

Great Expectations

in the Joint Advanced Manufacturing Region

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Too many new assets are mired in outdated bureaucratic practices that were developed for another era. As we enter the age of cyber, unmanned systems and advanced manufacturing, we cannot allow these overly complex, form-over-substance, often useless, and too often harmful, practices to slow or prevent development of some game changers, while simultaneously giving our potential adversaries the competitive advantage."

**—Navy Secretary Ray Mabus
DoN Innovation Vision**

Last year, in response to the Secretary of the Navy's direction to accelerate innovation across the Department of the Navy, a number of individuals responded with a hearty "Aye, Aye" and volunteered for duty on the Secretary's Innovation Task Force. The goals were aggressive: Challenge the status quo, reclaim a position on technology's leading edge, and defend it from our adversaries. The Vision represented clear guidance, a willingness to innovate, and a desire to slay bureaucratic demons. However, it was unclear how the engineers, scientists and junior military personnel in the field would tackle the Secretary's challenge from within the bureaucracy itself.

Buoyed by optimism and undeterred by sequestration logic, the individuals uttered a collective "damn the torpedoes" and set out to constructively disrupt the status quo. This article is a case

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Table 1. The Smart Manufacturing Grid

Digital Manufacturing Network	Distributed Manufacturing Topology	On-Demand Value Chain Management
- Information Technology - Operation Technology - Cyber-Physical Systems	- Node Location - Physical Logistics - Capacity/Mix Optimization	- eProcurement - eCommerce - Enterprise Resource Planning - Software Configuration Management - Product Life-Cycle Management

Source: Author.

study. It is one team's story. It represents risk, failure, success and, most importantly, an experience curve typical for individuals and organizations desiring to build and sustain a culture of innovation.

Playing Big

A number of engineers and scientists had been working together informally on projects that they knew to be more advanced than the programed baselines being delivered through acquisition and procurement processes. Individually, these projects represented new sensing, information processing, material science and automation paradigms. However there was no trigger, no Joint Urgent Needs Statement, no project funding or highly motivated Program of Record to provide a demand signal to mature these concepts beyond organizationally limited, stovepiped proofs of concept.

Solving the Fleet's hard problems requires bold plans and, sometimes, fighting above one's weight class. The Naval Innovation Vision represented a bold plan. Execution was being pushed to the deck-plate level and feedback was returned, largely unfiltered, to the senior staffs. In order for the individuals to contribute effectively, they realized they would need to band together, forgo heroics, and serve as a team.

Using the Navy Secretary's guidance as top cover, they decided to work together to try to integrate leading-edge, commercially available manufacturing technology into a regional fabric that could support military forces and diversify the defense industrial base. After scratching out a few acronyms on the back of a napkin, they decided to call their effort the Joint Advanced Manufacturing Region (JAMR) and manage it as an Integrated Product Team (IPT).

Gaining Situational Awareness

JAMR initially focused on establishing a dialog with other government, industry and academic community members. The first objective was to determine the general state of manufacturing and to gain a clearer understanding of what each group meant by the term "advanced." Definitions varied by manufacturing subsector, but an initial review of available literature

revealed that the manufacturing sector itself was experiencing a renaissance. The IPT realized it might be tapping into a vibrant "ecosystem" of emerging, complex, potentially groundbreaking capabilities that extended beyond the manufacturing sector itself. In fact, this convergence of advanced technologies is a megatrend that the World Economic Council refers to as the Fourth Industrial Revolution.

This new revolution is a framework for understanding where the forward line of technology—the technological edge—actually is located. Industrial

consortia such as Industrie 4.0 in Europe, China's "One Belt One Road," and the Industrial Internet in the United States already vie for comparative advantage in this space. Geopolitically, the new industrial revolution has sparked competition for domestic and international markets that could contribute to healthy global trade or result in comparative disadvantage for countries that cannot maintain the pace of adoption. The JAMR IPT members knew they had to explore the key themes of this broader industrial revolution in order to engage with the sector and to understand how manufacturing was being disrupted by innovation.

Thinking Globally, Acting Locally

The inaugural JAMR meeting was a teleconference of about 50 people. It included briefs by industry and academia on cyber-physical security, advanced materials and smart manufacturing. There was great interest shown by nondefense corporations, other federal departments and the academic community in collaborating with the Department of Defense (DoD) to mature advanced industrial concepts. The establishment of manufacturing institutes under the President's National Network for Manufacturing Innovation (NNMI) created strong anticipation that new business models and a new competitive landscape were emerging across the DoD and the U.S. Government.

The IPT's problem was that the opportunity was too broad to be addressed by a small team. As an ad hoc community of practice, JAMR opted to focus on adoption rather than theory. The IPT decided that its value-adding function would be continuous experimentation and risk reduction prototyping. The entire manufacturing life cycle—design, testing, product development, security, integration—was open for consideration. But the effort needed to be restricted and focused on a micro-experimentation platform that allowed collaboration across the life cycle. Borrowing lessons from the Smart Energy Grid, team members crafted a similar concept for a smart manufacturing grid. When mature, the Grid would allow small, medium-size and large manufacturers to become part of a mutually reinforcing ecosystem that could respond effectively to distributed manufacturing supply and demand cycles.

The Department of Energy (DoE) and the National Energy Reliability Corporation (NERC) concept of “microgrids” also resonated with the IPT. Microgrids allow alternative power providers and citizen-owned power sources (e.g., solar panels) to augment the power distribution infrastructure managed by the electric utilities. This contributes to dynamic capacity management and increased resilience in the power network. Micro-manufacturing capabilities appeared functionally equivalent. Therefore, the IPT incorporated small-batch niche manufacturing companies and the regional leaders of the Maker Movement into the dialog to see how they might benefit from being trusted suppliers on the grid.

“Smart” is a contemporary term technologists use to describe the integration of sensors, cloud computing, big data and predictive analytics into traditional operations (i.e.,

JAMR meetings continued through summer 2015, with as many as 250 registered attendees representing companies, universities and other federal agencies willing to share their ideas. However, by mid-autumn no external funding had been secured and the continuous experimentation planning came to a standstill. Industry, Federal Lab and university partners became discouraged by the lack of capital. Running out of collegial goodwill, the IPT members could think of only one thing to do. They called in the Marines.

In late October, the JAMR effort pivoted from its broad public-private partnership goals to a narrow government-led, platform-integration approach. Headed by a former Marine who had completed two combat tours in Iraq, and a former University of California, San Diego, research scientist who was brand new to the government, the IPT decided to continue as

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Smart Cities, Smart Ports, Smart Power). Smart Manufacturing incorporates the Information Technology elements of sensing, networking and analytics with Operation Technology breakthroughs in mechatronics, material science and robotics. When coupled with an on-demand business model, it is the Smart Manufacturing Grid—an infrastructure that enables distributed, digital manufacturing.

As originally conceived, the Smart Manufacturing Grid was comprised of three major components:

- The real-time, industrial protocol stack
- Physical manufacturing node topology
- On-demand eManufacturing contracting and procurement model

Like the Smart Power Grid, the Smart Manufacturing Grid would enable disconnected local operations (i.e., shipboard, field operations, individual factory), as well as broad area, networked manufacturing operations. In the Smart Manufacturing Grid, security must be built in, must accommodate machine-to-machine transactions and must allow for distributed, automated workflows.

Test-Bed Development

Armed with new information and confidence about what was possible, the IPT set out to leverage existing efforts that could serve as the experimentation venues and elements of the Grid.

an information exchange venue but double-down on a specific government project to stimulate creation and integration of nodes on the Smart Manufacturing Grid.

Other government employees and interns, with funding underwritten by their parent commands, were given leadership roles to extend the IPT’s reach. To help amplify the message, the IPT leveraged DoD and public interest in 3D printing or AM. Using 3D printing as a use-case for the broader distributed, digital manufacturing paradigm, the IPT believed it could help decision makers more rapidly internalize the value of the broader paradigm.

The IPT’s primary objective was modified to focus on delivering some form of new manufacturing capability to local Fleet Forces as quickly as possible. The goal was not to define acquisition quality requirements but to convert operational need directly into capability at a price-point and along a tactically significant timeline. To that end, the total schedule for concept development, equipment procurement, redesign, testing and organizational approval was compressed to approximately 9 months.

Based on the operational needs for expeditionary maintenance and repair experienced by the Marines in Iraq and Afghanistan, the JAMR Team secured a 20x8x8-foot tactical shelter and christened it the Expeditionary Manufacturing Mobile Test Bed (EXMAN). The first unit, EXMAN TB-100, was a

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prototype mobile facility designed to support the continuous experimentation of advanced manufacturing tactics, techniques and procedures under actual operational or combat conditions. The EXMAN prototype served as a benchmark for standard deployable and embarkable advanced, digital manufacturing capabilities that conform to existing logistics processes and lift constraints. The prototype shelter was an ISO (International Organization for Standardization) Certified, 1 TEU (twenty-foot equivalent unit) container that was road, ship and air transportable. The 1 TEU footprint allows modular expansion of the units to accommodate field manufacturing requirements based on characteristics of the mission.

Rapid Adoption

After Alpha testing in early 2016, Marine Corps leadership was able to secure more funding from Navy Secretary's Task Force Innovation. EXMAN was deployed by the Navy's Space and Naval Warfare Systems Center Pacific to the 1st Maintenance Battalion at Camp Pendleton in early March. Once on station, the pace of experimentation accelerated rapidly. Over the subsequent 60 days, the IPT conducted formal computer-aided design training for a dozen Marines, held onsite 3D printer assembly and operations events, drafted the initial bill of materials for additive and subtractive manufacturing equipment, negotiated license agreements for software, initiated new assembly designs and completed fabrication of several components.

Live capability demonstrations were conducted by junior enlisted Marines for the Commandant of the Marine Corps, the Commanding General, I Marine Expeditionary Force, the Assistant Deputy Commandant for Installations and Logistics, and the Commanding General, 1st Marine Logistics Group. In about 3 weeks, all four general officers personally visited the EXMAN shelter to understand the potential implications of the capability. Based on their initial impressions and with ongoing daily prototyping efforts, EXMAN TB-100 was scheduled for testing during an operational exercise. The results and lessons learned from that experiment will inform Marine Corps decisions relating to EXMAN sustainment and program objective memorandum planning.

It is too early to speculate on the full implications of adoption of digital manufacturing for maintenance and repair operations at the battalion level. However, the JAMR IPT estimated that the breakeven point for recovering the cost of the EXMAN TB-100 was reached during the initial 60 days of experiments. All subsequent experimentation is being calculated as Type I savings (e.g., direct) and Type II (e.g., cost avoidance) savings that represent a compounded return on investment. Most important, however, was a measurable improvement in opera-

tional readiness based on the Maintenance Battalion's ability to prototype, and in some cases produce, nonprocurable end-use items in the field.

Epilogue

JAMR is a story of enablement. Over 18 months, many JAMR members opted in and out of the IPT to create a healthy ebb and flow of ideas, challenges and needs. The dynamic nature of the community let the IPT leaders gauge commitment and the relative value of each stakeholder's contribution. It allowed the IPT as a whole to pursue promising leads and to abandon nonvalue-adding dead ends. JAMR projects such as EXMAN benefited from strong Marine Corps and Navy senior leadership, a healthy tolerance for limited risk and the innate “can do” attitude of junior personnel.

The Smart Manufacturing and Industrial Internet communities that originally influenced the Smart Manufacturing Grid effort continue to mature rapidly. Smart Manufacturing is the newest DoE-sponsored National Manufacturing Institute, and the Navy is now an official member of the Industrial Internet Consortium. The Maker-Mentor project, initiated under the JAMR IPT and being executed by Open Source Maker Labs, was recognized by the White House Office of Science and Technology Policy (OSTP) as an example of the emerging value of maker spaces for the revitalization of American manufacturing.

JAMR itself is an ongoing experiment. JAMR allowed a diverse, ad hoc team of stakeholders to experience the thrill of rapid learning and to contribute to the national dialog on innovation in a meaningful way. It highlighted the value of rapid prototyping and the chronic challenges of resource scarcity that often prevents scalability and sustainment. It reinforced the notion that human dedication and commitment are still the most important determinants of IPT success regardless of how promising or attractive the newest technology seems. Finally, it validated leadership's notion that we collectively need to nurture our culture of innovation to regain and maintain a dominant position on technologies' leading edge.

The IPT reflected and shared these lessons learned with the OSTP as part of a broader dialog on manufacturing innovation at the White House in June. All agreed that the JAMR mission remains important, but like advanced manufacturing itself, the IPT is evolving. JAMR's next phase will involve collaboration through the regional Advanced Manufacturing Partnerships, the Industrial Internet Consortium and other national organizations. 

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