



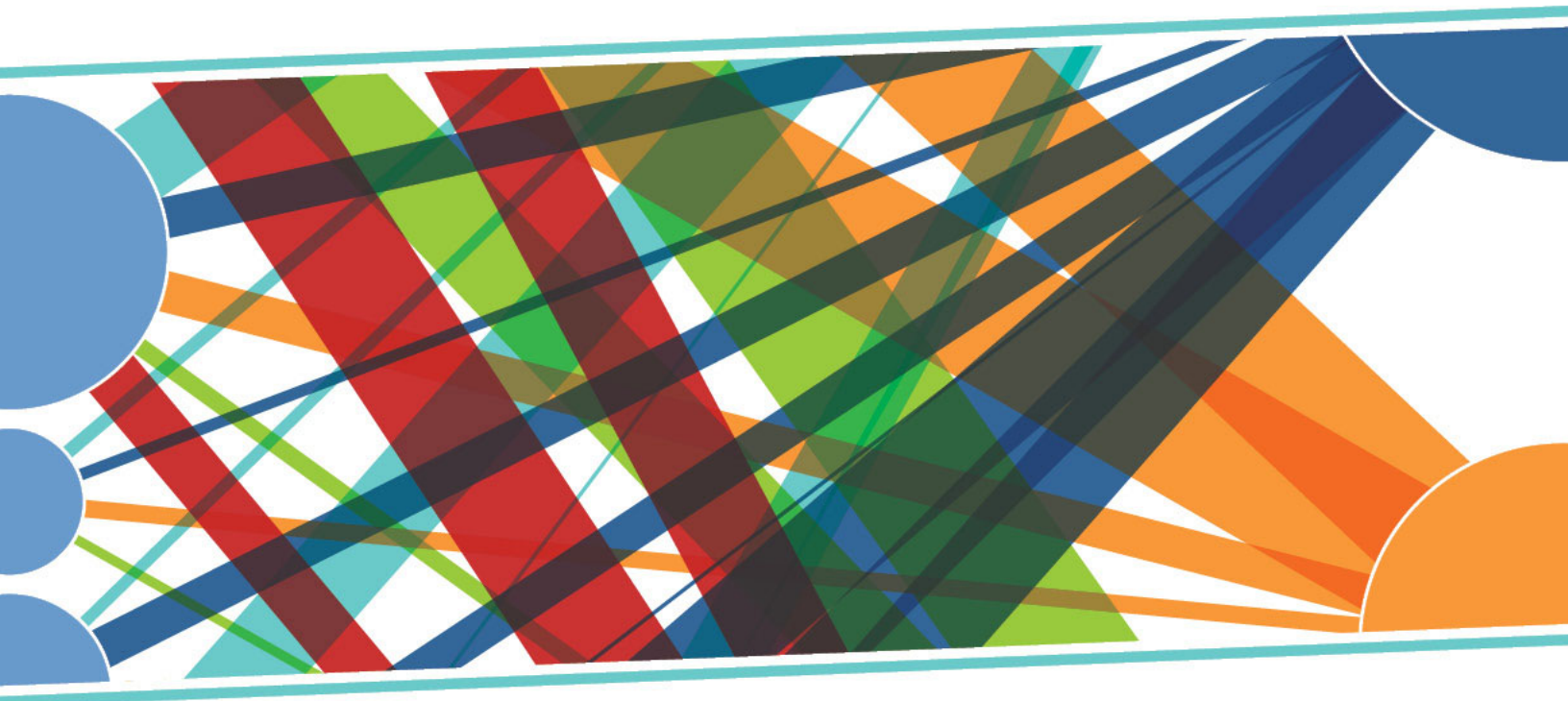
**NIST Advanced Manufacturing Series
NIST AMS 600-20**

Analysis of the Manufacturing USA Occupation and Competency Framework

A Shared Language for Careers in Advanced Manufacturing

NIST Office of Advanced Manufacturing

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Analysis of the Manufacturing USA Occupation and Competency Framework

A Shared Language for Careers in Advanced Manufacturing

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Statutory Authority

This publication is in direct response to the 2023 “Revitalizing America’s Manufacturing Workforce” national roadmap for education and workforce development published by the NIST Office of Advanced Manufacturing, which houses the Advanced Manufacturing National Program Office (AMNPO). This framework supports the public mission and responsibilities of the Manufacturing USA network and AMNPO, under 15 U.S.C. 278s, “to provide support services to promote workforce development activities, including the development of industry credentials.”

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About Manufacturing USA

Manufacturing USA[®] is a national network created to secure U.S. global leadership in advanced manufacturing through large-scale public-private collaboration on technology, supply chain, and education and workforce development. The network comprises the U.S. Departments of Commerce, Energy, and War; their sponsored manufacturing innovation institutes; and six additional federal agency partners, creating a whole-of-government, national effort to drive innovation in manufacturing. Each institute includes members from industry, academia, and state and federal governments with a shared interest in advancing manufacturing.

In 2024, the then 17 institutes collectively worked with over 3,100 member organizations to collaborate on more than 875 applied research and development technology projects of high priority to industry and engaged over 200,000 people in building workforce knowledge and skills in advanced manufacturing. The institutes attracted \$392M from state, federal, and private funds in addition to \$133M in base federal funding.

Abstract

This analysis describes the most common entry-level occupations in advanced manufacturing across the technology areas associated with the Manufacturing USA network through 2030. This review identifies 132 occupations connected to 235 KSAs (knowledge, skills, and abilities) that workers need, as of 2025 and into the future, to work with cutting-edge manufacturing technologies across five technology areas: biomanufacturing, digital/automation, electronics, energy/processes, and materials. This report uses data collected in 2025 to propose organizing the identified KSAs into 13 competencies and 68 sub-competencies as an extension of existing competency models. The objective of this framework is to provide a common language for and improve collaboration between industry, training providers, and workers.

Keywords

Manufacturing USA; Advanced Manufacturing; Competency; Manufacturing Innovation; Workforce; Advanced manufacturing credentials; Advanced manufacturing skills; Advanced manufacturing competencies.

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Executive Summary

Advanced manufacturing is a cornerstone of the U.S. economy, providing quality jobs and driving domestic innovation. Yet the industry continues to struggle to attract and retain a skilled workforce, posing a significant threat to U.S. global competitiveness and the nation's economic prosperity. To capitalize on emerging opportunities and maintain its leadership position, the industry must overcome this challenge by aligning workforce development programs with its evolving needs. However, the lack of a clear, consistent description of the skills and abilities required across multiple advanced manufacturing sectors hinders career navigation for workers and impedes broader workforce development efforts.

The Manufacturing USA Occupation and Competency Framework is a critical step towards addressing this challenge. Developed through a collaborative and iterative process with representatives from Manufacturing USA institutes, this framework provides a common language and shared understanding of occupational and skills needs for job seekers, employers, and trainers. The Manufacturing USA institutes identified and cataloged the essential **knowledge, skills, and abilities (KSAs)** required by workers and industry to grow U.S. advanced manufacturing.

The resulting framework offers a set of entry-level occupations most vital to the advanced manufacturing industry from 2026 through 2030, aligned to competencies, sub-competencies, and KSAs—including a completely novel group reflecting the leading edge of advanced manufacturing technology. **This document serves as a potential guide for other workforce frameworks, workforce professionals, and training providers in the advanced manufacturing sectors.**

The key findings of this report highlight the transferability of skills across advanced manufacturing technology areas and occupations. The report identifies 132 unique occupations, grouped into 52 engineering and scientific roles, 52 technician and associate roles, 17 specialist and analyst roles, and 16 machine operator and machinist roles. By 2030, advanced manufacturing occupations such as these will require skills in data collection and analysis, advanced tools for product development, and testing and troubleshooting. The data provides strong evidence that in-demand skills span multiple technology areas. Key takeaways include the following:

- Given the breadth of roles this study examines, the information in this report can provide a foundational set of skills that are beneficial across advanced manufacturing, regardless of specific job titles.
- At least half of the selected KSAs are shared by multiple technology areas.
- The most cited advanced manufacturing skills can be correlated with groupings of occupations spanning multiple technology areas.
- Overall, the Tier 4 competencies encompass over 75% of the KSAs identified by the MFG USA institutes, indicating a strong need for these foundational skills for future cutting-edge manufacturing processes. A more detailed list of sub-competencies and KSAs, along with provisional definitions, is available in Appendix A2.

- The Tier 5 competencies, sub-competencies, and KSAs were developed as part of this report and are an extension of the Department of Labor’s (DOL’s) model, as it reflects the skills and occupations which are in active development. As technology develops, so too must training programs to accelerate technology adoption.
- The KSAs identified in this framework can serve as a starting point for training organizations to increase the impact of their programming.
- Since many technology areas share KSAs, occupations, and connections, the findings of this report can help guide institutes and other organizations within the advanced manufacturing ecosystem in strategically choosing their collaborations.
- The occupation data at the sub-competency level and below reflects significant overlap in the types of KSAs that support overlapping advanced manufacturing career pathways, suggesting opportunities to promote transferable skills in training.
- This work reinforces the benefits of job providers (industry), training providers (academic and non-academic workforce training organizations), and job seekers (workers) using standardized, industry-validated vocabulary within and among technology areas.
- The mapping of interconnections between KSAs and occupations across technology areas allows for career pathway mapping, which is essential to guide the development of both training programs and occupation guidance.
- The breadth of KSAs that are unique to high-density areas such as the digital/automation technologies indicates that this emerging technology will require a concerted training effort to fully prepare a broad workforce, often outside the digital and automation technology area and upskilling training programs. This is true with many skills across all technology areas.
- Despite a large portion of the identified KSAs localizing to well-established frameworks, the skills required to design and produce advanced materials emerge in Tier 5 as advanced processing methods and materials (Table 5).

With this unified framework, the Manufacturing USA institutes and industry partners can collaborate more effectively, accelerate workforce development, and drive the adoption of industry credentials. By leveraging existing training content and developing new, highly specialized training, the Manufacturing USA institutes can drive impact across the U.S. manufacturing landscape. The relevance and utility of this framework will require frequent institute-led industry validation and updates. This initiative has the potential to promote a more scalable and coherent national workforce development strategy, ultimately supporting the growth of a skilled and adaptable advanced manufacturing workforce that drives U.S. economic competitiveness.

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1. Background: Closing the Gap in the Advanced Manufacturing Workforce

Advanced manufacturing represents the cutting edge of industry, applying new technologies, smart systems, and innovative processes to unlock enormous potential to benefit both industry and workforce development. The United States can lead in global manufacturing by leveraging advanced manufacturing, and training programs and workforce skills must evolve alongside technological developments. Education and workforce development programs for advanced manufacturing must develop curricula in parallel with the deployment of cutting-edge technology to increase adoption, enhance efficiency, and build a highly skilled, in-demand workforce. To remain competitive, training programs must work with the U.S. manufacturing industry to inform their curricula and meet industry needs.

To further illustrate the need, the U.S. manufacturing industry faces a persistent challenge in attracting and retaining highly skilled workers [1]. Estimates predict that an additional 3.8 million manufacturing jobs will be created by 2033, with many of these positions at the forefront of technological advancements [2]. However, more than half of those jobs could remain unfilled not only because employers cannot hire enough entry-level employees with the necessary knowledge to be trained effectively, but also because there is insufficient talent with the specialized or technical training needed to fill evolving and advanced roles. While upskilling remains essential to the manufacturing ecosystem, delays in developing needed upskilling training programs stifle both technology adoption and industry expansion. Bringing together industry, training providers, and educators to develop advanced knowledge, skills, and abilities (KSAs) can effectively address industry's most pressing needs [3].

To address these challenges, the Manufacturing USA (MFG USA) institutes serve as conveners for industry, economic developers, training providers, academic institutions, government agencies, and workforce development organizations. Their mission is to accelerate advanced manufacturing in the United States [4]. By focusing on shared and cutting-edge workforce development activities, often through regional and cross-cutting sectoral partnerships, the MFG USA institutes can fill the advanced manufacturing talent gap by focusing on three priorities: (1) equipping workers with new and needed technology adoption skills, (2) increasing access to advanced manufacturing KSAs and careers, and (3) generating interest in front-line advanced manufacturing careers [5]. Each institute in the MFG USA network works to address the needs of industry through education and workforce development training, products, and programs.

While each industry and technology sector has unique needs that can change rapidly, the Manufacturing USA network can develop industry-led, cost-effective programs. As an example, to address the growing need for machinists, the Institute for Advanced Composites Manufacturing Innovation (IACMI) developed the America's Cutting Edge (ACE) program with support from the U.S. Department of War [6]. ACE provides no-cost online and in-person training, led by industry professionals nationwide, as part of a training pipeline to support direct hiring and apprenticeships for machinists. In the expanding field of biomanufacturing, the Advanced Regenerative Manufacturing Institute (ARMI | BioFabUSA) established an effective registered apprenticeship program for biofabrication technicians, offering participants the opportunity to earn industry-recognized credentials [7]. The Collaborative Ecosystems Smart Manufacturing Innovation Institute (CESMII), the smart manufacturing institute, collaborated

with Tooling U-SME to offer fundamental courses in cross-disciplinary skills, including data collection, automation, cybersecurity, and smart manufacturing [8]. These types of programs connect future workers with essential KSA training programs to increase technology adoption.

Through expansion and coordination of education and workforce development efforts, Manufacturing USA drives impact across U.S. manufacturing. In 2023, the NIST Office of Advanced Manufacturing released the *Revitalizing America's Manufacturing Workforce: A Manufacturing USA National Roadmap* report, which uses the three priorities outlined above as an overarching strategy for developing initiatives with the potential greatest impact on addressing U.S. advanced manufacturing talent gaps [5]. As an outcome of the roadmap, this publication and an accompanying external report have been developed to provide a standardized, industry-informed framework for the KSAs relevant to in-demand needs and tasks in advanced manufacturing [5, 9].

1.1. Purpose and Applicability

A significant challenge in recruiting and retaining the advanced manufacturing workforce is aligning, documenting, and describing in-demand technical and cross-disciplinary KSAs. Training programs and education organizations use various methods and taxonomies, with differing levels of industry adoption, to address this KSA issue. Adoption also varies by geographic region and technology area, with some more cohesive than others. A lack of standardized language around advanced manufacturing skills means that efforts to promote career and technical education (CTE) programs, apprenticeships, pre-apprenticeships, industry-recognized credentials, post-secondary degrees, and other initiatives generally remain fragmented and difficult to navigate. This is especially true across technology areas, which further exacerbates shifts in the industry's worker needs. The Manufacturing USA Occupation and Competency Framework provides organizations with a standardized language to align curricula to the advanced manufacturing industry's needs.

This document serves as a potential guide for other workforce frameworks, workforce professionals, and training providers in the advanced manufacturing sectors. The framework is modeled on and incorporates components of previously established and recognized frameworks, such as those found in the U.S. Department of Labor's (DOL's) Competency Model Clearinghouse, the NICE Framework for the cybersecurity workforce, and frameworks published by individual MFG USA institutes [10, 11]. As a result, this framework builds and expands on previous work, highlighting translatable and transferable skills and advancing understanding of workforce needs in the advanced manufacturing space.

1.2. Audience

Advanced manufacturing careers encompass a wide range of job roles with varying degrees of cross-cutting skills. As such, organizations at the local, regional, and national levels support efforts to recruit, retain, and upskill the advanced manufacturing workforce. Therefore, the target audience for this document includes the broad MFG USA network, the members of the institutes, workforce development professionals, and associated groups.

2. Framework Structure

The MFG USA Occupation and Competency Framework is a first-of-its-kind framework that spans the five technology areas covered by the MFG USA institutes—biomanufacturing, digital/automation, electronics, energy processes, and materials—and their constituent members from industry and academia. The framework comprises 235 unique KSAs, 132 occupations, 20 competencies, 68 sub-competencies, and over 1,200 data points collected in 2025. Breaking down the data by competency, occupation, and KSA enables the information to be targeted towards different groups, including job seekers, trainers, and employers. This analysis allows stakeholders to identify connections and areas for growth in the skills and occupations essential to advanced manufacturing technology areas, as well as determine where those skills and occupations overlap across different technologies. By identifying areas of future growth in advanced manufacturing, each MFG USA institute can leverage this framework—together with its core capabilities, strengths, and partnerships—to develop targeted, industry-driven education and workforce development programs. Section 2 of this report provides a top-down description of the MFG USA Occupation and Competency Framework, specifically the KSA and occupation building blocks and their ties to other frameworks. Definitions of the terms used in this framework to categorize the necessary skills identified by the MFG USA institutes are provided in Appendix A2 of this document.

2.1. Alignment to Other Workforce Frameworks

The MFG USA Occupation and Competency Framework builds on existing competency models related to advanced manufacturing. The DOL Employment and Training Administration (ETA) collaborates with industry partners to develop competency models covering economically important industries and sectors of the U.S. economy through the Competency Model Clearinghouse, including the DOL Advanced Manufacturing Competency Model (AMCM) [11]. This specific model provided an initial foundation and organizing structure for the MFG USA framework, but it required updating to align with cutting-edge technology sectors.

The workforce leads and associated committees at each MFG USA institute predicted essential entry-level occupations for 2026–2030 and the associated technology-related KSAs required for each position. Where appropriate, the data was verified with input from network industry members. The data was then refined through a comparative analysis of skills and occupations across the MFG USA network, and KSAs were aligned to DOL’s AMCM.

The bottom three tiers of DOL’s model are known as the Foundational Tiers and focus on basic skills essential for success across all job types. While the MFG USA Competency Framework references these tiers as core KSA building blocks (see Figure 1), it focuses on the Industry-Wide Technical Competencies of Tier 4 and the Industry-Sector Technical Competencies of Tier 5—Tier 4 for broad skills relevant across the advanced manufacturing industry, and Tier 5 for more specialized, newly developed technology skills. MFG USA network data on essential KSAs for essential occupations was organized into the pre-existing Industry-Wide Tier 4 and a proposed Industry-Sector Tier 5, also modeled after DOL’s competency models. KSAs linked to DOL’s AMCM were categorized into Tier 4 competencies using DOL’s terminology, while KSAs

representing skills not previously associated with a competency in the DOL model were placed into new competencies in a newly-generated Tier 5. For many of these KSAs, Tier 5 placement indicates their relatively recent development or inclusion within the industry area.

KSAs and competencies in Tier 5 were aligned with additional industry-based frameworks beyond the DOL AMCM to identify the most appropriate categorization and avoid duplication. These complementary frameworks include the well-established NIST NICE Framework for Cybersecurity, the DOL Bioscience Competency Model, the DOL Information Technology Competency Model, and several industry-specific analyses conducted by the institutes that capture cutting-edge skills in advanced manufacturing [10, 11].



Fig. 1. Advanced Manufacturing Occupation and Competency Framework.

2.2. 2025 Manufacturing USA Network Technology Areas and Occupations

Future-oriented essential occupations in advanced manufacturing span a wide range of technologies and processes. In 2025, the MFG USA Network accelerated manufacturing within five broadly defined technology areas: biomanufacturing, digital/automation, electronics, energy/process, and materials. While a MFG USA institute will focus on developing a specific advanced manufacturing technology, its constituent members may be part of different technology sectors interested in adopting it. For example, both biology and vehicle manufacturing companies may rely on both cybersecurity and robotics. Specific definitions for these technology areas can also be found in the Glossary in Appendix C.

These technology areas serve as the basis for categorizing critical occupations and their associated skills, in the form of KSAs, into distinct bins. This categorization allows the network and its partners to visualize cross-technology skills that are potentially transferable from one area of advanced manufacturing to another, as well as more clearly identify how critical occupations across advanced manufacturing share foundational skills. This aggregate approach is crucial as foundational skills can be implemented differently across technology areas and at the individual company level.

When examining occupations, the MFG USA network identified critical entry-level positions for their industry members over the next five years. Three to 16 occupations were identified within each institute for a total of 132 occupations, 99 of which have unique names (e.g., three institutes separately submitted “biological technicians” as an essential role, which increases the total occupations count by three and the unique occupations count by one). The identified occupations were categorized, or grouped, by similar job roles and associated technology area. As shown in Table 1, occupations were classified as either technician/operator or engineer/scientist roles based on the skills and experience needed to accomplish work tasks. Specific occupation work tasks were analyzed across technology areas to ensure agreement across technology areas and confirm connections. In total, the 132 occupations were further broken down into 52 engineering and scientific roles, 52 technician and associate roles, 17 specialist and analyst roles, and 16 machine operator and machinist roles. This suggests a strong need for entry-level positions across the educational landscape, from high school graduates through advanced technical degrees.

Table 1. Technology Areas and Highly Selected Occupations in the MFG USA Network.

Technology Area	# KSAs ^a	Types of Occupations
Biomanufacturing (Bio/BioMFG)	65	<p><i>Technician/Operator</i></p> <ul style="list-style-type: none"> • Biological/Biofabrication Technicians • Quality Assurance/Control Technicians/Associates • Advanced Manufacturing Technicians/Industrial Engineering Technologists and Technicians <p><i>Engineer/Scientist</i></p> <ul style="list-style-type: none"> • Process Development Scientists • Process Engineers/Scientists
Digital/Automation (D/A)	104	<p><i>Technician/Operator</i></p> <ul style="list-style-type: none"> • Industrial Engineering Technologists and Technicians / Additive Manufacturing Technicians • Robotics Technicians/Controls/Automation Technicians/Specialists/Electro-Mechanical and Mechatronics Technologists and Technicians <p><i>Engineer/Scientist</i></p> <ul style="list-style-type: none"> • Process/Manufacturing Engineers/Industrial Engineers
Electronics (Elec)	78	<p><i>Technician/Operator</i></p> <ul style="list-style-type: none"> • Quality Technicians / Quality Control Technicians <p><i>Engineer/Scientist</i></p> <ul style="list-style-type: none"> • Electronics/Photonics Packaging Engineers • Materials Scientists/Engineers • Process Engineers
Materials (Mtrl)	43	<p><i>Technician/Operator</i></p> <ul style="list-style-type: none"> • CAD/CAM Technicians • CNC Machinists/Operators • Fabrication Specialists • Mechatronics Technicians <p><i>Engineer/Scientist</i></p> <ul style="list-style-type: none"> • Chemical Engineers • Electrical Engineers • Materials Scientists • Mechanical Engineers
Energy/Process (E/P)	57	<p><i>Technician/Operator</i></p> <ul style="list-style-type: none"> • Electronics Assemblers and Fabrication Specialists • Electronics Technicians and Fabrication Technicians <p><i>Engineer/Scientist</i></p> <ul style="list-style-type: none"> • Chemical Process Engineers • Control Systems Engineers • Process Engineers

^a Denotes KSAs selected by one or more occupations in a specific technology area

2.3. Connecting Critical Occupations to Skills and Competencies

As shown in Figure 2, KSAs are binned into competencies (X.X) and sub-competencies (X.X.X), based on the type of skills, technologies, and tasks required of the occupation. This framework links KSAs to occupations across the MFG USA Network. These occupations are binned by their technology area, as outlined in Table 1. Connecting the occupations with the KSAs essential for them, and standardizing where possible, produced a large data set that was then collated to analyze the common KSAs across entry-level occupations in advanced manufacturing and verified by MFG USA institutes and sponsoring agencies. The results of this analysis can be found in Section 3.

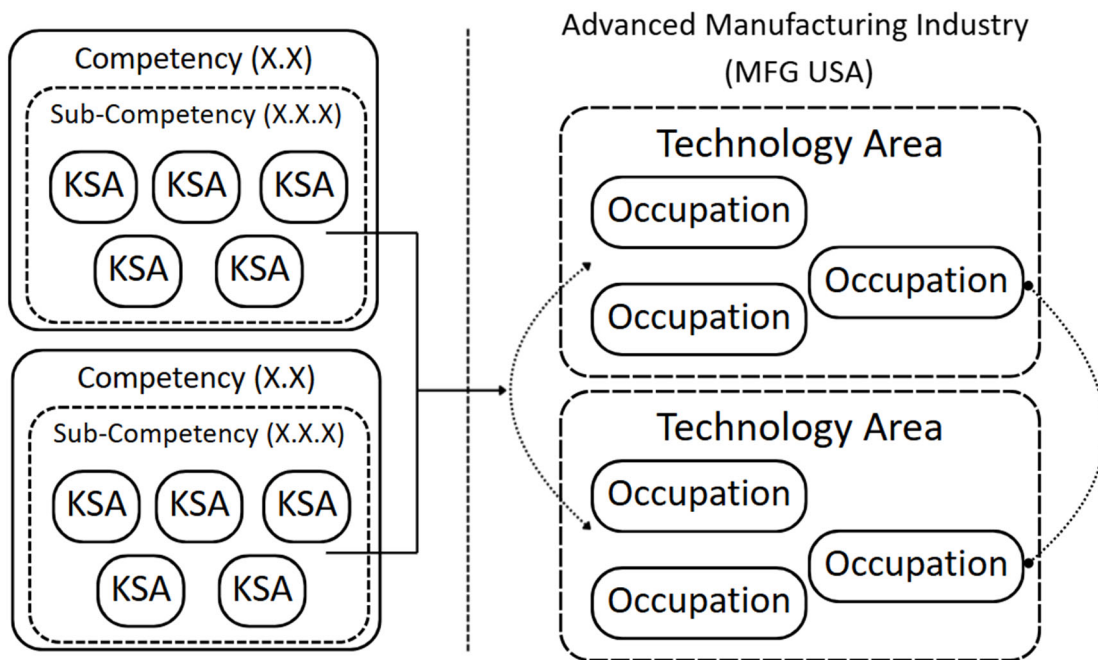


Fig. 2. Illustration outlining the approach of identifying connections between KSAs and occupations.

3. Key Findings

The competencies and associated occupations identified by the MFG USA institutes provide valuable insights into workforce development needs through 2030. Organizations can use this data to move beyond isolated skill statements toward providing systematic approaches for technology adoption and the associated training needed for advanced manufacturing. The analysis below outlines a standardized representation of how skills comprise occupations and how KSAs align across the advanced manufacturing ecosystem.

This framework analysis examines the extent to which competencies and underlying KSAs are shared across occupations in different technology areas, providing insight into cross-occupational linkages, skill transferability, and opportunities for coordinated workforce development strategies. This section also introduces Tier 5 Industry-sector Technical Competencies, which represent skills more specific to a technology area. These Tier 5 skills extend beyond existing national competency models for advanced manufacturing and reflect rapidly evolving manufacturing technologies.

Collectively, this approach provides an empirical basis for examining how workforce development needs manifest through competencies and offers a framework for aligning education, training, and credentialing efforts with the technical needs of the advanced manufacturing industry through 2030.

At a high level, the data in this competency framework reveals that knowledge, skills, and abilities (formulated in this framework as distinct KSAs) are broadly transferable across advanced manufacturing technology areas and occupations:

- 33% of all KSAs (i.e., “all KSAs” means the set of all 235 KSAs selected by MFG USA institutes) span multiple technology areas
- 50% of all KSAs are shared by three or more MFG USA institutes
- 29% of all KSAs align with eight or more occupations (Figure 3)

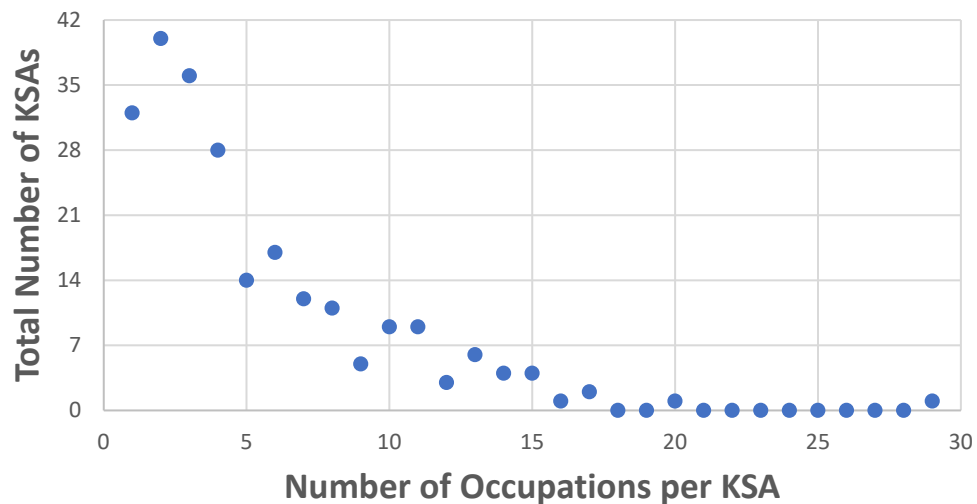


Fig. 3. Number of essential KSAs that align with a set of occupations.

The majority of KSAs selected by MFG USA institutes align with existing competency models, underscoring the solid foundation this framework provides in industry- and expert-recognized competencies. At least 91% of the KSAs identified by the institutes align with one of the previously cited models in Section 2:

- 78% of all KSAs align with competencies in the DOL AMCM
 - 34% of all KSAs reside in Operations Management (4.2)
 - 17% of all KSAs reside in Manufacturing Process Design/Development (4.1)

As shown in Table 2, many advanced manufacturing occupations across different technology areas are focused on specific skills aligned with the adoption of cutting-edge technologies. By 2030, occupations in the advanced manufacturing ecosystem will require increased knowledge and aptitude in data collection and analysis, the use of advanced tools for product development, and testing and troubleshooting manufacturing processes. These skills reflect both foundational requirements for a well-trained manufacturing workforce and the skills needed to adopt technologies such as robotics, artificial intelligence, advanced materials, and emerging biotechnologies.

Table 2. Most Cited Advanced Manufacturing Skills Across the Manufacturing USA Network.

Knowledge, Skill, Ability (KSA ID)	# Occupations	Technology Areas
Data collection and analysis (4.1.07.02)	29	Biomanufacturing; Digital/Automation; Electronics; Materials; Energy/Process
Knowledge and use of computer-aided design (CAD) and computer-aided manufacturing (CAM) software (4.1.02.04)	15	Digital/Automation; Electronics; Materials; Energy/Process
Use of basic hand tools in a safe and efficient manner to shape and form simple components (4.3.02.08)	20	Biomanufacturing; Materials
Understand and execute test and measurement assays (4.2.11.14)	17	Biomanufacturing; Electronics; Materials
Production and process troubleshooting (4.2.11.11)	14	Biomanufacturing; Digital/Automation; Electronics; Energy/Process
Use computers, computer-interfaced equipment, robotics, or high-technology industrial applications to perform work duties (4.2.06.11)	14	Biomanufacturing; Digital/Automation

3.1. Framework Competencies and In-Demand Occupations

Occupation or job title analysis is a common method for assessing future workforce needs, especially in academia. Occupations can be broken down into roles, tasks accomplished, and educational pathways leading to entry-level occupations or upskilling. This framework aims to identify the most essential skills for future-looking entry-level occupations by combining shared

KSAs with the breadth of technology areas in advanced manufacturing. The data in this framework identifies the in-demand occupations across the advanced manufacturing industry (Section 3.1.1), the most common and critical foundational KSAs to the industry (Section 3.1.2), and the skills required to work at the cutting-edge of technology (Section 3.1.3).

3.1.1. In-Demand Occupations

As previously stated in Section 2, the 132 occupations selected by the MFG USA institutes and their industry members can be categorized into engineering and scientific, technician and associate, specialist and analyst, or machine operator and machinist roles. This categorization can align with both career pathways and common educational preparation of workers in these roles. Further analysis reveals several entry-level roles spanning technology areas, underscoring the transferability of skills in the advanced manufacturing industry. The most frequently named occupations are shown in Table 3. While predictive models are inherently suggestive and not prescriptive, this list of industry-validated occupations could see increased demand, indicating a potential growing need in a wide variety of technical roles across the advanced manufacturing ecosystem, as shown in Table 1 and Appendix A1.

Table 3. Example Critical Occupations Across Advanced Manufacturing.

Top Occupations in MFG USA Network	Job Openings	Avg Salary	Avg Salary for Job Openings	Avg Entry-Level Salary Across Industries	Educational Pathway for Job Openings
Process Engineers/Scientists	–	–	–	–	Bachelor’s; 8% require a Master’s
Mechanical Engineers	127,646	\$112,300	–	\$76,800	Bachelor’s; 6% require a Master’s
Electrical Engineers	58,387	\$127,400	–	\$81,700	Bachelor’s; 9% require a Master’s
Machine Operators	–	–	\$45,387	–	High school or equivalent; <2% require an Associate’s/Bachelor’s
Industrial Engineering Technologists and Technicians	56,458	\$70,600	\$53,161	\$50,600	HS or equivalent; 12% require an Associate’s; 8% require a Bachelor’s

† Data as of Q3 2025 from JobsEQ+, which is consistent with the Quarterly Census of Employment and Wages, which is derived from quarterly contribution reports filed by almost every employer. This data comes from the U.S. Bureau of Labor Statistics covers 95% of U.S. jobs [12].

There are currently strong demand signals from industry for these careers. Using data from JobsEQ+, which is consistent with the Quarterly Census of Employment and Wages and is derived from quarterly contribution reports filed by employers, in the second quarter of 2025, over 291,000 workers had an occupation of Mechanical Engineer. This and the other data from Table 3 comes from the U.S. Bureau of Labor Statistics, which covers 95% of U.S. jobs. For Mechanical Engineers in 2024, educational pathways were primarily four-year degree programs and post graduate work: 387 earned a certificate or two-year degree, 33,257 workers achieved an associated four-year degree, and 9,213 achieved a postgraduate degree. The mean annual

wages exceed \$113,000 a year and the total demand is predicted to rise by over 88,000 workers over the next five years.

Another example includes a common career pathway for Electrical Engineers, which are not alone in these trends. In the second quarter of 2025, over 194,000 workers had an occupation of Electrical Engineer. For this group in 2024, educational pathways were also primarily through four-year degree programs and post graduate work: 687 earned a certificate or two-year degree, 15,651 workers achieved an associated four-year degree, and 11,910 achieved a postgraduate degree. For Electrical Engineers, the mean annual wages exceed \$124,000 a year and the total demand is predicted to rise by over 58,000 workers over the next five years.

Process Engineers are another common example for advanced manufacturing careers. While less clearly defined in the available data, in the second quarter of 2025, over 26,000 full-time workers had an occupation associated with Process Engineers. As a job title that does not have a specific Standard Occupation Classification (SOC) code, the role shares similarities to occupations such as Chemical Engineers, Manufacturing Engineers, Industrial Engineers, Validation Engineers, Materials Engineers, process-focused Mechanical Engineers, and a wide variety of other occupations such as Wastewater Engineers. For this group in 2025, active job ads sought educational pathways primarily through four-year degree programs with some postings for postgraduate work. While occupation titles may be common, with some significant and validated overlap between technology areas, it is apparent from the federal data sources above and Manufacturing USA industry member feedback that not all occupations with the same title have similar roles with identical tasks—strengthening the case for conducting these analyses to evaluate connection points for cutting-edge advanced manufacturing careers.

3.1.2. Tier 4 Industry-Wide Technical Competencies

Of the 235 essential KSAs identified by the MFG USA institutes, 183 clearly aligned with the Tier 4 Industry-Wide Technical Competencies of DOL’s AMCM, as shown in Table 4. DOL’s model has six competencies in Tier 4, designated 4.1–4.6 (see Table 4 for the list). All six competencies had KSAs identified as essential by at least one MFG USA institute. However, the connections to DOL’s model were not uniform: 34% of all KSAs aligned with Operations Management (4.2), followed by 17% aligned with Manufacturing Process Design/Development (4.1). The least commonly cited competency was Process & Equipment Health, Safety, and Environment (4.6).

Note that fewer citations within competencies do not correlate to relative importance in advanced manufacturing, only that institutes did not as frequently select them as essential skills for entry-level positions. This may be because these competencies are the purview of more senior positions or because institutes perceive those skills as baseline requirements and therefore less apt choices for a limited set of skills essential to a specific role (i.e., “don’t burn down the fab” goes without saying).

Overall, the Tier 4 competencies encompass over 75% of the KSAs identified by the MFG USA institutes, indicating a strong need for these foundational skills for future cutting-edge manufacturing processes. A more detailed list of sub-competencies and KSAs, along with provisional definitions, is available in Appendix A2.

Table 4. Essential KSAs Aligned to DOL Advanced Manufacturing Competency Model.

DOL ID	Competency Name	# KSAs
4.1	Manufacturing Process Design/Development	41
4.2	Operations Management	80
4.3	Maintenance, Installation, and Repair	25
4.4	Production in the Supply Chain/Supply Chain Logistics	13
4.5	Quality Assurance & Continuous Improvement	15
4.6	Process & Equipment Health, Safety, and Environment	9

Figure 4 lists the number of KSAs deemed essential as a function of Tier 4 sub-competencies, illustrating both a large variance in the number of essential KSAs that connect to occupations and strong overlap of KSAs among different occupations. This visualization allows for quick comparison of the relative frequency for the selected occupations. While not all sub-competencies were selected as being essential for these occupations, it is important to note those selected most often. Sub-competency 4.2.7 (**Manufacturing Process Applications and Operations**) contained the highest concentration of identified KSAs, followed by 4.2.11 (**Production and Process Monitoring**) and 4.1.2 (**Technical Drawings and Schematics**).

In Figure 4, the top five sub-competencies are indicated in red, with a full list of sub-categories: 4.1.2 Technical Drawings and Schematics, 4.1.3 Engineering Concepts, 4.1.5 Design Lifecycle and Concepts, 4.1.7 Testing/Troubleshooting, 4.1.8 Research and Development, 4.1.9 Workflow Assessment, 4.2.1 Critical Work Functions, 4.2.4 Precision Measurement, 4.2.5 Manufacturing Tool and Equipment Operations, 4.2.6 Automated Systems and Control Operations, 4.2.7 Manufacturing Process Applications and Operations, 4.2.8 Industrial Process, 4.2.9 Industrial Productions, 4.2.11 Production/Process Monitoring, 4.2.13 Project Management and Execution, 4.3.1 Critical Work Functions, 4.3.2 General Skills, 4.5.2 Quality Assurance, 4.5.12 Data Analysis and Presentation, and 4.6.8 Safety Procedures.

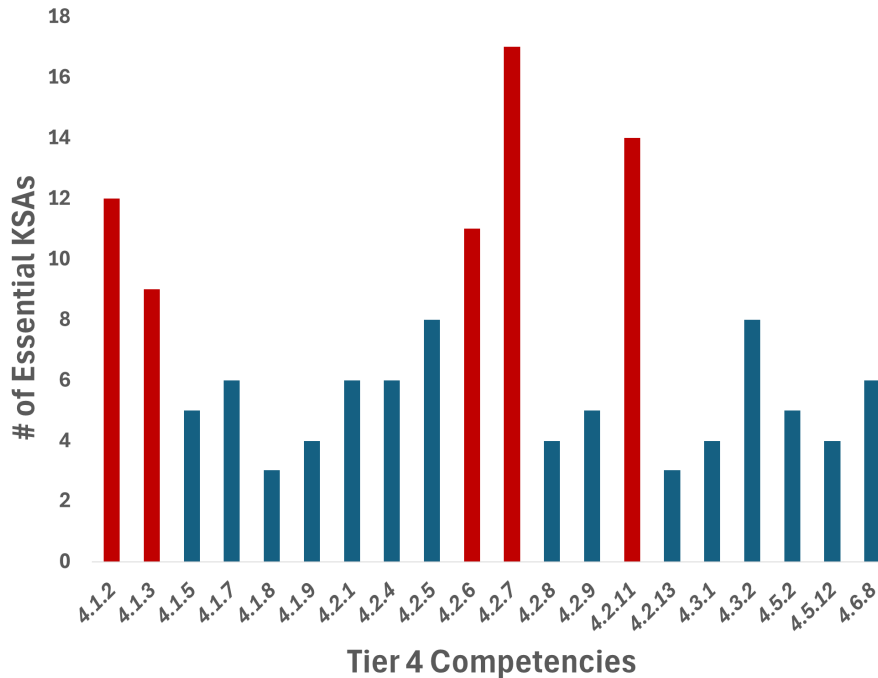


Fig. 4. Number of essential KSAs within DOL Tier 4 competencies.

3.1.3. Tier 5 Industry-Sector Technical Competencies

The KSAs classified within the Tier 5 Industry-Sector Technical Competencies reflect the leading edge of advanced manufacturing technology. While not comprehensive, these new competencies and sub-competencies are important focus areas for the MFG USA institutes and their associated technology areas. This new set was created because while competencies in Tier 4 represent essential KSAs for advanced manufacturing occupations that overlap across technology areas, there are specific KSA gaps for entry-level occupations within different industry sectors. For the occupations identified by the MFG USA institutes, the essential training of these roles requires the presence of Tier 5 KSAs. While there are fewer essential KSAs in Tier 5, these KSAs are critical to the future of advanced manufacturing and are expected to become increasingly relevant over the next five years as these occupations increase. In many cases, this new Tier 5 directly connects with pre-existing models and frameworks generated by the institutes themselves, NIST, or other technology-specific analyses.

The creation of this Tier is essential for categorizing the cutting-edge advanced manufacturing skills and trainings needs for both the Manufacturing USA network and manufacturing more broadly. This new newly generated Tier 5 focuses on industry- or technology area-specific competencies, based on a clear need to expand on the overlapping essential KSAs in Tier 4. Tier 5 KSAs comprise 52 of the 235 KSAs identified by the MFG USA institutes, representing over 20% of all KSAs contributed to this framework. Additionally, 82% of the Tier 5 KSAs are technology area-specific, compared with 62% of Tier 4 KSAs, and 32% of Tier 5 KSAs were only selected by one MFG USA institute, compared with 23% of Tier 4 KSAs. Tier 5 of this framework is an area of active growth and development but also essential for the training of entry-level

workers through 2030. Table 5 outlines the new Tier 5 technical competencies, sub-competencies, prevalence of KSAs in this study, and whether there is a closely associated deriving framework or model. This Tier will strongly benefit from regular adjustments and industry-led updates as it is based on the newest skills and occupations and is subject to refinement as the technologies continue to develop.

Table 5. Tier 5 Technical Competencies and Sub-Competencies.

Competency/Sub-Competency Name	# KSAs	Deriving Framework/Model
5.1 Additive Manufacturing	2	
5.2 Smart Manufacturing Technology	16	
5.3 Information Technology	14	DOL Information Technology Competency Model [11]
5.3.1 Programming	2	DOL ITCM 4.4.2
5.3.2 Databases and Applications	7	DOL ITCM 4.2
5.3.3 Networking and Communications	1	DOL ITCM 4.3.1
5.3.4 Virtualization and Cloud Computing	1	DOL ITCM 4.3.4
5.3.5 Software Acquisition, Management, and Maintenance	3	DOL ITCM 4.4.3
5.4 NICE Framework/Cybersecurity	10	NICE Framework [10]
5.4.1 Cybersecurity Fundamentals	3	NICE Framework ID: NF-COM-008
5.4.2 Access Control	1	NICE Framework ID: NF-COM-001
5.4.3 Cyber Resiliency	4	NICE Framework ID: NF-COM-007
5.4.4 Operating Technology (OT) Security	2	NICE Framework ID: NF-COM-010
5.5 Experiments, Tests, and Analyses	5	DOL Bioscience Competency Model 4.2.9
5.5.1 Microbiology Techniques	1	DOL BCM 4.2.9.2
5.5.2 Cell Biology Techniques	1	DOL BCM 4.2.9.3
5.5.3 Protein Techniques	2	DOL BCM 4.2.9.4
5.5.4 Biochemical Techniques	1	DOL BCM 4.2.9.5
5.6 Biomanufacturing Production	2	DOL Bioscience Competency Model 4.3
5.6.1 Production Process	2	DOL BCM 4.3.10
5.7 Material Design and Production	3	

3.2. Connecting Critical Skills Across Occupations and Technology Areas

Opportunities exist to streamline training in advanced manufacturing based on the transferable and foundational skills required for a skilled technical workforce. The KSAs identified in this framework can serve as a starting point for training organizations to increase the impact of their programming. These KSAs are also applicable across many technologies and processes.

This section highlights where these critical skills are tied to occupations that support the development of different technologies across the manufacturing ecosystem.

3.2.1. Technology Area Connections

Collaboration within a technology area is an important method for advancing education and workforce development goals. Each MFG USA institute has opportunities to collaborate with other organizations both within and outside their respective technology areas. Since many technology areas share KSAs, occupations, and connections, the findings of this report can help guide institutes and other organizations in the advanced manufacturing ecosystem in strategically choosing their collaborations.

The connections between the technology areas, measured by KSA overlap, can be seen in Figure 5, with darker shading indicating areas of stronger overlap. Figure 5 uses the following abbreviations: Bio references Biomanufacturing, D/A references Digital/Automation, Elec references Electronics, Mtrl references Materials, and E/P references Energy/Processes. It is important to note that not all areas provide the same number of occupations or KSAs, resulting in some technology areas having a stronger presence (represented by the dashed boxes in Figure 5). This is to be expected as technology areas advance at different rates and have differing levels of pertinence to other technology areas. For example, of the 65 KSAs required by occupations in biomanufacturing, 17 are also connected to occupations in the electronics technology area. The electronics technology area shares the most connections with the other technology areas in the MFG USA network: it shares 17 KSAs with biofabrication, 24 with digital/automation, 14 with materials, and 21 with energy processes, for a total of 76 connections (i.e., shared KSAs) across all other technology areas. The digital/automation technology area shares the most direct connections with energy/process technologies with 28 connections, suggesting important overlaps between process development enhancements and the integration of digital tools and smart manufacturing technologies. This is similarly true with digital/automation and electronics, which share 24 connections at the KSA level.

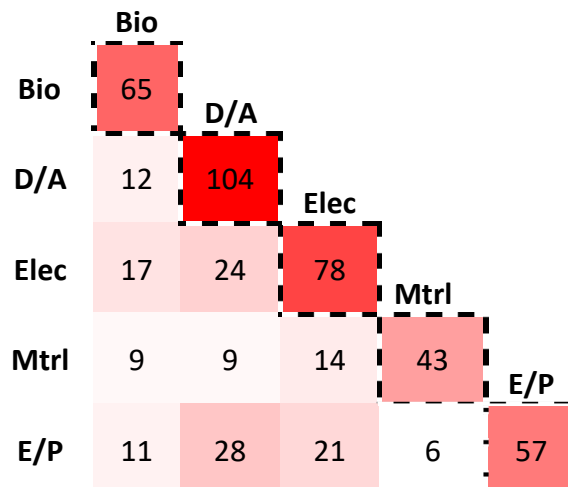


Fig. 5. Connections between technology areas by number of shared KSAs. Darker shading indicates more connections.

In this framework, over 38% of KSAs in the Tier 4 competencies span multiple technology areas. As seen in the summary of the Advanced Manufacturing Occupation and Competency Framework and Figure 6, which illustrates the number of total selected KSAs for all occupations in a specific technology area by competency, all six Tier 4 competencies encompass KSAs from more than one technology area. This reinforces the conclusion that there is significant overlap between specific skills and that skills can be clustered within these technology areas [9].

Specifically, the three competencies with the highest count of selected KSA that are shared across technology areas offer critical opportunities for cross-cutting approaches in the advanced manufacturing ecosystem. That is, for a list of KSA selections made by two institutes not in the same technology area (e.g., a KSA selected by both Biofabrication Technicians in biomanufacturing and Electronics Assemblers in the electronics), the competencies that contain the most of those technology area-crossing KSAs are:

- Manufacturing Process Design/Development (4.1): 54% of KSAs selected by multiple institutes
- Operations Management (4.2): 40% of KSAs selected by multiple institutes
- Quality Assurance and Continuous Improvement (4.5): 47% of KSAs selected by multiple institutes

Figure 6 shows that the 4.1 through 4.3 competencies (i.e., Manufacturing Process Design/Development; Operations Management; and Maintenance, Installation, and Repair) contain a larger volume of KSAs selected for the essential entry-level occupations, binned by technology area. The DOL demarcations listed in this figure are: 4.1 Manufacturing Process Design/Development, 4.2 Operations Management, 4.3 Maintenance, Installation, and Repair, 4.4 Production in the Supply Chain/Supply Chain Logistics, 4.5 Quality Assurance and Continuous Improvement, 4.6 Process and Equipment Health, Safety, and Environment, 5.1 Additive Manufacturing, 5.2 Smart Manufacturing Technology, 5.3 Information Technology, 5.4 Cybersecurity, 5.5 Experiments, Tests, and Analyses, 5.6 Biomanufacturing Production, and 5.7 Material Design and Production. Additionally, analysis of KSA level shows that the Quality Assurance and Continuous Improvement competency (4.5) has a larger number of unique KSAs than cross technology areas as a proportion to the overall selection of KSAs within that competency.

At the sub-competency level (4.X.X), more than half of the KSAs in 21 of 48 sub-competencies in Tier 4 span multiple technology areas, while only 15 sub-competencies contain KSAs specific to a single technology area. Three sub-competencies have the greatest number of KSAs that cross technology areas:

- Engineering Concepts (4.1.3) with six KSAs
- Testing/Troubleshooting (4.1.7) with six KSAs
- Production/Process Monitoring (4.2.11) with seven KSAs

This suggests that training focused on these KSAs could benefit from standardizing terms across technology areas and adopting cross-cutting approaches to address these workforce needs.

Figure 7, a heat-map of the number of KSA selections within a sub-competency based on technology area, further emphasizes the overlap between technology areas at the sub-competency level. The data shown is an analysis of the number of occupations within a technology area that require KSAs within a specific sub-competency. When comparing the sub-competency data above to the heatmap, it is worth noting that Figure 7 is a higher-level analysis that does not connect occupations across different technology areas at the KSA level. Rather, the occupation data at the sub-competency level reflects the significant overlap in the types of competencies that support advanced manufacturing occupations, suggesting opportunities to promote transferable skills in training. This reinforces the need to have job providers (industry), training providers (academic and non-academic workforce training organizations), and job seekers (workers) use the same vocabulary within and among technology areas.

	Bio	D/A	Elec	Mtrl	E/P
4.1	38	15	70	52	80
4.2	232	93	68	64	51
4.3	42	21	21	29	9
4.4	7	6	9	0	5
4.5	6	21	10	3	11
4.6	45	20	8	0	8
5.1	0	2	0	0	0
5.2	1	5	4	0	1
5.3	0	30	4	1	5
5.4	0	49	0	0	0
5.5	26	0	0	1	0
5.6	12	0	0	0	0
5.7	0	0	0	4	0

Fig. 6. Number of essential KSAs within Tier 4 competencies for occupations in a specific technology area. Darker shading indicates more connections.

	Bio	D/A	Elec	Mtrl	E/P		Bio	D/A	Elec	Mtrl	E/P
4.1.01	1	1	1	0	1	4.4.06	0	0	1	0	0
4.1.02	6	5	22	24	16	4.4.07	0	0	0	0	1
4.1.03	0	3	24	9	26	4.4.08	0	0	4	0	1
4.1.05	1	2	11	0	9	4.4.10	0	1	1	0	1
4.1.07	15	2	10	8	26	4.4.11	1	2	0	0	1
4.1.08	0	1	0	2	2	4.5.01	0	1	0	0	1
4.1.09	15	1	2	9	0	4.5.02	0	3	0	3	5
4.2.01	22	6	6	0	9	4.5.05	6	5	0	0	3
4.2.02	0	6	1	0	0	4.5.07	0	0	2	0	0
4.2.03	0	2	0	1	0	4.5.11	0	1	3	0	0
4.2.04	22	3	6	4	0	4.5.12	0	11	5	0	2
4.2.05	16	9	4	14	19	4.6.01	11	0	8	0	0
4.2.06	10	21	11	3	7	4.6.05	11	0	0	0	0
4.2.07	54	3	14	10	0	4.6.08	23	20	0	0	8
4.2.08	23	0	1	0	3	5.1.00	0	2	0	0	0
4.2.09	14	10	2	17	3	5.2.01	1	5	4	0	1
4.2.10	13	0	1	0	1	5.2.02	0	36	0	0	1
4.2.11	54	29	20	4	8	5.2.03	1	6	2	0	4
4.2.13	4	4	2	11	1	5.3.01	0	7	4	0	0
4.3.01	15	10	0	0	0	5.3.02	0	20	0	0	0
4.3.02	19	3	3	14	6	5.3.03	0	2	0	0	0
4.3.04	0	0	0	5	0	5.3.04	0	1	0	0	0
4.3.05	0	2	2	0	0	5.3.05	0	0	0	1	5
4.3.06	0	0	0	5	0	5.4.01	0	25	0	0	0
4.3.07	0	0	0	5	0	5.4.02	0	1	0	0	0
4.3.08	0	2	2	0	0	5.4.03	0	14	0	0	0
4.3.20	0	0	1	0	0	5.4.04	0	9	0	0	0
4.3.27	0	3	0	0	0	5.5.01	6	0	0	0	0
4.3.29	0	0	5	0	0	5.5.02	7	0	0	1	0
4.3.33	0	1	8	0	3	5.5.03	7	0	0	0	0
4.3.34	8	0	0	0	0	5.5.04	6	0	0	0	0
4.4.01	0	2	0	0	0	5.6.01	12	0	0	0	0
4.4.04	6	0	0	0	1	5.7.01	0	0	0	3	0
4.4.05	0	1	3	0	0	5.7.02	0	0	0	1	0

Fig. 7. Number of KSA selections within a sub-competency based on technology area. Darker shading indicates more connections.

3.2.2. Cross-technology Skill Connections

The occupations provided by MFG USA institutes contain both cross-cutting KSAs spanning several technology areas as well as KSAs that cluster around specific occupations. The data shows that some KSAs span many occupations, career pathways, and technology areas. The process for the total data collection is outlined above and in detail in the executive summary [9], with the data presented in Appendices A1-A3. The KSAs which connect to a relatively larger fraction of these future-looking occupations are those that would benefit from standard-setting and collaboration around training programs.

In Tier 4, as reflected in Table 6, the KSAs that span most technology areas reveal a similar list as Table 2, which shows the highly selected KSAs across the MFG USA network more broadly. The major difference between these tables is the KSA focused on Mechanical Engineering under the Engineering Concepts sub-competency (4.1.3). This KSA, unsurprisingly, strongly associates with the critical occupations listed in Table 3, as Mechanical Engineering concepts are foundational to many engineering and mechanically oriented roles, such as those involving robotics, electronics, materials, and additive manufacturing. While not unexpected, the mapping of interconnections between KSAs and occupations across technology areas allows for career pathway mapping which is essential to guide the development of both training programs and occupation guidance.

Table 6. Top KSAs in Tiers 4 and 5 That Span Technology Areas Across MFG USA Network.

Tier 4 Knowledge, Skill, Ability (KSA ID)	# Occupations	Technology Areas
Data collection and analysis (4.1.07.02)	29	Biomanufacturing; Digital/Automation; Electronics; Materials; Energy/Process
Knowledge and use of computer-aided design (CAD)/computer-aided manufacturing (CAM) software (4.1.02.04)	15	Digital/Automation; Electronics; Materials; Energy/Process
Production/process troubleshooting (4.2.11.11)	14	Biomanufacturing; Digital/Automation; Electronics; Energy/Process
Mechanical engineering (4.1.03.04)	11	Digital/Automation; Electronics; Materials; Energy/Process
Tier 5 Knowledge, Skill, Ability (KSA ID)	# Occupations	Technology Areas
Understand and apply Artificial Intelligence/Machine Learning fundamentals (5.2.01.04)	4	Digital/Automation; Electronics; Energy/Process
Process control and optimization (5.2.03.02)	3	Biomanufacturing; Digital/Automation; Energy/Process
Root-cause analysis (5.2.03.03)	4	Digital/Automation; Electronics; Energy/Process
Statistical data analysis (5.2.03.04)	4	Digital/Automation; Electronics; Energy/Process

While Tier 5 represents cutting-edge technology skills, specific KSAs still overlap across technology areas. In Table 6, these KSAs cluster under the Smart Manufacturing Technology (5.2) competency, highlighting the broader nature of integrating digital tools and processes into advanced manufacturing occupations. Furthermore, understanding the fundamentals of artificial intelligence and the other analytical skills listed will likely become increasingly important as artificial intelligence tools become more integrated into advanced manufacturing processes across various technology areas.

Figure 8 further illustrates the relationship between competencies. Each data label in Figure 8 represents the number of essential entry-level occupations that require *at least one* KSA within the two competencies along the x- and y-axis. The dashed boxes represent the total number of KSAs within a specific competency. For example, the first data label in the second row from the top shows that 57 different occupations require at least one KSA in the Manufacturing Process Design/Development (4.1) competency and at least one KSA in the Operations Management (4.2) competency.

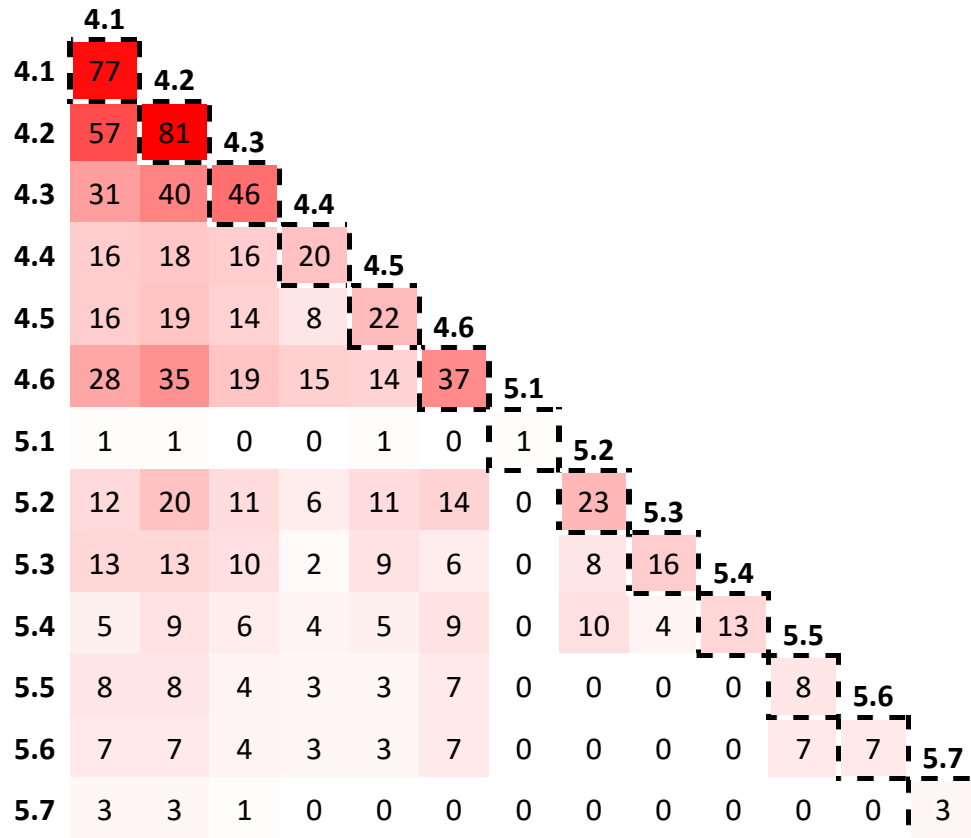


Fig. 8. Number of occupations that share KSAs among specific competencies. Darker shading indicates more connections.

Because the number of KSAs within each competency varies so widely, the numerical values of each cell alone conveys little information. But, viewed as a heat map, the figure shows interesting areas of overlap. For example, 4.1 and 4.2 competencies show relatively high overlap, as do 4.2 and 4.3, and 4.2 and 5.2 competencies; if a job requires skills within the

Smart Manufacturing Technology (5.2) competency, it is very likely also to require skills within the Operations Management (4.2) competency. Similarly, limited inferences can be made from areas with low overlap. Figure 8 shows that jobs that require skills within the Information Technology (5.3) competency have a relatively high overlap with several Tier 4 competencies, except the Production in the Supply Chain/Supply Chain Logistics (4.4) competency.

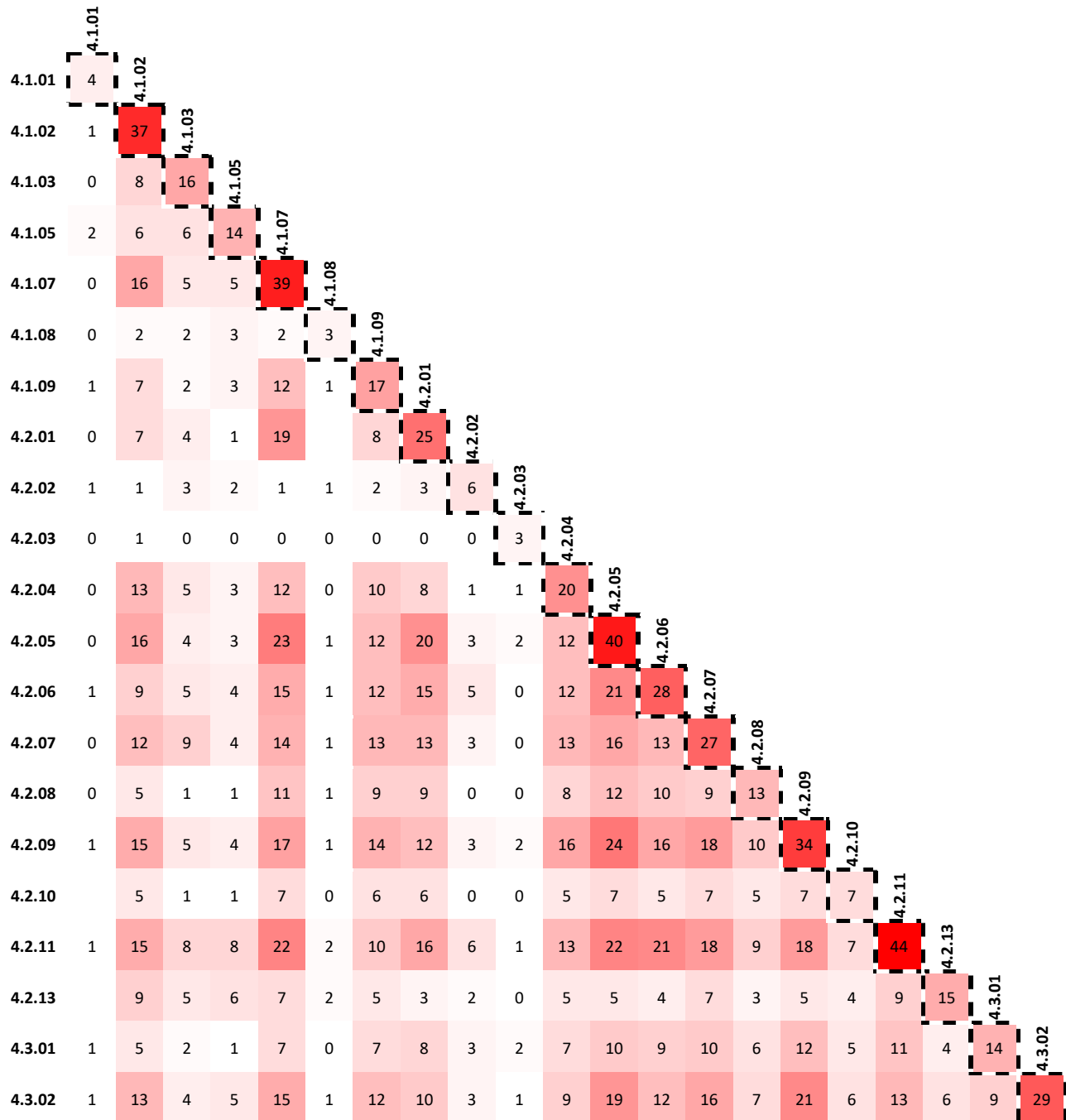


Fig. 9. Number of occupations that share KSAs among sub-competencies in 4.1 - 4.3 Tiers. Darker shading indicates more connections.

At the sub-competency level (x.x.x), the relationships between occupations and KSAs can be further refined. Figure 9 shows a subset of sub-competencies within the 4.1 through 4.3 competencies, as these competencies contained the largest number of occupations that shared KSAs in Figure 8. As in Figure 8, dashed boxes represent the total number of occupations in a specific sub-competency. Overall, the sub-competencies that contain a higher number of overall occupations within them also showed more connections with other sub-competencies, stressing their importance compared to the development of less common KSA training.

In general, a curriculum offered within the appropriate context for its intended use case can be more effective. For example, the Manufacturing Tool and Equipment Operations sub-competency (4.2.5) includes 40 occupations that require its KSAs. Of this set, 24 occupations also require KSAs within the Industrial Productions sub-competency (4.2.9). This specific data quantifies an intuitive relationship between the skills required to set up, operate, and adjust manufacturing equipment (in 4.2.5) and the need for knowledge of the methods and systems used to control, monitor, and validate advanced manufacturing processes (in 4.2.9).

When examining the most cited skills in the framework, KSA correlations can be derived based on the number of occupations that share multiple clusters of KSAs. For example, if an occupation needs *advanced fault finding on actual equipment* for Testing and Troubleshooting in the Manufacturing Process Design and Development competency, the most strongly associated other skills include:

- Follow SOPs and provide documentation
- Operate industrial equipment
- Review instructions to determine operational methods or sequences
- Use computers, computer-interfaced equipment, robotics, or high-technology industrial applications to perform work duties

While this specific skill has different implementations based on the technical area of the occupation, it connects to the following careers within this framework: Process Development Scientists, Mechanical Engineers, Manufacturing Technicians, Process Engineers/Scientists, Maintenance Technicians, and Instrumentation Technicians.

The training connection between technicians and engineers or scientists within technology areas is strong, highlighting a need for co-development of skills for both groups by industry and academia.

The most cited skill in the framework, *data collection and analysis* for Testing and Troubleshooting in the Manufacturing Process Design and Development competency, shows the most strongly associated other skills for an advanced manufacturing occupation include:

- Documenting and reporting information and data as part of production and process monitoring
- Follow SOPs and provide documentation as part of workflow processes

- Use computers, computer-interfaced equipment, robotics, or high-technology industrial applications to perform work duties as part of automated systems and control operations
- Follow SOPs and provide documentation as part of production and process and monitoring
- Understand and execute test and measurement assays as part of production and process monitoring

This collection of skills is essential for the following careers:

Digital Engineers, Biofabrication Technicians, Process Development Scientists, Biological Technicians, Biofuels Processing Technicians, Industrial Engineering Technologists & Technicians, Process Control Engineers, Control Systems Engineers, Chemical Equipment Operators and Tenders, Packaging and Filling Machine Operators and Tenders, Electronics Technicians, Fabrication Technicians, Industrial Technicians, Mechanical Engineers, Manufacturing Analytics Associates, Test Engineers, Quality Technicians, Process Technicians and Manufacturing Associates, Process Engineers and Scientists, Quality Control Associates, Quality Assurance Associates, Process Engineers, Process Technicians, Process Control Engineers, Systems Engineers, Chemical Process Operators, Machine Operators, Chemical Process Engineers, and Quality Managers.

The breadth of roles that this collection of skills touches provides a foundational set of skills that are beneficial across advanced manufacturing, regardless of specific job titles. Job titles and roles may also vary, specifically at many small and medium-sized manufacturers, where individual worker roles may span several occupations over the course of their tenure. The blending of roles is often deemed essential for industry flexibility and to account for blended processes with limited staff, strengthening the need for skills-based task analysis.

Table 2 also highlights skills in CAD and CAM. If a given occupation requires *knowledge and use of computer-aided design (CAD)/computer-aided manufacturing (CAM) software* for Technical Drawings and Schematics in the Manufacturing Process Design and Development competency, the most strongly associated other skills for the occupations studied include:

- Understanding of thermal, mechanical, and optical material properties as part of engineering processes
- Basic understanding of electrical and optical principles as part of engineering concepts
- Mechanical engineering as part of engineering concepts
- Data collection/analysis as part of testing and troubleshooting
- Work with project managers on production efforts to ensure that projects are completed satisfactorily, on time, and within budget as part of project management and execution

The *knowledge and use of computer-aided design (CAD)/computer-aided manufacturing (CAM) software* skill and the above list connect strongly to the following careers:

Digital Engineers, Electrical Engineers, Textiles Technicians, Designers, First-Line Supervisors, Electronics Technicians, Industrial Technicians, Machinists, First-Line Supervisors of Production and Operating Workers, Electronics Technicians, Industrial Technicians, Machinists, Mechanical Engineers, Electrical Design Engineers, Semiconductor Manufacturing Engineers, Manufacturing Engineers, Process Engineers, Electronics Technicians & Fabrication Technicians, and Quality Managers.

The data in this framework indicates distinct clustering of competencies, which can shape workforce needs and collaboration opportunities between industry partners and the associated workforce development ecosystem. Given the breadth and depth of the data, the utility of correlation analyses resides within the specific use cases, including curriculum development, which focuses on potential occupations and workforce development programs that span multiple technology areas. This data can help improve workforce program scaling and labor storage outreach.

3.3. Technology Area-Specific Insights

While previous sections of this report highlighted the cross-cutting connections across different technology areas, occupations, and competencies, further insight can be gleaned within specific technology areas. The advanced manufacturing technology areas identified by Manufacturing USA institutes exhibit substantial overlap in foundational KSAs. Of the technology areas examined, biomanufacturing shows the highest internal alignment, with 85% of KSAs shared across institutes and a strong mix of biomanufacturing-specific and network-wide skills, indicating the strong potential for coordinated curriculum development or standardization of training programs. The digital/automation technology area stands out for its wide set of unique, cutting-edge KSAs—many at the leading edge of advanced manufacturing—signaling a need for targeted, intensive training efforts to build emerging capabilities. In comparison, the electronics, materials, and energy/process sectors demonstrate moderate internal alignment but greater reliance on cross-sector collaboration, as their critical KSAs combine specialized technical expertise with widely shared competencies in manufacturing, data, safety, and automation. The sections below provide insight within the five specific technology areas and discuss how industry within those technology areas could maximize the impact of workforce training programs. The data for each technology area indicates a strong need for both occupations at the technician level, typically requiring high school education or two-year postsecondary training, and workers with a four-year degree or beyond in STEM fields.

3.3.1. Biomanufacturing

The biomanufacturing technology area contains 65 KSAs and occupations ranging from technician/operators such as Biological Technicians, QA/QC Technicians and Associates, and Advanced Manufacturing Technicians/Industrial Engineering Technologists, as well as engineers and scientists mainly focused on process development (Table 1). The most selected occupations in this technology area are Biological Technicians and Process Engineers/Scientists. Table 7 displays 2025 statistics and wage data about these and other careers within the field.

Table 7. Job Openings, Salary, and Career Pathway for Top Occupations in Biomanufacturing.†

Top Occupations in Biomanufacturing	Job Openings	Avg Salary	Avg Salary for Job Openings	Avg Entry-Level Salary Across Industries	Educational Pathway for Job Openings
Process Engineers/Scientists	–	–	–	–	Bachelor’s; 8% require a Master’s
Biological Technicians	6,875	\$64,300	\$54,215	\$42,300	High school or equivalent; 11% require an Associate’s; 26% require a Bachelor’s

† Data as of Q3 2025 from JobsEQ+, which is consistent with the Quarterly Census of Employment and Wages, which is derived from quarterly contribution reports filed by almost every employer. This data comes from the U.S. Bureau of Labor Statistics covers 95% of U.S. jobs.

Of the 65 KSAs in biomanufacturing, 34 KSAs (52%) are specific only to biomanufacturing careers. The relatively high specificity of KSAs in this technology area suggests that clearly defining unique skills across the biomanufacturing ecosystem could broadly benefit training programs for careers in this technology area [13]. As shown in Table 8, the sub-competencies in which biomanufacturing careers predominantly associate with are in the 4.2 Operations Management competency, further emphasizing the critical role that process development and monitoring plays in biomanufacturing.

Table 8. Highly Selected Sub-Competencies for Biomanufacturing Careers.

Biomanufacturing Sub-Competencies	# KSA Selections
4.2.1 Critical Work Functions (Operations Management)	22
4.2.4 Precision Measurement	22
4.2.7 Manufacturing Process Applications and Operations	54
4.2.8 Industrial Process	23
4.2.11 Production/Process Monitoring	54

This criticality of process development and monitoring can be further observed through the most highly selected KSAs specific to biomanufacturing careers:

- Understand and use volumetric measurement instruments and techniques
- Understand and use mass measurement instruments and techniques
- Comply with applicable regulations and standards
- Understand and execute safety and cleaning procedures

Biomanufacturing careers also require highly specific advanced skills, as shown in Table 5. Tier 5 of this framework draws on the DOL Bioscience Competency Model to emphasize the bioscience-adjacent skills required for biomanufacturing careers, specifically in the 5.5 Experiments, Tests, and Analyses and 5.6 Biomanufacturing Production competencies. While techniques that examine, isolate, purify, and process cell-based materials are commonplace in

bioscience careers, the intersection of these skills with manufacturing processes and scale-up provides a starting point for cutting-edge KSAs that will accelerate the biomanufacturing ecosystem. While there is strong internal alignment of KSAs within this technology area, there is significant overlap with other technology areas, particularly electronics and energy/processes.

3.3.2. Digital/Automation

The institutes in the digital/automation technology area identified 104 essential KSAs across their occupations. As shown in Table 1, these occupations span technician/operator roles (e.g., those focused on industrial engineering, additive manufacturing, robotics, automation, electromechanics, and mechatronics) to engineer/scientist roles (e.g., Process Engineers, Manufacturing Engineers, and Industrial Engineers). The top occupations in digital/automation technology are Process/Manufacturing Engineers and Electro-Mechanical and Mechatronics Technicians. Table 9 displays 2025 statistics and wage data about these and other careers within the field.

Table 9. Job Openings, Salary, and Career Pathway for Top Occupations in Digital and Automation.†

Top Occupations in Digital/Automation	Job Openings	Avg Salary	Avg Salary for Job Openings	Avg Entry-Level Salary Across Industries	Educational Pathway for Job Openings
Process/Manufacturing Engineers	–	–	–	–	Bachelor’s; 7% require a Master’s
Electro-Mechanical and Mechatronics Technicians	7,256	\$75,200	\$65,343	\$53,200	High school or equivalent; 14% require an Associate’s; 6% require a Bachelor’s

† Data as of Q3 2025 from JobsEQ+, which is consistent with the Quarterly Census of Employment and Wages, which is derived from quarterly contribution reports filed by almost every employer. This data comes from the U.S. Bureau of Labor Statistics and covers 95% of U.S. jobs.

Within digital/automation, 57 (54%) of the selected KSAs are not shared with any other technology area, a significantly higher number of unique KSAs than in other technology areas. Thirty of these 57 unique KSAs (54%) fall within the Tier 5 competencies, highlighting the importance of digital/automation technologies to technological advancements in advanced manufacturing. Table 5 highlights the strong prevalence of digital/automation skills in Tier 5 across the 5.2 Smart Manufacturing, 5.3 Information Technology, and 5.4 NICE Framework /Cybersecurity competencies, where frameworks such as the DOL’s Information Technology Competency Model and the NIST NICE Framework were used to build digital/automation-focused skills for manufacturing roles. The technological relevance of digital/automation skills is further amplified by the highly selected sub-competencies for digital/automation roles, mostly falling within Tier 5 competencies, as shown in Table 10.

Table 10. Highly Selected Sub-Competencies for Digital/Automation Careers.

Digital/Automation Sub-Competencies	# KSA Selections
4.2.6 Automated Systems and Control Operations	21
4.2.11 Production/Process Monitoring	29
5.2.2 IT/OT Integrations	36
5.3.2 Databases and Applications	20
5.4.1 Cybersecurity Fundamentals	25

Integrating emerging digital technologies into manufacturing processes and the processes that monitor and secure these technologies plays a major role in the highly selected KSAs for manufacturing careers in this technology area:

- Operational technology (OT)
- Manufacturing process flow
- Industrial Internet of Things devices
- Understand and use cybersecurity fundamentals
- Resilient cybersecurity response, administrative tools, and program implementation

The breadth of KSAs unique to the digital/automation sector indicates that this emerging technology will require a concerted training effort to fully prepare a broad workforce, often outside the digital and automation technology area and upskilling training programs.

3.3.3. Electronics

A total of 78 KSAs were deemed essential for at least one occupation in the electronics technology area. Common occupations in the electronics technology area include technicians focused on quality control and engineers/scientists with expertise in electronics/photonics, materials, and process development (Table 1). The top occupations are Electrical Design Engineers and Packaging Technicians, with the latter typically requiring a high school education for entry-level roles. Table 11 displays 2025 statistics and wage data about these and other careers within the field.

Of these 78 KSAs, 39 (50%) are specific to the electronics technology area. Within this framework, most KSAs for electronics careers are located within Tier 4 competencies, and the minority that exist in Tier 5 strongly overlap with competencies developed to support digital/automation careers, specifically the 5.2 and 5.3 competencies.

Table 11. Job Openings, Salary, and Career Pathway for Top Occupations in Electronics.†

Top Occupations in Electronics	Job Openings	Avg Salary	Avg Salary for Job Openings	Avg Entry-Level Salary Across Industries	Educational Pathway for Job Openings
Electrical Design Engineers	–	–	\$107,849	–	Bachelor’s; 8% require a Master’s
Packaging Technicians	–	–	\$44,719	–	High school or equivalent; <5% require an Associate’s or Bachelor’s

† Data as of Q3 2025 from JobsEQ+, which is consistent with the Quarterly Census of Employment and Wages, which is derived from quarterly contribution reports filed by almost every employer. This data comes from the U.S. Bureau of Labor Statistics and covers 95% of U.S. jobs.

As Table 12 shows, the sub-competencies specific to electronics careers are localized to the 4.1 Manufacturing Process Design/Development and 4.2 Operations Management competencies, suggesting that the skills needed for electronics careers are part of the fundamental skills required for success in manufacturing careers more broadly.

Table 12. Highly Selected Sub-Competencies for Electronics Careers.

Electronics Sub-Competencies	# KSA Selections
4.1.2 Technical Drawings and Schematics	22
4.1.3 Engineering Concepts	24
4.1.5 Design Lifecycle and Concepts	11
4.2.6 Automated Systems and Control Operations	11
4.2.7 Manufacturing Process Applications and Operations	14
4.2.11 Production/Process Monitoring	20

Given the well-established nature of the electronics industry, existing frameworks heavily consider KSAs for electronics technology for advanced manufacturing. Specific examples of this are visible in the highly selected electronics-specific KSAs:

- Assembly and printed circuit board (PCB) design
- Photonic system design, mechanically aware design
- Electrical and mechanical system operation familiarity
- Failure Analysis

As emerging technologies, such as digital twins, become integrated into electronics and semiconductor manufacturing, the electronics-specific skills may require the introduction of more cutting-edge skills that overlap with those in digital/automation technologies, including smart manufacturing and information technology.

3.3.4. Materials

For materials-focused manufacturing careers, 43 KSAs were identified as essential, with 19 (44%) unique to materials occupations. These occupations include technician roles dedicated to CAD/CAM, CNC machining, fabrication, and mechatronics, as well as more traditional engineering roles, such as Chemical Engineers, Electrical Engineers, Materials Scientists, and Mechanical Engineers (Table 1). The engineering roles in the materials technology area also correlate strongly to the critical/in-demand occupations needed across advanced manufacturing (Table 3). This data demonstrates the critical need for engineers not just across the manufacturing industry but specifically in roles interfacing with advanced material processes. Table 13 further emphasizes the common need for Mechanical Engineers in materials manufacturing and shows that some roles such as Fabrication Specialists provide another accessible entry-level pathway after a high school education.

Table 13. Job Openings, Salary, and Career Pathway for Top Occupations in Materials.†

Top Occupations in Materials	Job Openings	Avg Salary	Avg Salary for Job Openings	Avg Entry-Level Salary Across Industries	Educational Pathway for Job Openings
Mechanical Engineers	127,646	\$112,300	–	\$76,800	Bachelor’s; 6% require a Master’s
Fabrication Specialists and Technicians	–	–	\$48,310	–	High school or equivalent; 3% require an Associate’s; 14% require a Bachelor’s

† Data as of Q3 2025 from JobsEQ+, which is consistent with the Quarterly Census of Employment and Wages, which is derived from quarterly contribution reports filed by almost every employer. This data comes from the U.S. Bureau of Labor Statistics and covers 95% of U.S. jobs.

The foundational skills required for materials manufacturing mostly align with general equipment and assembly management through 4.2 Operations Management sub-competencies, followed by general skills in technical drawings and maintenance, installation, and repair (Table 14).

Table 14. Highly Selected Sub-Competencies for Materials Careers.

Materials Sub-Competencies	# KSA Selections
4.1.2 Technical Drawings and Schematics	24
4.2.5 Manufacturing Tool and Equipment Operations	14
4.2.9 Industrial Productions	17
4.2.13 Project Management and Execution	11
4.3.2 General Skills (Maintenance, Installation, & Repair)	14

Further emphasizing the importance of management operational skills to materials manufacturing, the following KSAs were highly selected for careers in materials:

- Work with project managers on production efforts to ensure that projects are completed satisfactorily, on time, and within budget
- Repair and calibrate pneumatic assemblies
- Repair and calibrate hydraulic assemblies
- Oversee the manufacturing process of devices

Despite a large portion of KSAs localizing to well-established frameworks, the skills required to design and produce advanced materials emerge in Tier 5 as advanced processing methods and materials (Table 5).

3.3.5. Energy/Process

The institutes in the energy/process technology area identified 57 KSAs as essential for at least one of their occupations. Energy/process occupations ranged from Electronics Assemblers and Fabrication Specialists and Electronics Technicians and Fabrication Technicians to Chemical Process Engineers, Control Systems Engineers, and Process Engineers. Table 15 displays 2025 statistics and wage data about these and other careers within the field.

Table 15. Job Openings, Salary, and Career Pathway for Top Occupations in Energy/Process.†

Top Occupations in Energy/Process	Job Openings	Avg Salary	Avg Salary for Job Openings	Avg Entry-Level Salary Across Industries	Educational Pathway for Job Openings
Process Engineers/Scientists	–	–	–	–	Bachelor’s; 8% require a Master’s
Machine Operators	–	–	\$45,387	–	High school or equivalent; <2% require an Associate’s or Bachelor’s

† Data as of Q3 2025 from JobsEQ+, which is consistent with the Quarterly Census of Employment and Wages, which is derived from quarterly contribution reports filed by almost every employer. This data comes from the U.S. Bureau of Labor Statistics and covers 95% of U.S. jobs.

At the sub-competency level, energy/process occupations show significant overlap with other technology areas, suggesting transferability between careers in this technology area and the other four in this framework (Table 16). A large portion of KSA selections for energy/process fall within the 4.1 Manufacturing Process Design/Development competency, followed by 4.2 Operations Management.

Table 16. Highly Selected Sub-Competencies for Energy/Process Careers.

Energy/Process Sub-Competencies	# KSA Selections
4.1.2 Technical Drawings and Schematics	16
4.1.3 Engineering Concepts	26
4.1.5 Design Lifecycle and Concepts	9
4.1.7 Testing/Troubleshooting	26
4.2.1 Critical Work Functions (Operations Management)	9
4.2.5 Manufacturing Tool and Equipment Operations	19

Energy/process occupations share cutting-edge skills in Tier 5 with the digital/automation technology area, specifically in 5.2 Smart Manufacturing and 5.3 Information Technology. This affirms that occupations focused on energy/process optimization share many traits with other occupations across the advanced manufacturing ecosystem. Furthermore, the essential KSAs for energy/process occupations were rarely specific to the technology area, with only 16 KSAs (28%) unique to it. The highly selected energy/process-specific KSAs were:

- Process flow diagram/piping and instrumentation diagram drawing
- Technology design/system design
- Life Cycle Analysis

The broad transferability of skills for energy/process occupations can be a focus for training programs seeking to demonstrate their applicability across the advanced manufacturing industry.

4. Conclusion

This analysis of the Manufacturing USA Advanced Manufacturing Occupation and Competency Framework reveals opportunities to enhance industry coordination, collaboration, and credentialing to accelerate technology adoption and strengthening alignment across the Manufacturing USA network. The dataset highlights a core set of critical occupations that span multiple technology areas, despite variations in job titles and sector-specific applications. At the skill level, a substantial portion of the identified knowledge, skills, and abilities—particularly within Tier 4 Industry-Wide Technical Competencies—cut across technology areas. Meanwhile, distinct clusters of KSAs and occupations remain unique to specific technology sectors, underscoring both common workforce foundations and meaningful sectoral differences. This mix of well-established, overlapping, and unique KSAs strengthens the need for standardization and clear definitions for new and emerging occupations.

Across the Manufacturing USA technology areas, existing training content can be leveraged to rapidly address workforce needs identified by institute member industries. The Manufacturing USA institutes play a crucial role in workforce development by adapting existing training content for new and emerging technologies and developing new, highly specialized training aligned with Tier 5 Industry-Sector Technical Competencies. However, the context and application of these KSAs vary significantly by technology area, requiring continued and active industry engagement to ensure relevance and effective implementation. As technology advances, regular and intentional industry engagement will be essential for proper KSA mapping, workforce development portal development, and technology adoption acceleration.

Through their member networks, technology roadmaps, and proximity to leading-edge manufacturing activity, Manufacturing USA institutes offer unique insights into the future of industrial technologies and associated occupations. As these technologies evolve, workforce requirements and associated KSAs will continue to change. To maintain the framework's relevance and utility, regular institute-led industry validation combined with annual institute-led updates will be essential. This approach will enable institutes to identify training, endorsement, and credentialing efforts that effectively support their members and determine where coordinated or collaborative actions across the network can strengthen workforce development outcomes and advance U.S. leadership in advanced manufacturing.

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Appendix A. Occupation and Competency Data

These appendices contain data and metadata used to develop the analyses shown in this technical report and other associated documents related to the 2025 Manufacturing USA Occupation and Competency Framework. See the following descriptions for each appendix for more information.

Appendix A1: Critical Occupations within Advanced Manufacturing Technology Areas

This appendix lists the critical occupations identified by MFG USA institutes, organized by their respective technology area. In each respective technology area, occupations with similar occupation titles were binned together and denoted in italics to signify that more than one institute selected that specific occupation (i.e. *(x#)*).

Appendix A2: Competency and Sub-competency Definitions

This appendix provides provisional definitions of the advanced manufacturing competencies and sub-competencies within this framework. These definitions aim to clarify and confirm that competencies and sub-competencies are standardized across the advanced manufacturing ecosystem, through the collective agreement of MFG USA institutes and usage of established definitions from other established frameworks at DOL and elsewhere.

Appendix A3: Manufacturing USA Network Occupations and Selected Competencies/KSAs

This appendix organizes the data collected from the MFG USA institutes into a direct relationship between KSAs, sub-competencies, and competencies from the DOL AMCM and this framework, and the essential occupations selected by the MFG USA institutes. This dataset was used for all analyses in this technical report. The table lists KSAs under their respective competency and sub-competency and displays which occupations from Appendix A1 are associated with each KSA. Occupations are further denoted by their associated technology area, which is especially crucial for similar occupations that are represented by different technology areas (e.g., Mechanical Engineers).

A.1. Critical Occupations within Advanced Manufacturing Technology Areas

Table 17. Critical Occupations within the Manufacturing USA Network.

Technology Area	Critical Occupations*	
<i>Biomanufacturing</i>	Biofabrication Technicians Advanced Manufacturing Technicians Automation Engineers Biofuels Processing Technicians <i>Biological Technicians (x2)</i> Industrial Engineering Technologists & Technicians Instrumentation Technicians Machine Operators	Maintenance Technicians <i>Process Development Scientists (x2)</i> Process Engineers Process Engineers/Scientists Process Technicians/Manufacturing Associate Quality Assurance Associates Quality Assurance/Control Technicians Quality Control Associates
<i>Digital/Automation</i>	Additive Manufacturing Technicians Controls/Automation Technicians/Specialists Cybersecurity Analyst for SMMs Data Annotators Designers Electrical and Electronic Technologists and Technicians Electrical Engineering Technologists and Technicians Electrical Engineers Electro-Mechanical and Mechatronics Technicians Industrial Engineering Technologists and Technicians Industrial Engineers Machinists	Maintenance and Repair Workers Manufacturing Analytics Associates Mechanical Engineering Technologists and Technicians Mechanical Engineers Premetaverse Integration Technologists Process Engineers Process/Manufacturing Engineers Quality Control/Assurance Inspectors/Analysts Robotics Integrators Robotics Specialists Robotics Technicians Supply Chain Cybersecurity Compliance Specialists
<i>Electronics</i>	Automation Technicians Chips Test & Packaging Technicians Circuit Design Technicians Design Engineers Electrical Design Engineers Electrical Engineers Electronics Assemblers Electronics/Photonics Packaging Engineers Electronics/Photonics Test & Packaging Technicians Engineers in R&D Equipment Operators Maintenance Technicians	Manufacturing Technicians Materials Scientists Materials Scientists/Engineers Mechanical Engineers Operations Technicians Process Engineers Process Technicians Quality Control Technicians Quality Managers Quality Technicians Semiconductor Manufacturing Engineers

	<p>Fabrication Designer Engineers Fabrication Technicians Failure Analysis Technicians Industrial Engineering Technologists and Technicians Logistics and Supply Technicians Maintenance Engineers</p>	<p>Semiconductor Packaging Engineers Silicon Photonics Design Engineers Software Engineers Test Engineers</p>
<i>Materials</i>	<p><i>CAD Technicians (x2)</i> CAD/CAM Technicians <i>Chemical Engineers (x2)</i> Civil Engineers CNC Machinists <i>CNC Operators (x2)</i> Digital Engineering Specialists Digital Engineers <i>Electrical Engineers (x2)</i> <i>Fabrication Specialists (x2)</i> Fiber Technicians Industrial Maintenance Technicians Industrial Technologists ITMS Technicians Layup Technicians</p>	<p>Machine Operators Machinists Manufacturing Operations Officers Manufacturing Process Engineers <i>Materials Scientists (x2)</i> <i>Mechanical Engineers (x3)</i> <i>Mechatronics Technicians (x3)</i> Metrology Technicians Process Engineers Quality Assurance Technicians Textiles Engineers Textiles Machine Operators Textiles Technicians Textiles Technologists Welder</p>
<i>Energy/Process</i>	<p>Chemical Engineers Chemical Equipment Operators and Tenders <i>Chemical Process Engineers (x2)</i> Chemical Process Operators Chemical Process Technicians <i>Control Systems Engineers (x2)</i> Design Engineers Electrical Engineers Electronics Assemblers Electronics Assemblers & Fabrication Specialists Electronics Technicians Electronics Technicians & Fabrication Technicians Fabrication Specialists Fabrication Technicians First-Line Supervisors of Production and Operating Workers</p>	<p>Industrial Engineers Industrial Technicians Life Cycle Analysts Machine Operators Manufacturing Engineers Mechanical Engineers Operators Packaging and Filling Machine Operators and Tenders <i>Process Control Engineers (x2)</i> <i>Process Engineers (x3)</i> Quality Assurance Technicians Quality Control Technicians Research Analysts Systems Engineers</p>

*Italics denote occupation titles selected by more than one institute in each technology area.

A.2. Competency and Sub-Competency Definitions

Table 18. Tier 4 and Tier 5 Competency and Sub-competency Definitions.

Tier 4	(Sub-)Competencies	Definitions	Source
4.1	Manufacturing Process Design/Development	Research design, implement, and continuously improve the manufacturing process to ensure product meets customer needs.	DOL
4.1.1	Manufacturing Process Design/Development Critical Work Functions	Broad knowledge of the manufacturing process and ability to communicate about it with clients.	Based on KSAs. Provisional.
4.1.2	Technical Drawing & Schematics	Design, produce using manual or digital tools, and interpret drawings for clear communication of technical requirements.	<i>MFG USA institutes</i>
4.1.3	Engineering Concepts	Knowledge of engineering concepts relevant to manufacturing operations.	<i>MFG USA institutes</i>
4.1.5	Design Lifecycle and Concepts	Develop, design, and test products and systems, including prototypes and support systems, within given constraints.	Based on KSAs. Provisional.
4.1.7	Testing/Troubleshooting	Collect and analyze data across multiple systems in a production environment for impact assessment, fault-finding purposes, and correction.	<i>MFG USA institutes</i>
4.1.8	Research and Development	Take a product and/or process through the stages of research and development with attention to IP protections and human subject protections.	Based on KSAs. Provisional.
4.1.9	Workflow Assessment	Evaluate and properly document manufacturing processes.	<i>MFG USA institutes</i>
4.2	Operations Management	Set up, operate, monitor, control, and improve manufacturing processes and schedules to meet customer requirements.	DOL
4.2.1	Operations Management Critical Work Functions	Support, operate, monitor, and maintain equipment, tools, workstation, and related processes.	<i>MFG USA institutes</i>
4.2.2	Systems	Knowledge of the linkages between the goals and operations of a manufacturing operation and the systems that support it--both physical systems (e.g., mechanical, electrical, computer) and human systems (e.g., projects, teams, work units).	Based on KSAs. Provisional.
4.2.3	Production Materials - Sources and Types	Knowledge of the types of materials used in advanced manufacturing and their sources.	Based on KSAs. Provisional.
4.2.4	Precision Measurement	Knowledge of the instruments and skill with the techniques used to measure things.	Based on KSAs. Provisional.
4.2.5	Manufacturing Tools and Equipment Operations	Set up, operate, and adjust manufacturing equipment.	<i>MFG USA institutes</i>

4.2.6	Automated Systems and Control Operations	Monitor and control process parameters via computer operations to attain desired outputs and maintain safety standards.	<i>MFG USA institutes</i>
4.2.7	Manufacturing Process Applications and Operations	Implement approved protocols for assembly, quality testing, treatment, and other processes of manufactured products.	<i>MFG USA institutes</i>
4.2.8	Industrial Processes	Execute procedures involving chemical, physical, electrical, or mechanical steps for specific manufacturing production outputs.	<i>MFG USA institutes</i>
4.2.9	Industrial Productions	Knowledge of the methods and systems used to control, monitor, and validate advanced manufacturing processes.	Based on KSAs. Provisional.
4.2.10	Manufacturing Types	Knowledge of various types of manufacturing (e.g., process batch, continuous, discrete, hybrid, repetitive).	Based on KSAs. Provisional.
4.2.11	Production/Process Monitoring	Assess an asset's operating conditions to detect and document any deviation from its normal state.	<i>MFG USA institutes</i>
4.2.13	Project Management and Execution	Plan, organize, and manage advanced manufacturing projects through the coordination of contracts, resources, and personnel.	Based on KSAs. Provisional.
4.3	Maintenance, Installation, and Repair (M/I/R)	Maintain and optimize manufacturing equipment and systems.	DOL
4.3.1	M/I/R Critical Work Functions	Basic knowledge and skills essential to the maintenance, installation, and repair of equipment.	Based on KSAs. Provisional.
4.3.2	M/I/R General Skills	Adjust, calibrate, clean, maintain, and troubleshoot laboratory and field equipment.	<i>MFG USA institutes</i>
4.3.4	Electrical Systems M/I/R	Install, maintain, troubleshoot, and repair electrical components and systems (e.g., power distribution systems, generators, circuit breakers).	Based on KSAs. Provisional.
4.3.5	Electronic Systems M/I/R	Install, maintain, troubleshoot, and repair electronic components and systems (e.g., sensors, circuit boards).	Based on KSAs. Provisional.
4.3.6	Hydraulic Systems M/I/R	Install, maintain, troubleshoot, and repair hydraulic components and systems (e.g., presses, injection molding machines).	Based on KSAs. Provisional.
4.3.7	Pneumatic Systems M/I/R	Install, maintain, troubleshoot, and repair pneumatic components and systems (e.g., pneumatic tools, automated assembly systems).	Based on KSAs. Provisional.
4.3.8	Mechanical Systems M/I/R	Install, maintain, troubleshoot, and repair mechanical components and systems (e.g., conveyers, pumps).	Based on KSAs. Provisional.
4.3.20	Process Controls M/I/R	Install, maintain, troubleshoot, and repair automated control systems (e.g., programmable logic controllers).	Based on KSAs. Provisional.

4.3.27	Programmable Logic Controlled Industrial Equipment M/I/R	Install, maintain, troubleshoot, and repair equipment controlled by programmable logic controllers.	Based on KSAs. Provisional.
4.3.29	Electromechanical Systems	Install, maintain, troubleshoot, and repair systems that combine electrical and mechanical components.	Based on KSAs. Provisional.
4.3.33	Reliability and Maintainability	Investigate failures and analyze data to determine and document causes for system failure.	Based on KSAs. Provisional.
4.3.34	Clean Room Protocol for Maintenance	Knowledge of techniques for maintaining cleanroom protocols during equipment and system maintenance.	Based on KSAs. Provisional.
4.4	Production in the Supply Chain/Supply Chain Logistics	Plan and monitor the movement and storage of materials and products in coordination with suppliers, internal systems, and customers.	DOL
4.4.1	Production in the Supply Chain/SC Logistics Critical Work Functions	Awareness of supply chain fundamentals sufficient to inform customers and market and sell products.	Based on KSAs. Provisional.
4.4.4	Detailed Scheduling and Planning	Knowledge of detailed material planning and inventory management.	Based on KSAs. Provisional.
4.4.5	Executing Operations	Procure, prioritize, plan, execute, and evaluate supply chain operations.	Based on KSAs. Provisional.
4.4.6	Managing Inventory	Forecast, monitor, and manage inventory materials and supplies.	Based on KSAs. Provisional.
4.4.7	Packaging & Distributing Product	Package and label product, and track it through warehouse management systems, transport systems, and customs.	Based on KSAs. Provisional.
4.4.8	Production Systems	Create and manage work orders (or similar documents) with attention to lead time and cycle time.	Based on KSAs. Provisional.
4.4.10	Supply-Chain Management	Knowledge of the elements of complex supply chains and management practices to navigate within them.	Based on KSAs. Provisional.
4.4.11	Workflow	Knowledge of the coordinated manufacturing processes that govern how materials, information, and tasks move through a production facility.	Based on KSAs. Provisional.
4.5	Quality Assurance & Continuous Improvement	Ensure product and process meets quality system requirements as defined by customer specifications.	DOL
4.5.2	Quality Assurance	Assess and implement industry standards and good manufacturing practices for approved product quality.	<i>MFG USA institutes</i>
4.5.3	Quality Improvement	Use statistical process control (SPC) to analyze data and improve product quality	Based on KSAs. Provisional.
4.5.5	Quality Inspection	Inspect incoming materials, in-process products, and outgoing final products for adherence to quality standards.	Based on KSAs. Provisional.

4.5.7	Quality Assurance Audits	Examine manufacturing systems to evaluate compliance with established procedures and ISO 9001 standards.	Based on KSAs. Provisional.
4.5.11	Probability & Statistics/Statistical Process Control Methods	Knowledge of the mathematical principles and practices to apply probability and statistics to advanced manufacturing process control.	Based on KSAs. Provisional.
4.5.12	Data Analysis and Presentation	Retrieve and analyze data; develop and present data visualizations.	Based on KSAs. Provisional.
4.6	Process & Equipment Health, Safety, and Environment	Equipment, practices, and procedures which promote a healthy, safe, and secure work environment.	DOL
4.6.1	Process & Equipment Health, Safety, and Environment Critical Work Functions	Broad knowledge and skills essential to ensuring compliance with health and environment safety protocols.	Based on KSAs. Provisional.
4.6.5	Preventive Health, Safety, or Environmental Inspections	Audit and/or inspect manufacturing systems and facilities for compliance with health, safety, and environmental regulations.	Based on KSAs. Provisional.
4.6.8	Safety Procedures	Knowledge of the safety procedures applicable to several different situations.	Based on KSAs. Provisional.

Tier 5	Competencies	Definitions	Source
5.1	Additive Manufacturing	Design and manufacture products using layer-by-layer fabrication by understanding and applying additive manufacturing principles.	America Makes KSAs; NIST AM Definition
5.2	Smart Manufacturing Technology	Implement fully-integrated, collaborative manufacturing systems that respond to changing factory operations in real-time.	NIST definition
5.3	Information Technology	Advanced knowledge and application of Information Technologies to manufacturing systems.	Modified from DOL IT Model (4.1)
5.4	NICE Framework/Cybersecurity	Advanced knowledge and application of cybersecurity fundamentals in manufacturing operations.	Modified from NIST NICE Framework
5.5	Experiments, Tests, and Analyses	Implement specific scientific techniques to synthesize, assess, and maintain manufactured products derived from biological system processes.	Modified from DOL Bioscience Model
5.6	Biomanufacturing Production	Implement advanced processes for the manufacture of bioscience products.	Modified from DOL Bioscience Model
5.7	Material Design and Production	Implement advanced material design and production methods to manufacturing systems.	Based on KSAs. Provisional.

A.3. Manufacturing USA Network Occupations and Selected Competencies/KSAs

Table 19. Competencies and KSAs with Associated Occupations in the Manufacturing USA Network

4.1	MANUFACTURING PROCESS DESIGN/DEVELOPMENT	
4.1.01	CRITICAL WORK FUNCTIONS	
4.1.01.01	Electrical, optical, thermal, and mechanical modeling and simulation	Maintenance Engineers - Electronics
4.1.01.02	System simulation/modeling	Robotics Integrators - Digital/Auto Automation Engineers - BioMFG Research Analysts - Energy/Process
4.1.02	TECHNICAL DRAWINGS AND SCHEMATICS	
4.1.02.01	Assembly and printed circuit board (PCB) design	Manufacturing Technicians - Electronics Electrical Engineers - Electronics Circuit Design Technicians - Electronics Quality Managers - Electronics
4.1.02.02	Design or redesign mechanical and thermal devices or subsystems, using analysis and computer-aided design	Electrical Engineers - Materials Mechanical Engineers - Materials CAD Technicians - Materials Maintenance Engineers - Electronics
4.1.02.03	Geometric dimensions and tolerances	Designers - Digital/Auto Machinists - Digital/Auto
4.1.02.04	Knowledge and use of computer-aided design (CAD)/computer-aided manufacturing (CAM) software	Digital Engineers - Materials Electrical Engineers - Materials Textiles Technicians - Materials Designers - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process Electronics Technicians - Energy/Process Industrial Technicians - Energy/Process Machinists - Materials Mechanical Engineers - Materials Electrical Design Engineers - Electronics Semiconductor Manufacturing Engineers - Electronics Manufacturing Engineers - Energy/Process Process Engineers – Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process Quality Managers - Electronics
4.1.02.05	Photonic system design, mechanically aware design	Electronics/Photonics Packaging Engineers - Electronics Mechanical Engineers - Electronics Semiconductor Packaging Engineers - Electronics Quality Managers - Electronics
4.1.02.06	Process flow diagram/piping and instrumentation diagram drawing	Chemical Process Engineers - Energy/Process Mechanical Engineers – Energy/Process Electrical Engineers - Energy/Process
4.1.02.07	Radio-frequency/very-large-scale integration/photonic integrated circuit design, modeling, layout	Silicon Photonics Design Engineers - Electronics Electrical Engineers - Electronics
4.1.02.08	Read blueprints, schematics, and diagrams to determine the	Textiles Engineers - Materials Textiles Technologists - Materials

	method and sequence of assembly of a machine or a piece of equipment	Mechanical Engineers - Materials Mechatronics Technicians - Materials CNC Operators - Materials Metrology Technicians - Materials Process Engineers - Electronics
4.1.02.09	Reading and interpreting schematics, blueprints, and technical and non-technical documents and drawings	Textiles Engineers - Materials Designers - Digital/Auto Machinists - Digital/Auto Machinists - Materials Layup Technicians - Materials Mechatronics Technicians - Materials Metrology Technicians - Materials Mechatronics Technicians - Materials Manufacturing Technicians - Electronics Electrical Engineers - Electronics Electronics Assemblers - Electronics Maintenance Engineers - Electronics Operations Technicians - Electronics
4.1.02.10	Semiconductor equipment design	Maintenance Engineers - Electronics Operations Technicians - Electronics
4.1.02.11	Set up, adjust, calibrate, clean, maintain, and troubleshoot laboratory and field equipment	Biological Technicians - BioMFG Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Process Technicians/Manufacturing Associate - BioMFG Process Engineers/Scientists - BioMFG
4.1.02.12	Technology design/system design	Chemical Engineers - Energy/Process Mechanical Engineers - Energy/Process Electrical Engineers - Energy/Process Process Engineers - Energy/Process
4.1.03	ENGINEERING CONCEPTS	
4.1.03.01	Analyze problems to see how mechanical and thermal devices might help solve a particular problem	Mechanical Engineers - Materials
4.1.03.02	Basic understanding of electrical and optical principles	Electronics/Photonics Test & Packaging Technicians - Electronics Chemical Process Engineers - Energy/Process Control Systems Engineers - Energy/Process Design Engineers - Energy/Process Electrical Engineers - Electronics Mechanical Engineers - Energy/Process Process Engineers - Energy/Process Manufacturing Technicians - Electronics Electrical Engineers - Energy/Process Process Engineers - Electronics Mechanical Engineers - Electronics Materials Scientists - Electronics Electronics/Photonics Packaging Engineers - Electronics
4.1.03.03	Design new ways to use electrical power to develop or improve products	Electrical Engineers - Materials
4.1.03.04	Mechanical engineering	Designers - Digital/Auto

		Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Chemical Process Engineers - Energy/Process Control Systems Engineers - Energy/Process Design Engineers - Energy/Process Electrical Engineers - Energy/Process Mechanical Engineers - Energy/Process Process Engineers - Energy/Process Mechanical Engineers - Materials Mechanical Engineers - Electronics
4.1.03.05	Understanding and application of materials science	Materials Scientists - Materials Mechanical Engineers - Materials Process Engineers - Electronics Mechanical Engineers - Electronics Materials Scientists - Electronics Materials Scientists/Engineers - Electronics
4.1.03.06	Understanding of electrical systems	Chemical Process Engineers - Energy/Process Control Systems Engineers - Energy/Process Design Engineers - Energy/Process Electrical Engineers - Electronics Mechanical Engineers - Energy/Process Process Engineers - Energy/Process Electrical Engineers - Energy/Process
4.1.03.07	Understanding of optics/electromagnetics	Silicon Photonics Design Engineers - Electronics Design Engineers - Electronics
4.1.03.08	Understanding of thermal, mechanical, and optical material properties	Electronics/Photonics Packaging Engineers - Electronics Chemical Process Engineers - Energy/Process Control Systems Engineers - Energy/Process Design Engineers - Energy/Process Electrical Engineers - Energy/Process Mechanical Engineers - Energy/Process Process Engineers - Energy/Process Mechanical Engineers - Materials Process Engineers - Electronics Mechanical Engineers - Electronics Materials Scientists - Electronics Electronics/Photonics Packaging Engineers - Electronics Operators - Energy/Process Process Engineers – Energy/Process
4.1.03.09	Understanding of thermal, mechanical, and optical reliability	Silicon Photonics Design Engineers - Electronics Mechanical Engineers - Electronics Process Engineers - Electronics Materials Scientists - Electronics Mechanical Engineers - Materials
4.1.05	DESIGN LIFECYCLE AND CONCEPTS	
4.1.05.01	Life Cycle Analysis	Life Cycle Analysts - Energy/Process Chemical Process Engineers - Energy/Process
4.1.05.02	Package and product design	Mechanical Engineers - Electronics Electrical Engineers - Electronics Process Engineers - Electronics
4.1.05.03	Process optimization	Process Engineers - BioMFG Industrial Engineers - Energy/Process

		<p>Mechanical Engineers - Energy/Process Chemical Engineers - Energy/Process Electrical Engineers - Energy/Process Process Engineers - Electronics Chemical Process Engineers - Energy/Process</p>
4.1.05.04	System and process design	<p>Robotics Integrators - Digital/Auto Premetaverse Integration Technologists - Digital/Auto Manufacturing Technicians - Electronics Mechanical Engineers - Electronics Electrical Engineers - Electronics Process Engineers - Electronics Software Engineers - Electronics Process Technicians - Electronics</p>
4.1.05.05	Technoeconomic Analysis	<p>Design Engineers - Energy/Process Research Analysts - Energy/Process</p>
4.1.07	TESTING/TROUBLESHOOTING	
4.1.07.01	Advanced fault finding on actual equipment	<p>Process Development Scientists - BioMFG Mechanical Engineers - Materials Manufacturing Technicians - Electronics Process Engineers/Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG</p>
4.1.07.02	Data collection/analysis	<p>Digital Engineers - Materials Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Process Control Engineers - Energy/Process Control Systems Engineers - Energy/Process Chemical Equipment Operators and Tenders - Energy/Process Packaging and Filling Machine Operators and Tenders - Energy/Process Electronics Technicians - Energy/Process Fabrication Technicians - Energy/Process Industrial Technicians - Energy/Process Mechanical Engineers - Materials Manufacturing Analytics Associates - Digital/Auto Test Engineers - Electronics Quality Technicians - Electronics Process Technicians/Manufacturing Associate - BioMFG Process Engineers/Scientists - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG Process Engineers - Electronics Process Technicians - Electronics Process Control Engineers - Energy/Process Systems Engineers - Energy/Process Chemical Process Operators - Energy/Process Machine Operators - Energy/Process</p>

		Chemical Process Engineers - Energy/Process Quality Managers - Electronics
4.1.07.03	Investigate equipment failures or difficulties to diagnose faulty operation and to recommend remedies	Mechanical Engineers - Materials ITMS Technicians - Materials Mechanical Engineers - Electronics Manufacturing Technicians - Electronics
4.1.07.04	Knowledge and use of analytical or scientific software	Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Process Engineers - Energy/Process Electronics Technicians - Energy/Process Fabrication Technicians - Energy/Process Electronics Assemblers - Energy/Process Fabrication Specialists - Energy/Process Fabrication Technicians - Electronics Chemical Process Technicians - Energy/Process Chemical Process Operators - Energy/Process Process Engineers - Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process Electronics Assemblers & Fabrication Specialists - Energy/Process
4.1.07.05	Knowledge and use of program testing software	Manufacturing Technicians - Electronics Chemical Process Technicians - Energy/Process Chemical Process Operators - Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process
4.1.07.06	Prepares test articles, fixtures, and data collection devices to perform various tests	Textiles Technologists - Materials Fabrication Specialists - Materials Data Annotators - Digital/Auto
4.1.08	RESEARCH AND DEVELOPMENT	
4.1.08.01	Develop and test device prototypes	Mechanical Engineers - Materials
4.1.08.02	Process optimization	Premetaverse Integration Technologists - Digital/Auto Chemical Process Engineers - Energy/Process
4.1.08.03	Technoeconomic Analysis	Chemical Process Engineers - Energy/Process
4.1.09	WORKFLOW ASSESSMENT	
4.1.09.01	Design of manufacturing processes	Manufacturing Process Engineers - Materials Process Development Scientists - BioMFG Biofabrication Technicians – BioMFG Mechanical Engineers - Materials Process Engineers - Electronics Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
4.1.09.02	Follow SOPs and provide documentation	Process Development Scientists - BioMFG Biofabrication Technicians – BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Mechanical Engineers - Materials Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG

		Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.1.09.03	Oversee the manufacturing process of devices	Industrial Technologists - Materials Mechanical Engineers - Materials Industrial Maintenance Technicians - Materials ITMS Technicians - Materials Mechatronics Technicians - Materials
4.1.09.04	System simulation/modeling	Robotics Integrators - Digital/Auto
4.2	OPERATIONS MANAGEMENT	
4.2.01	CRITICAL WORK FUNCTIONS	
4.2.01.01	Basic understanding of industrial manufacturing principles	Electronics/Photonics Test & Packaging Technicians - Electronics Logistics and Supply Technicians - Electronics Manufacturing Technicians - Electronics Quality Technicians - Electronics
4.2.01.02	Manage continuous improvement processes	Quality Control/Assurance Inspectors/Analysts - Digital/Auto Process/Manufacturing Engineers - Digital/Auto
4.2.01.03	Monitor industrial processes and systems	Quality Control/Assurance Inspectors/Analysts - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Control Systems Engineers - Energy/Process Chemical Equipment Operators and Tenders - Energy/Process Packaging and Filling Machine Operators and Tenders - Energy/Process Electronics Technicians - Energy/Process Fabrication Technicians - Energy/Process Industrial Technicians - Energy/Process Control Systems Engineers - Energy/Process Chemical Process Operators - Energy/Process Machine Operators - Energy/Process
4.2.01.04	Operate industrial equipment	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Maintenance Technicians - Electronics
4.2.01.05	Operates, monitors, and maintains equipment, tools, and workstations	Robotics Technicians - Digital/Auto Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG

		Industrial Engineering Technologists & Technicians - BioMFG Manufacturing Technicians - Electronics Quality Control Associates - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
4.2.01.06	Provide support and services for scientists and engineers working in fields such as agriculture, environmental science, resource management, biology, and health sciences	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG
4.2.02	SYSTEMS	
4.2.02.01	Understand and develop interdependence of teams, work units, departments, organizations, interorganizational systems, and the larger environment	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto
4.2.02.02	Understanding of mechanical systems	Robotics Technicians - Digital/Auto Robotics Integrators - Digital/Auto Mechanical Engineers - Electronics
4.2.03	PRODUCTION MATERIALS – SOURCES AND TYPES	
4.2.03.01	Materials	Fiber Technicians - Materials Machinists - Digital/Auto
4.2.03.02	Production materials	Additive Manufacturing Technicians - Digital/Auto
4.2.04	PRECISION MEASUREMENT	
4.2.04.01	Making electrical measurements	Electrical Engineers - Electronics Process Engineers - Electronics Manufacturing Technicians - Electronics Electronics Assemblers - Electronics
4.2.04.02	Measurement/metrology	Machinists - Digital/Auto Robotics Specialists - Digital/Auto Operations Technicians - Electronics Quality Managers - Electronics - Electronics
4.2.04.03	Microscope instruments and techniques	Designers - Digital/Auto
4.2.04.04	Understand and use mass measurement instruments and techniques	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG

		Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.2.04.05	Understand and use volumetric measurement instruments and techniques	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.2.04.06	Verify dimensions of parts using precision measuring instruments	Mechatronics Technicians - Materials Mechatronics Technicians - Materials Mechatronics Technicians - Materials Metrology Technicians - Materials
4.2.05	MANUFACTURING TOOL AND EQUIPMENT OPERATIONS	
4.2.05.01	Machine and equipment operations	Robotics Technicians - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Chemical Equipment Operators and Tenders - Energy/Process Packaging and Filling Machine Operators and Tenders - Energy/Process Electronics Technicians - Energy/Process Fabrication Technicians - Energy/Process Industrial Technicians - Energy/Process Fabrication Specialists - Energy/Process Manufacturing Technicians - Electronics Process Engineers - Electronics Electronics Assemblers - Electronics Equipment Operators - Electronics Chemical Process Technicians - Energy/Process Machine Operators - Energy/Process Quality Assurance Technicians - Energy/Process Quality Control Technicians - Energy/Process
4.2.05.02	Machine and equipment operations analysis	Process/Manufacturing Engineers - Digital/Auto Process Engineers - Energy/Process
4.2.05.03	Monitoring manufacturing operations	Textiles Machine Operators - Materials Textiles Technicians - Materials Manufacturing Operations Officers - Materials Robotics Technicians - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Packaging and Filling Machine Operators and Tenders - Energy/Process Chemical Equipment Operators and Tenders - Energy/Process CAD/CAM Technicians - Materials Industrial Maintenance Technicians - Materials Layup Technicians - Materials Machine Operators - Materials Mechatronics Technicians - Materials

		ITMS Technicians - Materials CNC Operators - Materials Chemical Process Operators - Energy/Process
4.2.05.04	Operate metalworking machines to make housings, fittings, and fixtures	Mechatronics Technicians - Materials CNC Operators - Materials Mechatronics Technicians - Materials CNC Operators - Materials
4.2.05.05	Set up and operate production and equipment in accordance with current good manufacturing practices and standard operating procedures	Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
4.2.05.06	Set up, adjust, calibrate, clean, maintain, and troubleshoot laboratory and field equipment	Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG
4.2.05.07	Set up, operate, and maintain additive manufacturing machines	Additive Manufacturing Technicians - Machinists - Digital/Auto
4.2.05.08	Systems analysis and evaluation	Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process Process Engineers - Energy/Process Chemical Process Engineers - Energy/Process
4.2.06	AUTOMATED SYSTEMS AND CONTROL OPERATIONS	
4.2.06.01	Analytical testing	Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Quality Control Technicians - Energy/Process
4.2.06.02	Automated equipment operations	Process Engineers - Electronics Manufacturing Technicians - Electronics
4.2.06.03	Automated equipment operations (test & packaging)	Electronics/Photonics Test & Packaging Technicians - Electronics Chips Test & Packaging Technicians - Electronics
4.2.06.04	Computer operations	Manufacturing Technicians - Electronics Equipment Operators - Electronics Quality Control Technicians - Electronics
4.2.06.05	Knowledge and use of industrial control software	Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process Chemical Process Operators - Energy/Process

4.2.06.06	Operate, test, or maintain robotic equipment	Robotics Technicians - Digital/Auto Mechatronics Technicians - Materials Mechatronics Technicians - Materials ITMS Technicians - Materials
4.2.06.07	Operation and control of automated systems	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Packaging and Filling Machine Operators and Tenders - Energy/Process Chemical Equipment Operators and Tenders - Energy/Process First-Line Supervisors of Production and Operating Workers - Energy/Process Automation Technicians - Electronics Chemical Process Operators - Energy/Process
4.2.06.08	Process control	Process Engineers - Electronics Manufacturing Technicians - Electronics Electronics Assemblers - Electronics
4.2.06.09	Robot programming	Robotics Technicians - Digital/Auto
4.2.06.10	Understand and use factory automation technologies	Robotics Integrators - Digital/Auto Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Premetaverse Integration Technologists - Digital/Auto
4.2.06.11	Use computers, computer–interfaced equipment, robotics, or high–technology industrial applications to perform work duties	Robotics Integrators - Digital/Auto Robotics Specialists - Digital/Auto Robotics Technicians - Digital/Auto Process Development Scientists - BioMFG Biofabrication Technicians – BioMFG Biological Technicians - BioMFG Premetaverse Integration Technologists - Digital/Auto Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.2.07	MANUFACTURING PROCESS APPLICATIONS AND OPERATIONS	
4.2.07.01	Assembly and packaging	Electrical Engineers - Electronics Manufacturing Technicians - Electronics Process Engineers - Electronics Mechanical Engineers - Electronics
4.2.07.02	Bulk/Continuous flow/line balancing processes	Advanced Manufacturing Technicians - BioMFG Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Industrial Engineering Technologists & Technicians - BioMFG

		Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
4.2.07.03	Clean bioprocessing work area, ensuring compliance with safety regulations	Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
4.2.07.04	Clean room processes	Advanced Manufacturing Technicians - BioMFG Biofabrication Technicians – BioMFG Biological Technicians - BioMFG Manufacturing Technicians - Electronics Quality Technicians - Electronics Logistics and Supply Technicians - Electronics Biological Technicians - BioMFG
4.2.07.05	Composite or fiberglass fabrication	Materials Scientists - Materials Layup Technicians - Materials
4.2.07.06	Equipment operation, troubleshooting, and monitoring for bioprocessing	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG
4.2.07.07	Fiber/waveguide coupling and assembly	Silicon Photonics Design Engineers - Electronics Fabrication Designer Engineers - Electronics
4.2.07.08	Fiber/waveguide coupling, assembly, and validation	Electronics/Photonics Packaging Engineers - Electronics Electronics/Photonics Packaging Engineers - Electronics
4.2.07.09	Finishing processes	Advanced Manufacturing Technicians - BioMFG Biofabrication Technicians – BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG
4.2.07.10	Monitor and adjust production processes or equipment for quality and productivity	Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Manufacturing Technicians - Electronics Quality Technicians - Electronics Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
4.2.07.11	Perform basic lay–up techniques (with or without core) using pre–preg material and wet lay–up	CAD/CAM Technicians - Materials Industrial Maintenance Technicians - Materials Layup Technicians - Materials Mechatronics Technicians - Materials

4.2.07.12	Prepare and assemble components and equipment	Advanced Manufacturing Technicians - BioMFG Biofabrication Technicians – BioMFG Biological Technicians - BioMFG
4.2.07.13	Prepare composite components for curing process by applying proper vacuum bagging methods and procedures	CAD/CAM Technicians - Materials Industrial Maintenance Technicians - Materials Layup Technicians - Materials Mechatronics Technicians - Materials
4.2.07.14	Preprocess feedstock in preparation for physical, chemical, or bioproduction processes	Biofuels Processing Technicians - BioMFG
4.2.07.15	Provide support and services for scientists and engineers working in fields such as agriculture, environmental science, resource management, biology, and health sciences	Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG
4.2.07.16	Review instructions to determine operational methods or sequences	Robotics Technicians - Digital/Auto Biofabrication Technicians – BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Manufacturing Technicians - Electronics Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.2.07.17	Understanding of electronics and controls	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto
4.2.08	INDUSTRIAL PROCESS	
4.2.08.01	Knowledge and application of fermentation techniques	Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
4.2.08.02	Operate processing equipment for downstream bioproduction/separations	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG

4.2.08.03	Provide support and services for scientists and engineers working in fields such as agriculture, environmental science, resource management, biology, and health sciences	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.2.08.04	Understanding and overseeing industrial processes	Equipment Operators - Electronics Chemical Process Engineers - Energy/Process Quality Control Technicians - Energy/Process Machine Operators - Energy/Process
4.2.09	INDUSTRIAL PRODUCTIONS	
4.2.09.01	Knowledge and use of industrial control software	Electronics Technicians & Fabrication Technicians - Energy/Process Electronics Assemblers & Fabrication Specialists - Energy/Process Process Engineers - Energy/Process
4.2.09.02	Operation and control of manufacturing machinery	Textiles Technicians - Materials Textiles Machine Operators - Materials Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto Machine Operators - BioMFG Quality Assurance/Control Technicians - BioMFG CAD/CAM Technicians - Materials Industrial Maintenance Technicians - Materials Layup Technicians - Materials Machine Operators - Materials Mechatronics Technicians - Materials ITMS Technicians - Materials CNC Operators - Materials Mechatronics Technicians - Materials
4.2.09.03	Qualification & certification	Additive Manufacturing Technicians - Digital/Auto Machinists – Digital/Auto Designers - Digital/Auto
4.2.09.04	Quality control analysis	Quality Assurance Technicians - Materials CAD/CAM Technicians - Materials Industrial Maintenance Technicians - Materials Layup Technicians - Materials Machine Operators Mechatronics Technicians - Materials Metrology Technicians - Materials Quality Managers - Electronics
4.2.09.05	Use computers, computer–interfaced equipment, robotics, or high–technology industrial applications to perform work duties	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG

		<p>Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Premetaverse Integration Technologists - Digital/Auto Manufacturing Technicians - Electronics Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG</p>
4.2.10	MANUFACTURING TYPES	
4.2.10.01	Monitor and adjust production processes or equipment for quality and productivity	<p>Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Process Engineers - Electronics Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Process Engineers – Energy/Process</p>
4.2.10.02	Monitor batch, continuous flow, or hybrid downstream bioproduction processes	<p>Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG</p>
4.2.11	PRODUCTION/PROCESS MONITORING	
4.2.11.01	Controlling process flow	<p>Process Development Scientists - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG</p>
4.2.11.02	Documenting and reporting information and data	<p>Process Development Scientists - BioMFG Biofabrication Technicians - BioMFG Advanced Manufacturing Technicians - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Manufacturing Technicians - Electronics Quality Technicians - Electronics Logistics and Supply Technicians - Electronics Process Technicians/Manufacturing Associate - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG</p>
4.2.11.03	Follow SOPs and provide documentation	<p>Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG</p>

		<p>Advanced Manufacturing Technicians - BioMFG Biological Technicians - BioMFG Manufacturing Technicians - Electronics Quality Technicians - Electronics Logistics and Supply Technicians - Electronics Process Technicians/Manufacturing Associate - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Quality Control Associates - BioMFG Process Technicians - Electronics</p>
4.2.11.04	Integrated circuit packaging (process flow and design-for-manufacturing)	<p>Electronics/Photonics Packaging Engineers - Electronics Electronics/Photonics Packaging Engineers - Electronics</p>
4.2.11.05	Manufacturing process flow	<p>Additive Manufacturing Technicians - Digital/Auto Designers - Digital/Auto Process Engineers - Digital/Auto Robotics Integrators - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Mechanical Engineers - Digital/Auto Electrical Engineers - Digital/Auto Industrial Engineers - Digital/Auto Premetaverse Integration Technologists - Digital/Auto</p>
4.2.11.06	Operational Technology (OT)	<p>Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Maintenance and Repair Workers - Digital/Auto Electro-Mechanical and Mechatronics Technicians - Digital/Auto Mechanical Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineers - Digital/Auto Electrical and Electronic Technologists and Technicians - Digital/Auto Industrial Engineers - Digital/Auto Industrial Engineering Technologists and Technicians - Digital/Auto Premetaverse Integration Technologists - Digital/Auto</p>
4.2.11.07	Operations monitoring	<p>Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Chemical Process Operators - Energy/Process Process Engineers - Energy/Process Electronics Assemblers & Fabrication Specialists - Energy/Process</p>
4.2.11.08	Oversee or inspect production processes	<p>Process Development Scientists - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Quality Control Associates - BioMFG</p>

4.2.11.09	Participates in troubleshooting, trend analysis, and root-cause analysis of operations	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biofuels Processing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Process Technicians/Manufacturing Associate - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Quality Control Associates - BioMFG
4.2.11.10	Performance of analytical tests	Textiles Technologists - Materials Process Development Scientists - BioMFG Biological Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.2.11.11	Production/process troubleshooting	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Process Development Scientists - BioMFG Controls/Automation Technicians/Specialists - Digital/Auto Packaging and Filling Machine Operators and Tenders - Energy/Process Chemical Equipment Operators and Tenders - Energy/Process First-Line Supervisors of Production and Operating Workers - Energy/Process Logistics and Supply Technicians - Electronics Manufacturing Technicians - Electronics Quality Technicians - Electronics Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Quality Control Technicians - Electronics Chemical Process Technicians - Energy/Process
4.2.11.12	Robot and system troubleshooting	Robotics Specialists - Digital/Auto
4.2.11.13	Tool calibration	Manufacturing Technicians - Electronics Equipment Operators - Electronics Quality Control Technicians - Energy/Process
4.2.11.14	Understand and execute test and measurement assays	Fabrication Specialists - Materials Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Metrology Technicians - Materials Logistics and Supply Technicians - Electronics Manufacturing Technicians - Electronics Quality Technicians - Electronics Process Technicians/Manufacturing Associate - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Quality Control Associates - BioMFG

		Electronics Assemblers - Electronics Equipment Operators - Electronics
4.2.13	PROJECT MANAGEMENT AND EXECUTION	
4.2.13.01	Project management	Robotics Specialists - Digital/Auto Mechanical Engineers - Digital/Auto Electrical Engineers - Digital/Auto Industrial Engineers - Digital/Auto Electrical Engineers - Electronics Chemical Process Engineers - Energy/Process
4.2.13.02	Select material quantities or processing methods needed to achieve efficient production	Process Development Scientists - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Industrial Engineering Technologists and Technicians - BioMFG
4.2.13.03	Work with project managers on production efforts to ensure that projects are completed satisfactorily, on time, and within budget	Chemical Engineers - Materials Digital Engineers - Materials Electrical Engineers - Materials Manufacturing Process Engineers - Materials Mechanical Engineers - Materials Textiles Engineers - Materials Civil Engineers - Materials Process Engineers - Materials
4.3	MAINTENANCE, INSTALLATION, AND REPAIR	
4.3.01	CRITICAL WORK FUNCTIONS	
4.3.01.01	Alignment of parts or workpieces	Advanced Manufacturing Technicians - BioMFG Biofabrication Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG
4.3.01.02	Inspect installed components	Biofabrication Technicians - BioMFG Advanced Manufacturing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG
4.3.01.03	Maintenance and troubleshooting	Additive Manufacturing Technicians - Digital/Auto Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Maintenance and Repair Workers - Digital/Auto
4.3.01.04	Maintenance equipment, tools, and workstations	Additive Manufacturing Technicians - Digital/Auto Machinists - Digital/Auto Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto

		Robotics Integrators - Digital/Auto Maintenance and Repair Workers - Digital/Auto
4.3.02	GENERAL SKILLS	
4.3.02.01	Assemble equipment	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Advanced Manufacturing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG
4.3.02.02	Component assembly	Manufacturing Technicians - Electronics Electrical Engineers - Electronics Mechanical Engineers - Electronics
4.3.02.03	Develop documentation and codebooks for data sets	Robotics Integrators - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Data Annotators - Digital/Auto
4.3.02.04	Disassembly/assembly skills	Electronics Assemblers & Fabrication Specialists - Energy/Process Process Engineers - Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process
4.3.02.05	Equipment/system/defect management	Electronics Assemblers & Fabrication Specialists - Energy/Process Process Engineers - Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process
4.3.02.06	Knowledge of computer-aided manufacturing (CAM) software	Digital Engineering Specialists - Materials Machine Operators - Materials CAD/CAM Technicians - Materials
4.3.02.07	Set up, adjust, calibrate, clean, maintain, and troubleshoot laboratory and field equipment	Biofabrication Technicians - BioMFG Biological Technicians - BioMFG
4.3.02.08	Use basic hand tools in a safe and efficient manner to shape and form simple components	Fiber Technicians - Materials Mechatronics Technicians - Materials Quality Assurance Technicians - Materials Textiles Technicians - Materials Advanced Manufacturing Technicians - BioMFG Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Industrial Engineering Technologists & Technicians - BioMFG CAD/CAM Technicians - Materials Industrial Maintenance Technicians - Materials Layup Technicians - Materials Mechatronics Technicians - Materials CNC Operators - Materials Welder - Materials ITMS Technicians - Materials Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG

Maintenance Technicians - BioMFG
Instrumentation Technicians - BioMFG

4.3.04	ELECTRICAL SYSTEMS MAINTENANCE, INSTALLATION, AND REPAIR	
4.3.04.01	Direct the manufacture, installation, and testing of electrical equipment to ensure that products meet specifications and codes	Electrical Engineers - Materials
4.3.04.02	Perform detailed calculations to develop manufacturing, construction, and installation standards and specifications	Electrical Engineers - Materials Metrology Technicians - Materials Mechanical Engineers - Materials
4.3.05	ELECTRONIC SYSTEMS M/I/R	
4.3.05.01	Configure electronics systems	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Manufacturing Technicians - Electronics
4.3.05.02	Equipment repair	Manufacturing Technicians - Electronics
4.3.06	HYDRAULIC SYSTEMS MAINTENANCE, INSTALLATION, AND REPAIR	
4.3.06.01	Repair and calibrate hydraulic assemblies	Mechatronics Technicians - Materials CNC Machinists - Materials Mechatronics Technicians - Materials CNC Operators - Materials ITMS Technicians - Materials
4.3.07	PNEUMATIC SYSTEMS MAINTENANCE, INSTALLATION, AND REPAIR	
4.3.07.01	Repair and calibrate pneumatic assemblies	Mechatronics Technicians - Materials Mechatronics Technicians - Materials CNC Machinists - Materials Mechatronics Technicians - Materials ITMS Technicians - Materials
4.3.08	MECHANICAL SYSTEMS M/I/R	
4.3.08.01	Knowledge and use of mechanical systems	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Mechanical Engineers - Electronics Process Engineers - Electronics
4.3.20	PROCESS CONTROLS M/I/R	
4.3.20.01	Process control	Process Engineers - Electronics
4.3.27	PROGRAMMABLE LOGIC CONTROLLED INDUSTRIAL EQUIPMENT M/I/R	
4.3.27.01	Robotic programming	Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto
4.3.29	ELECTROMECHANICAL SYSTEMS	
4.3.29.01	Electrical and mechanical system operation familiarity	Electronics/Photonics Test & Packaging Technicians - Electronics Logistics and Supply Technicians - Electronics Manufacturing Technicians - Electronics

Quality Technicians - Electronics
Chips Test & Packaging Technicians - Electronics

4.3.33	RELIABILITY AND MAINTAINABILITY	
4.3.33.01	Failure Analysis	Logistics and Supply Technicians - Electronics Manufacturing Technicians - Electronics Quality Technicians - Electronics Failure Analysis Technicians - Electronics Engineers in R&D - Electronics Operations Technicians - Electronics Quality Managers - Electronics
4.3.33.02	Understanding and evaluation of reliability and maintenance of machines	Process/Manufacturing Engineers - Digital/Auto Fabrication Technicians - Electronics Electronics Assemblers & Fabrication Specialists - Energy/Process Process Engineers – Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process
4.3.34	CLEAN ROOM PROTOCOL FOR MAINTENANCE	
4.3.34.01	Clean room protocol for hand tools and specific systems	Advanced Manufacturing Technicians - BioMFG Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG
4.4	PRODUCTION IN THE SUPPLY CHAIN/SUPPLY CHAIN LOGISTICS	
4.4.01	CRITICAL WORK FUNCTIONS	
4.4.01.01	Asset inventory management	Cybersecurity Analyst for SMMs - Digital/Auto
4.4.01.02	Supplier network monitoring & support	Supply Chain Cybersecurity Compliance Specialists - Digital/Auto
4.4.04	DETAILED SCHEDULING AND PLANNING	
4.4.04.01	Select material quantities or processing methods needed to achieve efficient production	Industrial Engineering Technologists & Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Process Engineers – Energy/Process
4.4.05	EXECUTING OPERATIONS	
4.4.05.01	Logistics	Logistics and Supply Technicians - Electronics Manufacturing Technicians - Electronics Quality Technicians - Electronics
4.4.05.02	Provide support for contracting & procurement	Supply Chain Cybersecurity Compliance Specialists - Digital/Auto
4.4.06	MANAGING INVENTORY	

4.4.06.01	Logistics	Logistics and Supply Technicians - Electronics
4.4.07	PACKAGING AND DISTRIBUTING PRODUCT	
4.4.07.01	Forklift operation	Machine Operators - Energy/Process
4.4.08	PRODUCTION SYSTEMS	
4.4.08.01	Forklift operation	Machine Operators - Energy/Process
4.4.08.02	Logistics	Mechanical Engineers - Electronics Electrical Engineers - Electronics Process Engineers - Electronics Manufacturing Technicians - Electronics
4.4.10	SUPPLY CHAIN MANAGEMENT	
4.4.10.01	Understand and apply supply chain fundamentals	Supply Chain Cybersecurity Compliance Specialists - Digital/Auto Quality Managers - Electronics
4.4.10.02	Understand and utilize just-in-case supply chain resilience	First-Line Supervisors of Production and Operating Workers - Energy/Process
4.4.11	WORKFLOW	
4.4.11.01	Material handling	Additive Manufacturing Technicians - Digital/Auto Machinists
4.4.11.02	Provide support and services for scientists and engineers working in fields such as agriculture, environmental science, resource management, biology, and health sciences	Biological Technicians - BioMFG Chemical Process Technicians - Energy/Process
4.5	QUALITY ASSURANCE AND CONTINUOUS IMPROVEMENT	
4.5.01	CRITICAL WORK FUNCTIONS	
4.5.01.01	Quality management	Quality Control/Assurance Inspectors/Analysts - Digital/Auto Quality Control Technicians - Energy/Process
4.5.02	QUALITY ASSURANCE	
4.5.02.01	Investigate complaints from customers or the public, evaluate problems, and recommend solutions	Mechanical Engineers - Materials Electrical Engineers - Materials
4.5.02.02	Knowledge and application of Current Good Manufacturing Practice (cGMP)	Quality Control Technicians - Energy/Process
4.5.02.03	Knowledge and application of Good Manufacturing Practice (GMP)	Chemical Process Operators - Energy/Process
4.5.02.04	Meeting customer needs	Designers - Digital/Auto Robotics Specialists - Digital/Auto
4.5.02.05	Quality control and assurance analysis	Quality Control/Assurance Inspectors/Analysts - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process

Chemical Process Operators - Energy/Process
Quality Control Technicians - Energy/Process

4.5.05	QUALITY INSPECTION	
4.5.05.01	Inspection/quality assurance	Additive Manufacturing Technicians - Digital/Auto Robotics Specialists - Digital/Auto Quality Control/Assurance Inspectors/Analysts - Digital/Auto Maintenance and Repair Workers - Digital/Auto Quality Assurance Technicians - Energy/Process
4.5.05.02	Monitor and adjust production processes or equipment for quality and productivity	Process Development Scientists - BioMFG Biofabrication Technicians - BioMFG Advanced Manufacturing Technicians - BioMFG Industrial Engineering Technologists & Technicians - BioMFG Quality Control/Assurance Inspectors/Analysts - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Process Engineers - Energy/Process
4.5.07	QUALITY ASSURANCE AUDITS	
4.5.07.01	Troubleshooting and audits	Process Engineers - Electronics Quality Control Technicians - Electronics
4.5.11	PROBABILITY AND STATISTICS/STATISTICAL PROCESS CONTROL METHODS	
4.5.11.01	Photonic integrated circuit device test & validation	Silicon Photonics Design Engineers - Electronics
4.5.11.02	Statistical Process Control (SPC) methods	Quality Control/Assurance Inspectors/Analysts - Digital/Auto Process Engineers - Electronics Quality Control Technicians - Electronics
4.5.12	DATA ANALYSIS AND PRESENTATION	
4.5.12.01	Data collection and reporting	Robotics Integrators - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process Data Annotators - Digital/Auto Electrical Engineers - Electronics Process Engineers - Electronics Mechanical Engineers - Electronics Software Engineers - Electronics Quality Control Technicians - Electronics
4.5.12.02	Data visualization and reporting	Robotics Integrators - Digital/Auto Quality Control/Assurance Inspectors/Analysts - Digital/Auto Manufacturing Analytics Associates - Digital/Auto
4.5.12.03	Understand and ensure data quality	Robotics Integrators - Digital/Auto Quality Control/Assurance Inspectors/Analysts - Digital/Auto Manufacturing Analytics Associates - Digital/Auto Data Annotators - Digital/Auto

4.5.12.04	Understanding and execution of data quality fundamentals and control	Robotics Integrators - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process Data Annotators - Digital/Auto
4.6	PROCESS AND EQUIPMENT HEALTH, SAFETY, AND ENVIRONMENT	
4.6.01	CRITICAL WORK FUNCTIONS	
4.6.01.01	Comply with applicable regulations and standards	Biofabrication Technicians - BioMFG Advanced Manufacturing Technicians - BioMFG Biofuels Processing Technicians - BioMFG Process Technicians/Manufacturing Associate - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.6.01.02	Health and safety compliance	Manufacturing Technicians - Electronics Mechanical Engineers - Electronics Electrical Engineers - Electronics Software Engineers - Electronics Process Engineers - Electronics Materials Scientists - Electronics Logistics and Supply Technicians - Electronics Equipment Operators - Electronics
4.6.05	PREVENTIVE HEALTH, SAFETY, OR ENVIRONMENTAL INSPECTIONS	
4.6.05.01	Clean bioprocessing work area, ensuring compliance with safety regulations	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Advanced Manufacturing Technicians - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.6.08	SAFETY PROCEDURES	
4.6.08.01	Material safety data sheets	Additive Manufacturing Technicians - Digital/Auto Machinists - Digital/Auto Process Development Scientists - BioMFG Biofabrication Technicians - BioMFG Advanced Manufacturing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG

		Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.6.08.02	Safe material movement	Additive Manufacturing Technicians - Digital/Auto Machinists - Digital/Auto Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto
4.6.08.03	Understand and execute safety and cleaning procedures	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Advanced Manufacturing Technicians - BioMFG Biological Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG Maintenance Technicians - BioMFG Instrumentation Technicians - BioMFG Quality Control Associates - BioMFG Quality Assurance Associates - BioMFG
4.6.08.04	Understand and follow chemical safety procedures	Machine Operators - BioMFG Process Engineers - BioMFG First-Line Supervisors of Production and Operating Workers - Energy/Process Chemical Equipment Operators and Tenders - Energy/Process Chemical Process Technicians - Energy/Process Chemical Process Operators - Energy/Process Chemical Process Engineers - Energy/Process
4.6.08.05	Understand and follow electrical safety procedures	Packaging and Filling Machine Operators and Tenders - Energy/Process First-Line Supervisors of Production and Operating Workers - Energy/Process Chemical Equipment Operators and Tenders - Energy/Process
4.6.08.06	Understand and follow safety procedures	Additive Manufacturing Technicians - Digital/Auto Machinists - Digital/Auto Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto Maintenance and Repair Workers - Digital/Auto Electro-Mechanical and Mechatronics Technicians - Digital/Auto Mechanical Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineers - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineers - Digital/Auto Industrial Engineering Technologists and Technicians - Digital/Auto
5.1	ADDITIVE MANUFACTURING	
5.1.00.01	Understand and apply Additive Manufacturing business case, including downflow and upflow	Designers - Digital/Auto

5.1.00.02	Understand and utilize Design for Additive Manufacturing principles (materials/hardware/software)	Designers - Digital/Auto
5.2	SMART MANUFACTURING TECHNOLOGY	
5.2.01	TOOLS AND TECHNOLOGIES	
5.2.01.01	Programmable Logic Controllers (PLCs), Human–Machine Interfaces (HMI), and mechatronics	Additive Manufacturing Technicians - Digital/Auto Advanced Manufacturing Technicians - BioMFG Controls/Automation Technicians/Specialists - Digital/Auto
5.2.01.02	Semiconductor equipment maintenance and troubleshooting	Maintenance Engineers - Electronics Operations Technicians - Electronics
5.2.01.03	Statistical Process Control (SPC), analytics, Artificial Intelligence/Machine Learning	Process/Manufacturing Engineers - Digital/Auto
5.2.01.04	Understand and apply Artificial Intelligence/Machine Learning fundamentals	Process/Manufacturing Engineers - Digital/Auto First-Line Supervisors of Production and Operating Workers - Energy/Process Manufacturing Analytics Associates - Digital/Auto Maintenance Engineers - Electronics
5.2.01.05	Understand current semiconductor manufacturing processes	Operations Technicians - Electronics
5.2.02	IT/OT INTEGRATION	
5.2.02.01	Cyber–Physical Systems (CPS)	Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Maintenance and Repair Workers - Digital/Auto Electro-Mechanical and Mechatronics Technicians - Digital/Auto Mechanical Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineers - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineers - Digital/Auto Industrial Engineering Technologists and Technicians - Digital/Auto
5.2.02.02	Industrial Internet of Things devices	Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Maintenance and Repair Workers - Digital/Auto Mechanical Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineers - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineers – Digital/Auto Industrial Engineering Technologists and Technicians - Digital/Auto Premetaverse Integration Technologists - Digital/Auto
5.2.02.03	Information Technology (IT)/OT integration	Controls/Automation Technicians/Specialists - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto

		Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineering Technologists and Technicians - Digital/Auto Premetaverse Integration Technologists - Digital/Auto
5.2.02.04	Measurement, quality, metrics	Robotics Integrators - Digital/Auto Quality Control/Assurance Inspectors/Analysts - Digital/Auto Quality Control Technicians - Energy/Process
5.2.02.05	Supervisory control and data acquisition (SCADA)/manufacturing execution system (MES) integration	Controls/Automation Technicians/Specialists - Digital/Auto
5.2.02.06	Understand and use digital twin technologies	Process/Manufacturing Engineers - Digital/Auto Premetaverse Integration Technologists - Digital/Auto
5.2.02.07	Understand smart sensors/ Internet of Things and their applications	Controls/Automation Technicians/Specialists - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineering Technologists and Technicians Premetaverse Integration Technologists - Digital/Auto
5.2.03	EFFICIENCY AND PROCESS IMPROVEMENTS	
5.2.03.01	Lean manufacturing, Six Sigma, and digital lean	Process/Manufacturing Engineers - Digital/Auto Quality Control/Assurance Inspectors/Analysts - Digital/Auto
5.2.03.02	Process control and optimization	Process Engineers - BioMFG Process/Manufacturing Engineers - Digital/Auto Chemical Process Engineers - Energy/Process
5.2.03.03	Root-cause analysis	Quality Control/Assurance Inspectors/Analysts - Digital/Auto Process Engineers - Energy/Process Quality Control Technicians - Energy/Process Quality Managers - Electronics
5.2.03.04	Statistical data analysis	Quality Control/Assurance Inspectors/Analysts - Digital/Auto Process Engineers - Energy/Process Manufacturing Analytics Associates - Digital/Auto Quality Managers - Electronics
5.3	INFORMATION TECHNOLOGY	
5.3.01	PROGRAMMING	
5.3.01.01	Advanced robot programming	Robotics Integrators - Digital/Auto Robotics Specialists - Digital/Auto
5.3.01.02	Knowledge and use of programming skills (Python, C++)	Silicon Photonics Design Engineers - Electronics Robotics Technicians - Digital/Auto Robotics Specialists - Digital/Auto Robotics Integrators - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Software Engineers - Electronics Electrical Engineers - Electronics Process Engineers - Electronics

5.3.02	DATABASES AND APPLICATIONS	
5.3.02.01	Data acquisition, IIoT, Edge Gateway, and cloud data platforms	Process/Manufacturing Engineers - Digital/Auto Manufacturing Analytics Associates - Digital/Auto
5.3.02.02	Data management	Robotics Integrators - Digital/Auto Quality Control/Assurance Inspectors/Analysts - Digital/Auto Data Annotators - Digital/Auto
5.3.02.03	Industrial Internet of Things (IIoT), data capture, and data platforms	Controls/Automation Technicians/Specialists - Digital/Auto Manufacturing Analytics Associates - Digital/Auto Data Annotators - Digital/Auto
5.3.02.04	Interpret and use Big Data sets	Robotics Integrators - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Manufacturing Analytics Associates - Digital/Auto
5.3.02.05	Proficient understanding of Structured Query Language (SQL) basics	Process/Manufacturing Engineers - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Manufacturing Analytics Associates - Digital/Auto
5.3.02.06	Understand and execute basic data cleansing procedures	Robotics Integrators - Digital/Auto Process/Manufacturing Engineers - Digital/Auto Data Annotators - Digital/Auto
5.3.02.07	Understand and use automated/no-code data annotation platforms and tools	Process/Manufacturing Engineers - Digital/Auto Data Annotators - Digital/Auto
5.3.03	NETWORKING AND COMMUNICATIONS	
5.3.03.01	Network optimization	Controls/Automation Technicians/Specialists - Digital/Auto Premetaverse Integration Technologists - Digital/Auto
5.3.04	VIRTUALIZATION AND CLOUD COMPUTING	
5.3.04.01	Cloud computing	Premetaverse Integration Technologists - Digital/Auto
5.3.05	SOFTWARE ACQUISITION, MANAGEMENT, AND MAINTENANCE	
5.3.05.01	Knowledge and use of configuration management software	Digital Engineers - Materials Process Engineers - Energy/Process
5.3.05.02	Knowledge and use of development environment software	Electronics Assemblers & Fabrication Specialists - Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process
5.3.05.03	Knowledge and use of object or component-oriented development software	Process Engineers - Energy/Process Electronics Technicians & Fabrication Technicians - Energy/Process
5.4	CYBERSECURITY	
5.4.01	CYBERSECURITY FUNDAMENTALS	
5.4.01.01	Cybersecurity processes	Controls/Automation Technicians/Specialists - Digital/Auto Electro-Mechanical and Mechatronics Technicians - Digital/Auto Mechanical Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto

		Electrical Engineers - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineers - Digital/Auto Industrial Engineering Technologists and Technicians - Digital/Auto Cybersecurity Analyst for SMMs - Digital/Auto Supply Chain Cybersecurity Compliance Specialists - Digital/Auto
5.4.01.02	Understand and adhere to regulatory guidelines, policies, standards, and control frameworks	Controls/Automation Technicians/Specialists - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineering Technologists and Technicians Supply Chain Cybersecurity Compliance Specialists - Digital/Auto
5.4.01.03	Understand and use cybersecurity fundamentals	Controls/Automation Technicians/Specialists - Digital/Auto Maintenance and Repair Workers - Digital/Auto Mechanical Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineers - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineers - Digital/Auto Industrial Engineering Technologists and Technicians - Digital/Auto Cybersecurity Analyst for SMMs - Digital/Auto Supply Chain Cybersecurity Compliance Specialists - Digital/Auto
5.4.02	ACCESS CONTROLS	
5.4.02.01	Understand and apply data privacy regulations and ethics	Data Annotators - Digital/Auto
5.4.03	CYBER RESILIENCY	
5.4.03.01	Audit Support	Supply Chain Cybersecurity Compliance Specialists - Digital/Auto
5.4.03.02	Cyber assessment/ audit tools and practices	Controls/Automation Technicians/Specialists - Digital/Auto Cybersecurity Analyst for SMMs - Digital/Auto
5.4.03.03	Penetration testing	Cybersecurity Analyst for SMMs - Digital/Auto
5.4.03.04	Resilient cybersecurity response, administrative tools, and program implementation	Controls/Automation Technicians/Specialists - Digital/Auto Electro-Mechanical and Mechatronics Technicians - Digital/Auto Mechanical Engineers - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineers - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto Industrial Engineers - Digital/Auto Industrial Engineering Technologists and Technicians Cybersecurity Analyst for SMMs - Digital/Auto Supply Chain Cybersecurity Compliance Specialists - Digital/Auto
5.4.04	OPERATING TECHNOLOGY (OT) SECURITY	
5.4.04.01	Cybersecurity standards in OT and CPS	Controls/Automation Technicians/Specialists - Digital/Auto Electro-Mechanical and Mechatronics Technicians - Digital/Auto Industrial Engineers - Digital/Auto
5.4.04.02	Understand IT/OT integration security	Robotics Integrators - Digital/Auto Controls/Automation Technicians/Specialists - Digital/Auto Mechanical Engineering Technologists and Technicians - Digital/Auto Electrical Engineering Technologists and Technicians - Digital/Auto

5.5	EXPERIMENTS, TESTS, AND ANALYSES	
5.5.01	MICROBIOLOGY TECHNIQUES	
5.5.01.01	Perform microbiological testing and culturing	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Process Technicians/Manufacturing Associate - BioMFG Quality Control Associates - BioMFG
5.5.02	CELL BIOLOGY TECHNIQUES	
5.5.02.01	Knowledge and execution of eukaryotic cell culture techniques	Textiles Technologists - Materials Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Biological Technicians - BioMFG Process Engineers/Scientists - BioMFG Process Development Scientists - BioMFG
5.5.03	PROTEIN TECHNIQUES	
5.5.03.01	Protein purification analysis	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Process Engineers/Scientists - BioMFG Biological Technicians - BioMFG Process Development Scientists - BioMFG Process Technicians/Manufacturing Associate - BioMFG
5.5.03.02	Protein purification decision-making	Biological Technicians - BioMFG
5.5.04	BIOCHEMICAL TECHNIQUES	
5.5.04.01	Perform titer measurements and biochemical testing	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Process Technicians/Manufacturing Associate - BioMFG Quality Control Associates - BioMFG
5.6	BIOMANUFACTURING PRODUCTION	
5.6.01	PRODUCTION PROCESS	
5.6.01.01	Inspects or samples materials at all stages of process to determine quality or condition	Biofabrication Technicians - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG Quality Control Associates - BioMFG
5.6.01.02	Operate processing equipment for downstream bioproduction/separations	Biofabrication Technicians - BioMFG Process Development Scientists - BioMFG Biological Technicians - BioMFG Biofuels Processing Technicians - BioMFG

Process Technicians/Manufacturing Associate - BioMFG
Biological Technicians - BioMFG
Process Engineers/Scientists - BioMFG
Process Development Scientists - BioMFG

5.7 MATERIAL DESIGN AND PRODUCTION

5.7.01 COATING PREPARATION AND APPLICATION

5.7.01.01 Applies routine organic coatings for corrosion protection and appearance requirements Fabrication Specialists - Materials

5.7.01.02 Performs basic organic chemical conversion and paint preparation Chemical Engineers - Materials
Fabrication Specialists - Materials

5.7.02 ADVANCED MATERIALS MAINTENANCE AND REPAIR

5.7.02.01 Composite or fiberglass repair Layup Technicians - Materials

Appendix B. List of Symbols, Abbreviations, and Acronyms

AMNPO	Advanced Manufacturing National Program Office
ARMI BioFabUSA	Advanced Regenerative Manufacturing Institute
Bio/BioMFG	Biomanufacturing
CAD/CAM	Computer-aided design/manufacturing
CESMII	Collaborative Ecosystems Smart Manufacturing Innovation Institute
cGMP	Current Good Manufacturing Practice
CNC	Computer Numerical Control
CPS	Cyber-Physical System
CTE	Career & Technical Education
D/A	Digital/Automation
DOL	U.S. Department of Labor
DOL ETA	U.S. Department of Labor, Employment and Training Administration
E/P	Energy/Process
Elec	Electronics
GMP	Good Manufacturing Practice
HMI	Human Machine Interface
IACMI	Institute for Advanced Composites Manufacturing Innovation
IIoT	Industrial Internet of Things
IT/OT	Information Technology/Operational Technology
KSA	Knowledge, Skill, and Abilities
M/I/R	Maintenance/Installation/Repair
MES	Manufacturing Execution System
MFG USA	Manufacturing USA
Mtrl	Materials
NICE	National Initiative for Cybersecurity Education
NIST	National Institute of Standards and Technology
OMB	Office of Management and Budget
PCB	Printed Circuit Board
PLC	Programmable Logic Controllers
QA/QC	Quality Assurance/Quality Control
SCADA	Supervisory Control and Data Acquisition
SOC	Standard Occupational Classification
SOP	Standard Operating Procedure
SPC	Statistical Process Control

Appendix C. Glossary

Framework

A collection or analysis of competency models.

Model

A collection of multiple competencies that together define successful performance in a defined work setting.

Competency (X.X)

The capability to apply or use a set of related knowledge, skills, and abilities required to successfully perform "critical work functions" or tasks in a defined work setting.

Sub-competency (X.X.X)

A specification of a competency category of knowledge, skills, and abilities that are required to successfully perform "critical work functions" or tasks in a defined work setting.

Knowledge, skill, or ability (KSA)

What a person needs to know and be able to do to perform well in a specific job, occupation, or industry.

Occupation

A person's specific type of work or field. May encompass multiple roles in a job.

Manufacturing USA institute (MFG USA institute)

Public-private partnerships that convene business competitors, academic institutions, and other stakeholders to test applications of new technology, create new products, reduce cost and risk, and enable the manufacturing workforce with the skills of the future.

Biomanufacturing

Biomanufacturing technology uses systems and processes to create biological products for commercial use, including in industries such as agriculture, energy, chemicals, materials, and pharmaceuticals.

Digital/Automation

Digital control and automation technologies use cutting-edge computer technology to optimize operational and information technology convergence in cyber-physical systems, improving the flexibility, efficiency, and productivity of the manufacturing industry.

Electronics

The electronics industry develops the semiconductors, integrated photonics devices, and hybrid integrated circuits critical to the functioning of advanced electronic devices, while also using emerging technologies like digital twins to improve electronics manufacturing processes.

Materials

Advanced materials are used in fields such as textiles, composites, metals, and other products. The materials technology area focuses on developing these advanced materials and the technology used to produce them.

Energy/Process

Energy and industrial process technologies increase efficiency in manufacturing processes and reduce manufacturing costs across a variety of industries.