D is allocated one third to research and two thirds to prototyping (development). In 1992 the funds allocated to R&D were 7.9 percent of total sales and is expected to increase continually.

In summary, the following list is a set of research and applications problems that Sony thinks would have an impact on their design process. The list is organized by product areas and engineering services:

- Security issues in high-speed networks
- Development of computational tools for molecular design
- Automatic testbed generation of for IC test. (VLSI)
- Methods for human interface development for a wide spectrum of products.
- Applications for multi-media systems
- Tools for making historical data available combining CAD and other data (Audio Systems)
- 3-D CAD systems that can create 2-D drawings for closer interference checking (Audio Systems)
- Research and development of functional simulators (Optical Disk)
- Visual prototyping tools (Optical Disk)

Automobile Tooling: Honda Engineering, Division of Honda Motor Company; Sayama City

Background: Honda Engineering is one of three divisions of Honda Motor Company: Honda Engineering, Honda Motors, and Honda Research & Development. The role of Honda Engineering is to provide tooling for the manufacture of automobiles. Honda

Engineering has been an innovator in the design of new manufacturing tools and processes such as its multi-engine type casting bay.

Honda's innovations in manufacturing processes include: the NDC process that uses a quick casting method to allow the removal of cast part while hot, the Ultra grinding machine for precision grinding, a flexible production line with a modular machine line, simultaneous casting of six different types of engines in a single casting bay with six heads, task-specific robotic systems for fitting radiators, bumpers, heater unit, and completely automated white body welding.

Until recently, Honda Motors was the sole customer of Honda Engineering's products. Due to change in the organization to make each of the division into a profit center and to move into other value-added products, Honda Engineering is supplying manufacturing equipment to GM in the U.S. and to Renault in France. The shift is from selling only end-products to selling manufacturing equipment as well.

Current design process: Honda as a whole has adopted concurrent engineering approach through project organization. Projects are classified as research projects, development projects and engineering projects. They are organized using cross-functional teams with representatives from all the different departments in the three divisions. Most people work on multiple projects. (See Figure 7.) Project teams are composed of people with specialized skills needed to accomplish the objectives in time. There is a hierarchical command structure in these teams, but all team members undertake their work in an atmosphere of equality. All projects are evaluated by an evaluation committee. The committee consists of people from the management and technical staff. The evaluation is based the site of the operation, the product and the realism of the project. The results of the evaluation are Stop, Go or Return (to the beginning).

For example, a new project for stamping die design would first use an existing processes for the new parts. Based on this experience, a new or modified process would be created in 8.5 months for the first trial of the new equipment. During this period, the team is evaluated for improvements or changes to the manufacturing process and on the initial prototypes. Once a go decision is made, a production prototype of the part is created using the new process within about 2 years. This prototype is then transferred to Honda Motor Company and its operations for implementation for mass production.

Computational support: Computational support in Honda Engineering has evolved from just CAD and CAM systems to include CAE systems since the late 80's. They intend to integrate these systems in the near future. Stamping design is the most computerized section of Honda Engineering. The equipment design division on the other hand still uses hand drafted drawings. Some of the parts are on the computer and others are created from existing drawings on paper. Currently, this division lacks adequate access to computers. Often computer-generated drawings are modified by hand for lack of access to computers. There is a program to digitize old drawings. However, many drawings due to their poor quality will have to re-entered. Computerization will address the three K working conditions in the same manner as the development of robots did for the manufacturing.

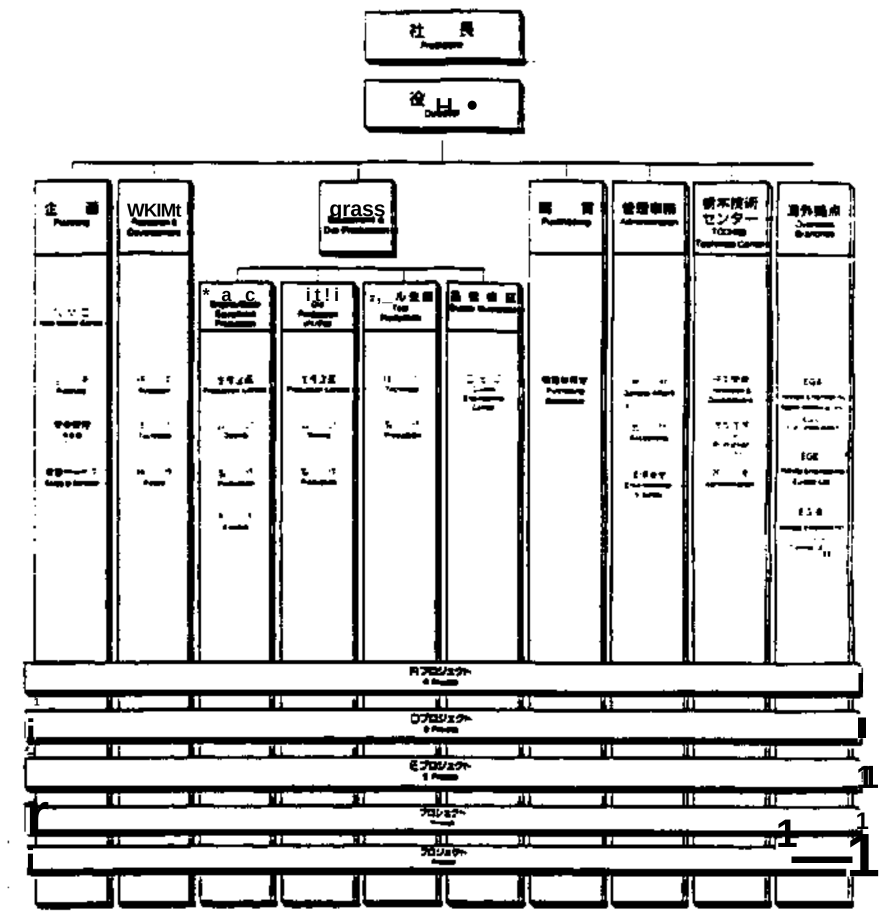

Figure 7: Organization of Honda Engineering

Expected changes in the next 5-10 years: Honda Engineering's efforts for change will be directed toward changing and improving existing equipment rather than creating new equipment. This reflects the change in the company policy to make Honda Engineering a separate profit center. Computerization of the design for process equipment design, such as stamping dies, is planned. Honda Engineering is approaching the computerization process by taking a single design area at a time to understand the process of computerization. Honda Engineering sees the clear need for computerization while also being concerned that the informal mechanisms for concurrent engineering that is currently practiced may be destroyed. They see their organizational structure as their primary strength and would like to retain those structures while providing additional flexibility in the use of computers. Honda's theme for change is based on automation to help people improve their productivity and working conditions. In their own words, " ... technology is the product of man; machinery is merely a tool ... our (Honda's) work in process mechanization and automation is conceived on the basis of machines being treated as machines and people being treated as people, a philosophy which permeates our entire operation."

Role of Research in Company Practice:

Most of Honda's R&D is conducted internally through their project system. They occasionally work with universities and other laboratories. They are part of the IMS consortium of Professor Yoshikawa at Tokyo University.

4. Conclusions

Our study of design in Japanese industries was limited and focused on identifying specific approaches that have been taken by a sample of companies from different industrial sectors. This study is by no means comprehensive and should be interpreted in light of the amount of data and the time spent in collecting the data. Hence the report should be viewed as case studies providing an overview of design practice and the role computers and engineering design research in Japanese design practice. Most of the companies rely on internal research and development that is closely tied to the needs of the product or process innovations required to improve quality and working conditions in terms of the three K's. The role of national institutions such MITI are limited in the sense that its research directions are chosen based on long term objectives. In the case of Sony, an entrepreneurial company, very little research is done outside the company. There does not seem to much collaboration between Japanese universities and industries except in the case of Honda who is a member of the IMS consortium of the University of Tokyo. However, it is clear that some companies do monitor relevant research in American universities.

In the case of use of computers in design, we have consistently found that all of the companies visited customized commercial packages or developed their own internally to meet their needs. Each company made it clear that commercial software by itself would not meet their needs. In the case of Honda Engineering, the amount of computerization was quite low and varied from design to design. The chemical companies, both MKC and Toyo were well on their way to a complete multi-functional support system based on information and data integration. This is seen as a critical area for competitive advantage both in the globalization of these companies as well as transfer of knowledge over time.

Appendix A. Questionnaire

EDRC Design Study Mission

Questions of interest

I. Introduction

We represent the Engineering Design Research Center of Carnegie Mellon University. The center is one of 18 centers sponsored by the U.S. National Science Foundation to conduct cross-disciplinary research and collaborate with industry on improving design practice. This mission is a special project funded by the National Science Foundation. Our interest is in learning how your design process is organized and how you see it changing in the future. We are also interested in your perspective on what the role of research organizations, such as ours, can be in changing the design process to better suit the needs of industry. We view this as a two-way discussion; as we pose these questions to you, we are also prepared to provide our own perspective on each of them.

II- The current design organization

A. How is information gathered **for** design?

- information about the ambient in which the artifact is expected to fiinc don
- availability of raw materials, types, limitations (procurement restraints)
- expected functionality and range of operation for the artifact
- standards, regulations within which artifact must be built and perform
- economic latititude that designer has (e.g. cost vs. functionality)

B. How fast is the complete loop from design to market?

- from concept to preliminary cost estimate
- from concept to prototype model
- from concept to finished design
- from concept to market

C. What is time differential between creation of a completely new design vs. model modification?

D. How is information managed and kept at any stage in the design process?

E. Do you track and record design errors? If so, how?

F. How are design errors corrected?

G. How do you access and use information from previous designs?

H. How is information or data transferred among diverse groups in the **prod-**

uct development process?

I. Do you integrate design and manufacturing?

J. What is the disciplinary composition of design teams? How are they organized and managed? Are they process or project-oriented? Does **their** composition change over time?

K. What is the relation between the company and its suppliers? (Most studies have concentrated on manufacturing; we are interested in the design relationship.) How do the company-supplier relationships influence your design procedures, reviews, results?

L. What software tools are used in the design process and at which stages **are** they employed?

M. How are design activities structured?

N. How do human human designers of various disciplines use software tools and knowledge/databases at each stage of design? Do models and/or databases change during the design process?

O. How would you characterize the role of computers in design and manufacturing?

P. In your view, what is the chief benefit and major shortcoming of computer-based CAD tools?

Q. How do you translate a geometric description of an object into manufacturing instructions?

R. How do you create and test prototypes?

S. What mechanisms do you employ for detecting and correcting product design defects prior to manufacture?

T. Are environmental issues a concern of the design process? If so, how are they incorporated into the design process?

U. How does the manufacturing process impinge on the early stages of design?

V. How is new technology developed in the research lab transferred to production?

- new computer software
- reports?
- prototypes?
- seminars?
- transfer or reassignment of people?

III. Expectations for change

A. Which areas, whether covered above or not, present the most critical bottlenecks for research to improve design practice?

B. How do you see the design process changing over the next 5 years?

C. What are the critical research topics of the next 5 years?

IV. Role of the research organization in modification of the design process

A. How do you select research projects and budget for them?

1. Do you select projects on the basis of overall corporate direction or on some other measurable criteria?
2. How much do you involve your customers in developing your R&D projects?
3. Are your research projects limited by availability of science or by availability, of opportunity to apply science?

B. How do you conduct research?

1. within the industry?
2. outside the industry?
3. with research labs?
4. through MITI?

C. How do you measure progress on research projects?

D. How do you stop unsuccessful efforts?

E. How do you motivate researchers?

F. What could be the role of EDRC in addressing the research topics that you view as critical to design?