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 advancements 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*.

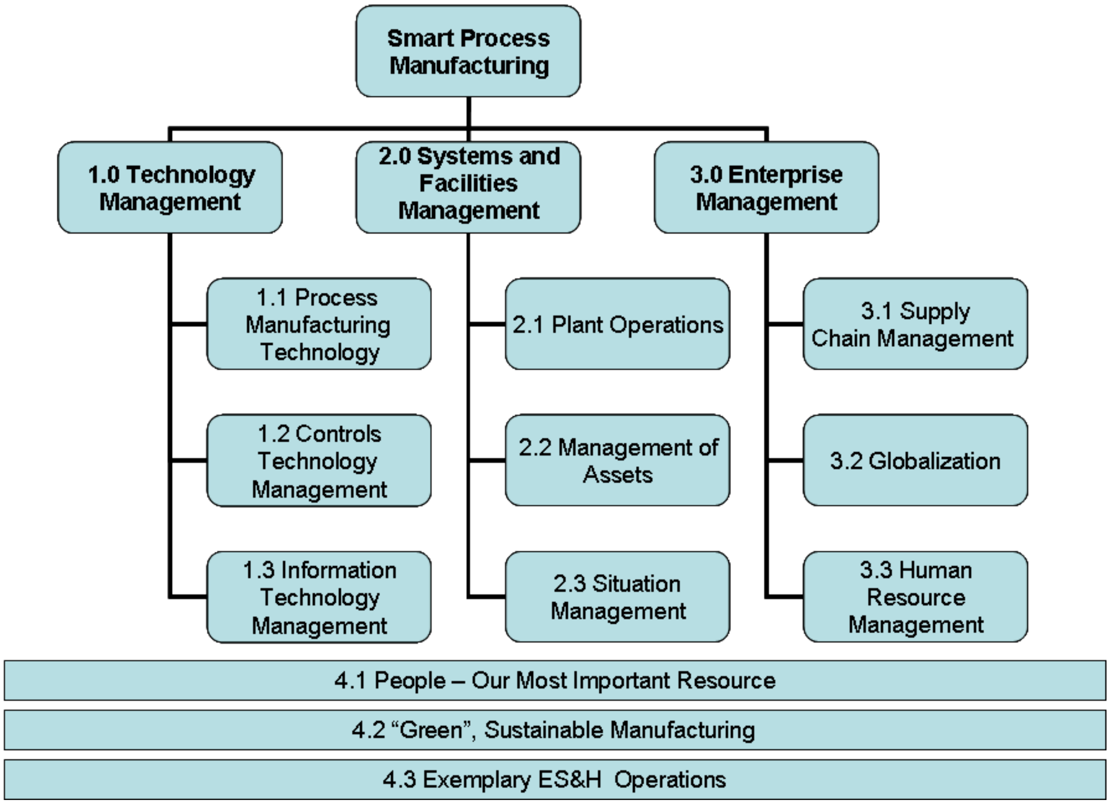
In April 2008, a workshop comprised of industrial practitioners and academic researchers in process systems engineering was held at the NSF headquarters in Arlington, VA. The objective of the Smart Process Manufacturing workshop was to provide much-needed focused collaboration through facilitated assessment and creation of the base foundation for a roadmap. The workshop was sponsored by the National Science Foundation under a grant to the CACHE Corporation on behalf of the Smart Process Manufacturing Engineering Virtual Organization (SPM-EVO). The paper is drawn from the workshop documentation and reflects the collective views of the industrial and academic participants.

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. SPM is the enterprise-wide application of advanced technologies, tools, and systems, coupled with knowledge-enabled personnel, to plan, design, build, operate, maintain, and manage process manufacturing facilities. This framework provides the basis for a strong predictive and preventive mode of operation with a substantially more rapid incident-response capability, ensuring safe and health-conscious operations. Driving toward 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 and a minimum environmental footprint (energy, water, emissions). Human resources (people) have to be knowledgeable, trained, empowered, connected (via cyber initiatives), and able to adapt/improve the system's performance.

The Figure below depicts a functional framework developed by PSE researchers from industry and academia for discussing SPM and how it is differentiated from current practices.



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

Technology Management

Technology management addresses the determination of all the technological resources required to sustain, protect, and improve operations of the manufacturing enterprise, and includes the subareas of process manufacturing technology, control technology management, and information technology management. Typically, many types of technology are involved, and they act as enablers for both local and cross-enterprise/global issues. Key components are specialized processes and systems, tools, control systems, modeling capabilities, and the people whose knowledge and practical expertise make the processing successful.

Increased use of technology has led to mountains of data and associated data management problems. However, the relationships of data to underlying processes and material properties are not well understood; the data are not integrated between systems and so important data are not fully exploited. The challenge is to understand relevant technologies and their associated data well enough to target acquiring and processing only the needed data. There is, however, increasing use of models and efforts to grow their scope, interoperability, and applicability to production operations – not just design. Technology investment decisions tend to be made with too short-term a view, expecting a payoff too quickly. Operations decisions tend to be highly reactive instead of proactive.

Smart plants will be developed, designed, and operated using molecularly-informed engineering and will operate in a robust fashion. Models and all associated knowledge will be maintained and enriched as part of the plant's routine operation. Models will be developed to the level of detail needed, including multi-scale modeling to achieve the higher fidelity needed for some functions. Business goals will be directly translated into technology plans. This will enable flexibility of operations, robustness, agility, and the ability to change product streams quickly (especially in batch) or to make grade changes (for continuous processing).

Systems and Facility Management

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. Subareas include plant operations, asset management, and situation management.

One of the largest barriers to continuous improvement is the need to maintain current production and not change anything. There needs to be more of a balance between keeping the plant at constant operations vs. improving the profitability. The application of computing power to analyzing system performance has been limited to personal computers. Applying advanced technologies such as model predictive control and real-time optimization has been successful for many continuous petrochemical plants but is not applied as much to batch processes and more specialized products. There are concerns about the cost of supporting and maintaining such technologies. An awareness of the value of computing technology does not uniformly exist in process manufacturing and there needs to be more meaningful metrics for valuing different technologies.

Smart Process Manufacturing systems and facilities will be managed for optimum availability and performance. Continuous sensing and control, at the appropriate level based on the need, will assure safe, optimized performance with the realization of zero incidents and zero emissions. Models will accurately predict plant performance and will support automated and computer-assisted decision-making for assurance of operation within the envelope for safety, environmental responsibility, and cost optimization.

Enterprise Management

Enterprise management takes an integrated view of all enterprise activities, from process loops (perhaps in many facilities within a 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. Subareas include supply chain management, globalization, and human resource management. Business planning determines the right business/product mix and how products and technologies should evolve. Achieving smart manufacturing capabilities in the process manufacturing industry will require a much higher level of integration, flexibility, and adaptability in enterprise management than exists today. Although many business functions and many manufacturing functions have been integrated in large, complex software systems (ERP/ERM, PDM, etc.), there is still a lack of interoperability of business and technical functions across the enterprise. Furthermore, there is no direct connection between the manufacturing production goals and the larger business objectives of the enterprise. As the enterprise extends its relationship with supplier partners, there is a lack of consistent understanding of quality, safety and environmental standards across the supply chain, especially on a global basis. In addition, as companies become more closely integrated with their supply network and global partners, there is still a reluctance to share information freely and risk losing the company's intellectual property.

Another challenge to enterprise management is lost expertise as the industry's aging workforce has the potential of creating a loss of critical knowledge by attrition. Companies find it difficult to acquire needed skill sets and hard to attract skilled workers for some jobs, such as facility management. University curricula are not producing sufficient numbers of graduates with the needed practical and technical skills, so there is an ongoing dialogue on how U.S. universities should address this need.

In the future enterprise management tools, cost-effective technologies and cross-industry standard practices will enable U.S. manufacturing companies to successfully collaborate and compete in the global economy. Beneficial technologies and productivity improvements will spread across global industry via the development of industry-wide standards. Interoperability of systems will enable use of the complete set of plant and enterprise data in decision-making. ES&H concerns will be effectively addressed by collective cross-industry practices on a global basis, enabled by the better tools and technologies that comply with industry standards. Cybersecurity technology will automatically provide protection of intellectual property, and liability and trust issues will be resolved to the extent that cross-industry relationships are encouraged. The cost-effective, flexible and adaptive operation that results from these improved technologies will ensure U.S. competitiveness in the global market.

Green Sustainable Manufacturing

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 the need to take a life cycle perspective.

Exemplary Environmental, Safety, and Health Operations

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.