SMART PROCESS MANUFACTURING – A VISION OF THE FUTURE

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There are a number of forces driving the U.S. chemical industry in the 21st century, including shareholder return, globalization, efficient use of capital, faster product development, minimizing environmental impact, new ways to realize economic value, improved and more efficient use of research, workforce transitions and efficient use of people. As the chemical industry responds to these forces and tries to redefine and achieve these goals, it is investigating the expanded use and application of new computational technologies employed in areas such as modeling, computational chemistry, design, control, instrumentation, and operations. The key technology driver over the past 20 years has been the continuing advances in digital computing. The 100-fold increase in computer speed each decade, the concomitant reductions in the cost of storing data, the significantly increased capability of high fidelity multiscale models, the advances in networking and connectivity and the expansive potential of integration regardless of geographical location have tremendously increased the scope of computer applications in chemistry and chemical engineering. The new paradigm that encompasses the process systems engineering (PSE) topics mentioned above is *smart process manufacturing*, which will require the development of computational research environments to support such activities, also known as *cyberinfrastructure*.

Smart process manufacturing (SPM) refers to a design and operational paradigm involving the integration of measurement and actuation, safety and environmental protection, regulatory control, high fidelity modeling, real-time optimization and monitoring, and planning and scheduling. This framework provides the basis for a strong predictive and preventive mode of operation with a substantially more rapid incident-response capability. Driving towards zero incidents and zero-emissions in the smart manufacturing paradigm recognizes that energy usage, energy production, safety, and environmental impact are inextricably linked.

What are the attributes of SPM? SPM systems have intelligent actions and possess a learning process to decide appropriate actions including the ability to actually implement that intelligent action. SPM systems are self-aware and proactive. They can adapt to new situations or perturbations (abnormal situations), and, by using feedback, smart systems can adapt or evolve for better performance. People are essential to SPM but play a more significant role than before. SPM systems integrate human expertise in new ways that allow for much more strategic, real-time decision making. In SPM pertinent information related to system performance is available, accessible, timely and appropriate and is understandable to the various parties or functions that need the information.

Plant assets are integrated and self-aware (via sensors) of their state. Assets may be many things: plant, equipment, knowledge, experience, models, or data properties. Field devices have CPU and sensors, recognize their condition, and publish that information so they or other devices can take appropriate actions. A typical device receives, processes, translates, and publishes or shares information. Specific process status variables can be related to larger business issues (profitability, zero incidents, zero emissions, etc.), i.e., beyond specific process and cross-industry impacts. Sustainable smart manufacturing includes reuse, with a life-cycle view of products and processes. A minimum environmental footprint (energy, water, emissions) is desirable. Human resources (people) have to be knowledgeable, trained, empowered, connected (via cyber initiatives), and able to adapt/improve the system’s performance. Figure 1 depicts a functional framework for SPM that has been developed by PSE researchers from industry and academia.

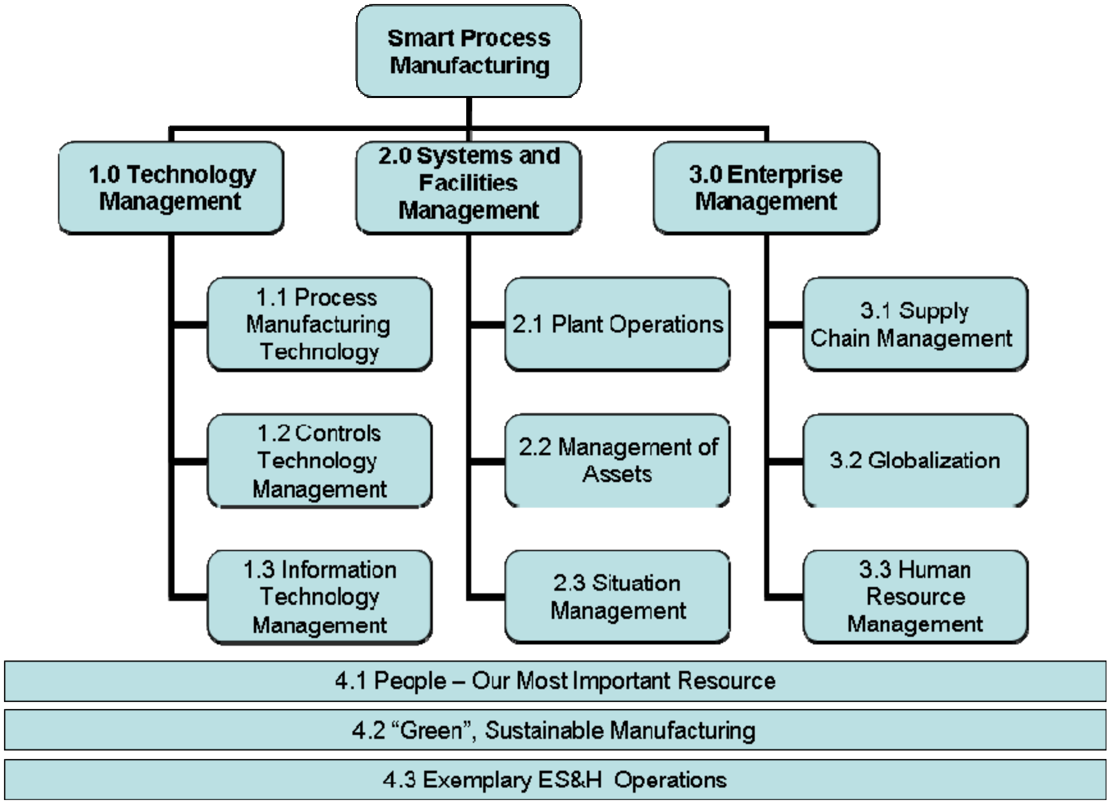

Figure 1. The Smart Process Manufacturing functional model provides a hierarchical, logical framework for analysis of technology research and development requirements.

There are a number of key elements in smart process manufacturing as shown in Figure 1, which are discussed below.

Technology management addresses the determination of all the technological resources required to sustain, protect, and improve operations of the manufacturing enterprise. Typically, many types of technology are involved, and they act as enablers for both local and cross-enterprise/global issues: specialized processes and systems, tools, control systems, modeling capabilities, and the people whose knowledge and practical expertise make the processing successful. *Process manufacturing technology* encompasses the capability to transform raw materials into useful products. This includes transformation of materials, intensification of materials, molecular transformation, and other processing and packaging. With *controls technology management*, a sense, analyze and control environment ensures that all critical parameters operate within control limits, providing needed information and communications, and respond properly to abnormal conditions.

Further, the analysis of existing conditions can predict and proactively respond to a changing environment. *Information technology management* ensures that the right information is available, at the right time, and in the right format. This includes the provision of a secure environment that protects the interests of the company and the individuals and is compliant with all relevant regulations.

Systems and facility management encompasses the oversight and assurance that the assets of the company and the enterprise are available to execute all needed functions within the defined operating envelope. *Plant operations* include the execution of processes through multiple molecular, chemical, and physical transformations to produce the desired products. *Management of assets* involves the optimization of asset procurement, retirement, liquidation, and all other aspects to ensure the appropriate assets are available to meet the corporate objectives. In the SPM environment, assets will have the capacity to self-evaluate their individual and integrated roles and consider sustainability metrics. *Situation management* is the detection, situational awareness, evaluation and understanding of existing conditions compared to the normal envelope for conduct of operations. In the event of deviations from the normal conduct of operations, the assessment includes the evaluation of options and the determination of best response.

Enterprise management takes an integrated view of all enterprise activities, from process loops (perhaps in many facilities within single company) up through strategic direction setting. It includes multiple plants working together, interaction between companies plus the global view, and integration and optimization of processing and business functions. Business planning determines if this is the right business/product mix and how we should evolve our products and technologies. *Supply chain management* is the coordination and management of the supply base to assure that the right components come together at the right place, at the right time, and in such a way that a useful product results all of the time. This includes the satisfaction of all business, technical, cultural, and regulatory obligations for every element of the supply network. *Globalization* is concerned with decisions concerning location of operations, satisfaction of requirements for operation in the global community, balance of operations to assure that corporate goals are not compromised, and cultural issues such as language and traditions. There is a growing cross-industry perspective, including environmental concerns, as well as investment and R&D and product portfolio management. *Human Resource Management* addresses the assurance of ready and sustained staffing to meet the needs today and at any point in the future. This includes trends and staffing projections, education, training and life-long learning, work rules, and compensation. In an SPM environment, people are critical in setting strategies and assuring that those strategies are carried out. A significant aspect of valuing knowledgeable workers is the capture and reuse of their knowledge and experience, in order to improve the overall plant performance.

Green, Sustainable Manufacturing in an SPM facility make environmentally sound practices become automatic, which are part of the business drivers that guide all operations. The benefits of improved environmental performance on manufacturing operations can extend beyond improving the quality of the environment and need to take a life cycle perspective. *Exemplary ES&H Operations* beyond ES&H regulatory compliance is a prominent business driver to "zero-incident" operations, where the goal is to have no negative impact on personnel, surrounding communities, or the environment in general. Smart plants proactively prevent environmental, health, and safety problems while they at the same time seize opportunities to optimize operational and financial performance and monitor environmental conditions, and any aberrations are immediately noted and mitigated.

The above framework defines a research agenda that can provide a coherent and orchestrated effort to achieve the vision of smart process manufacturing. To that end an NSF-sponsored workshop was held on April 21-22, 2008 under a grant to the CACHE Corporation. For more details on the research agenda and how the PSE community can participate, see http://www.oit.ucla.edu/nsf%2Devo%2D2008/.