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Introduction to e-Manufacturing

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97.1 Introduction

For the past decade, the impact of web-based technologies has added "*velocity*" to the design, manufacturing, and aftermarket service of a product. Today's competition in manufacturing industry depends not just on lean manufacturing but also on the ability to provide customers with total solutions and life-cycle costs for sustainable value. Manufacturers are now under tremendous pressure to improve their responsiveness and efficiency in terms of product development, operations, and resource utilization with a transparent visibility of production and quality control. Lead times must be cut short to their extreme extent to meet the changing demands of customers in different regions of the world. Products are required to be made-to-order with no or minimum inventory, requiring (a) an efficient information flow between customers, manufacturing, and product development (i.e., plant floor, suppliers, and designers), (b) a tight control between customers and manufacturing, and (c) near-zero downtime of the plant floor assets. Figure 97.1 summarizes the trends in manufacturing and function of predictive intelligence as an enabling tool to meet the needs [1–4].

With emerging applications of Internet and tether-free communication technologies, the impact of e-intelligence is forcing companies to shift their manufacturing operations from the traditional factory integration philosophy to an e-factory and e-supply chain philosophy. It transforms companies from a local factory automation to a global enterprise and business automation. The technological advances for achieving this highly collaborative design and manufacturing environment are based on multimedia-type information-based engineering tools and a highly reliable communication system for enabling distributed procedures in concurrent engineering design, remote operation of manufacturing processes, and operation of distributed production systems. As shown in Figure 97.2, e-manufacturing fills the gaps existing in the traditional manufacturing systems. The gaps between product development and supply chain consist of lack of life-cycle information and lack of information about supplier capabilities. Hence, designers, unless with years of experience, work in a vacuum, design the product according to the specification given, and wait for the next step. Most of the time, the design made according to specifications is realized to be infeasible for manufacturing with suppliers' machinery. As a result, lead times become longer. Similarly, for instance, because of the lack of information and synchronization between suppliers

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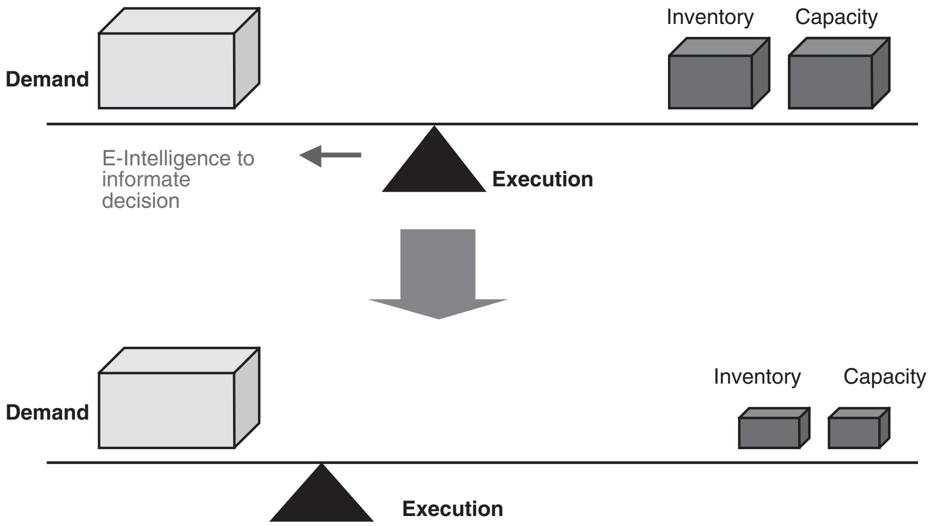

FIGURE 97.1 The transformation of e-Manufacturing for unmet needs.

and assembly plants, just-in-time manufacturing and on-time shipment become possible only with a substantial amount of inventory whereas with e-manufacturing, real-time information regarding reliability and status of supplier's equipment will also be available as a part of the product quality information. With these information and synchronization capabilities, less and less inventory will be necessary contributing to the profitability of the enterprise.

97.2 e-Manufacturing: Rationale and Definitions

e-Manufacturing is a transformation system that enables the manufacturing operations to achieve predictive near-zero-downtime performance as well as to synchronize with the business systems through the use of web-enabled and tether-free (i.e., wireless, web, etc.) infotronics technologies. It integrated information and decision-making among data flow (of machine/process level), information flow (of factory and supply system level), and cash flow (of business system level) [5–7]. e-Manufacturing is a business strategy as well as a core competency for companies to compete in today's e-business environment. It is aimed to complete integration of all the elements of a business *including suppliers, customer service network, manufacturing enterprise, and plant floor assets* with connectivity and intelligence brought by the web-enabled and tether-free technologies and intelligent computing to meet the demands of e-business/e-commerce practices that gained great acceptance and momentum over the last decade. e-Manufacturing is a transformation system that enables e-Business systems to meet the increasing demands through tightly coupled supply chain management (SCM), enterprise resource planning (ERP), and customer relation management (CRM) systems as well as environmental and labor regulations and awareness, (Figure 97.3) [4–7].

e-Manufacturing includes the ability to monitor the plant floor assets, predict the variation of product quality and performance loss of any equipment for dynamic rescheduling of production and maintenance operations, and synchronize with related business services to achieve a seamless integration between manufacturing and higher level enterprise systems. Dynamically updated information and knowledge about the capabilities, limits, and variation of manufacturing assets for various suppliers guarantee the best decisions for outsourcing at the early stages of design. In addition, it enables customer orders autonomously across the supply chain, bringing unprecedented levels of speed, flexibility, and visibility to the production process reducing inventory, excess capacity, and uncertainties.

The intrinsic value of an e-Manufacturing system is to enable real-time decision making among product designers, process capabilities, and suppliers as illustrated in Figure 97.4. It provides tools to access

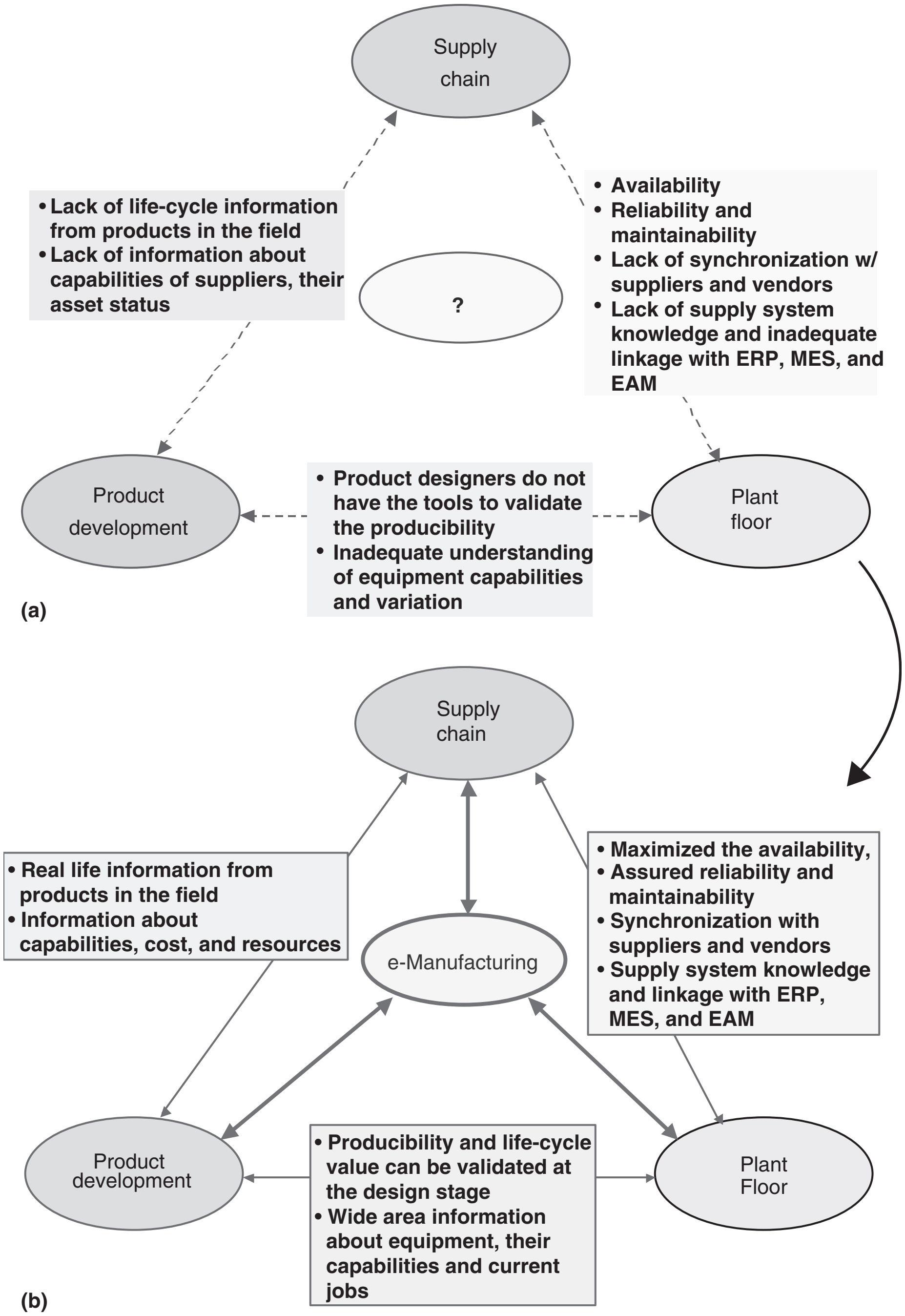

FIGURE 97.2 The transformation of e-Manufacturing for unmet needs.

life-cycle information of a product or equipment for continuous design improvement. Traditionally, product design or changes take weeks or months to be validated with suppliers. With the e-Manufacturing system platform, designers can validate product attributes within hours using the actual process characteristics and machine capabilities. It also provides efficient configurable information exchanges and synchronization with various e-business systems.

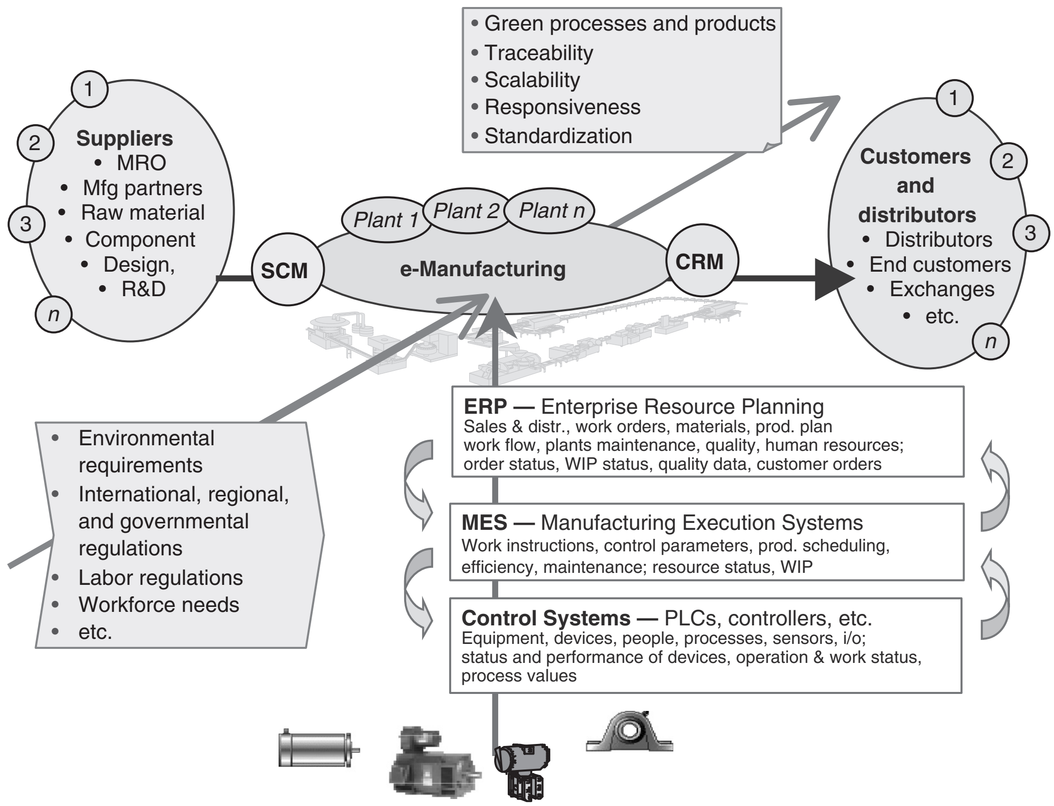

FIGURE 97.3 Integration of e-Manufacturing into e-Business systems to meet the increasing demands through tightly coupled SCM, ERP, and CRM systems as well as environmental and labor regulations and awareness.

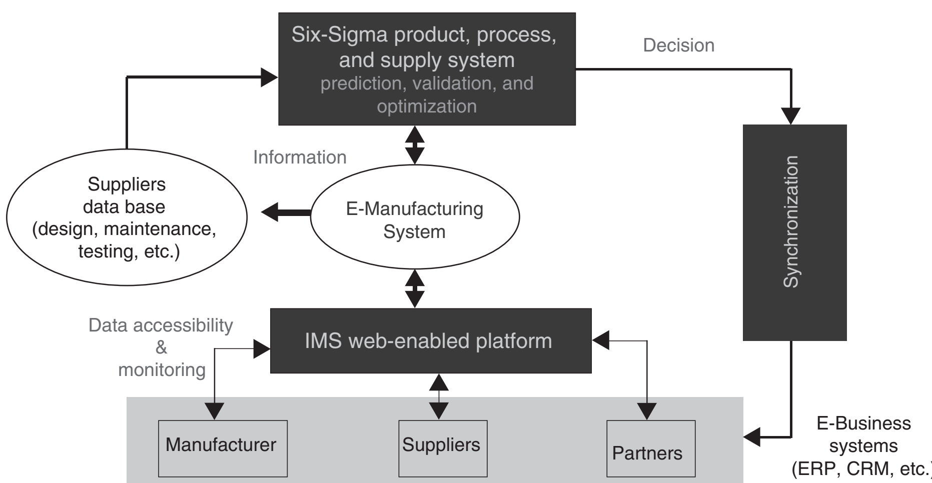

FIGURE 97.4 Using e-Manufacturing for product deign validation.

97.3 e-Manufacturing: Architecture

Currently, Manufacturing Execution Systems (MES) enable the data flow among design, process, and manufacturing systems. The ERP systems serve as an engine for driving the operations and the supply chain systems. However, the existing structure of the ERP and MES cannot *informate* (i.e., communicate the information in real-time) the decision across the supply chain systems. The major functions and objectives of e-Manufacturing are: (1) enable an only handle information once (OHIO) environment; (2) predict and optimize total asset utilization in the plant floor; (3) synchronize asset information with supply chain network; and (4) automate business and customer service processes. The proposed e-manufacturing architecture in this position paper addresses the above needs.

To address these needs, an e-Manufacturing system should offer comprehensive solutions by addressing the following requirements: (1) development of intelligent agents for continuous, real time, remote, and distributed monitoring of devices, machinery, and systems to predict machine's performance status (health condition) and to enable capabilities of producing quality parts; (2) development of infotronics platform that is scalable and reconfigurable for data transformation, prognostics, performance optimization, and synchronization; and (3) development of virtual design platform for collaborative design and manufacturing among suppliers, design, and process engineers as well as customers for fast validation and decision making. Figure 97.5 illustrates the proposed e-Manufacturing architecture and its elements [5–7].

Data gathering and transformation: This has already been done at various levels. However, massive raw data are not useful unless it is reduced and transformed into useful information format (i.e., XML) for responsive actions. Hence, data reconfiguration and mining tools for data reduction, representation for plant floor data

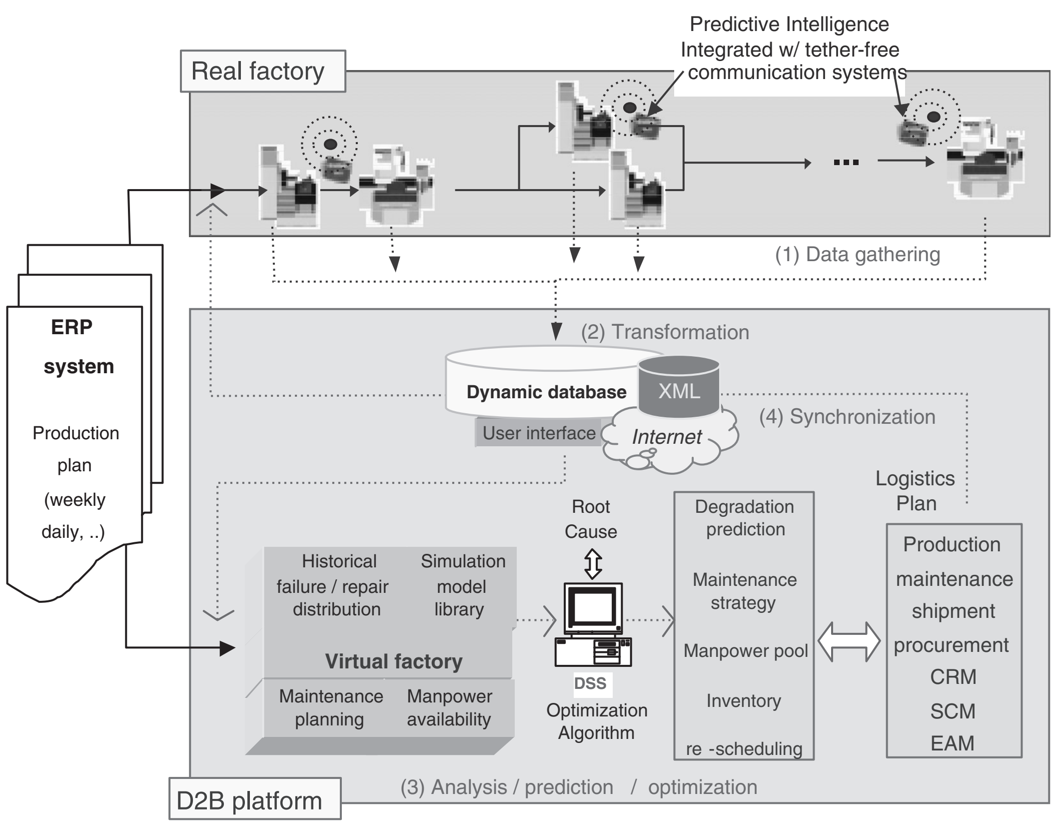

FIGURE 97.5 An e-Manufacturing architecture that comprises (1) and (2) data gathering and transformation, (3) prediction and optimization, and (4) synchronization [5].

need to be developed. An infotronics platform, namely, Device-to-Business (D2B™) has been developed by the Intelligent Maintenance Systems (IMS) Center. To make pervasive impacts to different industrial applications, existing industrial standards should be used (i.e., IEEE 802.xx standard committees, MIMOSA, etc.)

Prediction and optimization: Advanced prediction methods and tools need to be developed in order to measure degradation, performance loss, or implications of failure, etc. For *prediction* of degradation on components/machinery, computational and statistical tools should be developed to measure and predict the degradation using intelligent computational tools.

Synchronization: Tools and agent technologies are needed to enable autonomous business automation among factory floor, suppliers, and business systems. Embedded intelligent machine infotronics agent that links between the devices/machinery and business systems and enables products, machinery, and systems to (1) learn about their status and environment, (2) predict degradation of performance, (3) reconfigure itself to sustain functional performance, and (4) informate business decisions directly from the device itself [1–7].

Under this architecture, many web-enabled applications can be performed. For example, we can perform remote machine calibration and experts from machine tool manufacturers can assist users to analyze machine calibration data and perform prognostics for preventive maintenance. Users from different factories or locations can also share this information through these web tools. This will enable users to exchange high-quality communications since they are all sharing the same set of data formats without any language barriers.

Moreover, by knowing the degradation of machines in the production floor, the operation supervisor can estimate their impacts to the materials flow and volume and synchronize it with the ERP systems. The revised inventory needs and materials delivery can also be synchronized with other business tools such as CRM system. When cutting tools wear out on a machining center, the information can be directly channeled to the tool providers and update the tool needs for tool performance management. In this case, the cutting tool company is no longer selling cutting tools, but instead, selling cutting time. In addition, when the machine degrades, the system can initiate a service call through the service center for prognostics. This will change the practices from MTTR to MTBD (mean time between degradation) [10–13]. Figure 97.6 shows an integrated e-Manufacturing system with its elements.

97.4 Intelligent Maintenance Systems and e-Maintenance Architecture

Predictive maintenance of plant floor assets is a critical component of the e-Manufacturing concept. Predictive maintenance systems, also referred to as e-Maintenance in this document, provides manufacturing, and operating systems with near-zero downtime performance through use and integration of (a) real-time and smart monitoring, (b) performance assessment methods, and (c) tether-free technologies. These systems can compare a product's performance through globally networked monitoring systems to shift to the degradation prediction and prognostics rather than fault detection and diagnostics. To achieve maximum performance from plant floor assets, e-maintenance systems can be used to monitor, analyze, compare, reconfigure, and sustain the system via a web-enabled and infotronics platform. In addition, these intelligent decisions can be harnessed through web-enabled agents and connect them to e-business tools (such as customer relation management systems, ERP systems, and e-commerce systems) to achieve smart and effective service solutions. Remote and real-time assessment of machine's performance requires an integration of many different technologies including sensory devices, reasoning agents, wireless communication, virtual integration, and interface platforms [14–17].

Figure 97.7 shows an intelligent maintenance system with its key elements. The core-enabling element of an intelligent maintenance system is the smart computational agent that can predict the degradation or performance loss (Watchdog Agent™), not the traditional diagnostics of failure or faults. A complete understanding and interpretation of states of degradation is necessary to accurately predict and prevent failure of a component or a machine once it has been identified as a critical element to the overall production system. The degradation is assessed through the performance assessment methods explained in the previous sections.

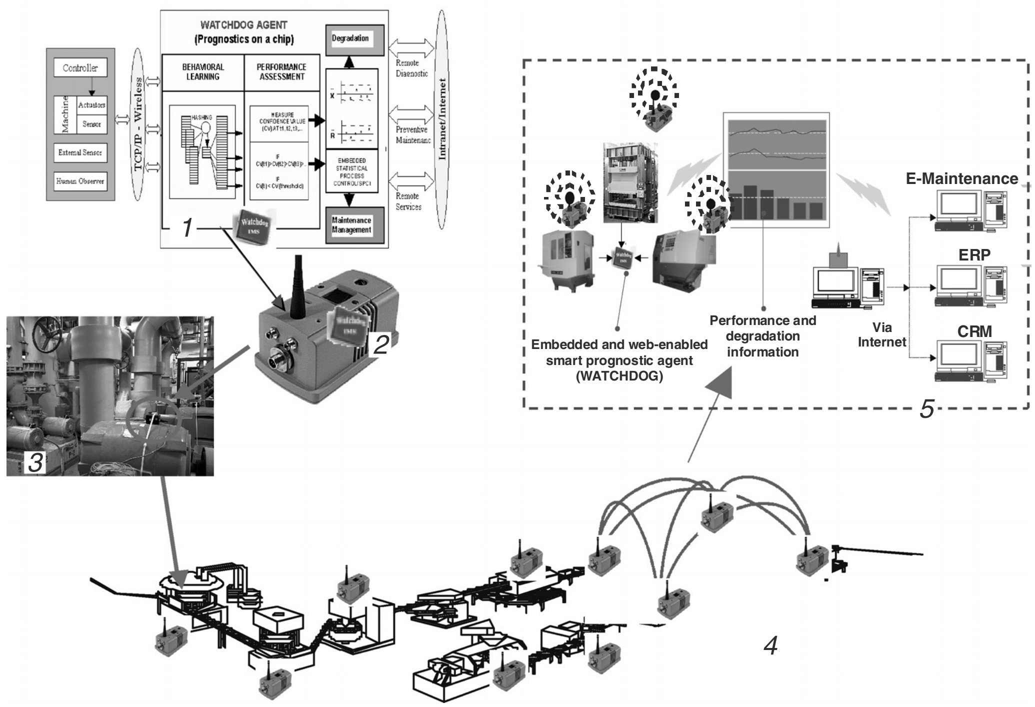

FIGURE 97.6 Various elements of an e-Manufacturing System: (1) data gathering and predictive intelligence-D2B™ platform and Watchdog Agent™, (2)–(4) tether-free communication technologies, and (5) optimization and synchronization tools for business automation.

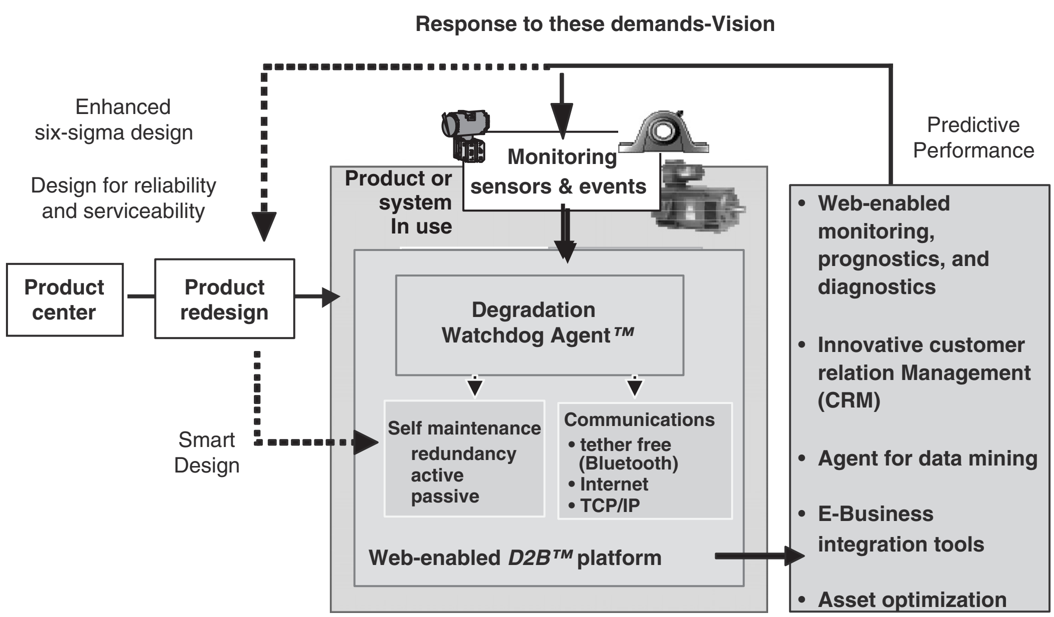

FIGURE 97.7 An Intelligent e-Maintenance System.

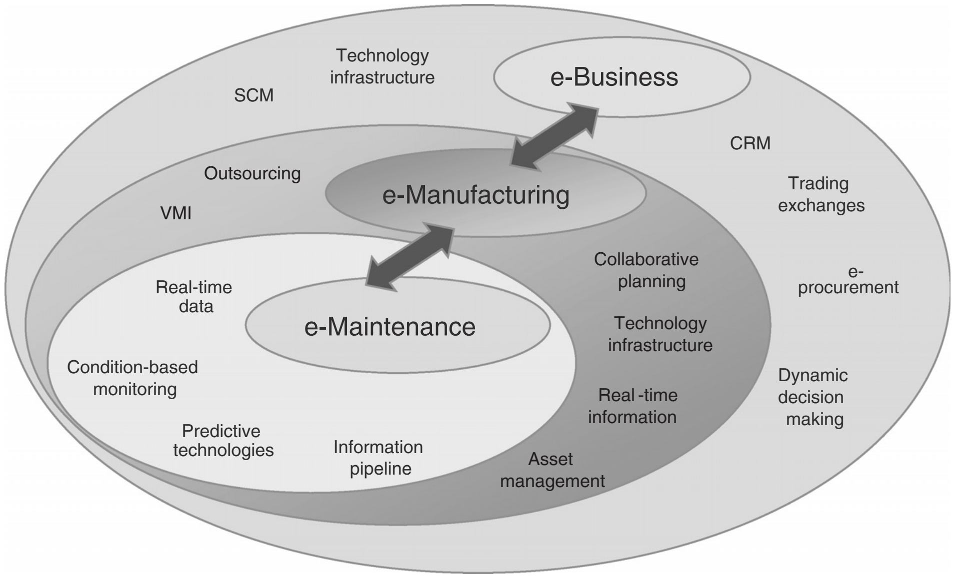

FIGURE 97.8 e-Manufacturing and Its Integrations with e-Maintenance and e-Business.

A product's performance degradation behavior is often associated with multi-symptom-domain information cluster, which consists of degradation behavior of functional components in a chain of actions. The acquisition of specific sensory information may contain multiple behavior information such as nonlinear vibration, thermal or materials surface degradation, and misalignment. All of the information should be correlated for product behavior assessment and prognostics.

97.5 Conclusions and Future Work

This position paper introduced an e-Manufacturing architecture, and outlined its fundamental requirements and elements as well as expected impact to achieve high-velocity and high-impact manufacturing performance. Web-enabled and infotronics technologies play indispensable roles in supporting and enabling the complex practices of design and manufacturing by providing the mechanisms to facilitate and manage the integrated system discipline with the higher system levels such as SCM and ERP. E-Maintenance is a major pillar that supports the success of the integration of e-Manufacturing and e-business. Figure 97.8 shows the integration among e-Maintenance, e-Manufacturing, and e-Business systems. If implemented properly, manufacturers and users will benefit from the increased equipment and process reliability with optimal asset performance and seamless integration with suppliers and customers.

In order to further advance the development and deployment of the e-Manufacturing system, research needs can be summarized as follows:

1. Predictive intelligence (algorithms, software, and agents) with a focus on degradation detection on various machinery and products.
2. Mapping of relationship between product quality variation and machine and process degradation.
3. Data mining, reduction, and data-to-information-to-knowledge conversion tools.
4. Reliable, scalable, and common informatics platform between devices and business, including implementation of wireless, Internet, and Ethernet networks in the manufacturing environment to achieve flexible and low-cost installations and commissioning.
5. Data/information security and vulnerability issues at the machine/product level.
6. Distributed and web-based computing and optimization and synchronization systems for dynamic decision making.

7. Education and training of technicians, engineers, and leaders to make them capable of pacing with the speed of information flow and understanding the overall structure.
8. Develop a new enterprise culture that resonates the spirit of e-manufacturing.

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