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NIST Special Publication 873

Joint DoD/NIST Workshop on International Manufacturing Systems Research and Development

John D. Meyer, Editor

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[1] At Boulder, CO 80303.
[2] Some elements at Boulder, CO 80303.

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Manufacturing Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899-0001

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Preface

An international workshop was held in Rockville, Maryland, on November 3-5, 1992 to discuss major research and development programs in manufacturing systems technology. Approximately 25 leading experts attended the workshop, which was co-sponsored by the U. S. Department of Defense's Manufacturing Technology Program.

Several papers, each covering a specific geographic region or topic, were presented at the workshop. Copies of the presentations are included in these proceedings.

In addition to individual R&D programs and technology sources in North America, Western Europe, Eastern Europe, and Asia, the workshop participants also discussed R&D needs, priorities, underlying motivations, and opportunities for international collaboration. The results of these discussions will be summarized in a separate report. Information about the summary report may be obtained from the editor of these proceedings.

J. D. Meyer
Gaithersburg, Maryland
October 1992

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Introductory Remarks

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It is widely recognized that most of the costs of manufacturing a product are not attributable to direct labor expenses or the costs of purchased materials and components. Instead, the primary cost drivers are often "above-the-shop-floor" types of expenses for such functions as production scheduling and control, material and supplier management, quality assurance, manufacturing engineering and other overhead categories. In addition to representing major cost elements, these non-direct functions also have a major impact on the overall effectiveness and efficiency of the entire manufacturing operation, and therefore are doubly important in determining a company's ability to compete successfully in world markets.

For the purposes of this workshop, these non-direct functions are referred to as "manufacturing systems" technologies, where the term "systems" is used in its broadest context and is not limited strictly to computer-based production processes or techniques. Included in this definition are the many approaches to integration of manufacturing systems and the engineering tools and methods for designing processes, manufacturing equipment, facilities, and enterprises.

Major advances in manufacturing systems technologies are being pursued by numerous organizations around the world. Undoubtedly, these research efforts will yield new and improved methods and technologies that will enable companies to manufacture products parts more flexibly, with better quality and lower costs in smaller volumes.

In the midst of this high level of on-going international research, there is a need for a mechanism for examining such efforts on a worldwide basis in an open forum, with an eye towards identifying collaborative research opportunities among regions. Workshops serves as one such mechanism.

To this end, a workshop was jointly sponsored by the U.S. Department of Defense (DoD) and the National Institute of Standards and Technology (NIST). Both DoD and NIST are actively involved in the development and implementation of advanced manufacturing technologies and each is interested in exploring international collaborative research projects in this field.

The purpose of the workshop was to provide an international forum for discussing major research and development programs in manufacturing systems technology. Specifically, the objectives of the workshop were to:

1. Identify major R&D programs and sources of advanced manufacturing systems technology in Europe, Asia, North America and other parts of the world.

2. Determine the approximate level of resources being expended in each R&D area.

3. Examine the goals and strategies of these R&D programs, as well as the underlying reasons and motivations for undertaking such efforts.

4. Explore any unmet needs or high-impact research opportunities that may exist in the area of manufacturing systems technology.

5. Discuss the potential for international collaborative R&D projects and any key issues associated therewith.

For the purposes of this workshop, the term "manufacturing systems" was very broadly defined and included the following topics:

-- Production scheduling and control
-- Material management
-- Supplier management
-- Quality assurance
-- Manufacturing and industrial engineering
-- Tool and equipment design
-- Facilities and enterprise design
-- Information management
-- Equipment justification
-- Manufacturing strategies

Other "above-the-shop-floor" costs, such as marketing and sales expenses, general management, equipment depreciation, and financing were considered to be outside the scope of the workshop.

Because of the focused and specific nature of the workshop's objectives, the meeting was conducted on a "by-invitation-only" basis. The total number of participants was limited to a maximum of 25 people. Each individual was expected to be an active participant in the discussions. Thus, only knowledgeable experts in the field were invited to participate in the meeting. The workshop was truly international in flavor, with leading observers from all regions of the world taking part in the meeting.

The meeting spanned a three-day period. The agenda was as follows:

Day 1:
Morning: Registration and individual presentations and questions
Afternoon: Individual presentations and questions

Day 2:
Morning: Group discussion of R&D framework and research programs
Afternoon: Group discussion of R&D needs and priorities

Day 3:
Morning: Group discussion of collaboration opportunities
Afternoon: Adjourn

Approximately 25 people attended the workshop. A list of the attendees is included in this proceedings.

As can be seen from the agenda, a considerable portion of the workshop was devoted to group discussions of various issues concerning manufacturing systems R&D. A separate report summarizing these discussions is planned for preparation in 1993. More information about the report is available from the editor of these proceedings.

North American R&D in Manufacturing

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I. INTRODUCTION

The American approach to manufacturing research is widely diverse, distributed, and unorganized. Not only do we lack a central authority or government body with responsibility for coordinating the work, there is not even a single source to find out what is happening. If outside observers find this confusing, so do insiders. But this typically American pluralistic approach has served us well in many other cases, so we live comfortably with more confusion that other cultures might allow. In particular, we resist centralized planning and control even when the alternative seems irrational and chaotic.

Before attempting to make some sense of the very complex picture relating to manufacturing research in the U.S. today, I must acknowledge several factors that limit my perspective. Although I am reasonably familiar with what is happening in several of the relevant government agencies, in universities, and in a few government labs, the total picture is too big and complicated for anyone to have a full grasp of the situation. Even if I were able to offer complete knowledge of the current situation, it is changing so rapidly that any conclusions could only be temporary. Indeed, one of the few statements that I can confidently make is that change is occurring rapidly. Any perspective on these issues can only be a personal one; many people could look at the same issues and interpret them very differently.

Having given those warnings, I will nevertheless attempt to interpret what I know in as bold a manner as possible. I will identify the principal players, as I see them, and try to sort out the roles of each. I will also state what I see as the major themes that emerge from the totality of all the manufacturing research going on today. I will even offer some predictions.

II. HISTORICAL BACKGROUND

By tradition and broad public preference over the period from 1950 to 1990, the U.S. government has not played a significant direct role in industrial affairs. Of course, government imposed tax policies and regulations have had a big effect, but in comparison to other industrialized nations, there has been relatively little governmental support for industry. The only interactions between business and government tended to be adversarial (that is, government was taxing or regulating industry), so the business community generally preferred less rather than more interaction. In order to understand this posture, one needs only to realize that U.S. supremacy in manufacturing was unchallenged for several decades following World War II. So, while other countries were pursuing aggressive industrialization policies, aided by a wide variety of government programs intended to stimulate development, the U.S. was content with things as they were. Therefore, for the last forty five years we have accepted the concept that business will thrive best if the role of government is minimized. These conditions prevailed so long that they came to be taken for granted. In fact, virtually all of the present workforce and management have spent their entire working careers knowing only these conditions.

Similarly, and for some of the same reasons, there has been relatively little interaction between universities and industry over the same period. During the 1950's and 1960's, most universities gradually eliminated their manufacturing laboratories and courses. Few American-educated students showed an interest in manufacturing, preferring instead the glamour of space, computers, and pure science. Manufacturing jobs were looked upon as routine, uninspiring, and inappropriate for college-educated people. The brightest young people, if they had any interest in a career in business, gravitated toward law, marketing, or finance. Most of our current corporate leaders came from such a background.

All of that began to change in the 1970's, when it became apparent that the rest of the industrialized world was catching up in manufacturing. Still, it was hard to break the patterns of thought and behavior that our entire population had grown up with. Through most of the 1980's, the mood was one of denial. Our failures were either blamed on others ("unfair practices") or rationalized as unimportant ("we are becoming a service economy anyway"). The Reagan and Bush administrations strongly resisted any form of industrial policy, believing that the best long run strategy is to allow free market forces to operate without government intervention. More and more, however, even the Bush administration came to accept the concept that a new relationship between government and industry was needed. Although there is still a deeply rooted bias in the American culture against direct federal involvement in private business, there is now widespread support for the idea that the government should engage in pre-competitive generic research that will benefit American industry.

We are now in a period of re-examination of our basic institutions and their role in promoting or facilitating industrial strength. The public, the political leaders, and industry itself have finally awakened to the importance of the task. We know that things have changed, but have not yet achieved consensus on what to do. Out of the many mixed views, conflicting directions, and imaginative proposals, I expect the U.S. to develop a strong, but still pluralistic, approach to industrial modernization.

III. WHO SUPPORTS MANUFACTURING RESEARCH?

There are many organizations, public and private, that purport to speak for the manufacturing community. In fact, to list them would require a large directory. For the most part, the companies that do manufacturing see themselves as independent of any of these organizations. Nevertheless, they are looking more openly toward partnership arrangements, and are attentive to what the universities and government are doing.

A. Private Organizations

In many companies, the term "research" is taken to mean "finding out what others have done", rather than "creating something new." This view is certainly appropriate for a company that wants to mimic the leaders (a reasonable strategy) or cannot afford its own original work. But it should not confuse us about the real meaning of research or distract us from concern about the creative energies that drive innovation. According to [1], approximately half of the total R&D expenditures in the U.S. come from private industry. (Industry *spends* about three quarters of the R&D, but part of this comes from the government.) Of the roughly $89 billion that private industry spends in R&D, most–perhaps $70 billion–is attributed to manufacturing. However, this accounting treats food, chemicals, lumber, petroleum, and many other industries as manufacturing, leaving only a few of the Standard Industry Classification industries as non-manufacturing. It is difficult to estimate what portion of privately funded R&D is associated with is normally considered product manufacturing, and of that, what portion is really concerned with true innovation as opposed to routine product development and equipment replacement. However, it is safe to assume that the reported figures for the amount of money spent on R&D by industry grossly exaggerate the effort, simply because the category is so loosely defined.

In their best days, many of the giant corporations, such as General Motors, Ford, IBM, General Electric, AT&T, and Xerox, maintained large research laboratories that conducted long range research only remotely related to company products. Most of those laboratories are greatly reduced today, and almost all of the work is pressured by immediate market demands. Perhaps because of the low stature of manufacturing during past decades, most of the privately supported research is related to product, rather than process, improvements. It has been reported and widely accepted that the balance between product and process research is roughly four or five to one in the U.S. versus the exact opposite proportions in Japan. [2]

Although attention naturally turns to large companies in discussions of research, small companies account for much of the infusion of new technology into the marketplace. Both as suppliers of new technology and as users who can adopt innovations more readily than large organizations, they often appear at the beginnings of the growth curves for new technology. The U.S. cherishes its small businesses. Compared to other countries, the U.S. makes it remarkably easy to start new businesses on a small scale, with a minimum of interference. Apple Computer and Microsoft are two examples of companies that started only about 15 years ago with the ideas and work of just a few people and grew quickly to industrial giants. Such success stories are held up as demonstrations that anyone can become rich in America through hard work.

Despite these extreme examples, most manufacturing companies are squeezed by economic forces that they cannot control and only dimly understand. For most, maintaining the broad based research to support innovation across their product and process lines in a sufficiently aggressive manner to remain competitive is simply too expensive. Consequently, they are turning more and more to various kinds of partnership arrangements. For example, Sematech (Semiconductor Manufacturing Technology) , a consortium of companies working together to keep semiconductor manufacturing competitive in the U.S., operates at a level of $200 million annually. [3] The Department of Defense pays half the cost. MCC (Microelectronics and Computer Technology Corporation) is another large consortium, drawing $65 million from 20 member companies. There are now many industrial consortia working on such technologies as batteries for electric vehicles, composites, plant biotechnology, and superconductivity.

There are, of course, many professional associations that deal with issues related to manufacturing research. They generate very little financial support for research, but have a lot to do with communications and professional networking. Prominent among these are the Society of Manufacturing Engineers (SME), the American Society of Mechanical Engineers (ASME), the Institute of Industrial Engineers (IIE), the Association for

Manufacturing Technology (AMT, formerly the National Machine Tool Builders Association), the National Coalition for Advanced Manufacturing (NACFAM), the Electronic Industries Association (EIT), the National Association of Manufacturers (NAM), the Aerospace Industries Association (AIA), the National Electrical Manufacturers Associations (NEMA), and many more. I would not attempt to give a complete listing; only to illustrate that there are many.

Among the organizations of private citizens that give formal advice to the government, the National Academy of Engineering (NAE) and the National Academy of Sciences (NAS) carry particular authority, because their membership consists of the country's most distinguished scientists and engineers. The NAE has had a special emphasis on manufacturing in its program for the past seven or eight years. The most recent annual meeting reaffirmed this emphasis. [4] Although it does not engage in very many studies, it has funded a few that were directly aimed at identifying manufacturing research needs. [5, 6]

The National Research Council (NRC) is an independent organization, operated through the NAS and NAE, whose function is to conduct impartial studies on technical matters for the government. The Boards and Committees are constituted of experts in specific areas assembled carefully to reflect balanced viewpoints as well as technical expertise. Their reports are subjected to a formal review process before release to the public. Most of the manufacturing-related studies are carried out under the Commission on Engineering and Technical Systems (CETS). Under this Commission, there are thirteen Boards, including the Manufacturing Studies Board (MSB), the National Materials Advisory Board (NMAB), the Board on Army Science and Technology (BAST), and others. Recent studies include [7-9]. The Manufacturing Studies Board is currently considering an expansion of its traditional role.

Several private non-profit foundations, such as the Sloan Foundation, the Carnegie Commission, and the Hudson Institute have directed significant funds to the addressing the needs of manufacturing. [10]

B. Universities

As mentioned above, academic research in the U.S. has been mostly oriented in directions that had little to do with manufacturing. There has been a small and active community of university researchers; however, they have operated primarily as individuals. A few universities, including Purdue, the University of Wisconsin, Rensselaer Polytechnic Institute, MIT, Georgia Tech, and Ohio State, are noteworthy exceptions to the general pattern because they retained research and education programs in manufacturing through the years when others were eliminating them. Now, of course, most engineering schools are attempting to build up their capabilities in manufacturing, and many new research and education programs have been started in the last five years. The primary factor impeding this progress seems to be the limited availability of qualified faculty. Only a handful of universities have either research or education programs in manufacturing that involve more than a few faculty members. Of course in academic circles, small programs can be important. Individual professors of particular distinction, such as K. K. Wang at Cornell, Dell Allen at Brigham Young, Sam Wu at Michigan, Roger Nagel at Lehigh, and several others, have been influential forces in manufacturing research for several decades.

At least part of the reason for renewed interest in manufacturing on university campuses relates to funding pressures. Since the late 1950's, when engineering began its transition to a more science-based group of disciplines, it dependence on federal funding for research has grown steadily. Over the last fifteen years, federal funds for university research has grown from $4 billion to $17 billion. During this time, graduate programs in engineering (which, incidentally, have been increasingly populated by foreign-born students) were funded largely out of federal research funds. This system is now coming under close scrutiny to determine whether national interests are really best served by such a system. [11] It appears that federal funding for university research in general is likely to flatten out or even decrease over the next decade. On the other hand, the emphasis on economic competitiveness is likely to produce an increase in federal funding for manufacturing research. Funding from industry is virtually certain to take the same direction. The resulting shifts may produce a "last water hole in the desert" phenomenon, in which previously uninterested researchers begin to cluster around the only sources of support.

In attempting to establish credential for participating in the new priorities, many universities will undoubtedly relabel past work as manufacturing-related. Presently, I estimate that no more than $250 million is being spent in universities on manufacturing research from both federal and industrial sources.

C. Government

The elections which have just passed are likely to unleash profound changes in the national priorities and mechanisms for research. Concern for the health of the economy and awareness of the more aggressive federal support by international competitors were prominent in the campaigns of all of the presidential candidates. Congress also "got the message" and will be eager to demonstrate positive actions.

1. The President and the Executive Office

The President and the branch of government that he controls, the Executive Branch, has a great deal of authority and latitude in carrying out programs within the limits established by Congress. Matters related to manufacturing technology are handled through the Office of Science and Technology Policy (OSTP), which is headed by the Assistant to the President for Science and Technology Policy (usually just called the President's Science Advisor). A good current reference on the views of the Bush administration Science Advisor, Dr. D. Allan Bromley, is [12].

Another important body in the Executive branch is the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET- pronounced "fix-it"). It consists of high level executive branch officials and is charged with the responsibility of coordinating federal activities in science and technology that cut across the missions of more than one agency. It has existed for some time, but only during the last four years has taken on a more powerful role. Of particular importance for the present discussion is the FCCSET's method for bringing together agency activities in "crosscuts". A crosscut is a national initiative in some large technical area. Prior crosscuts involved Global Change, Math and Science Education, High Performance Computing, Advanced Materials, and Biotechnology. Manufacturing is scheduled to take effect as the next crosscut in 1994. Officially, FCCSET has no authority to either fund or require any particular actions. However, the mere fact that it focuses attention on a problem area and brings a sense of order to the subject tends to raise the priority of that area in the Congressional budgeting process.

Other organizations that have reported to the President on manufacturing issues are the President's Commission on Competitiveness, the Council on Competitiveness, and the President's Council of Advisors on Science and Technology (PCAST). Just recently a new organization called the Critical Technologies Institute was created to conduct strategic planning. It remains to be seen, at the time of this writing, what effect the Clinton administration will have upon these organizations. Many observers believe that large changes are likely. The pre-election Clinton plan promised to "create a civilian advanced technology agency modeled after the successful Defense Advanced Research Projects Agency (DARPA)." [13]

2. Congress

Congress controls, through appropriations, the money that is available for use by the agencies of the federal government. In addition to a complicated set of committee and staff work, Congress receives advice from the National Research Council (mentioned above) and another organization called the Office of Technology Assessment (OTA). This organization, like the NRC, provides impartial technical advice, but it responds only to requests from Congress. A recent OTA report on the manufacturing needs of the country [14] documents the nature of the problem and makes several policy recommendations .

Both the House of Representatives and the Senate have members who are vocal advocates of manufacturing research and the institutions that support it. Representative George E. Brown, Jr., who is chairman of the Committee on Science, Space, and Technology recently published a very thoughtful paper on the way that the research community must adjust to address social needs. [15] Senators Bingaman, Hollings, and Rockefeller have been strong advocates of various new ideas in supporting manufacturing innovation.

Overall, there is great concern in the Congress that the traditional modes of conducting research are not as effective as they should be. In a time of tight budgets, they are looking for new approaches that are both less expensive and more productive.

3. The Department of Commerce

The governmental agency most naturally responsible for commercial activity would be the Department of Commerce. Historically, however, it has been more concerned with regulation than with research or innovation. However, within the Department of Commerce is an organization now called the National Institute for Standards and Technology (NIST), formerly the National Bureau of Standards. The name change, which came in 1988 as part of a congressional bill entitled the "Omnibus Trade and Competitiveness Act" clearly signaled the intention of Congress to change the basic mission and attitude of the Department of Commerce.

Since the 1970's, a group of programs under the Manufacturing Engineering Laboratory (MEL) has conducted standards-related research (broadly construed) in advanced manufacturing. It constructed a test and demonstration facility called the Advanced Manufacturing Research Facility (AMRF). This facility and the people associated with it provided an exemplary model which attracted a good deal of national attention.

Partly because of the visible success of the AMRF, Congress instituted a program for Manufacturing Technology Centers (MTCs) whose original purpose–since broadened–was to serve as regional technology transfer sites to move the results of NIST research into use. There are currently seven MTCs administered through NIST, and there are plans for up to fifty. Another program administered by NIST, aimed more at supporting particular R&D projects by groups of companies, is the Advanced Technology Program (ATP). Thirty eight of these awards were made in 1991 and 1992. One example is the ATP on Rapid Response Manufacturing, conducted through the National Center for Manufacturing Sciences (NCMS) in Ann Arbor, Michigan, and involving Texas Instruments, Ford, General Motors, United Technologies, Oak Ridge Laboratory, Parametric Technology, Spatial Technology, Aries, CIMPLEX, ICAD, and CIMFlex Teknowledge. Even in a tight budget year, Congress saw fit to increase funding for these NIST programs by 55% in FY '93. [16]

4. The Department of Defense

The Department of Defense (DOD) is struggling with the issue of downsizing the entire military establishment in the wake of the end of the cold war. [17-19] This is a massive adjustment that affects the entire economy. Even leaving aside the political pressures to maintain unneeded activities for the sake of preserving jobs, the challenge is enormous. For example, if the military services were to live off of inventories for the next ten years, the suppliers of military products would go out of business. Then, when they might be needed, there would be neither capacity nor capability to produce highly specialized military products. Furthermore, there is recognition that future conflicts are likely to take a different form. The DOD is charged with the responsibility for maintaining whatever military capability might be needed, but to do so with a budget that is reduced by at least one third.

A few simple concepts seem to dominate the discussions of basic strategy in reducing the cost of defense. One is the greater use of civilian suppliers for all but the most specialized military products. In terms of the technologies supported by the R&D expenditures, a priority will be placed on so-called "dual-use technologies," so that the costs and benefits of the research can be shared between the civilian and military sectors. A study commissioned by the Office of the Secretary of Defense Manufacturing Technology (MANTECH) program and carried out by a group of industry representatives led to a vision of "agile manufacturing" that would service both civilian and military needs. [20] Another basic strategy is to be ready to produce quickly in time of need, but avoid investing more in actual production than is absolutely necessary. This means that new weapons systems will continue to be developed to the stage of proven effectiveness and then put "on the shelf" in readiness for full scale production. The effect of this strategy will be to reduce procurements, but preserve or even slightly increase the R&D expenditures.

Historically, each of the services has maintained separate programs to improve the manufacturing base that supplies military products. They have been conducted relatively independently. For example, the Air Force Manufacturing Technology (MANTECH) program focuses on the industries that supply Air Force weapons systems, the Army MANTECH program on Army needs, and so forth. Research in advanced technologies that would be applicable to all services has been supported by the Defense Advanced Research Projects Agency (DARPA). With the reexamination of the roles of these various programs in the light of the downsizing pressures, it appears that relatively more of the research will be managed centrally. At the least, the MANTECH programs will be more closely coordinated than they were in the past.

Partly as a result of past successes in developing advanced technology for military applications (with many side benefits to civilian applications), Congress and many outside commentators have been advocating a "civilian DARPA" to address the research needs of manufacturing. The best current reference on Congressional thinking on this issue that I am aware of is by Senator Bingaman. [21] As mentioned earlier, the Clinton plan also uses similar language. It seems likely that something new along these lines will emerge in the months ahead. Whether this will take the form of an entirely new agency, a revised mission for DARPA, NIST, or NSF, or some coordinating body for the existing agencies remains to be seen. The most recent (FY '93) defense appropriations bill contained provisions for several hundred million dollars worth of programs in extension centers, dual use technologies, and manufacturing education.

5. The National Science Foundation

Compared to other agencies, the National Science Foundation does not have much money to spend. However, NSF's influence is great, because of the respect it commands and its role as the primary source of university research funding. Out of a total budget of about $2,500 million, approximately $90 million goes to fund research that can by some stretch of imagination be associated with manufacturing. If one were really being strict, perhaps one third to one half of that would be something that manufacturing companies would see as relevant to their needs.

Most of the manufacturing research is carried out through the Engineering Directorate, a smaller portion through the Computer and Information Science and Engineering Directorate, and just a little in five other directorates. In the Engineering Directorate, there is a Division of Design and Manufacturing Systems, which supports individual investigators through three programs: Operations Research and Production Systems, Design and Computer Integrated Engineering, and Manufacturing Processes and Equipment. The annual budget for the Division is around $6.5 million. There has been an annual Grantees meeting for the investigators in this program for the past fifteen years. The most recent Proceedings [22] contains 175 reports of grants to single investigators or small teams.

The NSF started in 1985 a program to establish Engineering Research Centers. These are large cross-disciplinary university-based centers focused on various topics of importance to national economic competitiveness. Each has funding from NSF and industry totaling from $2 to $5 million per year. There are currently eighteen ERCs, of which four relate directly to manufacturing. They are managed through the Division of Engineering Education and Centers (until recently called the Division of Cross Disciplinary Research), within the Engineering Directorate. The ERCs have been independently evaluated by several study groups and found to be fulfilling their intended goals well. [23]

Table 1. NSF Engineering Research Centers Focused on Manufacturing

University	Theme
Carnegie Mellon	Engineering Design
Ohio State University	Net Shape Manufacturing
Purdue	Intelligent Manufacturing Systems
Wisconsin	Plasma-Aided Manufacturing

Using the Purdue ERC as an example, the Engineering Research Center for Intelligent Manufacturing Systems conducts an integrated cross-disciplinary program of research, education, and industrial interaction involving over sixty companies, forty faculty members, and two hundred students. There is a long range strategic plan to create, implement, and educate personnel for a new generation of manufacturing capability called Intelligent Manufacturing Systems. The concept involves an integrated enterprise which is capable of responding quickly and correctly to changing requirements. ("Agility" and "rapid response manufacturing" are terms appearing recently that refer to much the same issues.)

Another program that is operated through the same Division of NSF is for Industry-University Cooperative Research Centers (IUCRCs). These involve relatively minor start-up funding from NSF and must become essentially self-supporting through industry memberships. Their research agendas are driven by the member companies. About 50 of these now exist, of which the seven shown in the table below relate directly to manufacturing. Only $4 million of NSF funds support all of the IUCRCs.

Table 2. NSF IUCRCs Focused on Manufacturing

University	Theme
Georgia Tech	Material Handling
U. of Southern California	Manufacturing Automation
U. of Michigan	Optical and Mechanical Measurement
U. of Connecticut	Grinding
Ohio State U.	Welding
Iowa State U.	Non-destructive Evaluation
Oklahoma State U.	Web Handling

Another variation of the centers concept is found in the State IUCRCs. These centers involve matching funds from states as well as industry in three equal shares. The program is new; there are currently six.

A program called the Strategic Manufacturing Initiative, administered through the Division of Design and Manufacturing Systems, funds medium sized groups to work on issues identified as strategically important to manufacturing. [24] A somewhat similar program exists in Canada's NSERC (Natural Science and Engineering Research Council of Canada), which is the Canadian equivalent of NSF. It is called the Strategic Grants Program for Advanced Technologies and funds work in information systems; biotechnology; industrial materials, products, and processes; manufacturing systems; and energy.

The NSF is currently considering its future role in supporting research. The Director, Walter Massey, laid out three options: (1) to revert to its traditional base as a small agency supporting individuals and small groups, (2) to continue its present course of exploratory and special programs, such as centers, or (3) to expand its role with a broader portfolio, including areas of economic priority. A special Commission was formed to study the options and report before the end of 1992. The entire research community is presently wrestling with the implications of the three options. [25] Meanwhile the National Science Board, which is the governing board of the NSF, recently issued a report that seems to endorse the third option. [26] An indication of Congress' view is contained in this year's appropriations bill. The overall funding was essentially flat at $2,733 million; with certain funding restrictions specified by Congress, there is actually less available than last year. There was language in the bill, kept out at the last minute, that would have placed minimum funding limits for manufacturing, high-speed computing, and interdisciplinary environmental science.

6. The Department of Energy

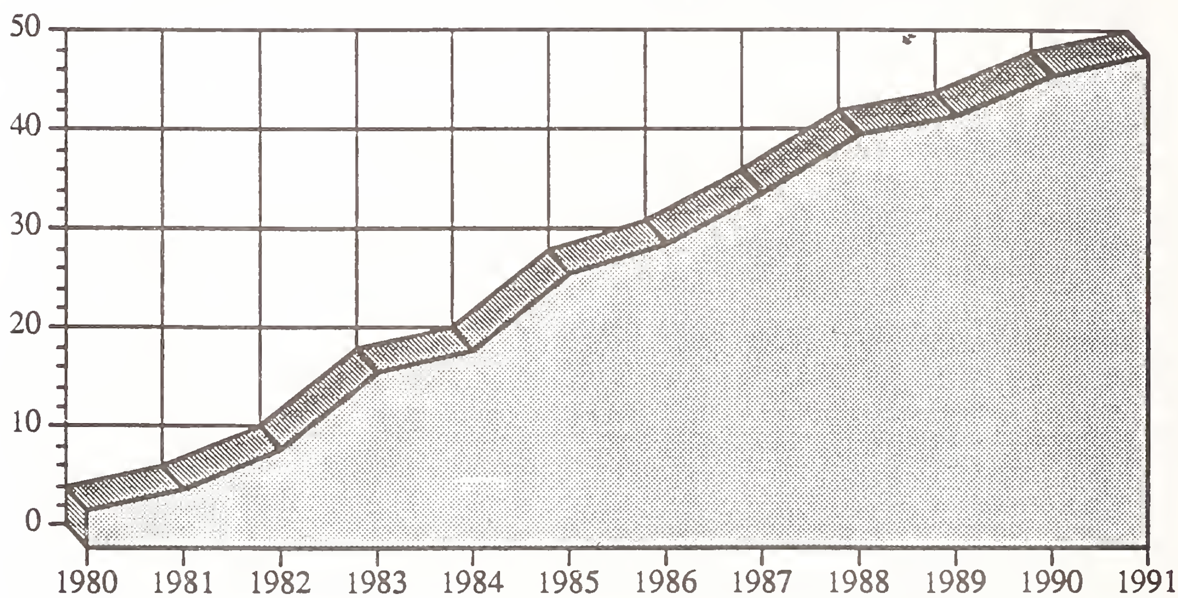
One might be surprised to see the Department of Energy even mentioned in connection with manufacturing research. It is not obvious from either its name or its past emphasis that the DOE would be involved. However, it is likely that the agency will have a lot to do with future manufacturing research in the U.S. The reason is that the agency has created some 21 large national laboratories with an array of talent and facilities that are truly impressive. They employ 23,000 scientists and engineers, have $100 billion worth of facilities in place, and have annual budgets totaling $22 billion (drawing from many sources, but especially defense). DOE's budget for research this year is about $2.4 billion. In the past, their efforts were focused on nuclear power and weapons systems, but these missions are generally viewed, rightly or wrongly, as declining in importance. As the funding for these missions declines, the labs will almost surely try to reorient to civilian needs, including manufacturing. It remains to be seen whether they can adjust to such radically different requirements.

The largest labs, which are most likely to play a major role in manufacturing R&D, are Sandia Laboratories (with an annual budget of $1.2 billion and 3600 researchers), Lawrence Livermore (with $1.1 billion and 3300 researchers), and Oak Ridge ($0.5 billion and 2000 researchers).

7. States

All of the states have programs that support science and technology development, with perhaps a greater emphasis on technology transfer than original research. The Benjamin Franklin Institutes in Pennsylvania and the Edison Institutes in Ohio are among the most prominent of these. Prior to 1980, only three states had such programs; by 1991, every state had created one. Figure 1 reflects this rapid growth during the 80's. Usually these programs are aimed more at economic development than at research *per se*. That is, the motives for funding work have more to do with creating an attractive climate so that companies will locate within the state than with creating knowledge and sharing it broadly.

Figure 1. The Growth of State Programs for Industrial Support



(data from [1], p. 338.)

E. Funding Summary

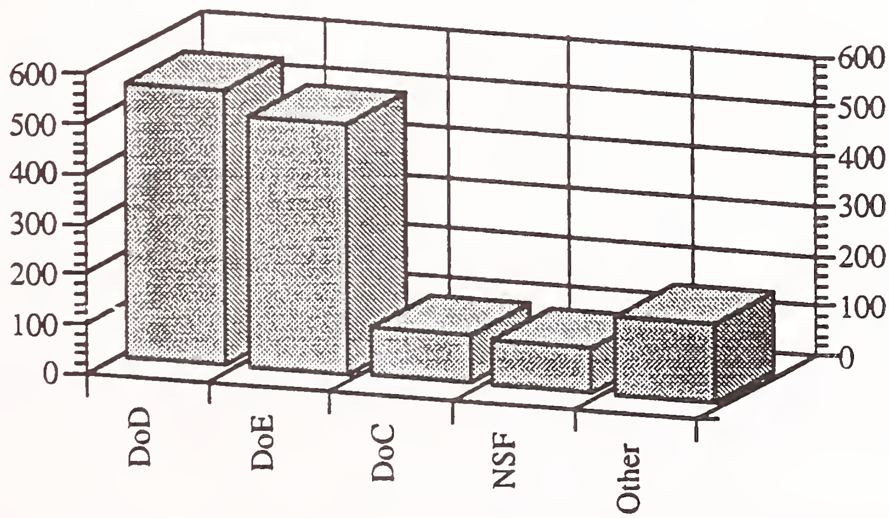
In table 3 below, I have attempted to estimate how much is spent on manufacturing R&D by the various government agencies, drawing upon a number of sources. I have also indicated by arrows my own guesses about whether the amounts are likely to increase, decrease, or stay about the same. Before interpreting these data, I must emphasize that the figures are highly questionable even as estimates. For example, I know that a lot of the research that is categorized as manufacturing R&D in the National Science Foundation is placed there only because it is administered by the Division of Design and Manufacturing Systems, while in reality a good deal of the research in this program has little to do with manufacturing. Other agencies are similar. These flaws in the data are not deliberate deception; they are simply artifacts of the accounting procedures.

Table 3. 1992 Expenditures in Manufacturing (in $ millions)

Source	Total Budget	R&D Expenditures	Manufacturing
DOD	$300,000 ↘	$38,000 ↗	$553 ↗
DOE	11,400 ↘	6,000 ↘	501 ↗
DOC	3,000 ↗	550 ↗	104 ↗
NSF	2,700 →	1,900 →	90 ↗
Other Federal	883,000 →	11,000 →	153 ↗
Total Fed.	1,200,000 →	68,000 →	1,400 ↗
Non-Federal	4,300,000 -	89,000 -	70,000 -
Total U.S.	$5,000,000 (GNP)	$157,000 →	71,400 ↗

In absolute terms, it is clear that the Department of Defense and the Department of Energy are the largest federal supporters of Manufacturing R&D, although even these pale by comparison to the private sector. Figure 2 illustrates the agency comparisons.

Figure 2. Federal Support for Manufacturing R&D, 1992 (in $ millions)



A different picture emerges, however, if one looks at the relative fraction that manufacturing R&D is relative to total R&D, as shown in Figure 3. Here, the Department of Commerce stands out. Yet another picture appears if one compares the manufacturing R&D budgets to the total budget of the agency, as shown in Figure 4. The Department of Energy, the Department of Commerce, and the National Science Foundation all spend about three to four percent of their total budget on manufacturing R&D, while the Department of Defense and other agencies spend only tiny fractions of their budgets in this category.

Figure 3. Fraction of R&D Budget Devoted to Mfg. R&D, 1992

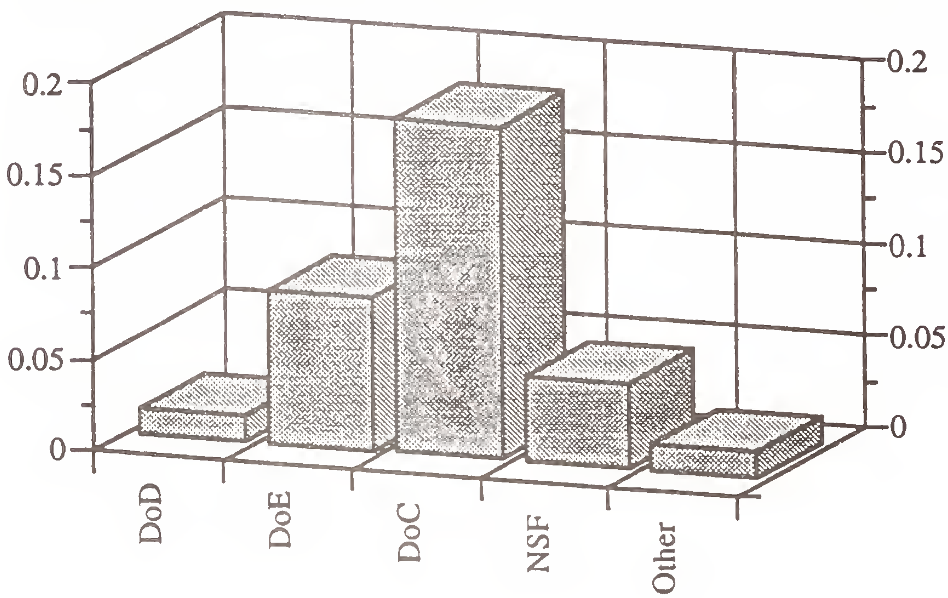
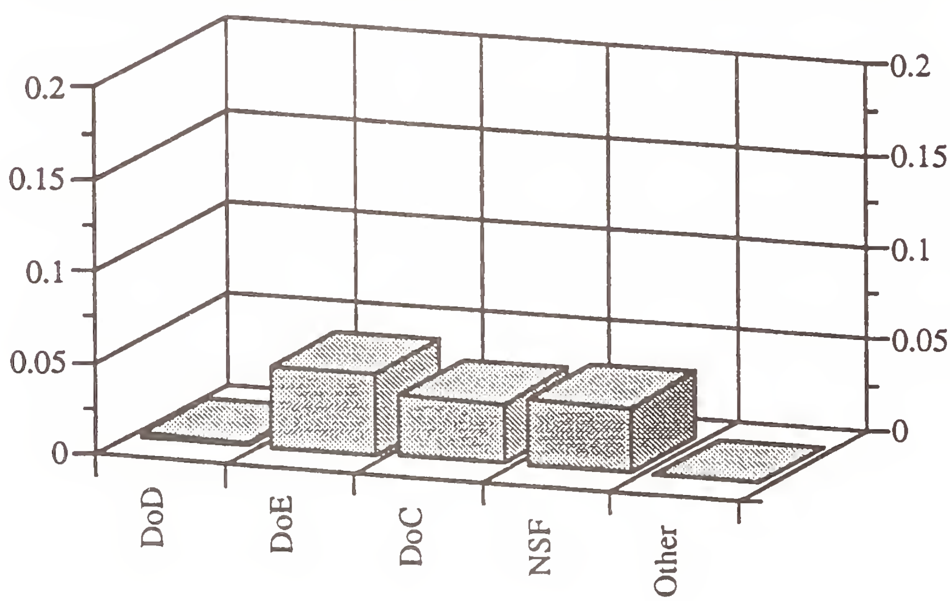


Figure 4. Fraction of Total Budget Devoted to Mfg. R&D, 1992



IV. THEMES

The U.S. has acknowledged its manufacturing problems and is attempting to do something about them. This fact alone is significant because it was not true five years ago. Along with the obvious fact that foreign competitors were capturing market share in U.S. markets, domestic companies have come to realize (slowly at first) that the basis of competition is not price alone. First, there was a realization in the past decade that our products were sometimes inferior in quality to what the best in the world could offer. This realization led to a broad-based "quality movement" that has now reached almost every manufacturing company in the U.S. Then, just within the past three or four years, companies began to realize that speed was also an important factor. "Time-to-market" and "time based competition" became driving influences for change in the product development process. Many companies have now gone beyond time, cost, and quality criteria to more abstract aspects of competitiveness, such as flexibility and volume-independence. The important point is that the companies have discarded the old simplistic, one-dimensional notion of cost-based competition and replaced it with a still evolving but much more sophisticated notion of multi-dimensional competition.

If there is any single issue that dominates all others, it would be change. Virtually all aspects of manufacturing are being reexamined, from the processes and technologies employed to the scope, scale, and organization of companies.

A. Technical Issues

As manufacturing companies have struggled with the fundamental issues of what to keep, what to discard, and what to create, the research community has also attempted to sort out priorities for manufacturing R&D. Almost all of the many organizations that deal with manufacturing research have issued reports in the past two years that attempt to lay out strategic agendas for future work. Most of the studies call attention to the fact that the problem is not entirely technical.

Several organizations have produced lists of "critical technologies" that deserve special emphasis for reasons of national interest. [27] Manufacturing always appears on these lists, along with such issues as communications networks or new materials. In Table 4, I have extracted the manufacturing-related themes mentioned in several of these studies and noted the commonalities. Having participated in numerous workshops where such lists were generated, I can attest to two contrasting conclusions. First, one has to be very cautious about taking such lists as true indicators of the most important issues. The workshop format tends to produce a kind of lowest-common-denominator conventional wisdom, rather than inspired thinking or deep analysis. Also, they are political events, with advocates of certain kinds of research speaking for their own interests. Secondly, despite these warnings and despite differences in these lists, I detect that there is a shared sense of what needs to be done.

First, there is a great need for much better understanding of basic manufacturing processes. Most are poorly understood by scientific standards, and obtaining better control and improved quality from them requires much more than the experience- based knowledge that manufacturers now rely upon. New processing methods, such as micro and nano-fabrication or composites forming, promise to open up whole new methods of manufacturing. We need new kinds of sensors and the methods to interpret the data they produce. In these areas and others, the critical technologies lists suggest a rich research agenda at the processing level.

Another category of need focuses on the product development process, with an emphasis on speed. There are fundamental issues of design representation, software integration, rapid prototyping, simulation and modeling, and knowledge capture that all could contribute to much faster development of products. These information-intensive activities are also key to achieving the "agility" or "intelligence" that many companies aspire to.

The theme of integration is another common thread. Integration of computer programs (which are notoriously incompatible), integration of the design to manufacturing transition, integration of customers and suppliers to the manufacturing organization, and integration of enterprises are all variations on the same theme. Many of the studies call out "systems behavior" or "systems management" as critical issues, suggesting a widespread feeling that out methods have not brought enough together to deal with the complexities that modern manufacturing involves.

These days, almost all technologies involve computers, so it is not surprising that computer hardware and software issues appear on the critical technologies lists. However, one must not assume that programming current knowledge is sufficient. In many if not most cases, current manufacturing practices are so *ad hoc* that to automate them would only speed up the rate of mistakes.

Table 4. Critical Technologies Lists Compared.

Theme	National Critical Tech.	Council on Compet. Crit. Tech.	Commerce Emerging Tech.	DOD Critical Tech.	NSF STRAT-MAN	IMS
<u>Manufacturing Processes</u>		x				
Micro and Nanotechnology	x					
Advanced Sensors	x		x	x		
Precision Engineering		x			x	
Process Modeling						x
Flexible Manufacturing	x		x			x
Intelligent Machines & Robotics	x			x	x	x
Clean Manufacturing						x
<u>Design Methodology</u>						
Integrated Product/Process Dev.		x			x	x
Rapid Prototyping					x	x
Product & Process Representation					x	x
<u>Software/Integration</u>						
Software Development	x	x		x		
Simulation	x			x	x	x
Sensor Fusion				x	x	x
Artificial Intelligence	x		x			x
Enterprise Integration						x
<u>Human and Organizational</u>						
Human-Machine Interaction					x	x
Teams						x
System Management	x					x
Global Manufacturing						x

B. Infrastructure Issues

There is also a good deal of agreement on some of the non-technical needs. We know that, compared to other industrialized nations, we are slow and inefficient in implementing the results of our research. We feel generally confident about our ability to invent new things, but are frustrated by an apparent inability to gain a commercial advantage.

We are also frustrated by obvious weaknesses in our educational system, particularly with respect to mathematics and science. We feel that our university system is among the best in the world, but the elementary, high school, and vocational training systems are far below world standards.

We are only beginning to comprehend what it means to compete globally. Americans are unaccustomed to thinking of non-U.S. markets, so product designs, distribution, and marketing methods are often ill-suited to the foreign customer. Because there is no systematic program or government support, each company learns its own lessons the hard way.

All of these challenges are also opportunities. We are responding to our perceived weaknesses in ways that would have been hard to imagine ten years ago. There are many new experiments in infrastructure support for technology deployment, workforce education, globalization, and collaborative research. The old view that each company is best off taking care of its own needs is largely discredited now. In its place is a new search for strategic partnerships. The regulations that previously inhibited joint ventures (based on anti-trust fears) have been greatly relaxed. Many forms of partnerships are being tried, including company to company, groups of companies either within or between industry sectors, company to university, and many other forms. We are working out new ways to deal with the apparently contradictory notions of competition and collaboration.

C. Emergent Issues

Compared to both European and Asian efforts, the U.S. has placed remarkably little focus on research involving human issues. We still tend to emphasize technologies that replace workers or lower the level of skill required, instead of improving the skills of the workers. Most companies have now learned–some at great expense–that no technological improvement can succeed without the help of a prepared and willing workforce. However, our research community has not yet focused on research contributions that would help with this problem. It demands not ergonomics or work methods, but a whole new approach to human factors research. Take, for example, the question of how to prepare an organization for a major innovation, viewed as a design problem. Field studies, designed experiments, and models could provide very helpful guidance in this common problem faced by industry. Although there is currently very little research activity along these lines, I predict that a new kind of human factors will emerge as a major research issue

Another class of issues that will grow enormously over the next decade is that related to environmental issues. Whether by choice or by force of law, manufacturing companies will have to contend with a host of issues that affect the design of products, the use of processes, the recycling of materials, the control of by-products, and systems to account for all of these things.

Finally, I would like to suggest that there is a beginning of a whole new way to look at manufacturing problems, generated out of the failures of the past. We have learned that reductionism does not work very well in the complicated world of contemporary manufacturing. That is, our standard method of breaking a complex problem down into manageable pieces and then working on the pieces independently does not yield results that make much sense in the whole. We have also learned that none of these problems are susceptible to one-time solutions. None of the buzzword, slogan, and "silver bullet" approaches of the last decade has delivered on its promise. What we need is a way to work on problems gradually and holistically. Instead of looking for *solutions*, we need to be able to synthesize workable *pathways* to sustainable, continuous improvement. The methods that would allow and support such an approach is a research issue in itself.

REFERENCES

1. National Science Board, *Science and Engineering Indicators - 1991*. 10th ed. Washington, D.C.: U.S. Government Printing Office, 1991.

2. National Center for Manufacturing Sciences, *Focus*. Ann Arbor, Michigan: NCMS, May, 1992.

3. Corcoran, E., *Semiready: A Consortium Prepares for the Second Half of the Battle*. Scientific American, 267, 5, November, 1992. 121-122.

4. White, R.M. *In Search of Technology Strategy*. in *28th Annual Meeting*. Washington, D.C.: National Academy of Engineering, 1992.

5. Compton, W.D., ed. *Design and Analysis of Integrated Manufacturing Systems*. Washington, D.C.: National Academy Press, 1988.

6. Heim, J.A. and W.D. Compton, ed. *Manufacturing Systems: Foundations of World Class Practice*. Washington, D.C.: National Academy Press, 1992.

7. National Research Council, Manufacturing Studies Board, *Toward a New Era in U.S. Manufacturing: The Need for a National Vision*. Washington, DC: National Academy Press, 1986.

8. National Research Council, *The Competitive Edge: Research Priorities for U.S. Manufacturing*. Washington, D.C.: National Academy Press, 1991.

9. National Research Council, *STAR 21: Strategic Technologies for the Army of the Twenty-First Century*. Washington, DC: National Academy Press, 1992.

10. Costello, R.B. and M. Ernst, *Regaining U.S. Manufacturing Leadership*. Indianapolis, IN.: Hudson Institute, 1992.

11. Marshall, E. and J. Palca, *Cracks in the Ivory Tower*. Science, 257, 28 August, 1992. 1196-1201.

12. Bromley, D.A., *Science, Scientists, and the Science Budget*. Issues in Science and Technology, 1992. (Fall), 41-48.

13. Clinton, B. and A. Gore, *Putting People First*. New York: Times Books, 1992.

14. U.S. Congress and Office of Technology Assessment, *Making Things Better: Competing in Manufacturing*. Washington, DC.: U.S. Government Printing Office, 1990,

15. Brown, G.E., *Rational Science, Irrational Reality: A Congressional Perspective on Basic Research and Society*. Science, 258, 9 October, 1992. 200-201.

16. Marshall, E. and D.P. Hamilton, *R&D Budget Collides With the Deficit*. Science, 258, 9 October, 1992. 208-209.

17. U.S. Congress, Office of Technology Assessment, *Redesigning Defense: Planning the Transition to the Future U.S. Defense Industrial Base.* Washington, DC: U.S. Government Printing Office, 1991.

18. U.S. Congress, Office of Technology Assessment, *American Military Power: Future Needs, Future Choices--Background Paper*. Washington, DC: U.S. Government Printing Office, 1991.

19. U.S. Congress and Office of Technology Assessment, *Building Future Security: Strategies for Restructuring the Defense Technology and Industrial Base.* Washington, D.C.: U.S. Government Printing Office, 1992.

20. Nagel, R. and R. Dove, *21st Century Manufacturing Enterprise Strategy, vol 1 and 2*. Bethlehem, PA: Iacocca Institute, Lehigh University, 1991.

21. Bingaman, J. and B.R. Inman, *Broadening Horizons for Defense R&D*. Issues in Science and Technology, 1992. (Fall): p. 80-85.

22. National Science Foundation, ed. *Proceedings of the 1991 NSF Design and Manufacturing Systems Conference*. Dearborn, MI.: Society of Manufacturing Engineers, 1991.

23. National Academy of Engineering, *Assessment of the National Science Foundation's Engineering Research Centers Program*. Washington, D.C.: National Academy of Engineering, 1989.

24. National Science Foundation, *Research Priorities for Proposed NSF Strategic Manufacturing Research Initiative*. Washington, D.C.: National Science Foundation, 1987.

25. Marshall, E., *NSF: Being Blown Off Course?* Science, 258, 6 November, 1992. 880-882.

26. National Science Board, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues*. Washington, D.C.: National Science Board, 1992.

27. Mogee, M.E., *Technology Policy and Critical Technologies*. Washington, D.C.: The Manufacturing Forum, December, 1991.

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WESTERN EUROPEAN R&D FOR MANUFACTURING SYSTEMS

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TABLE OF CONTENTS

0. SUMMARY

Research and Technology Development (RTD) in Western Europe is funded by public programmes. Of particular relevance to Advanced Manufacturing Technologies (AMT), a series of programmes has been initiated within the last ten years by the Commission of the European Communities (CEC) in order to coordinate RTD-activities on a European level.

This paper starts with a brief description of the RTD Framework-Programme of the Commission of the European Communities (CEC) and the major research programmes included. Subsequently an attempt is made to scan the major national activities for AMT in Western Europe, even though it is obviouly difficult to be complete and accurate.

In the second section AMT research institutes in Europe will be briefly presented to give an impression of the European competence and capacities. Again it is not claimed to be comprehensive as there are inventories on a European scale not yet available. More or less it reflects the overview of the authors compiled from own project cooperations.

The third section sketches motivations and European strategies in R&D within this decade. The RTD-Framework of the CEC as a follow-up of the negotiations about the Treaty of Maastricht, will be described.

The fourth section outlines some unmet needs and shortcomings in the current R&D activities. Of course, this is biased by the experiences and perceptions of the authors in this field.

Finally the fifth section describes the R&D potential for cooperation in the light of the ongoing globalization of markets.

1. RESOURCES FOR WESTERN EUROPEAN RESEARCH PROGRAMMES FOR MANUFACTURING SYSTEMS

Up to the early eighties, Research and Development (R&D) for manufacturing systems was mainly supported and managed independently by several national R&D programmes in each European country. These programmes were, and are, usually public programmes, initiated and managed by national government organizations and oriented towards the needs of the respective national industries.

Up to the beginning of the eighties the European administration, namely the Commission of the European Communities (CEC) in Brussels, was not concerned with manufacturing industry oriented R&D programmes on a broad scale. Early activities of the CEC were limited to the civil usage of nuclear power (EURATOM, CERN) and a European programme for aeronautics and space technologies, coordinated by the European Space Agency (ESA).

Although Article 235 of the European Economic Community (EEC) Treaty from 1957 gives the CEC the general opportunity to generate and develop policies for industrial R&D, in the sixties and seventies this legal basis was not employed to set up industrial R&D programmes.

A change in that understanding emerged with the "European Strategic Programme for Research and Development in Information Technology - ESPRIT". This programme, established in 1983, was the first R&D programme at the community level aimed at the development and dissemination of information technology for European industry.

The rules and procedures for cooperation between industry and university, precompetitive research and goal oriented projects, developed by ESPRIT, created a pattern for most of the subsequent R&D programmes in Europe.

In the eighties the success of ESPRIT and the growing insight into cross-national cooperation at all levels has led to a revised understanding and the development of a structured policy between national and European programmes.

In this process the authority for structured policies and R&D-programmes was shifted more and more to the CEC. This was formally acknowledged and extended by the Treaty of Maastricht in 1992, where the new article 130 F was introduced stating:

> "The Community shall have the objective of strengthening the scientific and technological bases of Community Industry and encouraging it to become more competitive at international levels, while promoting all the research activities deemed necessary by virtue of other Chapters of this Treaty."

Simultaneously it was also laid down in the Maastricht decisions that the

> "Community and the member states shall coordinate their research and technological development activities so as to ensure that national policies and community policy are mutually consistent."

1.1 The Programmatic Approach of the European Community for R&D on Manufacturing Systems

The Treaty of Maastricht has given the CEC a prominent role of defining goals for R&D and to allocate the necessary money to reach these goals. In Maastricht it was confirmed as well that each R&D activity should be embedded in a comprehensive programmatic approach for a consistent European development. This encompasses the obligation to create and continously update a Reference Framework for RTD.

1.1.1 From Single Research Projects to a European RTD-Framework Programme

Following the ESPRIT example, several R&D programmes for industrial technologies, materials, communication technologies and training activities were initiated or conceptualized in the first half of the eighties. Each of these programmes has its own set of objectives, its own administration and, of course, its own clients. In 1984, the first attempt was made to launch a common R&D framework, structuring single activities according to a common European innovation model as sketched in fig. 1.

Fig. 1: The European Innovation Model

This innovation model interrelates the functions of High-Technologies, industries and infrastructures to a structure, where High-Technologies mainly have the double function of firstly supporting industries by process innovation and secondly developing infrastructures by product innovation. In this model, industry has the role to expand this model by development of complementary applications and services.

The intention to systemize community actions was basically already the overall objective of the first Framework Programme valid for the period from 1984 to 1987. In the second Framework Programme from 1987 to 1991 this approach was enhanced and focused on the needs and opportunities for European IT-industry (see fig. 2)

Fig. 2: European Needs and Opportunities for IT-Industry

Based on the community goals towards improved competitiveness and market commitment and considering the social and cultural needs of the different Member States a transnational infrastructure for Europe was proposed to support integration of national business potential into a common market after 1992. In this context Information and Communication Technologies (ICT) were considered as key technologies for realizing such a transeuropean infrastructure. Based on this objective, technologies were selected and the requirements for focused R&D were specified in detailed R&D programmes.

This focus is maintained in the current Framework Programme issued for the period from 1990 to 1994. In this third Framework Programme the objectives and procedures have been refined and stronger attention is paid to establishing cross-national cooperation, especially between small and medium-sized enterprises (SME's). The installation of networks and cross-national mobility-programmes play a favourite role in the current Framework Programme.

The subsequent table gives an impression of the scope and relative weight of the individual programmes in the current third Framework Programme. The table shows that enabling technologies, the management of natural resources and the management of intellectual resources are the major action lines. Within this scope the budget allocation stresses the importance of enabling technologies. But in the medium term more attention will be paid to human capital and environmental questions.

	CEC-Programme	period	CEC budget in $ M	% of total budget
	I. Enabling Technologies			
1.1.	Information Technologies	90-94	1,731	23.7%
1.2	Communication Technologies	91-94	626	8.6%
4.3	Telematics Systems	91-94	486	6.7%
2.1	Industrial and Materials Technologies	91-94	957	13.1%
2.2	Measurement and Testing	92-94	179	2.5%
	II. Natural Resources			
3.1	Environment	91-94	530	7.3%
3.2	Marine Science	91-94	133	1.8%
4.1	Biotechnology	92-94	210	2.9%
4.2	Agriculture	91-94	426	5.8%
4.3	Biomedical/Health Research	91-94	170	2.8%
4.4	Life Sciences for Developing Countries	91-94	142	1.9%
5.1	Non-nuclear Energies	91-94	201	2.8%
5.2	Nuclear Fission Safety	91-94	255	3.5%
5.3	Controlled Thermonuclear Fusion	91-91	586	8.0%
	III. Intellectual Resources			
6.	Human Capital and Mobility	92-94	663	9.1%
Total budget			7,296	100.0%

Budget Allocation for the third CEC Framework Programme

After eight years of programmatic RTD the Commission of the European Communities has developed its own methodologies, an appropriate administrative structure and many transnational networks supporting successful refinement of this approach. This of course enhances the potential to guide the integration process. The project to complete the Single Market by 1993 was first conceived from a legal and regulatory viewpoint. The basic idea was mutual recognition and minimal harmonization of legislation. This was indeed a necessary pre-condition, but not in itself sufficient. To achieve European integration, it is equally important to make sure that the basis of interconnecting infrastructures, based on the idea of interoperability, is in place.

This understanding appears as well in the new perception of a European industrial policy. Unlike the seventies, where industrial policy was perceived as a dirigistic approach, it is recognized today that public intervention in this area must take the form of horizontal activities to achieve the right climate and balance to support the competitiveness of European industry.

An example of this revised understanding is also the rule of "rolling programme" when defining the Framework Programme. This means an overlap of one or two years between two successive programmes. Again this originates from a non-dirigistic understanding of the programmes as integrating guidelines rather than prescriptive plans.

1.1.2 Relevant R&D programmes for Manufacturing Systems within the European Framework Programme

Within the European Framework Programme, ESPRIT (European Strategic Programme for Research and Development in Information Technology), BRITE (Basic Research in Industrial Technologies for Europe) and RACE (Research and Development in Advanced Communications Technologies in Europe) are the most relevant programmes for R&D in manufacturing systems. The budgets and their development are shown in figure 3.

Fig. 3: CEC Programmes Budget Development

1.1.2.1 ESPRIT

ESPRIT was started in 1983 with a preparatory phase for establishing the approach to be used for precompetitive R&D in Information Technology (IT). Equipped with a budget of $14.7 million, 16 pilot projects on advanced microelectronics, software technology, advanced information processing, office automation, computer integrated manufacturing and information exchange systems were selected.

The result of the preparatory phase was a detailed programme structure for the ESPRIT I phase from 1984 - 1988 (total budget: $960 Million) specifying a catalogue of objectives and projects according to the above subjects.

The overall objective for the CIM area in ESPRIT I was to establish a technology base for progressive introduction of IT into all phases of the manufacturing cycle. The main emphasis was placed on manufacturing elements as needed for discrete batch manufacturing. In this CIM subprogramme 36 international projects were started.

In the second programme phase of ESPRIT, from 1987-1992, three general objectives were established:

- to provide European IT-industry with basic technologies
- to promote European industrial cooperation in IT R&D
- to pave the way for internationally accepted standards.

According to these objectives "Microelectronic and Peripheral Electronics", "Information Processing Systems" and "IT Application Technologies" were selected as R&D areas. The CIM activities were extended in scope, specifically including engineering as a R&D subject. The overall budget for this phase was $2.1 billion.

For the third phase of ESPRIT, from 1990 - 1994, emphasis has been placed on actions and projects accelerating the integration of advanced technologies in the business world. This phase comprises accompanying measures for technology transfer and training activities to increase the potential for participation especially in peripheral European regions. The total budget of this phase is $1.7 billion.

Within the subprogramme of Computer Integrated Manufacturing and Engineering (CIME) the work programme for ESPRIT III distinguishes three main sub-areas:

1. Architecture and Infrastructure for CIME
2. Management and Design of Industrial Enterprises
3. Mechatronics, Robotics and Sensing Technologies

The first sub-area comprises architectures, systems engineering and communications for CIME applications based on former ESPRIT projects like CIM-OSA, CNMA and CADEX.

The second sub-area encompasses design, engineering, production management and logistics with several tool development projects for design and evaluation of complex CIM systems.

The third sub-area addresses IT based automation and control systems for production processes, manufacturing units, autonomous mobile robots and mechatronics devices.

In 1991 the budget for this CIME area was $198 million (CEC-contribution = 50%).

ESPRIT is considered a very successful programme. In 1990 3,531 enterprises and universities were involved in various project consortia.

1.1.2.2 BRITE/EURAM

BRITE started as a programme in 1985 to encourage collaborative precompetitive R&D on advanced technologies with basic R&D and demonstration projects in the first phase. Areas of BRITE were: laser-technology, computer-aided testing, CAD/CAM-applications and application of new materials, particularly polymers in industry. The budget of this phase was $237 million.

In the second phase from 1989 - 1992 BRITE was extended in scope explictly addressing "European Research on Advanced Materials" (EURAM) and by a special section for aeronautics.

The areas of BRITE/EURAM are Advanced Materials Technologies, Design Methodologies for Products and Processes, Application of Manufacturing Technologies and Technologies for Manufacturing Processes.

For these subjects 374 projects were selected and initiated covering industrial applied research, focused on fundamental research and feasibility for small and medium sized enterprises. Current statistics show that approximately 56 % of BRITE/EURAM participants come from industry (1/3 of these are SME's), 27% are Universities and 17% are research centres.

For the second phase of BRITE/EURAM a total budget of $639 million was allocated.

In the third phase of BRITE/EURAM from 1990 - 1994, the focal points, defined in the second phase, are basically continued with a slight shift towards the integration of advanced technologies in user industries and technology transfer. Special emphasis is also placed here on materials, processes and technologies to reinforce the scope and effectiveness of recycling.

This current third phase is equipped with a budget of $858 million.

1.1.2.3 RACE

RACE was launched in 1985 by a 18-month definition phase for developing an Integrated Broadband Communication (IBC) reference model, to evaluate projects for technology options and to evaluate the techno-economic feasibility of the IBC reference model. For this work programme a budget of $28.3 million was allocated, to implement the programme.

The first RACE programme phase from 1987-1992 was focused on the community wide introduction of Integrated Broadband Communication (IBC), in coordination with the European national introduction of the Integrated Services Digital Network (ISDN), starting in 1995. Covering all aspects of terrestrial networks, satellite and mobile telecommunications, it includes narrowband networks and distribution networks of all kinds as well as specific broadband networks. This first phase of RACE was equipped with a budget of $704 million.

The second programme phase of RACE from 1990-1994 is basically a continuation of the activities defined in RACE I, but strengthening the research effort on optical communications and techniques of synchronic/asynchronic switching, intelligent networks and new value-added services that are both profitable and adapted to the developing needs of users. These actions include a community R&D effort of the prenormative type in order to guarantee the interoperability of the systems on the basis of common standards and protocols. Particular attention will be given to the growing demand for mobile telephony services and the integration of these services into networks. This second phase has eight priority areas:

1. IBC (Integrated Broadband Communications)
2. Intelligence in networks/flexible communication resource management
3. Mobile and personal communications
4. Image and data communications
5. Integrated service technologies
6. Information security technologies
7. Advanced communication experiments

8. Test infrastructure and interworking

The allocated budget for this current phase is $ 625.9 million.

RACE is ultimately concerned with services, their definition and their exploitation by end users. This means a very general, multi-purpose and public infrastructure.

The impact of RACE for manufacturing is related to distributed manufacturing and multi-supplier situations. This is a very exciting field for future applications. For a long time the scope of CIM was limited to internal enterprise functions. So CIM systems were designed to integrate functions of one enterprise. The cross integration of functions from different enterprises into one consortium was beyond this view and not supported. But complementary networks, composed of different enterprises are an important business reality. Especially in europe a relevant proportion of business is organized by flexible consortia formed out of SME's. For this kind of manufacturing business open-systems and public IBC-networks have an important potential.

1.1.2.4 Other relevant programmes

Additionally to the above mentioned R&D programmes aiming primarily at technology development, other programmes have been launched by the CEC to develop supportive structures. Examples of such programmes are COMETT, DELTA, DRIVE, SPRINT, STAR.

COMETT is the Community Action Programme for Education and Training for Technology. This programme was started in 1987 to promote European cooperation between universities and enterprises by fostering the joint development of training programmes and by improving the supply of training in the Community. The current COMETT phase from 1990 - 1994 has a budget of $256 million.

DELTA is the acronym for "Developing European Learning through Technological Advance" and was started in 1988, to stimulate European cooperation in learning technologies by the development, testing and validation of Advanced Learning Technology concepts. The pilot-phase of this programme was equipped with a budget of $25 million.

DRIVE is the acronym for Dedicated Road Infrastructure for Vehicle Safety in Europe. This programme aims for the introduction of an Integrated Road Transport Environment (IRTE) offering improved transport efficiency. DRIVE has a budget of $75 millon.

SPRINT (Strategic Programme for Innovation and Technology Transfer) is aiming to strengthen the assistance infrastructure for transnational technology transfer in Europe. The instruments of this programme are the creation of a cooperation network, conferences and the organisation of training activities to advise SME's on innovation. SPRINT started in 1989 and has a budget of $115 million.

STAR (Special Telecommunication Action for Regional development) is a general programme to support the development of less-favoured regions of the EC by access to advanced telecommunication services. This programme started in 1986 for a five year period and was equipped with a budget of $940 million.

1.1.3 National R&D-programmes on Manufacturing Systems in Western Europe

Subsequently a brief overview on publicly funded national R&D-programmes for manufacturing systems will be given, followed by a short presentation of the coordinating bodies and organisations.

1.1.3.1 Overview

In figure 5 several national R&D-programmes on Manufacturing systems in Western Europe are listed. This selection of current and recent programmes is probably not exhaustive, as there is no central institution or database, responsible for tracing and updating the actual programme-state in Western Europe.

Fig. 4: National R&D-Programmes in Western Europe

This table shows that in most of the European countries complementary programmes are in effect. The total budget of these programmes even exceeds the budget available to the CEC for RTD. So the total publicly funded effort for industrial manufacturing systems was in 1988 $6.2 billion (see fig. 5), whereas the total budget of the current third Framework Programme of the CEC sums up to $7.3 billion for five years! This stresses again the importance of the coordination principle, laid down in the Treaty of Maastricht and the potential for mutual synergy from that.

Fig. 5: National R&D-Effort in AMT

1.1.3.2 Coordinating Bodies

Subsequently the national coordinating bodies, mentioned in the table (see fig. 4) with their respective acronyms will be described in terms of the type of organisation, their responsibilities and objectives:

BMFT/Bundesministerium für Forschung und Technologie
Heinemannstraße 2, D-5300 BONN 2

- The BMFT is the central R&D National Ministry for Research and Technology, responsible for the preparation and execution of national programmes. Furthermore BMFT finances the major part of the scientific basic research in germany by providing funds for the "Max-Planck Gesellschaft zur Förderung der Wissenschaften (MPG)" and several other institutions like the "Fraunhofer Gesellschaft (FhG)". The total annual budget of BMFT is $6.7 billion.

CNR/Consiglio Nazionale delle Richerche
Piazza Aldo Moro 7, I-00100 ROMA

- CNR is the general italian governmental research organisation. It allocates the national budget for R&D to different projects and institutes within and outside the universities. It also advises the Interministerial Commission for Economic Planning (CIPE). This commission is responsible for the development of national R&D programmes.

CNRS/Centre National de la Recherche Scientifique
15, Quai Anatole France,F-75700 PARIS

- CNRS is a public institution for science and technology, reporting to the "Ministry of Research and Technology". The main task of CNRS is the management of national research programmes, the evaluation of programmes and projects and the dissemination of scientific results. CNRS has a budget to finance R&D and as well own institutes and laboratories.

CSIC/Consejo Superior de Investigaciones Cientificas
Serano 117, E-MADRID

- CSIC was setup in 1981 and is one of the main bodies in spain to promote scientific and industrial R&D. CSIC is directly reporting to the Ministry of Education an Sciences and manages about 23 % of the total R&D effort in spain.

DFG/Deutsche Forschungsgemeinschaft
Kennedyallee 40, D-5300 BONN 2

- The DFG is the German national organisation for the support and management of scientific research over all disciplines. The DFG has an advisory function on various levels of governmental departments. The annual budget of the DFG in 1991 was $877 Mio.

JNICT/Junta Nacional de Investigacao Cientifica e Tecnologica
Avenida Don Carlos I, 126, P-1200 LISBOA

- JNICT was founded in 1967 and is the governmental coordinating body to promote and finance scientific and technological research in Portugal.

KFWF/Kommission zur Förderung der Wissenschaftlichen Forschung
Wildhainweg 21, CH-3001 BERN

- THE KFWF is an public organisation for the administration of federal funds for R&D in Switzerland. The main subjects of this R&D are electronics, mechanical engineering and material science.

NBST/National Board for Science and Technology
Shelbourne House - Shelbourne Road, EI-DUBLIN 4

- The NBST is an Irish organisation, reporting to the Ministry of Industry, Trade, Commerce and Tourism. The NBST is responsible for the development of a "viable national research competence in key technologies". The NBST conducts several R&D-programmes on universities and research institutes. The annual budget of the NBST is 1,1 mio IRL (1988).

NTNF/Norges Teknisk-Naturvitenskapelige Forskningsrad
P.O. Box 70 Tasen, N-0801 OSLO 8

- NTNF's objective is to promote scientific, industrial and related research for the Norwegian industry. NTNF was founded 1946 as an independent institution. It advises the Norwegian government in trends and demands for R&d and is widely autonomous in the management of the annual R&D-budget granted by the government. NTNF's principal fields of interest are: industry and mining, energy supply and the continental shelf, building and civil engineering, shipping, transport and communication.

SERC/Science and Engineering Research Council
Garrick House, 3-5 Charing Cross Road, GB-LONDON

- The Science and Engineering Research council is the British national council supporting basic and applied research in natural sciences and engineering. SERC has close contacts to industry and provides grants for various R&D-projects.

SPIN/Stimulerings Projectteam Informaticaonderzoek
P.O. Boc 316, NL-2600 AH DELFT

- SPIN is an organisation within the framework of the "Dutch Information Technology Stimulation Programme (NL-INSP)". The function of SPIN is here to stimulate research in information technology, to administer the programme and to advise the Dutch Administration on strategic trends in technology markets.

STF/Statens Tekniskvidenkabelige Forkningsrad
Holmens Kanal 7, DK-1060 KOPENHAVN

- The STF is one of the six research organisations in Denmark, established in 1968, forming the so called "Central Danish Research Organisation". STF is responsible for technical sciences. Heading these research organisations is the "Council for Science Policy and Planning", established in 1973, which advises the government.

STU/Styrelsen for Teknisk Utveckling
Box 43200, S-10072 STOCKHOLM

- STU is the Swedish national board for technological development and supports various technical research projects, cooperative research and industrial developments. STU initiates, executes and monitors national R&D-programmes.

TEKES/Technology Development Centre
Malminkatu 34, SF-00101 HELSINKI

- TEKES was founded in 1983 and charged with the task of raising and maintaining the level of technology in Finland. TEKES advises the Ministry of Trade and Industry (MTI) in technology policy and is charged to implement national R&D-programmes through the financing and R&D-projects in cooperation with research units and other organisations which finance technological research. The funds of TEKES are intended to support corporate R&D projects, as well as research performed in institutions of higher educations, and at research institutes.

2. EUROPEAN INSTITUTES IN THE FIELD OF R&D FOR MANUFACTURING SYSTEMS

The following section provides an overview of European institutes working in the field of advanced manufacturing systems development. Most of these institutes are publicly funded and located at technical universities. This is the result of a widespread policy in europe to combine the public educational functions at universities with technology transfer functions to industry by dedicated and related R&D-centres at the same place.

The following list again does not claim to be complete or exhaustive. So it gives only a partial view and a brief characteristic of various institutes known by contacts, achieved in different European cooperation programmes. This list shows that there is a potential in all Western European countries to develop and adopt advanced manufacturing technology.

BIBA/Bremer Institut für Betriebstechnik und angewandte Arbeitswissenschaft an der Universität Bremen
Hochschulring 20, D-2800 BREMEN 33

- BIBA is an institute at the University of Bremen, working in the field of production techniques and the design of manufacturing systems. BIBA applies a broad multidisciplinary approach, covering mechanical engineering, electrical engineering, informatics, mathematics, economics and social sciences. One of the main functions of BIBA is technology transfer to industry. Moreover BIBA is involved in more than 200 project-cooperations with different European partners.

CIMRU/University College Galway
Nun's Bland, IRL-GALWAY

- CIMRU is one of the centres of excellence in Ireland in the field of factory automation, CIM architectures and control systems for CIM and CAD/CAM applications. CIMRU is one of four AMT Applied Research Units under the umbrella of the national AMT programme. CIMRU has close contact to industry and is here especially involved in the development of advanced production and inventory management systems. Moreover CIMRU is involved in various European programmes and projects.

EPFL-LPG/Ecole Polytechnique Federale de Lausanne Laboratoire de Gestion de la Production
ME-ECUBLENS, CH-1015 LUSANNE

- EPFL is one of the Swiss federal institutes of technology. CIM is one of the major areas of R&D. In this field, several laboratories contribute to other European projects like the ESPRIT projects CIM-OSA, CNMA and FICIM. Furthermore a demonstration-centre is set up for information and training of SME's.

FhG/Fraunhofer Gesellschaft
Leonrodstraße 54, D-800 MÜNCHEN 19

- The "Fraunhofer Gesellschaft" is a german association, operating various institutes in applied R&D in close cooperation with german technical universities. Fraunhofer institutes working in the field of Manufacturing Systems are the "Fraunhofer Institut für Arbeitswirtschaft und Organisation" and the "Fraunhofer Institut für Produktionstechnik und Automatisierung" in Stuttgart, the "Fraunhofer Institute für Produktionsanlagen und Konstruktionstechnik" in Berlin, the "Fraunhofer Institut für Produktionstechnologie" in Aachen, the "Fraunhofer Institut für Systemtechnik und Innovationsforschung" in Karlsruhe and the "Fraunhofer Institut für Transporttechnik and Warendistribution" in Dortmund. All these institutes work in close contact with industry and are involved in numerous national and international projects.

GPCIT/ Greek Productivity Centre IT
28 Kapodistrious Street, 106 82 ATHENS

- GPICT is a greek R&D centre of the greek ministery of National Economy in the fields of education and training, development of software application and standardisation in IT and CAD/CAM.

GRAI/Laboratoire GRAI - Universite de Bordeaux 1
Cours de la Liberation 351, F-33405 TALENCE Cedex

- GRAI is an institute at the University of Bordeaux working in the field of CIM and production techniques. The GRAI-institute is a specialist in modelling techniques for production systems. The GRAI-methodology is such a modelling technique designed for decision and information modelling. GRAI is involved in numerous European projects on advanced manufacturing technologies and production management systems.

HUT/IIA/Helsinki University of Technology, Institute of Industrial Automation

Otakaari 1A, SF-02150 ESPOO

- The Institute of Industrial Automation is a research institute at the Technical University, working in the field of automation, mechanical engineering, industrial engineering and information technology. HUT/TAI works in close contact with national industry. Approximately 90% of the activities are based on industrial projects. HUT/TAI is also involved in various European R&D-programmes like RACE, ESPRIT or BRITE/EURAM although Finland has to funf this participation with national money.

IIRS/Institute for Industrial Research and Standards
Ballymun Road, IRL-DUBLIN 9

- IIRS is a technical service institute for industry, aiming at encouraging and assessing the use of science and technology in industry. The main working areas are electronics, engineering, information technology, textiles and timbers.

IKERLAN/Centro de Investigaciones Tecnologicas
E-20500 MONDRAGON

- IKERLAN is the spanish research centre for applied R&D in advanced technologies for the basque machine tool industry. It offers R&D services on an contractual basis and as well training and consultancy services. The function of IKERLAN covers promotion of AMT and services to support regional development. IKERLAN is also involved in various European projects and programmes.

ITP-TNO/Instituut Informatie-Technologie voor Productieautomatisering
P.O. Box 513, NL-5600 MB EINDHOVEN

- The ITP is one of the varous institutes of the dutch organization for applied research and development called TNO. Similar to the german "Fraunhofer Gesellschaft" TNO covers a wide spectrum of application oriented technical research. Within this framework ITP's one institute working in the development and application of computer science for discrete production, process industry, logistics and production management. ITP is located on the campus of the Technical University of Eindhoven.

LAAS/Laboratoire d'Automatique et d'Analyse des Systemes
7 Av. du Colonel Roche, F-31077 TOULOUSE Cedex

- LAAS is a french institute, working in the field of automation, computer science, microelectronics and production systems. The annual budget is about $15 million.

LNETI/Laboratorio Nacional de Engenharia e Tecnologia Industrial
Estrada Paco do Lumiar 22, P-1600 LISBOA

- LNETI is a body with administrative and financial autonomy and has its own budget for disposal to R&D. The function of LNETI is to promote and implement R&D in industry and energy sectors. Furthermore LNETI performs training and consultancy projects for the portuguese industry. LNETI operates a technology institute called ITI and an energy institute. The ITI has 5 departments covering mechanical engineering, electronics and chemical R&D.

NEL/National Engineering Laboratory
East Kilbride, G75 0QU GLASGOW

- NEL is a governmental organisation of the Department of Trade and Industry (DTI) in London and works on expert systems and computer integrated manufacturing within the national R&D programmes. NEL is also involved in European projects to develop industrial oriented manufacturing systems.

RIT/Department of Manufacturing Systems and Computer Systems
for Design and Manufacturing - The Royal Institute of Technology
Brinnelvägen 81, S-10044 STOCKHOLM

- The Institute of Technology is part of the Stockholm University and has about 7000 students in Engineering. The staff is 150 professors and about 2000 administrators and technicans. The Department of Manufacturing Systems works especially in the area of robotics and CAD/CAM. This work includes human, organisational and economic aspects.

SI/Senter for Industriforskning
Forskningsveien 1, N-0314 OSLO 3

- SI is a multidisciplinary research institute, providing professional development and market orientated R&D for industry in the areas of automation, robotics, CAD/CAM and CAE. The application fields of SI are mechanical industry, offshore and marine industry. SI works mainly on a contractual basis.

SINTEF/The SINTEF Group Norway
Strindveien 2, N-7034 TRONDHEIM

- The SINTEF Group is an non-profit organisation with a total staff of nearly 2000 employees engaged in R&D for industry, public services and governmental departments. SINTEF and the Norwegian Institute of Technology (NTH) in Trondheim, work together in close cooperation. The basic disciplines within SINTEF cover microelectronics, computer architectures, image processing and information management. The key application areas are: telecommunication, simulation of industrial processes, CIM, medical technology and the social impacts of IT.

Teknologisk Institute (TI)/
Gregensensvej, DK-2630 Tastrup

- The TI is a polytechnical industrial development centre providing resources and projects on mechanical engineering, automation, software engineering, industrial psychology, business administration and industrial engineering. The main function of the TI is to operate as a technology transfer centre for the danish industry. The TI has about 650 employees organized in 17 departments or groups.

UDIRL/University of Durham Industrial Research Laboratory
South Road, U-DH1 3LE DURHAM

- UDIRL is a public research laboratory at the university of Durham. The working areas of UDIRL are electronics, information technology, production technologies, robotics and aerospace technologies.

WTCM/CRIF/Wetenschappelijk en Technisch Centrum van de Metaalverwerkende Nijverheid,
Campus Arenberg, Celestijenlaan 300 C, B-3030 HEVERLEE

- WTCM/CRIF is one of the industrial centres for technical research of the Belgian Metalworking Industry. WTCM has about 100 employees covering mechanical engineering, automation and surface technologies. Since 1987 WTCM has operated several R&D-programmes in CAD/CAM and CIM applications. It is closely linked to the Catholic University of Leuven. Other CRIF-institutes are linked to the universities of Brussels and Liege.

3. RESEARCH AFTER MAASTRICHT: THE POLICY OF THE EUROPEAN COMMUNITY FOR EUROPEAN RTD

Europe as it is in 1992 is considered by the CEC at a critical stage regarding integration, competitiveness and social needs. The process of moving into a common European market is extremely challenging and requires a wide scope of supportive actions. These challenges have to be reflected in the Fourth Framework Programme currently under preparation.

To achieve its goals - strengthening European cohesion and industrial competitiveness including volume products - the CEC has refined the programmatic approach as represented in figure 2 into a structure as shown in figure 6. The left hand column represents the activities which are normally attributed to the public sector. The right hand column represents the activities which are the prerogative of industry itself - the actual activities would vary according the specific industrial sector.

Fig. 6: Integration Processes for EC Framework

Based on these general structure four types of activities has been selected by the CEC for the Fourth Framework Programme:

1. Implementation of research, technological development and demonstration programmes, by promoting cooperation with and between industry, research centres and universities;

2. Promotion of cooperation in the field of Community research, technological development and demonstration with third countries and international organizations;

3. Dissemination and optimization of the results of activities in Community research, technological development and demonstration;

4. Stimulation of the training and mobility of researchers in the Community.

In the preliminary proposal of the CEC from the 2nd of October 1992, the group of activities is broken down into 35 individual activities covering Information and Communication Technologies, Industrial Technologies, Environment, Life Science and Technologies and Energy. The other groups of activities are also subdivided into 14 individual lines of action.

The total budget for this Forth Framework Programme (1994-1998) is calculated to a volume of $18.817 billion. This is two and a half of the budget allocated to the current Third Framework Programme.

The allocation of this budget to the individual action lines is not yet completed. For the time being specific figures are not yet available. But it can be expected that the new high priority rule for "subsidiary" will cause a major change to the allocation rules. The current recommendation in this field is to support in the future those branches showing a high R&D intensity, whereas branches with a low R&D intensity should be neglected. A first proposal for a classification of branches, considering this principle, is shown in figure 7.

Fig. 7: Technology Intensity Groups

4. UNMET NEEDS AND OPPORTUNITIES IN WESTERN EUROPEAN R + D

Research programmes normally originate from discussion between the financial sponsor and the various organizations being sponsored i.e. the industrial users and/or research institutes.

Through the cooperation of the partners, each considering his own interests, a more or/less well-balanced programme comes into existance. At the same time the economic interests of all parties are in the foreground. This holds true not only for the research institutes but even more so for the industrial users.

In order to recognize the requirements and chances of future production systems, the superordinate global context has to be taken into account in addition to the technical, business management and economic needs and interests.

Fig. 8: General Development Trends in Manufacturing

Derived from the current development trends of industrial production various classes of needs can be distinguished:

- global economic needs
- global environment-related needs
- regional economic needs
  (business management, macro economics)
- technical needs
  (performance and quality related)

Unmet needs and opportunities are not to be derived from single or individual problems. On the contrary, the overall context shaping a future working together in this world has to be emphasized.

Beginning with the global needs it will be possible, following a top-down approach to derive the other requirements emphasizing their general relevance.

4.1 Global Needs for Future Production Systems

The future state of the world can be characterized by the following:

- climatic threats
- environmental pollution
- indebtedness of the Third World
- population growth
- shortages of resources.

Fig. 9: World Population Growth

Fig. 10: Decreasing Quality of Copper Ore Mining in the USA (1900 - 1990)

Industrial production has a considerable impact on all these developments. Future production systems cannot shirk a global responsibility.

Through recent developments, such as the disintegration of the major military blocks, we are challenged to undergo a radical change. The necessity of a new orientation should be understood as a unique chance first time offered.

The fundamental rule of growth implies that when capital expands faster than the population, the standard of living rises.

Just the contrary is the case in the third world. Economic prosperity is declining and the population rate is climbing fast. This population increase hinders the growth of industrial capital, especially as an increased accumulation of capital is necessary in order to maintain life-essential services. The cause of the dilemma of the third world is the unequal spatial distribution of industrial growth. Economic growth is still concentrated in the already highly industrialized countries.

Fig. 11: Global Industrial Production

Fig. 12: Global Metal Consumption

The flow of refugees from developing and over populated countries - as it can currently be observed in Europe and the USA - will not cease until these people see a chance of reasonable development and adequate prosperity in their own country. Only a suitable global distributed prosperity can reduce the population growth, which, in turn, will guarantee and improve the prosperity for everyone, including the industrial nations. What is the value of a product, if there are no solvent customers. However, the prerequisites for this are fair market conditions with fair product and raw material prices.

Independent of an active part by the industrialized countries in this context, the production resources will inevitably have to be reassessed in the future. Mass production will continue to shift to newly industrialized countries (NID) because of cheap labour and loose environmental regulations etc.. A trend which can hardly be stopped.

The problems of overdevelopment on one hand and underdevelopment on the other have to be overcome simultaneously. Only in this way can the earth's ecological capacity and balance be preserved and the survival of future generations be secured.

Industrial production may only be, but also has to be, increased on the basis of conservational activities and environmental technologies.

The industrial nations are being urged upon to think about a worldwide labour distribution in accordance with global political demands. A conscious and deliberate shaping of the global distribution of labour can be the basis for preventing national conflicts on the one hand and the worldwide introduction of environmental protective production methods and systems on the other hand.

The production challenges for the industrial nations resulting from a global labour distribution will be described in the following paragraph.

4.2 Requirements for the Future Production Systems

In order to develop business and economic requirements for future production systems we have to redefine our role in the context of an increased global distribution of labour. The time has come to develop and implement a new production paradigm for the industrialized countries.

The introduction of a new product both on domestic and foreign markets was usually performed according to the "product cycle theory".

Fig. 13: Market cycle

During the first stage, the innovation phase, the product is developed and produced for the domestic market. After sufficient production and marketing knowledge has been gathered, the product is introduced to foreign markets (export phase) where such relevant know-how isn't available. In the third phase the production has been improved and standardized. Afterwards it is adopted by foreign producers (imitation phase) who normally have the advantages of low labour costs and limited environmental regulations.

The innovator's technological advantage at this point decreases step by step until he ultimately starts importing the product in question himself (import phase). Sometimes a further stage, the repatriation phase, follows. This can happen when the country which initially designed the product manages to come up with advances in the production technology. In such cases domestic production is reinstated.

This generally acknowledged theory emphasizes the close relationship between international competitiveness and innovative capacities.

Fig. 14: Economical Influences on the Product-life-cycle

As highly industrialized countries can usually only be competitive in the early stages of production, it is especially important for them to keep coming up with so-called intelligent product or process innovations which cannot easily be imitated. These however generally depend on a high research and development input requiring extensive funding. This pressure is increased by the fact that the market cycles which reflect the market penetration and customer demand are continuously becoming shorter. Often only he who is first to introduce a product can count on making profits. "Time to market" is increasingly becoming a critical factor for success.

The development, maintainance and enlargement of the protoyping capability, i.e. the domination of a short "time-to-market" on the basis of the most up-to-date manufacturing technologies, will become the crucial challenge of a modern Industrial Community. In the future only the rapid transformation of a new product idea into a prototype and related manufacturing equipment will guarantee early profits in the field of serial and mass production.

To meet these challenges industrialized nations have to aggressively pursue advanced manufacturing processes for products as well as to take into account major technology breakthroughs driven by advances in information and communication technologies and manufacturing processes.

4.3 One-of-a-Kind-Production Systems

If the statements up to now have emphasized the "Time to Market" approach they depict only a form of the perfection of the former phases of the Mass Production Paradigm (MPP). The limits of the MPP will be reached by reducing lot sizes and increasing product variance.

Fig. 15: Product quantity vs. Product variety

Fig. 16: Variants in car manufacturing

One extreme example: Due to the numerous possible varieties of the Daimler Benz 190 model there are only two identical cars each year in the Bremen plant which produces over 500 cars daily and more than 120,000 annually [2].

Even though consumer goods are continued to be produced in large batches in the future, product individualization will take place in more and more areas. While in the area of investment goods constantly growing customer requirements for technical and usability functions are leading to an increase of product complexity and uniqueness, the same tendencies are shown in the area of luxury goods due to the increasing requirements for prestige functions.

Fig. 17: Product oriented customer requirements

The extreme case of infinite product variance is attained when the product is only manufactured once. With the turning away from reproductive manufacturing the direct application and/or putting into operation of a uniquely developed product (a one-of-a-kind product) will be achieved. The following statements mainly focus on the single production of investment goods as is usual in shipbuilding, aircraft and aerospace technology, machine tools etc.

Fig. 18: One-of-a-Kind Production Characteristics

Based on these peripheral characteristics and reflecting the general development trends of the international markets (see Fig. 19), future requirements for the prototyping capability of production systems can be derived.

Fig. 19: Future Requirements for the Prototyping Capabilities of Production Systems

Ongoing research and even standardization activities like STEP factory integration modelling, research for rapid prototyping techniques like Desktop manufacturing (DTM), etc. must be strengthened. The aim is the enforcement of the prototyping capabilities of future production systems.

Although a systematic reappraisal for a new production paradigm is beyond the scope of this contribution, some elements can be highlighted.

In order to be competitive in a global context, prototyping capability means the ability to offer and manufacture incomparably unique sophisticated products based on continuously changing customer demands.

Fig. 20: Customer Intervention in the Product Life Cycle

This will require a focus on the quality and productivity of intellectual workers; higher levels of creativity will be demanded.

Fig. 21: Mass Production versus One-of-a-Kind Production

In mass and serial production a decrease in the learning curve can be achieved by incremental investments in the automation level of the applied production systems. The greater the product quantity, the lower the price of the product. The lower the price, the greater the need for low production costs. The lower the approved costs, the greater the need for a high automation level.

Depending on the history and tradition of industrialized nations in production management there are different approaches (I, II, III) to manage the correlation between cost per part and the number of parts as characterized by the different learning curves.

Fig. 22: Reconfigurability of Manufacturing Equipment

However all approaches are based on the idea of optimizing the production process and reducing the costs per part through reproduction strategies.

However, in the case of One-of-a-Kind production there is no possibility for optimizing the production process through reproduction strategies. The ultimate challenge will be: "Do it right the first time". In this context the reuse of experience will play a predominant role, in reducing the technical and economical risks.

Fig. 23: "To be" versus "As is" Information Level

Fig. 24: Experience-Centered Classification of Design and Planning Tasks

Fig. 25: Comparison of Production Programme Planning

Beside the reuse of data the use or reuse of experience is an important asset in the OKP business, but this experience must be acquired and maintained during the daily work. To obtain wholeness requires an involvement in a holistic loop to generate experience. The requirement for an experience generation loop is illustrated [1].

Fig. 26: Experience generation loop

With decreasing lot sizes and increasing customer interventions the basis of production systems is shifting from technical integration to human cooperation.

Due to the uniqueness and complexity of One-of-a-Kind products the human resource units as well as the machining resources should provide a high level of complexity in terms of capabilities. The one-task-one-employee principle in Adam Smith's pin fctory is not adequate here. Adam Smith's principle is based on standardization and specialization, but the OKP business implies nonstandard and fuzzy situations. This requires a complexity of capabilities a single employee cannot offer. This means that a high qualification level of the personnel, group work and the configuration of stable work teams are essential requirements. [1]

Fig. 27: Qualification of Personnel

The generation and the use of human experience will become on essential subject of modern production systems if the competence of the worker will be requested and maintained by suitable decision and responsibility structures.

4.4 Enterprise Integration and Enterprise Cooperation

The above outlined demands have led to efforts being made to parallelize the product development process and to extend the just-in-time idea to the process of product development with regard to the information flow.

Due to the decrease in production depth (increase in team manufacturing) this development is not only confined to internal processes but increasingly also covers enterprise internal tasks as they occur between manufacturers and/or customers and suppliers. Accordingly advantages will only emerge from cooperation in the sense of an "extended" enterprise comprising all partners taking part in a particular task.

Figure 28: Current and Future Enterprise Cooperation

The resulting level of specialization and integration between designing, planning, and producing a product has therefore not only become increasingly important on an internal level but is also especially influential with regard to the cooperation between customer and supplier. "The supplier becomes (the customer's) external special department...".

Nets of independent, cooperating partners emerge. To ensure well functioning cooperation, appropriate information systems, communication technology, and compatible enterprise organization are required. Internal and external data exchange as well as the functional inter-dependencies between the various business activities therefore have to be coordinated and integrated, in order to enable the involved enterprises to deal with a project in a joint and integrated manner.

Figure 29: Levels of Integration

Enterprises will have to become customers, suppliers, partners, and competitors all at the same time.

If the industrialized nations acknowledge their global responsibility, we have to extend this interpretation of integration on the basis of a justified global distribution of production resources.

4.5 Environmental Life-Cycle Analysis for Product and Production Systems

In the past both product design and production systems design were, in principle, market and legislation oriented. New materials, manufacturing processes, etc. were used without considering the consequences for recycling or waste deposition.

Public pressure, extremely increasing costs for waste disposal and our own conviction to conserve natural resources and to recycle most kinds of materials make it necessary to develop new strategies for products and manufacturing processes for the future.
Corresponding to their global responsibilites and their high technological standards the industrial nations have to assume the leading position in the discussion on and in solving the production related environmental challenges.

Fig. 30: Life-Cycle-Analysis

Based on extensive knowledge of the interaction between economy, technology and ecology we have to analyze the whole life-cycle of our products, beginning with the generation of raw materials and ending up with the recycling and the waste management of used products.

The aim must be to get a much better coherence between economy, technology and ecology.

First analyses of different kinds of highly sophisticated machining processes show surprising results. The impact on the environment and accordingly the production costs are strongly influenced by using cutting fluids [3].

Fig. 31: Machining Process Input/Output

The consequent application of an overall life-cycle analysis can be seen as the most essential procedure to elucidate the energy and material flows which influence economy, technology and ecology.

4.6 Performance Assessment on the Basis of Scenario Techniques

Performance assessment of production systems is becoming a more and more complex task. As customers' decisions tend to be less determined by prices alone. Other features of production sytems, such as leadtime, product quality or the capability to customize products, are gaining importance. Altough difficult to quantify, these features have to be taken into account when evaluating performance of existing or designed production systems.

It is therefore not sufficient to describe the performance by a set of numbers alone. What we need is a holistic approach that not only looks at technical or economical criteria, but also at "soft factors" like social, organizational, cultural impact etc. Instead of comparing sets of indicators, we should rather compare scenarios showing us the production system as a whole, explaining its behaviour - which may well be driven by the soft factors - and its realisations to the world around it. Such scenarios will substantially improve our understanding of production systems and will open new design choices for the factories of the future.

Fig. 32: Levels of Analysis in CRIMP

4.7 Long Term Re-Assessment of Industrial Potential e.g. Maritime Industries

According to the foregoing discussion on future requirements for production systems the industrial nations have to rearrange their areas of production activity. Non opportune alignments have to be identified; new chances have to be evaluated and developed. A strategic reassessment of the "value" of industrial potential with respect to production capabilities has to be carried out.

As an example we will derive the "value" of a Maritime Industry for Western Europe. Shipping, shipbuilding and equipment manufacturing are traditional industries in Western Europe. However the world market share of this european industry has decreased dramatically since the Sixties. Due to high labour costs and the application of more or less conventional production systems these industries were forced to retire from traditional areas of shipbuilding activities. Accordingly there have been proposals within the EC to reduce or even stop the fundings for related industrial and R&D activities. If this would come true Europe would loose its competitivness and influence over a nowadays as a "low-tech" rated potential which could be a major asset with respect to an important bussiness domain of the future. In the following this statement will be argued.

- Believing in serious predictions on the growth of populations we can imagine the future challenges in producing a suitable quantity and quality of food, but the potential of cultivateable ground is extremely restricted.

- An increasing shortage of nearly all kinds of raw materials including potable water and primary energy sources can be considered. Shedding the load of raw material and energy consumption can diminish but not solve this problem.

- The creation of the internal market leads to an increasing congestion in road traffic and a related increase of air pollution

- etc.

Facing these future challenges we should consider the following aspects:

- More than 70 % of the surface of the earth is covered with water.

- The sea and the sea-bed are composed of various kinds of resources (oil, gas, minerals, capabilities for aquaculture, etc.)

- Western Europe is more or less surrounded by the sea. Its coast - more than 10.000 miles long - is equipped with hundreds of small and medium sized ports, an excellent infrastructure for short sea shipping.

- etc.

Taking into account the long term industrial potential needed to meet this future challenge, a completely different approach for funding R&D and industrial activities will be needed. Up to now the R&D activities on production systems are more or less concentrated on terristrial approaches for production systems.
for future markets. The shipping, shipbuilding and equipment manufacturing activities need to be developed towards a cooperating Maritime Industry exploring the global and longterm opportunities and then to be transformed into a New Maritime Industry of the future. The requirements and potential supply of this new Maritime Industry are well known and crucial for the industrialized nations: High level R&D activities combined with prototyping capabilities.

For modern, trade and production oriented nations, the complexity of the transport function is increasing. Not just the port-to-port carriage of goods but their movement from original source to ultimate destination is becoming a total logistic industry.

5. THE POTENTIAL FOR COLLABORATION FOR RTD IN THE PERSPECTIVE OF INCREASING GLOBALIZATION

In order to recognize the potential for global collaborative R&D projects, the superordinate global economic and environmental needs and responsibilities of industrial nations have to be taken into account in addition to the individual technical, business management and economic needs and interests of the different partners. A number of starting points are given to describe the actual state of the world:

- climatic threats
- environmental pollution

- indebtedness of the Third World
- shortage of resources.

This contexts has already been discussed in chapter 4. Global needs are only manageable with collective approaches. Recent developments give us the first chance to tackle these global challenges.

Within these collaborations the various nations should work on complementary aspects, related to their traditions and history. The greater the challenge the greater the need to integrate these specialised capabilities if we are to tackle these problems effectively.

Another potential area for global cooperation is represented by tasks which are characterized by minor economic interests of individual partners. One example: For the future there will be an increasing social and political demand for higher global safety and environmental standards. An ultimate basis for a successful cooperation within this field will be the exchange of different cultural backgrounds and an increasing knowledge about each other.

However a global collaboration will be successful if all partners can see their advantages even if their views are dominated by global or national interests.
In the following some first approaches for international cooperations are listed in which our institute is involved to some extent:

- Intelligent Manufacturing Systems (IMS)
  Based on a japanese proposal from 1990 there is an ongoing discussion on a more or less global cooperation on Advanced Manufacturing System. During the IMS feasibility study which began in February 1992, approximately three test cases will be funded and launched internationally in order to test the emerging collaborative framework of IMS.

- EC - US cooperation on Enterprise Integration Modelling
  (CIM OSA - MCC cooperation)

- EC - US "Collaborative Action" on Product Modelling
  (NEUTRABAS - NIDDESC cooperation) Within this cooperation the funding is restricted to travel costs.

In addition there are several bilateral cooperation between many individual institutes and organisations.

The growing spirit of global cooperation is shown by TINA, a joint industrial R&D activity set up by BELLCORE, NTT and BT in the field of intelligent networking. This is the first time that development, rather than standardisation of a basic networking technology has taken place at a global level. TINA hopes to provide the communications building blocks necessary amongst others, for the development of fully integrated, globally distributed production.

LIST OF REFERENCES

[1] Hirsch, B.E.; Hamacher, B.; Thoben, K.-D.
Human Aspects in Production Management; in: Computers in Industry; 19 (1992) 65-77

[2] Zeyfang, D.; Hesse, R.
New Organizational Structures for Automobile Assembly; in [4]

[3] Haepp, H. J.; Byrnes, G.
Life Cycle Analysis - A Strategic Element for Future Products and Manufacturing Technologies; in: National Advanced Manufacturing Technology Programme; Sep. 1992, Galway, Ireland

[4] Hirsch, B. E.; Thoben, K.-D. (Editors)
"One-of-a-Kind" Production: New Approaches; Elsevier Science Publishers; B.V. (North-Holland); IFIP Transactions, 1992

[5] Hirsch, B. E. (Editor)
CIM in der Unikatfertigung; Springer Verlag: Berlin, Heidelberg, New York, u.a.; 1992

[6] Ley, W.
Simultaneous Engineering in der variantenreichen kundenauftragsspezifischen Anlagenproduktion; VDI-Berichte 758, 1989, S.43-64

[-] Meadows, D.H. and D.L.; Randers, J.
Beyond the Limits; Chelsea Green Publishing Co., Post Mills, Vermont, USA 1992

[-] Deutsches Übersee-Institut (Editor)
Jahrbuch Dritte Welt 1992; Verlag C.H. Beck, München 1992

[-] Information Technology Atlas - Europe; North-Holland; Amsterdam, New York, Oxford, Tokyo

[-] BRITE-EURAM Programme; Synopses of Current Projects 1990-1991; Office for Official Publications of the European Communities,
Cataloque number: CD-NA-14042-EN-C; Luxemburg 1991

[-] EC Research Funding; 3rd. Fully Revised Edition; A Quide for Applicants; Office for Official Publications of the European Communities, Cataloque number: CD-NA-14122-EN-C; Luxemburg 1992

[-] ESPRIT: European Strategic Programme for Research and Development in Information Technology; Tätigkeits- und Ergebnisbericht; Office for Official Publications of the European Communities, Cataloque number: CD-NA-13583-EN-C; Luxemburg 1991

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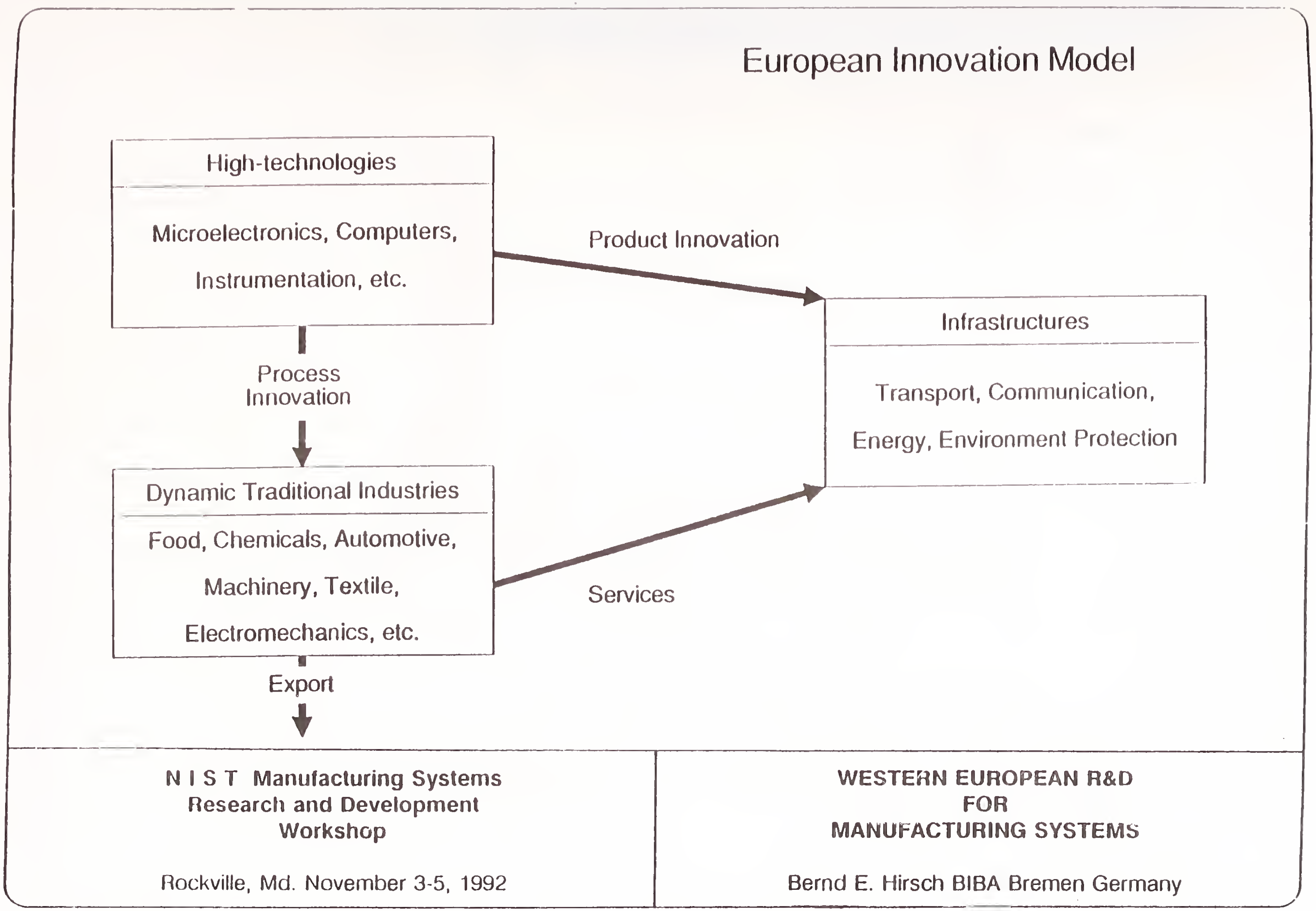
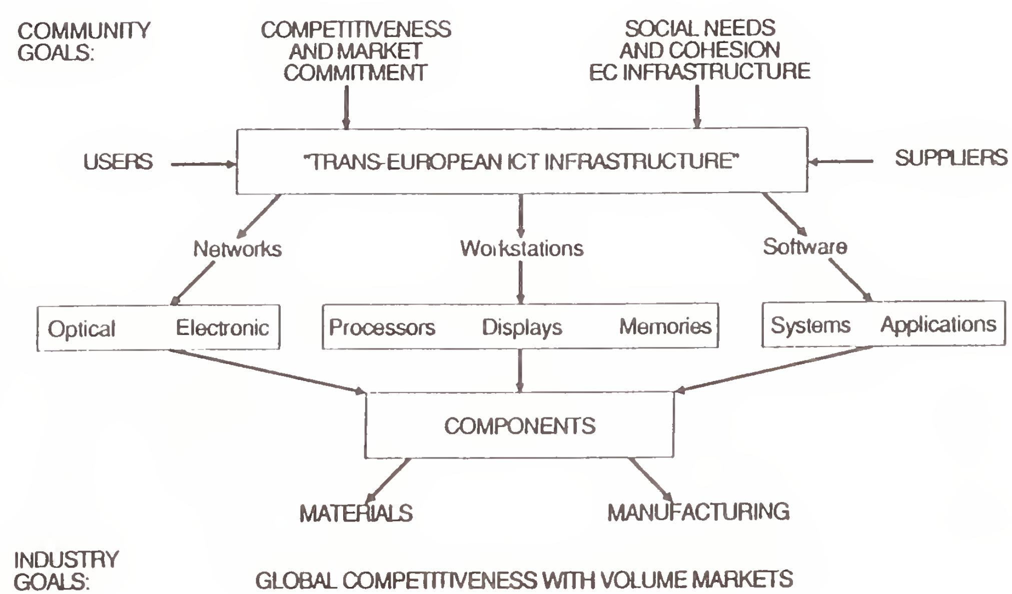


Figure 1. THE EUROPEAN INNOVATION MODEL



European Needs and Opportunities for IT Industry

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Figure 2. EUROPEAN NEEDS AND OPPORTUNITIES FOR IT-INDUSTRY

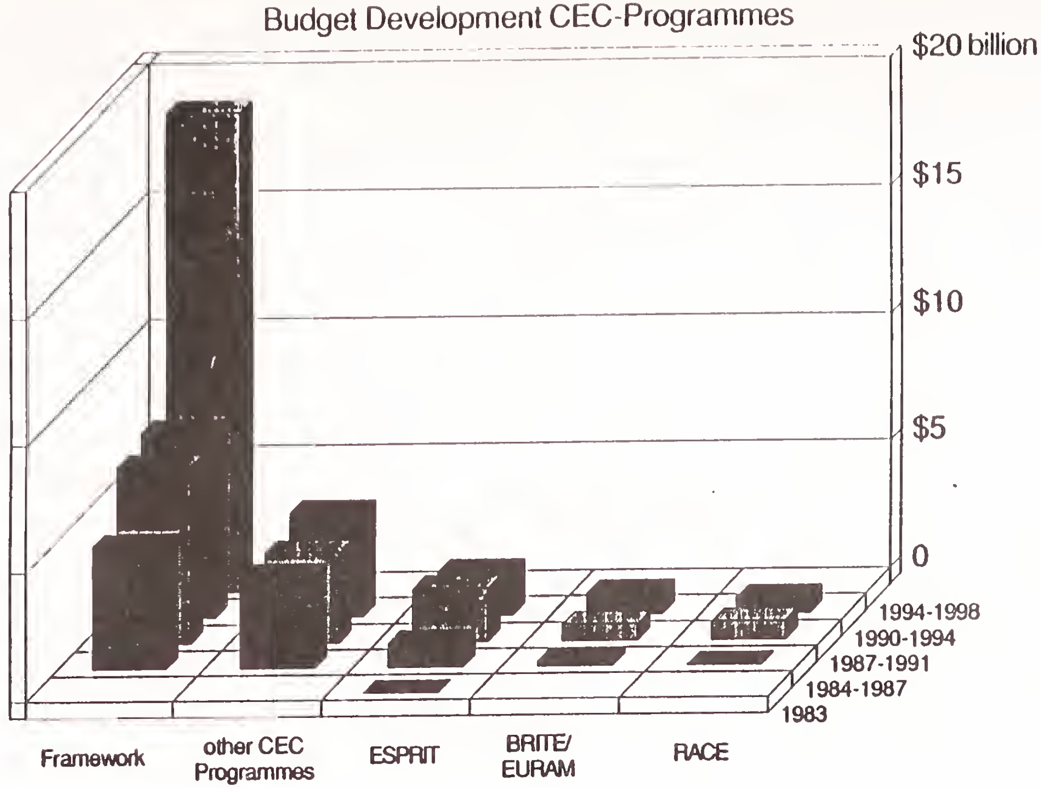

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Figure 3. CEC PROGRAMMES BUDGET DEVELOPMENT

National R&D Programmes in Western Europe

Country	current public RTD-programmes on Manufacturing Systems	Coordinating body	relevant RTD-institutes
BELGIUM	DIRV - the third industrial revolution (since 1985)	-	WTCM/CRIF
DENMARK	5 year programmes on AMT-development and dissemination	STF	Teknologisk Institute
FINLAND	SIMSON, CIM-programme of the Finnish metal industry	TEKES	HUT/TAI
FRANCE	PAFE - programme on applied microelectronics	CNRS	LAAS, GRAI
GERMANY	federal CIM-TT, "work & technology" programme , basic research funded by DFG	BMFT/DFG	fFhG, BIBA
GREECE	several single projects; no general budget	-	GPCIT
IRELAND	annual budget of NBST $2 M incl. biotechnology	NBST	CIMRU, IIRS
ITALY	no information on specific programmes available	CNR	MULTICON
NETHERLANDS	stimulation plan for AMT (since 1987)	SPIN	ITP-TNO
NORWAY	AMT action plan (since 1986)	NTNF	SI, SINTEF
PORTUGAL	no information on specific programmes available	JNICT	LNETI
SPAIN	PEIN action programme on IT (1987 - 1991)	CSIC	IKERLAN
SWEDEN	application programme for microelectronics (since 1984)	STU	RIT
SWITZERLAND	CIMEX - CIM-action programme (since 1990)	KFWF	EPFL-LPG
UNITED KINGDOM	ALVEY programme (since 1983); "IT in manufacturing" (since 1984)	SERC	NEL, UDIRL

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Figure 4. NATIONAL R&D PROGRAMMES IN WESTERN EUROPE

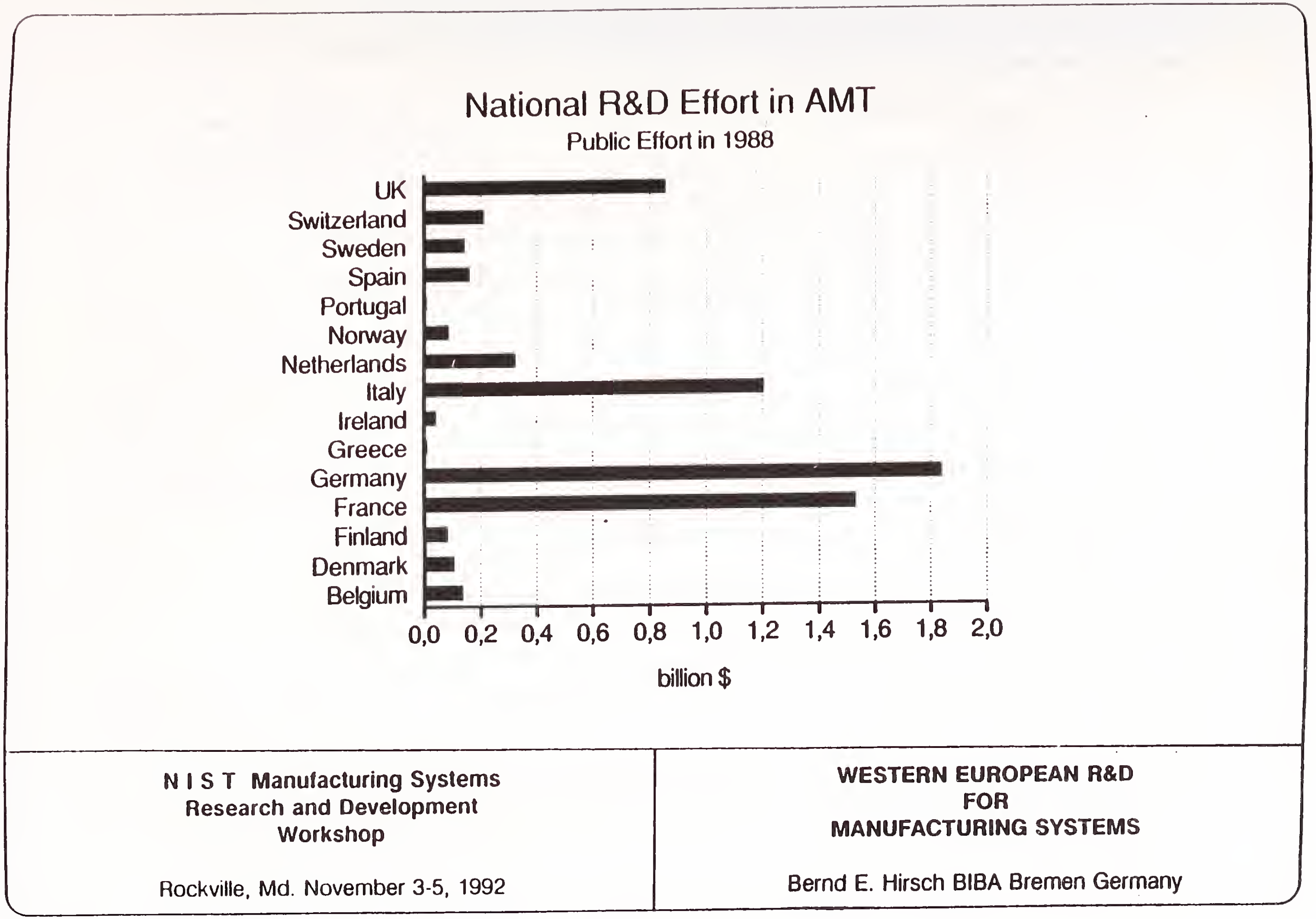

Figure 5. NATIONAL R&D EFFORT IN AMT

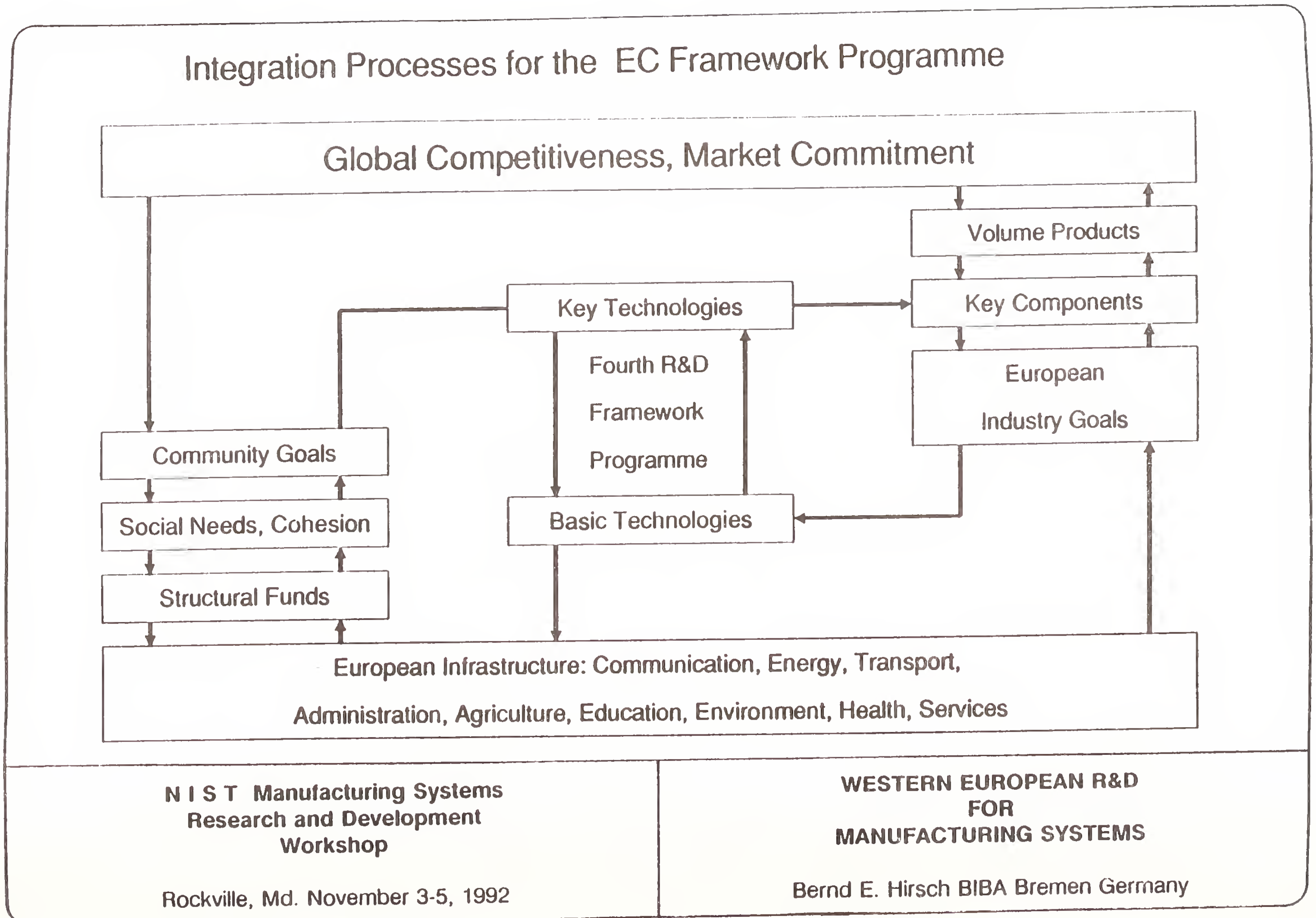

Figure 6. INTEGRATION PROCESSES FOR THE EC FRAMEWORK

The Technology Intensity Groups

High Technology	Medium Technology	Low Technology
Aerospace	Motor Vehicles	Stone, Clay & Glas
Computers and Office Machinery	Chemicals	Food, Drink & Tobacco
Communications & Semiconductors	Other Manufacturing	Shipbuilding
Pharmaceuticals	Non-electrical Machinery	Petroleum Refining
Instruments	Rubber & Plastics	Ferrous Metals
Electrical Machinery	Non-ferrous Metals	Fabricated Metal Products
	Other Transport	Paper & Printing
		Wood, Cork & Furniture
		Textiles, Footwear & Leather
R&D intensity: 11,4%	R&D intensity: 1,7%	R&D intensity: 0,5%

Note: R&D intensity defined as R&D expenditure / output

Source: CEC

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Figure 7. TECHNOLOGY INTENSITY GROUPS

General Development Trends in Manufacturing

- from mass production/large batch sizes to individual production/small batch sizes
- from regional/national markets to global markets
- from simple or less complex products to complex products
- from local production facilities to global production facilities
- short design-to-product lead time
- from competition to cooperation between companies
- from in-house responsibilities to global responsibilities
- from low costs to extremely high costs for waste disposal
- from a "Throw-away" society to a more environmental consciousness

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Figure 8. GENERAL DEVELOPMENT TRENDS IN MANUFACTURING

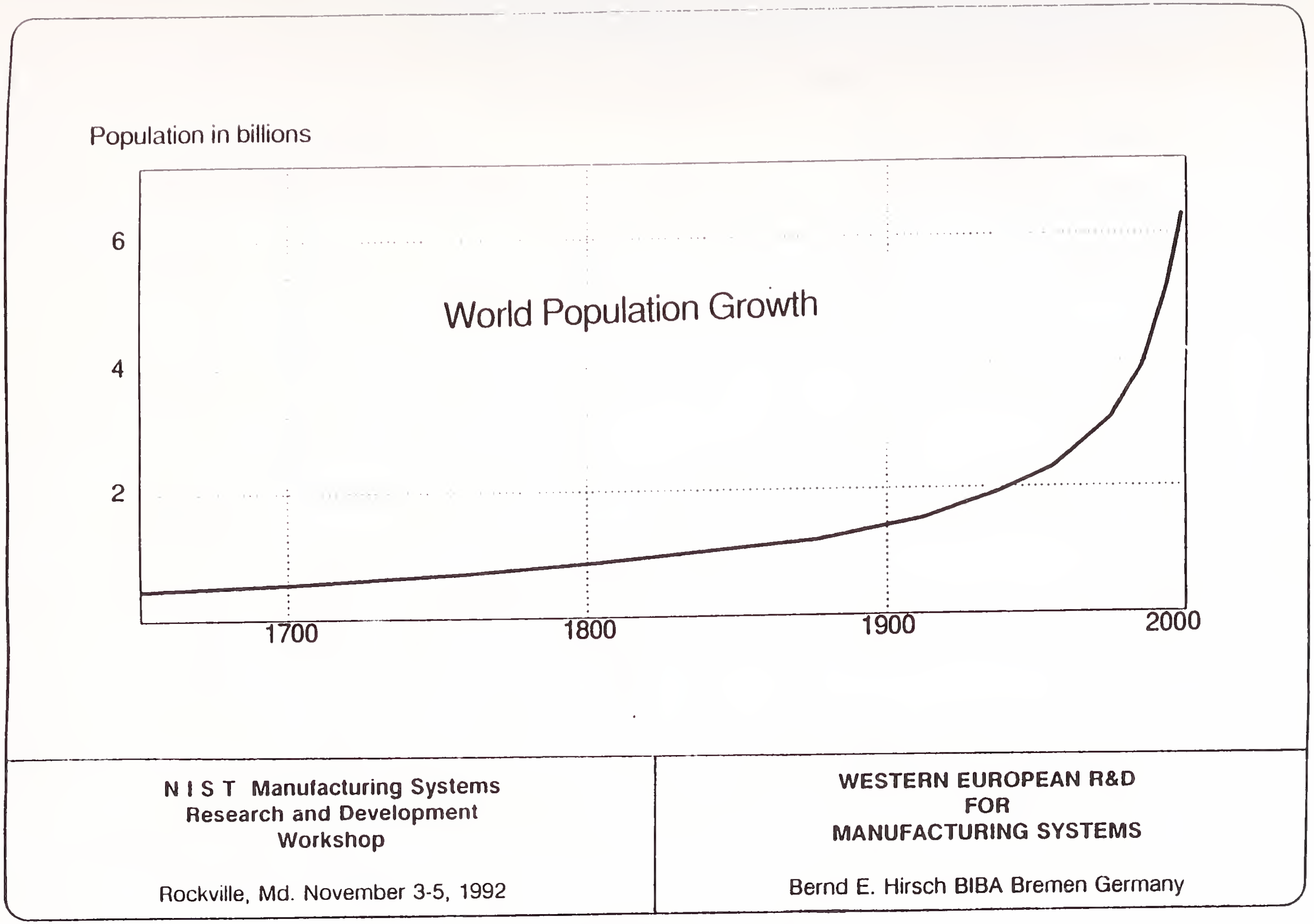

Figure 9. WORLD POPULATION GROWTH

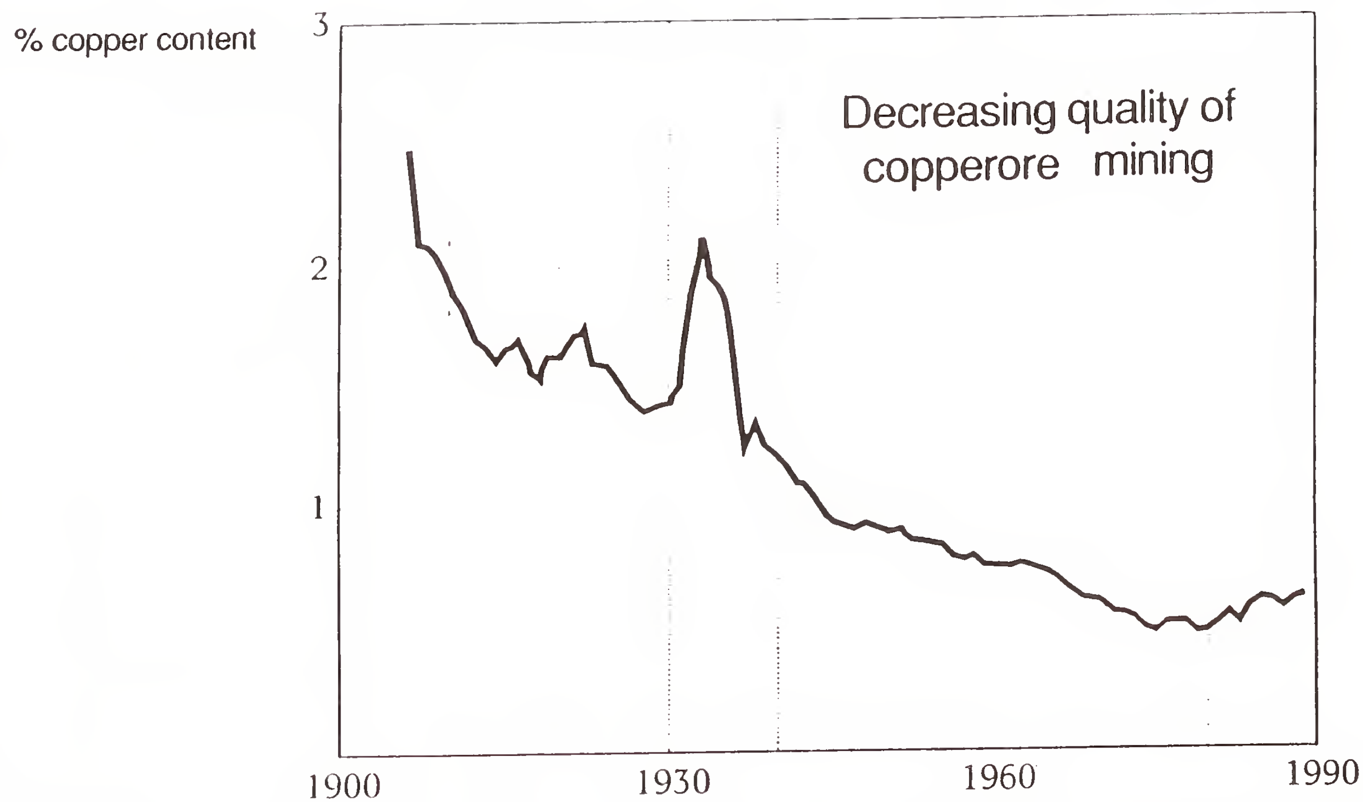

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Figure 10. DECREASING QUALITY OF COPPER ORE MINING IN THE USA (1900 - 1990)

Global Industrial Production

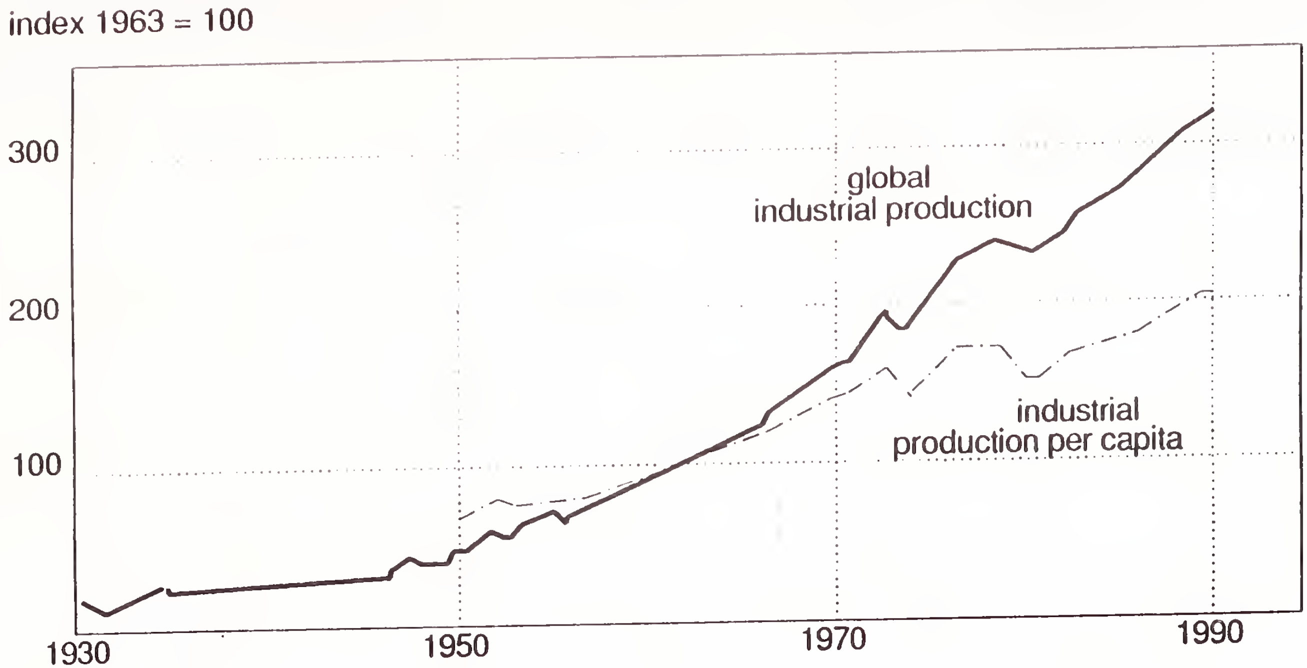

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Figure 11. GLOBAL INDUSTRIAL PRODUCTION

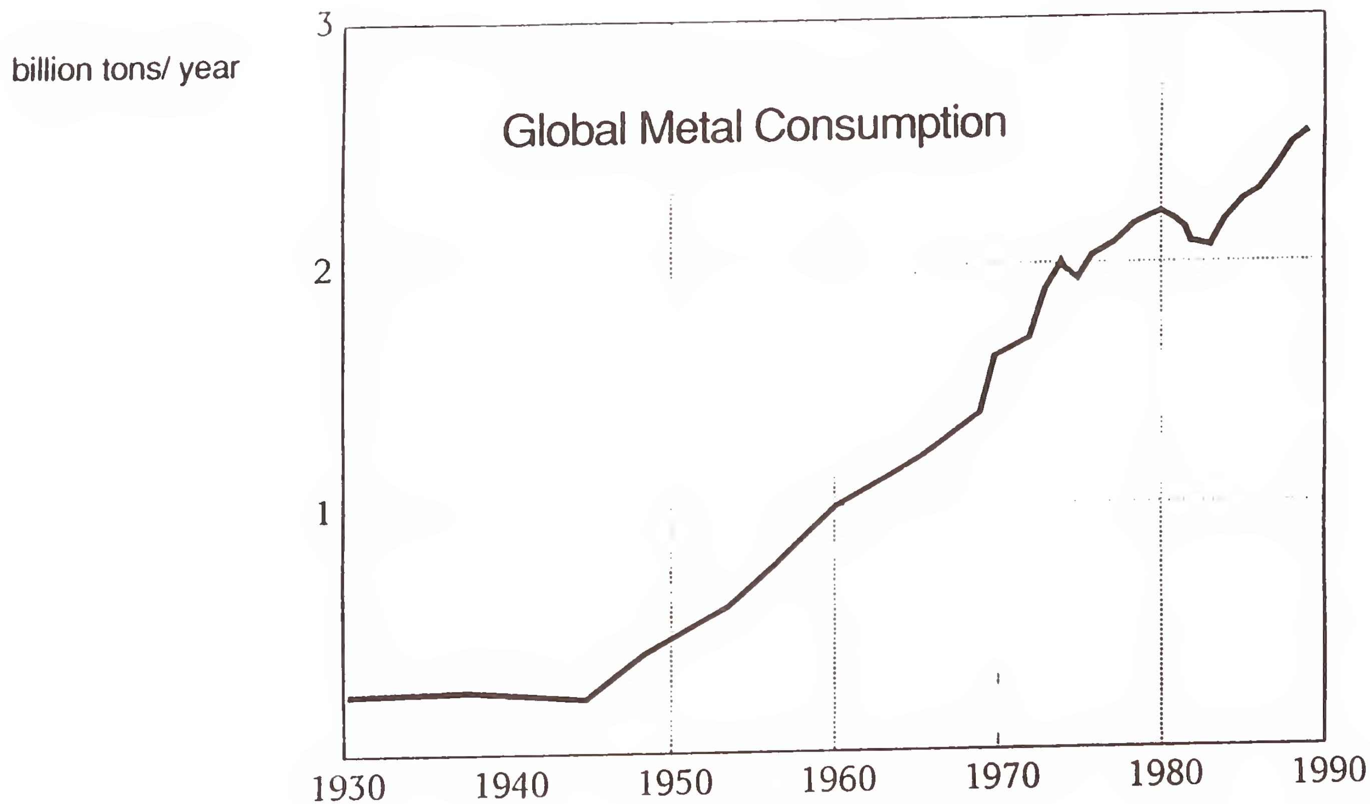

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Figure 12. GLOBAL METAL CONSUMPTION

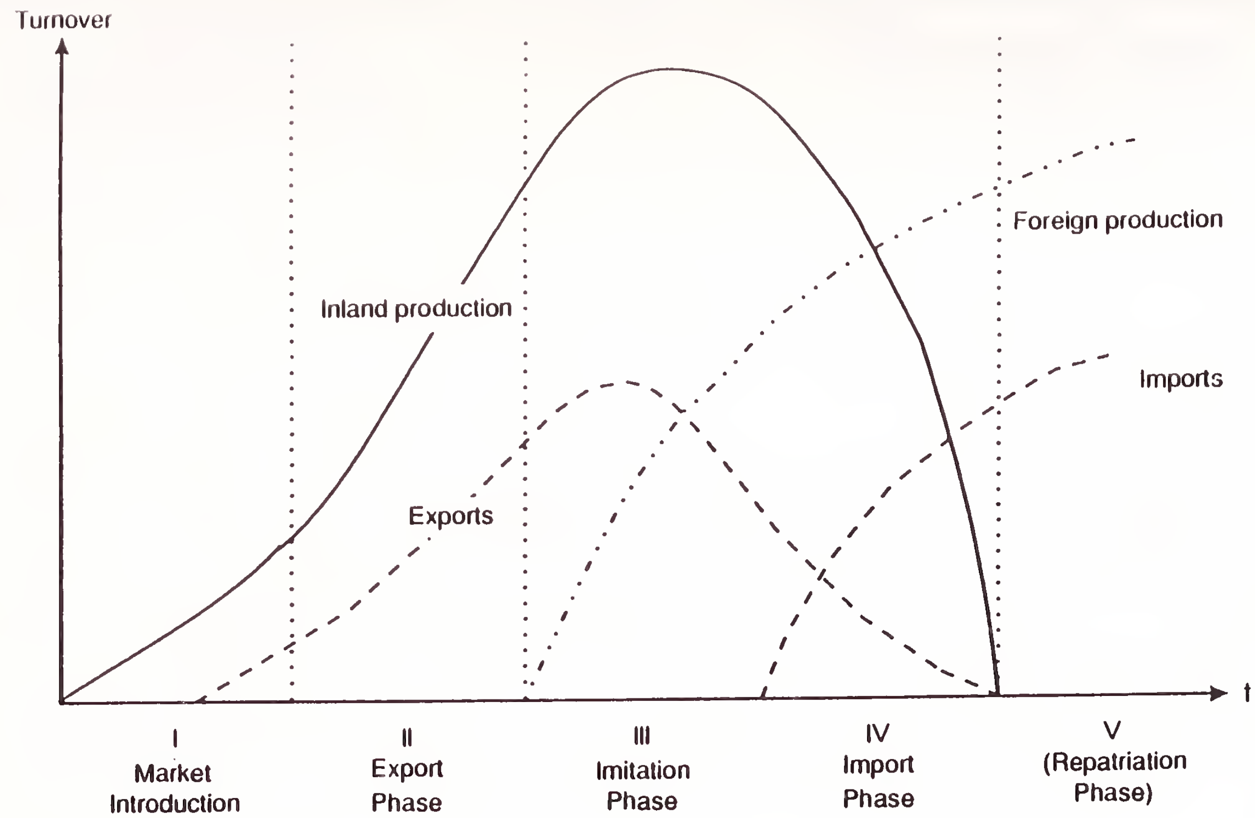

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Figure 13. MARKET CYCLE

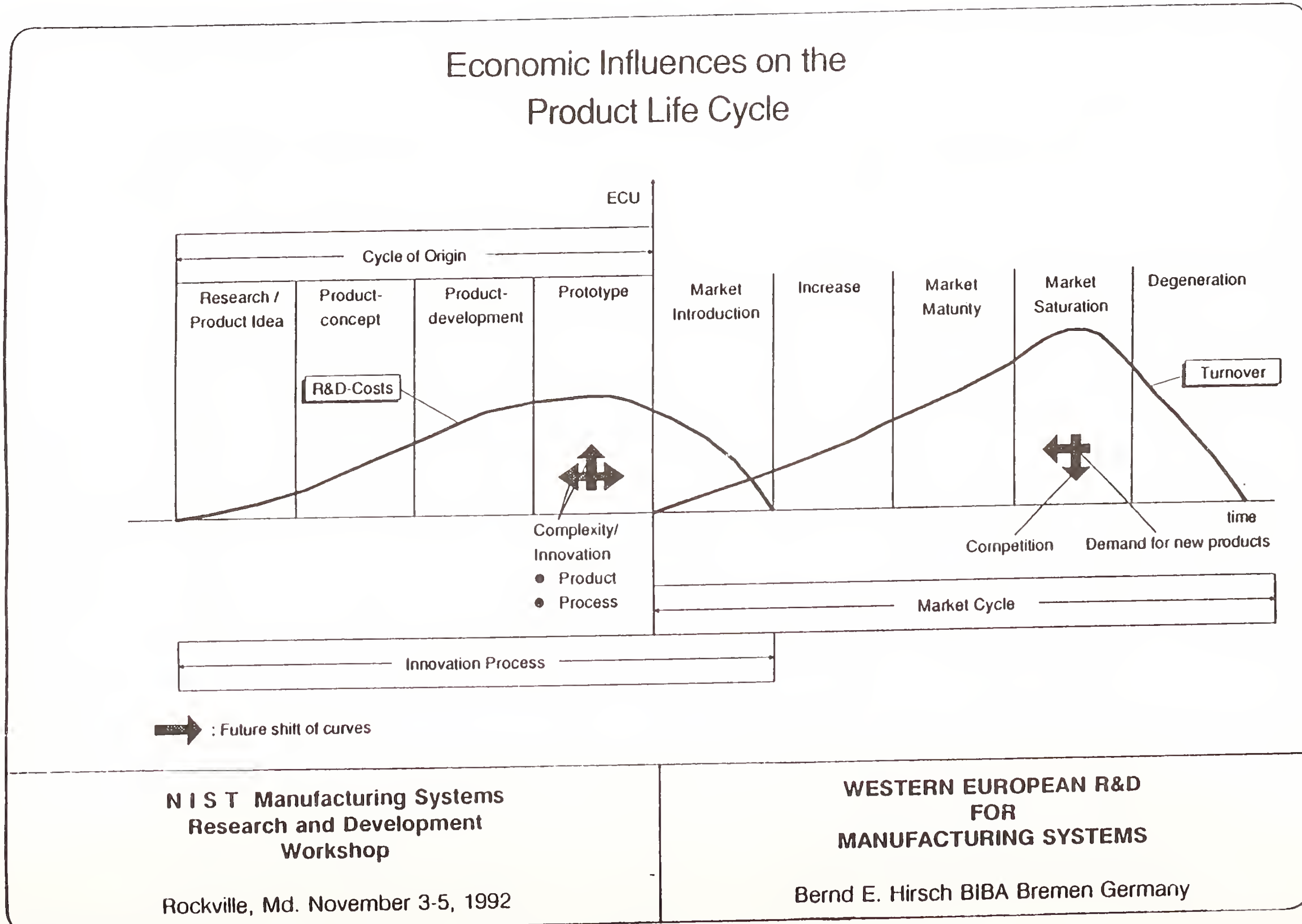
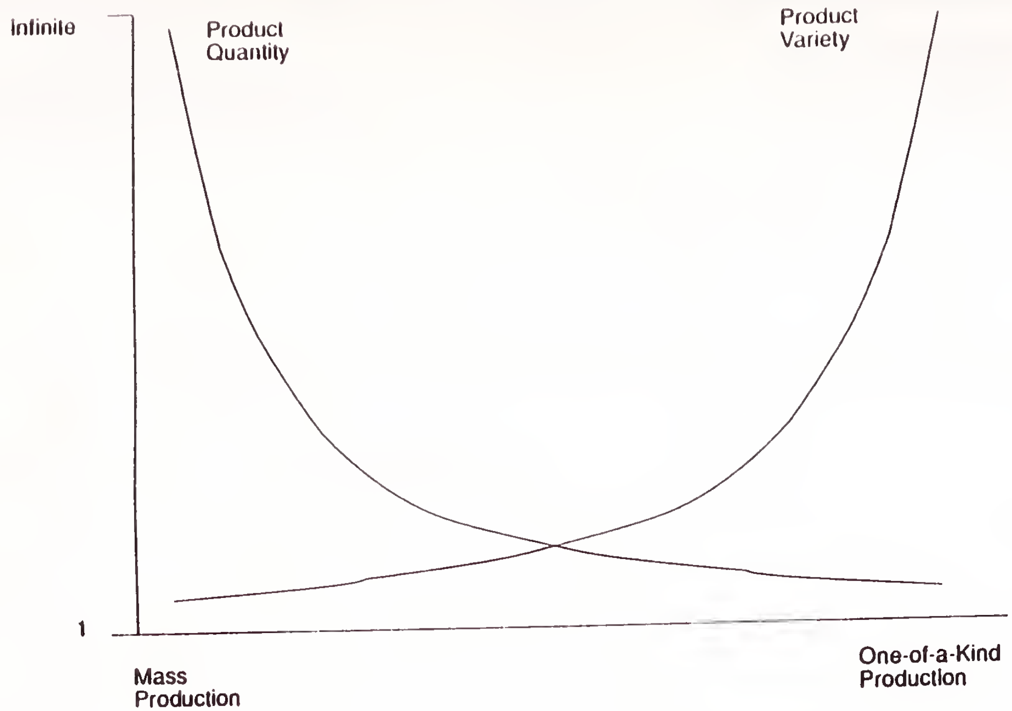


Figure 14. ECONOMICAL INFLUENCES ON THE PRODUCT LIFE-CYCLE



Product Quantity vs. Product Variety

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Figure 15. PRODUCT QUANTITY VS. PRODUCT VARIETY

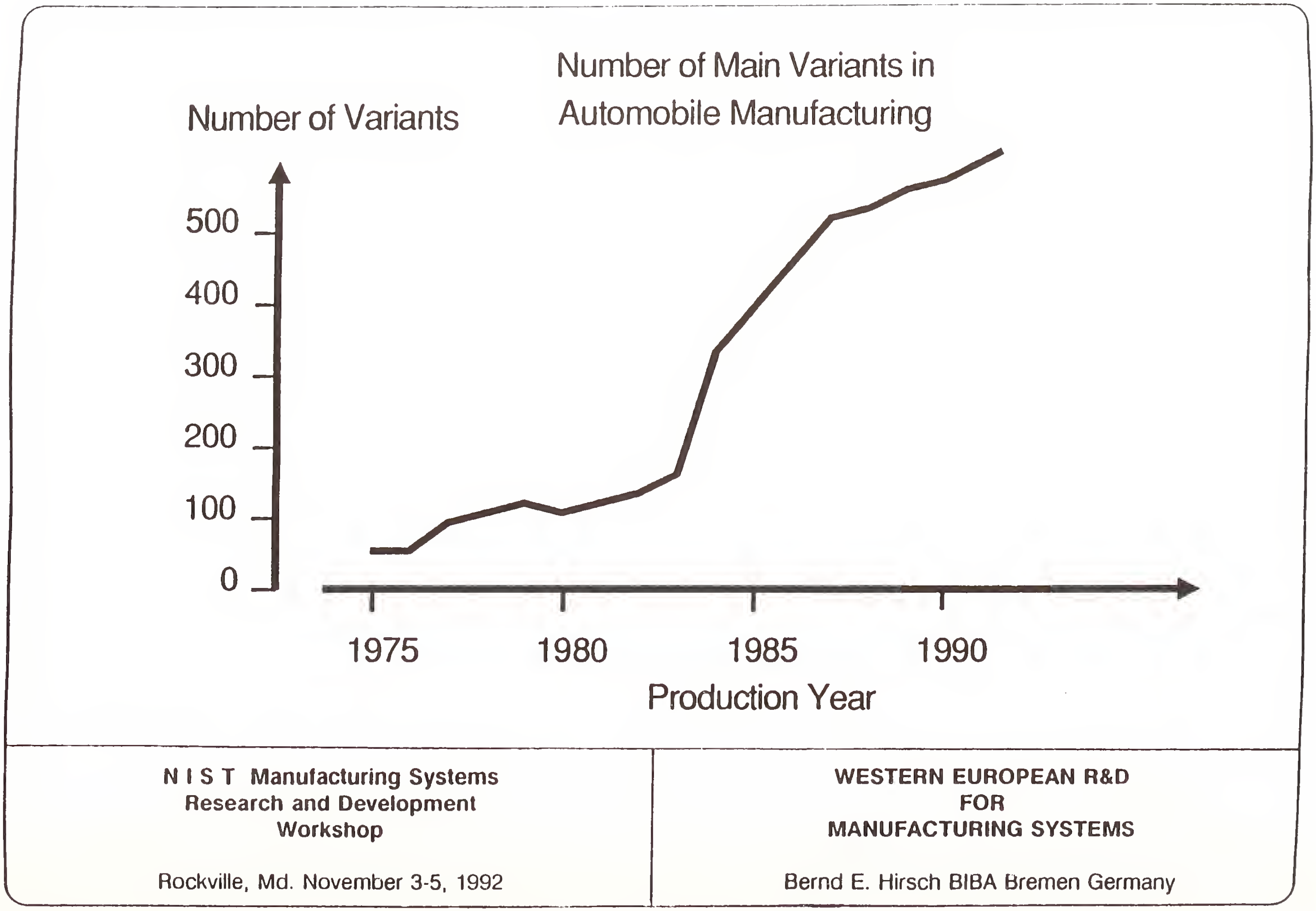
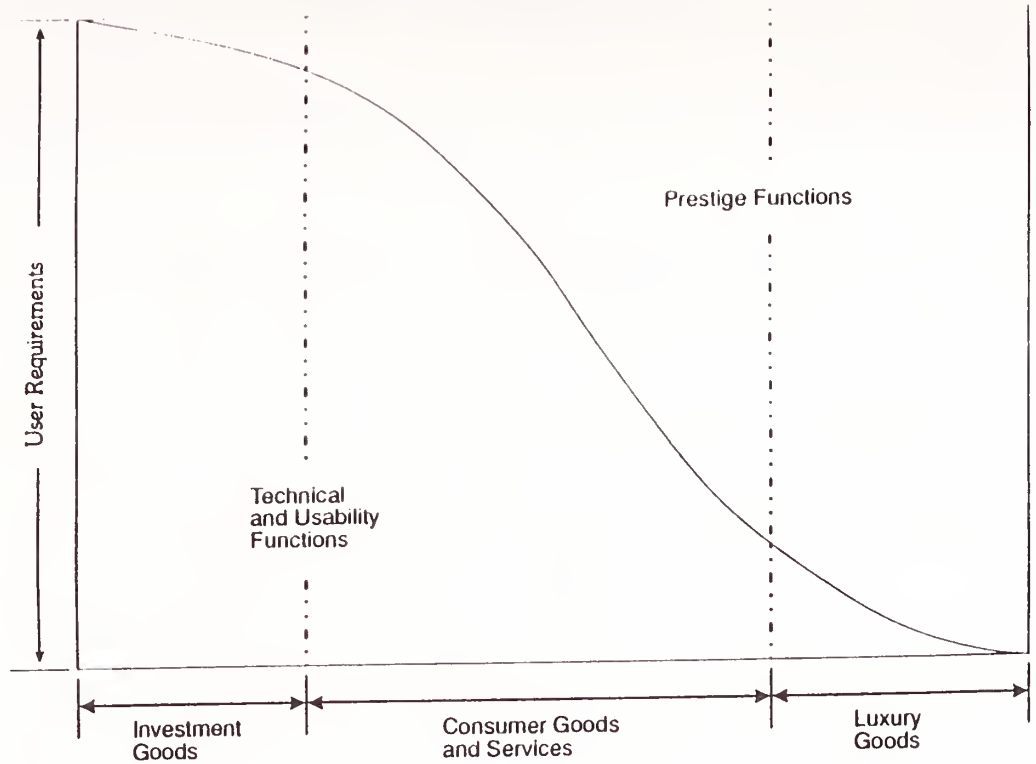


Figure 16. VARIANTS IN CAR MANUFACTURING



Product-oriented Customer Requirement

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Figure 17. PRODUCT-ORIENTED CUSTOMER REQUIREMENTS

One-of-a-kind Production Characteristics

- "Right-the-first-time" design and manufacturing
- Customer intervention in all product life-cycle phases
- Construction site manufacturing
- Complex product structures (process to product)
- Universal and flexible production resources
- International partnerships (decentralized production facilities)
- Decentralized engineering and information management
- Life-cycle centred engineering and information management
- A high degree of high-grade parallel engineering
- High social and technological worker competence

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Figure 18. ONE-OF-A-KIND PRODUCTION CHARACTERISTICS

Future Requirements for the Prototyping Capabilities of Production Systems

- Information management for continous customer orientation
- Information management for life-cycle engineering
- Supporting structures for creative engineering
- Communication and information management for decentralized engineering
- Concepts, strategies and information management for handling uncertainties
- Reuse of experience and product data
- Cooperation instead of competition (internal and external cooperation)
- Business integration
- Communication support for decentralized global production
- Dynamic factory layout
- Strategic performance assessment for company specific production system development
- Rapid Prototyping technologies and strategies for parts, units and products
- Incremental innovation strategies

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Figure 19. FUTURE REQUIREMENTS FOR THE PROTOTYPING CAPABILITIES OF PRODUCTION SYSTEMS

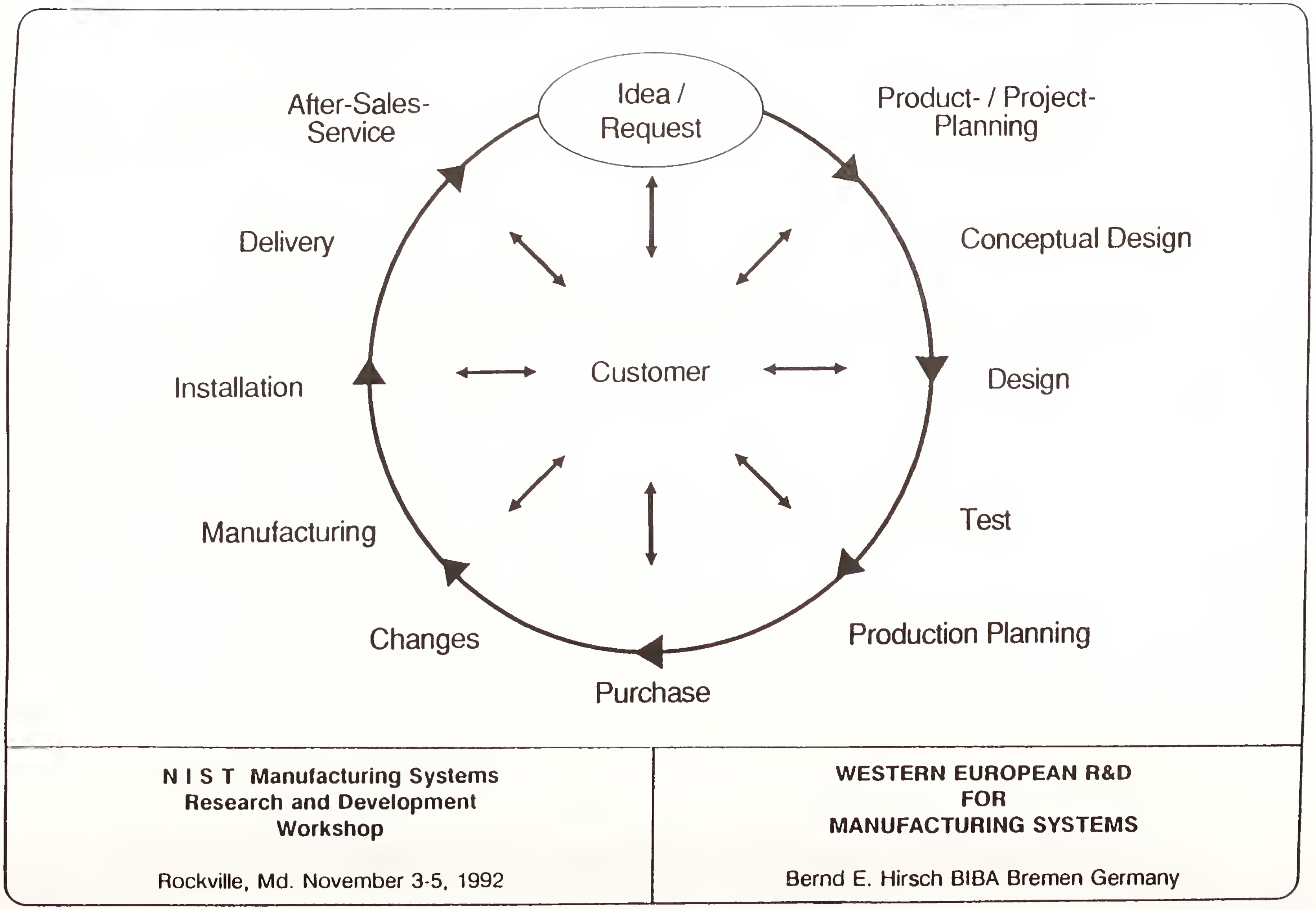

Figure 20. CUSTOMER INTERVENTION IN THE PRODUCT LIFE CYCLE

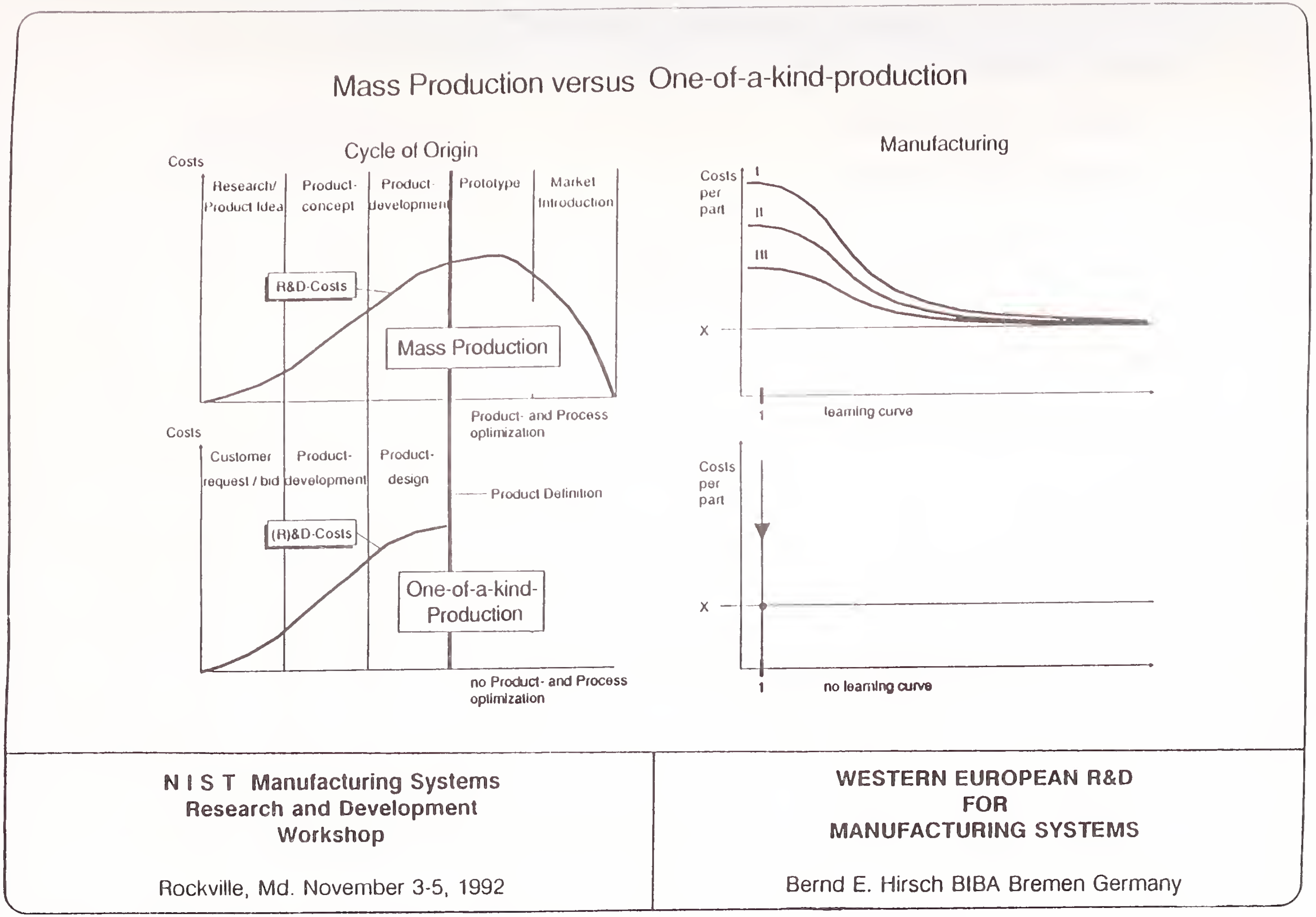

Figure 21. MASS PRODUCTION VERSUS ONE-OF-A-KIND PRODUCTION

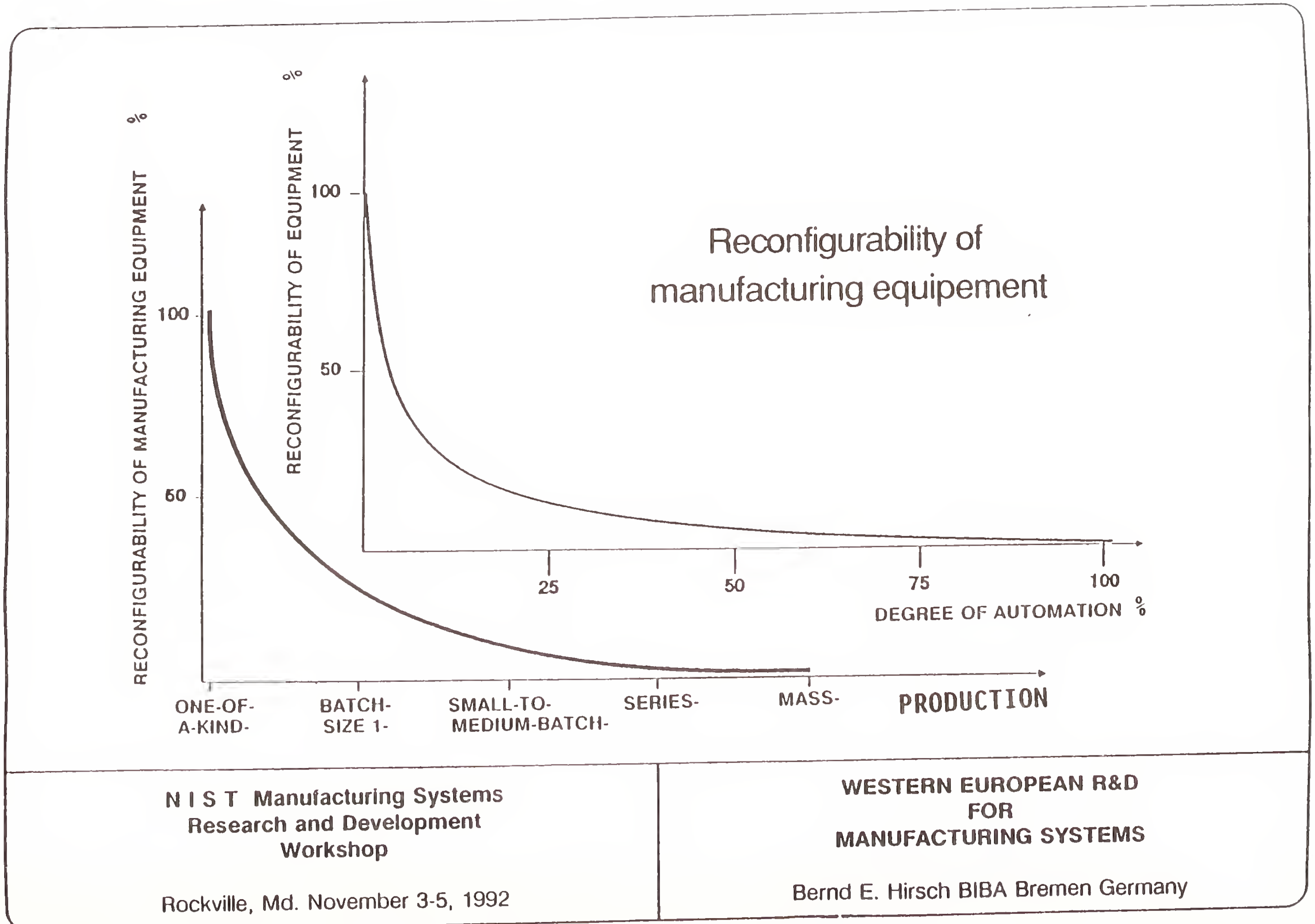

Figure 22. RECONFIGURABILITY OF MANUFACTURING EQUIPMENT

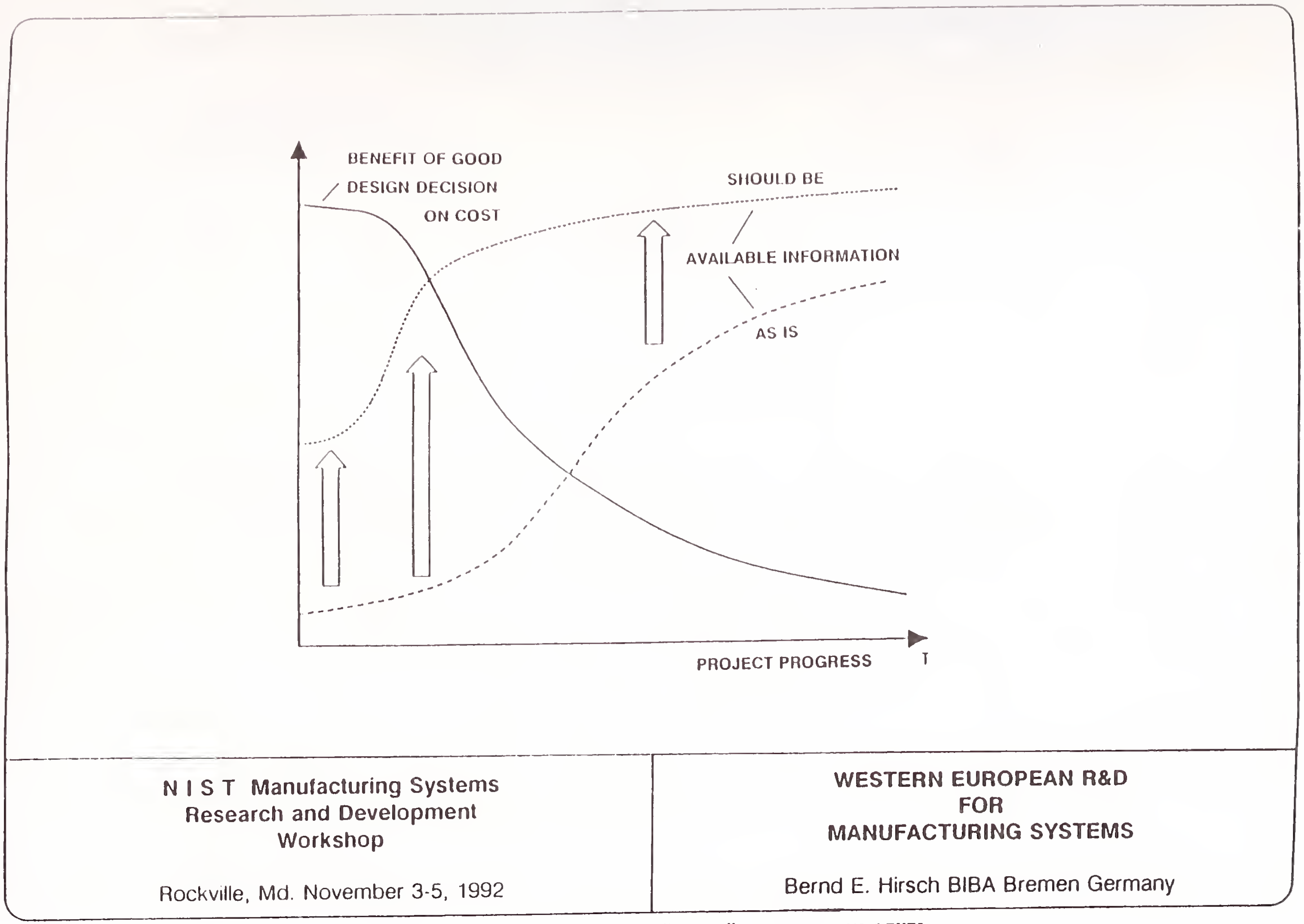

Figure 23. "TO BE" VERSUS "AS IS" INFORMATION LEVEL

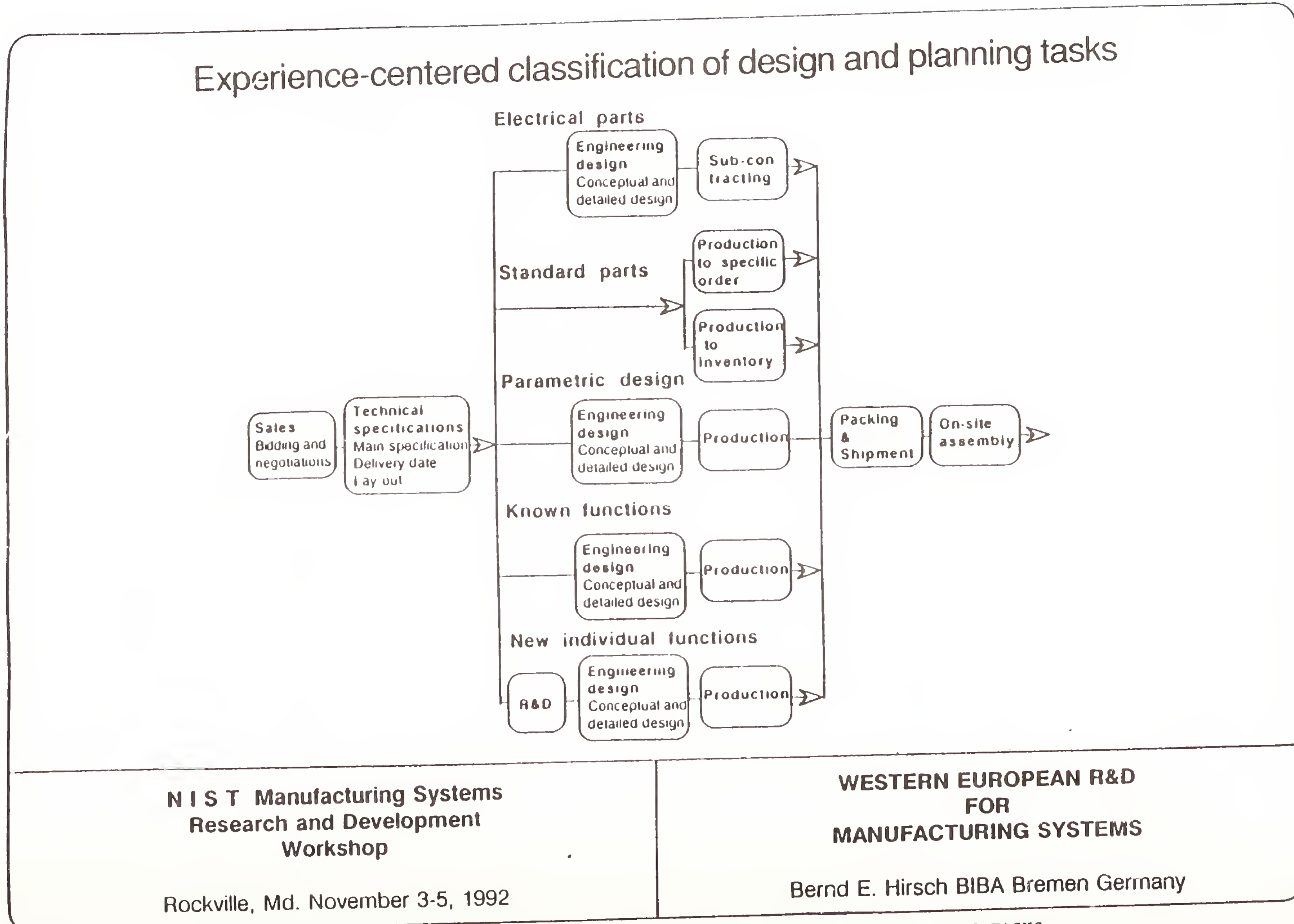

Figure 24. EXPERIENCE-CENTERED CLASSIFICATION OF DESIGN AND PLANNING TASKS

Comparison of Production Program Planning Approaches

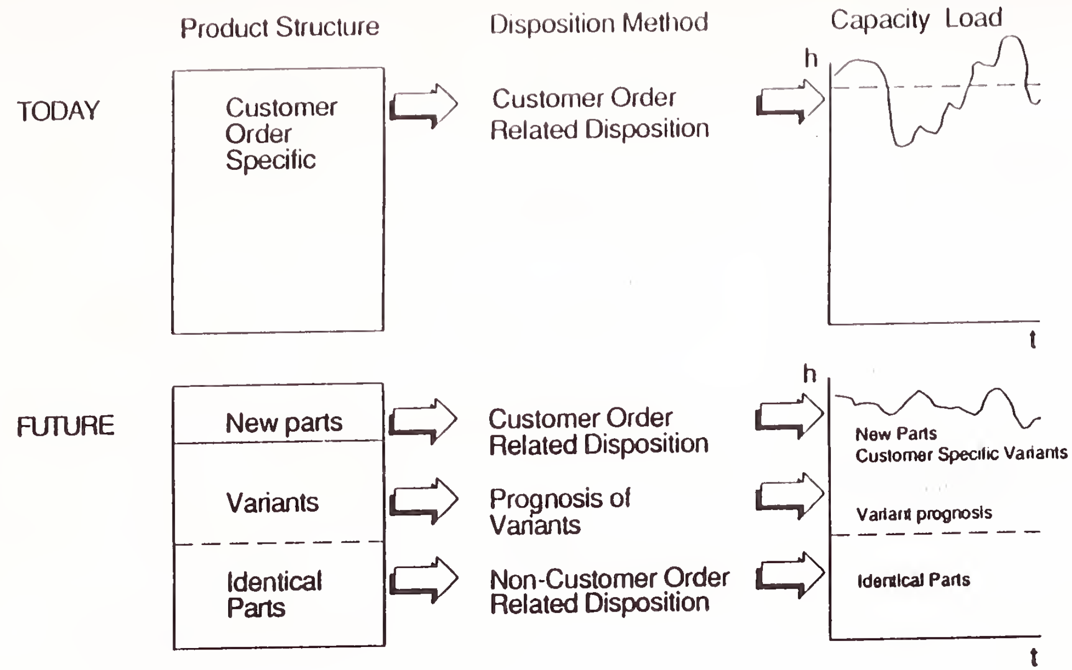

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Figure 25. COMPARISON OF PRODUCTION PROGRAM PLANNING

Experience generation loop

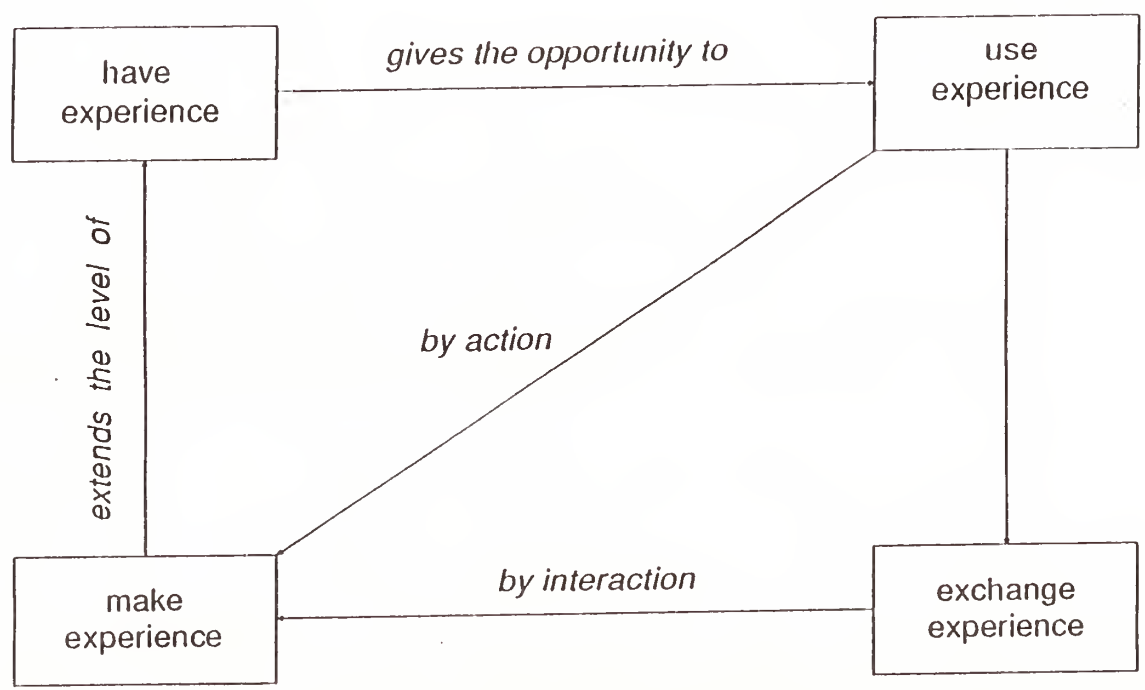

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Figure 26. EXPERIENCE GENERATION LOOP

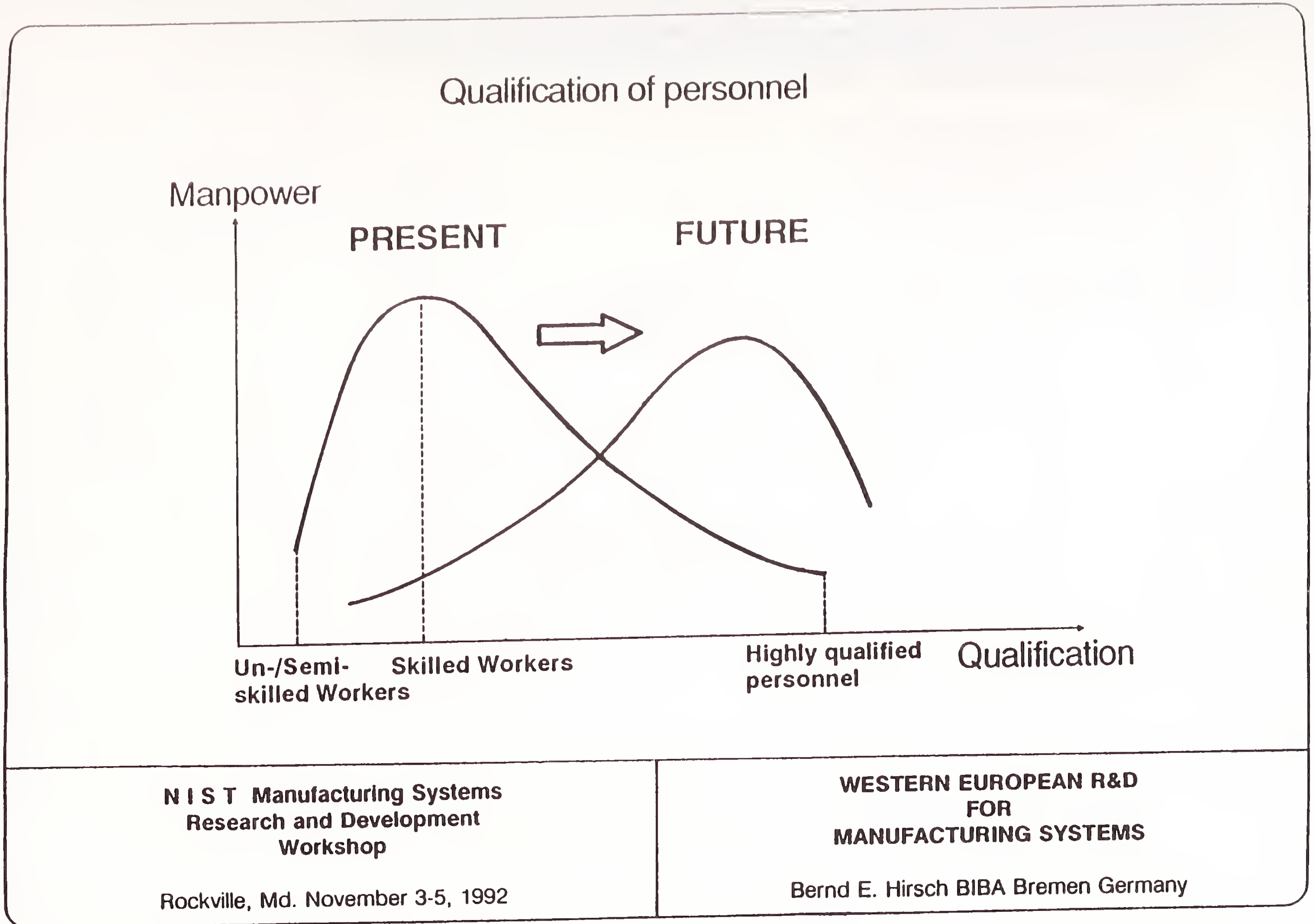

Figure 27. QUALIFICATION OF PERSONNEL

Current and Future Enterprise Cooperation

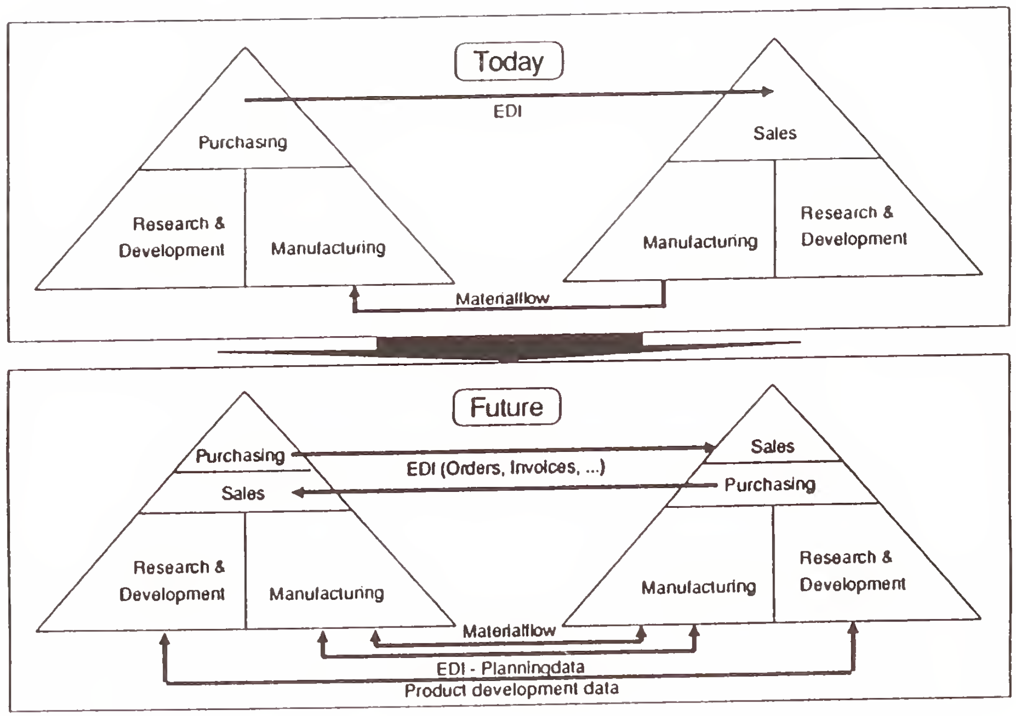

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Figure 28. CURRENT AND FUTURE ENTERPRISE COOPERATION

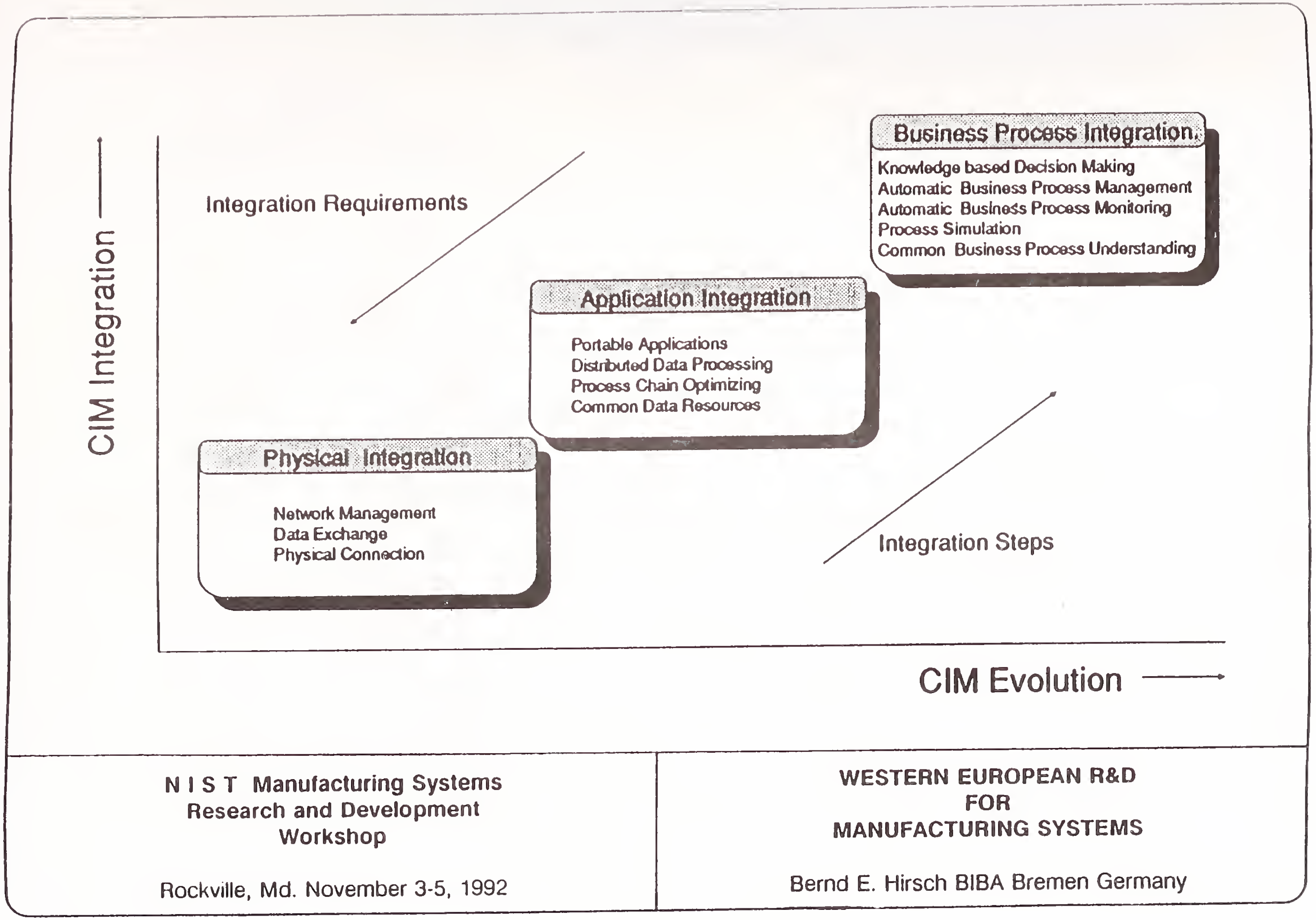

Figure 29. LEVELS OF INTEGRATION

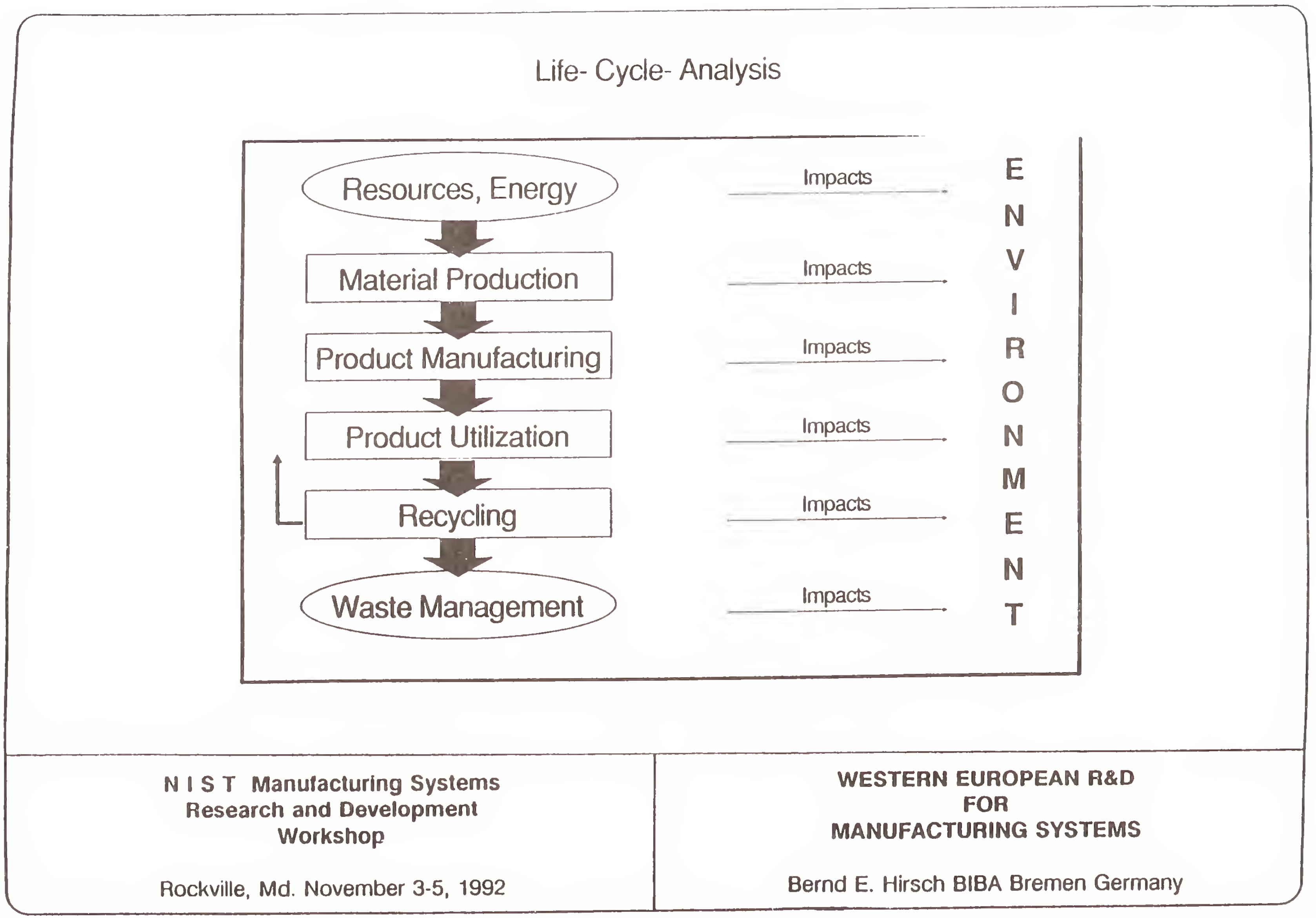

Figure 30. LIFE-CYCLE ANALYSIS

Machining Process
Input/ Output

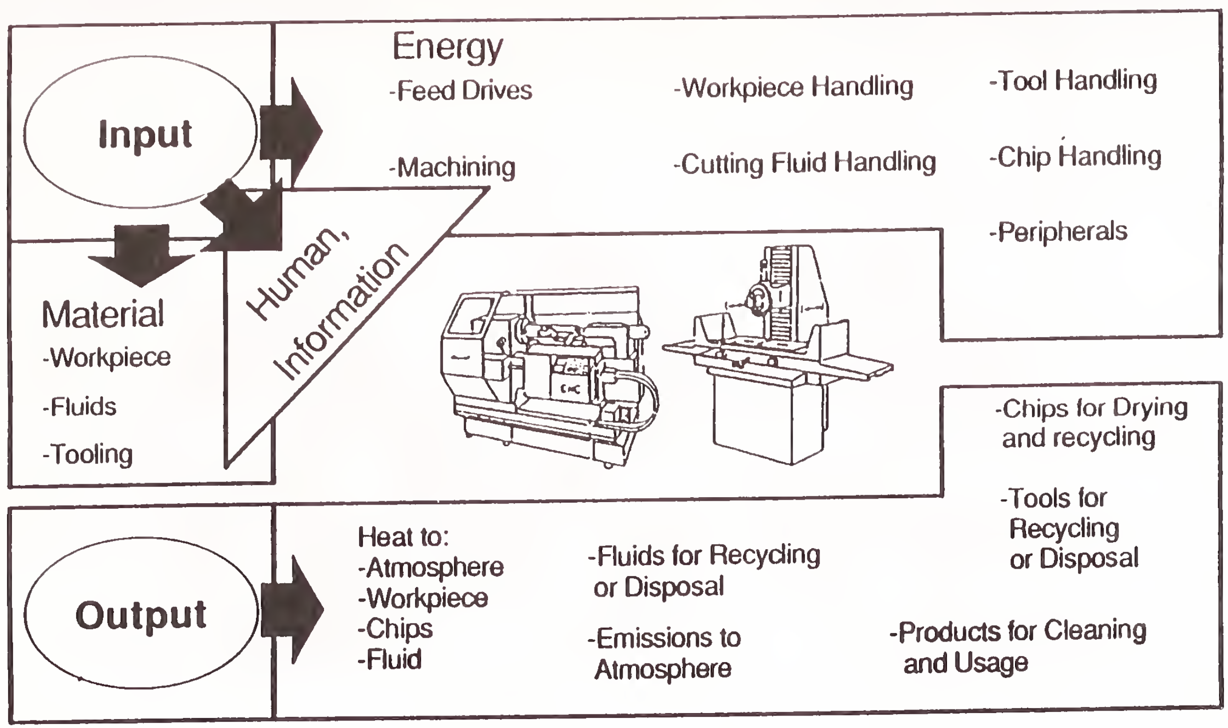

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Figure 31. MACHINING PROCESS INPUT/OUTPUT

LEVELS OF ANALYSIS IN CRIMP

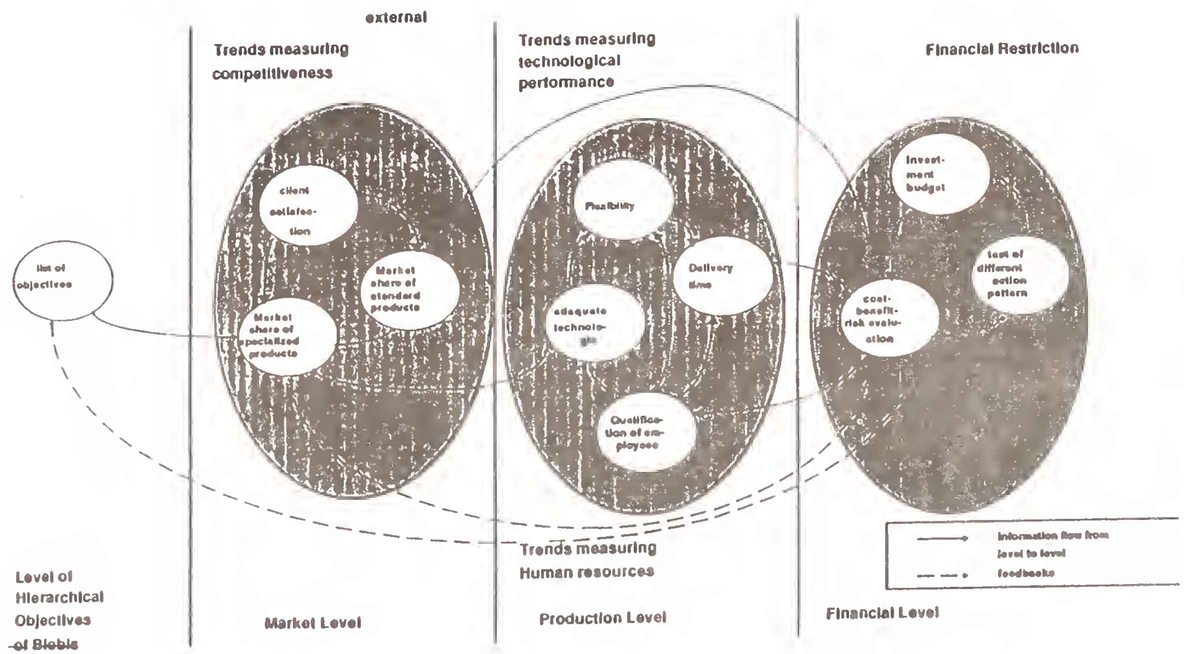

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Figure 32. LEVELS OF ANALYSIS IN CRIMP

Russian Academy of Sciences
St. Petersburg Institute for Informatics and Automation

Eastern European R&D in Manufacturing

Main Tendencies in Research and Development of Advanced Manufacturing Systems in Russia and Eastern Europe

St. Petersburg - 1992

Main Tendencies in Research and Development of Advanced Manufacturing Systems in Russia and Eastern Europe

Contents

Abstract: *Main tendencies are considered in the field of research and development of advanced manufacturing systems in Russia and Eastern Europe, caused by specific economic situation and engineering traditions in the countries.*

INTRODUCTION

The title of the paper implies that the content is devoted to the situation in East-European countries. Unfortunately, in a short period of time, it was not possible to get exhaustive information about all former socialist republics of Europe and USSR.

Therefore, the main summary and conclusions are made on the basis of analysis of the situation in Russia. But to the strong belief of the expert group preparing the paper, the situation in the other countries is very similar because of adequate conditions in which they are now. The information which we have by means of international relations and post exchange proves that we are not mistaken. So the narration is organized around Russian events but it is possible to extend the main principles and conclusions to all countries mentioned above. In the table exhibiting research organizations working in the fields being examined, representatives of East-European countries can also be found.

STATE OF ECONOMICS AND INDUSTRY IN RUSSIA

The main distinguishing features of the economic state of Russia are as follows:

<u>In Economic Branch</u>

a. Recession in economy shows that the gross national product has reduced correspondingly: in 1990 - by 3%, in 1991 - by 9%, and in 1992 - by 12-15%.

b. In essence, none are those production relations which are adequate to exchange economy. With 90% capital funds being state property, private enterprises do come into being.

c. Actually, the market relations are non-existent, forming in but only the commodity market; the capital and financial markets are none. The existing commodity market is deficient.

d. The government policy "profit-tax" is changing all the time and this, practically, excepts the possibility of strategic planning for the development of enterprises and their technical reconstruction. Add to this the perspective of privatizing the enterprises by the end of 1993 - 35% federal and state property - to be privatized, total cost of the capital fund being about 1.5 billion roubles.

e. There is an inflation outbreak in the financial sphere. The average speed of money issued for the last 15 months makes up 37.4% a month; therefore there is no market basis, i.e., producer's competition for a consumer's rouble. In this case, increased are sharp rates of interest on credit - they amount to 50-100% annual ones, this exceeding the world standards 5 times and more.

f. In energy and transport infrastructure, for the last 5 months, more expensive have become power-carriers and transportation services (more than 10 times). However, considering the existing rate of the Russian rouble converting, this is considerably lower than world prices (the price of oil is 10% of the world price).

g. As to the sphere of labor resources, wages have grown 10-20 times (mainly in the raw materials and extractive industry), in the science-consuming branches, those do not exceed 2-3 times, the living standard of the population has fallen 3-5 times. All of the above indications lead to the loss of qualified personnel draining off from the production and scientific sphere.

h. Because of political reasons, there takes place breaking off of the economic connections among the enterprises, substituting of the civilized character of the commercial agreements "commodity-money-commodity" for the form "commodity-commodity".

i. The level of inflation in 1992 will amount to 2100%, comparing with the developed countries where it is 3.3%.

<u>In Industry Branch</u>

a. In the industry of Russia, predominant is the proportion of "non-market" branches: extractive and raw material industry and military industry (the latter in St. Petersburg makes up 70%); necessary is structural reconstruction of the industry which leads, as it is known, to the decline of the traditional branches.

b. Giving up the militarization of the economy has resulted in essential reduction of the state order for the enterprises of the military industry complex (in 1992 - by 30%, for St. Petersburg - by 75%). These conditions bring the necessity of carrying out their civil conversion.

c. By force of historic reasons which have dictated the existence of the Russian enterprises within the bounds of the tough centralized state systems of planning, the life cyclical phases such as - "marketing" and "follow up" - are, practically, in embryo at present time.

d. On the threshold of privatizing, the large-scale enterprises begin to disintegrate and form mobile small enterprises with their own subject-closed specialization of production.

e. In connection with raw materials and materials becoming more expensive, the expenses of the enterprises for the first months of 1992 has exceeded their incomes 3-4 times. That has brought, for example, over 20% of the enterprises of St. Petersburg to the verge of ruin.

f.. Under the conditions of existence of the deficient domestic market, in fact, there fallen away are the requirements to be satisfied by the products' quality.

g. Simplification of the foreign economic activities has required from some developed branches as avia-, motor-, and power-plant industry to increase competitiveness of products. This being expressed, among other things, for example, in increasing the proportion of individual orders up to 30-50% of the production volume.

h. The processing equipment of most parts of the enterprises is worn out (17%). This has resulted in reduction of industrial production rate, for example, in May of 1992 - by 15%.

i. Most of the enterprises have practically no present-day information technology, as the Russian computer science has lagged behind the world level for no less than 10 years. Acquiring the up-to-date equipment and programs requires hard currency, but this, under the existing conditions of forming the state currency equalization fund (about 50% of hard currency income is withdrawn from the enterprises), is significantly difficult. This is the cause of isolation from the information recourse of the civilized world, and among other things, from the wold bases of data and knowledge.

j. The level of capital investments in the industry has abruptly been reduced. Compared with the 1st quarter of 1991, it has reduced by 43% with the largest drop being observed in machine-building; it making up 60%.

k. During the last two years, the volume of financing of research and development in the field of advanced manufacturing systems has reduced no less than 3-4 times.

Nowadays in the frame of the newly established Ministry of Industry of Russia, special funds for research and development of advanced manufacturing systems are being founded:

- The fund for tool and equipment design,
- The fund for support of industrial engineering works.

But up to this moment, the volume of these funds has not yet been defined.

RESEARCH STRATEGIES AND MOTIVATIONS IN DEVELOPING OF ADVANCED MANUFACTURING SYSTEMS

In order to organize designing and development of the manufacturing systems within the ministries and departments, in former days, leading designing institutes were created specializing in development and design of new plans and specifications for erecting the enterprises engaged in production of articles in conformity with the type of the ministry. These designing institutes formed scientific research programs, worked out the plans of financing the creation of new productive capacities, and developed the existing ones of these ministries. Uncoordinated and closed designing works resulted in their duplicating, choosing the subjective decisions connected with using the processing equipment from that for machining, preparing processes, and for the specialized machines intended for performing the unique processing operations. This tendency was maintained and at transition to ordering and purchasing the processing equipment abroad. The leading institutes dictated not only the technical policy aimed at working out the projects but at the reconstruction and technical requirement of the enterprises as well.

At present, such a tendency has weakened significantly due to decentralization of planning and financing of the enterprises. If finances, in particular, relating to long-term programs, have been reserved by the state structures (committees and commissions), the enterprises have consolidated their initiatives to define the directions of the scientific-technical development and their realization, and the administrators (mainly chief engineers) of the existing enterprises have to become chief designers of programs for technical reconstruction being responsible fully for the strategy and realization of chosen direction.

For the last ten years, observed are several periods concerning strategy of creating and developing the enterprises peculiar to the tendencies in the society. At the beginning of the 1980s, the extensive way of development of the productive capacities at their high specific amount of metal per structure as well as high power consumption has resulted in exhaustion of most natural resources. The direction adopted in reconstruction of the society has influenced the strategy of development of the enterprises and caused the changes in it. Aiming at intensification of the production has led to creating the all-union and regional programs for reconstruction of the enterprises. The base of this being introduction of automated or "substantially" automated production systems based on using the flexible manufacturing systems. Investments of considerable capital of the centralized use into the processing equipment (indices, as a rule, has let down from the top, at least, relative to automation level of processing operations) have led, most commonly, to the fact that the general production process has not been developed as required. Thus, introduction of high-efficient equipment for the local processes increasing production 2-3 times, has led to general growth of productivity 2-3% maximum.

Such an insignificant general effect of automation level change has been caused by lagging in other types of provision, for example, in information servicing means (technical preparation of production, managing the materials' flow was mainly carried out only on paper base). Even there, where the introduction of flexible modules (FM) into production process was successful, the production preparation was not in time for their requirements. The effect from their introduction corresponding to the amount of financing was obtained only in large-scale production, but this requiring considerable cooperation of customers of the given products.

The experience of five-seven year introduction of the automated modules, sections, and shops, as well as considerable reduction of centralized financing have led to the necessity changing the strategy of development and reconstruction of the enterprises. In 1989, the decision was taken to concentrate financing for special purposes in the form of the projects for creating the plants of the future which are a testing ground of integration of the automated systems for different purposes (see Appendix 1).

Such testing grounds of the state budget financing for special purposes are meant to solve the problems of creating the integrated automated systems based on the typical designs for different-purpose automated systems followed by their circulation.

At present, the concentration of financing does not give the due effect, although it reduces the level of duplicating the developments being financed by the state. To our mind, this is connected with the following shortcomings of organizing these works:

- insufficient experience of creating the industrial software: the USSR had no market of the programs of domestic production and, as a rule, each software product had single-introducing equal to (93%), two-or-three times introducing - (5%), and the rest - (2%) for the circulated software product (data of 1991). This tendency (ordering by myself-using by myself) has led to the deep-rooted technology of carrying the program product to completion in the shortest time in order to pass it to the electronic computers of the customers considering their remarks and by no means satisfying the requirements of the technology of the software being circulated (though operation was not services by the development engineer);

- not strict enough discipline of executing the specifications for each subsystem (long terms of development and introduction - lead to the changes improving each component, but the characteristics of their integration are growing worse);

- insufficient, to our mind, financing for purchasing the computer facilities results in orientation to personal computers (both - in developing organizations and in computing centers of the plants under design). These are effective for solving test problems in designing institutes, but as far as real volumes of information are concerned, their field changes are lengthening out for long terms (half a year - year);

- high barrier of currency rate in respect to a rouble on the domestic market has not allowed wide use of western software and this leading to complete and, rarely to partial lack of the discipline of standardization of data exchange on specialized developments. The level of user interface has made no provision for strict control of the data being introduced. Widely used were own database management systems without deeply analyzing the requirements to the typical ones, and in these cases any transition to the up-to-date software led to partial and, sometimes, complete loss of information (this being a deterrent for their introduction), or to parallel accompaniment of several versions of program systems for one-two years.

TENDENCIES IN THE FIELD OF AUTOMATION OF MANUFACTURING SYSTEMS

The problems which are stated today in the field of production automation can be classified conditionally into two groups:

- the first group is brought to mass covering with partial automation of some machines, units, and processing operations as part of their reconstruction and modernization;

- the second group is brought to radical changes in the processes and to putting into operation of integrated production processes.

As the domestic experience shows, 50-70% of the defects found in the ready machine-building products are caused by errors in the design, 20-30% are due to the limitations of the production processes, 5-15% are through the workers' fault. Therefore, throughout the processing requirement of our country, of great importance are automated integrated processes. The integrated processes are developing in two directions:

- integration of processing operations through concentrations of the operations when a number of operations are being tied together on one machine or on the complex of machines;

- computer-integrated processes realized by means of integrated production complex (IPC). This direction is considered defining in development of the production processes now.

Integration of the processing operations is realized by two ways:

1. Creating the multi-zone processing centers (complexes), including several operating zones, for example, St. Petersburg State Technical University has created the complex with the zones of plasma jet hard facing and machining by cutting and grinding. The use of such complexes, to the experts' mind, will provide the possibility of increasing the time of proper machining with the use of equipment from 5% to 28% of the operating time fund.

2. The units with several machining heads, for example, centers of АГП-400 and АГП-300 type (with four and three capstans) developed by Research Institute for Technology and Organization of Production (in Moscow).

The development of automation goes in parallel with development and usage of information processes. Today the production is characterized by complication and complexity, this requiring the creation of new management approaches. Thus, the decisive role of success of the production processes belongs to such information processes by which completed are the production processes.

The basis of these facts (in principle, making provision for the status of IPC at our time) becomes apparent in the tendency making provision for development in two directions. This tendency is oriented to real and wide introduction into the industry of the fully automated complex system of production. The first of these two directions is a "management" one, and it stimulates development and usage of new management methods of production systems. Both directions are important when mastering the new and high-efficient method of the production organization which is assumed as the basis of IPC.

Within the technological direction outlined are two development tendencies. The first is a clearly defined tendency aimed at creating the powerful potential for simultaneous designing the articles, planning and realization of their production as well as servicing. The second important technological tendency is directed at development of artificial intelligence for the production systems. Within the management direction defined may be four types of important development tendencies regarding correspondingly, organizational, professional, educational, and financial aspects of the enterprise activity.

In Russia, these important strategical directions of the production systems development are not widely spread enough for now. The main reasons are as follows:

- the manufacture of modern qualitative and safe complexes of the processing program-controlled equipment with numerical control realizing ecologically-pure "breaking-through" resources and power saving technologies have not been corrected;

- enough qualitative and safe computer facilities of all the classes necessary for IPC have not been manufactured;

- there is no qualitative and safe equipment and software for creating the computing networks;

- the manufacture of the peripheral equipment necessary for recording and primary processing the information is not organized. The question is remote collection of data, operating control of the manufacture processes, information representation, commutation and data transfer;

- cheap and reliable supply stabilization units for computing means, including built-in control systems of the processing equipment with numerical control are not manufactured;

- there is no series production of system, problem, and application software for flexible manufacturing systems.

TENDENCIES IN THE FIELD OF TOOL DESIGN AND INDUSTRIAL ENGINEERING

The analysis of the methods and means used in the process of designing the equipment and tools shows that their development depends on the technical possibilities of computing means. At the beginning of the 1980s, computers were mainly used for engineering calculations of the parameters based on physical models of the objects under design. Among these methods are, for example, strength analysis carried out with the use of the method of finite differences for constructions, gear-boxes of processing equipment, fastening elements of cutting tools, temperature distribution in stamps and so on.

The next stage was the creation of data bases for design decisions. This allowing:

- to reduce labor-consuming search of scientific and technical information and specification and standards to pass to designing with the use of prototypes; this resulting in considerable effect when using the borrowed and most successful designs;

- to carry out realization of most functions of the technical systems with the use of one physical phenomena;

- to form a considerable number of versions to realize one physical function choosing the effective designs.

In the middle of the 1980s, started was the active use of computing means for automating the solution of the problems connected with turning out the design plans and specifications, drawings, sketches, and text. The first successful attempts in graphic documenting or of typical machine-building drawings have changed into difficulties connected with the organization of automated files (data bases). Limited volumes and low safety of data storage facilities of search of parameterized drawings, lack of full volume of technical means for preparation of documents - all this has led to existence of a double standard. Left was the technology of turning out the paper documents by hand in conformity with the old standards; designations, code classifiers, and so forth. At the same time, it was the new system of simplified requirements that was developing actively. The latter allowing to formalize the process of graphic and text documenting. Naturally, the double standard of documents has not allowed to introduce full volumes of data-retrieval, reference, and other automated data processing systems for information service of the production.

Another important problem for creating CAD/CAM systems is predominance in using personal computers. During the first stage-wide use, personal computers gave the possibility at the end of the 1980s to increase sharply the number of automated working places in design offices and in production. Convenient "friendly" interfaces for the users have stimulated to a great degree their use on a mass scale. Their spreading was greatly connected with lack of legal protection for software in the USSR. Availability of western automation facilities has given the possibility to include them into the production cycles within the shortest terms. In many cases, the software on a personal computer has not required money investments, at least, on the stage of its mastering and introducing. But this had also a negative effect. For medium-scale and large scale computers such a method of getting software was not realized. Such a situation has led to an abrupt disproportion of using the computers of different classes - main orientation is directed to personal computers. They are used for multi-hour engineering computations, for creating the production data base and so forth, i.e., solved are the problems with the specifications unsuitable to them. Usage of local computer networks based on the personal computers of IBM PC-type does not solve the principle difficulties of using the computers of this class.

The mentioned problems hold back the development of CAD/CAM systems in the states of the former USSR. However, great scientific potential allows us to make optimistic prognosis for developing these systems. To our mind, creating the financing mechanisms on the basis of the requirements for creating the industrial software will give the possibility to raise their technical level.

The main tendencies of creating CAD/CAM systems in Russia as well as in the former USSR can be presented by the following directions:

- creation of interactive designing medium that makes provision for multi-functional graphic user's interface in order to operate it with multi-media information;

- actively including into the designing process the knowledge bases with different reasoning mechanisms by means of creating the expert systems, decision-support systems, intellectual CAD/CAM;

- development of the means for geometric modeling of the complicated details and space constructions;

- creation of the distributed data bases (deduction, object-oriented, semantic, weak type-designed ones, and so forth;

- development of parallel process decision-support in CAD/CAM systems.

TENDENCIES IN THE FIELD OF PRODUCTION SCHEDULING AND CONTROL

One of the key directions of the large-scale automation which was started at the beginning of the 1970s is automation of production scheduling and planning tasks. In this case, the main tendency of solving these problems is connected with their position in the hierarchy of the production tasks.

The automatic control systems was designed by tradition as a multi-level storage system. The top level (of the formation) is intended for solving the tasks of computations of volume and cost indices, for analysis of technical indices, redistribution of materials and labor resources, and for information servicing the administration. At the level of the plant solved are the tasks of operative-calendar management, engineering calculations, and designing and technological tasks. The next level is intended for solving the planning management tasks of separate shops and sections.

The first advance in this direction is connected with solving the tasks of automating the control of the technological conditions of separate production links (machines, production units, transport). The main means of formalization for such systems were finite-automation models. The subsequent stages were the works aimed at automation of dispatching control level of management and planning tasks (tasks in on-line moment mode of the technological complex members' activity in conformity with the schedule of actuation/release of details). In this case, the most effective are: situation analysis, recognition, classification, and elaboration of the decisions under the strict limits for the time of taking the decisions. At least, the present stage being considered is connected with complex decision of control and planning tasks as lower levels, so the top ones, including the tasks of operating control and planning the production. The methods and models used at this level are based, to a large extent, in simulation, combinatorial optimization, and artificial intelligence.

In spite of substantial simplicity and traditional character of general consideration of control processes and planning the production, the particular development of these systems runs against a number of problems of the principle character. Primarily, it is a high structural and functional complication of the technological objects under control. Besides, control does grow substantially considering the alternative equipment, processing operations and routes of processing the details. The control processes of production are characterized by the main features of the complicated technical systems, such as distributiveness, asynchronous, dynamic, and parallel character. Control of production systems is connected with processing the large volumes of information (about 100 Mbytes), the substantial part of which has, in principle, an illegible and heuristic character.

This has resulted in the following main demerits of control systems existing in most enterprises of Russia:

- excessive overloading by control and recording functions;

- planning the range and series of products based on the results obtained by studying the consumer's demand not being carried out. In fact, it is determined to a large extent by the consumer's requests and is not investigated by the enterprise itself;

- excessively low level of automation of the working places of the management subdivisions;

- deficient interrelations of the services when solving through control tasks requiring the unique information base and complex economic calculations;

-duplicating the work by the subdivisions;

- prevalence of the current (for a day) planning;

- most part of the working time is spent for the works out of plan (the main reasons of that are as follows: deficient operativeness of getting the necessary information; waiting for business meetings; necessity of frequent travel and long terms of their routes; shortage of personnel specializing in calculation of typists, messengers, and so forth);

- weak discipline of fulfilling the duties, high labor-consuming control of executing orders and directions;

- unsatisfactory organization of operative registering of the motion of material, blanks, semi-products, completing details, and assembly units.

THE ROLE OF INFORMATION MANAGEMENT AND STRATEGIC PLANNING IN DEVELOPMENT OF MANUFACTURING SYSTEMS

Now some words about Information Management (IM) and Strategic Planning (SP), one can say that in former socialist countries, these methodologies have been developed only during the last few years. That is true if we speak about them in western meaning. Namely we mean economically-oriented accumulation and systematic analysis of information for the purposes of development of the enterprise. It is very important that this kind of analysis is oriented mainly to support business activities of the company.

First about strategy, in the conditions of command system, there was no need to formulate the objectives of enterprise development based on philosophy of the firm and consideration of the market situation. In that, goals of each enterprise were defined rather strictly, at least for the last five years, by Ministry. Therefore, not so many top-managers were thinking about long term development of the enterprise. The main task was to fulfill the already defined five year plan. Of course, inside this plan there were special parts devoted to application of new equipment and technologies but in the majority of cases, the main directions were also determined by the Ministry or sometimes even by the Government. A good example is a case of universal recommendations for Automatic Control Systems (ACS) in the 1970s. In such conditions, the only task of the development group was to confirm on paper the possible efficiency of new equipment which was already recommended. From this came the fact that methods for evaluating the costs and benefits of new technologies were poorly developed. No methods of work analysis, very rare comparison of different innovation variants, and no top-down decomposition of enterprise structure were used.

One simple formula was applied for each unit of new technique, usually not in good connection with the other parts of the enterprise.

There was a kind of methodology of pre-design investigations for computer systems applications, publicated by the Ministry of Instrumentation. But it was formulated in an arbitrary way, fixing only the consequence of steps in the investigation. As a result, the generated documents couldn't be used as a base for project management, realizing systematic approach for the purpose of enterprise development.

The described activities did not bring to the situation when methodologies, devoted to development of the enterprises and organizations, were based on scientific achievements of systematic analysis and other branches of science.

We stress here that there was no need in usage of symbolic languages for description of activities, special methods of top-down decomposition, analysis/synthesis procedures, software packages, supporting the methodology and special CASE tools for production, adaptation, and follow-up of these packages.

As a conclusion, one can say that methods, connected with IM and SP were poorly developed. Automation tools for systematic analysis did not exist at all.

One of the reasons of the workshop is to identify unmet needs or gaps in our current R&D. We can state here that one of the tasks of specialists working in the field of Information Management is to adapt and develop the above mentioned methodologies for the needs of East-European countries. Only with this condition, the economy of East-European countries can be successfully integrated with the others.

Moreover, we can say that these methods should be developed further, representing a better link with such areas as strategic marketing and organization planning.

These additional needs are connected with specificity of the economical situation in East-European countries. It was said previously that many large enterprises, which were under the control of the government, have the tendency to be decentralized and are trying to find their place in the market.

For this purpose, they need an instrument for modeling new organizational structures and decision support systems for marketing.

Beginning in 1985 in former socialist countries, research in this direction was made separately by groups mainly organized inside universities and high schools. Appendix II shows the facilities of these research groups. It is visible that they are small. Maybe it is worth it to organize some type of common project to concentrate the efforts of the researcher.

POTENTIAL FOR COLLABORATION

Here we come to the most important point: Potential for Collaboration. In the opinion of the expert group who had prepared this report, it would be very useful to concentrate the efforts of international teams in solving the technological problems of conversion for military enterprises. We think this task is of common interest for many countries. We mean elaboration of a special methodology and decision support system which can help to convert the former military enterprises in the direction of civil production, keeping as much as possible of its property. In this paper we imply under term "conversion" mainly a technological not a social problem as it was understood before. In that case, the solution was simple: only buildings were kept, all other things belonging to the former enterprise were changed, including people. If we look at this task from the side of technological problems to be solved, we can find it much more attractive. As the result of application of such kind of methodology, you don't need to make any sharp decisions, such as lock-outs, etc. Instead, you have the opportunity to keep the most valuable parts of the enterprise and make a rather soft turn from production with centralized finance support to a market-oriented profitable factory.

In our opinion, this problem is closely connected to the topics which we discuss today because they are a part of reconstruction and development of the enterprise. Moreover, the main achievements in these topics, in principle, may be used as a basis for new advanced methodology. Let's try to describe it.

The most important thought is to determine new goals of the enterprise for civil purposes and to formulate a long-term strategy and actions for the immediate future. For this reason, it is thought that we will need a better link of "above-the-shop-floor" activities with marketing and general management. Such a support system has to be highly computerized because we need to examine plenty of variants.

After the strategy is formulated, we shall need a special tool for evaluation of facilities of existing equipment and one which is going to be purchased by the firm. At this stage, the main task is to keep the most suitable for new goal units and find the best new equipment to accomplish the whole system.

This procedure is going to be repeated many times from the very beginning until we can find a good solution. Each iteration has to include cost/benefit analysis evaluating plenty of technical and economic parameters of every unit.

One of the features of new methodology is a possibility of top-down decomposition of the problem area by way of modeling the area in the graphical language. As a basis for such an approach, already existing methods may be used such as Information Systems and Analysis of Changes (ISAC) elaborated in Sweden or Structured Analysis and Design Technique (SADT) used in the USA.

A number of different models may be used in the development of such a system: functional models to define what the system must do, implementation models to tell how, and so on.

In many aspects, the application of expert systems, knowledge bases, and other tools might also be very efficient.

We think international research in this direction might be very fruitful. Many countries now need such an approach and special methodology.

APPENDIX I

RUSSIAN PROJECTS OF AUTOMATED PLANTS

Creation of automated plants (AP) in Russia is financed now by the Ministry of Science, high school and technical policy based on the program "Technologies, Machines, and Production of the Future". In 1992, the volume of financing for scientific research to the experts evaluation, made up no less than 100 million roubles.

The leading organizations and the main executors of this program are: Experimental Research Institute of Metal Cutting Machine Tools, Research Institute for Technology and Organization of Production, Institute of Management Sciences (in Moscow), and St. Petersburg State Technical University.

The main principle for the organization of this program is financing the typical projects. Here are two examples of such in the machine-building field. Both projects are financed from 1989, expenses for the projects for the last two years amounting to:

	1991	1992
MPO "Krasny Proletary" (machine-tool plant):	15 mln	25 mln
Tushinsky machine-building plant (stamps and moulds):	4 mln	11 mln

The terms of creating the base automated plants (AP): 4-5 years

As does show the analysis of a number of the projects of the automated plants being realized in Russia, the cost of scientific-research and research and development works, if considering as the expenditures is comparable with the cost of the equipment of an automated plant. The expenditures for S&R and R&D works are distributed, in their turn, among the directions as follows:

- Development of new technologies - 19%
- Development of tools providing system - 2%
- Development of CAD for product - 2%
- Development of CAD for tools - 2.5%
- System of automated programming for numerical control system - 7.6%
- Designing an automated plant - 32.5%
- Designing the quality assurance system - 19.2%
- Development of new information technologies:
  - hardware - 8.9%
  - software - 4.7%

The characteristics of the production as expected for the automated plants in comparison with the existing productions are as follows:

Labor productivity growth - 9 times
Reduction in the number of staff - 4.5 times
Capital productivity increase - 1.5 times
Increase of production output per unit of production area - 2.3 times
Level of CAD works and technological preparation of the production (TP) - up to 90%
Level of automating the manufacture, control, and tests - up to 70-90%

In connection with the high labor-consuming process of automation of control and designing tasks at an automated plant, they will be realized in the following turn (in brackets indicated is a relative cost):

The first turn (20%):

- Forming a portfolio of orders,
- Considering the plan of finished products supply,
- Designing the control programs for the machines with numerical control (NC),
- Unification of products and technological processes,
- Information retrieval systems for the technological purposes.

The second turn (25%):

- Designing the operational technological processes,
- Grouping the details and designing the group technological processes,
- Unification of technological equipping,
- Technical and economic planning,
- Volume and calendar planning,
- Taking account of material resources on warehouses and in storerooms.

The third turn (50%):

- Production scheduling,
- Construction and modeling the lines, sections, shops (the task is carried out after detail and/or subject-closed areas in the shops being organized),
- Primary accounting,
- Personnel registering,
- Designing the articles (stamps and moulds),
- Designing the technological equipment.

The fourth turn (5%):

- Informant of director and chief engineer,
- Control of the production technological preparation, informants of chief product engineer and chief designer,

- Control of the financial activity of an enterprise.

Main statements laid in the indicated projects are as follows:

In the field of Production Organization:

- subject specialization of the areas, creation of closed productions which permit to carry out TP in whole (from a blank to a finished detail);
- creation of a buffer production zone, "an automated plant-environment", aimed at localization of external sources of breaking down the operation keeping a steady pace;
- the possibility of change-over from the transport scheme "machine-machine" to the scheme "machine-storage-machine";
- realization of the block-module structure of the production processes, including one for their wide circulation;
- creation electronic system for coding and identifying of the material objects of an automated plant.

In the field of Technologies and Equipment:

- economy of expensive materials when passing over to the more progressive methods of production of blanks with the utilization factor of material 0.65-0.75 (precision steel casting in combination with gas staticizing process, laser and jet water-abrasive cutting-out of blanks, repeated usage of rejects);
- creation of integral machine stations to perform all the operations in conformity with the single controlled program on one field. The question is sized processing, strengthening, and control of stamp and mould details. It is expected that performing this integrated equipment will permit to reduce abrupt time losses for intermediate operations, to achieve reduction of labor consumption by 2-10 times, production defects by 3-5 times, production areas by 2-3 times, production cycle by 1.5-2 times, transport expenses by 50-60%, and to increase reliability by 1.5-2 times;
- utilization of rejects (briquetting and packaging);
- electrodeposition with separation for processing the slurry;
- manufacture of combined tools permitting to perform several transition of processing in one setting;
- creation of complex equipment realizing electrophysical and chemical technology of the new level for finishing the complicated space (shared) surfaces of stamps and moulds;
- usage of surface strengthening methods for strengthening the surfaces of stamps, moulds, and cutting tools;
- introduction of independent technology for manufacture and assembly of stamp and mould details being tied up on the basis of using the experience of the automated production of heat-protective coating of multiple spacecraft "Buran".

In the field of Designing:

- computerization of forecasting and considering the demand, creation of the perspective design-and-processing decisions' bank, prediction of the required production arrangement;
- usage of the block-mould principle for building up the article (ganging up) based on design-and-processing unification of the product details and assemblies;
- classification of the product components according to their resistance against time for invariable ones (terms of renewal-10-15 years), changing for 3-5 years and quickly changing;
- creation of standard-sized series of the product unified components on the similarity base;
- usage of the new easily-processed materials, (for example, organic concrete, posessing high dumping ability and low susceptibility to short-term environmental fluctuations).

In the field of Planning and Control:

Creation of the problem-oriented automated work stations containing the following functional software components;

- facilities for introduction, representation, and editing of the primary information, which are oriented to the sets of the documents entered for a particular working place. The facilities for diagnosis of the information being entered permits essential lowering of the labor-consumption for preparation of the primary data.
- data base of norms and standards (All-Russian state standards, branch standards, directions and methodical documents, and so forth);
- computation-and-logic facilities (computation, analysis of the decisions having been taken, visualization and archiving the designs) oriented to the particular list of tasks.
- the facilities for interacting with the other work stations (network facilities, multi -machine complexes);
- the facilities for text and graphic documentation (forming the output text and graphic documents) as well as the facilities for generation of new output forms at introduction of changes in the made up documents' turn-over.

In the field of Quality Control:

- with the aim of increasing the quality of stamps and mould, usage of nondestructive tests (controlling the structure and residual stresses in the surface layers of tool working surfaces) based on metallographic and physical methods.
- high resistance of product (about 100 thousand working cycles and over) is obtained by means of "breaking-through" processing methods for coating (plasma coat under the conditions of vacuum and microexplosion);
- obtaining the required quality of products by means of active automated operational

control and of using "breaking-through" strengthening technologies based on heat treatment in vacuum furnaces with the use of induction and gas heating, as well as multi-layer titanium carbides and nitrites vacuum evaporation, plasma-mechanical treatment, and so on);

- creation of quality control systems for details and assemblies; systems of control, prediction and failure diagnosis of treatment equipment.

Asian R&D in Manufacturing

Manufacturing Systems Research and Development in Japan and Asian Countries

Fumihiko Kimura
The University of Tokyo

Manufacturing Systems Research and Development Workshop
November 3-5, 1992
Woodfin Suites Hotel, Rockville, MD

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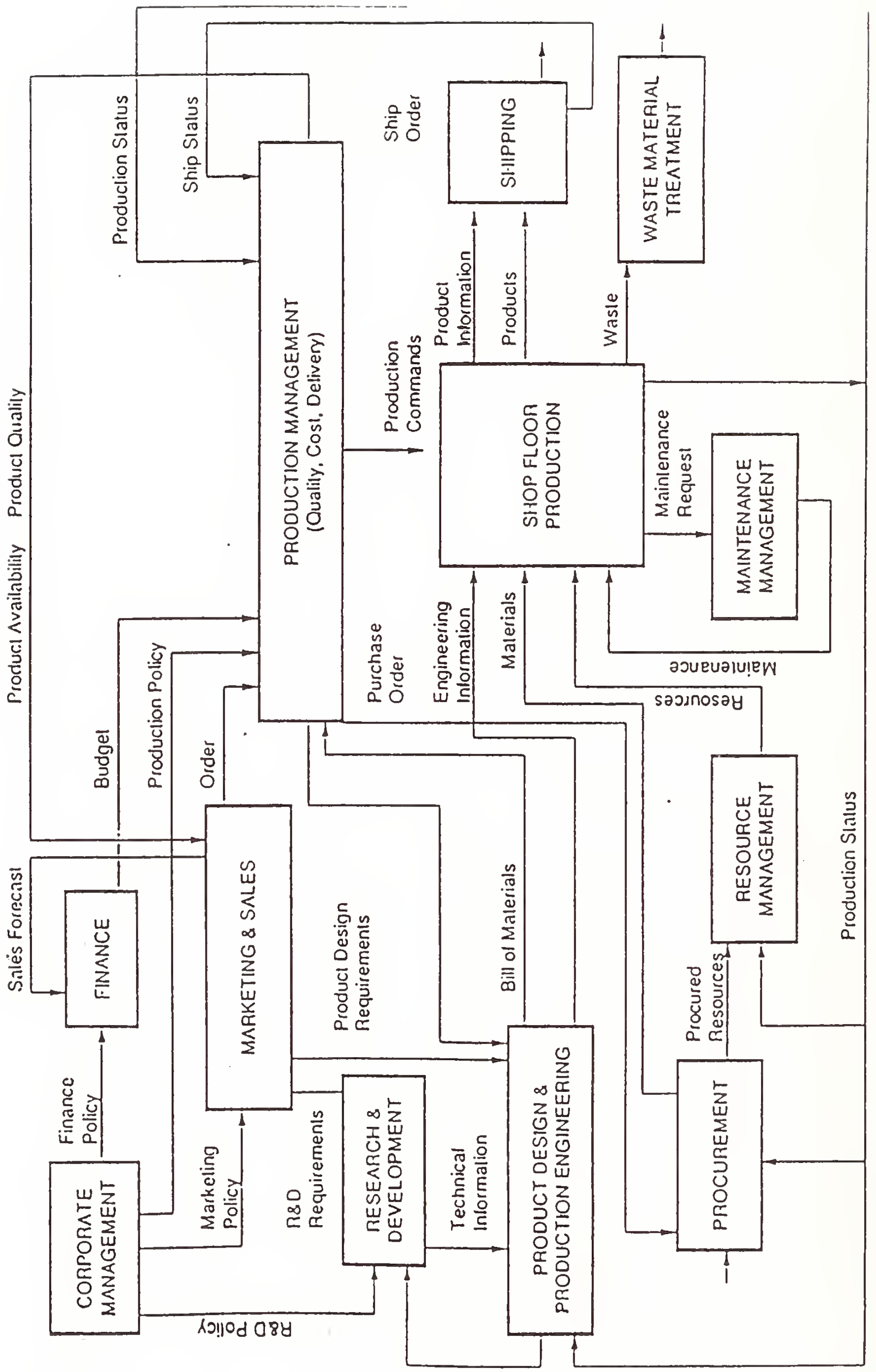
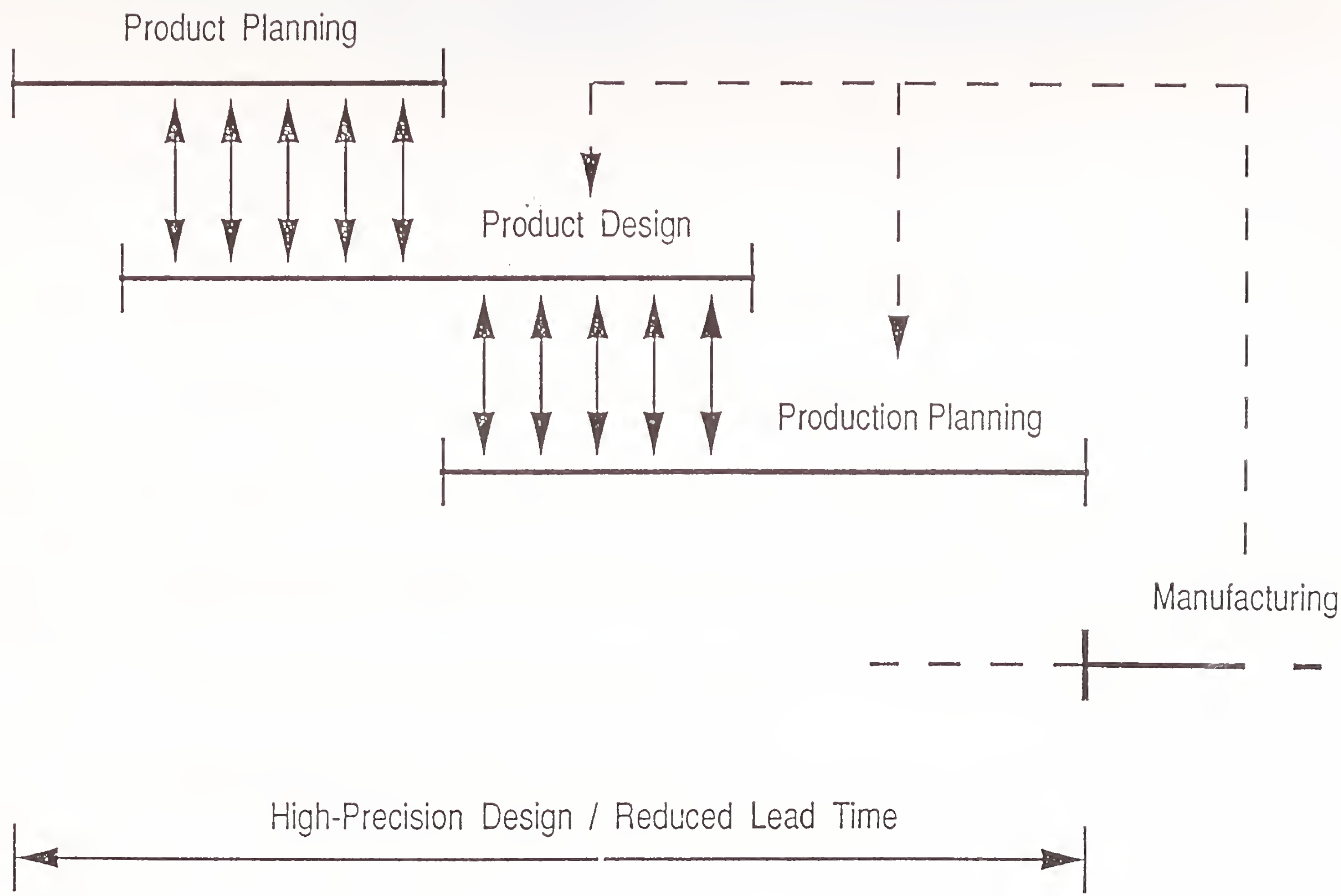


Figure 2 - Typical Arrangements of Manufacturing Functions



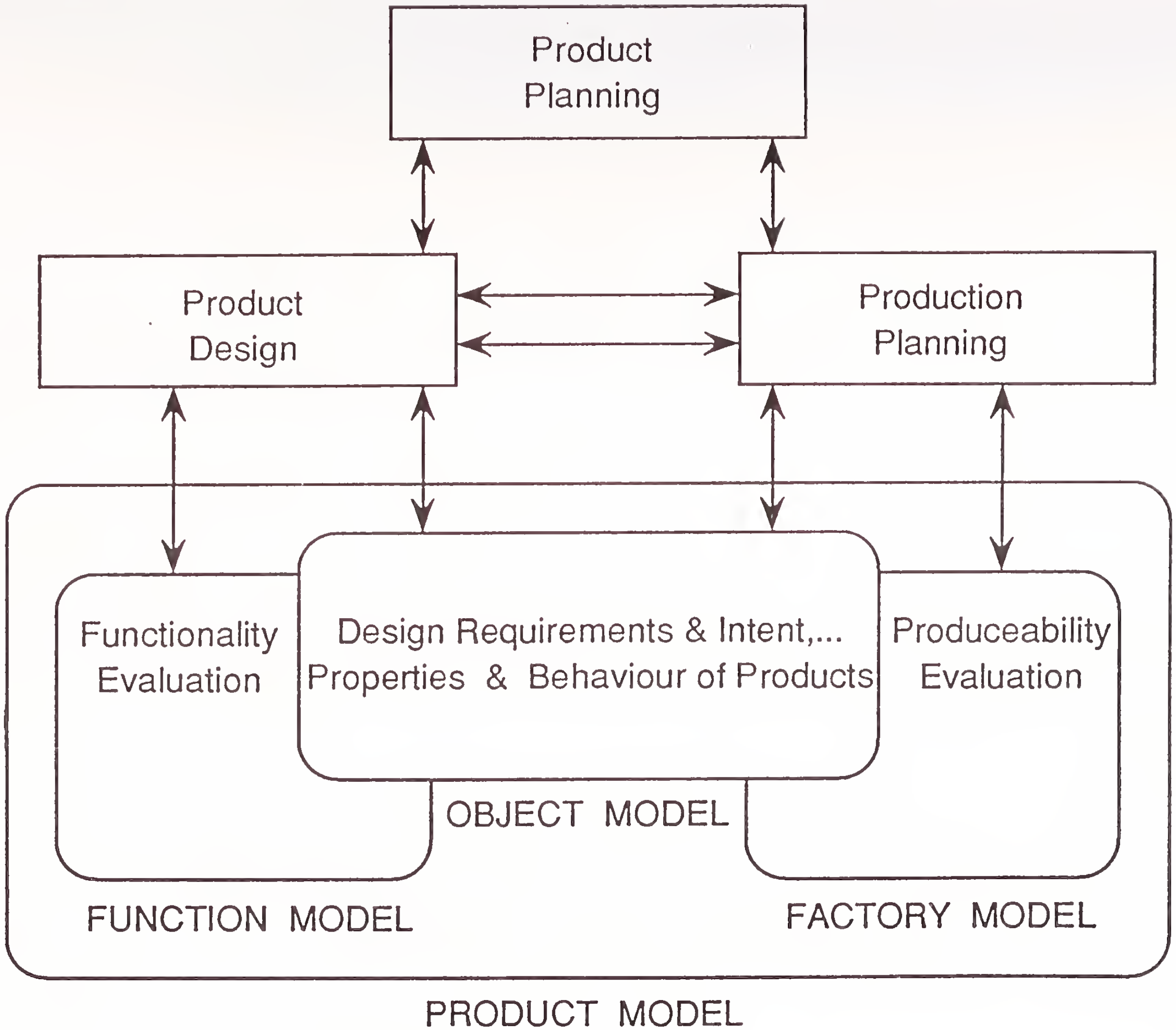
Simultaneous Processes of Engineering Activities.

Concurrent Engineering

Practice in Japanese Industry

- Parallel and Overlapping Work
- Early Delivery of Incomplete Information
- Quick Feedback by Preliminary Study
- High Efficiency in Individual Work
- Flexible Communication with Subcontractor

Primarily Manual, not based on Computer-Aid



Flexible Integration of Production Processes

Characteristics of the next-generation systems

- modular, distributed and open architecture,

- user customization,

- higher level of modelling,
  such as product, process and factory modelling.

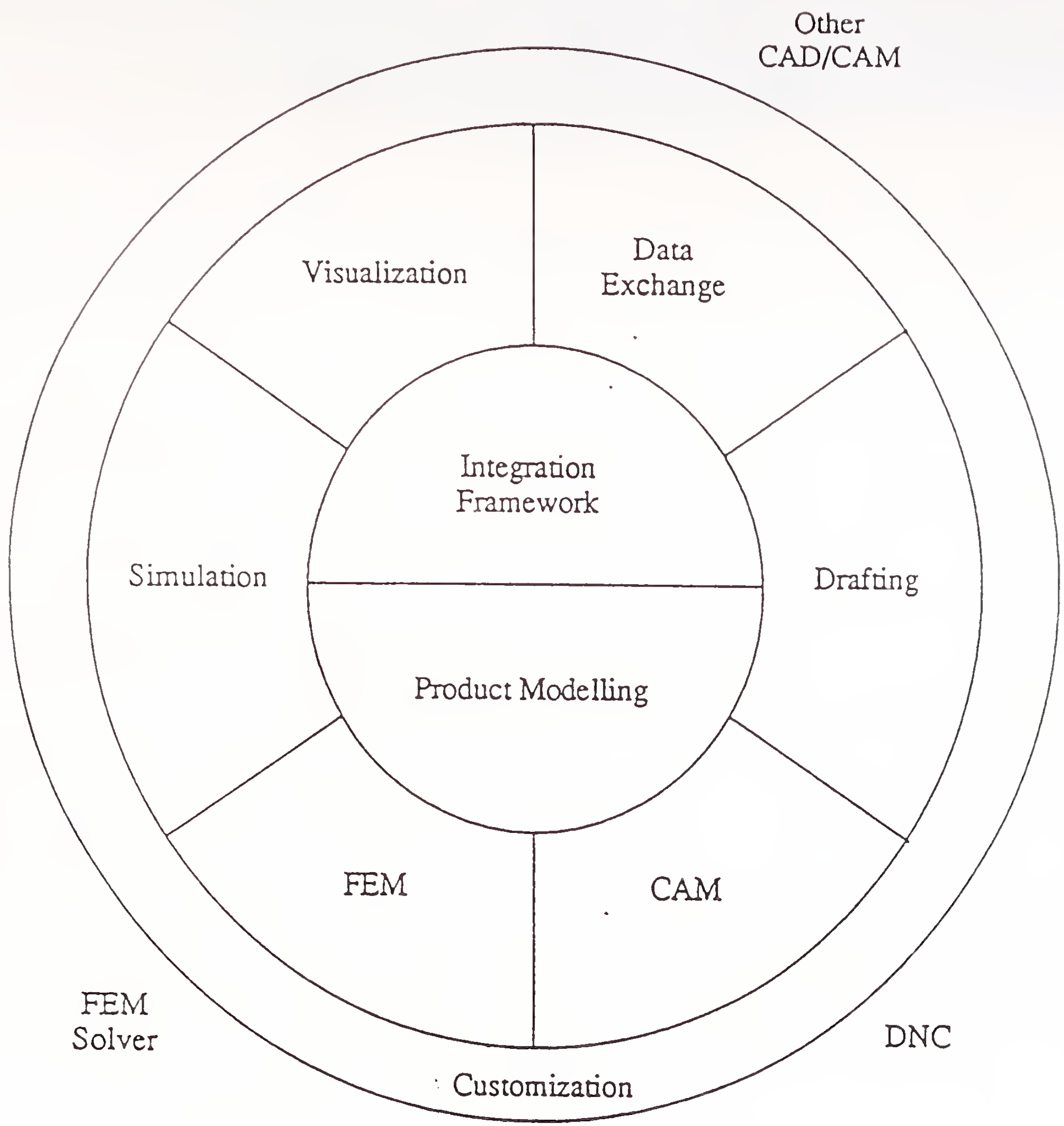
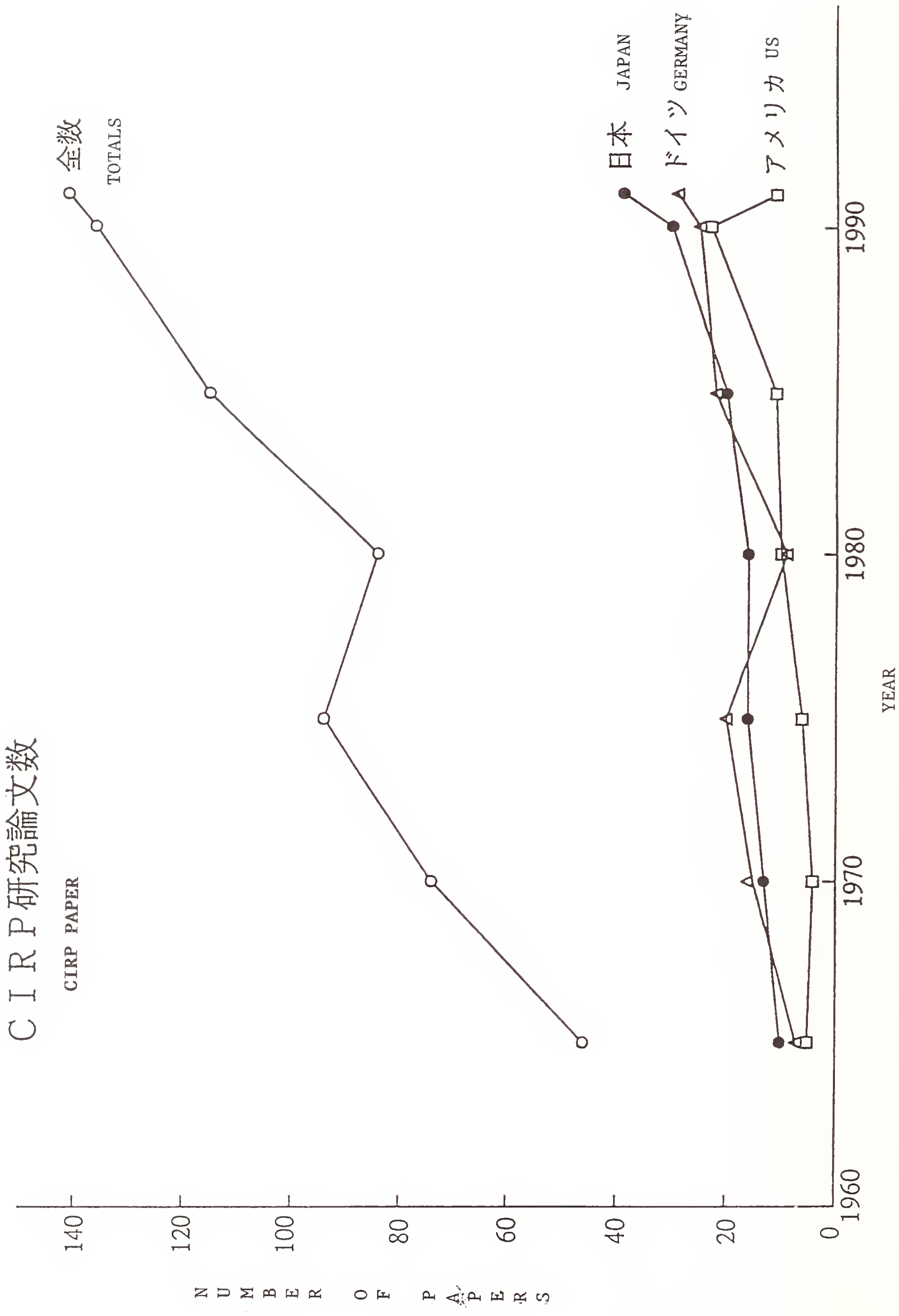


Fig.7 General Architecture for Modularized CAD/CAM


CIRP研究論文数
CIRP PAPER
全数
TOTALS
日本 JAPAN
ドイツ GERMANY
アメリカ US
YEAR
NUMBER OF PAPERS
0
20
40
60
80
100
120
140
1960
1970
1980
1990

Characteristics of Japanese Machine Production

- Productivity: High-Level Automation
  (High Work Rate, 24 hours/Year-Round Production,
  Untended Operation)

- Flexibility: Small stock, Just-in-Time,
  Many-Variation/Small-Volume, FMS

- Quality Reliability: TQC

- Lead Time: Team Work in Development, Concurrent Engineering
  Computer Aided Technology

Future of Japanese Manufacturing Technology

- Lead Time Reduction and High Quality Products by use of Computer Aided Technology in Engineering
- Introduction of CIM in Planning and Management
- Manufacturing Optimization based on Total Product Life Cycle
- Globalization of Manufacturing
- Recruit and Education of Young People

Future Issues in Manufacturing Technology

Process:	Nanometer Order Manufacturing Process New Materials (Ceramics, Composite, ...) High-Speed/High-Precision Near-Net-Shape Forming
Facility:	Ultra-High-Precision Machine Tools (10nm) Ultra-High-Speed Machine Tools (50 - 100 m/min feed rate) High Durability (MTBF 2000 hours, Precision 10 micro-m) Flexibility by Sensor Fusion
System:	Re-Configurable Manufacturing Systems Rapid Prototyping Highly Efficient One-Piece Production
Computer:	Concurrent Engineering Virtual Manufacturing

Public Acceptance of Manufacturing Discipline

- Engineers have been Highly Esteemed.
  - Historical Reasons
  - Not High Salary

- Top-Level Students in Engineering as well as Science

- Many Good Students go to Industry.
  - Even Shop Floor Works

- Good Collaboration between Universities and Industry
  - Human Communication
  - No Rigid Contract-based Research

- Manufacturing Engineering Sections are well Recognized.
  - Career Path by Job Rotation

- Highly Educated Workers

- High Technology even in Small-Scale Companies

Research and Development Sources

- Companies:
  - Product Development and Manufacturing Preparation Division
  - Product and Process Technology Division for Corporate Wide Support
  - Research Laboratories for Basic Research (5 years range)
  - Centralized and Long-Range View for R & D

- Universities:
  - Eight Major National Universities,...
  - Major Private Universities
  - Very Basic Research (10 years range)
  - Active Professors & Graduate Students
  - Financially Poor, Old Facilities, but Very Flexible

- National Laboratories:
  - MITI: MEL & ETL, ...
  - Very Basic Research and National Projects (big to small)
  - Very Good Researchers
  - Moderate Budget and Facilities, but Very Inflexible

Research and Development Projects

- National Project
    - Primarily Supported by MITI
    - Advanced Topics from Academia
    - No or Little Participation from Universities
    - No Direct Industrial Application Expected
    - Good Opportunity for Information Exchange and Education
    - 3 to 8 years, several 100 million US dollar
    - Partly Paid by Government

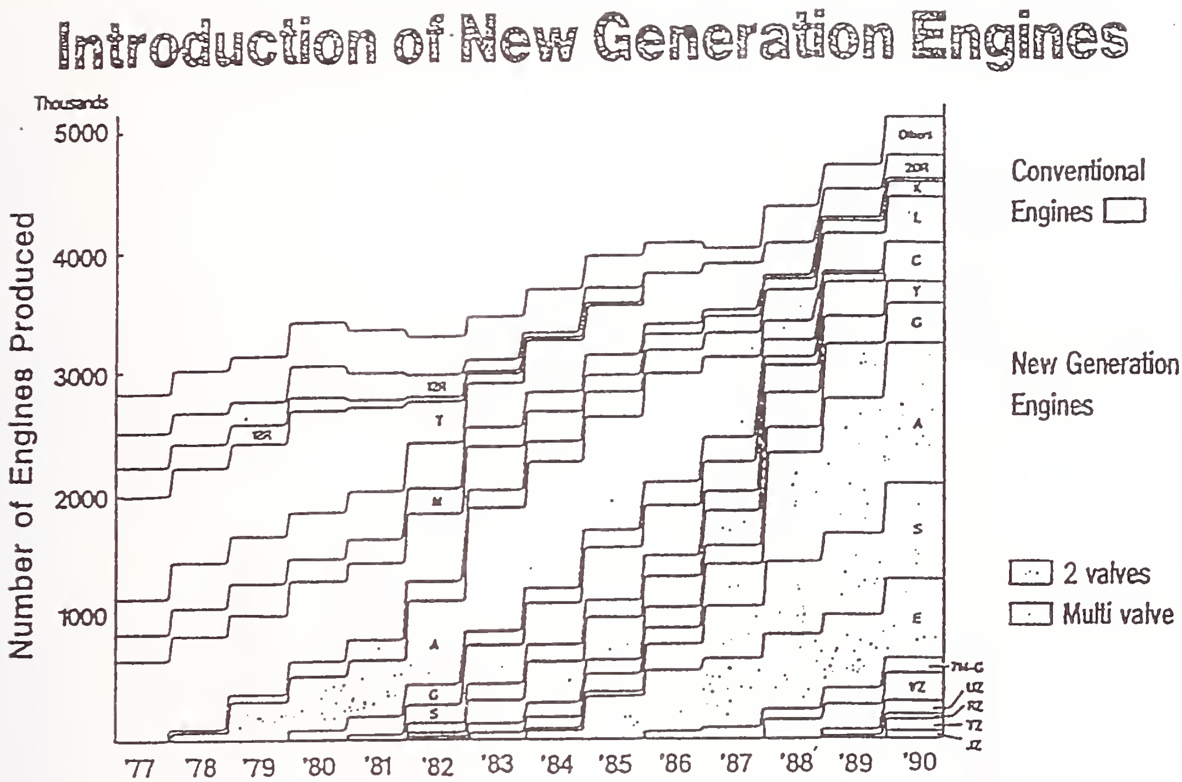
Real Developments in Private Companies

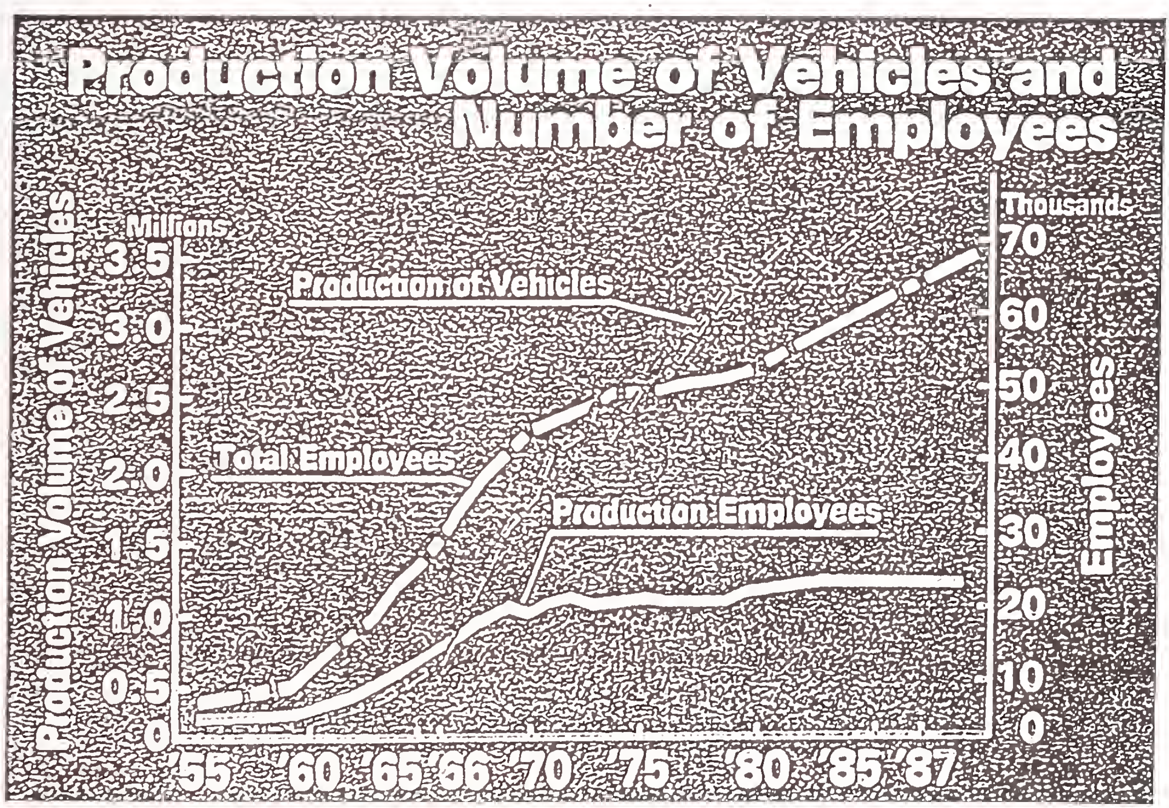
Technology Transfer by National Projects
    Open Forum for
        Universities and Research Laboratories
        Big-Scale Companies
        Small-Scale Companies

Contents

Manufacturing Technology in Japan

- Characteristics of Japanese Manufacturing Technology
- Development of Mechanical Manufacturing in Japan
- Japanese-Style Manufacturing
- Flexible Manufacturing Systems
- Applications of Robots and Automatic Assembly
- Development of CAD/CAM Systems
- Contributions from Academia
- Future Directions of Manufacturing in Japan


Introduction of New Generation Engines
Thousands
Number of Engines Produced
5000
4000
3000
2000
1000
'77
'78
'79
'80
'81
'82
'83
'84
'85
'86
'87
'88
'89
'90
Conventional Engines
New Generation Engines
2 valves
Multi valve


Production Volume of Vehicles and Number of Employees
Production Volume of Vehicles
Millions
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Production of Vehicles
Total Employees
Production Employees
Thousands
70
60
50
40
30
20
10
0
Employees
'55
'60
'65
'66
'70
'75
'80
'85
'87

Characteristics of TOYOTA Manufacturing System

- Intensive Research and Development in Manufacturing Technology

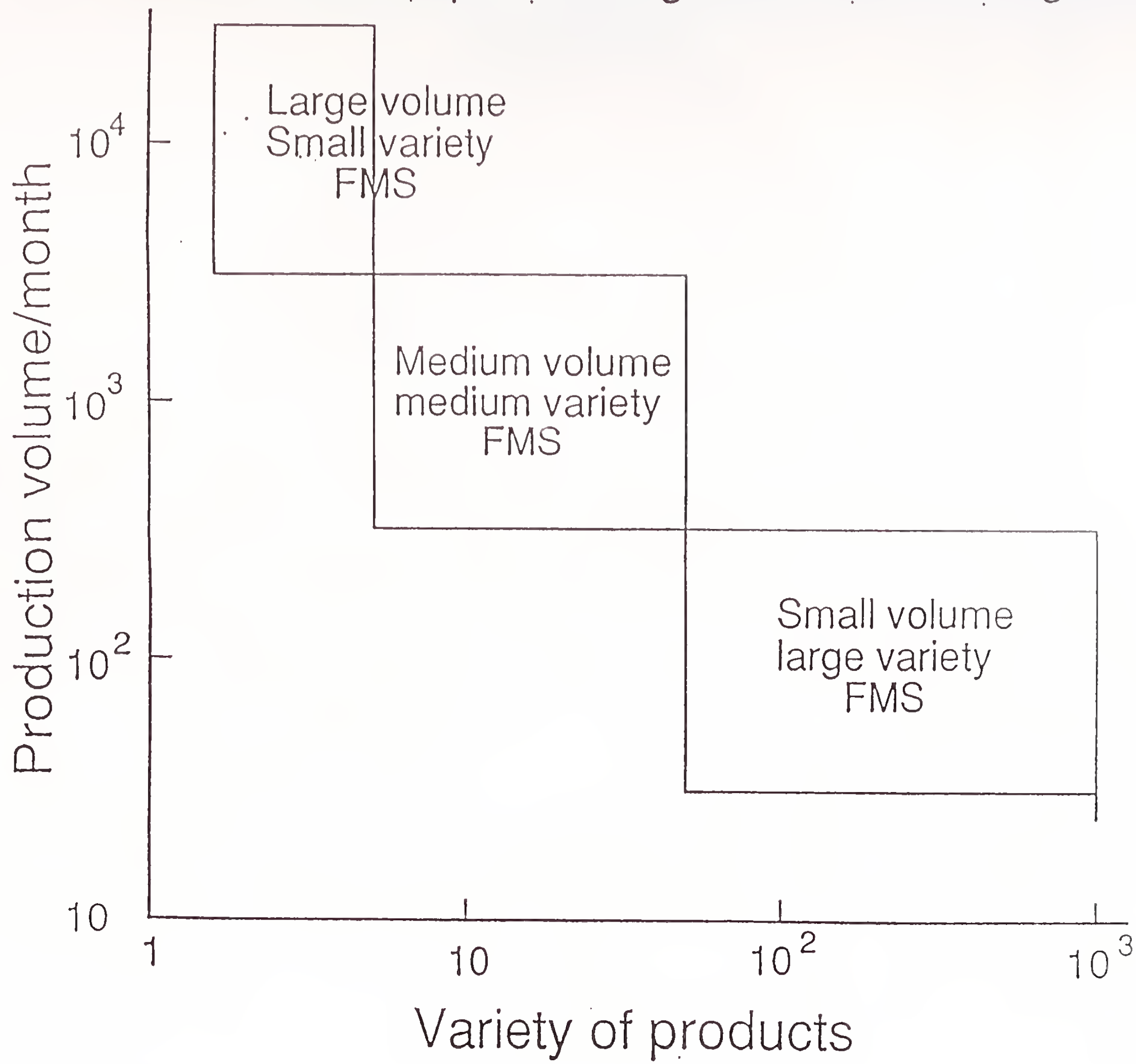
- Investment for Advanced Manufacturing Facilities

- TOYOTA Manufacturing System

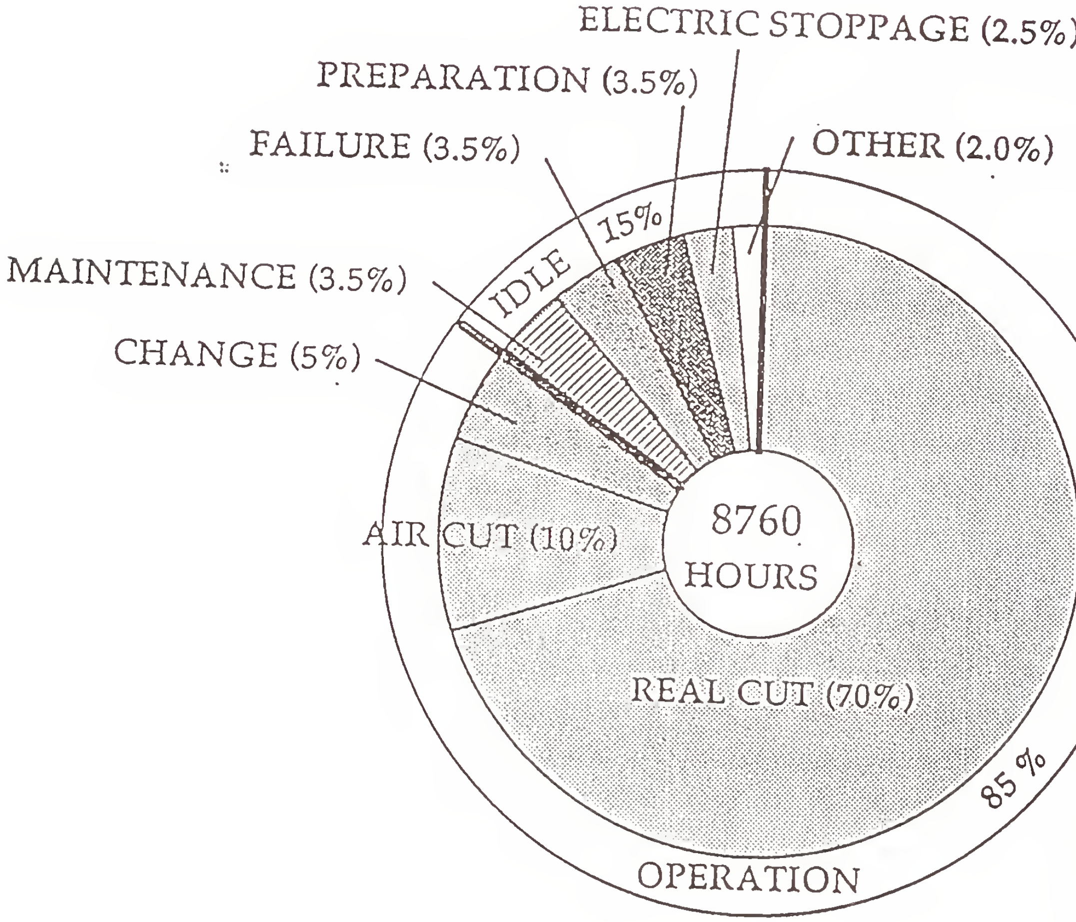
    High Quality Products
    Lead Time Reduction by KANBAN
    Leveled and Continuous-Flow Production

- Tight Collaboration of Employers and Labour

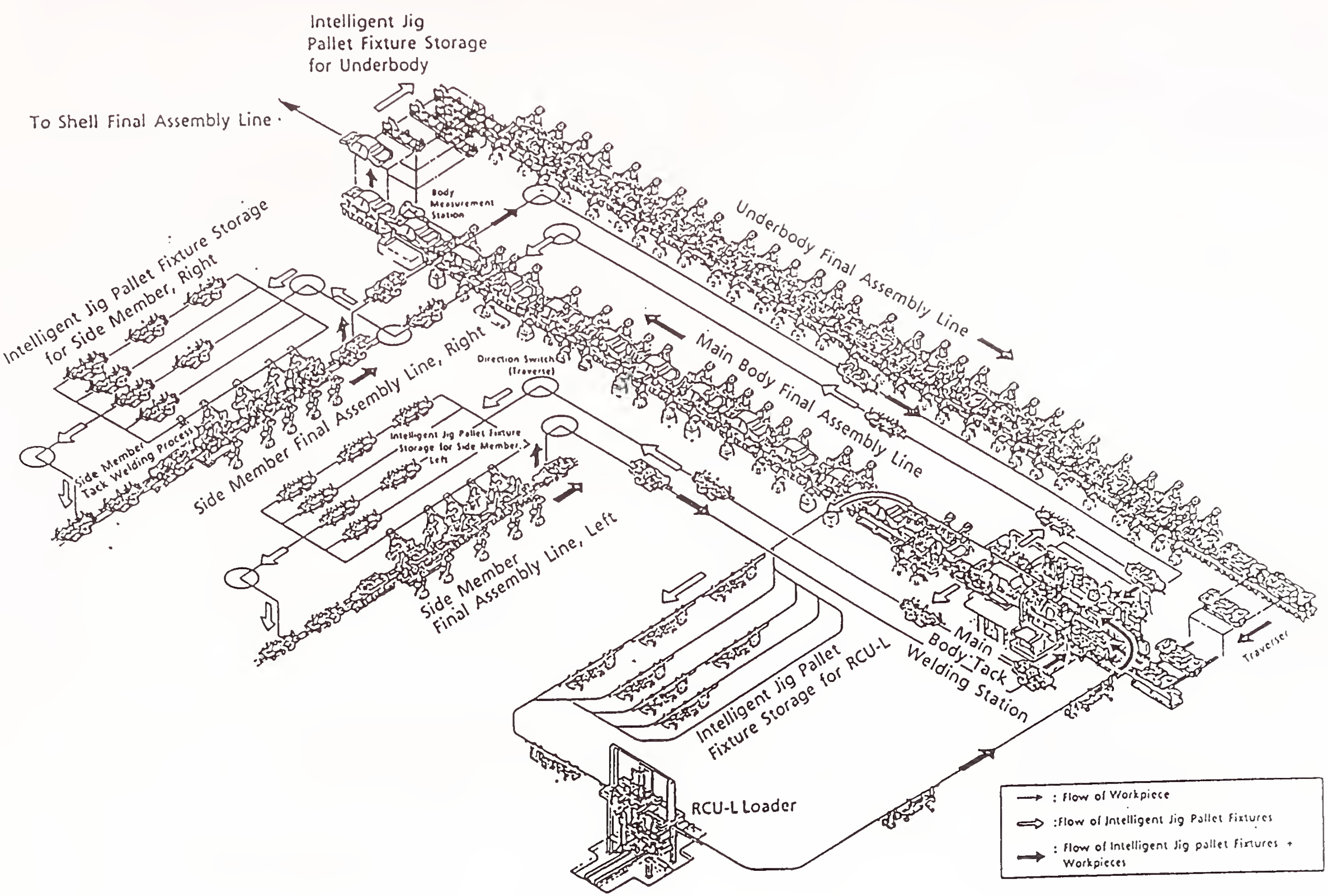
Flexible manufacturing system for other processings and assembling



ANNUAL OPERATION HOURS



LAYOUT OF SMALL VARIETY LARGE VOLUME PRODUCTION FM



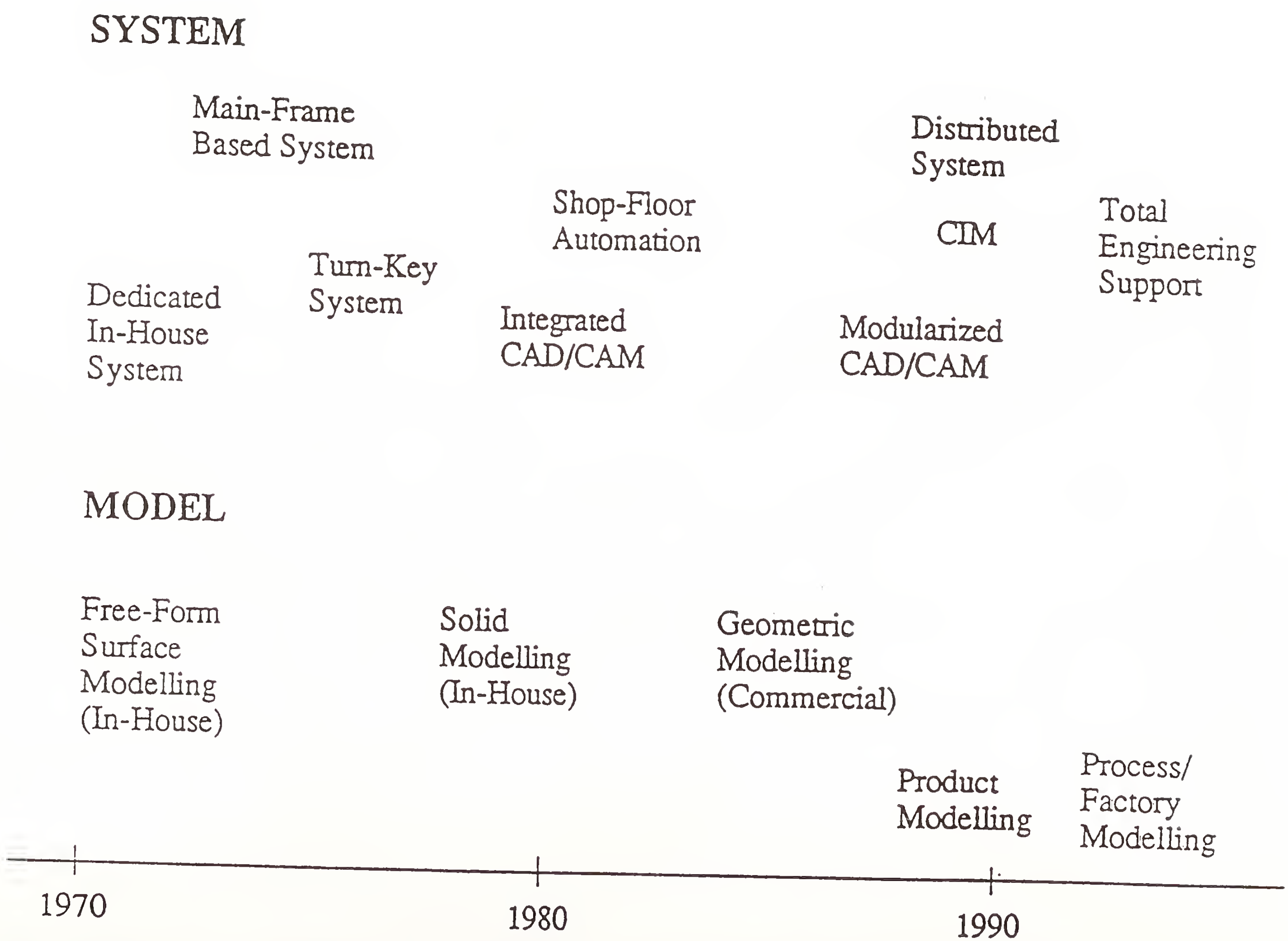


Fig.1 Technological Development of CAD/CAM

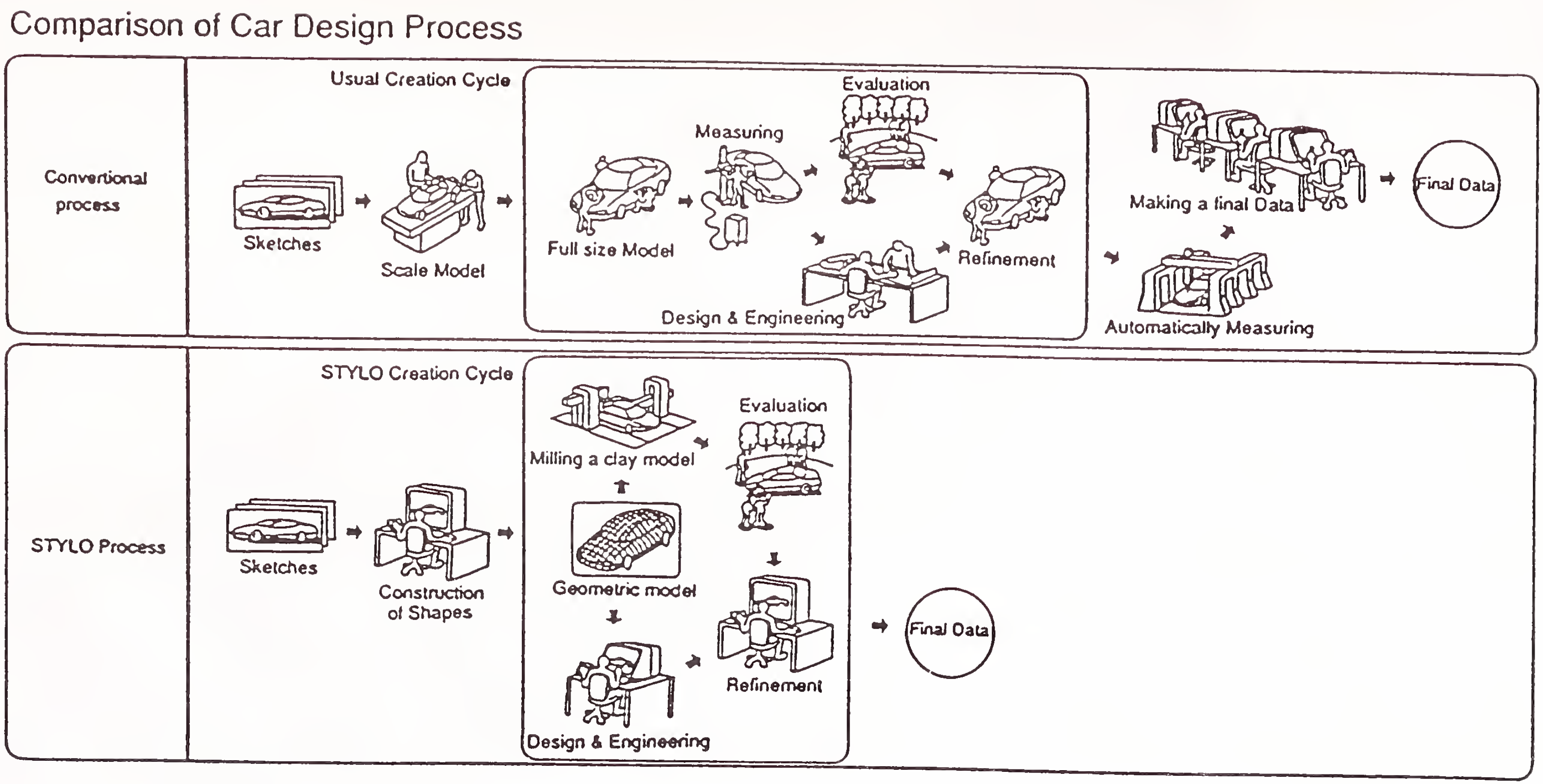
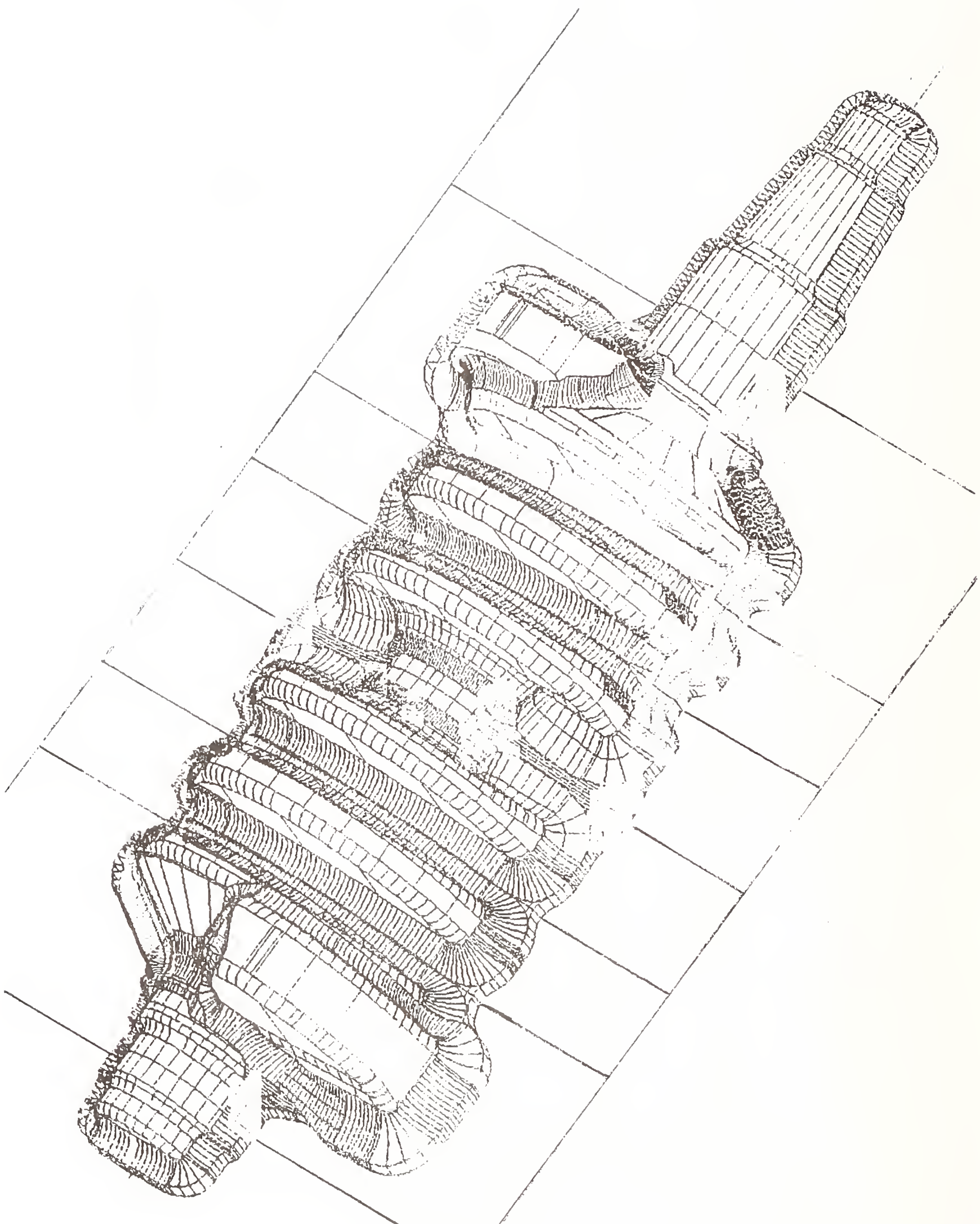


Fig.2 Change of Car Style Design Process by Use of CAD



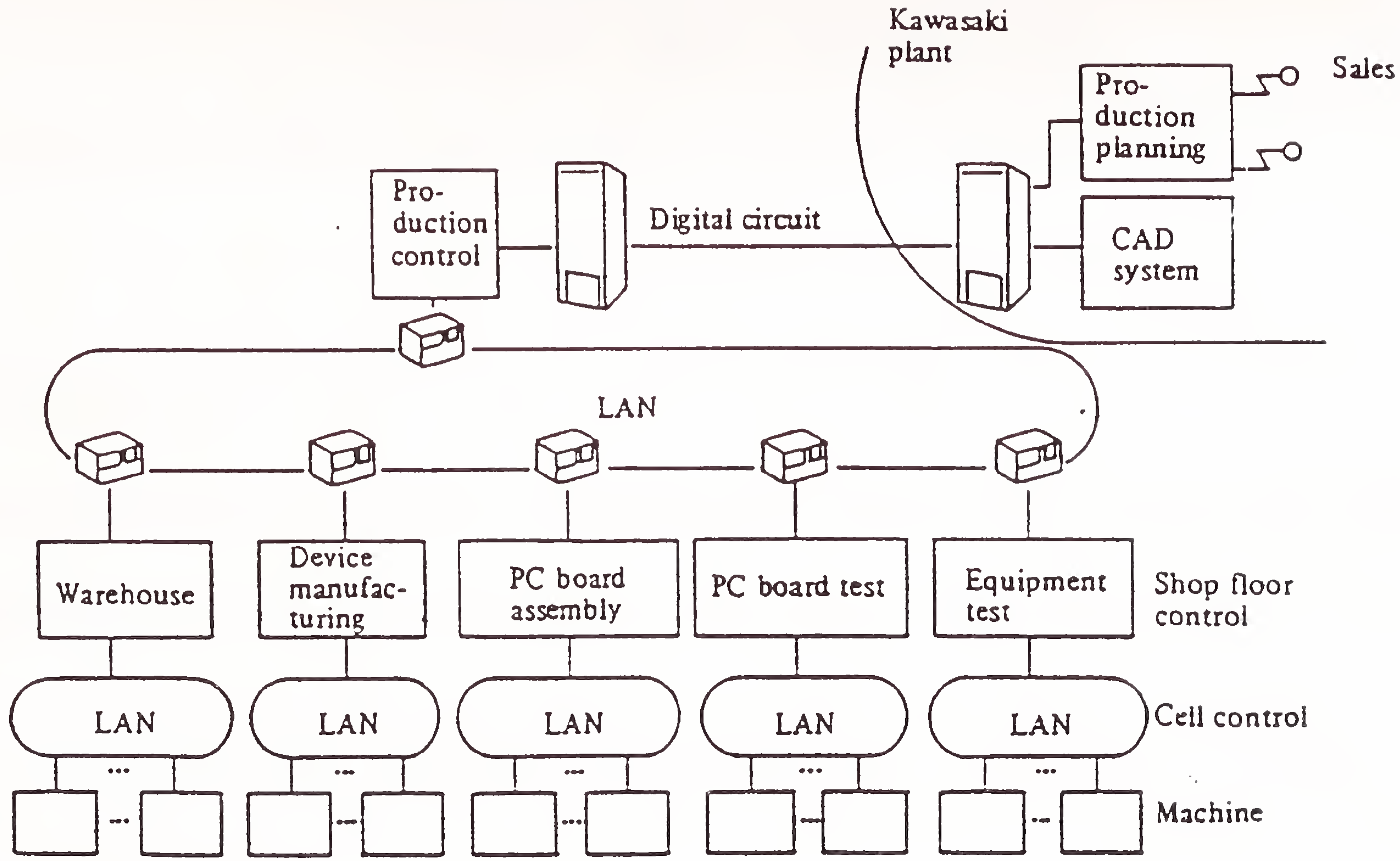


Fig.6 Typical CIM System Architecture

Trends of Renovation for CAD/CAM

from integrated and black-box style systems to modularized and open systems,

from simple tasks to complicated value-added tasks,

from in-house systems to buy-and-make type systems,

from mainframe-based to distributed workstation-based.

Future Directions of Research and Development

- flexible integration of total engineering activities, such as concurrent engineering,
- easy access and utilization of technological information,
- engineering verification by use of computational simulation,
- computer supported cooperative working environment,
- high-quality and robust design with respect to functionality and manufacturability.

Requirements for CAD/CAM & CIM

- Front Loading
  - Concurrent Engineering
  - Easy Access to Engineering Information
  - Design Validation with Engineering Simulation
  - Cooperative Design

- Data-Driven Development
  - Complete Product Modelling in Design Stage
  - Error-Free Design

Concurrent Engineering

- Improvement of Product Quality

  Optimal Design

- Shortening of Development Time
- Reduction of Development Cost

  Problem Solving in Early Stages

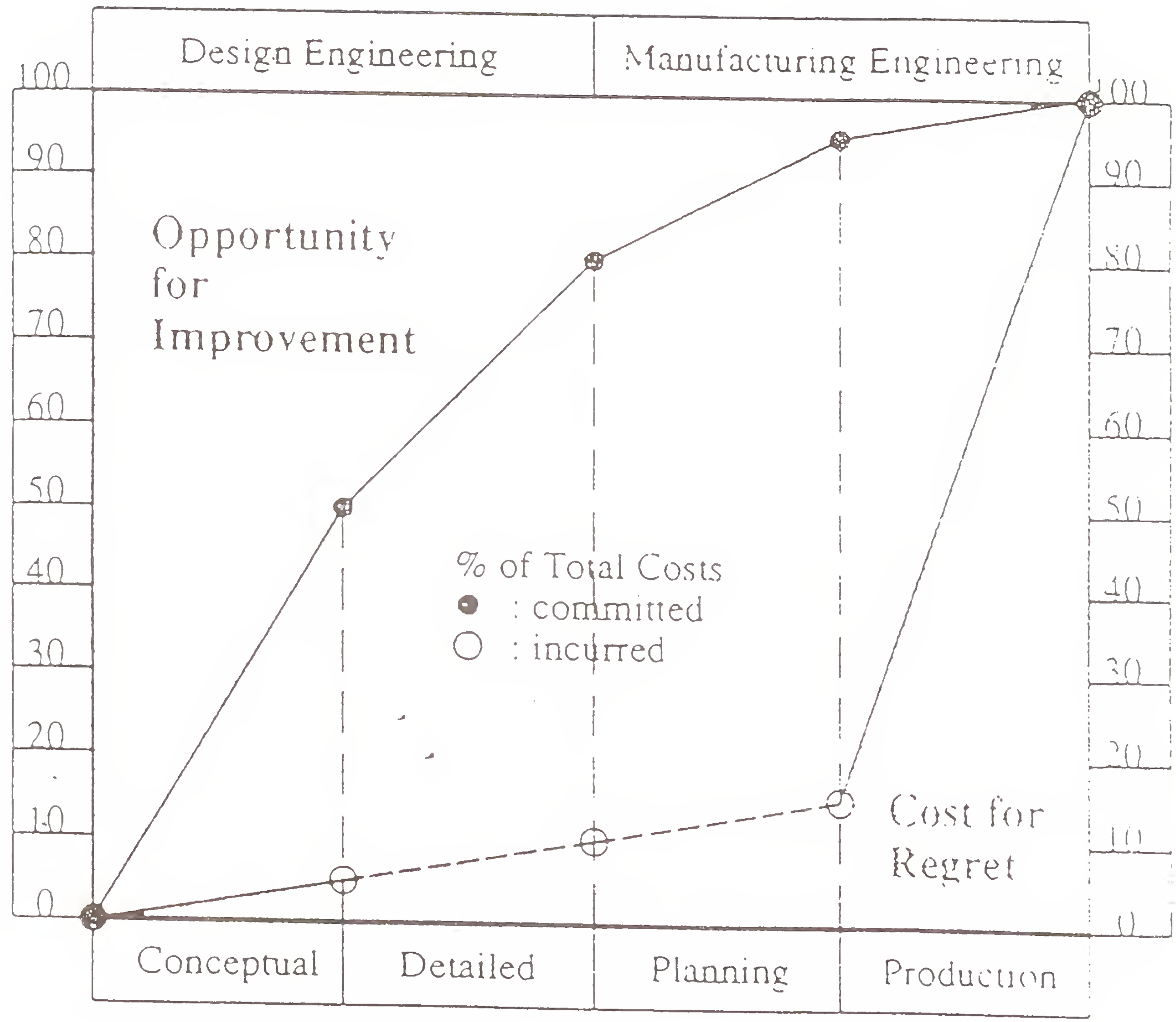


Figure 5: Different Costs during Product Development Stages

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1. Introduction

2. Manufacturing Technology in Japan

3. IMS Program in Japan

4. Manufacturing R&D Programs in Japan

5. Situations in Other Asian Countries

6. Conclusion

IMS Program

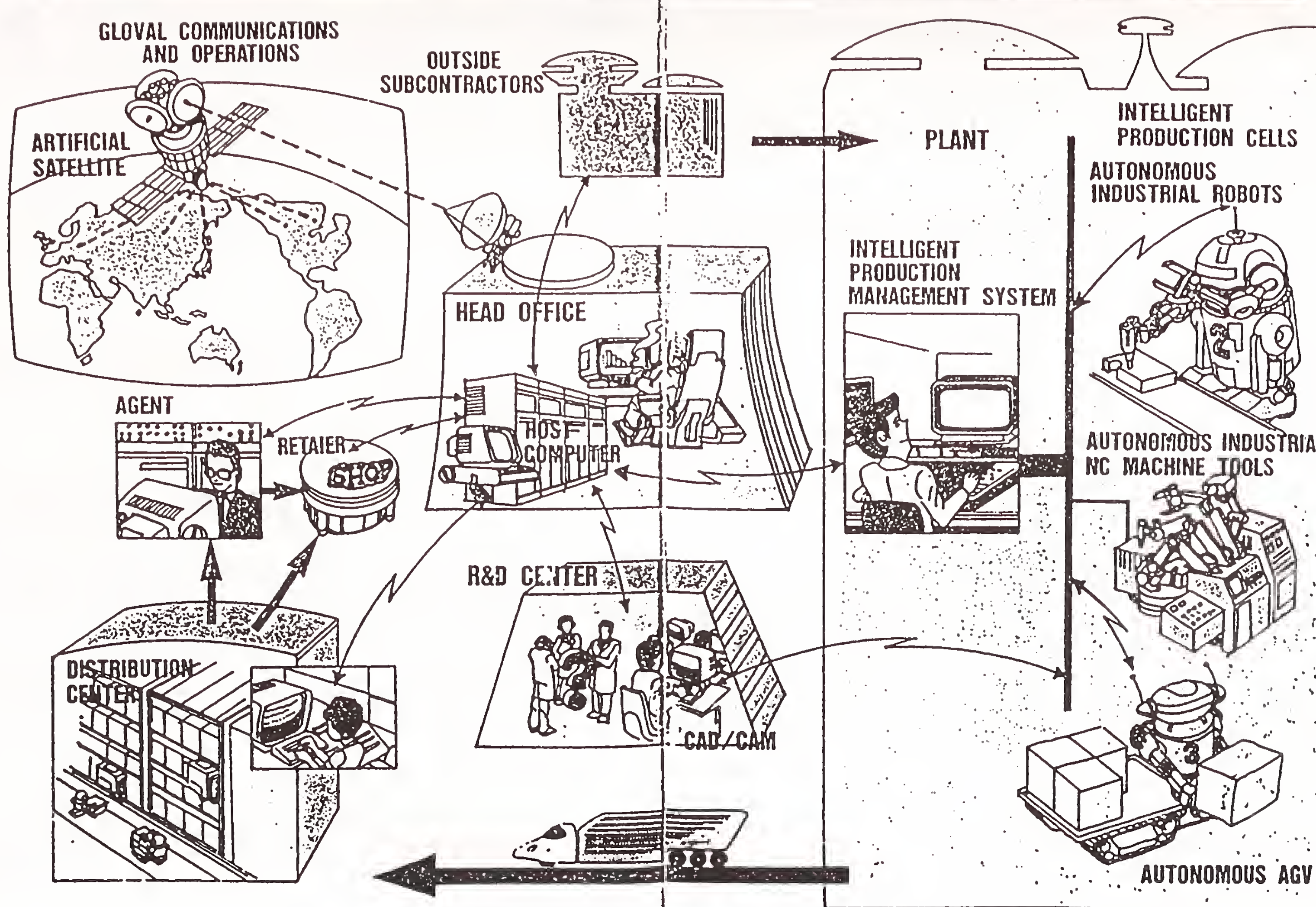
[Strictly Personal View]

- International Program for Developing the Next-Generation Manufacturing Systems

    Australia, Canada, EC, EFTA, Japan, USA

    start in 1994?, 10 years range
    budget unknown

DIAGRAM OF THE FUTURE IMS: APPLIED PLANTS ENVISIONED



Three Major Approaches

- Next-Generation Technology (Pre-Competitive)
- Rationalization of Technology (Post-Competitive)
- Standardization

Scope of IMS

- Architecture and Configuration of the Integrated Systems
- Component Technology for Manufacturing Processes
- Management and Control of Manufacturing Activities

Test Case Proposal

- Schedule

Deadline of proposal submission	Oct.31, 1992
Selection of proposals	Nov., 1992
Start of the test cases	Jan., 1993
End of the test cases	Dec., 1993
Start of the Full-scale IMS	1994 ?

- Proposed research Area
    - Enterprise Integration
    - Global Manufacturing
    - System Component Technologies
    - Clean Manufacturing
    - Human and Organizational aspects
    - Advanced Materials Processing

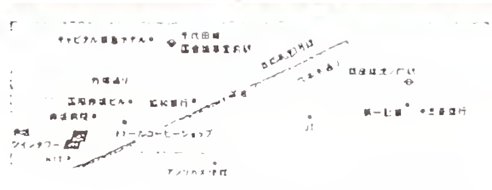
㈱池貝	IKEGAI IRON WORK LTD.	日産自動車㈱	NISSAN MOTOR CORPORATION
NKK	NKK CORPORATION	日本アイ・ビー・エム㈱	IBM JAPAN, LTD.
NTN㈱	NTN CORPORATION	日本板硝子㈱	NIPPON SHEET GLASS CO., LTD.
オークマ㈱	OKUMA MACHINERY WORKS LTD.	日本精工㈱	NIPPON SEIKO K.K.
㈱大林組	OBAYASHI CORPORATION	日本電気㈱	NEC CORPORATION
沖電気工業㈱	OKI ELECTRIC INDUSTRY CO., LTD.	日本電装㈱	NIPPON DENSO CO., LTD.
オムロン㈱	OMRON CORPORATION	㈱間組	HAZAMA CORPORATION
鹿島建設㈱	KAJIMA CORPORATION	日立精機㈱	HITACHI SEIKI CO., LTD.
カルビー㈱	CALBEE FOODS CO., LTD.	日立精工㈱	HITACHI SEIKO, LTD.
川崎重工業㈱	KAWASAKI HEAVY INDUSTRIES, LTD.	㈱日立製作所	HITACHI, LTD.
神崎製紙㈱	KS SYSTEMS INC.	日立造船㈱	HITACHI ZOSEN CORPORATION
キヤノン㈱	CANON INC.	ファナック㈱	FANUC LTD.
㈱クボタ	KUBOTA CORPORATION	㈱不二越	NACHI-FUJIKOSHI CORPORATION
光洋精工㈱	KOYO SEIKO CO., LTD.	富士ゼロックス㈱	FUJI ZEROX CO., LTD.
㈱小松製作所	KOMATSU LTD.	㈱富士総合研究所	FUJI RESEARCH INSTITUTE CORPORATION
三洋電機㈱	SANYO ELECTRIC CO., LTD.	富士通㈱	FUJITSU LTD.
清水建設㈱	SHIMIZU CORPORATION	富士電機㈱	FUJI ELECTRIC CO., LTD.
シャープ㈱	SHARP CORPORATION	古河電気工業㈱	THE FURUKAWA ELECTRIC CO., LTD.
住友電気工業㈱	SUMITOMO ELECTRIC INDUSTRIES LTD.	ホンダエンジニアリング㈱	HONDA ENGINEERING CO., LTD.
ソニー㈱	SONY CORPORATION	㈱牧野フライス製作所	MAKINO MILLING MACHINE CO., LTD.
ダイキン工業㈱	DAIKIN INDUSTRIES LTD.	松下電器産業㈱	MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
大成建設㈱	TAISEI CORPORATION	マツダ㈱	MAZDA MOTOR CORPORATION
大日本スクリーン製造㈱	DAINIPPON SCREEN M.F.G. CO., LTD.	三井造船㈱	MITSUI ENGINEERING & SHIPBUILDING CO., LTD.
㈱ダイフク	DAIFUKU CO., LTD.	三菱重工業㈱	MITSUBISHI HEAVY INDUSTRIES, LTD.
㈱竹中工務店	TAKENAKA CORPORATION	三菱電機㈱	MITSUBISHI ELECTRIC CORPORATION
千代田化工建設㈱	CHIYODA CORPORATION	三菱マテリアル㈱	MITSUBISHI MATERIALS CORPORATION
㈱東芝	TOSHIBA CORPORATION	ミネベア㈱	MINEBEA CO., LTD.
東洋エンジニアリング㈱	TOYO ENGINEERING CORPORATION	村田機械㈱	MURATA MACHINERY, LTD.
東洋紙業㈱	TOYO SHIGYO PRINTING CO., LTD.	㈱安川電機	YASUKAWA ELECTRIC MFG CO., LTD.
豊田工機㈱	TOYOTA MACHINE WORKS LTD.	ヤマザキマザック㈱	YAMAZAKI MAZAK CORPORATION
トヨタ自動車㈱	TOYOTA MOTOR CORPORATION	山武ハネウエル㈱	YAMATAKE-HONEYWELL CO., LTD.
㈱豊田自動織機製作所	TOYOTA AUTOMATIC LOOM WORKS LTD.	横河電機㈱	YOKOGAWA ELECTRIC CORPORATION
㈱新潟鉄工所	NIIGATA ENGINEERING CO., LTD.	㈱リコー	RICOH COMPANY
日揮㈱	JGC CORPORATION		

平成4年3月5日現在　計67社

IMS参加サポートメンバーリスト(五十音順) LIST OF "SUPPORT MEMBER COMPANIES"

アマダ㈱	AMADA CO., LTD.	セイコーエプソン㈱	SEIKO EPSON CORPORATION
アップルオペレーションズアンド テクノロジーズジャパン㈱	APPLE OPERATIONS AND TECHNOLOGIES JAPAN, INC.	戸田建設㈱	TODA CORPORATION
㈱イーゼル	EZEL INC.	トムソン ジャパン㈱	THOMSON JAPAN KK
鐘淵化学工業㈱	KANEBUCHI CHEMICAL INDUSTRY CO., LTD.	日本ユニシス㈱	NIHON UNISYS, LTD.
キタムラ機械㈱	KITAMURA MACHINERY CO., LTD.	浜井産業㈱	HAMAI CO., LTD.
㈱三和銀行	SANWA BANK, LTD	日立プラント建設㈱	HITACHI PLANT ENGINEERING & CORPORATION CO., LTD.
㈱島津製作所	SHIMAZU CORPORATION	㈱フジキン	FUJIKIN INCORPORATED
神鋼電機㈱	SHINKO ELECTRIC CO., LTD.	藤倉電線㈱	FUJIKURA LTD.
㈱住友銀行	THE SUMITOMO BANK, LTD.	㈱松浦機械製作所	MATSUURA MACHINERY CORPORATION
住友商事㈱	SUMITOMO CORPORATION	三井物産㈱	MITSUI & CO., LTD.
スズキ㈱	SUZUKI MOTOR CORPORATION	㈱ミツトヨ	MITSUTOYO CORPORATION

平成4年3月5日現在　計22社



財団法人 国際ロボット・FA技術センター IMSセンター
〒107 東京都港区赤坂2-17-22 赤坂ツインタワービル本館11F
TEL.(03)5562-0331　FAX.(03)5562-0310

IMS Promotion Center International Robotics and Factory Automation Center
11th Fl., Akasaka Twintower Bldg. 2-17-22 Akasaka,
Minato-ku Tokyo 107
Phone (03)5562-0331 Fax (03)5562-0310

National Feasibility Study

For 2 years starting from 1992,
Total budget of about 930,000,000 Yen, about half from the Government

24 Projects (100,000,000 Yen - 10,000,000 Yen)
5 to 10 Members per Project
Company Leadership, University/Laboratory Participation

Feasibility Study for the Full Scale IMS
Primarily Advanced, Some Standardization
No Direct Application Expected
Clarification of the IMS Idea
Input to the International Projects (Test Cases, ...)

Examples of the Feasibility Study Projects

- Comprehensive Modelling of Manufacturing Activities for Construction of the Next-Generation Manufacturing Systems
- Evaluation of Product Design based on Machinability and Assemblability
- Planning and Management of Manufacturing Systems
- Software Development for Quality Engineering
- Rationalization of Design and Manufacturing Knowledge
- Architecture for Bio-Mimetic Manufacturing Systems
- Integrated Information Processing Framework for Manufacturing Systems
- Intelligent Manufacturing Systems based on Distributed Object Oriented Manufacturing Models
- Management Support System for Distributed Manufacturing Systems

Examples of the Feasibility Study Projects (Cont.)

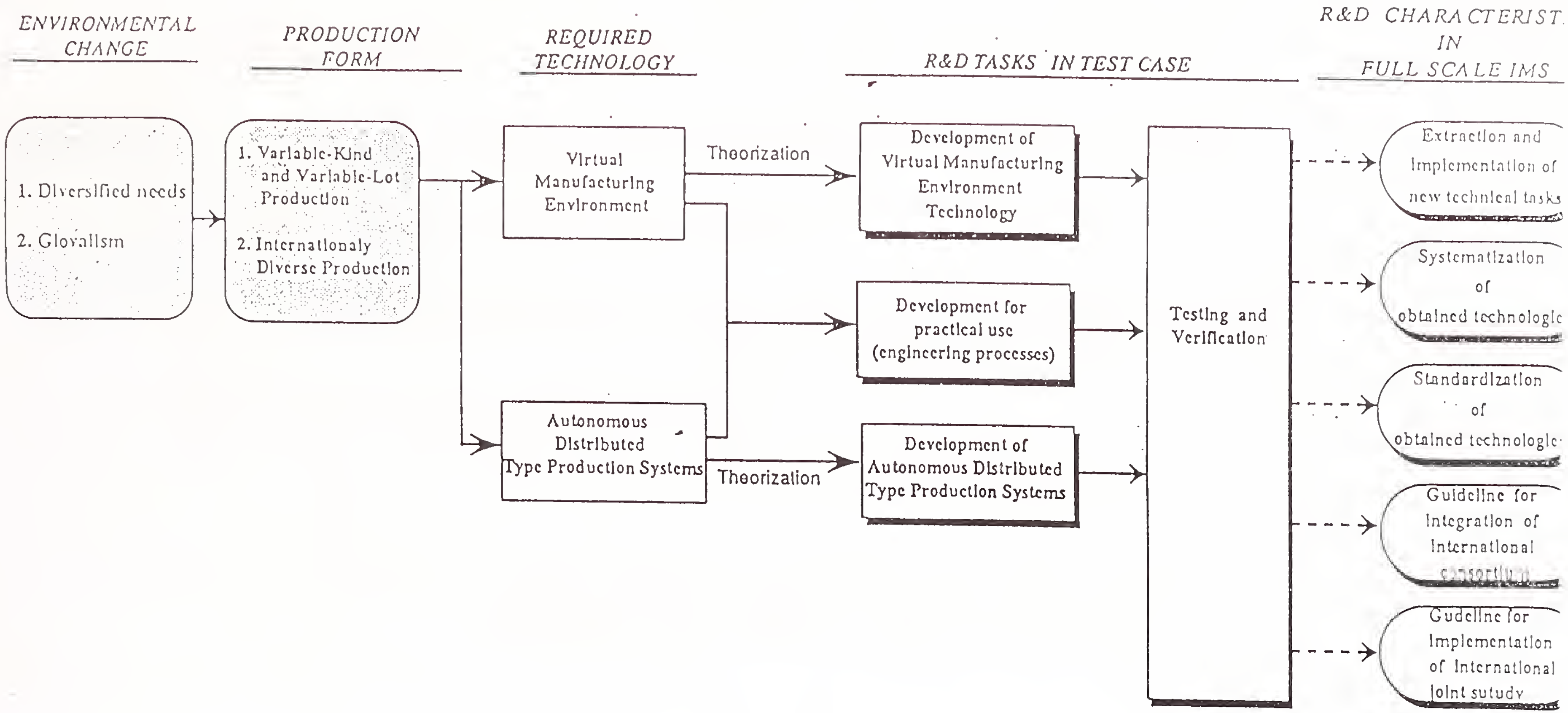
- Standardization of Material Flow Management (Standardization of Remote ID in Automotive Applications)
- High-Precision Self-Adaptive Machining Module for Intelligent Manufacturing Systems
- Metamorphic Material Flow System for Advanced Factories
- Sensor Fusion for Optimizing Machining Process Monitoring
- Knowledge Base for Supporting Intelligent Assembly Systems
- Visual Inspection of Products (Automatic Recoginition of Three Dimensional Objects)
- Standardization of Factory Amenity Design for Harmonizing with Environment
- Standardization of Tooling based on Intelligent Tools
- Metamorphic Complex Machining System

REQUIREMENTS

- High-Quality, Value-Added Products → Advanced Technology
- Change in Products, Technology, Human and Environment → Flexibility in Manufacturing
- Reduction of Human Resource → Productivity Enhancement
- Total Product Life Cycle → Manufacturing Optimization

→→ **Virtual Manufacturing**

GOAL OF TENTATIVE FULL IMS



Virtual Manufacturing

- Virtual Manufacturing Construct:

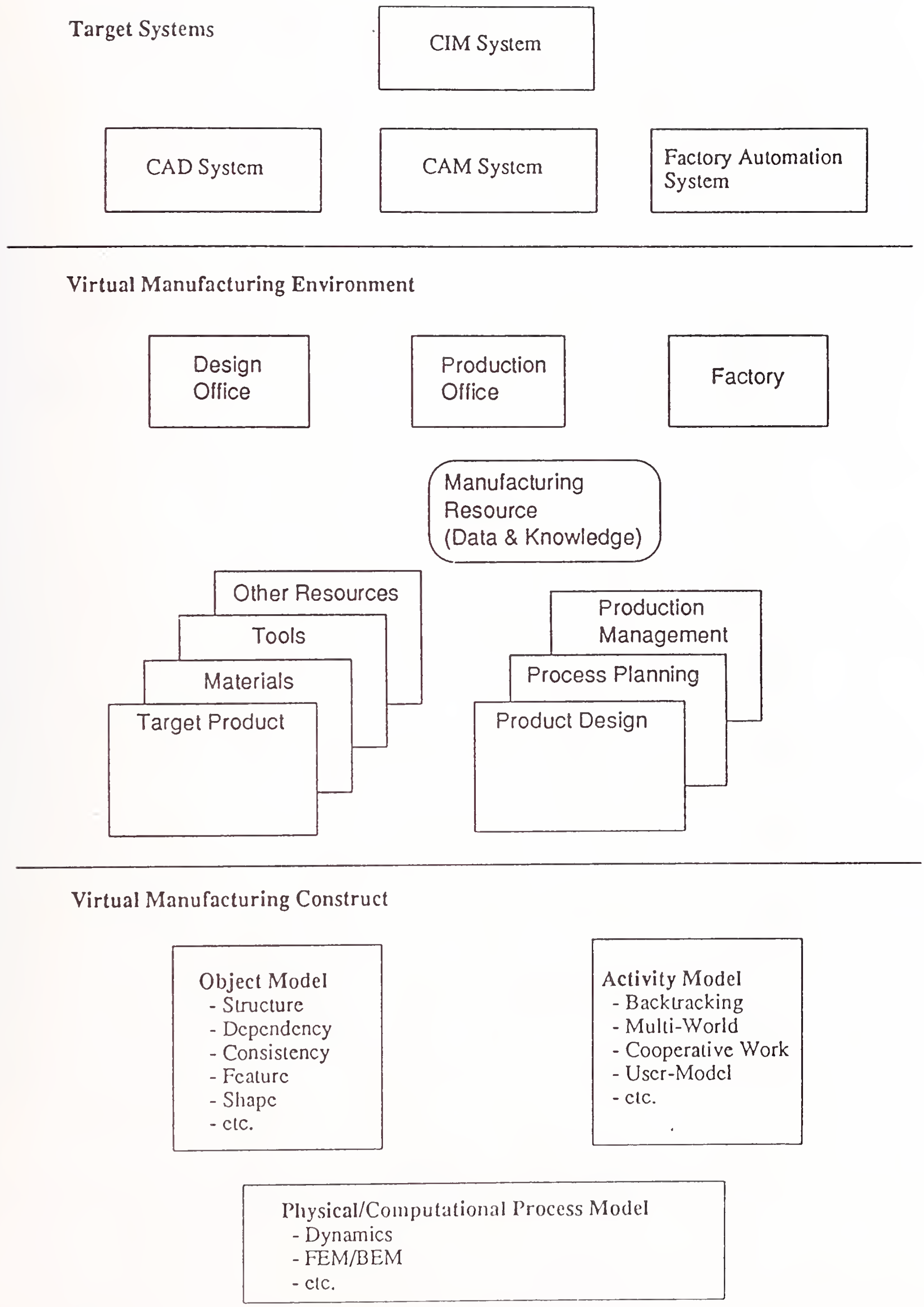
  underlying generic models used from the upper level,

- Virtual Manufacturing Environment:

  software tools to generate target application systems,

- Target Systems:

  tailor-made application systems.



Virtual Manufacturing Environment

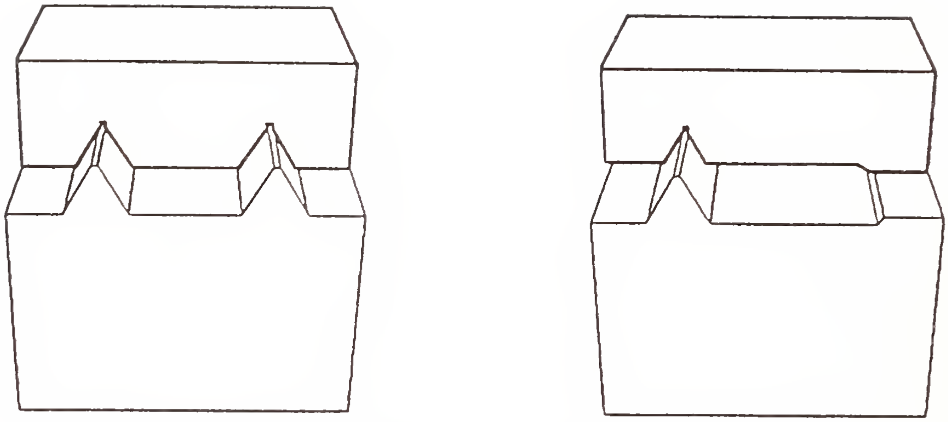


Figure 1: Two types of linear motion guide mechanisms.

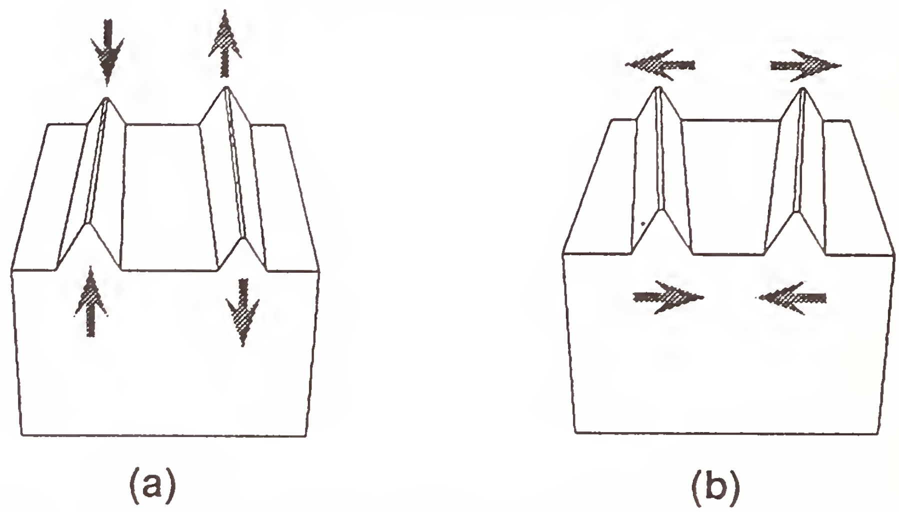


Figure 2: Two types of shape errors: (a) Twisted error (b) Horizontal inclination error.

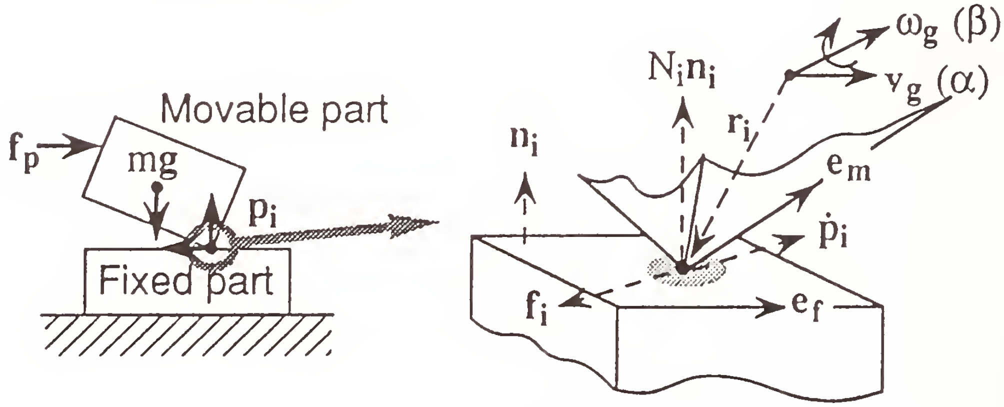


Figure 3: Terminology; a contact of a vertex and a face.

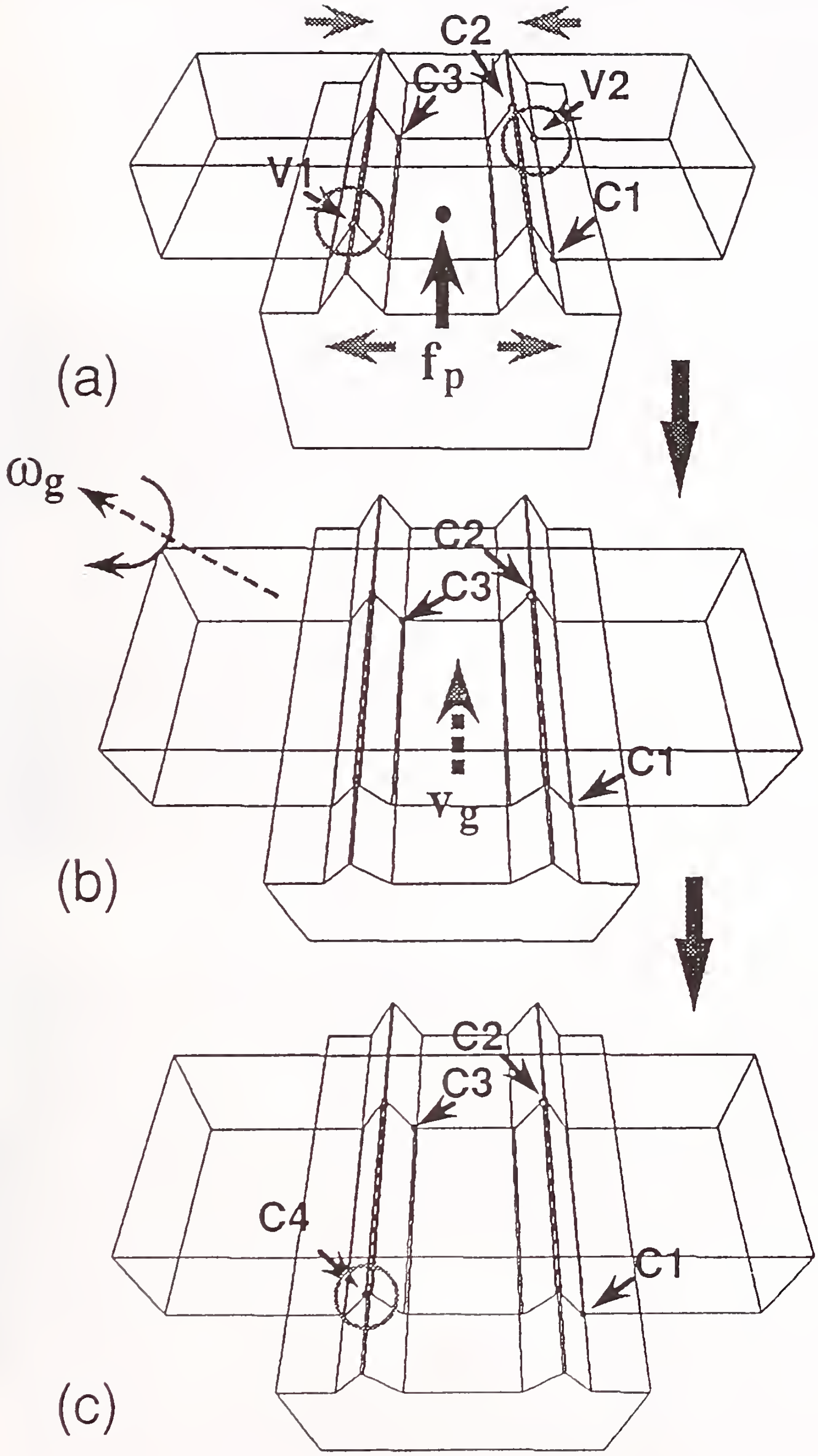
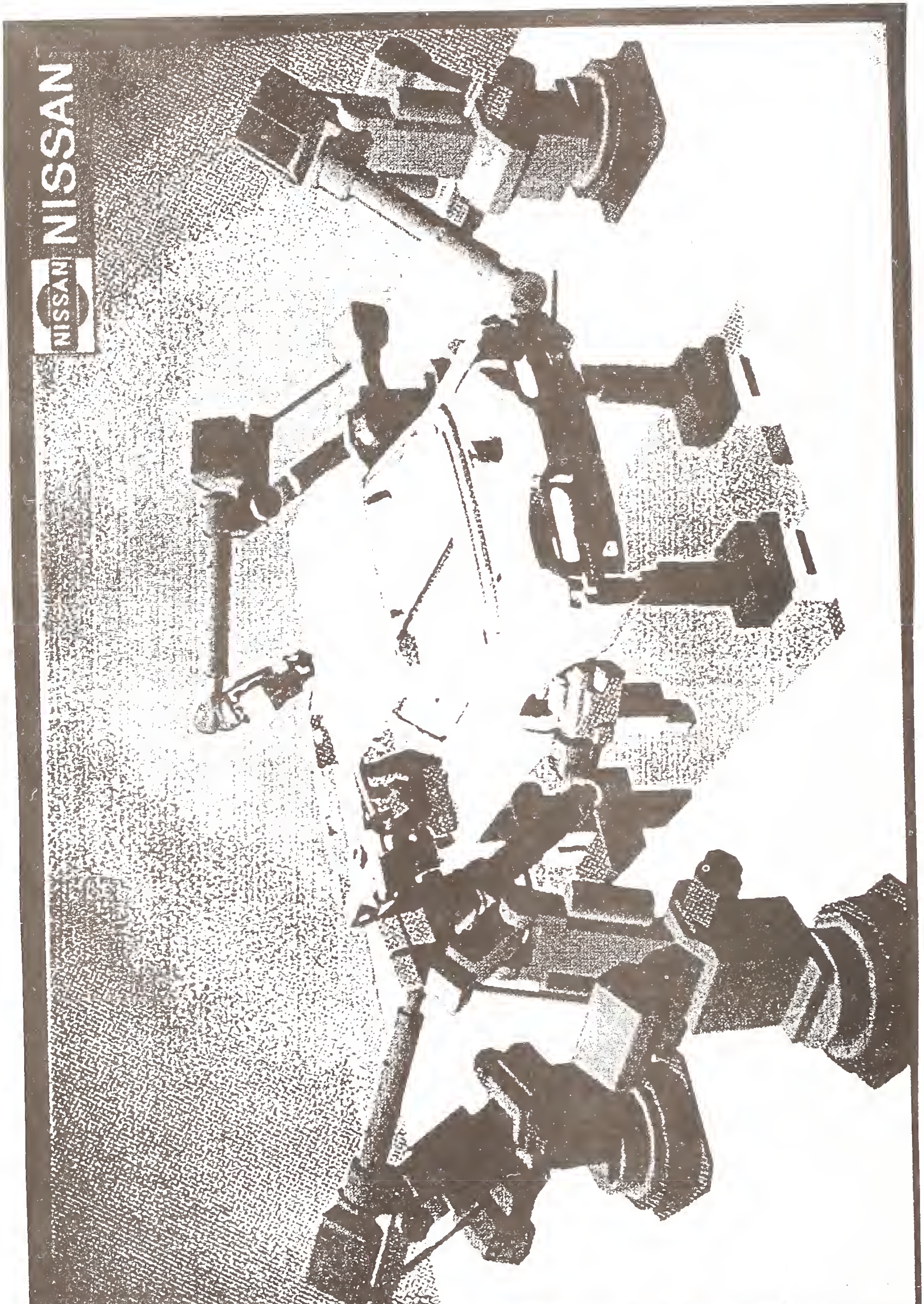
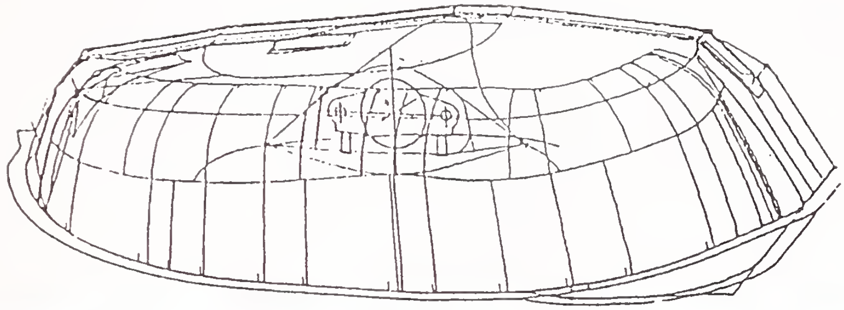
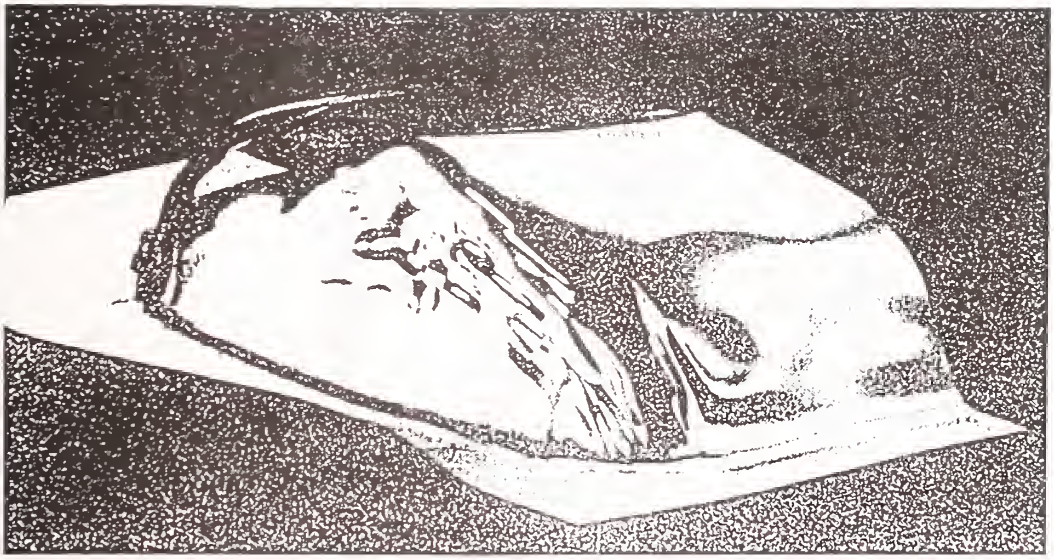


Figure 5: Example of the effect of horizontal inclination error: (a) Initial contact state (b) Intermediate state (c) New contact state.

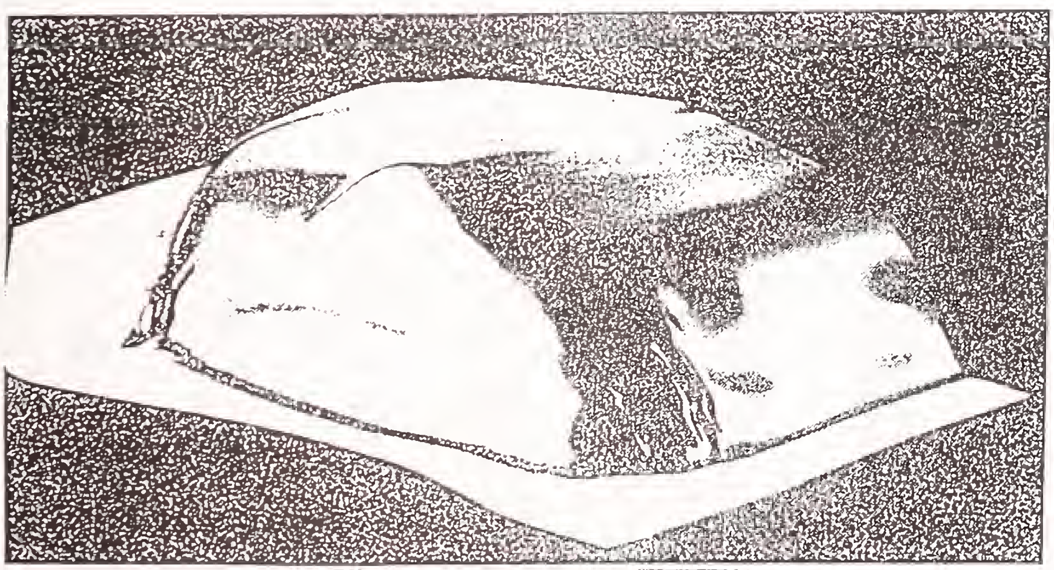

NISSAN
NISSAN



Tool geometry



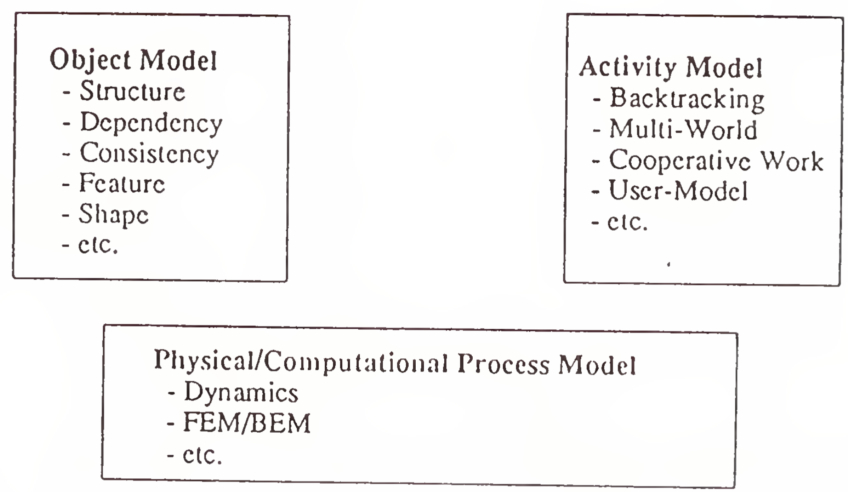
(a) Blank holding load = 689kN



(b) Blank holding load = 980kN

Fig.4 Prediction of wrinkles in drawing process of a wheel house by ROBUST. A post-process graphic software visualize wrinkles clearly. Effect of blank holding pressure is demonstrated.

Virtual Manufacturing Construct



Virtual Manufacturing Environment

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1. Introduction
2. Manufacturing Technology in Japan
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Government-Led Projects in Manufacturing

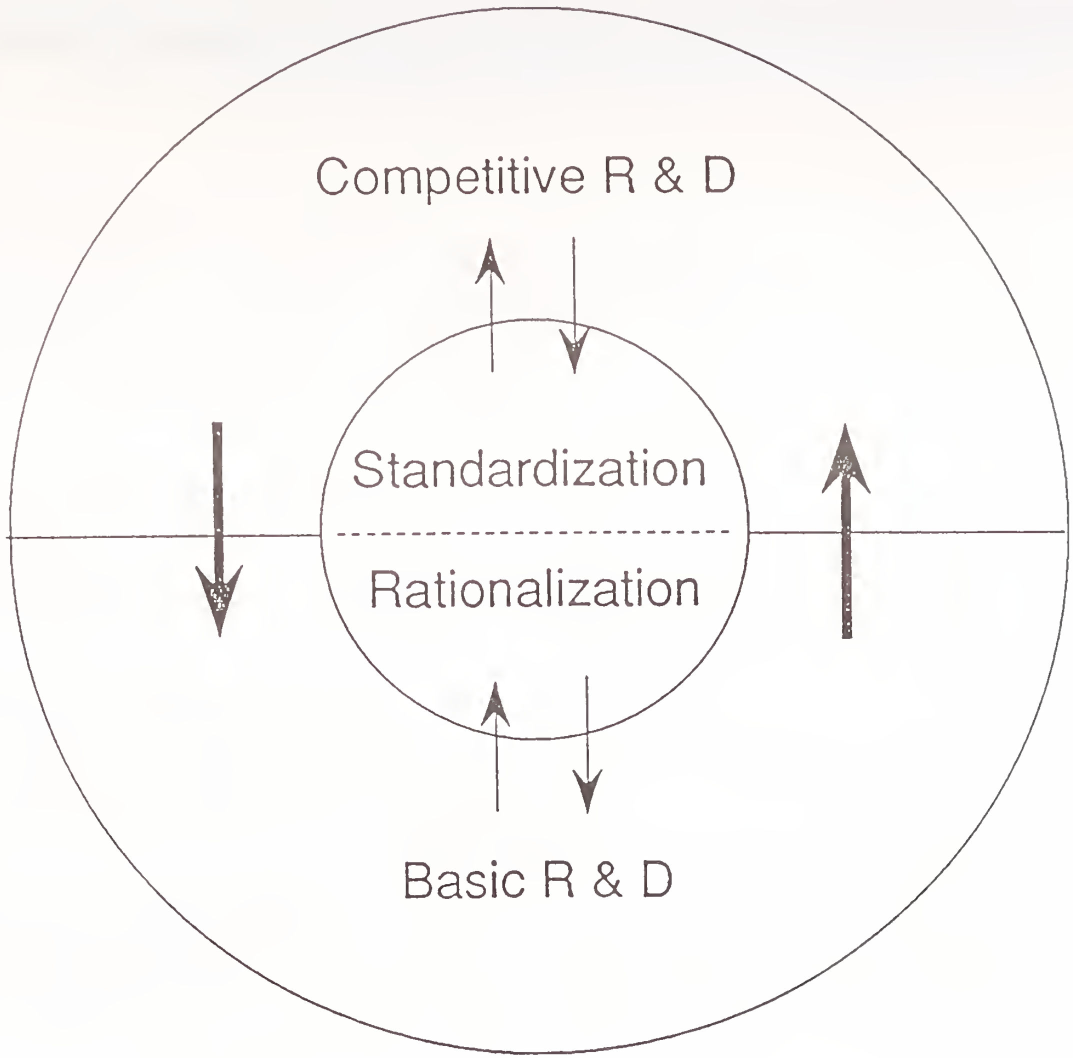
Not so Many Projects in Manufacturing

Some Projects in Automation and FMS
No Software Intensive

Primarily Industry Driven, Government Support
    Competitive Technology

National Interest:

- Maintenance of High Technology in Manufacturing
- Harmonization with Society and Culture
    - Change of Working Style
- Environmental Issues
- Globalization
- Technology Diffusion
    - Standardization



Importance of Standardization Activity

Step-by-Step Activities for Project Set-Up

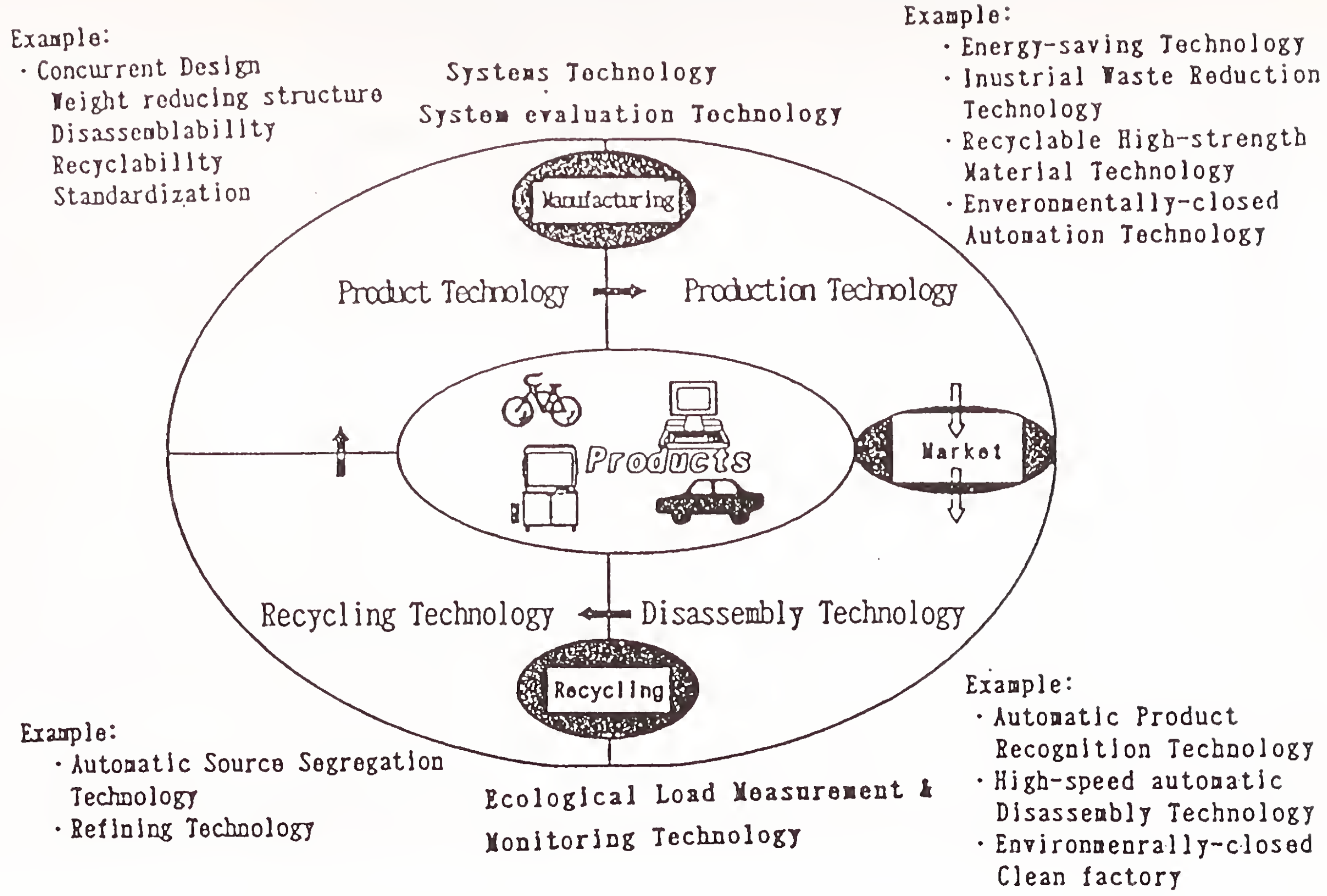
[1] Individual Basic Research in University and Laboratory
No Special Budget

[2] Small Projects for Specific Topics
ex. 3 years, 50,000 K Yen
Government Support

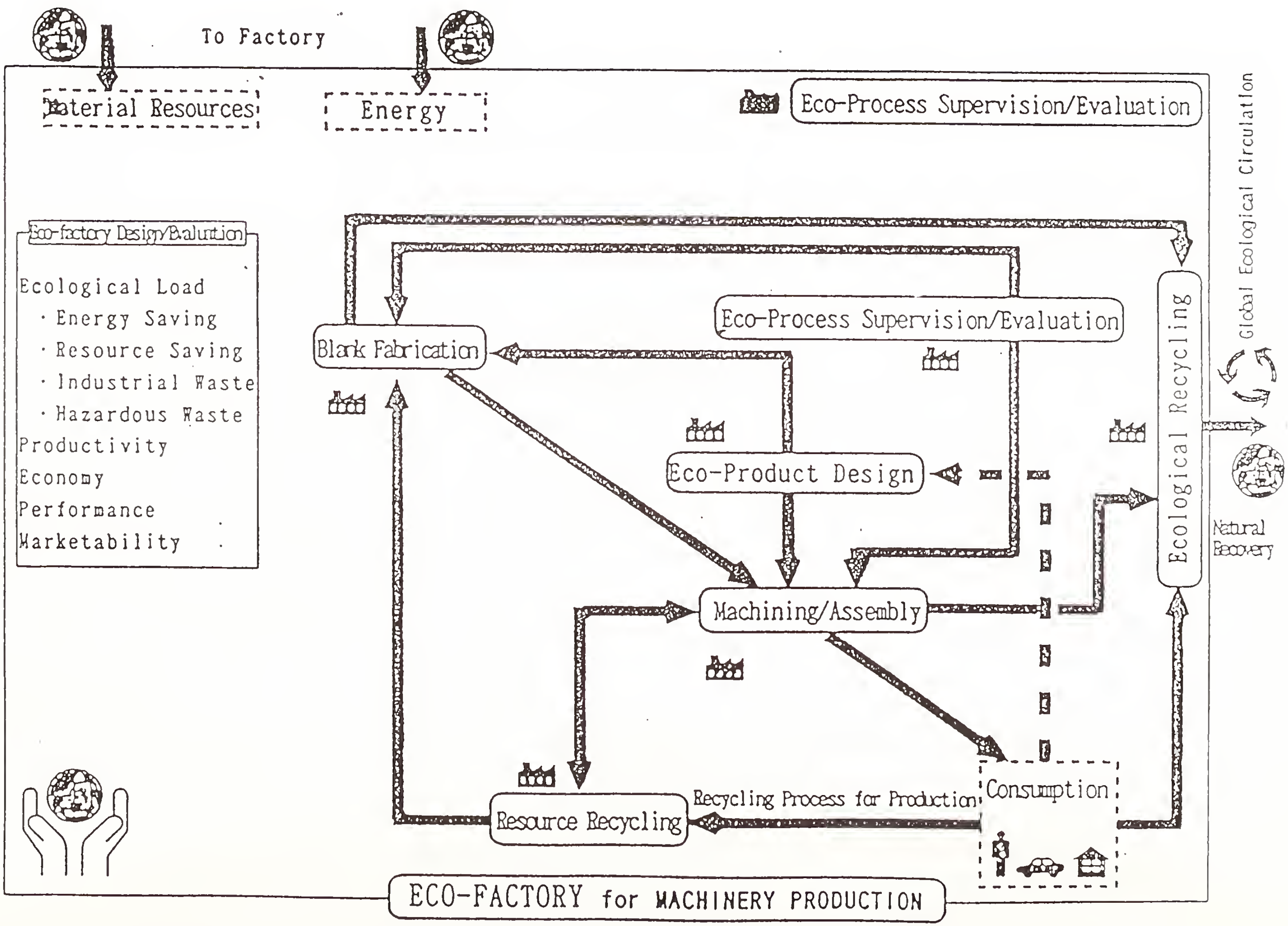
[3] Survey Projects for Possible Big Research
ex. 3 years, 30,000 K Yen
Government Support

[4] Medium-to-Large Scale Projects
Advanced, Competitive, Standardization
ex. 3 - 8 years, 500,000 - 50,000,000 K yen
Industry Participation

Ex. Eco-Factory Project



Technologies for Eco-factory(Machininig & Assembly Products)



Overview of Eco-factory

NECESSITY AND USEFULNESS OF DATA EXCHANGE

- Robust Data Management Independent from Systems
- System Integration for International Work Sharing
- Management, Accumulation and Sharing of Engineering Knowledge

ISO TC184/SC4

- TC184:
  SC1: Physical Device Control
  SC2: Robots for Manufacturing Environment
  SC4: Manufacturing Data and Languages
  SC5: Architecture and Communication

- Title:
  Industrial Data and Global Manufacturing Programming Languages

- Scope:
  Standardization in the field of data and languages for manufacturing applications

- New Work Item:
  Standard for the Neutral Representation of Standard Parts

```
STEP;
HEADER; FILE_NAME('tel2', ... ); ...; ENDSEC;
DATA; ...
#845=LINE(#299, #592); #846=LINE(#301, #595); ...
#1006=VERTEX(#275); ...
#1162=EDGE(#1003, #984, #848);
#1163=EDGE_LOGICAL_STRUCTURE(#1007, .F.); ...
#1545=EDGE_LOOP((#1459,#1460,#1461,#1462)); ...
#1696=SURFACE_LOGICAL_STRUCTURE(#922, .T.);
#1697=CLOSED_SHELL((#1549,#1550,#1551, ...
#1615,#1617,#1618,#1619,#1620,#1621,#1622));
#1698=MANIFOLD_SOLID_BREP(#1697);
ENDSEC;
ENDSTEP;
```

Fig. 5 STEP Exchange File (total 1,708 lines)

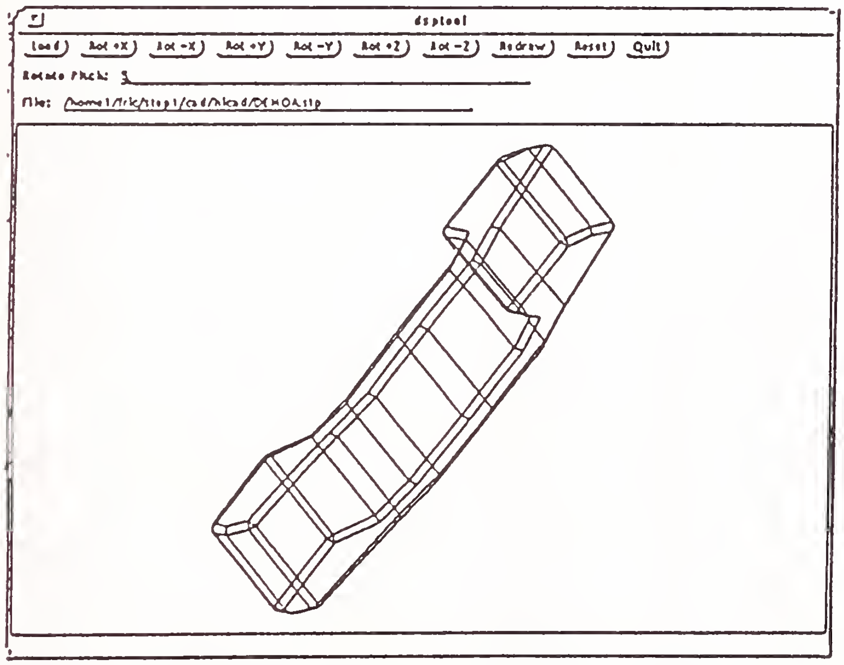


Fig. 6 Telephone Handset (STEP data) on the CRT

1. ORGANIZATION

- ☐ Japan National Committee for ISO TC184/SC4

Official Committee for ISO Matters

13 Academic Members (University, National Laboratory)
17 Industrial Members (Computer, Electronics, Peripheral, Automobile, Heavy Industry, Machine, Software)
3 Liaisons with Other Industrial Associations (Electronics, Ship, AEC)
2 MITI Officials (Standard Division)
Staffs from NICOGRAPH (Secretariat)

No Strong Financial Support from Government
Survey Project with Small Budget

Subcommittees according to the ISO/SC4 Structure
Experts from Pertinent Sectors, Volunteer-Based

- Japan National Committee for ISO TC184/SC4/WG2 (Standard Parts)

  Subcommittee for Standard Parts Issues

  About 20 Members from Academia and Industry
  (Mechanical and Electronics Parts Manufacturers)

  No Strong Financial Support from Government
  Survey Project with Small Budget

- Japan STEP Committee

  Non-Governmental Committee by Industry
  Contribution and Support for Japanese ISO Activity
  Dissemination of ISO Information to Industrial Sectors

  20 Regular Members, 39 Corresponding Members
  (Computer, Machine Automobile, Heavy Industry, Software, ...)

- STEP Center, NICOGRAPH

  Industrial Consortium for Developing a STEP Processor
  11 Primary Members, 8 Secondary Members
  Half-Supported by Government
  4 Year Project, 900 Million Yen

- Future Issues:

  How to Integrate the above Organizations

3. PROJECT AT STEP CENTER

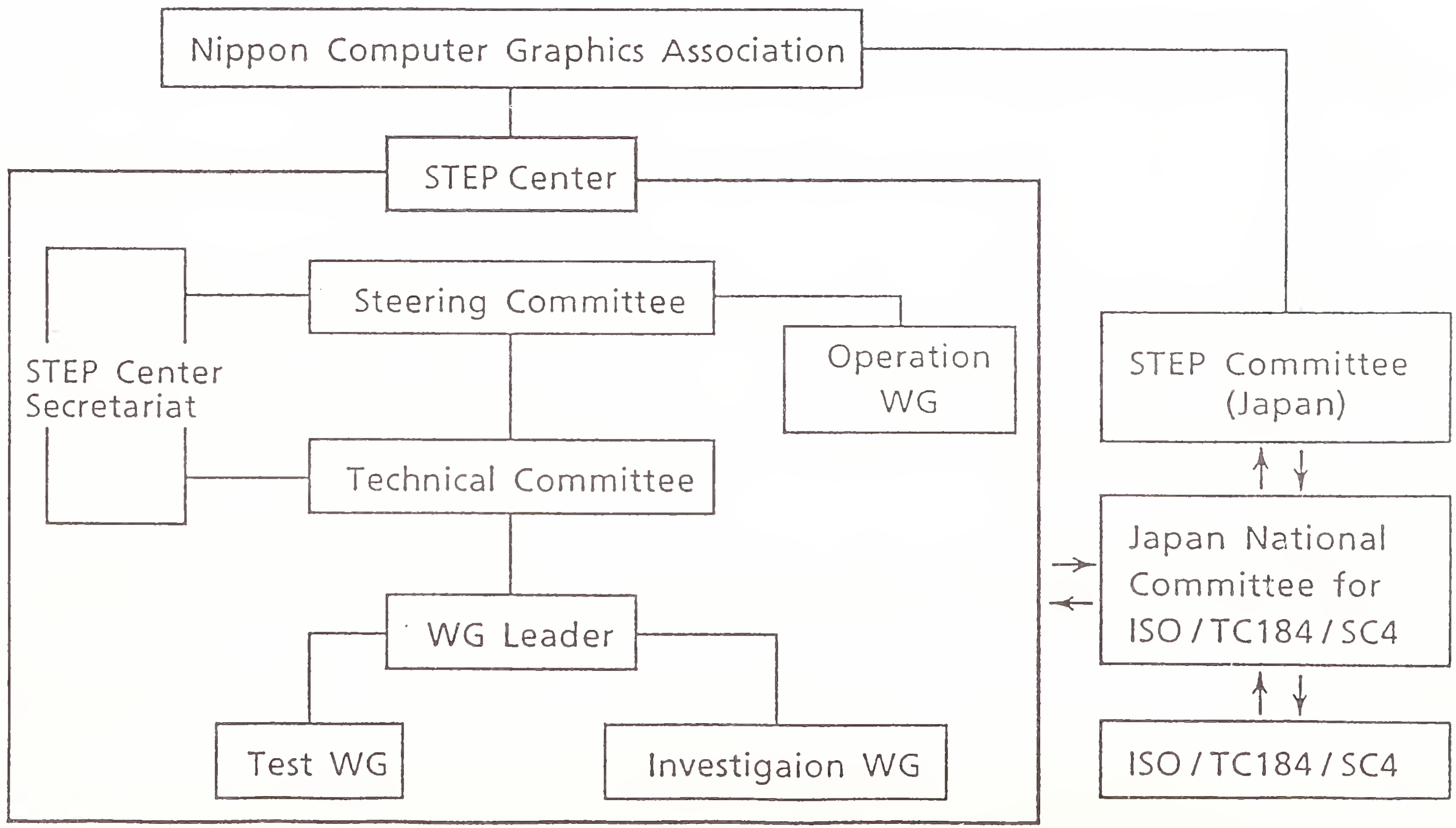
❑ STEP Center

Joint Industrial/Governmental Effort to Promote STEP Establishment and its Use in Industry

- Accelerate the Establishment of an International Standard STEP
- Promote its Use in Industry
- Increase the Use of CAD/CAM Systems via STEP Technology

❑ International Contribution

This activity leads to further potentiality of Japanese industry, and also to an international contribution as one of the leading countries in this field of technology.



Organizational Structure

❒ Membership

- Class 1: 11 members.
  Participate in the implementation activities (WG work).
  Apply the results for internal use and for their commercial software products.
  Annual membership fee and development share of 10,300,000 Yen.

- Class 2: 8 members.
  Participate in the Technical Committee.
  Apply the results for internal use only.
  Annual membership fee and development share of 3,090,000 Yen.

❐ Target

- Exact Implementation of STEP Release 1
- Evaluation of STEP by STEP/CAD Data Exchange Processes

❐ Technical Approach

- STEP Data Exchange by Using Files and Intermediate WFD
- Program Generation by Using EXPRESS Compliers, etc.

❐ Implementation Plan

- 2D Geometry Set
- B-Rep Solid Model
- Surface Model
- Draughting Model

4. FUTURE

- ☐ Establishment of Standardization Organization for SC4 Matters

  Supported Jointly by Industry and Government

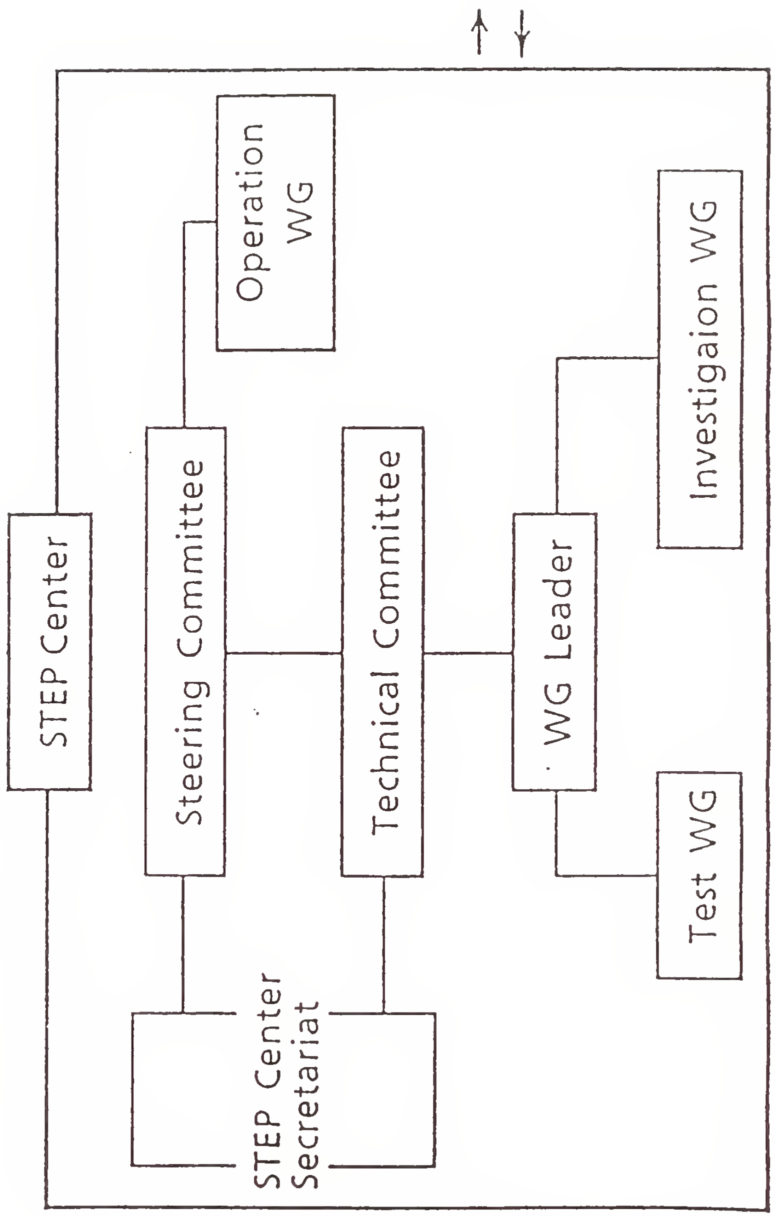
- ☐ Promotion of National/International Projects Related with Standard

  IMS ??

- ☐ Industrial Penetration of STEP in Practical Level

  Users Contribution for Applications

- ☐ Long-Range Basic Study for Engineering Information Infra-Structure



STEP Center
Steering Committee
Operation WG
Technical Committee
WG Leader
Investigaion WG
Test WG
STEP Center Secretariat

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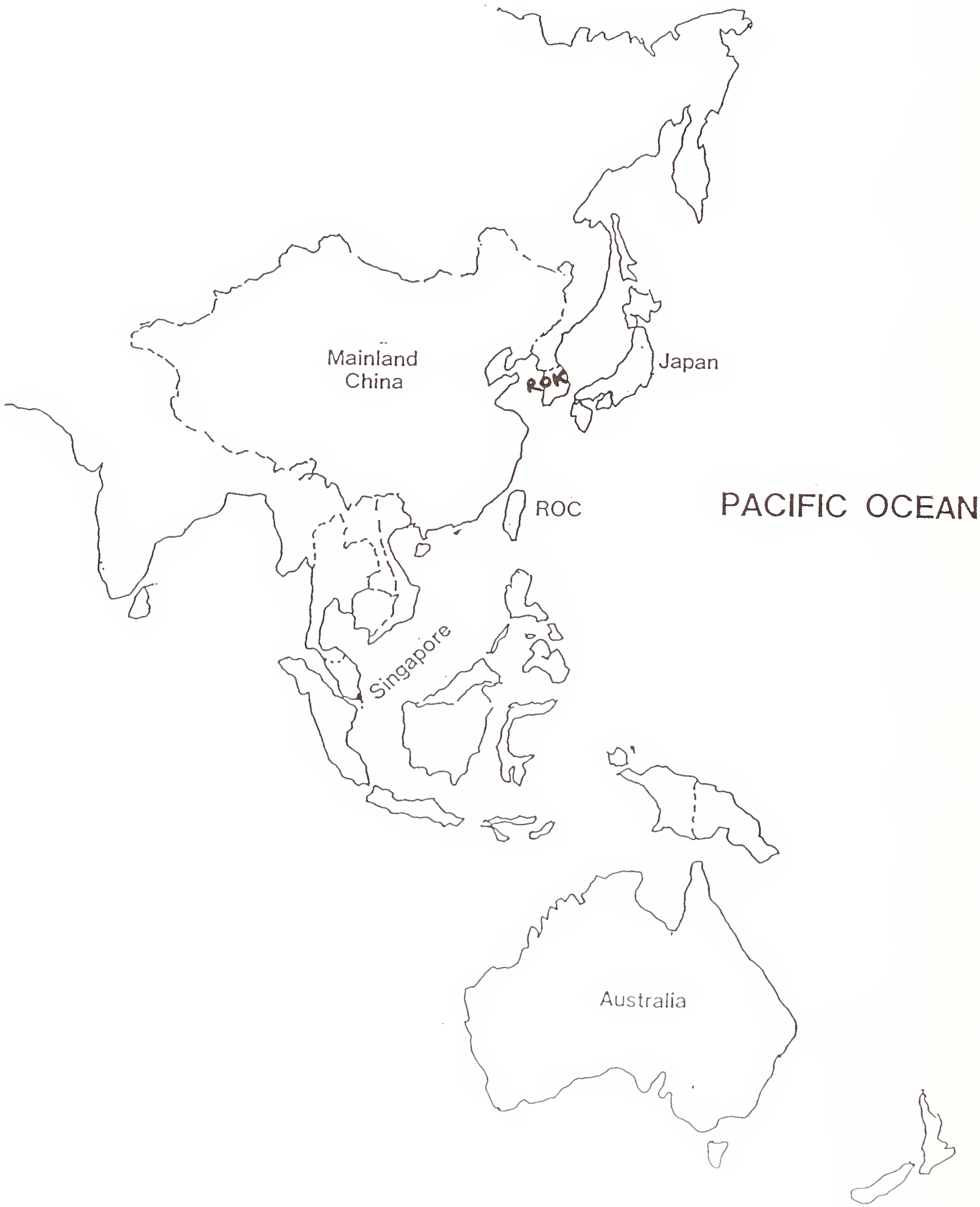
THE WESTERN PACIFIC COUNTRIES



SOCIAL INDICATORS FOR MAJOR ASIA-PACIFIC COUNTRIES

Country	Pop. (m.)	Pop. growth rate	Infant* mortality	Literacy	People per doctor	People per tel.
Japan	124.2	0.4%	5	100.0%	635	1.8
Australia	17.2	1.2%	7	99.5%	438	1.8
New Zealand	3.4	0.8%	9	100.0%	522	1.4
R O C	20.5	1.2%	5	91.2%	1010	3.0
R O K	43.0	0.9%	21	92.7%	1216	3.3
Singapore	2.7	1.1%	8	82.9%	888	2.3
H. K.	5.9	0.9%	6	88.1%	1024	2.1
Malaysia	18.0	2.3%	20	72.6%	2986	11.0
Thailand	56.2	1.4%	24	88.8%	5564	53.0
Indonesia	184.3	1.8%	65	74.1%	8010	193.0
Philippines	61.9	2.3%	40	88.7%	1090	67.0
M'Land China	1143.3	1.4%	27	72.6%	724	134.0
India	843.0	2.1%	88	40.8%	2522	180.0

Source: Asiaweek, April, 1991

* Note: Infant Mortality records death rate per 1000 live births.

R&D STATISTICS OF ASIA-PACIFIC COUNTRIES

Country (Year)	R&D Exp. (US$ Billion)	% of GNP	% financed by Govt.	Researchers (1000 persons)	Researchers Per 10000 Population
Japan (1988)	51.1	2.9	21.5	442	36
Australia (1987)	2.6	1.2	60.7	35	21
New Zealand (1987)	0.4	1.0	60.3	–	–
R O K (1988)	3.4	1.9	17.8	57	14
R O C (1989)	2.0	1.3	49.5	38	19*
Singapore (1987)	0.2	0.9	38.3	3	13
Malaysia (1986)	0.2	0.5	–	3	2
Thailand (1986)	0.1	0.3	64.0	5	1
M'Land China (1988)	3.9	1.0	–	341	4

* Researchers: Persons presently engaged in R&D activities, hold a bachelor, master or Ph.D. degree or graduated from junior colleges with 3 or more years of research experience,
Excluding those under master or doctor's programs in the university.

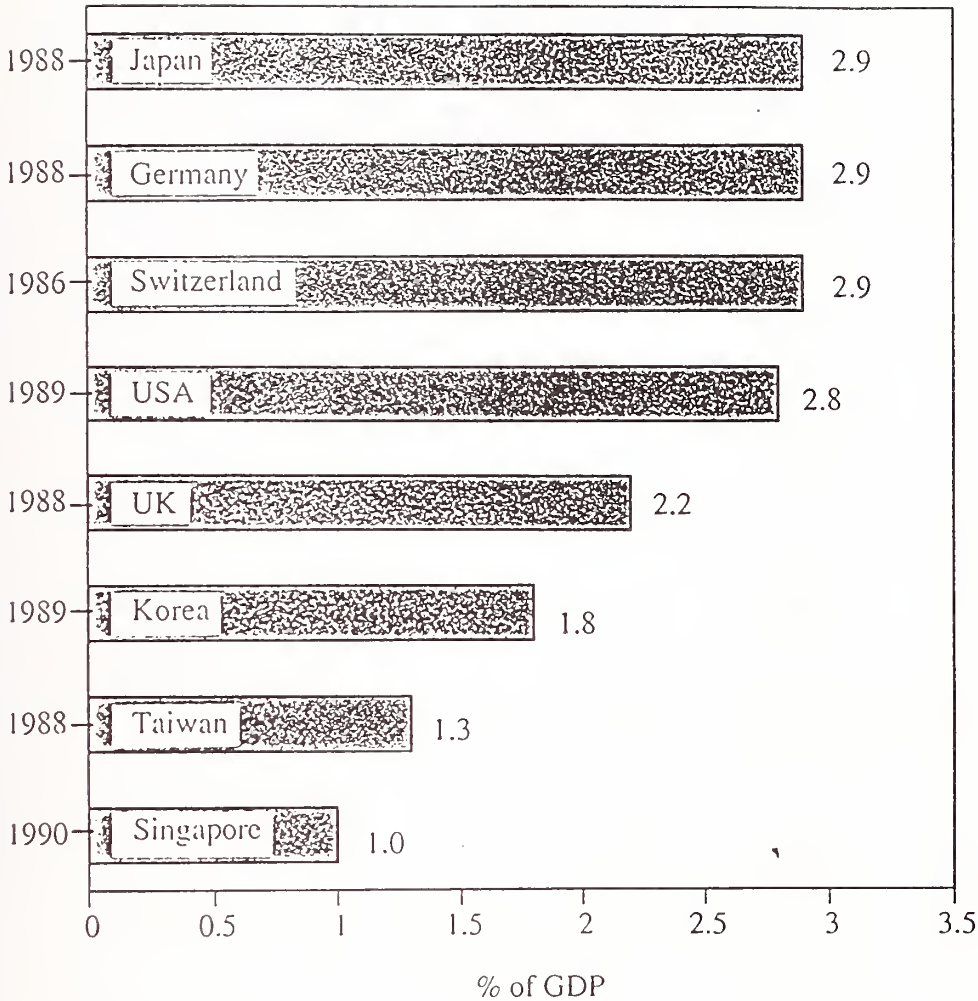
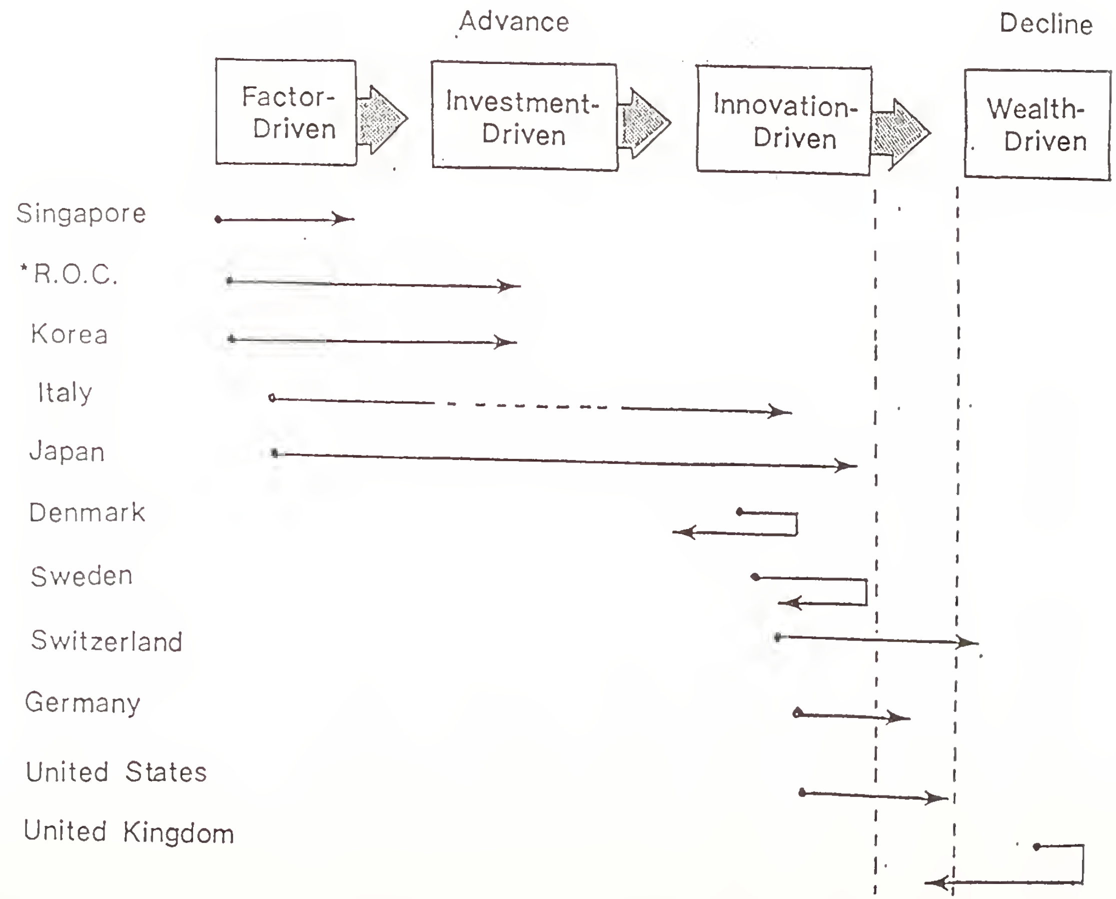


Figure 2.9 International Comparison: R&D Spending

Source: World Competitiveness Report 1991

EVOLUTION OF NATIONAL COMPETITIVE DEVELOPMENT DURING THE POSTWAR PERIOD



Source: "The competitive advantage of nations", 1990, Michael E. Porter
*R.O.C.——from STAG

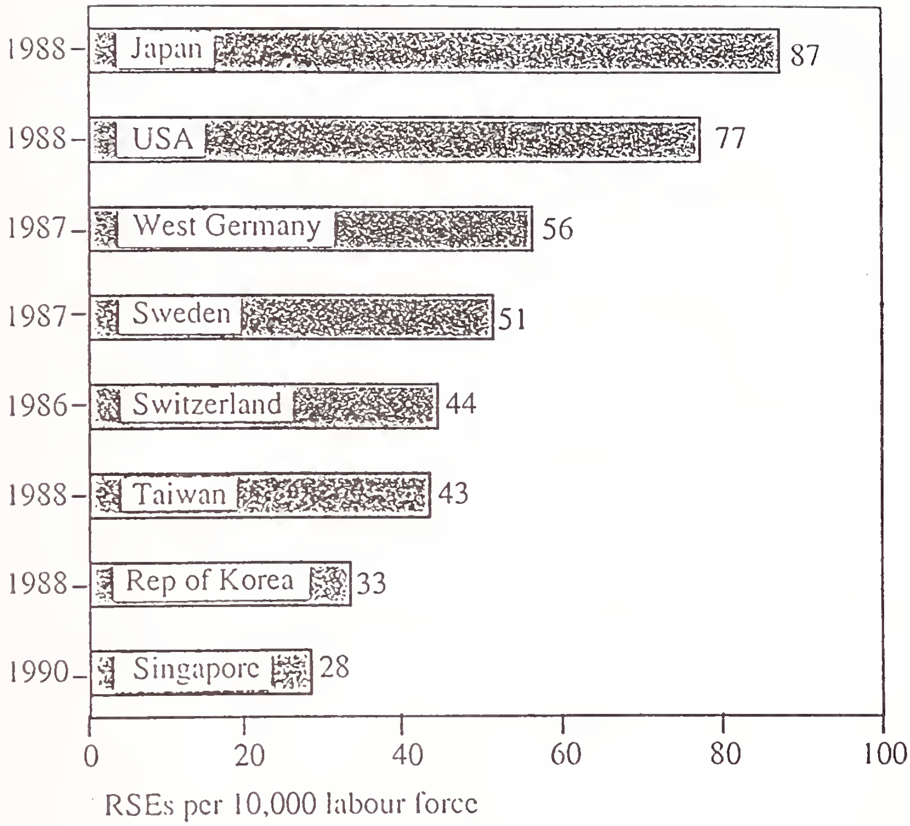


Figure 2.10 International Comparison: RSEs
Source: OECD & National Sources

QUALITY OF LABOUR

Sources: 1. "Annual Survey of Labour Quality", Business Environment Risk Intelligence, U. S.
2. Asiaweek, April 26, 1991

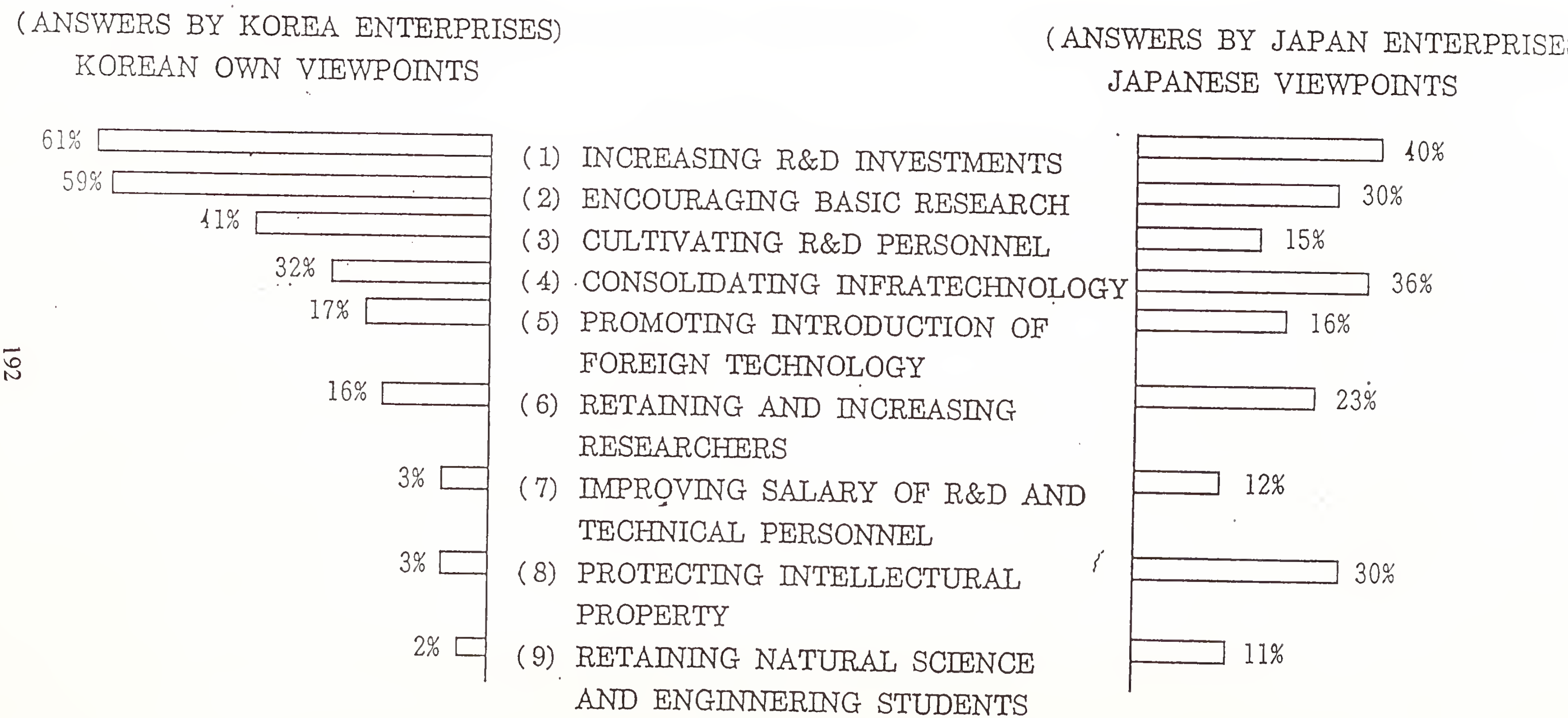
Notes: 1. Labour Quality Index, Considers Productivity, Legal Protection of Workers, Attitudes and Technical Skills
2. Singapore Topped the First Two Categories, 3rd in Attitudes, 14th in Skills in 1990, its Employers Invested the Equivalent of 2.3% of Payroll Training up from 1.5% in 1986.

INTERNATIONAL COMPETITIVENESS OF THE WORLD'S LEADING NATIONS

Developed Countries			Developing Countries		
Rank	Country	Best Feature	Rank	Country	Best Feature
1	Japan	• R & D	1	Singapore	• International Orientation (Foreign Investment)
2	Switzerland	• Political Stability	2	ROC	• R & D
3	United States	• Market Orientation	3	Hong Kong	• Market Orientation
4	West Germany	• International Orientation	4	South Korea	• Industry Growth (Conglomeries)
5	Canada	• Natural Resources	5	Malaysia	• Natural Resources (Low Cost Labor)

Source: IMD, 1990 World Competitiveness Report

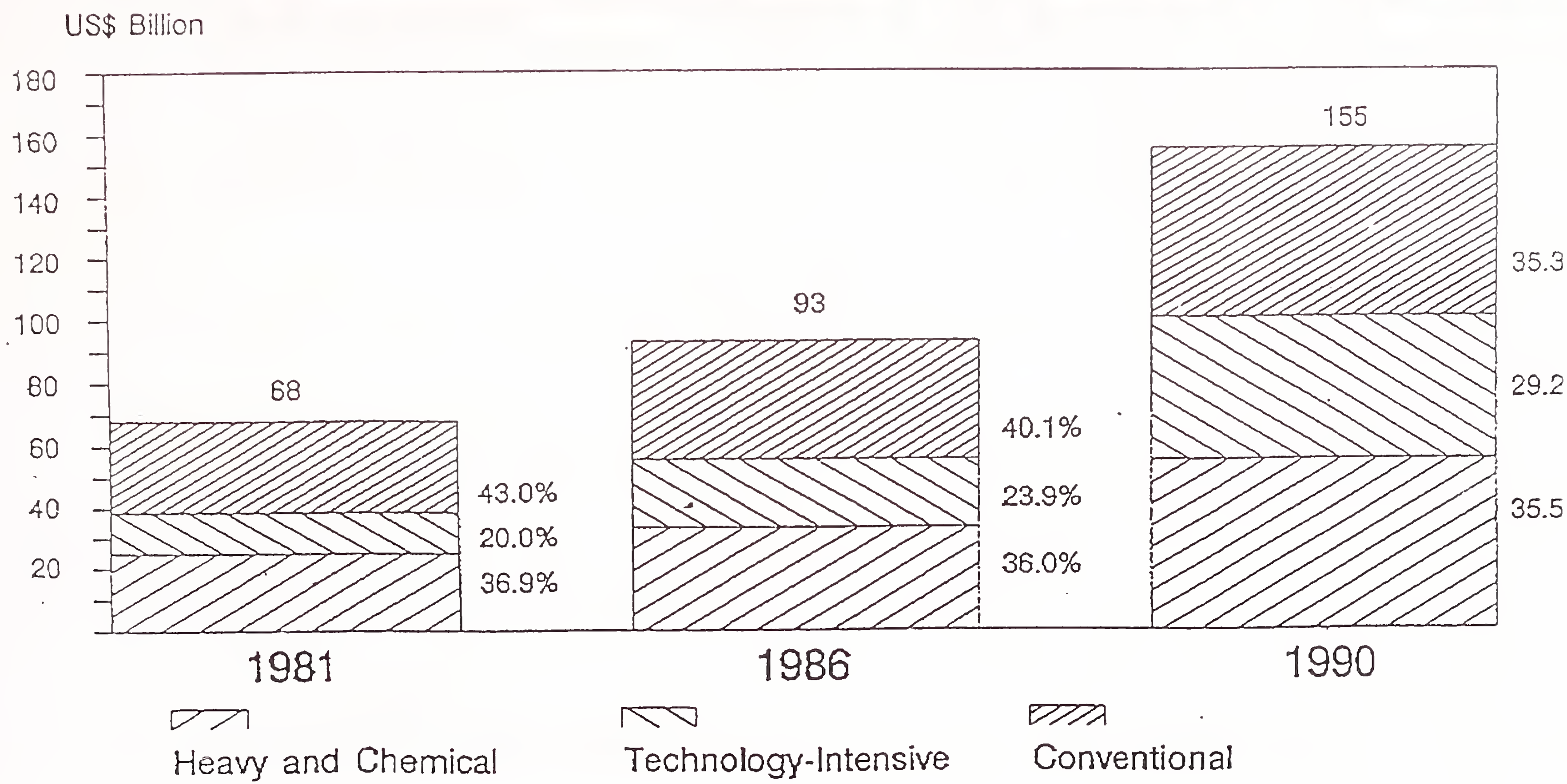
MAJOR ISSUES OF R&D IN KOREA



SOURCE : "Survey on industrial Technology of Korea", Japan Industrial Economic news,. January 1991

(Multiple-Choice)

Structure of Manufacturing Industry



1990s – FUTURE TREND

–Traditional Industry– upgrade	–Hi-Tech Industry–
• Electrical Machinery • Textiles & Textile Articles • Plastic, Rubber • Footwear • Toys & Sports Requisites	• New Materials • E-O • Medical industry • Bio-tech Industry • High Performance Systems
–Social-Service– industry	**–New Space Development– & Utilization**
• Environmental Protection • Health & Medicare • New Community Construction • Disaster-prevention/Protection	• Underground • Ocean • Aeronautics • Aerospace

Basic Industry

STRATEGIC ISSUES--

INTERNATIONAL COORPORATION/ COMPETITION

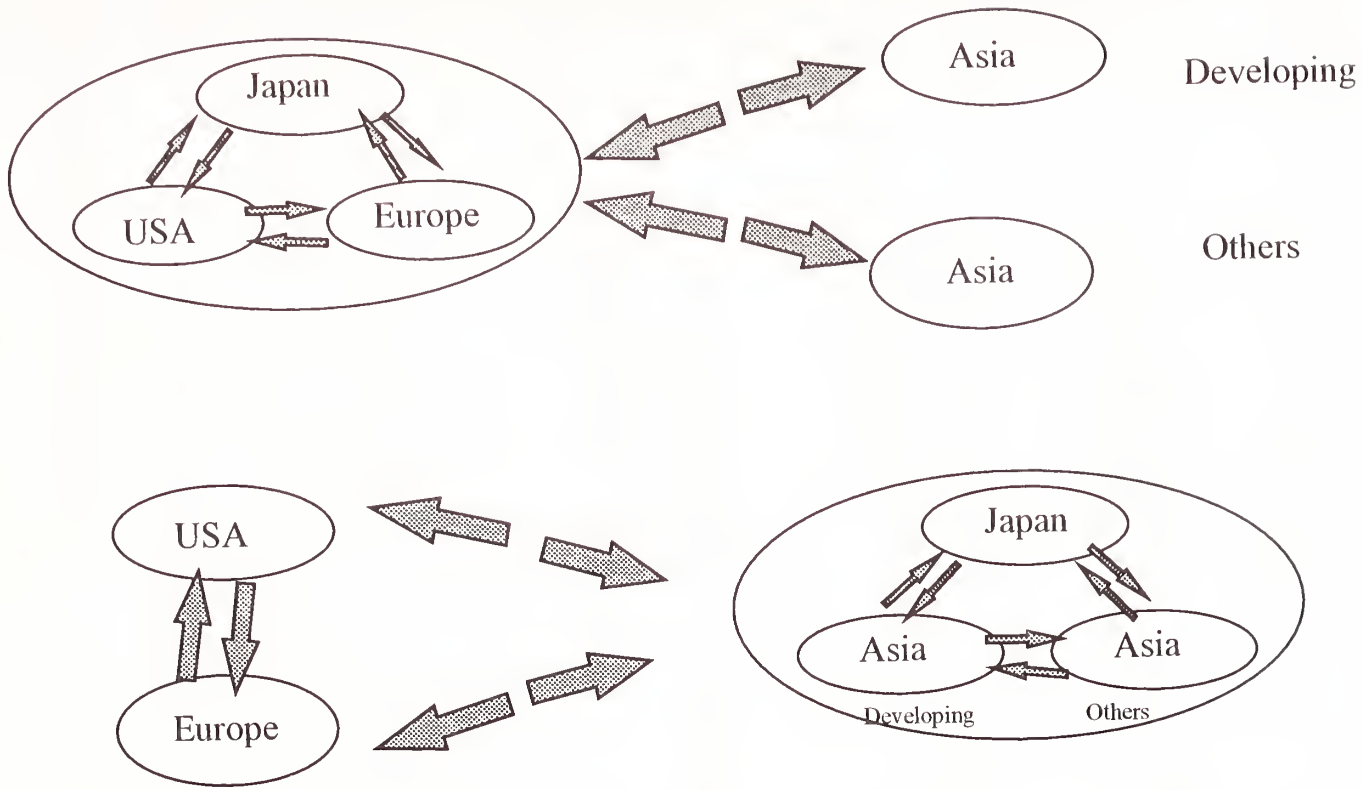
Competitiors	Issues	ROC Strategy
A. Developed Countries (USA, JPN, Europe)	* Still in Market Leading Postition * Moving into Advanced Technology & New Products * More Automation for Lower Cost * Increasing Technology Transfer & Royalty Cost	* Tech-Coorporation * Tech Import * Merge & Aqusition
B. Developing Countries (ROK, SIN, HK---)	* Need for Developing Larger Size Companies to Meet International Competition * Strengthening Component Industry * More Automation Needed & More emphasis on Quality & Productivity	* Regional Community * Technology Alliance
C. Other Countries (Malaysia, Thailand Philippines,---)	* Labor Intensive Industries Fast Developing * Joint-Venture Business Growing up * Infrastructure is Improving	* Technology Export * Joint-Venture

Figure 14.1: R&D Projects in Manufacturing Technology

(i)	Development of a design methodology to ensure the successful implementation of CIM systems.
(ii)	Methodology and Technology supporting Concurrent Engineering (framework, database management system, open system, design for manufacturing/automation/testing).
(iii)	Development of Manufacturing Planning Control System.
(iv)	AI and Knowledge Based Systems applied to Quality Control/Industrial Engineering/Design.
(v)	Development of expertise in communications networking for manufacturing.
(vi)	Computer Aided Instruction for manufacturing system.
(vii)	Man machine interfaces using multi-media and AI.
(viii)	Sensors Technology.
(ix)	Development of thin and thick film coatings.
(x)	Development of laser technology for CNC machine.
(xi)	Development of expertise in the design and development of high speed, and/or high precision assembly equipment.
(xii)	Development of expertise in quick mould fabrication using stereolithography.
(xiii)	Development of CAD/CAM linkage for metal moulds.
(xiv)	Development of a generic low-cost automatic visual inspection system.

Promotion of Collaboration

- Recognize the Differences
- Find out the Complementary Areas



What is the Model?

- Western (top-down) ⟷ Japanese (bottom-up)
- Developed ⟷ Developing
- Collaborative ⟷ Competing

Korea:	**Rather Advanced** **Technology Intensive**
ROC:	**Rapidly Developing** **Intermediate State:** **Primitive . . . . Developed**
Singapore:	**Knowledge Intensive** **Scale Problem** **Focused Development**

Future Strategy for Japan

- Manufacturing as a New Discipline

- Focus on High Technology ➡ Profitable
- Globalization ↘
  ➡ Optimization in Globe-Scale
- Clean Manufacturing ↗

↕

- Keep Country Profit
- Evolution of the World

- **Important Factor:** **Human**

Development and Maintenance of Knowledge

➡ Attract Good Students to Manufacturing

➡ Share Generic Knowledge

↘ IMS Program

Factors for Manufacturing R&D

☞ **Long Range Strategy**

Japan:
- ❒ Renovation of Manufacturing Technology (Ex. Ship-building, Textile, ...)

Others:
- ❒ Focus on Product Design Technology

☞ **Government Committment**

Japan:
- ❒ Industry Leadership, Government Support

Others:
- ❒ Strong Government Control

☞ **R&D Sources**

Japan:
- ❒ University - National Labs - Industry
- ❒ Different Roles
- ❒ Bottom-up, Informal Contact

Others:
- ❒ Overlapping Roles
- ❒ Top-down, Formal Contact

☞ **Human Resource**

Japan:
- ❒ All-Round Player
- ❒ Life-long Employment

Others:
- ❒ Expert (Ph.Ds from foreign universities)

What is the Performance Measure?

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A New Challenge for Manufacturing

Rapid technological evolution

Human resource reduction

Total product life cycle concept

Characteristics of Asian Region

- Rich Human Resource
- Manufacturing Oriented
- Labour Intensive
- Large Internal Market
- Large Variety of Industrial Development

UNIFY OR DIVERSIFY ?

New Requirements for Manufacturing

- Rapid Change of Human, Technology and Environment

  Development and Maintenance of High Technology

- Globalization

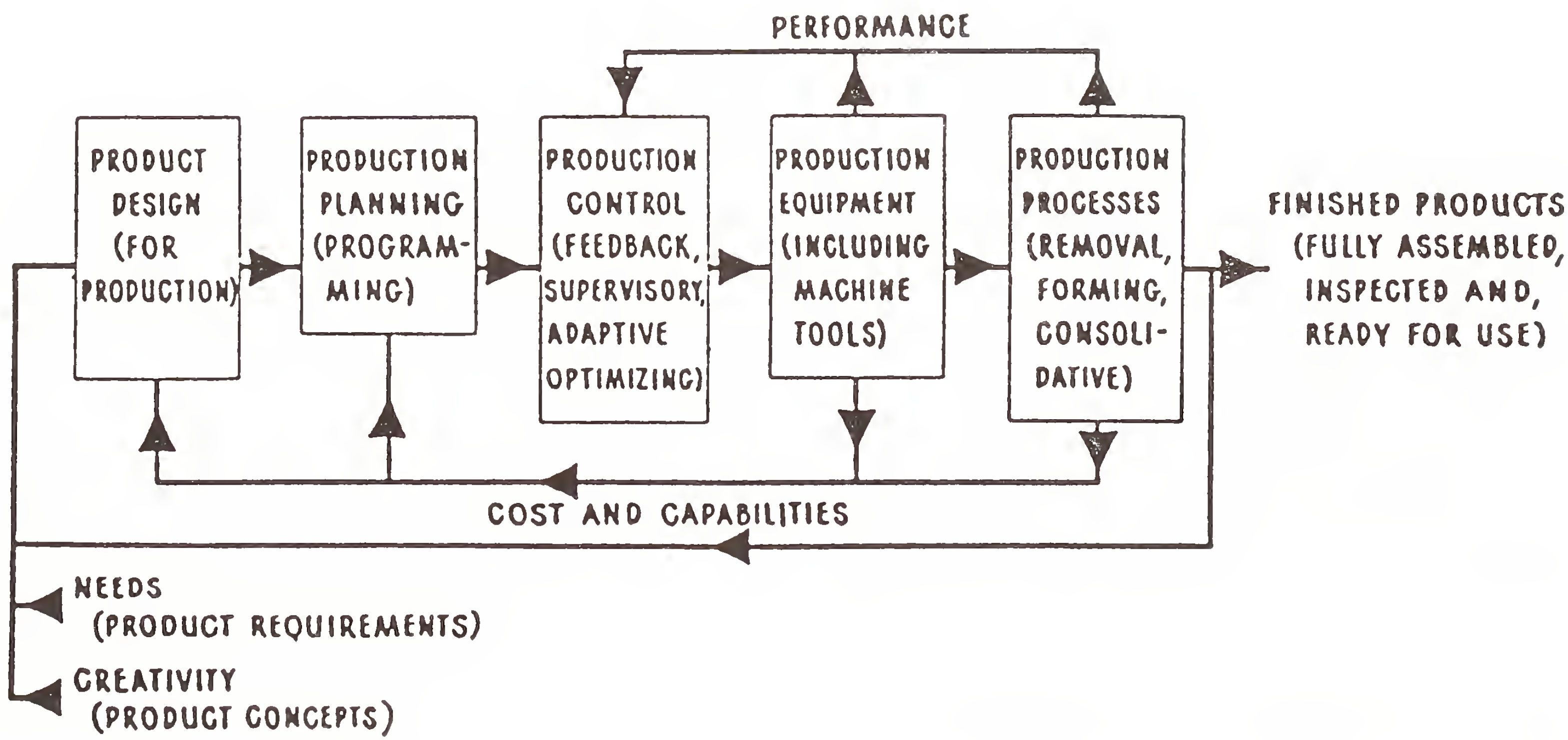
  Difference of Development Status

- Clean Manufacturing

  Difference of Environment

MANUFACTURING HISTORY

Handicraft	before	1913
Taylorism		1914
High Volume Automation		
Flexible Automation		1950-60
Design for Manufacturing		1960-70
Customized Order Controlled Manufacturing		1970-80
Just in Time Production		1980
Concurrent Engineering		1989
Lean Production		1990
Environmentally Friendly Production		1990-2000



Concept of the computer-integrated-manufacturing system.

MANUFACTURING SYSTEMS

R&D STUDY RESULTS

3 November, 1992

Study Charter

- **Purpose**

  Reduce costs of weapons systems & other defense material through Manufacturing Technology projects focusing on above the floor activities

- **Mission**

  - Collect and analyze data
  - Define broad goals, specific objectives and technical areas
  - Estimate costs and potential benefits
  - Identify related efforts
  - Recommend OSD Man Tech funding to technical areas

- **Emphasize technologies that**

  - Are generic
  - Can be sucessfully implemented
  - Accomplish measurable objectives
  - Are broadly transferable

Manufacturing Systems Committee

- Leo Plonsky - Chairman - Navy
- Bruce Rasmussen - Vice Chairman - AF

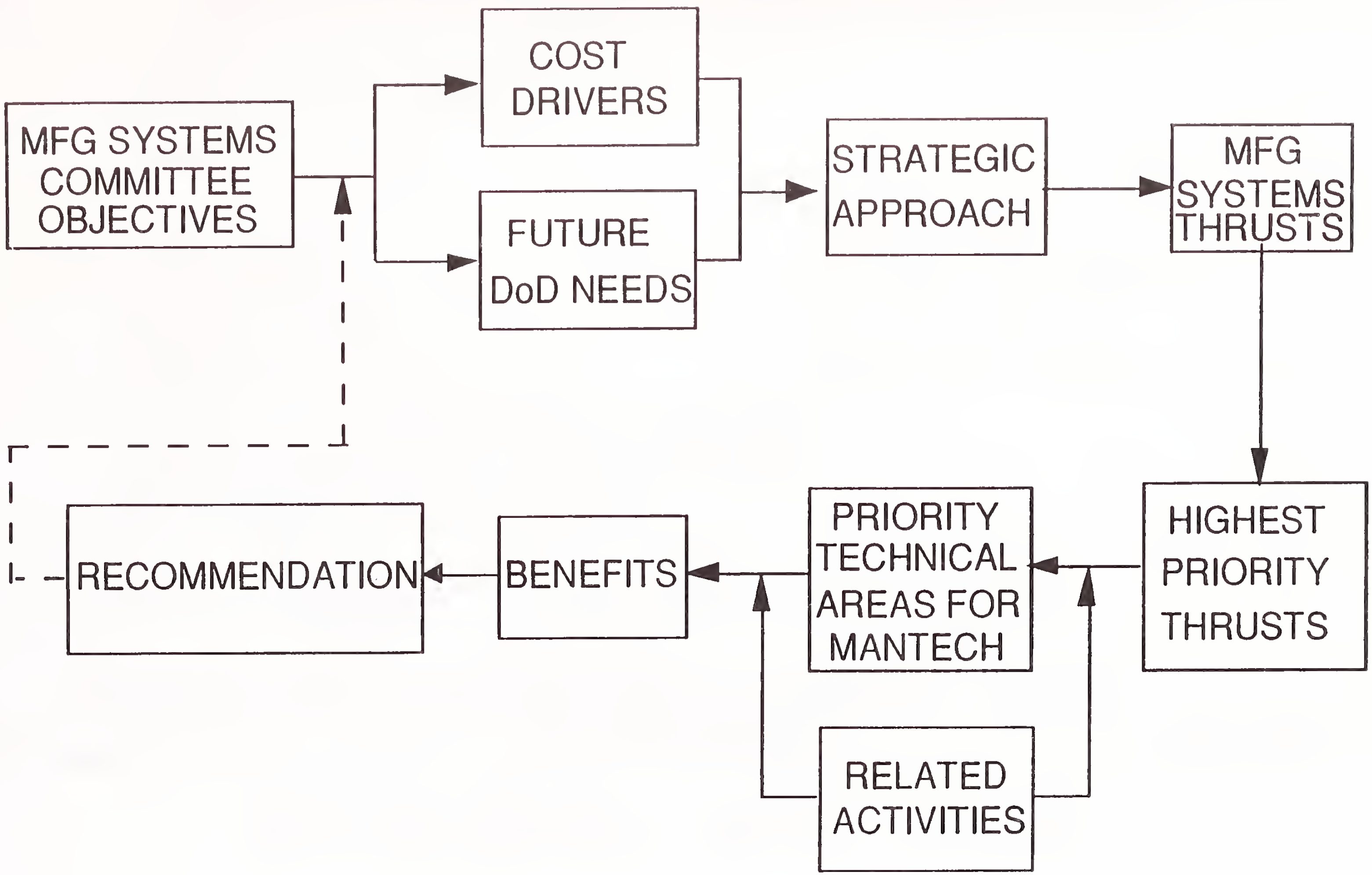
- Bill Billiard - OSD/CALS
- Jack Brainin - Navy
- Mickey Hitchcock - AF
- Mike McGrath - DARPA
- John Meyer - NIST
- Phil Nanzetta - NIST
- Don O'Brien - DLA
- Walter Roy - Army
- Brent Starkey - Army
- Julie Tsao - DLA

Scope

Committee-developed taxonomy of above the floor functions

- **Production Management**
  - Production Planning
  - Supplier Management
  - Production Control
- **Quality Assurance**
  - Quality Factors in Design
  - Inspection Technique R&D
  - Production Planning
  - Production Quality
- **Project Management**
  - Customer Interface
  - Project Planning
  - Conformance to Plan
  - Project Change Management
- **Interfaces to:**
  - Accounting and Finance
  - Design Engineering
  - Personnel Management
- **Manufacturing Engineering**
  - Interface with Design
  - Process with R&D
  - Process Planning
  - Tooling
  - Production Support
- **Information Management**
  - Architecture Development
  - Systems Operation
  - Systems Maintenance
  - Hardware and Software Acquisition
  - Communications and Networks
- **Facilities**
  - Plan Facilities and Equipment
  - Perform Maintenance
  - Implement Plan

Planning Methodology



Cost Data - Approach

Collect and analyze total corporate costs

- **Relate "standard" accounting data to the taxonomy**

- **15 manufacturing companies**
  - **mix of civilian and military products**
  - **sizes from $10M to $3B annual sales**

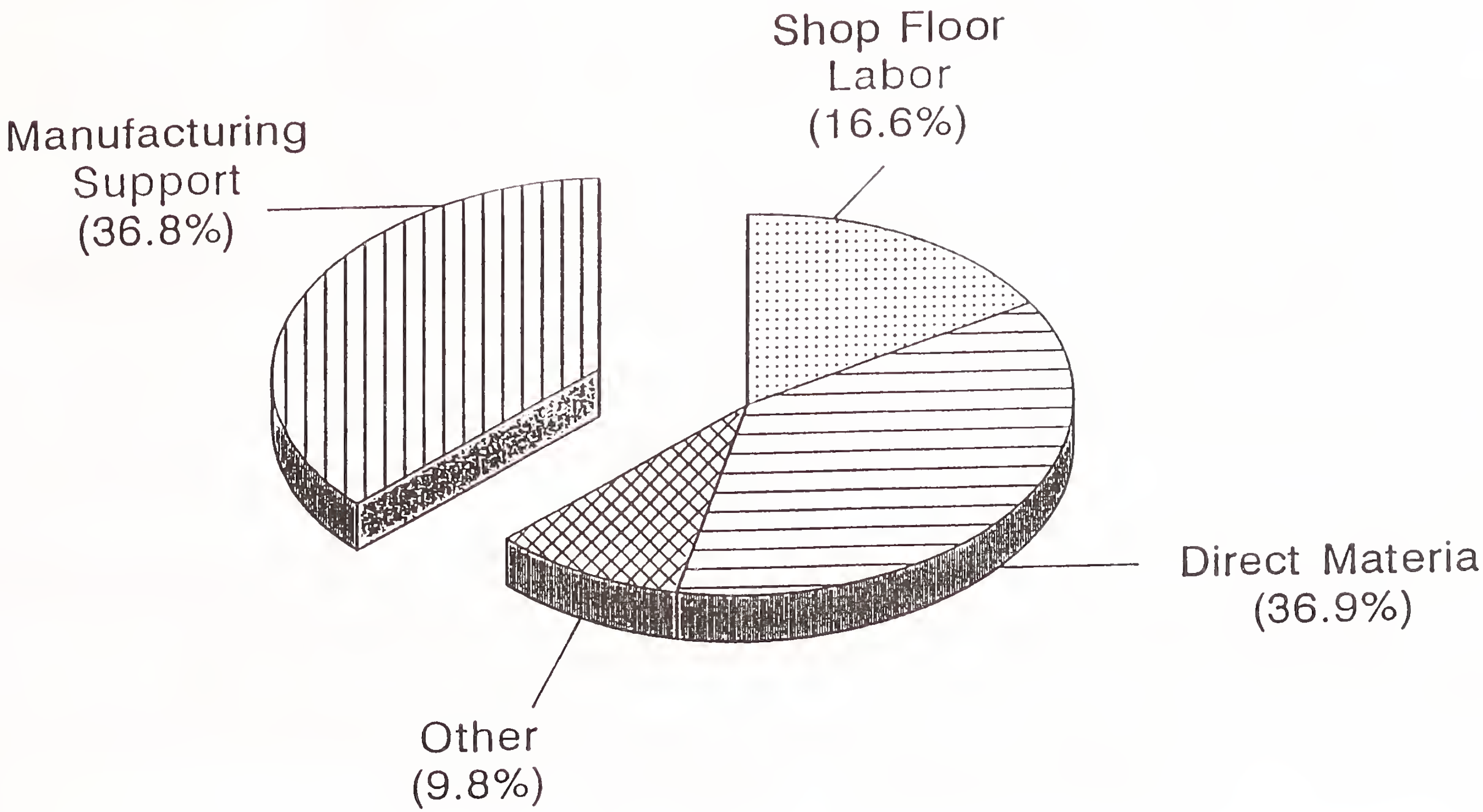
  - Electronics assemblies
  - Precision metal parts
  - Microelectronic devises
  - Processed foods
  - Industrial gases
  - Special purpose vehicles
  - Mechanical assemblies
  - Welded metal products
  - Computing & test equipment
  - Heavy equipment

- **Validate data with:**
  - 6 additional companies
  - NIST/ITI survey of 230 firms
    - metal stamping, plastics, and tool & die sectors
    - mostly small and medium-sized enerprises (20-499 employees)

- **Analyze for ranges, averages and confidence intervals**

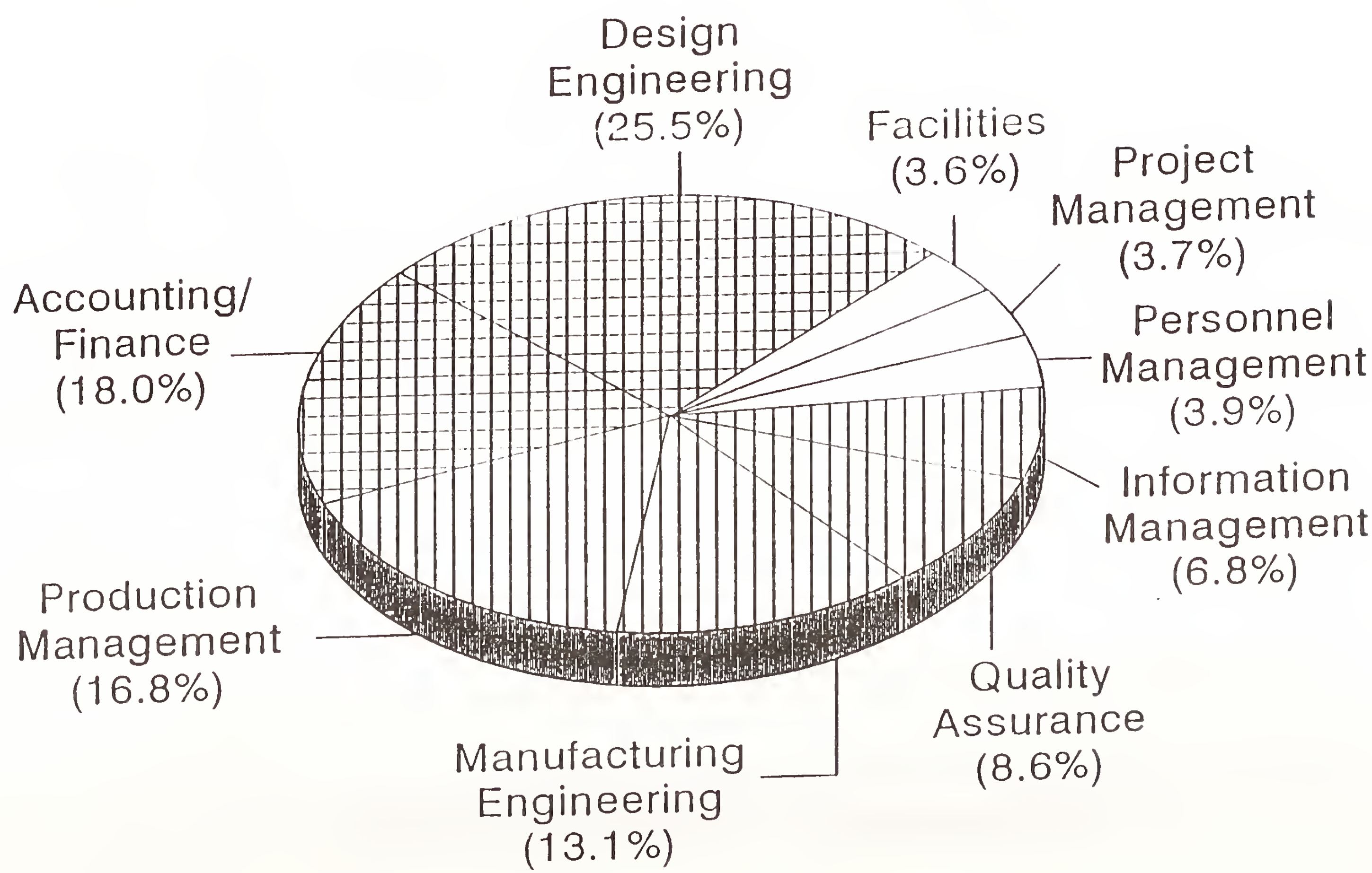
Cost Data - Results

Distribution of Total Corporate Costs



Cost Data - Results

Distribution of Manufacturing Support Costs



Priority Thrusts

Concurrent Engineering - Simultaneous design of the product, the mfg facilities, processes, tooling, and associated field support processes.

- Includes the supplier chain as partners in the design & mfg activities
- Includes the information systems which support the entire process

Customer-Supplier Relationships - All activities involved in linking a company, its suppliers and its customers.

- Focus is on reducing costs time associated with the supplier chain
- Includes the full range of technical and business fumctions
- Includes the information system elements which enable the functions

Enterprise Integration - Technical and non-technical activities & capabilities to enable far more efficient operation of the extended enterprise

- Includes process understanding and simplification
- Includes seamless integration of multi-vendor information systems

Technical Areas Related to Thrusts

Priority Thrusts / Tech. Areas	Concurr. Engrg	Cust-Supp Relat.	Enter. Integ
Integration Methodologies	X	X	X
Simulation & Modeling	X	X	X
Mfg/Ind. Engrg Support Tools	X	X	X
Prod. Data Rep & Exch	X	X	X
Electronic Mockups & Prototypes	X		
Knowledge-based Systems	X	X	X
Networks & Communications	X	X	X
Architecture	X	X	X
Distributed Intelligence	X	X	X
Electronic Data Interchange		X	X
Perf & Conformance Testing		X	X
Value-Added Networks		X	X

Top Twelve Technical Areas

Technical Area	Brief Description
Integration Methodologies	Emphasizes tools, methodologies for designing, maintaining and improving integrated environments. Includes information systems development as well as management; integration of different models (including different companies' dynamics in configuration management); computer & human intepretable.
Simulation & Modeling	Computer-based representation of key functional activities within/among multi-organizations as an aid to planning, analysis, control including accessing process models as req'd.
Mfg/Ind Engineering Support Tools	Design support, facilitates planning and layout, quality analysis, information access. Includes detailed planning for all fab & assembly operations, including preparation of specific instructions (manual & NC); ties to tech order preparation; fixture & tool designs; includes virtual reality techniques.
Product Data Rep. & Exchange	Augments product design data to include mfg information.
Elect. Mock & Proto.	CAD models to replace physical mockups/prototypes
Distributed Intelligence	Distributed multi-enterprise databases plus decision support; meta models for federating heterogeneous databases, common user interface, coherency control, includes groupware user interface requirements.

Top Twelve Technical Areas (cont.)

Technical Area	Brief Description
Knowledge-based Systems	AI applied to mfg, includes knowledge capture (human & automated), neural nets, expert systems, voice data entry.
Networks & Communications	Hardware/software protocols; high speed, high capacity infrastructure; includes transmission of text, graphics, video.
Architecture	Inter/intra enterprise, multi-sector/vendor, interoperability, national/international, all business processes and functions.
Performance & Conformance Testing	Products conforming to interoperability standards and functional standards; test suite development, objective regional test service providers (small/medium sized enterprise emphasis) included as part of standards development.
Value-added Networks	Nation-wide electronic networks providing interconnection and interaction among manufacturers as well as information about a company's manufacturing ability.
Electronic Data Interchange	Business data (such as order processing, pricing), multi-sector standards for protocols.

Technical Area Evaluation Criteria

- Impact on Thrusts - Importance to one or more priority thrusts

- Technical Leverage - Impact to other technical areas

- Implementation Path - Existence of a clear path to broad industry implementation of results

- Impact of Man Tech - Ability of Man Tech to make a difference

(degree to which support for the Area is already being provided from other programs was an important consideration)

Technical Area Evaluation Summary

Criterion / Technical Area	Impact on Thrusts	Tech. Leverage	Implem Path	Impact of MT	Total
Integration Methodologies	H	H	H	H	H
Simulation & Modeling	M	M	H	H	H
Mfg/Ind Engrg Supp. Tools	M	M	H	H	H
Prod. Data Rep. & Exch	H	M	H	M	M
Elec Mockups & Prototypes	L	L	M	M	L
Knowledge-based Systems	H	M	M	L	L
Networks & Comm.	H	H	H	L	L
Architecture	H	M	M	M	M
Distributed Intell.	H	M	M	L	L
Electronic Data Interchange	M	L	H	L	L
Per. & Conformance Testing	M	M	M	H	M
Value-Added Networks	L	L	M	L	L

Integration Methods

Methods, techniques and technologies which enable straightforward interoperation of new and existing information systems regardless of hardware vendor, software vendor, or physical location of the system.

- Interactions among information systems, versus focus on individual information systems

- Two major aspects:

Information Infrastructure Design - Advanced technologies & techniques for design & implementation of new, integratable capabilities.

Provides guidance to information systems developers.

Legacy Systems Integration - Emerging methods and techniques to integrate existing information systems (the legacy).

Information Infrastucture Design

Key Problems -

- Complexity and scope of the systems
- Perceived & real differences among industrial base sectors
- Scarcity of consensus standards
- Closed, proprietary information systems products

Recommended Focus -

- Demonstrate methodologies, techniques & standards
- Emphasize new systems which are interoperable with products from other vendors
- User consensus on requirements & standards
- Emphasis on systems involving only non-geometric data

Legacy Systems Integration

<u>Key Problems</u> -

- Legacy systems are vital to manufacturing systems fumctions
- Enormous number of different technologies and vendors
- Poor Documentation
- Need for human interfaces between systems costs time, labor & errors
- Ownership of data & systems

<u>Recommened Focus</u> -

- Demonstrate advanced technology tools for integration
- Start with existing technology, employ advanced emerging technology later
- User consensus on technology, including standards
- Emphasis on major systems in large companies
- Subsumption techniques

Simulation & Modeling

Methods, techniques and technologies which help understand and make decisions about the manufacturing system. Includes business, production and information management processes.
- Three major aspects:

<u>Simulation</u> - Advanced capabilities for evaluating both current practice and proposed changes to individual processes and groups of processes, including the extended enterprise

<u>Enterprise Modeling</u> - Techniques to describe the enterprise in ways which foster understanding the effects of change

<u>Model Federation</u> - Methodologies to improve the information systems which support manufacturing systems functions

Simulation

Key Problems -

- Simulations must be created and analyzed by simulation experts
- Require tuning by actual data to attain sufficient accuracy
- Individual standalone systems difficult to integrate with other systems
- Computationally intensive

Recommended Focus -

- Executable simulation
- Interfaces for the general user
- Integrate simulation with other information systems
- Couple demonstrations with related programs

Enterprise Modeling

Key Problems -

- Lack of techniques appropriate to the needs of middle and executive management
- Difficult to describe how the many manufacturing systems functions interrelate
- Inability to predict the effects of change in one area on the other enterprise activities related to that area
- Explanation of integration strategies and issues

Recommended Focus -

- Enterprise process models for executive decision support in re-engineering the enterprise
- Predict impact of change on time and cost
- Capture experiences in implementing concurrent engineering, enterprise integration, and better customer-supplier relations

Model Federation

Key Problems -

- Separate approaches to modeling functions and information
- Models are complex, expensive and time consuming
- Must be created by modeling experts
- Difficult to integrate

Recommended Focus -

- Demonstrate emerging modeling approaches
- Integration of models based on different methods
- Base integration approach on standards
- Reduce the cost of information systems while improving their performance and ease of change

Manufacturing/Industrial Engrg Support Tools

Integration and refinement of existing tools and techniques for design and analysis of products, processes,equipment, tooling and facilities

- Four major aspects:

Integrated Environment - Software environment that organizes and unifies support tools used by manufacturing and industrial engineers

Design/Analysis of Products for Producibility - Tools to assist in analyzing products for producibility, quality & serviceability

Design/Analysis of Processes, Equipment and Tooling - Tools to support fabrication and assembly planning and equipment and tooling design

Flexible Manufacturing - Fundamental change in production philosophy from mass production to a concepts more appropriate to small production quantities of highly engineered products

Integrated Environment

Key Problems -

- Existing support tools are suboptimized and independent
- Time and cost associated with most mfg & industrial engrg functions
- Upgrading support tools is difficult and expensive
- Human interfacing of independent tools is error prone

Recommended Focus -

- Framework for integrating tools
- Demonstrate initial set of tools - specific set established by user consensus
- Demonstrate integration with other related systems
- Standards

Design/Analysis of Products for Producibility

Key Problems -

- Difficult to assess producibility at early design stages
- Designs are immature at transition to production
- Frequent design changes
- High rate of change in product technologies

Recommended Focus -

- Enhance existing tools
- Develop new methods and tools
- Application in conceptual design and early preliminary design
- Standards to enhance tool portability and reduce time for new tool development and customization

Design/Analysis of Processes, Equipment and Tooling

Key Problems -

- Computer aids to planning generally inaccessible to smaller firms
- Planning is time consuming, labor intensive and error prone
- Transition to production paced by planning
- Multi-enterprise planning is very difficult and rarely done

Recommended Focus -

- Tools to automatically generate process and assembly plans
- Mechanical and electronic products
- Tailor for small and medium-sized companies
- Portable to different sizes and makes of computers

Flexible Manufacturing

Key Problems -

- High unit cost, long transition to production and slow technology insertion pace
- Mass production philosophy increasingly inappropriate to the needs of small volume manufacturing
- Production philosophy embedded in manufacturing systems
- Dedicated "lines" make mixed production inefficient

Recommended Focus -

- Stimulate the first stages of change to flexibility concepts
- Demonstrate techniques for flexible processing sequences and factory layout
- Electronics assembly beyond the board level
- Couple demonstrations with related programs

Summarize

- Manufacturing support is a major cost driver

- The problems are common across sectors & company size

- Key technical problems still exist

- Committee fells the highest priority technical areas are:
  - integration methodologies
  - simulation and modeling
  - manufacturing/industrial eng. support tools

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