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ADVANCED MANUFACTURING TECHNOLOGY—COMPUTERS, OPEN SYSTEMS INTERCONNECTIONS, INTERNATIONAL STANDARDS, AND THE JAPANESE

The industrial world, as well as the U.S. industry and government (especially DoD), are making progress in integrating the power of the computer at all levels of their activities. This article provides some examples of the worldwide pursuit of this goal and its effect on international relationships.

INTRODUCTION

Computers and communication technology are having a major worldwide effect on how manufacturing companies are being controlled, organized, and managed. Major changes in manufacturing and engineering philosophy and processes have already been made possible because of the power of present-day computer devices. Computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), computer-integrated manufacturing (CIM), robotics, and management tools (for example, the Just In Time system for the delivery of materials) are all important developments during the latter part of the 20th century; certainly all will be major factors in the way organizations are established and conduct business during the 21st century. This article identifies some of the building blocks of this new "industrial revolution"—sometimes known as the "electronic revolution."

I will begin by discussing some of the national and international activities for the development of standards that ensure that industrial facilities, government agencies, and international bodies can communicate effectively via electronic media, including some Japanese applications of open system interconnection (OSI). This article is a follow-up on one in which I discussed manufacturing automation in Japan, as observed in 1986.[1] Information is also provided about the development of international manufacturing automation standards by the leading technical nations of the world, under the cognizance of the International Standards Organization (ISO).

OPEN SYSTEMS INTERCONNECTIONS

Powerful computer tools can be made available to all elements of an organization today via computer networking. The problem is how to assure that units such as computers, machine tools, and robots—regardless of their manufacturing origin—can communicate with each element of the CIM wheel (Fig. 1).[2] The necessary ingredient to eliminate computer incompatibility is the development of standards that would allow different kinds of computer-directed and -aided equipment to be harmonious—in other words, to allow all levels of computers within an organization to communicate with one another easily in real time. The telephone system is one example of a system with successful interconnections. Telephone systems are based on universally recognized links. Such standardization allows European, American, Japanese, and other telephone systems to be readily interconnected and to operate as a network. Coordinated by ISO, the General-Motors-developed manufacturing automation protocol (MAP) and technical office protocol (TOP) are being used as the basis for international standards for electronic information exchanges.

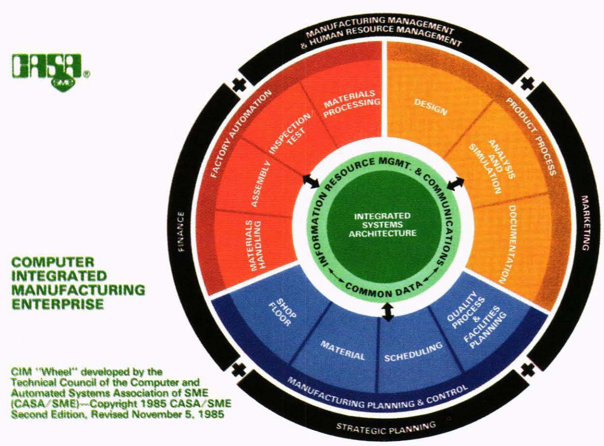

Figure 1—The CIM wheel provides fundamental dimensions of an integrated enterprise: business management, product and process definition, manufacturing planning and control, factory automation, and information resource management.

OSI is based on the seven-layer model of an enterprise developed by ISO and now is used worldwide for inter-operation and interconnections within an enterprise. A shortened version of the seven-layer model is shown in Fig. 2. The lower levels concern production, and the upper levels are dedicated to management activities. Starting from the shop floor: At Level 1, information is physically transferred between adjacent machine tools or other devices that are controlled in some form by Level 2, the data link that establishes and controls the messages being transferred. Level 3 provides the standards to be used to establish connections between equipment, and Level 4 transports the data in a reliable manner from end device to end device. The four layers are essentially the basis for the interoperational standards being developed for that part of a manufacturing organization in which the actual physical work is done. In the upper layers, data are generated and transmitted for engineering, management, sales, etc. This culminates at Level 7, where decisions are made that manage all the lower levels. While all of these elements have existed in a manufacturing organization, even during the early days of the industrial revolution, engineering and manufacturing technology is at a point today where (1) management information systems are replacing traditional reporting systems, (2) CAD is replacing traditional production and process design, (3) CAM and CAE are replacing conventional manufacturing and engineering processes, (4) CIM is automating traditional manual systems, and (5) the proper management of assets requires understanding of, extraction of, and acting on pertinent information from a large database made available by computers.

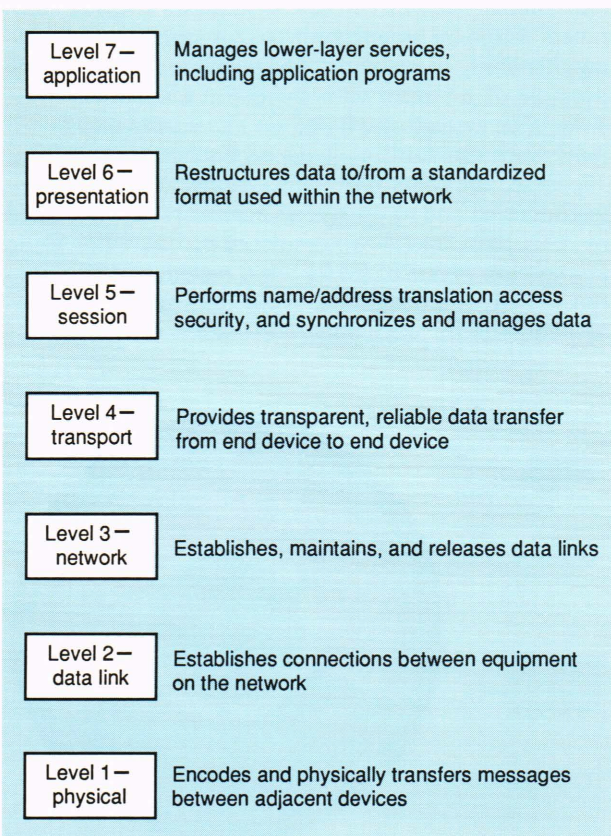

Figure 2—The ISO 7-layer model, developed by the International Standards Organization and used by all member countries. The model identifies those elements of a computer-integrated enterprise that require a set of internationally recognized standards so that devices can communicate with one another.

U.S. AND EUROPEAN INDUSTRIAL ACTIVITY

There is worldwide activity among industrial nations to develop standards and protocols that enable multivendor equipments to communicate with each other with the same ease that present telephone exchanges and equipment can be interconnected. MAP and TOP are examples of such activity in the United States. They were developed to ensure that all communication and factory-automation requirements were met by standardized equipment. The protocols also identify standards to be used by all the elements involved—the subcontractors, various suppliers, banking affiliates, and the customers—who talk to each other through devices based on identifiable protocols.

The objective of MAP and TOP has already been accomplished, as demonstrated at recent Society of Manufacturing Engineers (SME) meetings that were supported by the manufacturing industries of the United States, Europe, and Japan. In 1988, "Enterprise," an SME convention held in Baltimore, was a clear demonstration of the applicability and status of worldwide activity in the development of national and international standards for engineering and manufacturing. Using OSI standards, exhibition participants demonstrated the compatibility and interoperability of computer hardware and software produced by different manufacturers. The message frequently mentioned during the convention was that "vendors will continue to offer products with advanced capabilities and features which seem attractive in their own right. However, if these products cannot share information and communicate with other devices on your Enterprise network, buying them is the equivalent of purchasing a very fancy telephone that you cannot plug into the phone system."[3]

The international community that participated in the Enterprise exhibition included 13 European countries that are part of the European Strategic Program for Research and Development and Information Technology (ESPRIT). The ESPRIT countries that adopted many of the MAP and TOP protocols have held exhibitions in Europe for several years, in forums such as the Hanover Industrial Fair and a demonstration plant at the Bayerische Motoren Werke (BMW). The Enterprise participants included British Aerospace, Air Italia (Italy), Bull (South Africa), Olivetti (Italy), Siemens (Germany), the Federal Republic of Germany, Peugeot (France), and several others from the ESPRIT community.

Some of the work on international standards for automated manufacturing that APL has participated in includes the ISO Systems Integration and Communications subcommittee (TC 184 SubC-5). One of the more important standards being developed by that subcommittee is ISO/DP 9506 Part I, Manufacturing Message Specification—Service Definition, and Part II, Protocol Specification. That document is part of standards developed by the United States and other nations to facilitate the interconnection of information-processing systems used in the seven-layer model shown in Fig. 2. Work with the subcommittee included a meeting in Tokyo in April 1988. What follows is a description of my trip to Japan, where I visited several Japanese corporations that operate in an OSI environment.

JAPANESE ACTIVITIES

Before the formal ISO meetings, arrangements were made for the members of the subcommittee (representatives from the United States, France, Great Britain, Italy, Japan, Switzerland, and Sweden) to visit Japanese factories involved in the design and manufacture of machine tools, office-automation equipment, and telecommunications.

The first plant visited was the Toshiba Corporation's Ome Works, which produces distributed-data-processing computers, microcomputers, personal computers, word processors, optical character readers, Winchester disk drives, and other peripheral devices. Production is the main function of the plant. Design and engineering is done at Toshiba Headquarters at Kawasaki-shi, several kilometers away, and networked to the Ome Works by a ring network shown in Fig. 3. One of the Toshiba product lines that has recently become popular in the United States is the lap-top T3100 and T5100 computers, which are frequently used by passengers on commercial aircraft for word-processing and other tasks. The Toshiba plant emphasizes a flexible manufacturing system with distributed processing computers connected to host computers and optical local area networks as well as minicomputers. The printed-circuit-board assembly lines using automatic inserters were impressive. The printer line was highly automated (Fig. 4). The CAD for manufacturing systems and the CAM setup were well manned, with many stations at design and manufacturing levels.

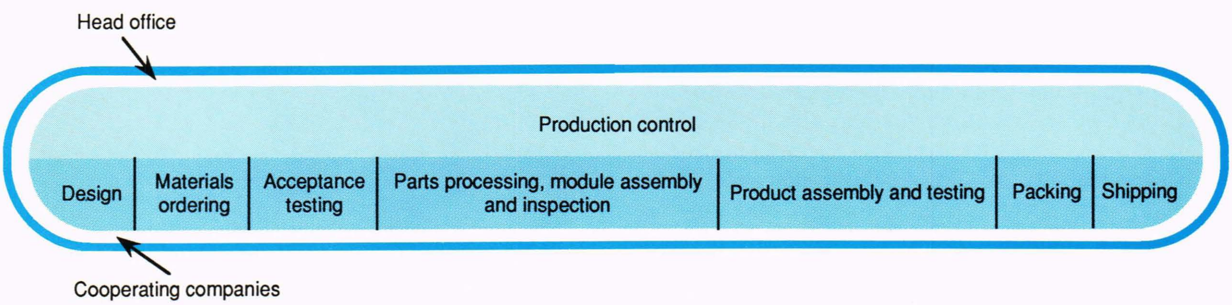

Figure 3—Local area network on-line system at Toshiba is an example of integration by electronic techniques, in a ring network, of all the elements involved in producing the various computer products.

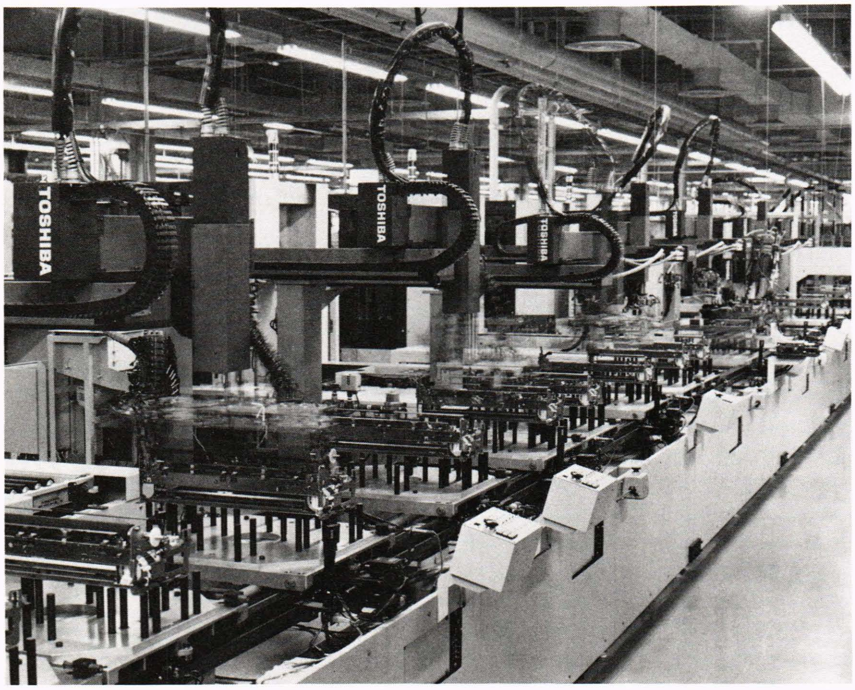

Figure 4—An automated printer production line at Toshiba uses a computer-integrated manufacturing system with robots, and automatic testing and shipping techniques.

The clean rooms for the various manufacturing lines were state-of-the-art facilities. The entire production system (which includes design, materials ordering, acceptance testing, parts processing, modular assembly, inspection, packing, and shipping) were all observed during the visit. While the physical plant gave one a sense of efficiency, it was not that much advanced over similar U.S. factories. The interest in international standards for machinery used in manufacturing and local area networking was apparent. The Ome Works has 4000 employees; 1600 are design engineers, 2000 are university graduates in other specialities, and the remaining 400 are high school graduates. Twenty thousand units per month (printers, computers, Winchester disk drives, and workstations) are manufactured on a 5-day per week, 8-hour per day basis.

The group toured the Fujitsu's Oyama Works, which manufactures switching and transmission equipment and business communication systems. The plant was modern and highly automated. Process automation included receiving inspection, component insertion, printed-circuit-board function tests, and systems tests. It was a clear demonstration of why the Japanese are doing so well in the area of high-technology electronic products. The Oyama Works product line includes electronic transmission equipment (including digital multiplexing devices), fiber-optics communication systems, and highly reliable cable repeaters for overseas telecommunications. Fujitsu has recently installed a submarine coaxial cable system between Denmark and Norway, and they are working on a submarine fiber-optic cable between Tokyo and Hawaii.

Fujitsu practices a company-wide campaign for product quality and reliability. Their quality assurance program includes automated on-line inspection by automatic sensors (Fig. 5). The in-process reliability system demonstrates Fujitsu's dedication to the reliability of their products. For example, automatic on-line testing of submarine fiber-optic cables and components included pressure as well as high- and low-temperature testing of each unit. The highly automated component insertion line and the well-lighted, clean plant are shown in Fig. 6. Also, quality circle teams were observed in session, with apparent interest and dedication of the factory personnel to this aspect of company/personnel interrelationships.

The third company visited was the Atsugi Factory of the LeBlond Makino Milling Machine Company, a large machine-tool manufacturing plant affiliated with an American firm. An interesting side note to this visit was that the numerically controlled milling machines in the machine shop of APL's Technical Services Department were built at the Atsugi Factory. Informative discussions were held with their design and production personnel, including plant manager Makato Sato. Mr. Sato was interested in a description of APL's experience with Makino machining centers. The scope of the technical exchange included the controllers for conversational programming, and the APL use of and modifications to the programming system. A description of the APL-designed instrument for monitoring tool breakage during unmanned machine operations resulted in a discussion of engineering details concerning different types of sensors used for automatic shutdown of unattended machines. The Atsugi Factory, in addition to producing milling machines, also manufactures numerically controlled electrical discharge machines (EDMs). A competitor's EDM is in use in APL's Machine Shop. The technical discussions were very useful, generating a mutual understanding of performance and feature requirements that could affect APL's future machine tool procurement. The Atsugi Factory was cleverly automated and was very efficient. Figure 7 shows the layout of the Makino machining complex, a state-of-the-art automated machine-tool factory using a flexible manufacturing system (one-of-a-kind or multiple units) based on the OSI approach. The computer-integrated system, including automatic tool transfer, machining, warehousing, and dynamic scheduling and control is a good demonstration

Figure 5—Automated unit testing at Fujitsu, with each stage of the manufacturing process using electronic controls and sensors to assure quality.

Figure 6—Automated component insertion at Fujitsu. Robotic component insertion into printed circuit boards is accomplished with a minimum of human intervention.

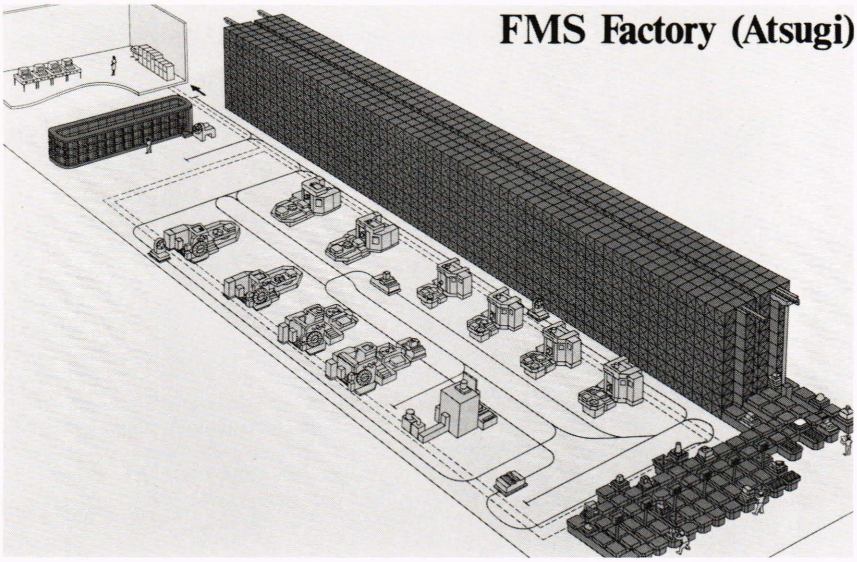

Figure 7—Layout of the Makino machining complex. The automatic warehouse, work carriers, tool carriers, work set stations, automatic tool room, and the programming processing system are shown.

of OSI. The quality and characteristics of the Makino Plant may explain why the Japanese have done so well in both the electronic and machine tool manufacturing product areas.

CONCLUSION

Combining and comparing the present European and U.S. major activities in OSI and CIM with my recent observations in Japan indicate that the world's advanced technological countries are integrating their activities at a rapid pace. Under the ISO standardization, common worldwide standards are being developed to accelerate the growth of computer-based information exchange.[3] OSI, based on the seven-layer model for manufacturing communication networks (Fig. 2), will probably be a basic international standard within the next two years. The power of the computer is resulting in worldwide unification of countries in the field of industrial automation.

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