

PARTNERS IN CONNECTION

THE DIGITAL WORKFORCE SUCCESSION IN MANUFACTURING

DIGITAL MANUFACTURING &
DESIGN JOB ROLES TAXONOMY



ManpowerGroup®



DMDII

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Welcome to **Partners in Connection**, the report out of the public-private effort to define digital manufacturing workforce frameworks. **Partners in Connection** describes an 'omni-facturing' workforce, a talent pool that has augmented the manual origins of its legacy name with many digital and digitally enabled capabilities. For today and tomorrow, we see a highly connected and cross-discipline digitally enabling and digitally opportunistic community of work roles that bring together many disciplines. Newer and legacy work capabilities - design, engineering, production, supply network, and more – empower the innovation of America's global manufacturing base. ManpowerGroup/Right Management and the Digital Manufacturing and Design Innovation Institute led member and non-member subject matter experts, reviewers, and contributors to define and develop these digitally oriented workforce frameworks. The project was completed under the Department of Defense Cooperative Agreement No. W31P4Q-14-2-0001 Control No. 15-09-01 between March 2016 and June 2017. The DM&D Taxonomy of Technical Domains and Roles, the Success Profiles, and the Call to Action, along with inclusion of some of Manpower's general considerations for the Digital Manufacturing Organization and Digital Leader all serve as platform for change in manufacturing for the many stakeholders. Awareness of the workforce changes needed to empower manufacturing as technologies continue to advance and become interconnected is shared here. With the Taxonomy's adoption, all stakeholders should see the acceleration of digital manufacturing and design's potential for those who choose to embrace digital innovations.

The Digital Manufacturing and Design business ecosystem grows and evolves every day. For small companies and large enterprises, the digital transformation beckons brightly, capturing broad attention and commanding major initiatives. From the high school and community college "maker space classrooms" – the 21st century "shop class" - to the technology innovation labs of startups; from the C-suite of a global appliance maker to the crafter entrepreneur's loft workshop; from the floor of the modern aerospace factory of the future to the bullpen where a factory automation manager combines old and new, digital represents an opportunity, a requirement, an equalizer and an accelerator all in one. Few will escape the challenge of digital transformation. Most hope to embrace it.

Along the way, the entire ecosystem of manufacturers, government, educators and the workforce itself needs to ask and answer:

- **What's on the roadmap to being successful in adopting Digital Manufacturing and Design technologies?**
- **Where are the skills and capabilities to lead and delivery on the promise of digital technology?**
- **How do we describe the work to be done, the jobs and the roles, and workforce to do it?**
- **How can workforce role and job structures flex to accelerate the succession - the change in response to a disruption - of a transforming global industry?**

We intend that some of the most foundational answers begin with this Roles Taxonomy and the related outputs and assets. We invite you to engage and benefit from the innovative changes available to the many stakeholders in manufacturing and our broader economy and society. Join the conversation about the workforce – the people and roles that operate as Partners in Connection – for digital manufacturing and a resurgent manufacturing ecosystem.

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Additional copies of the report and the profiles is available for download from:
UI LABS at www.uilabs.org/taxonomy

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PARTNERS IN CONNECTION

1. Introducing the MPG/DMDII Digital Manufacturing Roles Taxonomy

Why We Built This Bridge

Commerce. Business. Profit. Jobs. Work. Value. Innovation. Career. Employment. Reskilling. A hundred essential concepts appear on the list of workforce factors when it comes to defining a talent framework needed for an industry in transformation – especially one that is in the middle of broader social and economic transformation.

If you are reading this, chances are you have something in common with others who access this resource. Do you share a need to understand, build, develop, or even become part of the digital manufacturing workforce? Is it your job or your mission to help lead or support a successful digital enterprise? Are you running a plant that is going digital? Does your goal include executing on the opportunity to win in Industry 4.0?

Digitization has been changing – and will increasingly change – everything. Manufacturers need the right workforce in place to survive and thrive in this new paradigm.

But few understand what the optimal reskilling of the digital manufacturing workforce will look like.

And few are optimally positioned to manage the organizational, cultural, and leadership changes that accompany this workforce shift.



The Skills Revolution, ©2017 ManpowerGroup

A recent effort between The Digital Manufacturing and Design Innovation Institute (DMDII) and ManpowerGroup (NYSE: MAN) has produced an essential starting point for better definition of who and what digital manufacturing and design workers and work are and will contribute. The future of manufacturing work has been mapped to roles and knowledge areas across the digital manufacturing enterprise, which will serve as a primer for business, academia, and workforce development as they move to and through their digital transformation.

DMDII brings together universities and industry – along with startups, nonprofits, and government stakeholders – on technical and workforce development projects. The institute engages in research and policy efforts, as well as in promoting the new digital enterprise and connected factory of the future and new data-centric manufacturing enterprise connected by the digital thread as shown below.



In 2016, DMDII entered into a partnership with the leader in innovative workforce solutions, ManpowerGroup, to embark on a project to identify the digital manufacturing workspace, as well as the work roles needed now and into the future, and then map them to DM&D technical domains, and profile 20 of those emerging roles in detail.

Our Process

This workforce design clarification is needed for all stakeholders: industry, government, educators and individuals. For the United States to remain a leader in global manufacturing, it needs to adopt digital technologies that harness data to more effectively drive the development of more advanced products and make the industry more innovative, efficient, and cost-competitive. Technologies like digital design and simulation, additive manufacturing, bio-inspired materials and processes, connected machines, automation, and advanced materials and manufacturing systems are transforming the way we produce goods.

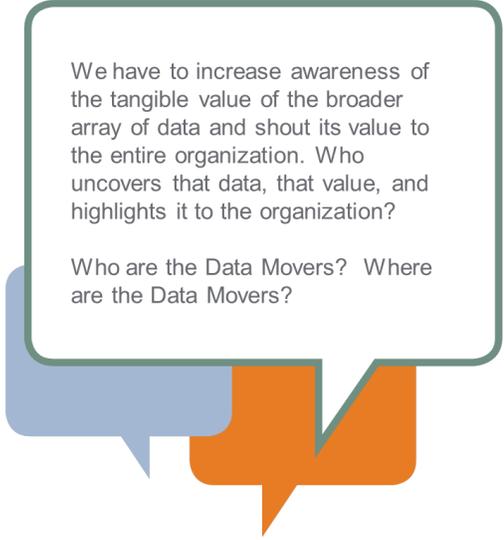
Leveraging the capabilities of those breakthrough innovations and the greater levels of data connectivity throughout a manufacturing enterprise, however, requires preparing the US workforce for a set of skills not typically used in traditional, more siloed, more analog manufacturing. We've seen progression to digital already but this progress has not been made at the rates that support innovation, market opportunities, and labor/citizen needs for employment and career mobility throughout manufacturing and its many contributing fields.

As a transformative and rapidly evolving field, digital manufacturing brings accelerated workforce challenges. The macro challenges around manufacturing workforce shortages are widely known; what may not be as well-known is what the digital skill areas and digital related roles are, where the target digital workforce sources are, and when to invest in those skills and roles. For example, employers are often unsure or unaware of the types of skills needed to program machines or perform data analytics or how to connect their manufacturing systems to business side-data systems, and what the utility of these skills yields for their business versus the skills required on a manufacturing floor even a decade ago. As we work to close a skills and labor gap in manufacturing, we cannot forget to look to the skills our workforce needs to thrive in the next and future manufacturing environments.

Throughout our research process, we learned that, for a meaningful and useful workforce taxonomy and role structure to emerge, we had to start by connecting past, present, and future. As a result, the taxonomy reflects an “AND” approach:

- Areas of focus in certain work and technology areas **and** the need for multi-domain specialists who are by definition, generalists
- Digital **and** human role focus
- Legacy manufacturing wisdom **and** digital innovations
- The enterprise **and** the individual
- Small manufacturers **and** global enterprise
- Incubations by R&D groups **and** optimizing the entire supply network
- Looking and collaborating inward across the digital thread **and** sensing and reaching outward across the customer journeys
- Joining the Manufacturing Scientists **and** the Organizational Change Strategists
- Enabling the wisdom of the Sales Solution Engineers **and** that of the Digital Ethicists
- Rallying around the Chief Digital Officers **and** Embedded Product Prognostics Analyst.
- Demands for the manufacturing system and roles to manage people **and** profit, planet **and** product.

Based on the outcome of our efforts, we’ve identified the **Digital Manufacturing and Design Roles Taxonomy**, consisting of a technical domain structure, the identification of the broader set of 165 potential roles and role descriptors in digital manufacturing and design, and 20 success profiles for representative roles. These roles are a portion of the ones we believe will provide the bridge between our current and future workforce. With the fuller picture of the broader community of the roles and the technical domain structures, we see a more aligned and accelerated path for digital manufacturing workforce development and the economic benefits for individuals and companies alike.



We have to increase awareness of the tangible value of the broader array of data and shout its value to the entire organization. Who uncovers that data, that value, and highlights it to the organization?

Who are the Data Movers? Where are the Data Movers?

First, A Few DM&D Definitions

What is Digital Manufacturing and Design?

Digital Manufacturing and Design (DM&D) is an integrated approach that brings together software, data, sensors, and control systems to model, simulate, analyze, control, and optimize both the performance of a product and the manufacturing and business systems that produce it.

The connectivity of data and systems between all elements of the product lifecycle creates channels for real-time collaboration between product stakeholders, and enables us to make smarter, more efficient, and more fully informed business decisions.

In this body of work the use of the word “Digital” is in an attempt to emphasize the overwhelmingly shared nature of work and information performed between humans and machines. Its use is an attempt to envision and build a “data-centric enterprise” powered by shared information, better insights and decisions, collaborative access to build and use that information, and efficiencies across the product life cycle powered by “one source of truth”.

“Digital” emphasizes the tools, techniques, work flows, and mindsets that allow us to build greater levels of actionable data connectivity across the enterprise, large or small. In the Technical Domains, “Digital” is used to call out the move beyond the individual and often segmented legacy technologies and systems toward greater levels of connectivity that in turn will drive business, design, and manufacturing systems toward greater levels of performance and productivity across an enterprise.

Manufacturing With or Without DM&D: A Workforce and Industry In Succession

For any number of reasons, different views are held on the digital transformation underway in life and in industry. Conscious conversations are essential and the issues are real. Our project had both a solid focus on workforce and a holistic view of the change territory that this workforce has to operate in and what is needed by organizations enabling and employing digital talent. Consider these basic factors:

- Advanced manufacturing – often synonymous with digital manufacturing – is 7.5% of the US economy¹
- Each job in an advanced manufacturing industry supports 3.5 additional jobs in the supply network¹
- Annual compensation in manufacturing averages \$73K and in advanced manufacturing averages nearly \$95K¹
- 65% of the jobs that Generation Z (born in 1996 and after) will work at have not yet been invented

Remembering back to our 9th grade biology class and seeing how applicable it is here, we can think of how other large systems respond to changes – dramatic or gradual – in order to flourish. This process of regrowth that an ecosystem undergoes after a major change event is known as “succession”. In Digital Manufacturing and Design, the workforce has been undergoing early stages of this succession for decades, and will continue to do so. However, the speed of those stages of change and conversion are taking shorter and shorter windows of time. And so, our efforts to define and develop the workforce must also accelerate.

This process of regrowth that an ecosystem undergoes after a major change event is known as “succession”.

In Digital Manufacturing and Design, the workforce has been undergoing early stages of this succession for decades, and will continue to do so.

So, where does a manufacturer look for guidance?

How can we take advantage of early adopters, and those who are investing in innovation and have seen some of the horizons?

Our framework captures the “*now* and *next*” views of the critical work and technical areas and roles; it also profiles what value those roles bring to the manufacturing enterprise

65% of the jobs that Generation Z (born in 1996 and after) will work at have not yet been invented

¹ Soltesz, John Paul, et al. “The Workforce of the Future: Advanced Manufacturing’s Impact on the Global Economy.” Apr. 2016

and ecosystem. The taxonomy work isn't a complete reboot of all manufacturing jobs, since many of those are essential and represent the legacy of production, and form the life cycle basis that digital is built on. Our framework does, however, have fundamental definition across the digital manufacturing enterprise so it is wide in scope, and has unique roles and conventional areas with innovative digital application focus; the full life cycle of products; the new operating environments; and the many roles with direct digital effect that enable the business.

A changing environment as major as the one that we are seeing broadly in digital technology, society, and business is one that affects the entire manufacturing enterprise and will take an enterprise effort to succeed in commerce and to balance the talent ecosystem.

The impacts of automation and digital and other influences on the workforce has legitimately been on the skilled worker area of manufacturing. This body of work purposefully worked with manufacturing experts in all disciplines and collectively took an enterprise scope including and going beyond the manufacturing production portion to the full product life cycle and the broader data-centric organization. That said, not every possible function was deeply examined. Project participants and experts evolved a scope of roles and work that reflected the following work and worker factors:

- Those that were “more native” digital – those that are newer and do not have a conventional or early automation twin, those that wouldn't exist without digital technologies
- Those most needed to deeply understand the cross-functional dynamics of the digital enterprise in order to best guide the digital enterprise transformation
- Those having their outputs changed more dramatically than others based on using digital technologies and data as a primary “input or tool” or those creating or producing digital products, interim or final
- Those changing or augmented by digital technologies well beyond the primary automation seen in prior decades and where the pace of change and new contributing tools and technologies is fastest
- Those areas that reflect the digital design, digital thread, and digital product areas – domains that have more of the next generation roles than some others

While digital is changing work, social practices and consumer behavior for almost everyone, this effort looked at those work areas and workers where participants sensed the highest “digital change delta” is occurring.

While digital is changing work, social practices, and consumer behavior for almost everyone, this effort looked at those work areas and workers that participants sensed have the highest “digital change delta” – a composite view of the change made due to the above factors. The taxonomy also had an imperative to bridge the higher “delta” digital work and workers to more established roles and work areas where there is a **connection** for use of digital elements and even **progression** of work and workers. These connected areas include the production and processing arenas of manufacturing where there is a change delta also but with a lower sense of the above factors. The taxonomy presents “**connected roles**” and “**transition roles**”, both bridges that connect more of the manufacturing roles with different digital change deltas into a broader workforce system.

Building from the present and in some cases replacing the past roles affected by the “disturbance” of digital technologies, it's useful to understand how pace, uptake, and specific workforce needs will vary across sectors and individual manufacturers. Flexible building blocks are needed, and so we focused on roles versus specific jobs, although in many cases they will be the same. In other cases, these roles will combine to describe a wider breadth of work performed by a person or a position.

Another obvious requirement of an industry in change, in succession and regrowth, is to see the phases and the clusters of how that growth occurs and how to build on its natural energy and connections. Some roles easily produce business benefits and energize other productivity and innovation.

And so we look at the impact of the roles generally on the growth of a broader digital enterprise. New growth is first seeded by the **pioneer** digital roles; it is anchored and optimized by the **keystone** roles; and scaled and optimized by the growth created by roles that are the prime **producers** or creators of the manufacturing value (generalists and specialists in many innovation and digitally impacted areas). This emergence and increase of new capabilities can occur much more quickly when the environment is understood and stakeholders see roles that can take advantage of the new conditions for quicker, healthier and more sustainable growth and business outcomes. Of course, changes will keep occurring in manufacturing, and so succession will continue.

By getting even more comfortable with the workforce capability changes needed and the job opportunities available, while seeing the change through the eyes of the natural business and technology rhythms, higher digital change thresholds, connections and transitions, all stakeholders can become more agile and adaptive.

Industries and, in this context, manufacturers that optimize change wear the top-finisher badge of a resilient economy and a resilient workforce.

Building a Taxonomy

Taxonomy Content – An Overview

Our taxonomy outputs came from a process that consistently emphasized our core principles:

1. The frameworks would be based on industry demand and expertise of the future, enhanced and carried by workforce and organizational change innovation and best practice
2. We would build towards the opportunities of digital and not from the destructive perceptions of disruption
3. The reality of identifying and timing talent and workforce plans and investments should be staged and diversified to meet market opportunities and the diversity of the manufacturing base
4. And lastly, we would take a systems approach – as it is a systems challenge – and look for inspiration and proof from successful adaptations and changes

When it came to demand and expertise, we engaged experts and manufacturers. Over 50 representatives participated from over 30 different members. Dozens of others were engaged in major conversations; hundreds of others regularly heard presentations, received updates, and provided general acceptance and encouragement. These informal but insightful resources would shine a light on the diverse sets of needs and demands that influenced the work.

When it came to attitude and approach, we built towards a positive future and are knowingly leaving some of the essential debates about automation and workforce impacts to other important conversations and strategies. They were part of the conversations that focused on need and demand, and part of the challenges and the framing of scalable ways to look at the people and the work.

We know that there are over 250,000 manufacturing entities in the US each facing both common and diverse challenges and opportunities. We accepted and welcomed the idea that investments in workforce development and new technology implementation are tied to market opportunities – local, national, and global. So we, too, staged and modularized the frameworks as much as possible to have agility and

modularity in investment and technical evolution; from concepts like ‘pioneer’ roles to describing technologies and roles using a framework of ‘generations’, the taxonomy offers modularity. We hope the flexibility is obvious and workable.

Building a taxonomy means engaging in a process of describing how a group of items are similar and how they are different. The purpose is to have a consistent way to identify, define, organize, and track important matters that you want to be able to distinguish and optimize. Taxonomies work best when they allow for groupings at several levels; in the case of a workforce taxonomy, it is important to be able to use it to describe the micro level – of an individual person (titles and success profiles); and also, to work at the macro to describe groups of workers or a large pool of talent (the talent ecosystem and major body of technical information). From frameworks and lists to the broad community map and the domain maps there are multiple views and ways to segment the DM&D workforce using the taxonomy.

The pivotal success factors in building a taxonomy – whether for people, plants, or production parts – are to set up a firm set of guiding rules for the broad set of the items you are going to describe and classify; then group by meaningful and differentiating characteristics; and then classify consistently so that the taxonomy is a reliable structure for organizing and understanding your group of items or an individual item.

As a result, the DM&D job roles taxonomy effort and structure resulted in creating a meaningful structure to organize the work, workers, and work environment of the digital manufacturing and design industry.

Here is a summary of the pieces available to users of the taxonomy.

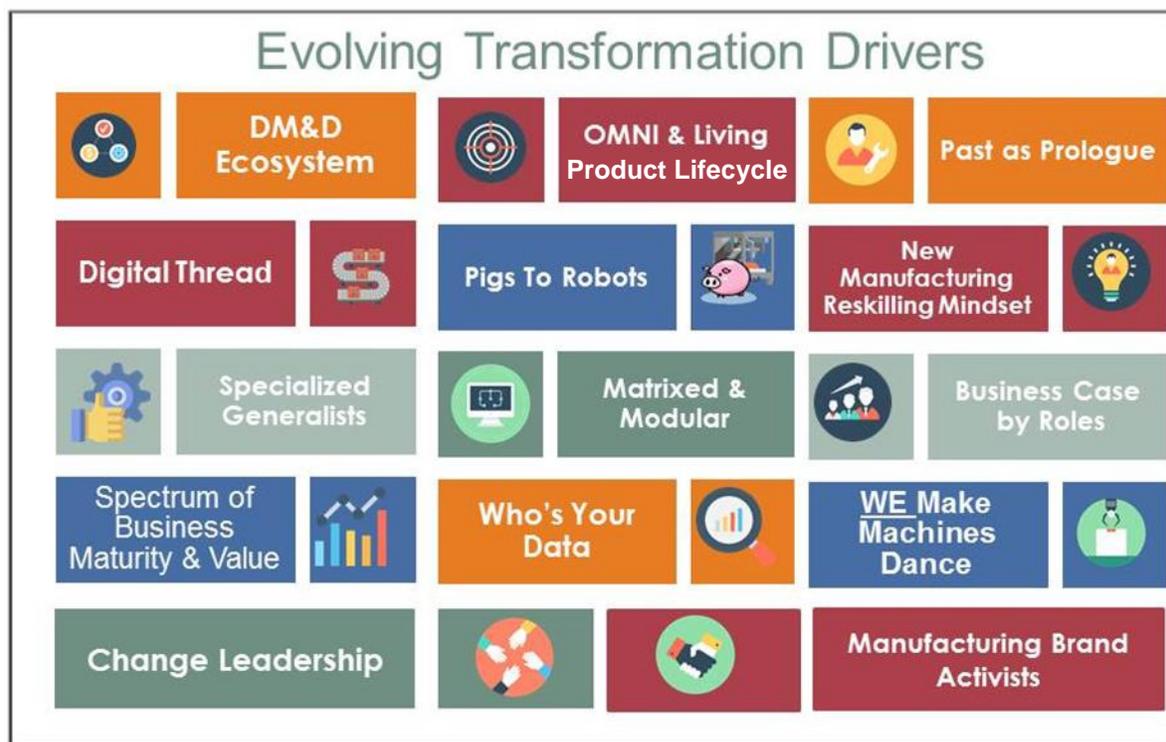
Taxonomy Structure Content Previews

<p>Roles vs. Jobs </p> <p>Role identification and development is the focus of the Taxonomy in order to accommodate the diverse business and work environments that the identified skills will be performed in. Roles can be combined and blended to build out Jobs specific to each employer.</p>	<p>Generations </p> <p>Generations are used to distinguish between periods of development across manufacturing tools, technologies, and work concepts. They are utilized in the Role definitions to identify ranges of background knowledge, work practice, and development focus.</p>	<p>Technical Domains </p> <p>Technical Domains are used to breakdown and demonstrate the interactions between technologies and business concepts in the Digital Manufacturing & Design space.</p>	<p>Breakout Roles </p> <p>Identification of Roles that align to a classic definition of breakout: “...having, causing, or marked by sudden and great success that comes usually after a time without much attention”, Roles we expect to contribute significantly to the digital (re)evolution for manufacturing, and to possibly attract major early interest for more definition and development focus.</p>
<p>Role Clusters </p> <p>Role Clusters are used as a check on workplace applicability through associated skills, interactions, and ability to grow in the organization.</p>	<p>Role Impacts </p> <p>Role Impacts are used to demonstrate the impact a role has in an enterprise as it grows into greater levels of integration and connectivity across the DM&D landscape.</p>	<p>Transition Roles </p> <p>Identification of Roles that provide skill transition or career expansion opportunities to traditional skilled worker roles.</p>	<p>Drivers </p> <p>The background topics and interests driving the advancement of a Digital Manufacturing and Design workforce, and key narrative themes.</p>

2. Fourteen (14) Drivers Influencing the DM&D Workforce Taxonomy

Introduction to the Drivers

A year of executive interviews, research reviews, academic assemblies, model brainstorms, database pulls and analysis, field interviews, supplier sessions, plant visits, domain conferences, conversations in the foundry, visits with virtual reality vendors, and core project team work: ManpowerGroup and DMDII, with members and others, joined together to ask, listen, discover, observe, revisit, evolve, and invent the elements of the taxonomy. These elements were influenced by many needs, opportunities, solutions and challenges. From the many discussions, a set of factors emerged that we believe embody what is shaping and accelerating the evolution of the Digital Manufacturing and Design workforce and the related organizational changes.



Each driver deserves its own report and some are treated deeply in other work; here is an introduction to each emerging as a key influence on the taxonomy.

1. **DM&D Ecosystem:** At the largest and most overarching level, it is known now more than ever that **any industry – DM&D especially with its emphasis on connectivity and its integration to economies and individuals – exists only as an Ecosystem:** all stakeholders succeed, adapt, decline, or sustain together. While it's important at times to have focus and smaller pieces to address, the solution to an adaptive workforce has to be systemic. Operating and maintaining an ecosystem is a huge challenge, never a single stakeholder challenge, and a natural state of challenge that will always be in place. It's big and it's complex, but that is the challenge and the opportunity.

2. **Digital Thread:** Weaving that connection across the companies that succeed in DM&D, is the build out and use of the **Digital Thread: the digital life-blood of data and connectivity** between process, technology, people, customers, and more. The thread defines and connects the data, the work, and the product. It is both tangible and touchable and, as with many electronic and digital infrastructures, it is at times unnoticed and unseen. But make no mistake: **it is the real backbone.** It has to be built and managed, accessed and encouraged.

3. **Specialized Generalists:** From the very first conversation on DM&D skills with a major manufacturer, we have focused on **how blended and integrated the knowledge base has to be** for many roles today in Manufacturing. Digital is a connector, and to build and use a connector, many disciplines converge. In the DM&D workforce roles that have emerged, we see specializations converge. Many real jobs require real integration. The idea of being an electro-mechanical engineer or a multi-skilled worker can bring great benefits to both employer and worker. Across a product's life cycle in the truly connected digital factory of the future and in the other functions – from marketing, to customer support, to supply network management – you will see more utility players as valuable generalists, and you will also see deep expertise in more narrow domains. But in both cases, all roles require broader understanding of the product life cycle and the digital connection. There is a rise in the roles that have a definite hybrid/"tri-brid"/"omni" scope; it's an era of **Specialized Generalists.**

4. **Spectrum of DM&D Business Maturity and Value:** Starting points and adoption rates for technology will be different and vary by everything from sector to geography, to even the availability of the workforce to design or use or operate the digital technology. As a result, there is a spectrum of DM&D Business Value: **entry options exist for many.** More individuals and companies can find their digital niche or role than less with the expanded views of manufacturing and new ways of applying technology and discovering new business value.

Connectivity to the value of the digital thread overall is essential when defining the roles. We need to identify how each role connects to the top-down business value. With new technologies available, yet having many existing platforms that still work, the business will need to make a case to invest in DM&D roles.

It is a real journey each organization – large and small – will have to make. Whether to integrate, gradually replace, or leapfrog are all options for digital tech and the people who will make it work.

5. **Change Leadership:** Change management practices, change mastery as an organizational capability was an imperative from the first meeting, and it never wavered. While much of the technical evolution and the tools and processes must anchor the digital transformation, investments are needed on the people side to accelerate and remove barriers to the technical and production side. **Changing work means changing minds.** The "soft stuff is the hard stuff", and to have a workforce apply their effort with an "owner's perspective" (another requirement we often heard) requires investments in engagement and purposeful involvement of all roles.

6. **Omni and Living the Product Life Cycle:** Expanding on the specialized generalists, there will be premiums for those who truly develop **omni-/cross-domain competence** and seek experiences that enable them to work across the entire Product Life Cycle. Ironman® and Wonder Woman® roles exist; superhero opportunities are available in DM&D where knowledge of multiple

areas and the whole process of manufacturing from idea to decommission is not just a bonus, but in many instances a requirement. All workers in DM&D benefit and bring value from seeing the big picture and having skills in more than one stage of the life cycle. DM&D is a place where the “Jacks and Jills of all trades” can flex their skills.

7. **Pigs to Robots:** One of the most powerful stories of the impact of DM&D on talent and the workforce – and one repeated other times although with possibly less colorful real-life experience – involved pigs (yes, pigs) and robots. It was one shared by a Factory Automation Manager working in the Heartland at a major manufacturer’s flagship plant. While at a plant that had evolved through several generations of digital technology, we asked about his skill base and DM&D training. He shared his career story:

This manager had been given a chance in the military to learn some technical skills, which parlayed into the first of many roles in manufacturing and related areas. He returned to school, earned degrees and kept taking advantage of new technology opportunities, even if it meant leaving behind past success and comfort. He is currently responsible for combining legacy, existing hardware and software into new robotics, automated cells, and module set-ups. Those set-ups leverage and actually highlight older technology by combining it with new DM&D tech. His team’s contributions have been highly praised and valued for how they enabled DM&D transformation at more reasonable investments for the company. As he shared, “I would have never thought when I was a high-school farm boy here in the Midwest that my life would go **from pig poop to robots** but it did, and I couldn’t be more proud.” A powerful, personal story of career opportunity that showcases new passions for “minds on” manufacturing.

8. **Matrixed and Modular:** Many new forms of “manufacturers” are evolving and the manufacturing “enterprise” extends farther when it’s rightly viewed as an ecosystem. Niche companies in part of the life cycle are prevalent such as the design firm that hands-off designs for production. New networks and relationships are created. Start-up sponsorships and partners jumpstart new methods or extend the connected enterprise. Setting up groups, teams, or even subsidiaries for flexibility is smart manufacturing organizational design. It is obvious both inside and outside an organization. The death of the silo is confirmed. Verticals, industries, and functions are going horizontal to work with competitors and providers alike; nests and networks flourish as innovation incubates before it’s commercialized, and supply chains need people to predict and manage their increasingly complex nature.

The integrated team is non-negotiable when it comes to importance; silos are officially dead with DM&D in the model-based enterprise.

9. **Who’s Your Data?** Obviously in DM&D, data is large and in charge! From digital threads to digital twins to increasingly valuable skills like design thinking, problem solving, analytics, and working with integration of operational and information systems, they all requires a base of analytical skills and openness to being a data mover. Recognizing that DM&D highly revolves around connections, a new DM&D T-shirt could proudly read, “**Who’s Your Data?**”
10. **Past is Prologue:** There is no separating from the legacy of manufacturing but there is an emphasis on what amounts to bookends: the designs on the front end and the product or service support on the other end. Add to this the involvement of the customer all around as well as the overarching need for an enterprise that can integrate these elements. The DM&D space is expansive from a work point of view and the scope of Manufacturing grows. It doesn’t go away, yet it evolves and changes. **The past is prologue**, as they say, and the end of some aspects of conventional manufacturing creates change in many places with new skills added to the base.

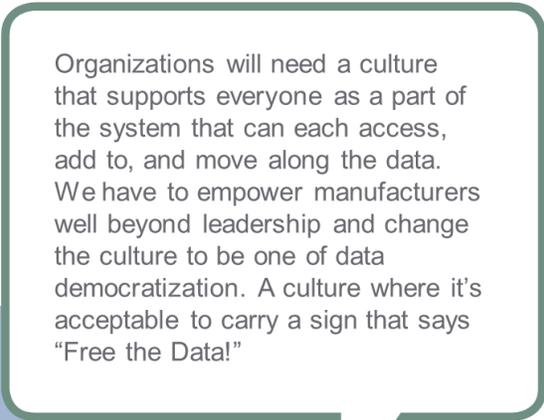
DM&D honors and leverages the legacy of production and mechanics and crafting since that is still the focus; to make something. We appreciate and welcome the augmentation of human performance and human engineering and production legacy and look for smart decisions and policies to be considered as the rate of adoption increases and opportunities for some and transitions for others come with it.

11. **Manufacturing Reskilling Mindset:** Organizational relationships are changing as are the ways that workers find themselves interacting with their employer manufacturer. The concept of **Community and a more open Social Mindset** comes with 21st century living, but is even more strongly felt in DM&D where data and shared use is a Connector-in-Chief. People are exposed to digital before and outside of work. Demands and strategies for connecting the advanced manufacturing mindset of today and tomorrow via new communities of practice; active employer branding; restoring Manufacturing’s image; developing lifelong learning mindsets – all drive the opportunity to create community around improving the skillset of DM&D workers. There are many new roles on the people side, not just technology side, to be included in the taxonomy and many are responsible for building the new skillsets for DM&D.

12. **WE Make Machines Dance:** What would the list be without mentioning robots, increasing automation, and the augmentation of the human productivity and contributions? The most positive technical and business production teams we spoke to have a “love” relationship with their technology. “Make machines dance with us” was a goal and shared purpose stated by a plant executive as he introduced his engineering team. Some have concerns – there are legitimate issues to explore with the rate of automation and machine intelligence and learning. It is the role of ethicists, strategists, and experience designers to remind us that we own the power in enlivening our human-machine partnerships.

13. **Business Case by Roles:** Another direct request for the practical use of the taxonomy was to be able to better understand the outcomes, the **Business Case Basis**, the value of investing in these roles and capabilities. Profiles and other descriptors enable the roles to show their ready ROI. This element was built into the profiling and should help manufacturers envision the goal state and route the talent roadmap through the maturity and value curve.

14. **Manufacturing Brand Activists:** When asked what the #1 barrier to finding talent and getting the skillsets needed was, especially those regarding those who have choices in other work arenas such as software development, the issue of reputation and attraction of manufacturing as a career or vocation continues to get top billing. We need more internal and external Manufacturing Industry Brand Activists. We see a bright future for DMDII as an activist to support using the innovation of DM&D to rebrand Manufacturing as *Partners in Connection* who drive the People/Data/Product/Experience behind some of the world’s most popular product and commercial successes.



Organizations will need a culture that supports everyone as a part of the system that can each access, add to, and move along the data. We have to empower manufacturers well beyond leadership and change the culture to be one of data democratization. A culture where it’s acceptable to carry a sign that says “Free the Data!”

These drivers each have specific connections to the many Taxonomy and success profile outputs and efforts. What do they all have in common? Many of these drivers themselves are a hybrid of needs and opportunities in the space where people determine how they will meet and experience technology.

It's almost as simple as that in summary. What drives the taxonomy? First, recognizing many conventional and new disciplines – physical and digital – converge in the DM&D technologies. Second, remembering that our early adopters shared that, while the technology had to be designed, implemented, and paid for, technology was actually the easier part. It was the changes to the mindsets, the work structures, the culture, working relationships, and the organizational that was the harder part. When done in partnership, it made for faster and greater success.

3. The Seven (7) Domains: Establishing the Work, the Tools, the Technologies

Overview of Technical Domains

Domains are commonly known as a body of knowledge or, more practically, an area of expertise. In the case of the DM&D Technical Domains, we have identified a major business and/or technical area of DM&D work activity, skill, knowledge, and/or tools. These Technical Domains define the space and place where digital manufacturing and design “happens”. This definition is necessary to outlining requirements, valued performance, and knowledge areas which in turn were used by us to design the DM&D roles. From here, we could also use the frameworks of the new and enhanced roles to further build out the domain.

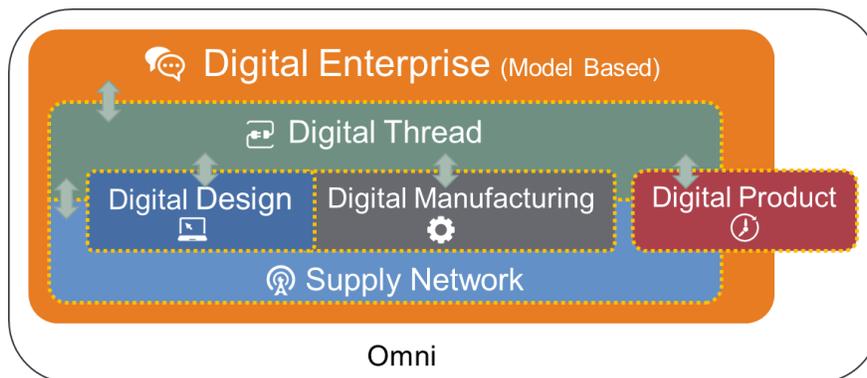
To develop a stronger understanding of the DM&D workforce and to structure or map roles to DM&D technologies, a cohesive baseline of those contributing domains was needed to answer:

- What are the work areas for DM&D?
- What technologies and tools are most defining DM&D at this time and into the foreseeable future?
- What business or technical knowledge areas will enable best performance?
- Where are the value added areas of digital manufacturing and design connecting across the enterprise?

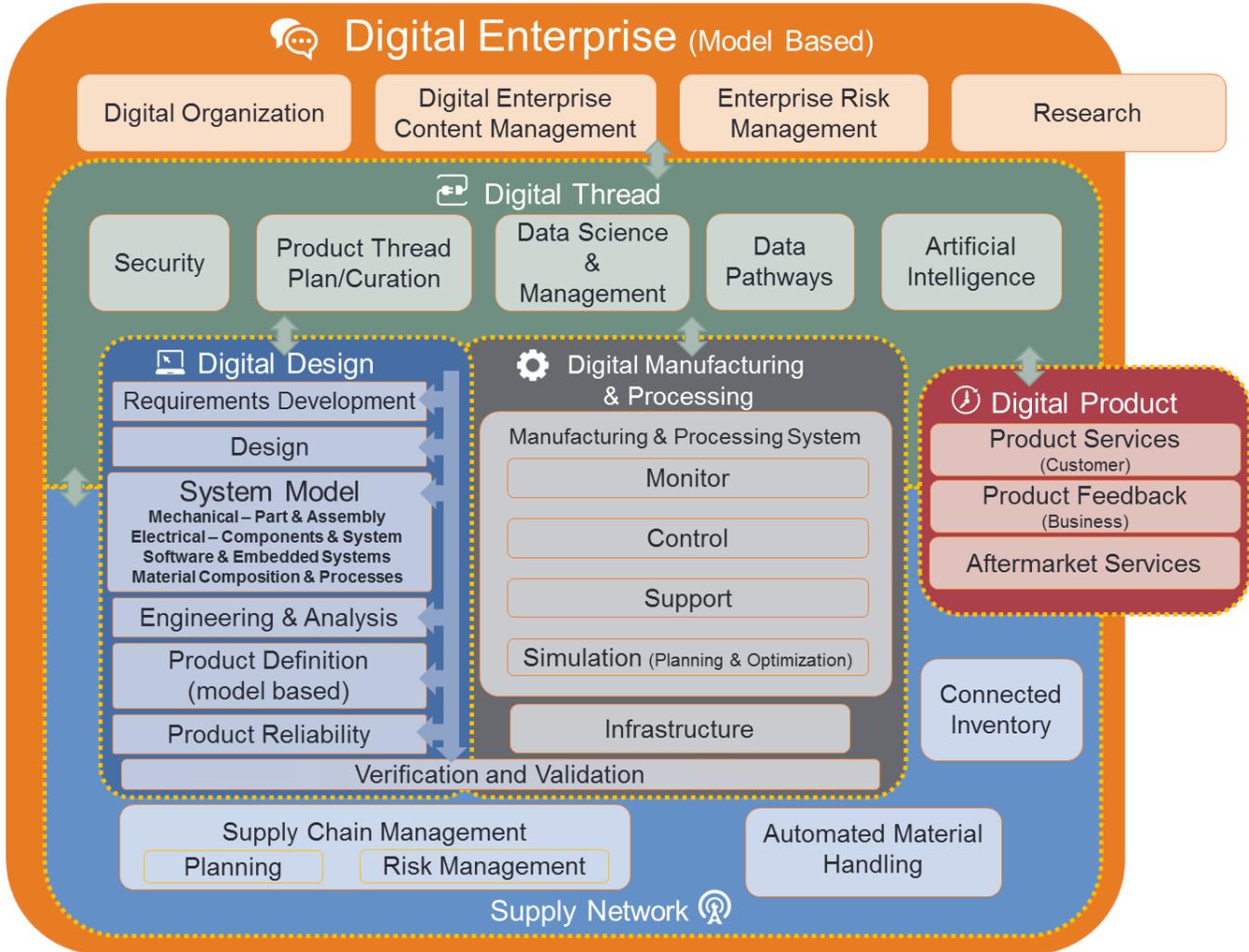
Six primary DM&D domains have been identified. There is also a seventh domain discussed within the Roles – Omni – which is a domain area meant to establish the intentional cross-domain areas of work and expertise that are a hallmark of DM&D capability.

Digital Manufacturing and Design Domain Maps

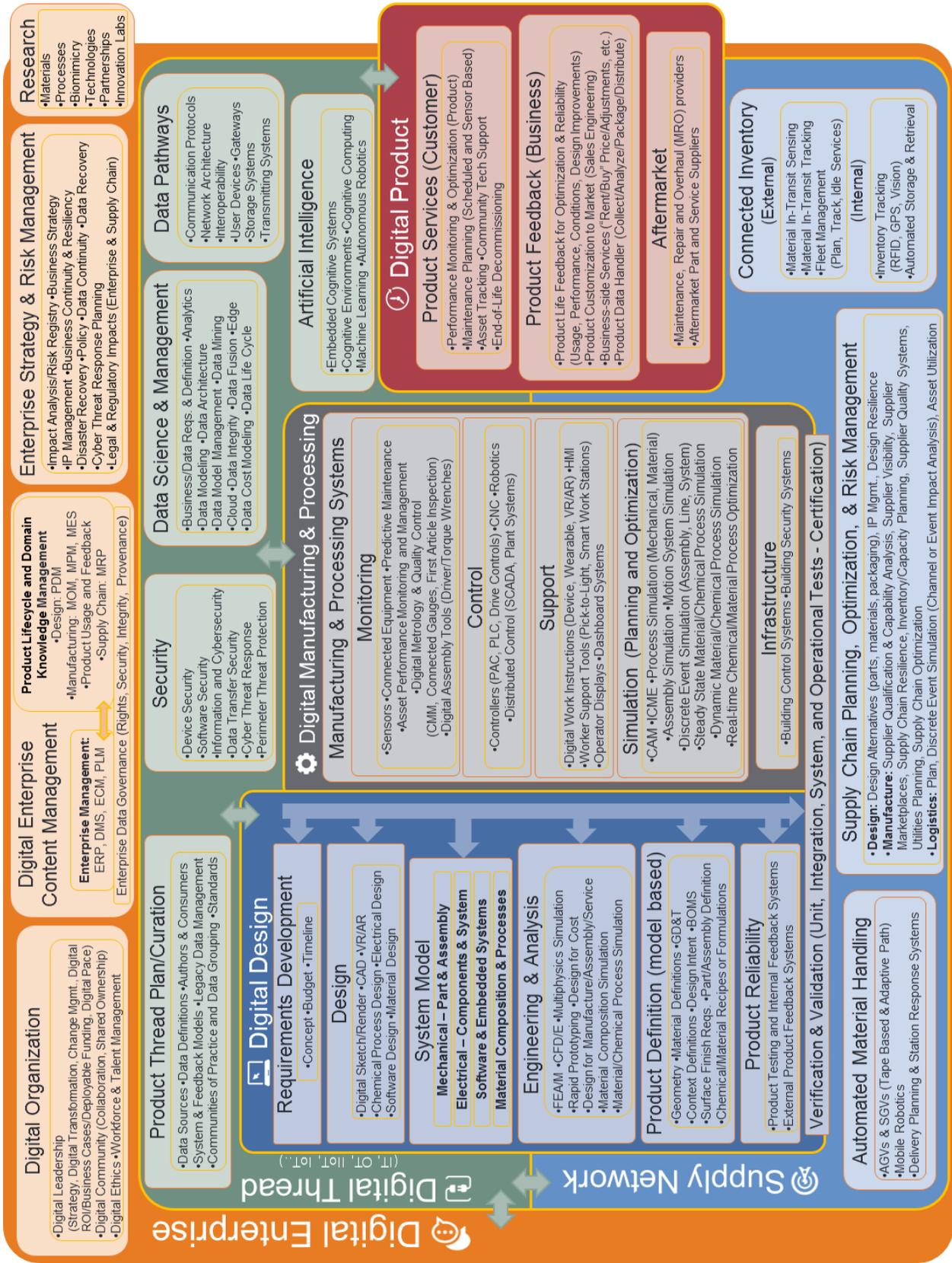
A nested graphical view allows for a spatial representation of the six primary domains. Enterprise wraps at the higher level and around the other domains. Digital Thread is established and then the core of Digital Design and Digital Manufacturing are positioned in the center. Digital Product shares in line space with Design and Manufacturing, as well as Digital Thread and Supply Network which envelops the other primary domains showing its fuller life cycle relationship. Digital Product like Enterprise has some external extension shown, by design, to be reaching “outside” the enterprise. Following are the six primary domains starting at the first level of definition.



The next level of the graphic provides more detail, outlining some of the primary functions that reside within the domains.



The following page provides the most detailed version of the Domain mapping.



Digital Organization

- Digital Leadership (Strategy, Digital Transformation, Change Mgmt., Digital ROI/Business Cases/Deployable Funding, Digital Pace)
- Digital Community (Collaboration, Shared Ownership)
- Digital Ethics • Workforce & Talent Management

Digital Enterprise Content Management

Enterprise Management: ERP, DMS, ECM, PLM

Enterprise Data Governance (Rights, Security, Integrity, Provenance)

Product Lifecycle and Domain Knowledge Management

- Design: PDM
- Manufacturing: MOM, MPM, MES
- Product Usage and Feedback
- Supply Chain: MRP

Enterprise Strategy & Risk Management

- Impact Analysis/Risk Registry • Business Strategy
- IP Management • Business Continuity & Resiliency
- Disaster Recovery • Policy • Data Continuity • Data Recovery
- Cyber Threat, Response Planning
- Legal & Regulatory Impacts (Enterprise & Supply Chain)

Research

- Materials
- Processes
- Biomimicry
- Technologies
- Partnerships
- Innovation Labs

Data Science & Management

- Business/Data Reqs. & Definition • Analytics
- Data Modeling • Data Architecture
- Data Model Management • Data Mining
- Cloud • Data Integrity • Data Fusion • Edge
- Data Cost Modeling • Data Life Cycle

Data Pathways

- Communication Protocols
- Network Architecture
- Interoperability
- User Devices • Gateways
- Storage Systems
- Transmitting Systems

Artificial Intelligence

- Embedded Cognitive Systems
- Cognitive Environments • Cognitive Computing
- Machine Learning • Autonomous Robotics

Security

- Device Security
- Software Security
- Information and Cybersecurity
- Data Transfer Security
- Cyber Threat Response
- Perimeter Threat Protection

Digital Design

Requirements Development

- Concept • Budget • Timeline

Design

- Digital Sketch/Render • CAD • VR/AR
- Chemical Process Design • Electrical Design
- Software Design • Material Design

System Model

- Mechanical – Part & Assembly
- Electrical – Components & System
- Software & Embedded Systems
- Material Composition & Processes

Engineering & Analysis

- FE/AM • CFD/E • Multiphysics Simulation
- Rapid Prototyping • Design for Cost
- Design for Manufacture/Assembly/Service
- Material Composition Simulation
- Material/Chemical Process Simulation

Product Definition (model based)

- Geometry • Material Definitions • GD&T
- Context Definitions • Design Intent • BOMS
- Surface Finish Reqs. • Part/Assembly Definition
- Chemical/Material Recipes or Formulations

Product Reliability

- Product Testing and Internal Feedback Systems
- External Product Feedback Systems

Digital Manufacturing & Processing

Monitoring

- Sensors • Connected Equipment • Predictive Maintenance
- Asset Performance Monitoring and Management
- Digital Metrology & Quality Control (CMM, Connected Gauges, First Article Inspection)
- Digital Assembly Tools (Driver/Torque Wrenches)

Control

- Controllers (PAC, PLC, Drive Controls) • CNC • Robotics
- Distributed Control (SCADA, Plant Systems)

Support

- Digital Work Instructions (Device, Wearable, VR/AR) • HMI
- Worker Support Tools (Pick-to-Light, Smart Work Stations)
- Operator Displays • Dashboard Systems

Simulation (Planning and Optimization)

- CAM • CME • Process Simulation (Mechanical, Material)
- Assembly Simulation • Motion System Simulation
- Discrete Event Simulation (Assembly, Line, System)
- Steady State Material/Chemical Process Simulation
- Dynamic Material/Chemical Process Simulation
- Real-time Chemical/Material Process Optimization

Infrastructure

- Building Control Systems • Building Security Systems

Digital Product

Product Services (Customer)

- Performance Monitoring & Optimization (Product)
- Maintenance Planning (Scheduled and Sensor Based)
- Asset Tracking • Community Tech Support
- End-of-Life Decommissioning

Product Feedback (Business)

- Product Life Feedback for Optimization & Reliability (Usage, Performance, Conditions, Design Improvements)
- Product Customization to Market (Sales Engineering)
- Asset Tracking • Community Tech Support
- Business-side Services ("Rent/Buy" Price/Adjustments, etc.)
- Product Data Handler (Collect/Analyze/Package/Distribute)

Aftermarket

- Maintenance, Repair and Overhaul (MRO) providers
- Aftermarket Part and Service Suppliers

Connected Inventory

(External)

- Material In-Transit Sensing
- Material In-Transit Tracking
- Fleet Management (Plan, Track, Idle Services)

(Internal)

- Inventory Tracking (RFID, GPS, Vision)
- Automated Storage & Retrieval

Supply Chain Planning, Optimization, & Risk Management

- **Design:** Design Alternatives (parts, materials, packaging), IP Mgmt., Design Resilience
- **Manufacture:** Supplier Qualification & Capability Analysis, Supplier Visibility, Supplier Marketplaces, Supply Chain Resilience, Inventory/Capacity Planning, Supplier Quality Systems, Utilities Planning, Supply Chain Optimization
- **Logistics:** Plan, Discrete Event Simulation (Channel or Event Impact Analysis), Asset Utilization

Automated Material Handling

- AGVs & SGVs (Tape Based & Adaptive Path)
- Mobile Robotics
- Delivery Planning & Station Response Systems

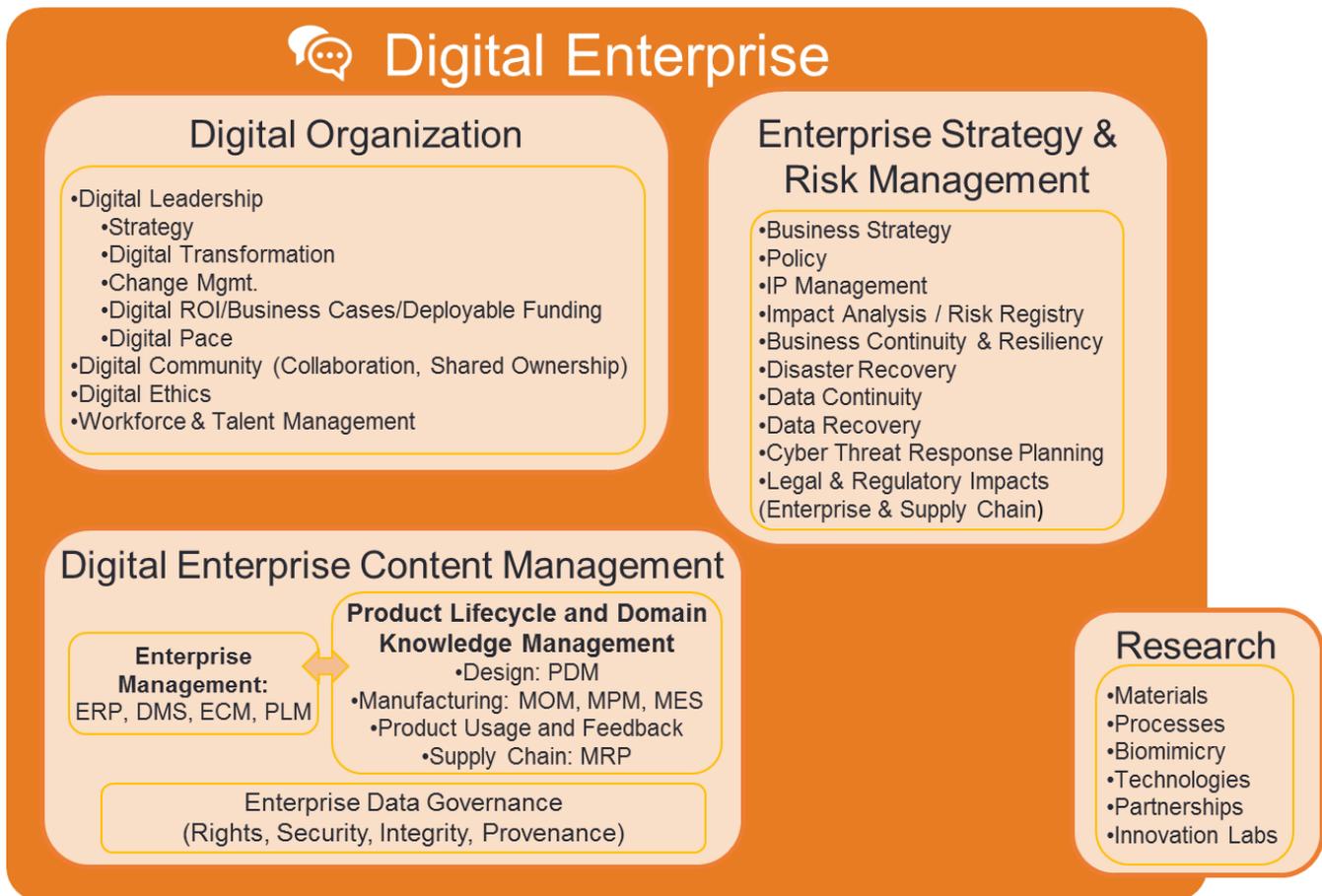
Digital Enterprise

Supply Network

Digital Thread

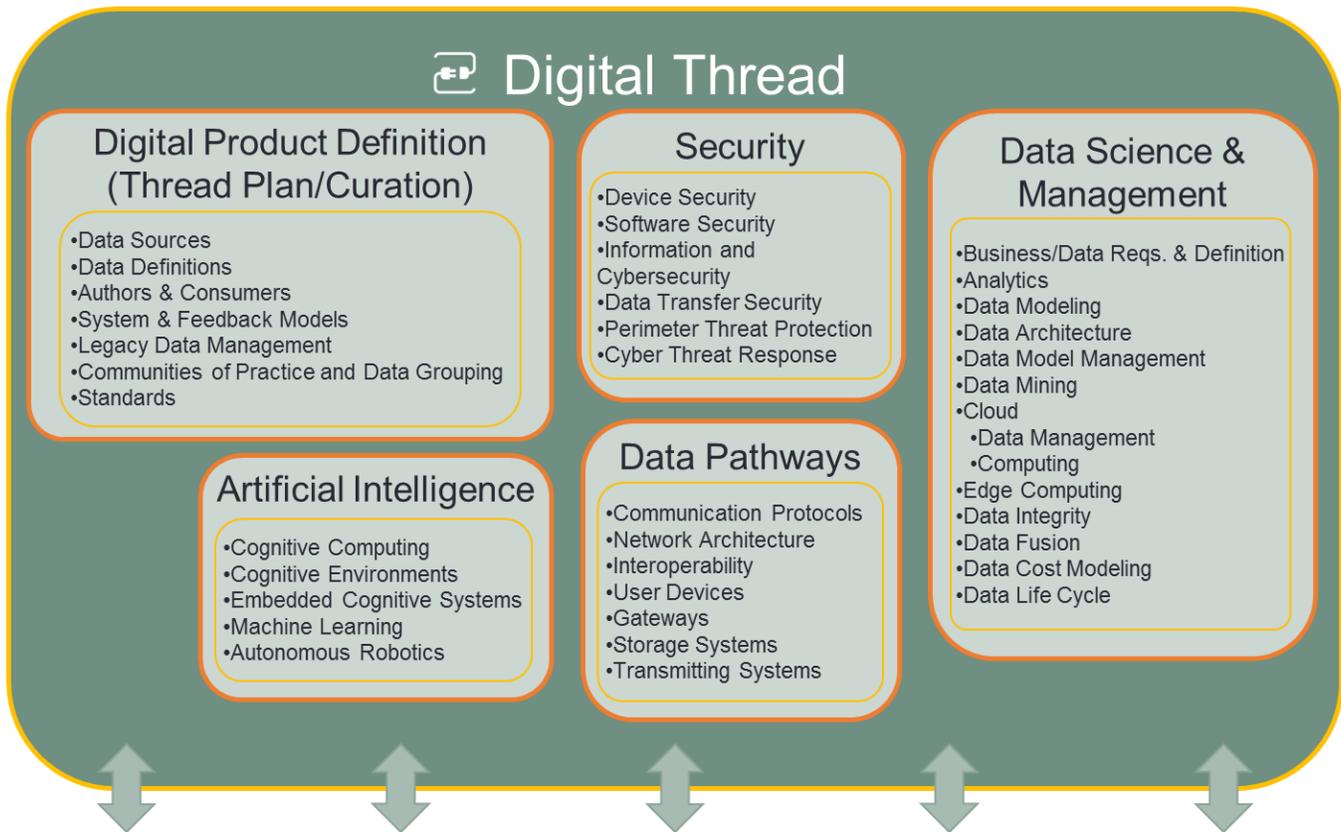
Technical Domain: Digital Enterprise

Digital Enterprise is the domain that recognizes the organizational-level business connections and overarching digital model commitment that enables and manages the digital manufacturing organization. Foundational to the Digital Enterprise are information systems and work relationship connectivity throughout the organization and into the supply chain. It positions the business' technical leadership and structural elements; risk/reward propositions; talent and cultural considerations; and pervasive commitment to data utilization, in a manner necessary for all other domains to flourish. In the graphical representation, Research is seen extending beyond the boundary of the Digital Enterprise to capture the importance of research partnerships and engagement with external technology communities to make sure new product and business opportunities are not missed.



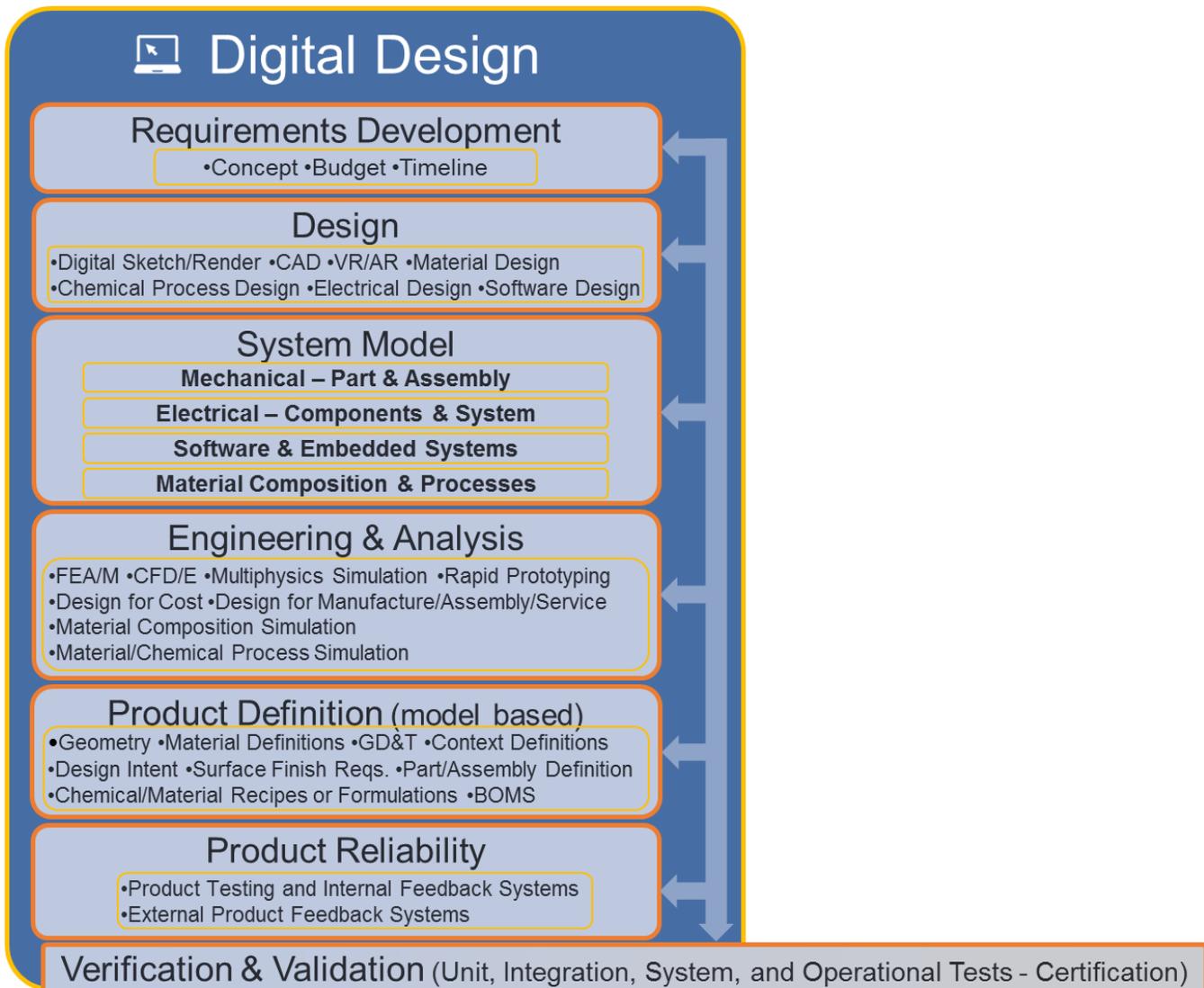
Technical Domain: Digital Thread

Digital Thread is the domain that covers the guidance, integration, and security of data across the full product lifecycle and enterprise digital arena, providing intersection with all other Technical Domains. It can be thought of as “the thread of data, information, work flows, and decisions surrounding a product that run between and across the other domains.” It provides the continuous connections for the flow of information, opportunity, and organizational enablers associated with a fully connected enterprise across the DM&D space. The efficient, interoperable, secure, well managed connectivity of data across once siloed organizations and disparate systems is critical for the future success of an organization and their supply chain.



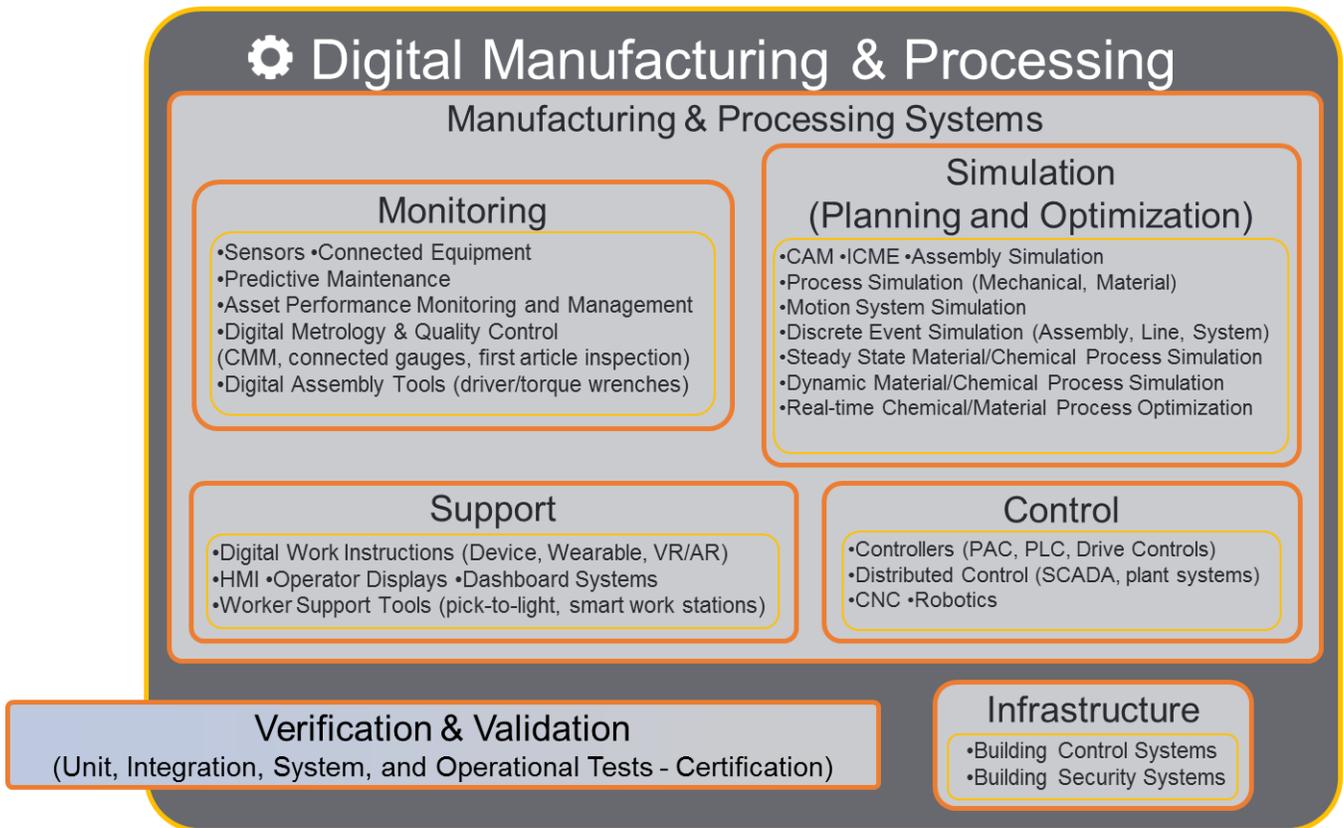
Technical Domain: Digital Design

Digital Design is the domain that covers the digital tools, techniques, and expanded mindset used to design, simulate, and plan a product through development, manufacturing, and operation. Increased information systems connectivity in the design space drives a greater blending of art and science, and enables advances in innovation and efficiency throughout a product's life cycle. This domain defines the behavior, context, and core for product improvement. Digital Design ties closely into Digital Manufacturing and Processing to enable efficient Verification and Validation of product and subsystem performance across the product lifecycle and supply chain.



Technical Domain: Digital Manufacturing & Processing

Digital Manufacturing is the domain that covers the digitally enabled tools, technologies, and work concepts that aid in the execution of manufacturing, processing, or assembly of a product. Technologies that influence Digital Manufacturing include digitally controlled/sensed equipment, shop floor tools/systems/software, infrastructure systems, and simulations used to optimize production and product quality. Digital Manufacturing & Processing ties closely back into Digital Design to enable efficient Verification and Validation of product and subsystem performance, enhancing the enterprise's ability to respond with design fixes or improvements to meet product performance requirements or improve productivity and cost in manufacturing.



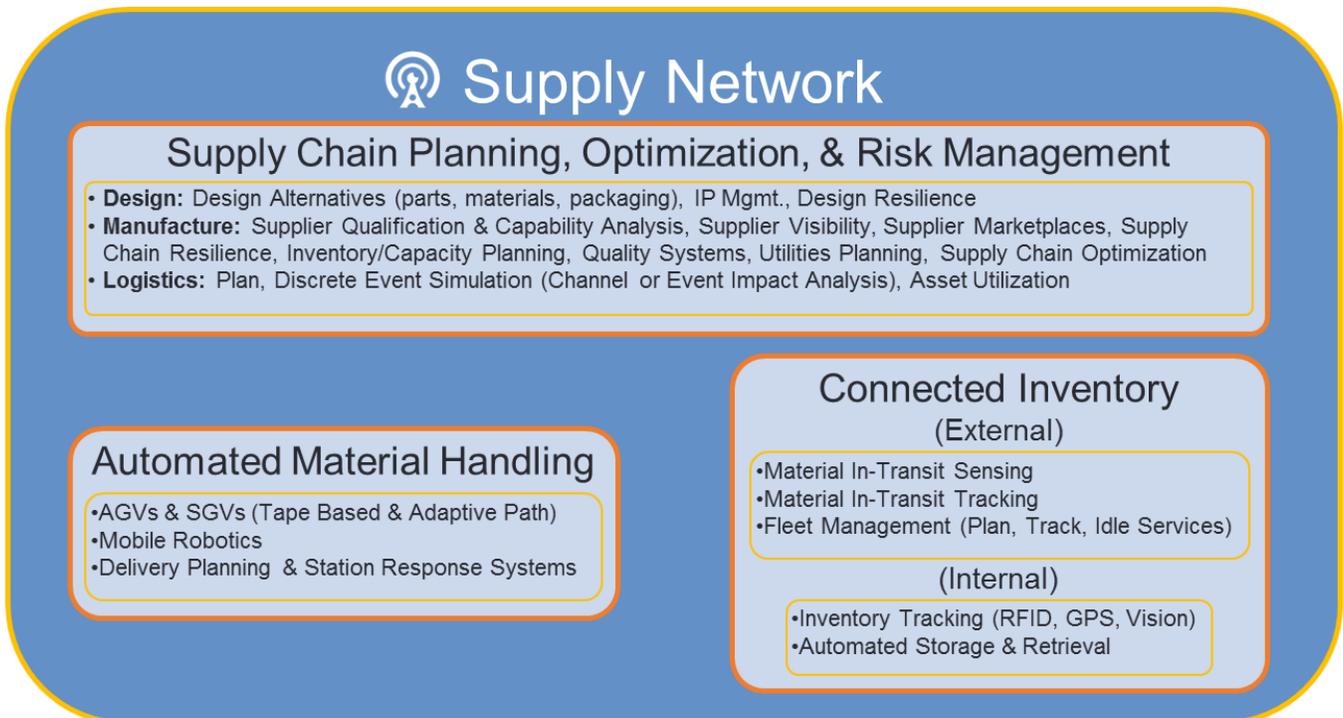
Technical Domain: Digital Product

Digital Product is the domain where a product's digital data and potential for connectivity back to the enterprise or consumer can be utilized for product services benefitting the customer, to provide product feedback to the business, or to support product aftermarket. These technologies can range from performance optimization to product life feedback. After a product has left the manufacturer and is in the hands of the customer the Digital Thread may become interrupted and data may no longer be readily traceable or attainable.



Technical Domain: Supply Network

Supply Network is the domain of technologies that support the supply and delivery of production materials to manufacturing & processing environments, and product across the enterprise on a path to the customer, including material handling and logistics services. A greater level of data connectivity within the Supply Network enables real time supply chain optimization and risk management. Supply Technologies can integrate into all domains directly impacting product life (Design, Manufacturing, and Product). Increased levels of connectivity between design and supply network workers can lead to product designs supported by more robust supply networks, or the identification of more cost-effective design solutions. Enhanced engagement and connectivity between manufacturing & processing environments and the supply network can lead to increased levels of production, and reduced inventory and interruptions. Connectivity between the product and supply network can lead to new service opportunities, and the availability of repair parts before a product has to undergo maintenance procedures, reducing the need for large spare parts inventories.



Summary

In these DM&D Technical Domain Maps we indicate the set of business, technology, tool, skill, or work areas as required areas of expertise for those who perform most successfully in the role. By design not all generic technology, skill, or work areas for a role are described in the diagram. Our focus is on those – generic and digitally direct areas – that are seen as most essential at this time for digital transformation, operation, and success.

We believe that these Technical Domain maps and descriptions will better help enable stakeholders to understand and align aspects such as business planning, research, education, talent management, and workforce planning.

4. 165 Roles: Populating the Community of DM&D Roles

Introduction to the Roles

Manufacturers have a tall order as they move forward to digitize their business models, customer and product strategies, and life cycle operations. One challenge is adopting the technology itself, but perhaps the greater hurdle – and opportunity – is transforming the workforce, whether that workforce is directly employed or engaged through other workforce management or throughout one’s supply chain and broader talent platform. As goes the workforce, so goes the entire organization.

The DM&D transformation begins with understanding the emerging roles in digital manufacturing and design and identifying at which stage their business is in terms of optimizing those roles and capabilities.

The main purpose of the taxonomy is to provide a way to define and classify the work that is being done in DM&D to enable workforce planning, development, and hiring. In a parallel to the domain definition, work role analysis and design efforts address DM&D opportunities and needs. Drawing on conventional manufacturing roles and jobs information as well as recommending novel roles only for the DM&D domains, a community of 165 roles across the domains evolved.

165 DM&D Roles Were Identified & Mapped to the Technical Domains

Our priority focus is on **Roles**, a cluster of related duties, skills, or knowledge that contributes to key outcomes of a work effort. **Jobs** are one or more roles tied together to meet a need or focus of an organization and managed as a position for one or more people to do. Organizations can assemble roles into jobs as needed. A Role can be an entire job and often is an entire job, especially in larger organizations; other organizations will combine roles especially in early stages or where the volume of work does not require dedicated positions.

This project’s focus on identifying **Roles rather than Jobs** is an important distinction. The US manufacturing industry is diverse, encompassing a variety of work environments. These roles are seen as critical to the success of digital manufacturing enterprises. Each manufacturing organization will need different sets or combinations of these roles on different timelines depending on their life cycle and their business focus.

The roles fall within the six business and technical domains and some are also aligned to the Omni domain, based on the primary set of work activity, skills, knowledge, or tools used. Secondary domains and beyond are also available as part of the extended data set while the primary listing is with the primary domain.

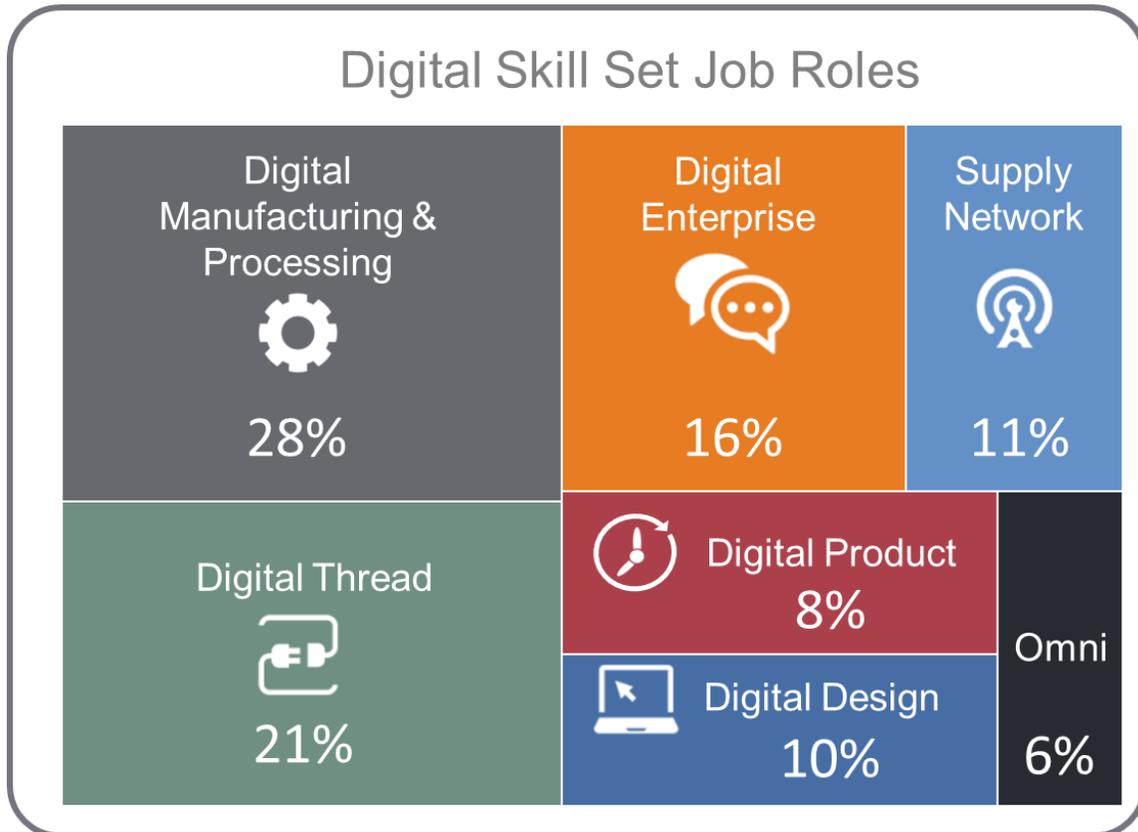
Generic Levels and Generic Roles

Of the 165 roles identified, the profile of levels developed 3 Technician roles, 24 Specialist roles, 84 Professional roles, 30 Engineer roles and 24 Management roles. Most roles are within an enterprise; some key roles actually operate in the broader talent ecosystem but not always as an employee of a modern manufacturer.

The specific DM&D and digital organizational roles include: Technician, Specialist, Analyst, Tester, Engineer, Architect, Designer, Manager, Strategist, Project Manager, Program Manager, Product Manager, Application Developer, Programmer, Modeler, Statistician, Scientist, Community of Practice Manager, Instructor, Technical Trainer, Educator, C-Level Officer, Knowledge Curator, and Ethicist.

These roles take on domain specialization – or cross-domain specialization with one or more of the technical domains defined for DM&D.

Below is the distribution of the roles across the domains. Digital Manufacturing draws the largest number of roles, with Digital Thread second, and Digital Enterprise roles the third most frequent home domain.



The roles represent the “assemblies” of skills that optimize the digital environment across the domains and each organization will put together the combination of roles into jobs as it needs. One first aspect of roles that all DM&D organizations actually have in common is how to we lead and manage the digital workforce.

Who Will Lead the DM&D Roles? Becoming a Digital Leader

Defining the future of digital manufacturing work includes a focus on leadership and enterprise management. The digital era brings shared challenges and opportunities for all leaders and workers in all industries. A key perspective in successfully driving and managing through change as a digital leader is to recognize these are different business, social, and technological times requiring some additional leadership areas of skill and focus.

Across the community of DM&D Roles there were 24 leadership roles identified with titles of Manager, Senior Leader, or Executive. While we focused on those roles in the DM&D enterprise with higher “digital change deltas” (see Page 6), and while many roles have elements of “leadership” in them, several specific or generic DM&D leadership roles were called out.

Often it was because these managers and leaders will be directing and guiding key digital technologies; other times it was because of the responsibilities to closely guide the manufacturing company as it becomes a digital enterprise and all that comes with that transformation. Some leader roles were identified to deliver on updated manufacturing management responsibilities now with the extra requirements of running a digital enterprise versus an automated enterprise. Some technical leadership roles for designing or producing digital products and material products but with digital tools, etc. were identified. Some leader roles have increased accountability for driving organizational change and leading the renewals with the “silo-less” connected digital enterprise; some Digital leaders’ roles are emphasized for their expanded internal and external range of accountability. Overall, leadership roles ranged from the C-suite to projects and key specialty areas; these include Chief Digital Officers, Digital Manufacturing Program Managers, Enterprise Supply Network Managers, and more.

Before describing the many DM&D roles that will make the digital manufacturing enterprise succeed, we ask: What kind of leader will be needed to lead the digital manufacturing organizations overall and across domains? For all of these leaders we see enhanced responsibilities and perspectives.

Right Management, a subsidiary of ManpowerGroup, has a view of the Digital Leader in Digital Manufacturing Age that is informed by their workforce solutions efforts in manufacturing and other sectors and their research on the Human Age™, macro-economic forces, leader assessment and development, and the shift of client organizations to digital enterprise. Those who are charged with leading in the digital era need to amplify certain skill sets, mind sets, behaviors, perspectives, and practices.



Right Management views the Digital Leader as needing to see through several lenses to be effective in the digital manufacturing and design business environment while running a DM&D enterprise. Having both short- and long-term visions; managing the many paradoxes (more technology connections yet people feel isolated by digital tech); extreme demands for connections and collaborations; greater diversity in everything from business models to products to work arrangements; having to lead through transformations, plural as they will continue. These five are the hallmarks of a digital leader in the digital era.

Digital leaders – in manufacturing and other sectors – will need to use five major “lenses” to be successful.

- **Vision: The ability to not only create vision, but to mobilize transformation.** This will require leaders to be able to lead to and through ambiguity; consciously choose positives, not perils; morph products to services and long-term relationships; and lead collaboration between people, machines, and data.

- **Paradox: The ability to lead through paradox.** This requires recognition that you are asking your organization to embrace and live within multiple paradoxes such as more technology, but also more human connection; more data which actually requires more interpretation; innovation while operating – flying the airplane while building it (because you can't just stop what you are doing, switch to digital and turn back on); ecosystems and shared data, yet security, data, and data governance are essential; and leveraging what was good about legacy while transforming the organization.
- **Collaboration: More than ever before** – and whether global, remote, internal, and external **one can't go on this journey alone.** It's about partner networks, customer communities, and employee enclaves. As manufacturers move through transformation, it requires leaders to have a high degree of empathy, communication, and internal and external feedback loops that feed continuous improvement, innovation, employee engagement, and customer satisfaction.
- **Diversify: the ability to be more than one thing at any point in time** which will require that you can foster diverse, creative ideas about products and services and the teams that will make them happen; vary the many possible structures of teams and partners, makers and customers; and flexibly address the overall dynamism around how teams and programs are formed.
- **Transformation: no longer about adoption or integrating or transitioning...it's now about transforming.** This implies changing a lot of underlying structures, organization, culture, business model. Fundamental shifts at the same time in multiple areas mean that there is more people and culture transformation than even technical and data transformation – this includes upskilling and reskilling talent. Critical here will be the ability to execute while simultaneously being in an experimentation and fast-fail mode.

These focus areas for manufacturing leaders will benefit a company moving towards digital adoption and transformation, and then through the digital transformation including future waves of successive digital transformation. Being through transformation, an enterprise views digital manufacturing as a natural part of the organization – where the company can see and then execute the practices, culture, business model, and vision of a digital manufacturer viewing them as 'native' and not calling them out as 'new'.

Roles by Domains

Where will these leaders lead? Where will the next generations of digital manufacturing leader come from? Where will technical and business leadership evolve? Who are all of experts in the workforce? Where is all the work being done and by what roles? Where are all the skills that the modern manufacturer looks to as they drive their mission?

The following sub-sections present the community of 165 roles through sub-lists of the roles by domain and impact, which will be further explained in the coming pages. Later views will present sub-lists of the community of DM&D roles using the other filters of generations and impact.

Welcome to the Digital Manufacturing and Design Community of Roles!

Digital Enterprise Associated Roles

This domain holds a total of 26 DM&D roles.



4



7



15

Domain	Community Role	Role Impact
Digital Enterprise	Chief Digital Officer	Keystone
	Cognitive Systems Scientist	Pioneer
	Data Management Scientist	Producer
	Digital Enterprise Vocational Instructor	Producer
	Digital Enterprise and Integrated Product Intellectual Property Senior Manager	Keystone
	Digital Enterprise Community of Practice Manager	Keystone
	Digital Enterprise Technical Trainer	Producer
	Digital Manufacturing Biomimicry & Sustainability Specialist	Pioneer
	Digital Manufacturing Leader - Functional Business Senior Manager	Keystone
	Digital Manufacturing Organizational Change Management Strategist	Keystone
	Digital Manufacturing Organizational Effectiveness Specialist	Keystone
	Enterprise Digital Ethicist	Producer
	Enterprise Risk Manager	Producer
	Enterprise Supply Network Manager	Keystone
	Information Scientist	Producer
	Innovation Strategist - Enterprise Direction	Producer
	Integrated Computational Material Engineering Scientist	Producer
	Manufacturing Analytics Scientist	Producer
	Manufacturing Scientist	Producer
	Manufacturing Systems Scientist	Producer
	Manufacturing Systems Simulation Scientist	Producer
	Process Simulation Scientist	Producer
	Product Embedded Cognitive Systems Scientist	Pioneer
	Regulatory Analyst	Producer
	Software Scientist	Producer
	Virtual Reality/Augmented Reality System Scientist	Pioneer

These domain roles – from the Chief Digital Officer leading the company charge on digital to the Biomimicry and Sustainability Specialist who can bring innovation and environmental design thinking to research and production – are those that establish the key Digital Enterprise workforce with the most prominent “Digital Delta” in this domain. They are seen as those most opportune for delivering on the organizational-level business connections, the overarching digital model, and the innovation commitment that enables the digital manufacturing organization. This collection of roles enables the enterprise to flourish through impactful data utilization and a commitment to a “digital” strategy.

Digital Thread Associated Roles

This domain holds a total of 34 DM&D roles.



Domain	Community Role	Role Impact
Digital Thread	Cognitive Systems Designer	Producer
	Cognitive Systems Engineer	Pioneer
	Cognitive Systems Specialist	Pioneer
	Data Management Analyst	Producer
	Data Management Manager	Producer
	Digital Data Tester	Producer
	Digital Knowledge Community Curator	Keystone
	Digital Manufacturing IT Systems Analyst	Producer
	Digital Manufacturing Systems Architect	Producer
	Digital Manufacturing Systems Specialist	Producer
	Digital Thread Engineer	Keystone
	Digital Thread Technical Educator (Teachers 9-12)	Producer
	Digital Thread Technical Trainer	Producer
	Digital Twin Analyst	Pioneer
	Digital Twin Architect	Pioneer
	Digital Twin Manager	Keystone
	IT Systems Optimization Engineer	Producer
	IT/OT Application Developer	Producer
	IT/OT Systems Analyst	Producer
	IT/OT Systems Architect	Pioneer
	IT/OT Systems Engineer	Keystone
	IT/OT Systems Specialist	Producer
	IT/OT Systems Strategist	Producer
	IT/OT Systems Technician	Producer
	IT/OT Systems Tester	Producer
	Manufacturing Cybersecurity Analyst	Producer
	Manufacturing Cybersecurity Application Developer	Pioneer

Domain	Community Role	Role Impact
Digital Thread	Manufacturing Cybersecurity Architect	Producer
	Manufacturing Cybersecurity Engineer	Pioneer
	Manufacturing Cybersecurity Programmer	Pioneer
	Manufacturing Cybersecurity Strategist	Pioneer
	Manufacturing Cybersecurity Technician	Pioneer
	Manufacturing Cybersecurity Tester	Producer
	Product Life Cycle Data Engineer	Producer

The roles in the Digital Thread Domain span from IT/OT Systems Engineers to Digital Twin Architects to Manufacturing Cybersecurity Strategists. This collection of roles supports the connectivity of data across the enterprise, an effort that ranges from guidance, integration, and security of data from manufacturing and supply chain environments into business systems. The activities of workers in these roles drive “digital” across the whole enterprise and even out across the supply chain, distinguishing them from traditional more compartmentalized data, networking, and computer systems roles. The connectivity of data across multiple systems and layers of an organization that Digital Thread roles establish breaks down the walls and information silos, driving new opportunities for collaboration and feedback across the product lifecycle.

Digital Design Associated Roles

This domain holds a total of 17 DM&D roles.



4



3



10

Domain	Community Role	Role Impact
Digital Design	Digital Design Analyst	Producer
	Digital Design Community of Practice Manager	Keystone
	Digital Design Engineer	Pioneer
	Digital Design Specialist	Producer
	Digital Design Technical Trainer	Producer
	Digital Design Vocational Instructor	Producer
	Model Based Systems Engineering (MBSE) - Engineer	Producer
	User Experience Analyst	Producer
	User Experience Architect	Producer
	User Experience Designer	Keystone
	Virtual Reality/Augmented Reality Hardware Engineer	Pioneer
	Virtual Reality/Augmented Reality Software Engineer	Pioneer
	Virtual Reality/Augmented Reality System Manager	Keystone
	Virtual Reality/Augmented Reality System Modeler	Producer
	Virtual Reality/Augmented Reality System Specialist	Pioneer
	Worker Experience Analyst	Producer
	Worker Experience Designer	Producer

The roles in Digital Design Domain span from the Worker Experience Designer to the Model Based Systems Engineering (MBSE) – Engineer. This collection of roles leverages increased information systems connectivity in the design space, and across the enterprise, to enable advances in product innovation and design efficiency. These greater levels of data connectivity and alignment of design systems distinguish these roles as “digital”. They design, analyze, optimize, and define the product and its subsystems, establishing the foundation of data around a product. Their work interactions with staff in the Digital Manufacturing and Processing Domain support design for efficient manufacturing, operations, and worker engagement during production.

Digital Manufacturing and Processing Associated Roles

This domain holds a total of 46 DM&D roles.



8



6



32

Domain	Community Role	Role Impact
Digital Manufacturing	Augmented Reality Manufacturing Systems Specialist	Pioneer
	Collaborative Robotics Specialist	Pioneer
	Collaborative Robotics Technician	Producer
	Digital Factory Automation Analyst	Producer
	Digital Factory Automation Architect	Producer
	Digital Factory Automation Engineer	Producer
	Digital Factory Automation Manager	Keystone
	Digital Manufacturing Analyst	Pioneer
	Digital Manufacturing Chief Technology Officer	Keystone
	Digital Manufacturing Community of Practice Manager	Keystone
	Digital Manufacturing Engineer	Pioneer
	Digital Manufacturing Executive - Cross Domain Business Leader	Keystone
	Digital Manufacturing Executive - Functional Business Leader	Keystone
	Digital Manufacturing IT Specialist	Producer
	Digital Manufacturing Knowledge Manager	Producer
	Digital Manufacturing Program Manager	Producer
	Digital Manufacturing Project Manager	Producer
	Digital Manufacturing Safety Systems Specialist	Producer
	Digital Manufacturing Technical Educator (Teachers 9-12)	Producer
	Digital Manufacturing Technical Trainer	Producer
	Digital Manufacturing Technician	Producer
	Digital Manufacturing Vocational Instructor	Producer
	Factory Prognostics Engineer	Pioneer
	Instrumentation Engineer	Producer
	Machine Learning Scientist	Pioneer
	Machine Learning Specialist	Pioneer
	Manufacturing Analytics Analyst	Producer
	Manufacturing Analytics Manager	Producer
	Manufacturing Analytics Specialist	Producer
	Manufacturing Process Engineer	Producer
	Manufacturing Process Specialist	Producer
	Manufacturing Systems Designer	Producer
Manufacturing Systems Engineer	Producer	
Manufacturing Systems Modeler	Producer	

Domain	Community Role	Role Impact
Digital Manufacturing	Manufacturing Systems Simulation Engineer	Producer
	Manufacturing Systems Simulation Manager	Producer
	Manufacturing Systems Simulation Specialist	Producer
	Operation Technologies Integration Engineer	Producer
	Predictive Maintenance System Specialist	Pioneer
	Process Engineer	Producer
	Process Quality Data Analyst	Producer
	Process Quality Data Manager	Keystone
	Process Quality Data Specialist	Producer
	Process Simulation Engineer	Producer
	Process Simulation Manager	Producer
	Process Simulation Specialist	Producer

The roles in Digital Manufacturing & Processing Domain range from the Digital Manufacturing Technician to the Digital Manufacturing Chief Technology Officer. This group of roles is responsible for the monitoring, simulation, support, and control of manufacturing operations and processes. Their roles are brought into the “digital” space through new sensing, control, data collection, and connected technologies. Many workers in this domain are able to grow their skills and capabilities by learning how to deploy or use new technologies in the manufacturing environment, providing greater impact and data insights to others across the enterprise. Their close relationship with workers in the Digital Design Domain enables efficient Verification and Validation of product and subsystem design and performance through manufacturing, leading to improvements in product quality, cost, and performance.

Digital Product Associated Roles

This domain holds a total of 14 DM&D roles.



Domain	Community Role	Role Impact
Digital Product	Digital Product Community of Practice Manager	Keystone
	Digital Product Manager	Producer
	Digital Product Market Customization Engineer	Pioneer
	Digital Product Marketing Specialist	Pioneer
	Digital Product Safety Systems Engineer	Producer
	Digital Product Safety Systems Specialist	Producer
	Digital Product Support Manager	Producer
	Digital Product Technical Trainer	Producer
	Digital Product Vocational Instructor	Producer
	Embedded Product Prognostics Analyst	Pioneer
	Embedded Product Prognostics Engineer	Pioneer
	Product Embedded Cognitive Systems Engineer	Pioneer
	Product Embedded Cognitive Systems Specialist	Pioneer
	Product Performance Optimization Engineer	Producer

The roles in the Digital Product Domain range from the Product Embedded Cognitive Systems Specialist to the Digital Product Market Customization Engineer. This group of roles takes advantage of a product’s potential for data connectivity and computation to establish new services for customers and new value to the enterprise. These new opportunities around data and connectivity at the product level establish these roles in the next generation of “digital” capabilities for an organization. The technologies applied by roles in this domain can lead to performance optimization of the product, insight on product usage and behavior over extended periods of time and in varying conditions, and unlock predictive maintenance opportunities for the customer and manufacturer.

Supply Network Associated Roles

This domain holds a total of 18 DM&D roles.



Domain	Community Role	Role Impact
Supply Network	Automated Guided Vehicle (AGV) Systems Engineer	Pioneer
	Automated Guided Vehicle (AGV) Systems Specialist	Producer
	Fleet/Asset Optimization Analyst	Producer
	Fleet/Asset Optimization Manager	Keystone
	Fleet/Asset Optimization Specialist	Pioneer
	Inventory Systems Automation Specialist	Producer
	Predictive Supply Network Analytics Engineer	Pioneer
	Sales Engineer	Producer
	Self Guided Vehicle (SGV) Systems Engineer	Pioneer
	Self Guided Vehicle (SGV) Systems Specialist	Producer
	Supply Network Business Analyst	Producer
	Supply Network Community Manager	Keystone
	Supply Network Integration Community of Practice Manager	Keystone
	Supply Network Quality Data Analyst	Producer
	Supply Network Quality Data Manager	Keystone
	Supply Network Quality Data Specialist	Pioneer
	Supply Network Technical Trainer	Producer
	Supply Network Vocational Instructor	Producer

The roles in the Supply Network Domain range span from Supply Network Quality Data Analysts to Automated Guided Vehicle (AGV) Systems Specialists. This collection of roles supports the efficient supply and delivery of production materials across the manufacturing environment, and ultimately the distribution of a completed product. A greater level of data connectivity, the integration of once disjointed information systems, and the introduction of new automation and inventory tracking technologies across the supply network further establishes these roles as “digital”. The integration of supply network technologies and data into all domains can have a strong impact on enterprise performance across a product’s lifecycle, from design, to manufacturing, to operation, and ultimately disposal/reuse.

Domain Associated Roles for Omni

This domain holds a total of 10 DM&D roles.



Domain	Community Role	Role Impact
Omni	Continuous Improvement Engineer	Producer
	Continuous Improvement Manager	Keystone
	Continuous Improvement Specialist	Producer
	Omni Technical Educator (Teachers 9-12)	Producer
	Omni Technical Trainer	Producer
	Omni Vocational Instructor	Producer
	Product Life Cycle Quality Data Analyst	Producer
	Product Life Cycle Quality Data Manager	Keystone
	Product Life Cycle Quality Data Specialist	Pioneer
	Statistician	Producer

The roles in the Omni Domain span from Continuous Improvement Specialists to Technical Educators. This group of roles captures the workers who have established knowledge and work practices that span all the other domains. Their intentional cross-domain areas of work and expertise support the pursuit of higher levels of data connectivity and collaboration across an enterprise and the actionable insights that data and interaction may bring. These roles distinguish themselves as “digital” not just due to their interactions across the domains, but due to their ability to leverage and increase data use in new ways across environments and the full product lifecycle.

These 165 roles are those that best represent the digital succession of manufacturing workforce. Using them as new language and structure for business planning, research, education, talent management and workforce planning will enable the broader transformation of the manufacturing industry.

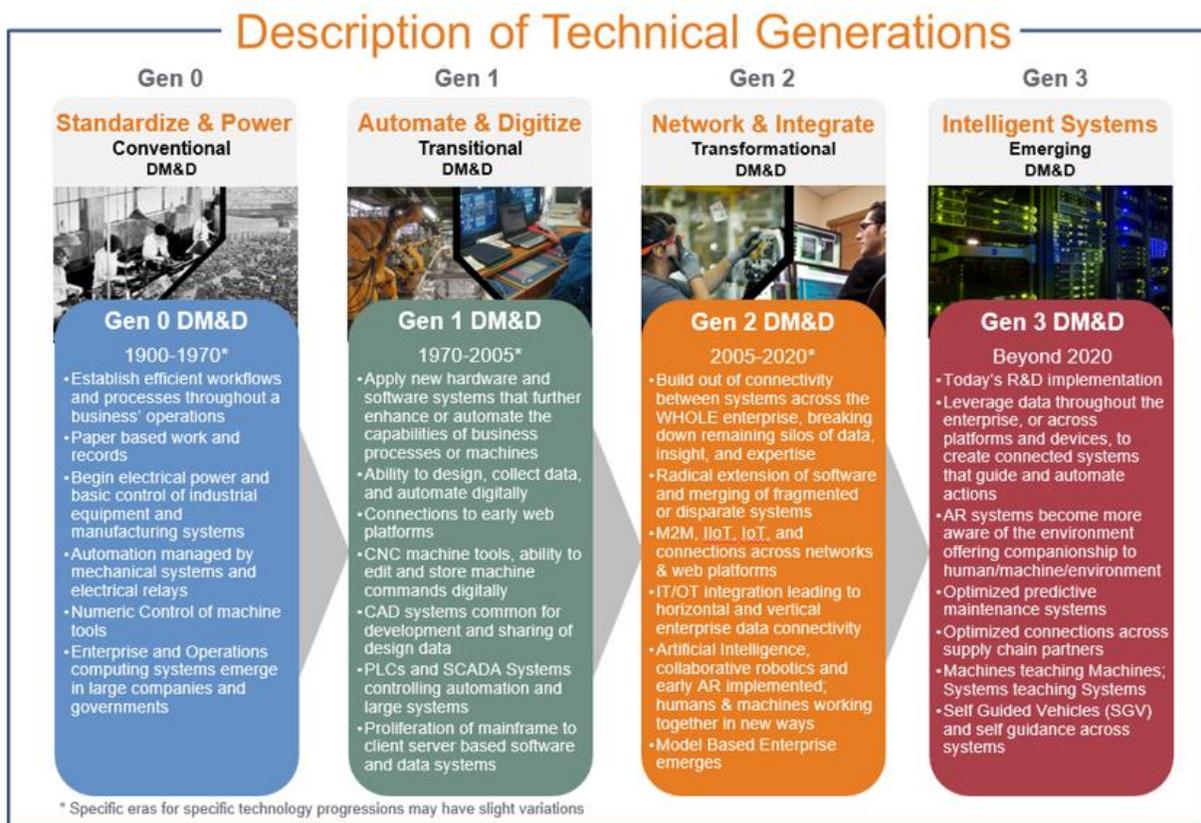
Technical Generations

Background

With the broader community established, we can look at other aspects of the Taxonomy that provide richness to how the workforce is changing and evolving.

We have considered how the roles in the DM&D Community Map are reflective of evolving technologies. The concept of technology “generations” provides general markers of identifiable eras. Four possible “generations” of current or emerging roles – aligned to generations of manufacturing tools, technologies, and work – were identified.

Descriptions of the generations are provided in the graphic below. General eras in years are provided as are highlights of those periods and the purpose of that generation, technology targets, and influence on the work and workers.



In the Taxonomy, a domain technology or a role was assigned to a generation when the following was known:

- Associated technologies were out of the lab and into commercial introduction and use; the tools and technologies were mainstreamed beyond early adopters
- Identified academic or training pipelines had emerged; programs were available and workers in those roles were trained
- Evidence of a labor pool (supply) existed for the roles

DM&D technologies have a past even though they are seen as very current and innovative. Advanced automation and early digitization have been taking place for decades. While modern manufacturing has roots in the early 1900's, digital technologies started development in earnest a few decades ago, and continue to evolve and adapt at an increasingly fast pace. DM&D Technologies of previous years are still in place and have definite value for various manufacturers. There will be many transitional efforts and hybrids of the generational technologies, and hence the same would apply for roles. Most definitely the future is with later Generation technologies that forge new horizons.

These “generations” of technologies are important to understand as we migrate, leverage, enhance, and replace skills and knowledge of the existing workforce. As we transform our manufacturing organizations and support systems educators, workforce development entities, and others will need to understand the mix and migration to these DM&D technologies.

The mix of generations of digital technology available has a shelf life that relates to the maturity and adoption rate of digital technologies. How long is that shelf life? How long are the related skills needed? What is the business case for shifting technologies and shifting skills? Those are decisions for the manufacturer; the taxonomy gives language and framework to make those assessments and plan the workforce accordingly.

Distribution of Roles across Generations

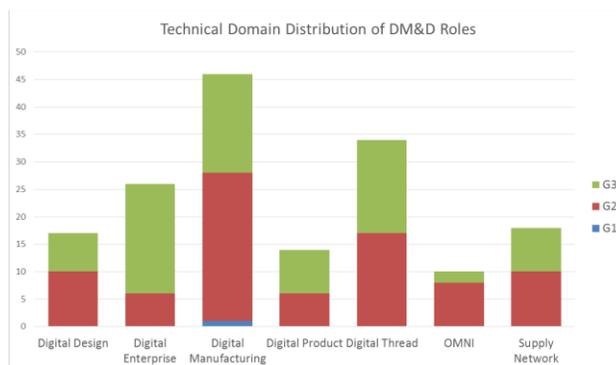
Based on the generation definitions above, each role was mapped in three ways and given a generation “profile”:

- **Generation Knowledge Range:** The useful background knowledge range for a role
- **Generation Work Focus Range:** The useful technology generation focus range for a role (where the majority of work takes place)
- **Generation 5-Year Industry Use Target:** The technology generation of the role we need to focus investment into over the next 5 years

The three “ratings” form a generational profile for the role: the knowledge range, the work focus range, and the estimated 5-year industry use/need target. The Generation 5-Year Industry Use Target is the primary generation used when placing a role in a generation view. It is the most applied of the three ratings and most useful for workforce planning and educational purposes.

Note: Where there is a very strong foot in two adjoining generations (e.g. G2 and G3) we round up to the higher generation for the primary role placement (evidence of strong growth).

The generation profiles will be shown in a later view for each role; a summary view of how the roles in each domain were distributed in each range follows.



Role Impacts

Consideration of Role Impact

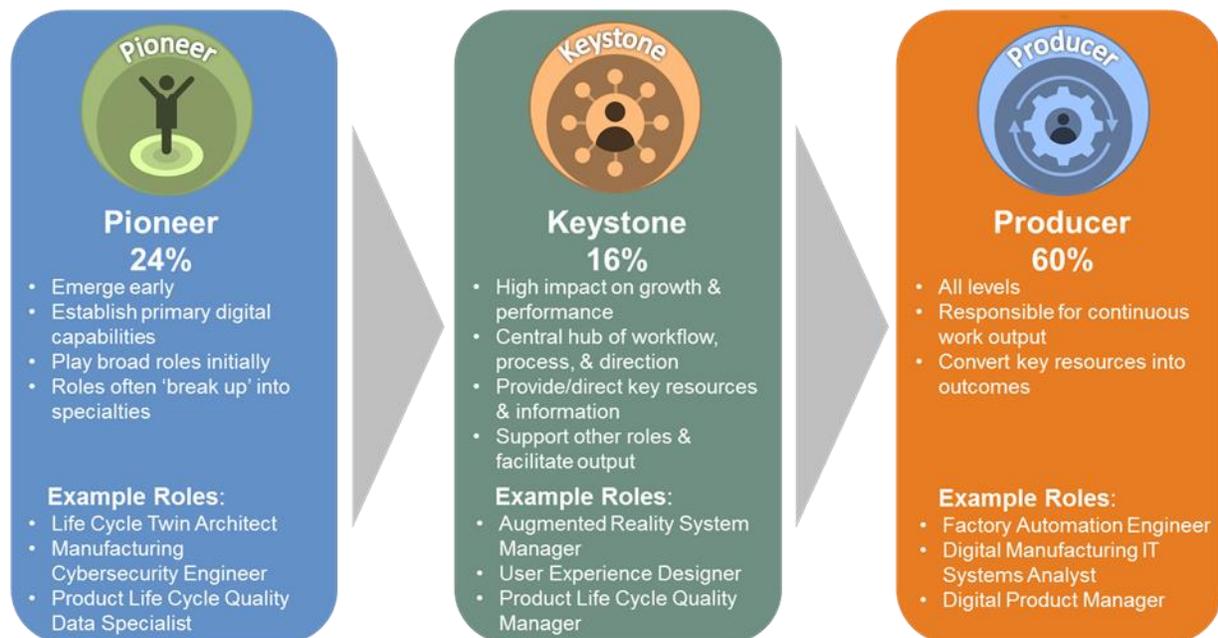
Which roles serve which purpose when examining or planning a workforce overall?

- Do some help sooner in a transformation?
- Do some offer specialization and generalization at scale?
- Do some evolve to be 'workforce valves' to enable the flow of work and information?

Another aspect of the taxonomy considers the relationships of the roles to each other and to the organization in terms of general impact.

We identified three initial types of impact that a role can have in the succession of the conventional manufacturing industry as it grows through Digital Manufacturing and Design technology adoption. As shown in the graphic below, three types of roles emerged – each with important contributions from a workforce planning perspective. Looking at the broad taxonomy with this lens should help as companies examine the blend of capabilities they need based on where the company is its evolution and where it wants to move to in its adoption of DM&D.

Organizational Impact of DM&D Roles



Use of Impact "Lens"

Considering the Pioneer, Keystone and Producer role types – all important and required in a DM&D organization, or any organization – should inform an owner's or leader/planner's view of what capabilities to hire, develop, or position as business and talent planning occur. As companies are executing on their business plans to advance DM&D, this framework of role impact should become key language and method for considering what roles to grow, position, or leverage to achieve business goals.

On the following pages, each set of roles is listed by impact type.

The Pioneers

As we worked across the broad view of DM&D activity and outputs, some roles appeared as important initial sets of capabilities and outputs. Pioneer roles are just that – roles that emerge early as foundational when looking at a large work area. Pioneer roles in DM&D establish primary digital capabilities and play broader roles initially that can lead to other related yet more specialized roles. These pioneer roles may be roles that organizations develop and hire for earlier in the workforce planning, or roles that evolve faster and appear to take on large amounts of early effort to build out company capability. People in these roles themselves tend to learn and evolve rapidly as their roles can consist of both generalized and specialized responsibilities. These roles expand or refine quickly as the organization matures and grows. Examples in this category include Digital Twin Architect, Manufacturing Cybersecurity Engineer, and Product Life Cycle Quality Data Specialist. About one quarter of the DM&D Role Community is comprised of these forerunner roles.

DM&D PIONEER ROLES



DM&D Community Role	Generation Knowledge Range	Generation Work Focus	Generation 5 Year Work Focus	Primary Domain
• Digital Design Engineer	G1G2	G2G2	G2G2	Digital Design
• Virtual Reality/Augmented Reality Hardware Engineer	G1G2G3	G2G3	G3	Digital Design
• Virtual Reality/Augmented Reality Software Engineer	G1G2G3	G2G3	G3	Digital Design
• Virtual Reality/Augmented Reality System Specialist	G1G2G3	G2G3	G3	Digital Design
• Cognitive Systems Scientist	G2G3	G3	G3	Digital Enterprise
• Digital Manufacturing Biomimicry & Sustainability Specialist	G1G2G3	G2G3	G2	Digital Enterprise
• Product Embedded Cognitive Systems Scientist	G2G3	G3	G3	Digital Enterprise
• Virtual Reality/Augmented Reality System Scientist	G1G2G3	G3	G3	Digital Enterprise
• Augmented Reality Manufacturing Systems Specialist	G1G2G3	G2	G2	Digital Manufacturing
• Collaborative Robotics Specialist	G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Manufacturing Analyst	G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Manufacturing Engineer	G1G2G3	G2G3	G3	Digital Manufacturing
• Factory Prognostics Engineer	G1G2G3	G2G3	G2	Digital Manufacturing
• Machine Learning Scientist	G1G2G3	G3	G3	Digital Manufacturing
• Machine Learning Specialist	G1G2G3	G2G3	G2	Digital Manufacturing
• Predictive Maintenance System Specialist	G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Product Market Customization Engineer	G2G3	G2	G2	Digital Product
• Digital Product Marketing Specialist	G1G2G3	G2G3	G2	Digital Product
• Embedded Product Prognostics Analyst	G1G2G3	G2G3	G3	Digital Product
• Embedded Product Prognostics Engineer	G1G2G3	G2G3	G3	Digital Product

• Product Embedded Cognitive Systems Engineer	G2G3	G3	G3	Digital Product
• Product Embedded Cognitive Systems Specialist	G2G3	G2	G2	Digital Product
• Cognitive Systems Engineer	G2G3	G3	G3	Digital Thread
• Cognitive Systems Specialist	G2G3	G3	G3	Digital Thread
• Digital Twin Analyst	G2G3	G2	G2	Digital Thread
• Digital Twin Architect	G2G3	G2G3	G3	Digital Thread
• IT/OT Systems Architect	G1G2G3	G2G3	G3	Digital Thread
• Manufacturing Cybersecurity Application Developer	G1G2G3	G2G3	G3	Digital Thread
• Manufacturing Cybersecurity Engineer	G1G2G3	G3	G3	Digital Thread
• Manufacturing Cybersecurity Programmer	G1G2G3	G2G3	G3	Digital Thread
• Manufacturing Cybersecurity Strategist	G1G2G3	G2G3	G3	Digital Thread
• Manufacturing Cybersecurity Technician	G2G3	G2G3	G2	Digital Thread
• Product Life Cycle Quality Data Specialist	G1G2G3	G2G3	G3	Omni
• Automated Guided Vehicle (AGV) Systems Engineer	G1G2G3	G2G3	G2	Supply Network
• Fleet/Asset Optimization Specialist	G1G2G3	G2G3	G3	Supply Network
• Predictive Supply Network Analytics Engineer	G1G2G3	G2G3	G3	Supply Network
• Self-Guided Vehicle (SGV) Systems Engineer	G1G2G3	G2G3	G3	Supply Network
• Supply Network Quality Data Specialist	G1G2G3	G2G3	G3	Supply Network

The keystones

Working across the broad view of DM&D activity, some roles appear as important sets of capabilities and outputs that also have a pivotal place in the flow or influence on the work volumes and outputs of others and the broader processes.

While all roles have that to some extent, some roles play an even stronger position in the expansion of roles around them. These roles are called Keystone roles. Keystone roles are a smaller, less frequent group within a large body of work compared to their pioneer and producer counterparts. Approximately 16% of the defined roles in the DM&D taxonomy are Keystone roles.

However, even when smaller in number (how many serve in that role or how many a manufacturer may need), these roles usually exert a high impact on the growth and performance of digital manufacturing and design overall. They support the other types of roles and facilitate their output often by creating outputs that increase the demand for other roles and guide their impact; they provide or direct key resources and information even more than other roles, all positioning the keystone category as the central hub of workflow and direction for an organization. Roles like Factory Automation Manager, User Experience Designer, and Product Life Cycle Quality Data Manager are examples of keystone roles that are in central positions of key processes and workflows.

DM&D KEYSTONE ROLES



DM&D Draft Community Roles	Generation Knowledge Range	Generation Work Focus	Generation 5 Year Work Focus	Primary Domain
• Digital Design Community of Practice Manager	G1G2G3	G2G3	G2	Digital Design
• User Experience Designer	G1G2G3	G2G3	G3	Digital Design
• Virtual Reality/Augmented Reality System Manager	G1G2G3	G2G3	G3	Digital Design
• Chief Digital Officer	G0G1G2G3	G1G2G3	G3	Digital Enterprise
• Digital Enterprise and Integrated Product Intellectual Property Senior Manager	G1G2G3	G1G2G3	G3	Digital Enterprise
• Digital Enterprise Community of Practice Manager	G1G2G3	G2G3	G2	Digital Enterprise
• Digital Manufacturing Leader - Functional Business Senior Manager	G1G2G3	G2G3	G3	Digital Enterprise
• Digital Manufacturing Organizational Change Management Strategist	G1G2G3	G2G3	G2	Digital Enterprise
• Digital Manufacturing Organizational Effectiveness Specialist	G1G2G3	G2G3	G2	Digital Enterprise
• Enterprise Supply Network Manager	G0G1G2G3	G2G3	G3	Digital Enterprise
• Digital Factory Automation Manager	G1G2G3	G1G2	G2	Digital Manufacturing
• Digital Manufacturing Chief Technology Officer	G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Manufacturing Community of Practice Manager	G1G2G3	G2G3	G2	Digital Manufacturing
• Digital Manufacturing Executive - Cross Domain Business Leader	G1G2G3	G2G3	G3	Digital Manufacturing

• Digital Manufacturing Executive - Functional Business Leader	G1G2G3	G2G3	G3	Digital Manufacturing
• Process Quality Data Manager	G0G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Product Community of Practice Manager	G1G2G3	G2G3	G2	Digital Product
• Digital Knowledge Community Curator	G1G2G3	G2	G2	Digital Thread
• Digital Thread Engineer	G0G1G2G3	G1G2G3	G2	Digital Thread
• Digital Twin Manager	G0G1G2G3	G1G2G3	G3	Digital Thread
• IT/OT Systems Engineer	G1G2G3	G2G3	G2	Digital Thread
• Continuous Improvement Manager	G0G1G2	G2	G2	Omni
• Product Life Cycle Quality Data Manager	G1G2G3	G2G3	G2	Omni
• Fleet/Asset Optimization Manager	G1G2G3	G2G3	G3	Supply Network
• Supply Network Community Manager	G1G2G3	G2G3	G3	Supply Network
• Supply Network Integration Community of Practice Manager	G1G2G3	G1G2G3	G2	Supply Network
• Supply Network Quality Data Manager	G0G1G2G3	G2G3	G3	Supply Network

The Producers

The majority of roles (over 60%) are known as Producer roles. In any broad community of related workers, some roles are responsible for the group’s major accomplishments and output. These are the roles that are usually larger in number and through their work they elevate the volume of output that the overall organization accomplishes.

The size of the workforce in these roles is a business factor for each manufacturer based on their size and their “niche” or area of business across the manufacturing life cycle. Producers can be at any level or any type (technician to engineer to manager, etc.). In their roles, they magnify and amplify the resources given. These essential functions, across any domain where some are more specialized and others more generalized, are responsible for much of the continuous work output of a manufacturer – they convert key resources into outcomes for the business and produce the lion’s share of the overall value. Producers enable the ecosystem to flourish by expanding and optimizing resources through both generalist and specialist role making. Digital Design Specialist, Digital Manufacturing IT Systems Analyst, and Digital Product Manager are among the roles within this category.

DM&D PRODUCER ROLES



DM&D Draft Community Roles	Generation Knowledge Range	Generation Work Focus	Generation 5 Year Work Focus	Primary Domain
• Digital Design Analyst	G1G2	G2	G2	Digital Design
• Digital Design Specialist	G1G2	G1G2	G2	Digital Design
• Worker Experience Designer	G1G2G3	G1G2G3	G2	Digital Design
• Worker Experience Analyst	G1G2	G1G2	G2	Digital Design
• Model Based Systems Engineering (MBSE) - Engineer	G1G2G3	G2G3	G2	Digital Design
• Digital Design Technical Trainer	G0G1G2G3	G2G3	G3	Digital Design
• Digital Design Vocational Instructor	G0G1G2G3	G1G2G3	G2	Digital Design
• Virtual Reality/Augmented Reality System Modeler	G1G2G3	G2G3	G2	Digital Design
• User Experience Architect	G1G2G3	G2G3	G3	Digital Design
• User Experience Analyst	G1G2G3	G2G3	G2	Digital Design
• Innovation Strategist - Enterprise Direction	G1G2G3	G2G3	G3	Digital Enterprise
• Enterprise Digital Ethicist	G0G1G2G3	G1G2G3	G3	Digital Enterprise
• Enterprise Risk Manager	G0G1G2G3	G1G2G3	G3	Digital Enterprise
• Regulatory Analyst	G0G1G2G3	G0G1G2G3	G2	Digital Enterprise
• Digital Enterprise Vocational Instructor	G0G1G2G3	G1G2G3	G2	Digital Enterprise
• Digital Enterprise Technical Trainer	G0G1G2G3	G2G3	G3	Digital Enterprise
• Data Management Scientist	G1G2G3	G3	G3	Digital Enterprise
• Information Scientist	G2G3	G2G3	G3	Digital Enterprise
• Integrated Computational Material Engineering Scientist	G2G3	G3	G3	Digital Enterprise
• Manufacturing Analytics Scientist	G0G1G2G3	G3	G3	Digital Enterprise
• Manufacturing Scientist	G0G1G2G3	G3	G3	Digital Enterprise
• Manufacturing Systems Scientist	G0G1G2G3	G3	G3	Digital Enterprise
• Manufacturing Systems Simulation Scientist	G1G2G3	G3	G3	Digital Enterprise
• Process Simulation Scientist	G1G2G3	G3	G3	Digital Enterprise

• Software Scientist	G1G2G3	G3	G3	Digital Enterprise
• Manufacturing Analytics Analyst	G1G2	G2	G2	Digital Manufacturing
• Manufacturing Analytics Manager	G0G1G2G3	G2G3	G3	Digital Manufacturing
• Manufacturing Analytics Specialist	G0G1G2G3	G2G3	G2	Digital Manufacturing
• Digital Manufacturing Program Manager	G0G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Manufacturing Project Manager	G1G2G3	G2	G2	Digital Manufacturing
• Manufacturing Process Engineer	G0G1G2	G1G2	G2	Digital Manufacturing
• Manufacturing Process Specialist	G1G2G3	G2G3	G2	Digital Manufacturing
• Process Engineer	G0G1G2	G1G2	G1	Digital Manufacturing
• Process Quality Data Analyst	G1G2G3	G1G2	G2	Digital Manufacturing
• Process Quality Data Specialist	G1G2	G1G2	G2	Digital Manufacturing
• Process Simulation Engineer	G1G2G3	G2G3	G2	Digital Manufacturing
• Process Simulation Manager	G1G2G3	G2G3	G2	Digital Manufacturing
• Process Simulation Specialist	G1G2	G2	G2	Digital Manufacturing
• Operation Technologies Integration Engineer	G1G2G3	G2	G2	Digital Manufacturing
• Digital Manufacturing IT Specialist	G0G1G2G3	G2G3	G2	Digital Manufacturing
• Collaborative Robotics Technician	G1G2	G1G2	G2	Digital Manufacturing
• Digital Factory Automation Analyst	G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Factory Automation Architect	G1G2G3	G1G2G3	G3	Digital Manufacturing
• Digital Manufacturing Safety Systems Specialist	G0G1G2G3	G1G2	G2	Digital Manufacturing
• Digital Factory Automation Engineer	G1G2G3	G1G2	G2	Digital Manufacturing
• Instrumentation Engineer	G1G2G3	G2G3	G2	Digital Manufacturing
• Digital Manufacturing Technician	G0G1G2	G1G2	G2	Digital Manufacturing
• Manufacturing Systems Designer	G0G1G2	G1G2	G2	Digital Manufacturing
• Manufacturing Systems Engineer	G0G1G2	G1G2	G2	Digital Manufacturing
• Manufacturing Systems Modeler	G1G2G3	G2G3	G3	Digital Manufacturing
• Manufacturing Systems Simulation Engineer	G0G1G2G3	G2G3	G3	Digital Manufacturing
• Manufacturing Systems Simulation Manager	G0G1G2G3	G2G3	G3	Digital Manufacturing
• Manufacturing Systems Simulation Specialist	G2G3	G2	G2	Digital Manufacturing
• Digital Manufacturing Knowledge	G1G2G3	G2G3	G2	Digital

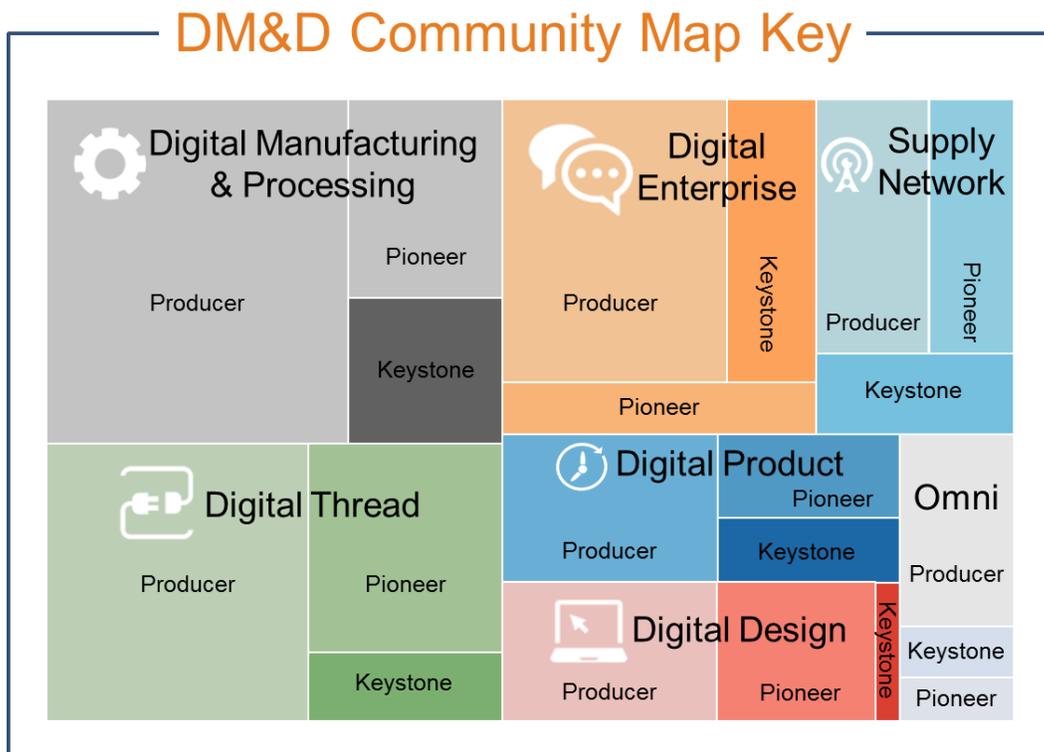
Manager				Manufacturing
• Digital Manufacturing Technical Educator (Teachers 9-12)	G0G1G2G3	G1G2	G2	Digital Manufacturing
• Digital Manufacturing Technical Trainer	G0G1G2G3	G2G3	G3	Digital Manufacturing
• Digital Manufacturing Vocational Instructor	G0G1G2G3	G1G2G3	G3	Digital Manufacturing
• Digital Product Safety Systems Engineer	G0G1G2G3	G1G2G3	G3	Digital Product
• Digital Product Safety Systems Specialist	G0G1G2G3	G1G2	G2	Digital Product
• Digital Product Manager	G0G1G2G3	G2G3	G3	Digital Product
• Digital Product Support Manager	G1G2G3	G2G3	G2	Digital Product
• Product Performance Optimization Engineer	G1G2G3	G2G3	G3	Digital Product
• Digital Product Technical Trainer	G0G1G2G3	G2G3	G3	Digital Product
• Digital Product Vocational Instructor	G0G1G2G3	G1G2G3	G3	Digital Product
• Manufacturing Cybersecurity Analyst	G1G2G3	G2	G2	Digital Thread
• Manufacturing Cybersecurity Architect	G1G2G3	G2G3	G3	Digital Thread
• Manufacturing Cybersecurity Tester	G1G2G3	G2	G2	Digital Thread
• Data Management Analyst	G1G2G3	G2	G2	Digital Thread
• Data Management Manager	G1G2G3	G2	G2	Digital Thread
• Digital Data Tester	G1G2G3	G2G3	G2	Digital Thread
• Product Life Cycle Data Engineer	G1G2G3	G2	G2	Digital Thread
• Cognitive Systems Designer	G2G3	G3	G3	Digital Thread
• IT/OT Application Developer	G2G3	G3	G3	Digital Thread
• IT/OT Systems Analyst	G1G2G3	G2	G2	Digital Thread
• IT/OT Systems Specialist	G1G2G3	G2G3	G3	Digital Thread
• IT/OT Systems Strategist	G1G2G3	G2G3	G3	Digital Thread
• IT/OT Systems Technician	G1G2G3	G1G2	G2	Digital Thread
• IT/OT Systems Tester	G1G2G3	G1G2	G2	Digital Thread
• Digital Manufacturing IT Systems Analyst	G1G2	G2	G2	Digital Thread
• IT Systems Optimization Engineer	G1G2G3	G2G3	G3	Digital Thread
• Digital Manufacturing Systems Architect	G0G1G2G3	G2G3	G3	Digital Thread
• Digital Manufacturing Systems Specialist	G1G2G3	G1G2	G2	Digital Thread
• Digital Thread Technical Educator (Teachers 9-12)	G0G1G2G3	G1G2	G2	Digital Thread
• Digital Thread Technical Trainer	G0G1G2G3	G2G3	G3	Digital Thread
• Statistician	G1G2G3	G1G2	G2	Omni
• Product Life Cycle Quality Data Analyst	G1G2	G2	G2	Omni
• Continuous Improvement Engineer	G0G1G2	G2	G2	Omni
• Continuous Improvement Specialist	G0G1G2G3	G1G2	G2	Omni
• Omni Technical Educator (Teachers 9-12)	G0G1G2G3	G1G2	G2	Omni
• Omni Technical Trainer	G0G1G2G3	G2G3	G3	Omni
• Omni Vocational Instructor	G0G1G2G3	G1G2	G2	Omni
• Sales Engineer	G1G2G3	G2G3	G2	Supply Network
• Supply Network Quality Data Analyst	G1G2	G2	G2	Supply Network
• Supply Network Business Analyst	G1G2G3	G2	G2	Supply Network
• Automated Guided Vehicle (AGV) Systems Specialist	G1G2G3	G2	G2	Supply Network
• Inventory Systems Automation Specialist	G1G2G3	G1G2	G2	Supply Network
• Self-Guided Vehicle (SGV) Systems Specialist	G1G2G3	G2G3	G2	Supply Network
• Fleet/Asset Optimization Analyst	G1G2	G2	G2	Supply Network
• Supply Network Technical Trainer	G0G1G2G3	G2G3	G3	Supply Network
• Supply Network Vocational Instructor	G0G1G2G3	G1G2	G2	Supply Network

Community Map of Roles: Bringing it All Together

The Community Map of Roles is a way of visualizing a number of role attributes across the Technical Domains including Role Impact, and the Technical Generation focus. This is the collective view of how the domains and the roles – with their impacts and technology generations – assemble together as a community of workers and capabilities. Seeing the community as a whole is the foundation for workforce planning and development. Viewing the full community across all of the domains and inclusive of all 165 roles, enables all stakeholders to see the whole landscape: areas of alignment, adjacencies, evolution of technology use, potentials for progression, and the broad framework in which to explore and refine one’s own workforce and talent management strategy.

Below is a summary key of the layout for the Community map.

- There are three shades of color for each domain as shades denote the different impacts (Pioneer, Keystone and Producer).
- The generations are shown from highest to lowest from the upper to lower corner of each subsection.



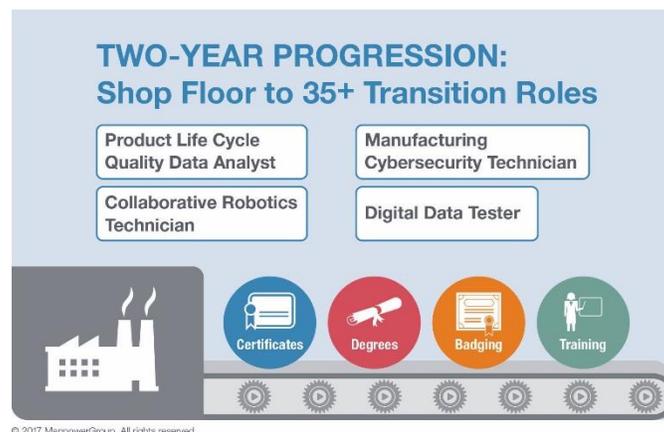
On the following page is a full map of the 165 roles (view in enlarged format).

Transition Roles

Connecting DM&D Roles to Skilled Worker Roles

An area of critical importance when planning for the DM&D workforce is to understand how much the issue of in-place transitions and modernizing in place can be to the future of DM&D and the mobility of workers in manufacturing as it moves across technical generations and connects domains. Recruiting Generation Z who aren't even in college so they might consider Manufacturing as a career as interesting and well-paying as other high tech industries is essential. Going into high schools and middle school STEM programs is another high-value, early engagement strategy to build a pipeline for manufacturing. Changes to the number and range of roles on the shop floor – the manufacturing production space – are often seen as the only manufacturing roles that are changing. As this Taxonomy shows, manufacturers need to understand the full range of roles necessary for a successful digital organization. From enterprise roles to design roles to supply network roles, there is a broad range to be developed and incorporated. These and many other will help increase new candidates for manufacturing roles.

However, relying on up-and-coming manufacturing talent is simply not enough. We must address the skills of the 12.3 million manufacturing workers already working in the industry across the United States. In its Skills Revolution report, ManpowerGroup surveyed 14,000 companies and asked how digitization would affect headcount. Nineteen percent (19%) said digitization would increase it and 64% said there would be no change. While this speaks to general employment levels, it is also suggesting leaders are likely counting on the current workforce to adapt or transition skills and roles.



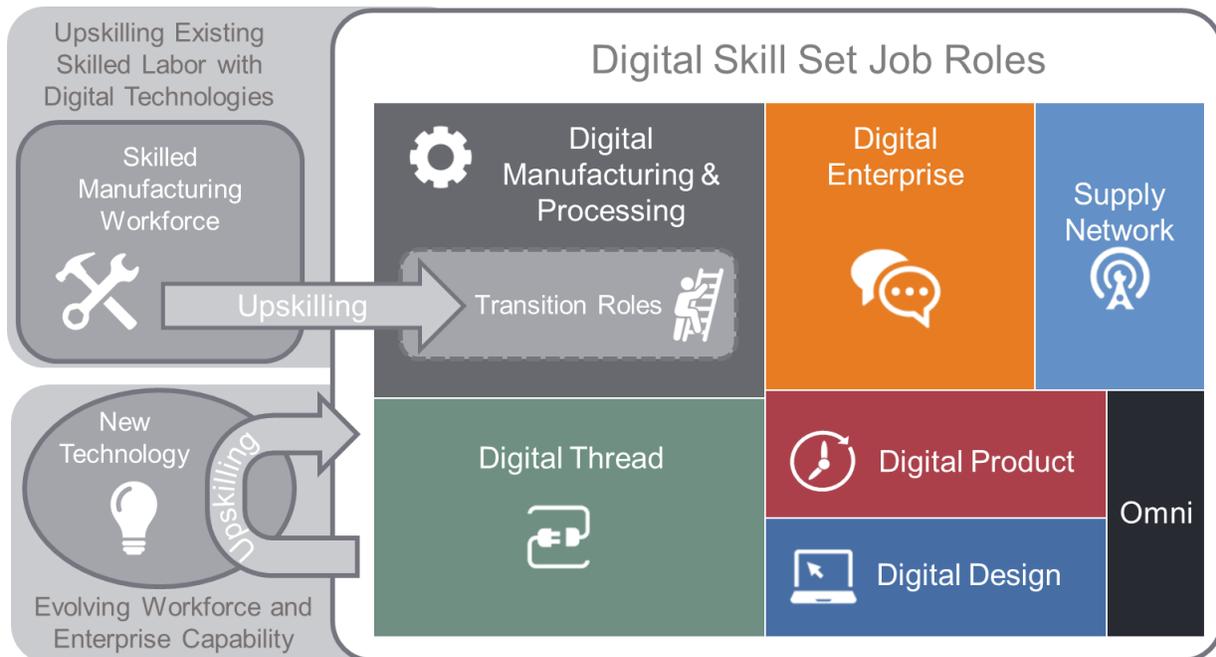
As manufacturing technologies and processes change, it is essential to mobilize and progress the well-matched team members from conventional production worker roles into new manufacturing positions. This leverages the capabilities and manufacturing and company knowledge and the investment made in those employees to date. We asked ourselves:

- What roles from the DM&D community map could be opportunities for the reskilling and development of experienced skilled workers?
- Which roles in the production area are going through a transition to “more digital,” gaining more digital base knowledge and experience?

While it is in the longer view as far as career options for some skilled workers, the Taxonomy work has identified horizons for career transitions and expansions. These opportunities are available and growing now where supply, demand, and development can be mutually connected.

“Transition roles” in DM&D have been identified that may be target roles where the experience of employees who are interested and bring core capabilities can be the Launchpad to DM&D careers in the areas the Taxonomy establishes. These roles represent transition opportunities from some of the discrete analog or independently digitally-based automation areas of conventional production. With additional training and development, opportunities are seen for some to move to the newer, connected, smart-machine, augmented tech areas of the increasingly digital manufacturing space.

The following graphic illustrates the connection between the skilled manufacturing workforce and the DM&D taxonomy. Upskilling will create a bridge to the Transitional roles so critical to the Digital Manufacturing & Processing Domain.



Where May Transition Roles Build DM&D?

We have identified over sixty roles – primarily Technicians, Specialists, and Analysts – from the DMDII taxonomy Roles that are seen as opportunistic for skilled workers. These roles:

1. Leverage and enhance existing expertise, skills, and knowledge
2. Require additional education and training potentially equivalent to a 2-year program (subject to future continued work with educational and workforce development partners)
3. Provide a path to other DM&D roles after performing “Transition” roles; for example, after time and experience in various Analyst or Specialist roles, and with additional development and education as needed, other roles such as Engineer or Developer would become opportunistic.

Following is a list view of the DM&D roles seen as “Transition” opportunities for today’s skilled workers in the manufacturing production space.



DM&D Transition Roles

• IT/OT Systems Technician	• Digital Manufacturing Biomimicry & Sustainability Specialist	• Digital Manufacturing IT Systems Analyst
• Collaborative Robotics Technician	• Process Quality Data Analyst	• Digital Factory Automation Analyst
• Digital Manufacturing Technician	• Process Quality Data Specialist	• Digital Manufacturing Systems Specialist
• Predictive Maintenance System Specialist	• Digital Manufacturing Analyst	• Fleet/Asset Optimization Analyst
• IT/OT Systems Specialist	• Manufacturing Analytics Analyst	• Manufacturing Systems Designer
• Collaborative Robotics Specialist	• Digital Design Analyst	• Digital Design Technical Trainer
• Digital Manufacturing Safety Systems Specialist	• Worker Experience Analyst	• Digital Design Vocational Instructor
• Augmented Reality Manufacturing Systems Specialist	• Manufacturing Cybersecurity Analyst	• Digital Manufacturing Technical Educator (Teachers 9-12)
• Digital Design Specialist	• Manufacturing Cybersecurity Technician	• Digital Manufacturing Technical Trainer
• Manufacturing Cybersecurity Tester	• Data Management Analyst	• Digital Manufacturing Vocational Instructor
• Supply Network Quality Data Specialist	• Digital Data Tester	• Digital Product Technical Trainer
• Continuous Improvement Specialist	• Product Life Cycle Quality Data Analyst	• Digital Thread Technical Educator (Teachers 9-12)
• Digital Manufacturing IT Specialist	• Product Life Cycle Quality Data Specialist	• Digital Thread Technical Trainer
• Automated Guided Vehicle (AGV) Systems Specialist	• Supply Network Quality Data Analyst	• Omni Technical Educator (Teachers 9-12)
• Inventory Systems Automation Specialist	• Manufacturing Process Specialist	• Supply Network Technical Trainer
• Fleet/Asset Optimization Specialist	• Embedded Product Prognostics Analyst	• Supply Network Vocational Instructor
• Process Engineer	• Supply Network Business Analyst	• Virtual Reality/Augmented Reality System Modeler
• Continuous Improvement Engineer	• IT/OT Systems Analyst	• Process Quality Data Manager
• Digital Factory Automation Engineer	• IT/OT Systems Tester	• Fleet/Asset Optimization Manager
• Instrumentation Engineer		

Who Could Transition?

Who can we see transitioning? Many existing roles and incumbents can progress and expand into digital transition roles. From experienced operators, technicians, and programmers, as well other established shop floor roles, we believe these roles can be candidates for the Transition Roles with DM&D supplemental skills development from participating in programs or experiences with approximately 2 years of education and training. More work on curriculums needs to be defined.

The experience of these “connecting” team members is invaluable as candidates for the Transition roles as they bring expertise in the core production functions and often have deep component or machine process level expertise at the very touch point of direct product processing and creation – the heart of manufacturing. Leveraging and building on that expertise with the technologies and tools that increase connection across the product life cycle with efficiency presents an opportunity for both employer and employee.



Reskilling Today’s Skilled Manufacturing Workers Connecting DM&D Roles



- | | |
|---|----------------------------|
| • Assembler | • Machine Setup |
| • Welder | • Quality |
| • Controls (Hydraulic, Pneumatic, Electrical) | • Molder (Sand Cast, etc.) |
| • Caster | • Operator |
| • Fabricator | • Packager |
| • Finisher | • Painter/coatings |
| • Grinder | • Pattern Maker |
| • Heat Treater | • Processor (Processing) |
| • Imager | • Repair/Maintenance |
| • Instrumentation Calibration & Repair | • Setter/Tender |
| • Inspector | • Sorter |
| • Machinist | • Specialist |
| • Material Handler | • Technician |
| • Metal Worker | • Tester |
| • Model Maker | • Weigher |

In order for current manufacturing workers to remain competitive and advance in their jobs, they must be open to development and demonstrate “learnability”, the desire and ability to learn new skills to stay relevant and remain employable. This includes getting trained on new manufacturing technology and “upskilling”, expanding their skill set with higher order skills. Manufacturing companies can help by evaluating their employees’ skills against the needs of the business, and finding ways to guide them toward expanded or new roles in advanced manufacturing. By looking closely at their shop floors and identifying where interactions between work functions are occurring, manufacturers can derive insights about what types of skills are needed to steer their operations in a more digitally enabled direction.



Very importantly, upskilling and learnability isn’t only an issue for shop floor. Not by a long shot. By looking across the entire company- including in design, in IT, in supply chain, in HR, in the boss’s office and the executive suite as we’ll discuss next - new skills and knowledge, learnability, and upskilling for digital appear on everyone’s to-do list.

Breakout Roles

All 160+ DM&D Roles are important and will be supported and communicated. It’s hard to start a review of a company’s talent pool with all of those roles. From an awareness and early adoption point of view, a shorter initial list can begin or accelerate workforce planning and conversations about the broader DM&D workforce needs.

Another way the community of roles was viewed included Breakout Roles. A Breakout Role is a Role from the DMDII Role Community which we expect to contribute significantly to the digital (re)evolution for manufacturing, and to possibly attract major early interest for more definition and development focus. Breakout Roles for our purposes align to a classic definition of breakout: “...having, causing, or marked by sudden and great success that comes usually after a time without much attention.” In identifying Breakout Roles, we asked ourselves:

- Which Roles are possibly some of the best examples of the wider DM&D community?

- Which Roles as an initial set can be better understood in terms of being innovative or differentiating across all sizes of manufacturers?
- Is there a list that highlights a good mix of domains, impacts, and types that would be a good initial audit to begin the assessment of DM&D talent plans?

Breakout Roles won't be the only ones to be seen as important – that is certain – but we believe it is critical that they receive immediate consideration.

There may be some overlap with some of the Roles we have identified as having major impacts such as Pioneer or Keystone Roles. Breakout Roles that are also Pioneer and Keystone deserve even more attention or further consideration as an early Role for focus.

Some of these Roles may be newer or future roles and so they are not necessarily the same as our Pioneer Roles. They may also be solo players of sorts and so may not be a key link across bands of other Roles as some of our Keystone Roles.

Breakout Roles can be some of the most novel Roles that showcase how the broader set of Roles establishes differentiators for digital manufacturing and design. The Breakout list is notable as specific roles and capabilities that showcase the transition of conventional manufacturing; some can qualify as game-changing roles for broader DM&D development and use.



Breakout Roles Across the Domains

- | | |
|---|---|
| • Digital Product Marketing Specialist | • Digital Manufacturing Engineer |
| • Cognitive Systems Specialist | • Self-guided Vehicle (SGV) Systems Engineer |
| • Cognitive Systems Engineer | • Factory Prognostics Engineer |
| • Machine Learning Specialist | • Process Engineer |
| • Virtual Reality/Augmented Reality System Specialist | • Enterprise Digital Ethicist |
| • Predictive Maintenance System Specialist | • Digital Twin Architect |
| • IT/OT Systems Specialist | • Supply Network Community Manager |
| • Collaborative Robotics Specialist | • IT/OT Systems Architect |
| • Digital Manufacturing Safety Systems Specialist | • Digital Manufacturing Organizational Change Management Strategist |
| • Augmented Reality Manufacturing Systems Specialist | • Product Embedded Cognitive Systems Scientist |
| • Digital Product Safety Systems Engineer | • Digital Manufacturing Organizational Effectiveness Specialist |
| • Manufacturing Cybersecurity Engineer | • Digital Manufacturing Biomimicry & Sustainability Specialist |
| • Digital Thread Engineer | • Process Quality Data Analyst |
| • Embedded Product Prognostics Engineer | • Process Quality Data Specialist |
| • Predictive Supply Network Analytics Engineer | • Digital Manufacturing Analyst |
| • Product Embedded Cognitive Systems Engineer | • Digital Twin Manager |
| • Operation Technologies Integration Engineer | • Chief Digital Officer |
| • IT/OT Systems Engineer | |

We also suggest the Breakout Roles may or should get some early special attention of workforce development resources, digital manufacturing organizations, hiring managers, and potential or current candidates.

These groups should consider how Breakout Roles would have significant importance for the associated organization or be attractors for workforce that want to make contributions, develop key skills, and have opportunities for progression.

5. Twenty Success Profiles: Representative DM&D Roles

Success Profile Overview

Initial Roles Selected for Success Profiles

With 165 roles to choose from, which would be highlighted with an initial success profiling effort? Several of our most senior representatives from business, education, and government worked with recommendations and selected the targeted list of DM&D profiles.

New Futures, New Roles

<p> DIGITAL ENTERPRISE</p> <ul style="list-style-type: none"> • Chief Digital Officer • Digital Manufacturing Organizational Change Management Strategist • Enterprise Supply Network Manager • Enterprise Digital Ethicist 	<p> DIGITAL THREAD</p> <ul style="list-style-type: none"> • Digital Thread Engineer • Manufacturing Cybersecurity Strategist • Digital Twin Architect • IT/OT Systems Engineer 		
<p> DIGITAL DESIGN</p> <ul style="list-style-type: none"> • Model Based Systems Engineering (MBSE) — Engineer • Virtual Reality/Augmented Reality System Specialist • Worker Experience Designer • User Experience Architect 	<p> DIGITAL PRODUCT</p> <ul style="list-style-type: none"> • Embedded Product Prognostics Engineer 		
<table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> <p> DIGITAL MANUFACTURING</p> <ul style="list-style-type: none"> • Digital Manufacturing Engineer • Predictive Maintenance System Specialist </td> <td style="width: 50%; vertical-align: top;"> <ul style="list-style-type: none"> • Machine Learning Specialist • Factory Automation Engineer • Collaborative Robotics Specialist </td> </tr> </table>		<p> DIGITAL MANUFACTURING</p> <ul style="list-style-type: none"> • Digital Manufacturing Engineer • Predictive Maintenance System Specialist 	<ul style="list-style-type: none"> • Machine Learning Specialist • Factory Automation Engineer • Collaborative Robotics Specialist
<p> DIGITAL MANUFACTURING</p> <ul style="list-style-type: none"> • Digital Manufacturing Engineer • Predictive Maintenance System Specialist 	<ul style="list-style-type: none"> • Machine Learning Specialist • Factory Automation Engineer • Collaborative Robotics Specialist 		
<p> SUPPLY NETWORK</p> <ul style="list-style-type: none"> • Predictive Supply Network Analytics Engineer • Digital Manufacturing Biomimicry Specialist 			

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These profiles are representative of the kinds of changes the workforce is experiences in DM&D. The 20 roles are not to be seen as the most critical or highest value or where to start. Those decisions need to be made by individual companies or within supply networks and depend on DM&D maturity, business needs, and current talent supply and demand factors.

Yet these 20 profiles pave the way for deep understanding of the opportunities for manufacturers and the workforce alike, and represent targets for educators and workforce development programs.

The Success Profiles are an enhanced “job” or “role” description:



Success Profile Contents

The profiles have the following elements for each identified role:

Section 1: Job Role Identification Section	
This section identifies the role and provides an overview as well as its impact, generation and business case. Sidebar roles – digital roles closely associated with the role being profiled – may be introduced	
Summary Scope	The summary scope is used to capture the overall scope and contributions of a successful employee in this role. The summary captures the role’s focus in work efforts, the environment of work, its importance, and the current/future influence the role will have on digital manufacturing enterprise.
Role Title	Title of job role
Role Impact	Indicates the impact of the role within an organization within our classification of Pioneer, Keystone, and Producer. Role impacts may progress over time such as a Pioneer becoming a Keystone or Producer; or a Producer becoming Keystone as more staff begin to work in various areas and the business environments mature.
	Producer – The majority of roles (over 60%) are known as producer roles. These essential functions occur at all levels and where some are more specialized and others more generalized, are responsible for much of the continuous work output within an organization. They convert key resources into outcomes for the business and produce the lion’s share of the overall work effort.
	Pioneer – The early emerging roles that establish new primary digital capabilities and play a broader initial role are referred to as pioneer roles. These roles often lead to more specialized roles as an organization’s capabilities grow. Approximately one quarter of the roles in the community map are pioneers.
	Keystone roles are less common than their pioneer and producer counterparts (~15% of the defined roles), yet they exert a high impact on the growth and performance of DM&D technologies within an organization. They support the other types of roles and facilitate output often positioning themselves as a central hub of workflow and direction within an organization.

Generational Profile	The generational profile helps develop understanding around the historic and future business and technical requirements for this role. This segment captures the current generational work focus of the role assuming interaction with existing commercial technologies and technologies entering industry in the next 5 years. A more in-depth description of Technical Generations can be found in the support materials.
Business Case Contribution	The business case contribution captures the “elevator pitch” for the job role, an efficient pitch for the value of the job role within an organization. The business case contribution offers the job role value to the business including contributions towards company objectives, and how the role differentiates an organization.
Domain Profile	The domain profile provides the primary and secondary work domains or bodies of knowledge required for this role. (Digital Enterprise, Digital Thread, Digital Design, Digital Manufacturing & Processing, Digital Product, Supply Network, and Omni).
Outcomes	The outcomes list focuses on foundation items or tangible outputs and outcomes of a successful employee in this role; these are inputs to Key Performance Indicators (KPIs) and performance measures that serve as an indicator of the value an organization receives from the job role.
Sidebar Roles	This section may be used to summarize roles that work in a similar technology area, have shared skills, outputs, duties, or values. A sidebar role shares similar technical and skill backgrounds but will have some differentiating work responsibilities or scope.
Progression Roles	This section may be used to summarize roles that work in a similar technology and skills progression. They have skills, outputs, duties, or values that contribute to common goals within an organization and follow a progression of skill and depth of expertise. Progression roles may capture the lineage of roles between technician, specialist, analyst, engineer, architect, etc.

Section 2: Key Responsibilities

Key Responsibilities is the section that provides the behavioral and mental task profile that the role is accountable for achieving.

Activities	A list of the key duties of successful workers in this role. A focus is placed on behaviors/tasks/actions, and outputs from the role. The listing works to capture a full range of work including the activities that set this role apart from others.
Accountabilities & Decisions	A list of the accountabilities and decisions made within a role. These are listed as a set of questions for an employee to ask themselves to check their performance within the role and help guide decisions or actions.
Interactions	A list of the stakeholder groups who the role interacts with while performing activities.
Success: Mastering Situational Factors	Identifies the key drivers of change and influence on the job role. Bold indicates an applicable driver.

Section 3: Role Positioning

Role Positioning is used to help identify where the role fits within the broad workforce community, the overall job framework, and how the role interacts with other aspects of an organization's structure. Ratings range from; More (high impact, strong influence), Hybrid (mixed input, some feedback and influence), and Less (minimal input and minimal influence).

Line of Sight	Lists the connection between the role and the business strategy ranging from creation of vision through delivery of tasks contributing to vision. It also addresses levels of customer interaction.
Peer Context	Lists the ways a role may interact with others on their team or across their organization.
Life Cycle Business Process	Lists the connections of the role to the processes and value chain of the organization, team, or product where the work is delivered.

Section 4: Competencies

The DM&D Technical Domain Map shows certain technology, tool, skill, or work areas that are the required areas of expertise for those who are most successful in the performance of a DM&D role. (By design, not all generic technology, skill, or work areas for a role are described in the Digital Manufacturing & Design Domain Diagram; our focus is on those – generic and digitally direct areas – that are seen as most essential at this time for digital transformation and success). Three levels can be indicated.

- ◆ = Deep comprehension and/or comprehension of interactions (Level 1)
- ✦ = Practiced engagement and/or application (Level 2)
- ★ = Direction setting and/or expert application (Level 3)

While many areas may be '*nice to have*', or some initial knowledge of many areas is '*preferred*', the focus here is on those areas seen as "*need to have*" at Level 1 or above, as well as those that *differentiate* between "average" and "great" performance.

Section 5: Experience and Education

Role Cluster	Identifies the cluster of roles within the community map that work adjacently to one another
Associated Roles	Lists the roles that are associated in the same general organizational or progression role cluster to the role defined in the success profile.
Overview of Progression	<p>Describes the potential progression between/across roles or job clusters. Identifies potential paths of mobility, progression, and skill adjacency.</p> <p>Some progressions may capture the addition of next generation technologies or practices into an existing role. Some progressions may result from advancing skill/knowledge/practice within the same technology area.</p>
Considered as a Transitional Role	Identifies if the role may provide an opportunity for a "connected role" (a manufacturing producer level role in an adjacent area) to transition with (estimated) 2 years of additional reskilling and development. In a manufacturing environment, an experienced production worker may be likely to transition to this role with 2 years of additional new training and development.

The 20 Success Profiles are available as a separate download from DMDII.

6. One Shared Call to Action: Partnering to Connections

Talent is the key to unlocking the promise of Manufacturing 4.0. But, developing the Manufacturing 4.0 workforce requires heavy lifting from more than just one entity. In this section, we outline a call to action for stakeholders across the Talent 4.0 Ecosystem.

Our work to define the Digital Manufacturing Workforce was developed along four core principles:

1. Frameworks would be based on demand and expertise
2. We would build toward opportunity – not disruption
3. Talent and Workforce Plans and investments will need to be both phased and diverse to align with market opportunities
4. Closing the talent gap will require a systems approach





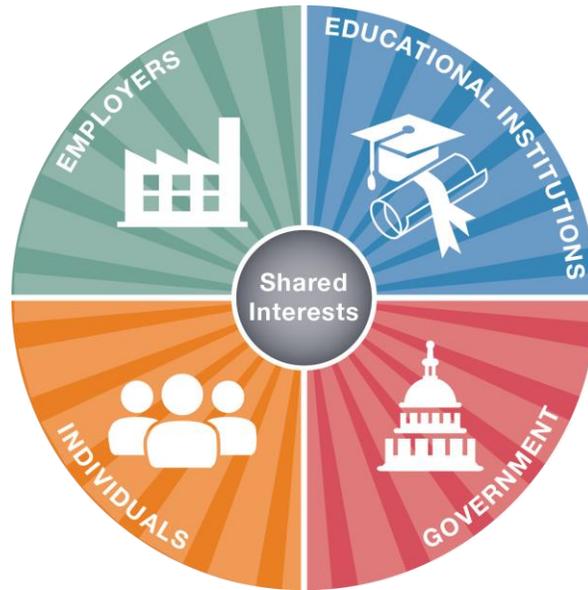
Improving the system of digital manufacturing talent will hinge on a better balance between supply and demand, including a fuller pipeline of workforce candidates. From a workforce perspective, restoring the balance in the Digital talent ecosystem and the business transformations in manufacturing relies on people seeing opportunity; having learnability; organizations making investments; and all engaging in a culture of design and innovation. These factors will need to stand on the shoulders of a legacy of creation and production, to redraw those system guiderails and create new work, new workers, and new commercial opportunities. The old job boundaries, outdated workforce processes, or conventional leadership practices towards the manufacturing organization will grow less and less relevant.

The DM&D Taxonomy and Success Profile effort is, at its heart, a workforce “infrastructure” project that created a solid foundation of what work needs to be done, and what domain knowledge needs to be applied by what combinations of work roles. These guiding principles of the Taxonomy provide that foundation and ensure that the work can have impact and influence in the most critical spaces of the manufacturing sector and the fuller system by generating awareness. Next the foundation and awareness needs to move to adoption. Stakeholders each can advance their efforts by working with and implementing the Taxonomy, augmenting it and extending it for their particular uses. Then, as the benefits of having a clearer picture enable all parties to see how the workforce is succeeding and adapting to change, we should see acceleration of the promise of Digital. Acceleration of the manufacturing sector’s workforce and for the economy at large should occur as we move into making progress on changes and adaptations that will take us into the future.

This taxonomy effort has illustrated an integrated and cohesive platform of people and capability that will power the US journey toward leading the future of manufacturing. It is our belief that manufacturers will be able to see their own future even more clearly with a key part of the path outlined: the workforce and the work that adapts to a new environment and establishes new places for growth and change.

Where to Begin?

Digital transformation carries with it a significant risk to disrupt business segments in manufacturing and beyond. However, Digital is also a rapidly transforming creative force that is generous to innovators and those willing to adapt. These innovations and adaptations will be required not just in industry, but across the entire Talent 4.0 Ecosystem which must work together in order to generate the talent and organizational systems needed for innovation and growth to thrive.

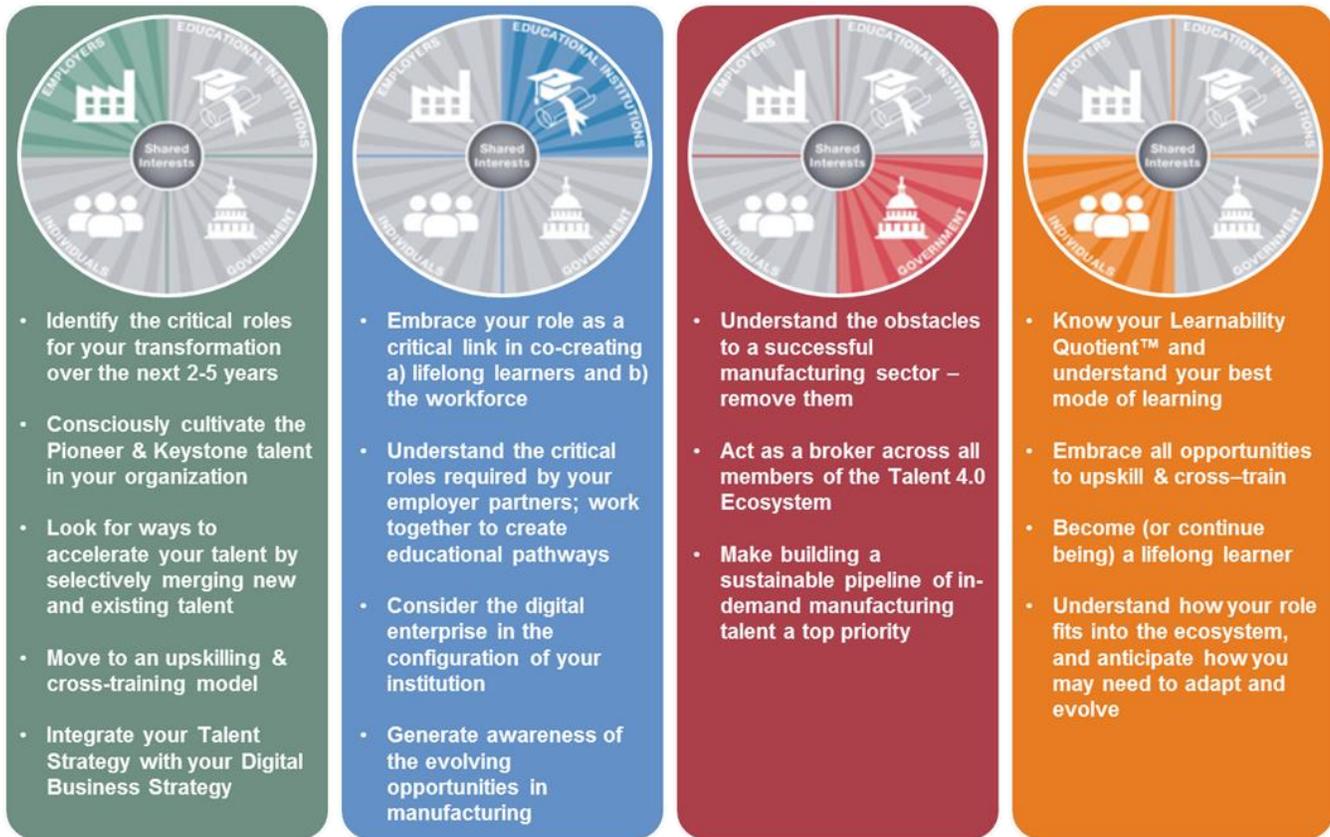


Employers, Government & Policy Advisors, Education, and Individuals must begin by asking some essential questions:

<p>Employers</p> 	<ul style="list-style-type: none"> • What does our digital manufacturing and design enterprise workforce look like now? • What will it need to look like in the future? • What must we do differently to create the workforce of the future and sustain it?
<p>Education</p> 	<ul style="list-style-type: none"> • What implications do such significant role evolutions have for the way we approach education across a variety of disciplines? • How can we increase the awareness of manufacturing opportunities for current and future workforces and accelerate across the education system?
<p>Government & Policy Advisors</p> 	<ul style="list-style-type: none"> • How are our collective investments and systems of policy, research, workforce funding, and other programs coordinated to build a healthy ecosystem of talent, opportunity, and national innovation?
<p>Individuals</p> 	<ul style="list-style-type: none"> • What are the new career opportunities that are possible? • How high is my learnability so that I can navigate and adapt? • What are the skills I need to learn and evolve rapidly?

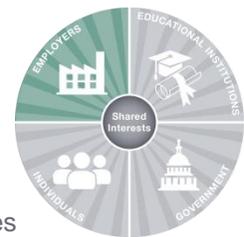
From Questions to Actions...

From our research, we have identified several potential starting points for action for each stakeholder in the Talent 4.0 Ecosystem:



Employers have the lead role in the Talent 4.0 Ecosystem. Their decisions on technology and talent investments drive demand on which all other activities in the Ecosystem hinge. Although there are many focus areas employers can take, we believe the most immediate benefit will be derived from:

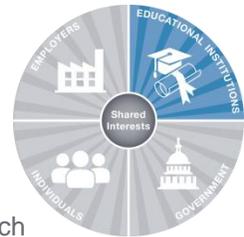
- Identifying The Critical Roles For Your Transformation** – The Success Profiles and Taxonomy Map provide an excellent starting point for where you will need to galvanize change in your organization in order to deliver business impact. As you consider which roles are most critical, you can easily navigate to all the touchpoints across the domain areas which will also help you build your Workforce Plan.
- Cultivating Pioneer & Keystone Talent** – Wherever you are on your transformation journey, your Pioneers will lead you there and break new ground, while your Keystone talent acts as an important integration point to drive systemic change.
- Accelerating Talent** – We know there is a significant shortfall of talent overall in manufacturing; this will be exacerbated by the shift to digital and will require employers to be increasingly creative. Balancing the need to maintain organizational know-how with future skills is a must. By selectively merging new



talent with existing talent, you have the opportunity to accelerate all talent. By embracing modular job structures and flexible careers, you can also get a more sustained impact than your demographics may suggest.

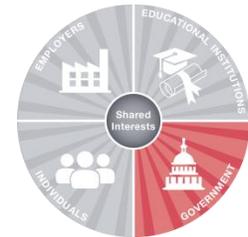
- **Upskilling and Cross Training** – It can't be said enough: there isn't enough rightly skilled talent available to justify taking shortcuts with your existing workforce. You will need to quickly determine the Learnability Quotient™ of your workforce and plan for upskilling. A shrewd move is to also cross-train talent on multiple roles as the nature of the Digital Manufacturing workforce is that it will continually evolve.
- **Integrating your Talent Strategy to the Digital Business Strategy** – Talent will be the driving force in Manufacturing 4.0 – nothing will be made of the fantastic technology and processes without the talent; so, why keep the strategy in two different tracks? An integrated approach will help keep a proper balance and make sure that talent doesn't become a decelerator on the strategy.

Education refers to the collection of K12, 2 year colleges, technical schools, universities, and workforce systems that provide educational opportunities for learners of all ages. Education, as a system, has been working hard to adapt to the changing needs of employers and learners and Manufacturing 4.0 represents an exciting opportunity to accelerate many of these efforts; specifically:



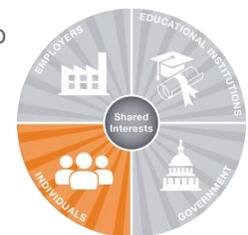
- **Embrace Your Role As A Critical Link** – Education is a journey and our research indicates that now more than ever it will be a lifelong journey. Consider ways in which the education system in your state can work together to cultivate a lifelong love of learning as well as a sustainable pipeline of in-demand talent. At a time when rapid evolution of skills will be the norm, agility of approach, the ability to quickly build-up, take down, and re-assemble programs will be critically important.
- **Understanding Critical Roles & Creating Pathways** – Just as employers are considering critical roles and creating their talent plans, education must develop a clear understanding of the picture that is emerging locally as well as on a national basis. Our work outlines several critical roles that are good starting places for reviewing curriculum and understanding how pathways may need to change to help people progress through their learning journey to ensure that they remain employable in well-paying jobs.
- **Consider The Digital Enterprise In Your Configuration** – This is a recommendation that impacts mostly on higher education. A review of the full Taxonomy Map suggests a review of each area of discipline within the university. The role of Digital Ethicist, for example, has implications for the School of Law as well as the School of Business – how will you factor this into your strategic planning?
- **Generating Awareness** – The shortage of talent in manufacturing is partially because we missed the opportunity to share a message. Let's not miss it again. Manufacturing is where meaningful work will be done in the US for years to come; there's ample opportunity to be part of amazing work.

Government & Policy Advisors have a powerful role to play in helping stakeholders find common ground, removing obstacles, and setting the right priorities for economic growth at the local, state, and federal level. There are many success stories to be told at the local, state, and federal level – DMDII’s existence demonstrates the priority we are putting on future workforce in the US, but more needs to be done to nurture and sustain progress.



- **Be a Barrier Buster** – Understand the obstacles to developing a thriving manufacturing economy in the US, your state, and your local economy – remove them. Aging infrastructure, lack of bandwidth, transportation, and outdated regulations that need to be revised to reflect the needs of digital manufacturing are all potential obstacles for thriving growth in the manufacturing sector. That said, the number one issue employers cite is access to talent, and the number one concern of individuals is well-paying jobs. Just as employers need to integrate their Talent Strategy to their Business Strategy, government will need to take steps to do the same.
- **Act As A Broker** – Government has a multitude of opportunities to optimize the connections across the ecosystem. Opening pathways to creating a continually upskilled and relevant workforce should be a central part of the remit. Just as industry needs to integrate its Talent Strategy into the Business Strategy, so too should Government look to build and integrate its Workforce Development Strategy into its plan for economic growth.
- **Make Building A Sustainable Pipeline Of Talent A Top Priority** – The biggest proof around whether this is a top priority is to consider how investments and systems are coordinated around building a pipeline of talent. There needs to be a clear connection between policy, research, workforce funding, and education with the strategic impact we are looking to have in the manufacturing space. Do we have the plan, checkpoints, and audits to ensure this is the case?

Individuals are the talent that educators seek to educate, that employers seek to employ, and that government protects and serves. If employers are the most influential stakeholder in the Talent 4.0 Ecosystem, surely the individual is the most important – if they don’t show up, nothing is produced! The rhetoric around Manufacturing 4.0 is all too often about jobs being eliminated, but the true storyline is really about new jobs being created. Therefore, the call to action for individuals is tightly tied to learning and adaptation:



- **Know your Learnability Quotient™** – ManpowerGroup’s The Learnability Quotient™ tool is free to use and provides an excellent assessment of how you learn. We see this as a key starting point for individuals. Knowing your best mode of learning is the first step in unlocking your human potential.
- **Understand How Your Role Fits** – This is critical as it will help you understand how you will need to adapt to ongoing change in your organization.
- **Embrace All Opportunities To Upskill & Cross-Train** – The picture we have painted in our research is one of a continually evolving system of roles. Depending on where your organization is on their Manufacturing 4.0 journey, some of these roles may not yet have emerged while others may be quite mature. In many cases, these roles will be merged into a single job description where some of the roles will fall away and others will be added. The bottom line is that in order to adapt and stay relevant, you will want to take advantage of every opportunity to upskill, cross-train through employer provided training, free training (such as the Digital Manufacturing and Design Specialization DMDII co-developed with Coursera) or tuition-based training.
- **Become (Or Continue Being) A Lifelong Learner** – of all the skills you can have today, your ability to learn and adapt is number one!

Conclusion

Understanding the changing nature of our industry and the evolving nature of how the workforce is going through succession to a newer and more adapted state, demands the time to both honor our productive past and create a talent base for the future. Doing so will require alignment on the workforce as a community of capability, and leveraging its management as a talent ecosystem, where taking action collectively and having mutual accountability is the only guarantee of sustained existence. As waves of innovation continue to digitally connect our World and Industry 4.0 matures, smart DM&D people will design smart products and smart factories; smart manufacturing will need the right, smart workforce across the entire product life cycle and into the customer experience. To achieve results as digital leaders and be digital optimizers overall, manufacturers will first and always need to optimize their talent.

Now, with the Manpower/DMDII DM&D Taxonomy and an increased understanding of the roles, technical areas, and needed capabilities, all stakeholders have more of the roadmap for success. This taxonomy and role profiling effort powers manufacturing to smarter and more connected talent, a community of dynamic and adaptive roles – current and future – that is a partner in connection with each other as a workforce and with industry, education, and government overall to achieve our mutual goals.