Smart Manufacturing as a Real-Time Networked Enterprise and a Market-Driven Innovation Platform

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Role/Viewpoint of panelist or organization
The Smart Manufacturing Leadership Coalition (SMLC) is a non-profit organization comprised of manufacturing practitioners, suppliers and technology companies; manufacturing consortia; universities; government agencies, laboratories and regional consortia committed to improving U.S. manufacturing competitiveness through the comprehensive adoption of Smart Manufacturing (SM) systems and the application of manufacturing intelligence across the entire manufacturing ecosystem (supply chains, complete product lifecycles, multiple industries, and small, medium and large enterprises). The SMLC’s implementation approach is to build scaled, shared and networked information technology infrastructure called the Smart Manufacturing (SM) Platform to significantly lower the barriers of cost and complexity for applying data analytics, modeling and simulation to manufacturing operations, orchestrate data and computation-based information into real-time action, and facilitate access and innovation through an open architecture approach.

Unique to SMLC are implementation objectives supported through collaborative participation by industry, government, and universities. Cross industry involvement covers defense and commercial interests and continuous, batch and discrete structures. The SMLC understands the value in identifying key manufacturing challenges and building the SM Platform around tangible business objectives, and has developed an SM Platform implementation roadmap that is keyed off of industry test bed sites and situations. The SMLC is currently organized around four cross industry workgroups – (1) test beds and industry problems, (2) the SM Platform infrastructure, standards practices and security, (3) industry driven business and value development for the platform, and (4) workforce, training and skills development. In coordination, these four workgroups are providing the collaborative, cross industry guidance and oversight of the Platform architecture, structure, business, and operations model. By definition, the SM Platform is industry driven (made by manufacturers for manufacturers and technology developers).

Visionary goals, however, motivate the SMLC. The SMLC is committed to substantially lowering the barriers to pervasive deployment of SM systems that make all information and intelligence about the manufacturing process available when it is needed, where it is needed, and in the form that it is needed. The SM Platform is being implemented to mitigate risks and accelerate testing and adoption of new and next generation technologies. Key goals are infusion of intelligence into our manufacturing base beyond “one-off” solutions and the ability to modernize, innovate and adopt disruptive approaches, both of which have been severely limited by a lack of infrastructure. With new industry infrastructure, modernization can become an affordable continuum and aggressive, bold new manufacturing technologies and designs will be in reach. Envisioned is a 21st century SM enterprise (from suppliers, OEMs, and companies to supply chains, and across industries) that is fully integrated, knowledge-enabled, and model rich. Such visibility across the enterprise (internal and external) would radically improve the ability for operating actions to be determined and executed, proactively applying the best possible information and a wide range of performance metrics. If broadly adopted, SM systems become one of the best examples of manufacturing technology with the comprehensive scope to achieve transformational impact in economic growth, manufacturing innovation, global competitiveness and homeland security.
Views on Smart Manufacturing

**Smart Manufacturing and the Commitment to a Comprehensive Systems Approach**

The SMLC has defined SM as the sophisticated practice of generating and orchestrating the use of data-driven manufacturing intelligence using multiple real-time SM Systems pervasively deployed throughout all operating layers (i.e. control, automation, maintenance/reliability, tradeoff decisions, operations, logistics, risk, business management, etc.) across the entire factory and supply chain. SM integrates network-based data and information that comprises the real-time understanding, reasoning, design, planning and management of all aspects of the manufacturing and supply chain enterprise, i.e. manufacturing intelligence. This is achieved through pervasive, comprehensive and orchestrated use of advanced sensor-based data analytics, modeling and simulation, and integrated performance metrics constructed for real-time action. Manufacturing intelligence takes the form of (1) a much deeper behavioral understanding of the manufacturing process through modeling and analysis, (2) new capacity to observe and take action on integrated patterns of operation through networked data, information, analytics, and metrics, (3) new insights for manufacturing innovation through a broader base of innovators, and (4) a significantly greater ability to reuse and repurpose integrated practice with the physical, human, information, sustainability, economic, social, and regulatory systems through common infrastructure. SM’s strength is in applying manufacturing intelligence by taking a comprehensive design to manufacturing life cycle approach illustrated in **Figure 1**.

![SMLC Commitment to a Comprehensive Approach](Image)

**Figure 1**

SMLC has organized itself to deliver industry-driven, networked based infrastructure optimized for a comprehensive design and manufacturing systems approach and designed to orchestrate the actionable use of data and models to address integrated enterprise performance objectives, plant modernization through information, and rapid evaluation and insertion of new technologies. The focus has been on infrastructure that makes it possible to bridge control and automation, business, workforce, measurement and resiliency systems. The SMLC is also focused on an “open” smart manufacturing technology platform for collaborative industrial
networked information applications. Small, medium and large companies can access the various kinds of levels of modeling and data analytic technology when needed, based on company-specific objectives. The open architecture is also designed to facilitate a broad base of contributors to application solutions, building a market value approach to new applications and innovation. The SMLC has already undertaken planning the sustainability of the systems modeling methodology and open platform infrastructure.

**Smart Manufacturing Open Platform Infrastructure**

The SM Platform (prototype in development) comprises an open architecture and precompetitive software development and management cloud environment that integrates the components required to assemble customized systems on a common, standards-based deployment infrastructure. At its technical core, the SM Platform supports systems that can define what data is collected and shared, how computationally-generated results can interface with operating equipment and automation infrastructures and how results are displayed in an actionable form to operators, engineers, and managers. The SM Platform’s open architecture includes an app store, workflow toolkits, and makes resources easily and openly available through providing infrastructure to small, medium and large companies at little or no cost.

An open architecture approach sets the stage for secure community-based architecture and applications development with value-add and specialized security through private and hybrid cloud services. Workflow as a Service (WFaaS) has been established as a foundational construct. WFaaS is foundational in orchestrating dynamic, adaptive, actionable decision-making through the contextualization and understanding of data across the enterprise “compartments” and throughout the design and manufacturing process. Workflow opens the ability to constrain data, define time, orchestrate the use of multi-vendor databases, software environments, interface with proprietary operations platforms and solve a specific problem using workflow code that defines a particular function. A workflow function gives data context and makes data useful through timely application. Workflow is foundational as the basis for managing “real-time” across a wide range of time scales based on objective. It is the structural basis for separating data from application, providing an effective cyber physical interface for real-time “cloud”/operation integration and it is the basis for pre-competitive reusability and competitive customization.

The SM Platform emphasizes a venture model for technology infusion and commercialization that facilitates a sustainable business and financial roadmap through enabling a broad base of innovators such as third-party app developers to participate in an “App Store” community. The strength of the SM Platform is that it is IT provider and production technology agnostic, thereby making extreme sharing of apps and deployment capabilities possible while ensuring the interoperability between disparate factory and supplier IT provider platforms.

**Systems Modeling from Design to Manufacturing**

The principles of an Advanced Manufacturing Enterprise (AME) are inherently factored into the design of the SM Platform. JPL/NASA’s comprehensive, systems modeling approach integrated in the design of the open architecture SM Platform facilitates the execution of a model-based approach that extends model breadth beyond traditional CAD-based extensions to include integrated programmatic, risk, supply chain, environmental and other market features. In result, the system model can evolve as a full lifecycle construct from conceptual design through manufacturing and operation in a rapid fashion. Data from suppliers, as well as the factory floor, are integrated with models of product performance and manufacturing processes to produce significantly better-informed decisions and predictions of operational and business performance. With respect to the SM Platform, operational objectives are supported with Toolkit assemblies of customized real-time sensor and data-based workflows that include a library of workflows, workflow functions, and workflow apps at low cost, low barrier deployment. Real-time analytic, model, and simulation workflows provide decision support or insertion in control/automation schema; and accessible interoperable technology at the level of need.

Similarly, design models of materials and products can be used in planning and manufacturing. Integrated
Computational Materials Engineering (ICME) is a key principle incorporated into the SM Platform’s development. The SM Platform facilitates ICME in the form of using materials and product design models for source material selection and certification; in-production, real-time part and material qualification; pre- and post-production quality assurance and validation; and on-going sustainment. This is the case in the development of new products and systems, as well as, for the insertion of next-generation or replacement materials in legacy products or systems.

The SM Platform supports the development of an agile, distributed concurrent design methodology specifically for model-based design, executable at all stages of the lifecycle and a mechanism to identify, exercise, and evaluate emerging manufacturing technologies from research organizations, as model elements of larger-scale commercial system design emerge. As infrastructure, the SM Platform is designed for virtual test and analysis in early design phases using model representations in a free-market library available to qualified commercial entities. The concurrent design model, in addition to networked, data-driven manufacturing intelligence, dramatically reduces the cost and time of producing complex systems.

A Multi-Layer, Multi-Dimensional Infrastructure Approach

Pervasive deployment of architecturally consistent workflow applications creates the enterprise environment for manufacturing intelligence. The workflow foundation defines responses to changes and readily extends to include intelligent process monitoring, fault diagnosis, procedural synthesis, and resilient systems as more sophisticated tasks in an orchestrated workflow. Thus, workflow allows the level of sophistication that can be readily established for the needs of specific business objectives and company readiness. Figure 2 graphically describes this multi-layer problem space, and their relation to control and automation system information.

![Multi-Layered Smart Manufacturing Workflow Management](image)

**Figure 2**

**Portfolio of SM Addressable Problems**

The SMLC has identified a full range of new or untapped opportunities that have been identified across multiple manufacturing industries including oil and gas, chemical, metal, glass, pharmaceutical, automotive, aerospace, food, and defense (defined in Table 1). There are many examples of operational manufacturing intelligence opportunities for SM applications that have significant economic and performance benefits and are priority
interests by cross sections of companies across a number of industry segments. These opportunities exist at different operational layers – control, automation, operations enterprise, and supply chain management.

Table 1: Smart System Opportunities

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<td>Machine product management</td>
<td>Better management complex behaviors</td>
<td>Performance management global integrated decisions</td>
<td>Variability reduction</td>
<td>Design models in production</td>
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<td>Benchmarking machine-product interactions</td>
<td>Rapid qualification components products materials</td>
<td>Untapped enterprise degrees of freedom in efficiency, performance time</td>
<td>Risk and compliance management</td>
<td>In production product material produce ability</td>
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<td>Machine-power manage management</td>
<td>Integrated computational materials engineering</td>
<td>Business operational tradeoff decisions</td>
<td>Tracking traceability genealogy</td>
<td>New product, material technology insertion</td>
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<td>Adaptable machine configurations</td>
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<td>External partner integration into business process</td>
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Through the WfaaS architecture, each of the opportunity areas in Table 1 can be addressed through the orchestration of workflows that give data the necessary context in which actions can be executed manually or automatically in real-time to achieve a specific goal. SM workflows can interface with control and automation systems, and factory optimized proprietary workflows. The use of any models and simulations can be architected for computational tractability in a data-driven workflow framework designed to address specific performance objectives. Workflow as a web service offers a new and accessible capability for manufacturers building on regular cloud technology foundations.

References