CESMII
THE SMART MANUFACTURING INSTITUTE

The CESMII Story – A CTO Perspective

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Smart Manufacturing – by Jim Davis

The Clean Energy Smart Manufacturing Innovation Institute (CESMII) story begins with digitization, data, and manufacturing's transition to digital controllers, the first surge of AI and "expert systems," and the advent of modular modeling over 40 years ago. The coalescing of digital operations, modeling, and the internet into a comprehensive U.S. strategy called "Smart Manufacturing" can be traced back to 2006. The term "Smart Manufacturing" was coined at an NSF workshop considering a new (at that time) internet capability called 'cyberinfrastructure.'

With roots also in Enterprise Resource Planning (ERP), enterprise Key Performance Indicators (KPIs), and Internet Communications Technologies (ICT), Smart Manufacturing (SM) uses real-time data about resources, operations, and quality, at scale, to open new business and operational capabilities for making products. Today, SM defines a digital transformation (i.e., digitization to digitalization) for the industry that emphasizes scaled business collaborations, new ways to include a much greater diversity of manufacturers, new job skills and demands that engage a far greater and more diverse workforce, and essential new ways to address utilities, energy, materials, decarbonization, environmental sustainability, climate change, and public safety, that are not possible when companies act in isolation. It is the information-driven, event-driven, efficient, and collaborative orchestration of business, physical, workforce, and digital processes within plants, factories, and across the entire value chain. By managing from the factory floor to the supply chain, new precision product markets are better addressed, products are further optimized, material availability better assured, end-to-end quality assurance is enhanced, new business opportunities for manufacturers are exposed, and workforce innovation is unleashed.

SM starts at the factory floor where unit processes and machine operations make materials and products using advanced instrumentation and predictive, real-time management and control. Visualization, automation, robotics, and autonomy become a progression of capability and maturity with human and machine decision-making so that resources and the workforce can be used in smarter ways. Energy intensive industries like pulp and paper, iron and steel, cement, chemicals, oil and gas, and food and beverage all benefit directly from smart energy management systems.

Discrete manufacturing and assembly-based industries like aerospace and automotive will benefit from preventive maintenance for reducing maintenance costs, machine failures, and production downtime. Not only are energy, material quality, waste, and operational issues affecting supplied parts and materials for the individual factory addressed, but the effects cascade through thousands of small and medium companies in which the combined impact on energy productivity accumulates significantly.

Data by themselves do nothing; SM addresses where and how to use data with managed security including how to protect trade secrets, intellectual property, and personal privacy. SM's roots in AI, machine learning, modeling, applying domain knowhow with enterprise thinking, and IT provide the operational mechanisms to act at the interface of physical impact as well as scale to enterprise management. SM focuses on data and modeling for timely assessment, prediction, prevention, optimization, and action but with a macro impact approach that spans raw materials to the manufactured, assembled, packaged, and distributed products that are purchased and consumed globally. SM greatly expands the realm and scale of innovation beyond just physical side innovation with end-to-end management and control of physical assets, threading product quality assurance throughout an entire supply chain, moving from reactive to preventive and predictive operational management, and using people, data, and machines together in far better, more democratized, and more protected ways that can be extended throughout the industry. As a macro strategy, SM significantly impacts:

1. U.S. global manufacturing competitiveness, economic market share, and new revenue sources
2. Product and supply chain resilience
3. Essential industry-scaled strategies to address energy, resources, climate, decarbonization, safety, and contamination
4. Scaled requirements for greater data security, privacy, and ethics for a much broader, more diverse, and more involved manufacturing and workforce base

The Smart Manufacturing Institute – by Haresh Malkani

CESMII is the DOE-funded, public-private partnership that was formed to address and accelerate access to the full potential of Smart Manufacturing. Its focus is on industry strategies and the adoption of infrastructure, technologies, practice, and markets that no one company can address alone. Untapped *productivity* (maximum use of all resources throughout a supply chain, including energy and water, to drive down the cost per unit of product made), *precision* (ensuring the application of all operating assets to make the product right the first time), and *performance* (achieving maximum capability of all assets at all times) are the economic and competitiveness drivers. These optimization capabilities are not possible with physical innovation alone. SM relies on secure, real-time driven, digital interconnectedness and greater interoperability for small, medium, and large manufacturers and suppliers. Key to SM is the *democratization* and adoption of technology, capability, practice, and skills throughout the industry about how to use networked resources together with data and modeled systems for both business value and competitiveness. Technology, solutions, skills, practice, and knowhow are brought together to enable the frictionless movement of information, putting the power of information and innovation at the fingertips of everyone who touches manufacturing, regardless of organization size, industry sector and experience, ensuring that people and systems create value in and across manufacturing operations on a national scale. Democratization ensures geographical inclusiveness and manufacturer diversity by combining business and technology methods and practices together that are secure, privacy preserving, and ethically sensitive.

SM solutions must be interoperable and open, sustainable and energy efficient, secure, scalable, resilient and orchestrated, flat and real-time, and proactive and semi-autonomous. For CESMII, SM is enabled by building block technologies such as sensing, control, analytics, and modeling; platform technologies that enable frictionless movement of information in context from data acquisition to data consumption; education and workforce development for the talent pipeline and the existing workforce; and a national ecosystem of leaders, experts, educators, and innovation centers to demonstrate and proliferate SM.

[1] Technology, solutions, skills, practice, and knowhow to enable the frictionless movement of information, putting the power of information and innovation at the fingertips of everyone who touches manufacturing, regardless of organization size, industry sector and experience, ensuring that people and systems create value in and across manufacturing operations on a national scale.

GOALS, METRICS AND THE ROADMAP

The goals and metrics for the Institute are focused around improving energy and manufacturing productivity, reduction in cost of SM deployment, broad adoption of SM including supply chains and increasing SM workforce capacity. The Institute's strategy to accomplish these goals and metrics are articulated in a comprehensive Institute Roadmap with four strategic pillars:

- SM Ecosystem Integration
- Enabling Technologies and R&D
- SM Innovation Platform (SMIP)
- SM Education and Workforce Development

These pillars are tightly integrated and interdependent. Each pillar defines the focus areas and deliverables that align with and impact our goals and metrics ensuring a well-balanced and impactful project portfolio for the Institute.

DEVELOPING & DEMONSTRATING SM TECHNOLOGIES & KNOWLEDGE

Funded projects are the primary means through which the Institute achieves its objectives. Projects facilitate the development of key, breakthrough SM technologies, implementation practices, and educational content for training, objectives that are difficult and costly for individual companies to develop and execute. The Institute issues RFPs and selects impactful projects, executed by member organizations, to create a diverse, compelling portfolio that addresses all pillars of the Institute and has tangible outcomes that impact Institute metrics. Our current portfolio has nearly 45 projects and an additional 15 on the horizon. Technologies, solutions, and training content created by these projects are demonstrated and proliferated through our national ecosystem and SM Innovation Centers (SMIC).

Enabling R&D Projects are targeted toward closing gaps in building block technologies such as sensing, control, modeling, analytics, and optimization. These projects help solve deep technical issues that prevent manufacturers from creating smart solutions for their processes. Enabling R&D projects has a direct impact on Institute metrics for improving both energy and manufacturing productivity and help to create significant IP for the Institute and its members.

Platform Capability Projects are targeted toward building the capabilities of the SM Platform (enabling movement of data in context from ingestion to consumption), SM Profiles (structured, reusable information models) and the SM Marketplace (repository for reusable SM Profiles and SM Apps). These projects have a direct impact on making SM solutions interoperable, reusable, cost effective, and broadly deployable, hence impacting Institute metrics on the cost of SM implementation and supply chain adoption. These projects also directly impact democratization and the ability for all manufacturers and all of those in the workforce to have access to the skills and capabilities needed and to participate in industry-wide innovation.

SM Innovation Projects are focused on solving specific manufacturing use cases using Smart Manufacturing technologies, while also developing reusable SM Profiles and SM Applications for the SM Marketplace. The use cases serve as powerful SM demonstration examples, and the Profiles and Apps populate our Marketplace to benefit other manufacturers within and outside of CESMII, impacting Institute metrics related to broad deployment of SM across industries and supply chains.

Education and Workforce Development Projects are targeted toward developing SM education and training content and programs (knowledge base, learning infrastructure, educator network alignment and engagement, training, certification) to strengthen the talent pipeline in educational institutions as well as the incumbent workforce. These projects have a direct impact on Institute metrics for workforce development as well as broad SM adoption across the manufacturing supply chain and ecosystem.

Additionally, CESMII has funded several SM Innovation Centers (SMICs) across the country. These SMICs are 'lighthouse' extensions of CESMII. They demonstrate and stress test the use of the SM Innovation Platform for various industry segments and types of processes, and they help disseminate technology and training across the nation and throughout different industry sectors. To increase the reach of the SMICs, CESMII has fostered synergistic relationships with the National Institute of Standards and Technology (NIST) network of regional Manufacturing Extension Partnerships (MEP) and Department of Energy (DOE) Industrial Assessment Centers (IAC).

OUTCOMES & IMPACT

With several of CESMII's projects coming to conclusion in 2021 and 2022, the Institute is poised to compile, document, and showcase the outcomes from these projects to highlight how they benefit the project team, the industry, and other CESMII members, as well as how they impact Institute metrics. Figure 1 illustrates how our technologies and workforce development efforts impact Institute metrics. Listed below are a few examples from the project portfolio, one for each of the project categories.

- *Enabling R&D Project:* *Arcelor Mittal* and its partners developed and demonstrated advanced sensing (strain and displacement in high temperature environment), machine learning (prediction of caster plug-in), and digital twin (simulation for preventive maintenance) for improving caster performance and product quality in steel continuous casting. The solution has a potential impact of $90M in energy savings for the steel industry from improved quality, and $2M/line from predictive maintenance. This project has a direct impact on Institute metrics for energy productivity and efficiency in an energy intensive industry vertical.

- *Platform Capability Project:* *SM Innovation Platform Capabilities* were demonstrated during the CESMII Annual SM Summit and at ECM, a small manufacturer in Ohio. Capabilities included expanded real-time connectivity to equipment via standard protocols, SM Profile based programming interfaces for software applications, the SM Profile Designer, and a user interface for the SM Marketplace. The SMIP is currently being used by over 20 project teams. SMIP, SM Profiles, and SM Marketplace technologies directly impact Institute metrics on cost of SM implementation and supply chain adoption.

- *SM Innovation Project:* *Tyson Foods* and *ThinkIQ* demonstrated the use of the SM Innovation Platform for monitoring performance and energy consumption in chicken processing facilities. The project demonstrated SMIP capabilities including connectivity, contextualization, and access to structured information models for visualization, analytics, and machine learning. Improved decision making through the use of the SMIP resulted in an immediate 1% increase in yield for the plants, which was sufficient to justify the investment. Recognizing that SM is a journey involving an insight-implementation cycle, the project identified additional energy reduction opportunities for Tyson. The project impacts Institute metrics for energy productivity, manufacturing productivity, and reduction in cost of SM deployments.

- *Education & Workforce Development Project:* *Penn State* and *MIT* developed and demonstrated a benchtop fiber extrusion hardware and software kit integrated with educational modules for training in sensing, control, data acquisition, process simulation models, machine learning, prediction, and optimization. The course has been administered over two semesters for nearly 60 engineering technology students and incumbent workforce at small manufacturers. The kit is expected to be adopted by CESMII HQ and partner institutions and directly impacts Institute metrics for workforce development.

CONCLUDING REMARKS

CESMII has a strong portfolio of projects that cut across technologies and manufacturing use cases that were selected to close industry gaps defined by the roadmap. As the Institute moves into an impact phase, the outcomes of the projects are combined to form an adoption strategy for small, medium, and large manufacturers, from the factory floor to the industry ecosystem. The projects are demonstrating the use of SM technologies that span sensing, machine learning, process modeling, process control, and simulation, which are building blocks of an SM solution. The use cases span both process industries like steel, cement, and chemical as well as discrete manufacturing, including machining, grinding, and additive manufacturing to name a few where an impact is being made. The SM Innovation Platform, SM Profiles, and the SM Marketplace (recognized by Plattform Industrie 4.0, OPC Foundation, and others) will enable these SM solutions to be interoperable, scalable, and cost effective, to be reusable by a broad community of manufacturers. To help us get there, CESMII's internal resources, partnering with SM Innovation project teams, are helping populate the SM Marketplace with tools, information models, and apps that form building blocks that can be used to construct SM solutions for manufacturers to transition to Industry 4.0.

But technology is not sufficient to ensure sustainable smart manufacturing. CESMII's workforce development efforts will ensure that SM technologies are complemented by a strong pipeline of diverse and talented professionals coming out of academia, as well as a trained workforce that can understand, deploy, and sustain these SM systems and methodologies. Moreover, the Institute's SM Innovation Centers, with strategic relationships with regions and industry verticals, together with CESMII's network of domain experts from a diverse membership of over 135 organizations, will help showcase and disseminate the technologies and training content at a national level.

It is important to reiterate that these four pillars of CESMII's strategy need to, and will continue to, work in a tightly integrated fashion to help create the desired transformational impact on U.S. manufacturing.

Finally, CESMII's impact on DOE's energy mission is clear – whether it is through projects addressing specific large processes in energy intensive industries, or through projects that focus on hundreds of thousands of discrete manufacturing assets and processes used by entire supply chains in the U.S. Accelerating improvements in process and supply chain productivity, quality, yield, and throughput, with wide industry adoption, have a direct impact on energy productivity and align entirely with our urgent efforts to affect climate change, decarbonization, and evolution to a cleaner, energy efficient Smart Manufacturing Future that depends on democratization.

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FIGURE 1

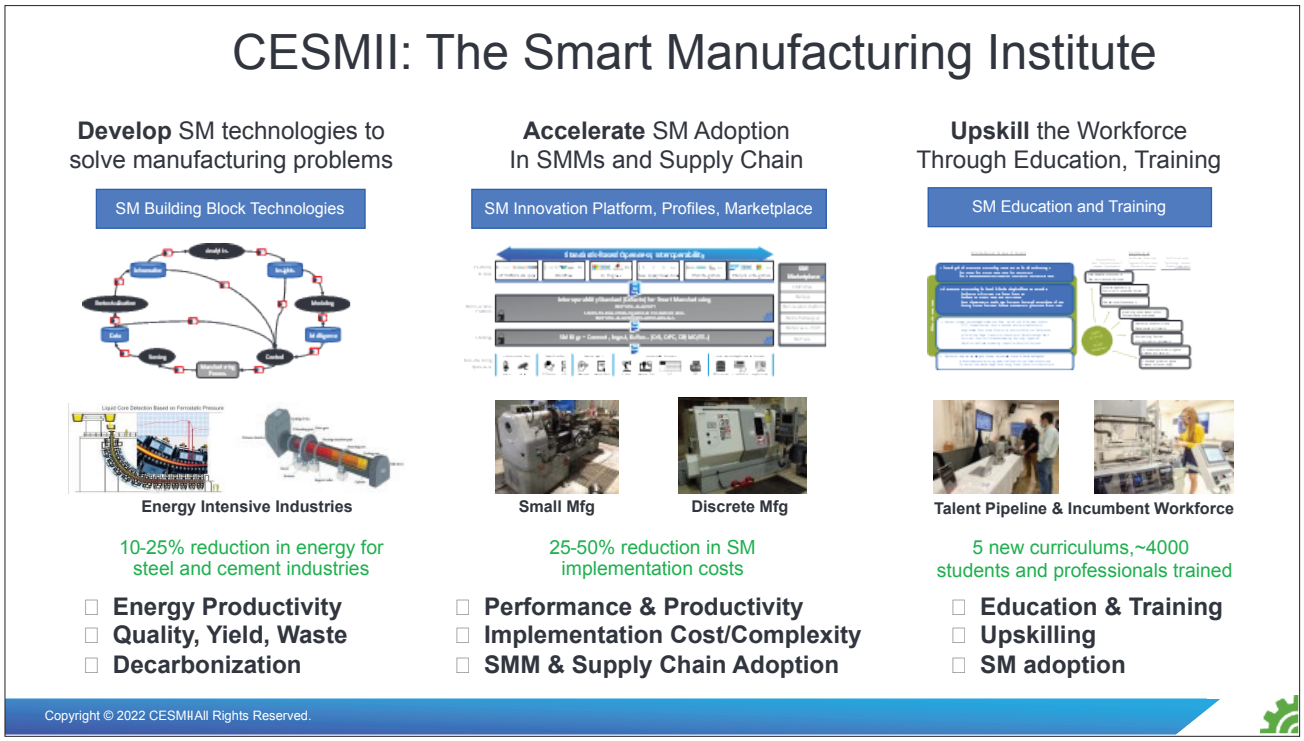

Figure 1: CESMII's Technology and Workforce Development Efforts and their Impact on Institute Metrics