Stitching Together the "Digital Thread"

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The Digital Manufacturing and Design Innovation Institute (DMDII) is one of the eight institutes established by a compendium of federal agencies under the umbrella of the National Network for Manufacturing Innovation (NNMI). We think of DMDII as being the institute with the broadest technical jurisdiction—in fact, we like to call our technical focus area "foundational" for all of the other institutes—but it also seems to be the most difficult institute to explain.

Essentially, DMDII has a mandate to expand the field of "digital manufacturing and design," which we describe as the creative use of data at every stage of the manufacturing process in order to move parts and components through their production stages more efficiently, more quickly and less expensively so they can become more competitive in the marketplace and help bring manufacturing jobs back to the United States. Under the

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Cooperative Agreement signed in February 2014 by the Chicago-based nonprofit UI LABS, and by the U.S. Army (on behalf of the federal government), we have broken down "digital manufacturing and design" into four separate "Technical Thrust Areas," including:

- **The Advanced Manufacturing Enterprise**, which is the digital thread of the transfer of data from one stage of production to another. For example, the communication of digital data developed by a part designer on a Computer Aided Design (CAD) system to a separate Computer Aided Manufacturing (CAM) system used on the manufacturing floor. DMDII looks at the gaps between different stages of production—and the impediments to interoperability that plague these systems—and tries to find ways to make the digital thread more efficient and more seamless.

- **Intelligent Machining** is the aspect of manufacturing that places sophisticated sensors on an individual piece of manufacturing equipment on the factory floor in order to assess that equipment's performance in real time. By monitoring a piece of equipment's through-put, temperature, lubrication, vibration, scrap rates and many other performance characteristics—and analyzing that data quickly—intelligent machining software and tools can determine when the machine is operating at less than optimal levels. Ideally, the intelligent machining software can adjust the performance of the machine in real time and bring it back into specifications.

- **Advanced Analysis** is the niche within advanced manufacturing that examines mountains of "Big Data," with an eye toward deriving new insights from the data that can lead to improvements in design and production processes. Sometimes, this field includes the use of Big Data, coupled with high-powered computing resources, to offer modeling and simulation capabilities to a manufacturer that it could never achieve on a manual basis.

- **Cyber Physical Security**, a topic that has become increasingly prominent in the years since DMDII was established, involves the protection of production equipment on the factory floor from harm that could be caused by hackers with malicious intent. The damage might take the form of piracy of proprietary intellectual property (IP) residing on a specific piece of manufacturing equipment, or the operation of the machine itself could be subverted by hackers who want to alter the characteristics and performance of specific manufactured parts. (Imagine the dimensions or strength of a critical component of an aircraft engine being compromised by a hacker.)

DMDII's Mission

DMDII is expected to advance the field of digital manufacturing and design throughout the United States. We strive to accomplish this ambitious goal in three fundamental ways:

(1) Applied Research and Development (R&D). Our institute is responsible for identifying the technical challenges we pose to our industry and academic members; developing the formal solicitations we publish to invite teams to submit their proposed technical solutions; evaluating the white papers we receive from self-formed proposal teams; selecting the most promising technical approaches; negotiating R&D contracts with the selected teams; signing contracts with the "team leads," and managing the progress of individual R&D projects as they proceed.

To date, DMDII has announced the award of 18 separate R&D projects valued at $34 million, with many more in the pipeline. These publicly announced projects have distributed prime contracts and subcontracts to more than 60 unique industry and academic organizations across the United States.

These topics typically are too complex to be tackled by any single organization in the manufacturing sector. They generally require the combination of skills and resources that can only come from teams of large and small companies, software developers, and leading research universities. Fortunately, since DMDII was established in early 2014, we have attracted more than a dozen multibillion-dollar, multinational corporations as industry partners (including Boeing, Caterpillar, Dow Chemical, Faurecia, General Electric, Illinois Tool Works, John Deere, Johnson and Johnson, Lockheed Martin, Microsoft, Procter & Gamble, Rolls-Royce, and Siemens).

In addition, we have signed to our consortium more than 120 small- to medium-size manufacturers and not-for-profit organizations, as well as more than 40 leading research universities.

(2) Technology Transition. This has two key components. DMDII takes steps to make the intellectual property developed and/or matured during an R&D project better prepared for commercialization. This requires us to push the project beyond the realm in which we usually operate (Technology Readiness Levels [TRLs] 4 through 7) to even higher TRLs, where the newly developed technology becomes ready to be introduced into the marketplace.

We spend time and money perfecting a product's design, building prototypes of it, testing it in laboratory conditions, and then testing it in real-world conditions. Our institute has come to recognize that if we are to achieve lasting value in the manufacturing sector, we need to provide guidance, a framework, and a process to propel our most-promising projects closer to commercialization.

That's one side of the "Technology Transition" coin. The other side involves encouraging all manufacturers, especially the small- and medium-sized enterprises (SMEs) to embrace these new digital manufacturing and design technologies in their own factories. Given the fast pace that SMEs must maintain to meet their day-to-day obligations with limited staffing, dedicating time to planning for the future can seem a luxury—however necessary it may be to maintain the company's competitiveness.

(3) Workforce Development. Here is a final ingredient in our model and includes training and educating workers to acquire the skills they'll need to operate in a digitized factory environment. Specific to operators, administrators, and executives, DMDII works with its network of industry partners to identify the job profiles specific to digital manufacturing and design.

This is a highly complex task. To be clear, we are not the folks who will actually train the workers of the future. Instead, DMDII is assigned the mission under the Cooperative Agreement to "architect" a U.S. workforce development plan. With the assistance of a workforce advisory committee, including some of our key industry and academic members, we help determine what kinds of curricula (at what educational levels) need to be developed; on what platforms the training should be delivered (face-to-face traditional classroom instruction, massive open online courses, or "MOOCs," video instruction, etc.); and to whom it should be delivered (high schools, community colleges, universities, vocational schools, and/or manufacturing companies).

DMDII Projects and Value to Partners

Applied R&D projects are central to the DMDII process, but partners also see value in the institute's wide-ranging network, idea and thought leadership generation, and the possibilities that surround the adoption of new technologies.

DMDII, using experts from our industry, academic, and government partners, created a digital roadmap for the institute, highlighting the gaps and necessary building blocks for digital manufacturing adoption. "Enterprise projects" come from this strategic roadmap and leverage government and private funds together with at least a 1-to-1 ratio of private to government funding. All of our DMDII partners benefit from the shared risk from this leveraged R&D.

Our other project category is dubbed "partner innovation projects." These are entirely partner led and are often more specific to problems experienced by that partner. Using our framework, network, and innovation processes, we help partners pull together unique teams and solutions that would be difficult to source individually. The project partners once again determine and own the resulting IP and the pathway to commercialization.

Now 2 years old, the DMDII is a relative newcomer to the decades-old manufacturing industry, but the model—with its strong emphasis on partnership building, technical collaboration, and shared risk—has the potential to be a catalyst that transforms American manufacturing by creating outcomes and assets that can be used by the entire industry's transition to a digital era.

See the website at http://dmdii.uilabs.org/.

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