National Advanced Manufacturing Apprenticeship Program

Apprenticeship works!

Appendix A - Additive Manufacturing/ 3D Printing Technician

DEVELOPED BY

Robert C. Byrd Institute

National Advanced Manufacturing Apprenticeship Partnership

RAPIDS 2078HY O*NET 17-3029.09

In cooperation with the US Department of Labor Office of Apprenticeship, under the American Apprenticeship Initiative grant funding. Employers interested in participating in the Group Standards of Apprenticeship and utilizing the related outlines may contact Lucinda Curry at lcurry@rcbi.org or 304.720.7742 (All OJT and related training may be customized to meet employer needs.) This program is available nationwide.

1. During the Apprenticeship Program the Apprentice shall receive work experience and job-related training in all phases of the occupation, including safe work practices, necessary to develop the skill and proficiency of a skilled professional.

2. The employer and Program Sponsor/Apprenticeship Works committee will ensure Apprentices are rotated throughout the various work processes to ensure a well-rounded professional upon completion of the Apprenticeship and will provide a learning management system to track progression of on-the-job and related training.

3. On-the-job Training shall be carried out under supervision of a qualified professional. Up to 24 hours of Train-the-Trainer will be provided by Apprenticeship Works to each company site.

4. Related Training of at least 144 hours per year will be completed through online courses with interactive labs.

WORK PROCESS SCHEDULE
ADDITIVE 3D PRINTING TECHNICIAN
O*NET-SOC CODE: 17-3029.09 RAPIDS CODE:

OJL (2000-4000) Hours

Competency: A - Industrial Safety	**Minimum Hours**	**Maximum Hours**
A1: Demonstrate the ability to adhere to personal grooming requirements in the facility.		
A2: Demonstrate the ability to use personal protective equipment including eye, ear, hand, respiratory, body and foot protection, by ensuring that a correct fit and optimum protection is provided to the wearer for the specific task, in accordance with applicable safety legislation, government regulations, manufacturers' specifications and company standards/procedures.		
A3: Demonstrate the ability to follow fire safety procedures including: determining the potential for fire posed by the work being performed; locating and assessing the severity of the fire; selecting and operating fire extinguishing equipment; suppressing minor fires; activating alarms; following fire evacuation plans; and, reporting incidents; in accordance with applicable Acts, Regulations, Legislation, and Codes, manufacturers' specifications, and company standards or procedures.		
A4: Demonstrate the ability to work around energy sources by observing limits and procedures for approaching energy sources to ensure personal safety and protection of equipment in accordance with standards.		
A5: Demonstrate adherence to performing lock-out/tag-out procedures and energy isolation for assigned machinery in accordance with facility regulations.		
A6: Demonstrate the ability to handle and store hazardous materials as assigned, while adhering to safe practices in accordance with Occupational Safety and Health Administration (OSHA) and Environmental Protection Agency (EPA) requirements and guidelines, including completing the required documentation.		
A7: Demonstrate the ability to identify all pinch points on primary and supportive machine tools and proper guard placement.		
A8: Demonstrate both emergency and standard shut down of equipment.		
A9: Demonstrate the use and location of workplace eye-wash stations.		
A10: Demonstrate the use and location of workplace first aid kits.		
A11: Demonstrate the ability to practice good housekeeping, ensuring the workplace is clean, organized, and free of		

obstructions, spills, or fire hazard and that materials and equipment are cleaned and sorted in designated areas after use.		
A12: Demonstrate the safe use of hand and power tools.		
A13: Demonstrate how to identify and recognize hazardous conditions and apply proper procedures (includes following guidelines to prevent spread of blood borne pathogens and spill control).		
A14: Demonstrate how to locate a Material Safety Data Sheet (MSDS) and describe how you interpret it.		
Total Hours	**20**	**30**
Competency: B – Workplace Skills	**Minimum Hours**	**Maximum Hours**
B1: Demonstrate the ability to listen to and comprehend instructions.		
B2: Demonstrate the ability to read and comprehend English.		
B3: Interpret specific supervisor instructions.		
B4: Demonstrate the ability to write clear letters, instructions and reports		
B5: Use e-mail and other electronic means for communication.		
B6: Communicate non-documented processes to fellow employees or supervisors.		
B7: Read and interpret non-English information, such as material specifications.		
B8: Demonstrate, as a group, the ability to identify problems and develop consensual solutions.		
B9: Adhere to company policies of timeliness, punctuality, and confidentiality.		
B10: Demonstrate time management skills.		
B11: Work effectively in workforce or group teams.		
B12: Manage conflict effectively and with sensitivity to the needs and perceptions of others.		
B13: Plan and conduct effective meetings		
B14: Demonstrate life-long learning geared toward personal growth.		
B15: Demonstrate strong presentation skills for small and large groups.		
B16: Exercise proper use of computer systems.		
B17: Demonstrate adherence to computer security policies.		
B18: Demonstrate keyboard skill proficiently.		
B19: Use email and text messaging effectively with correct grammar and spelling.		

B20: Create and use spreadsheets for data analysis, graphic, record keeping and other uses.		
B21: Use the internet effectively for researching and acquiring technical information.		
B22: Create well-written documents using word processing software.		
B23: Create and use database applications.		
B24: Integrate documents containing word processing, spreadsheets and graphics.		
B25: Analyze test data, compare information and draw rational conclusions.		
B26: Demonstrate mastery in basic arithmetic, including proportions, percentages, etc.		
B27: Show that data, calculations and results are reasonable.		
B28: Use mental arithmetic and calculators as computation tools.		
B29: Prepare and interpret graphs using a variety of scales and presentation techniques.		
B30: Perform conversions for units from one system to another.		
B31: Use accurately both U.S. Customary units and the International System of Units (ISU).		
B32: Demonstrate use of accuracy and precision.		
B33: Utilize concepts of perimeter, area and volume of basic shapes.		
B34: Apply concepts of angles and triangles.		
Total Hours	**20**	**30**
Competency: C – Problem Solving	**Minimum Hours**	**Maximum Hours**
C1: Recall key job-related information (processes, references, terminology, acronyms).		
C2: Show proficient observation skills during process or equipment demonstrations.		
C3: Perform equipment and instrumentation troubleshooting.		
C4: Perform basic setup, diagnosis and repair of industrial machinery and equipment.		
C5: Use vendor catalogs to acquire troubleshooting information and identify materials and components for work tasks.		
C6: Demonstrate flexibility, problem solving and a willingness to learn.		
C7: Demonstrate how to trace defects to find out what caused them.		

C8: Demonstrate how to use cause mapping during Root Cause Analysis.		
C9: Demonstrate the ability to apply 5-Why methodology to isolate equipment problems.		
C10: Demonstrate the ability to effectively observe and interview methods of identifying and troubleshooting problems.		
Total Hours	**20**	**30**
Competency: D – Quality Assurance and Part Analysis	**Minimum Hours**	**Maximum Hours**
D1: Measure dimensions using scales, micrometers and related tools.		
D2: Measure, with accuracy, material hardness, impact strength and other related properties.		
D3: Know the order of measurement and scale magnitude.		
D4: Measure, with accuracy, temperature, pressure, force, torque and other related quantities.		
D5: Measure mass, using appropriate devices.		
D6: Apply precision metrology devices and inspection tools.		
D7: Read and interpret technical drawings.		
Total Hours	**100**	**200**
D8: Interpret and apply tolerances on component dimensions and specifications.		
Competency: E – Material Selection, Sourcing, Requisitioning	**Minimum Hours**	**Maximum Hours**
E1: Choose and apply material to render parts.		
E2: Compare the differing properties and characteristics of common materials used for additive manufacturing models.		
E3: Perform formal historical sourcing analysis for upcoming events, tapping into internal/external data to identify trends, opportunities and threats.		
E4: Execute structured formal bid processes, (Request for Information [RFI], Request for Quotation [RFQ], Request for Proposal [RFP]), with appropriate suppliers, which include favorable terms and conditions to the enterprise.		
E5: Evaluate supplier capabilities against a standard set of well-documented criteria by providing a comprehensive supplier comparison.		
Total Hours	**50**	**100**
Competency: F – Part Design (CAD)	**Minimum Hours**	**Maximum Hours**

F1: Create and modify technical drawings using computer-aided design (CAD), including three-dimensional (3D) modeling.		
F2: Demonstrate the proper use of computer-aided design (CAD) software.		
F3: Apply the computer-aided (CAD) design three-dimensional (3D) coordinate system for three-dimensional objects.		
F4: Demonstrate and apply basic software utilities for arranging, detailing and plotting views of an object.		
F5: Align, rotate and mirror three-dimensional (3D) objects.		
F6: Create and render a three-dimensional (3D) model.		
F7: Perform analysis on the computer model and refine the design, as needed.		
F8: Enter and save data for an object drawing.		
F9: Create an assembly drawing with proper dimensioning and appropriate views.		
F10: Apply basic solid-modeling commands.		
F11: Create multiple parts using design-tree components.		
F12: Choose and apply material to render parts.		
F13: Demonstrate basic product design principles of visual and spatial form.		
F14: Capture physical three-dimensional (3D) objects, and reverse engineer accurate computer-aided design (CAD) models from three dimensional (3D) scans.		
F15: Describe the fundamentals of material selection for product and system design.		
F16: Measure and calculate part properties.		
F17: Apply orthographic projection principles to drawing's layouts.		
F18: Perform analyses on the sketch procedures and refine the sketch design.		
F19: Perform advanced mating using multiple parts or sub-assemblies.		
F20: Create and insert render parts into the sheet environment of a solid-modeling drawing.		
F21: Create basic building construction, architectural and object designs in three dimensions.		
F22: Demonstrate a thorough knowledge of three-dimensional (3D) file formats as applicable.		
F23: Demonstrate the ability to manipulate and modify a three-dimensional (3D) file.		

F24: Explain and illustrate the advantages of using different 3D file formats.		
F25: Describe characteristics of different 3D file formats.		
F26: Differentiate part orientation using x, y, z, coordinates in the build platform.		
F27: Define and illustrate part orthogonal-orientation-notation.		
F28: Demonstrate the right-hand rule for positive rotations on build volume origin.		
Total Hours	**1000**	**2220**
Competency: G – Cost Modeling: Pricing Parts Correctly	**Minimum Hours**	**Maximum Hours**
G1: Prepare detailed cost estimates of capital and annual operating costs, maintenance and repair, and replacement costs for a project or component of a project, such as equipment, materials, assembly, inspection, modification, quality assurance, etc.		
G2: Calculate the return on investment, present worth and/or annual cost and benefit of a project having initial capital and annual operation, maintenance, repair, salvage value and replacement costs using appropriate interest, discount, and projected inflation rates.		
G3: Identify and quantify the economic risks of a project or product, including how warranty costs are considered.		
G4: Compare design alternatives with varying cost profiles on a present worth or annual cost basis.		
G5: Interact with managers and other professionals to provide project economic information and opinions through financial analysis and financing procedures.		
Total Hours	**50**	**100**
Competency: H – Process Selection	**Minimum Hours**	**Maximum Hours**
H1: Identify standards of ASTM International (formerly the American Society for Testing and Materials) relative to additive manufacturing.		
H2: Define basic additive manufacturing terms used in oral and written communications.		
H3: Explain and illustrate the various additive manufacturing processes.		
H4: Compare and contrast the various additive manufacturing processes.		
H5: Compare and contrast additive manufacturing processes to other manufacturing processes.		
Total Hours	**50**	**100**
Competency: I – Machine Operation	**Minimum Hours**	**Maximum Hours**

I1: Practice safety precautions required to operate each additive manufacturing device.		
I2: Demonstrate the proper use of safety goggles, face shields, ear protection and required clothing used in additive manufacturing.		
I3: Know how to respond to a workplace emergency.		
I4: Know how to find and use workplace safety manuals.		
I5: Know how to find and operation all power sources for additive manufacturing equipment.		
I6: Set up a 3D printer and supporting equipment for a build, including uploading the file, placing support structures, selecting part orientation, and loading the materials and platform.		
I7: Start and stop an operation in accordance with standard operating procedures.		
I8: Fabricate a part or an assembly using additive manufacturing equipment.		
Total Hours	**100**	**200**
Competency: J – Machine Maintenance: Troubleshooting, Install, etc.	**Minimum Hours**	**Maximum Hours**
J1: Verify equipment is ready to use by using a safety checklist.		
J2: Identify machine malfunctions by observing control panels or other notifications.		
J3: Use five-senses to make sure machines are running properly.		
J4: Recognize symptoms of equipment malfunction.		
J5: Check for leaks, dirt and loose connections during equipment operation.		
J6: Read and interpret pressure gauges, flow meters, fluid levels, temperature gauges and voltages and current.		
J7: Use Human Machine Interface (HMI) equipment to monitor machine performance.		
J8: Replace or install additive manufacturing equipment components to maintain proper working order.		
J9: Select applicable diagnostic or configuration software so that controls, instruments, equipment, and systems can be calibrated, configured, and tested, in accordance with manufacturers' specifications and company standards/procedures.		
J10: Identify required configuration licensing so that controls, instruments, equipment, and systems can be calibrated, configured, and tested, in accordance with manufacturers' specifications and company standards/procedures.		

J11: Use spreadsheets, databases, and word processors so that controls, instruments, equipment, and systems can be calibrated, configured and tested, in accordance with manufacturers' specifications and company standards/procedures.		
J12: Use handheld, laptop, and modem interfaces so that controls, instruments, equipment, and systems can be calibrated, configured, and tested, in accordance with manufacturers' specifications and company standards/procedures.		
J13: Update software and firmware so that controls, instruments, equipment, and systems can be calibrated, configured, and tested, in accordance with manufacturers' specifications and company standards/procedures.		
J14: Back-up data and equipment configurations so that controls, instruments, equipment, and systems can be calibrated, configured, and tested, in accordance with manufacturers' specifications and company standards/procedures.		
Total Hours	**50**	**100**
Competency: K – Post Processing, Finishing and Breakout	**Minimum Hours**	**Maximum Hours**
K1: Know how to use basic hand tools (hammers, pliers, screw drivers, hand saws, wrenches, sanding blocks).		
K2: Know how to use standard machine tools (electric: drills, saws, grinders, sanders).		
K3: Know how to select the proper tool for the job.		
K4: Know the process of investment casting and how additive manufacturing is used as a secondary process.		
K5: Know the process of sand casting and how additive manufacturing is used as a secondary process, including making the cope and drag using additive manufacturing.		
K6: Know the process of die casting and how additive manufacturing is used as a secondary process.		
K7: Know the process of silicone molding and how additive manufacturing is used as a secondary process, including making the master pattern using additive manufacturing to create silicone molds.		
K8: Know the process of composite molding and how additive manufacturing is used as a secondary process.		
K9: Know the process of metal spraying and how additive manufacturing is used as a secondary process.		
K10: Know the process of metal stamping/forming and how additive manufacturing is used as a secondary process.		
K11: Know the process of hydroforming and how additive manufacturing is used as a secondary process, including making molds using additive manufacturing.		

K12: Know the process of thermoforming and how additive manufacturing is used as a secondary process.		
K13: Know the process of EDM (electrical discharge machining) and how additive manufacturing is used as a secondary process.		
K14: Demonstrate a working knowledge of important additive manufacturing post-processing procedure, such as abrasive finishing, heat treatment, support structure removal, and painting.		
K15: Know how to apply coatings used in additive manufacturing post-processing.		
K16: Demonstrate a knowledge of additive manufacturing assembly procedures, such as adhesive bonding and welding.		
K17: Demonstrate a working knowledge of the various metal cutting procedures, such as turning and milling.		
K18: Demonstrate a working knowledge of manual machining, including using an engine lathe.		
Total Hours	**390**	**590**
Competency: L – Electrical Systems	**Minimum Hours**	**Maximum Hours**
L1: Adhere to National Electric Code (NEC) safety procedures for tightening, disconnecting or connecting electrical conductors and components.		
L2: Adhere to hazard avoidance in contact with live electrical systems.		
L3: Adhere to guidelines regarding safe approach distances while working on electrical systems.		
L4: Use a multimeter to measure circuit voltage and current.		
L5: Use a multimeter to measure electrical circuit resistance.		
L6: Use a multimeter to check electrical circuit continuity.		
L7: Calculate circuit power given current and voltage.		
L8: Size fuses and circuit breakers, using National Electric Code (NEC) requirements, based on circuit load and wiring ampacity.		
L9: Install fuses and circuit breakers.		
L10: Inspect circuit breakers to determine if they have been tripped.		
L11: Reset a circuit breaker.		
L12: Recognize all protective tags and lockout devices used to isolate equipment and components from hazardous energy sources.		
Total Hours	**50**	**100**

Optional Competency: M – Computer-Numerical Control (CNC) Systems	**Minimum Hours**	**Maximum Hours**
M1: Identify and select the Computer-Numerically Controlled (CNC) machines using information from job specifications to ensure that the correct machining process is used to make parts or components.		
M2: Input and process program data to the machine memory using information from machine-tool manual and programming data so that the data is input correctly to machine the part in accordance with the job process sheet.		
M3: Determine tool path and calculate the proper coordinates to establish cutter start-point, cutter finish-point, and path geometry relative to set-up sheets and job specifications.		
M4: Identify, select, and set up Computer-Numerically Controlled (CNC) cutting tools and tooling (tool holders, end and face mills, carbide insert tools, center-drill, drill, taps, reamers, counter bores, and boring head) to pre-determined reference points outlined from the prepared sequence sheets and tool lists, to ensure that the tools and tooling selected are the correct ones to machine the workpiece efficiently and safely.		
M5: Identify, select, and set machine parameters (spindle feeds, table feeds, and power settings) using speed and feed charts and according to the type, size, grade, and hardness of the material to be cut so that the workpiece is machined efficiently and safely without damage to the tooling, machine, or workpiece and ensure personal safety in accordance with job specifications.		
M6: Position and align workpiece in Computer-Numerically Controlled (CNC) machine to specified datums and required alignments, using chucks, face plates, collets, vises, clamps, stops, and fixtures to locate and position the workpiece, avoid collisions, and, ensure maximum stability during machining in accordance with job specifications.		
M7: Input and verify the part program at Numerically Controlled/Computer Numerically Controlled (NC/CNC) machine controls by: performing a dry run; taking a test cut; interrupting machining; measuring and checking dimensions; adjusting machine feeds, speeds, and offsets; editing the program; taking a final cut; and, performing an inspection prior to the production run; to ensure that the dimensions, shape, and tolerances of the machined part conforms to job specifications.		
M8: Store and record a verified program on storage media for future use so programs can be retrieved and available for repeat machining jobs relative to job specifications.		
M9: Monitor the Numerically Controlled/Computer Numerically Controlled (NC/CNC) machining process by interrupting machining, measuring or checking dimensions, and adjusting machine feeds, speeds, and offsets, so that the dimensions, shape, and tolerances of		

the machined work piece are maintained during machining in conformance job specifications.		
M10: Using inside and outside micrometers, Vernier height gauges/indicators, gauge blocks, and pin gauges, perform final inspection of sawed work piece to ensure tolerances and dimensions are compliant with engineering drawings and job specifications.		
Total Hours	**100**	**200**
Total Hours	**2000**	**4000**

RELATED INSTRUCTION OULINE
ADDITIVE 3D PRINTING TECHNICIAN
O*NET-SOC CODE: 17-3029.09 RAPIDS CODE:

This instruction shall include, but not be limited to, at least 144 hours per year for each year of the apprenticeship. The related theoretical education is tightly integrated with real work projects. The curriculum is defined as a variety of classes, around which the exams and projects are based. By defining the classes in this way, all competencies required of the students are met, through project work.

Industrial Safety 10 hours

Occupational Safety Health Administration (OSHA) Training (Personal protection equipment [PPE], hazard communication, accident/near miss reporting, hazardous materials, emergency plan, fire prevention, blood borne pathogens, lock-out tag- out, ergonomics, walking and working surfaces, machine guarding, Additive Manufacturing Hazards: Mechanical; Electrical; Thermal; Airborne Particles)

Advanced Mathematics 6 hours

Applied Mathematics Review (Units of measurement, algebra, geometry, trigonometry, statistics)

History of 3D Printing 4 hours

History (Uses of additive manufacturing parts, industries using additive manufacturing, etc.)

3D Printing Theory 16 hours

Introduction to Additive Manufacturing (Terminology, sources of input, additive manufacturing materials, additive manufacturing processes, current technology and equipment supporting additive manufacturing, secondary processes)

International Organization for Standardization (ISO)/American National Standards Institute (ANSI) Standards 4 hours

Additive Manufacturing Quality Systems (Key quality factors, digital file configuration and control, vendor and raw material management, device inspection/control, machine calibration, preventative maintenance, sample testing, production/process flow documentation, final part inspection)

Practical Metrology 24 hours

Dimensional Measurement (Blueprint reading and interpretation, part tolerance, measurement equipment and gauges, scales, hardness testing, optical comparators, vision systems, coordinate measuring machines)

Additive Manufacturing Materials 12 hours

Additive Manufacturing Materials (Materials: polymers; metals; ceramics; hybrid, microstructure, properties, qualification, vendor considerations, material life cycle.

Applied 3D Printing 80 hours

3D Printing Equipment Operation (Equipment overview and setup, AM file input, auxiliary equipment setup and operations, troubleshooting, part verification)

Additive Manufacturing Materials 12 hours

Additive Manufacturing Materials (Materials: polymers; metals; ceramics; hybrid, microstructure, properties, qualification, vendor considerations, material life cycle)

Additive Manufacturing Secondary and Post Processing 24hours

Secondary Processing (Investment casting, sand casting, die casting, silicone molding, lay-up tooling, metal spraying, metal forming, stamping, metal spraying, jigs and fixtures, thermoforming, paper pulp tooling, electrical discharge machining [EDM] tools)

Post Processing (Materials, methods, automating processes, processes for parts and components, processes for final products/use)

Workplace Communications 4 hours

Communications (Active listening, reading and comprehension, writing clearly, communicating through multiple means of communication)

Geometric Dimensioning and Tolerancing (GD&T) 12hours

Applied Geometric Dimensioning and Tolerancing (GD&T) *for Design for Additive Manufacturing (DFAM)* (terminology and key elements, goals and objectives, roadmaps, integrating GD&T for rapid prototyping)

Intermediate Computer-Aided Design (CAD) 40 hours

Applied computer-aided design (CAD) Design (Software navigation, drawing creation and modification, arranging/detailing and plotting views of an object, capture three-dimensional cans of objects and reverse engineering in software environment, save and render parts)

Additive Part Design 80 hours

Design for Additive Manufacturing (DFAM) (Design strengths, design weaknesses, design considerations, computational modeling, design for direct digital manufacturing, legacy parts optimization, customer requirement specifications, design verification, risk management)

Basic Electrical Systems 16 hours

Core Electrical Systems (Safety, interpreting schematics, electrical theory, power supply, circuits, basic wiring)

Basic Computer Numerical Control Systems 24 hours

Core Computer Numerical Control (CNC) Systems (Safety, Cartesian coordinate system, controls, part programs)

Problem Solving 16 hours

Problem Solving (Root cause analysis, the 5 why's, creative thinking, preventative and predicative maintenance)

Design Economics and Costs 16 hours

Manufacturing Economics (Time value of money, accounting basics, capital budgeting, risk identification, cost-benefit analysis, profit/loss)

Total Hours **400 Hours**