MANUFACTURERS' GUIDE TO ROBOTICS

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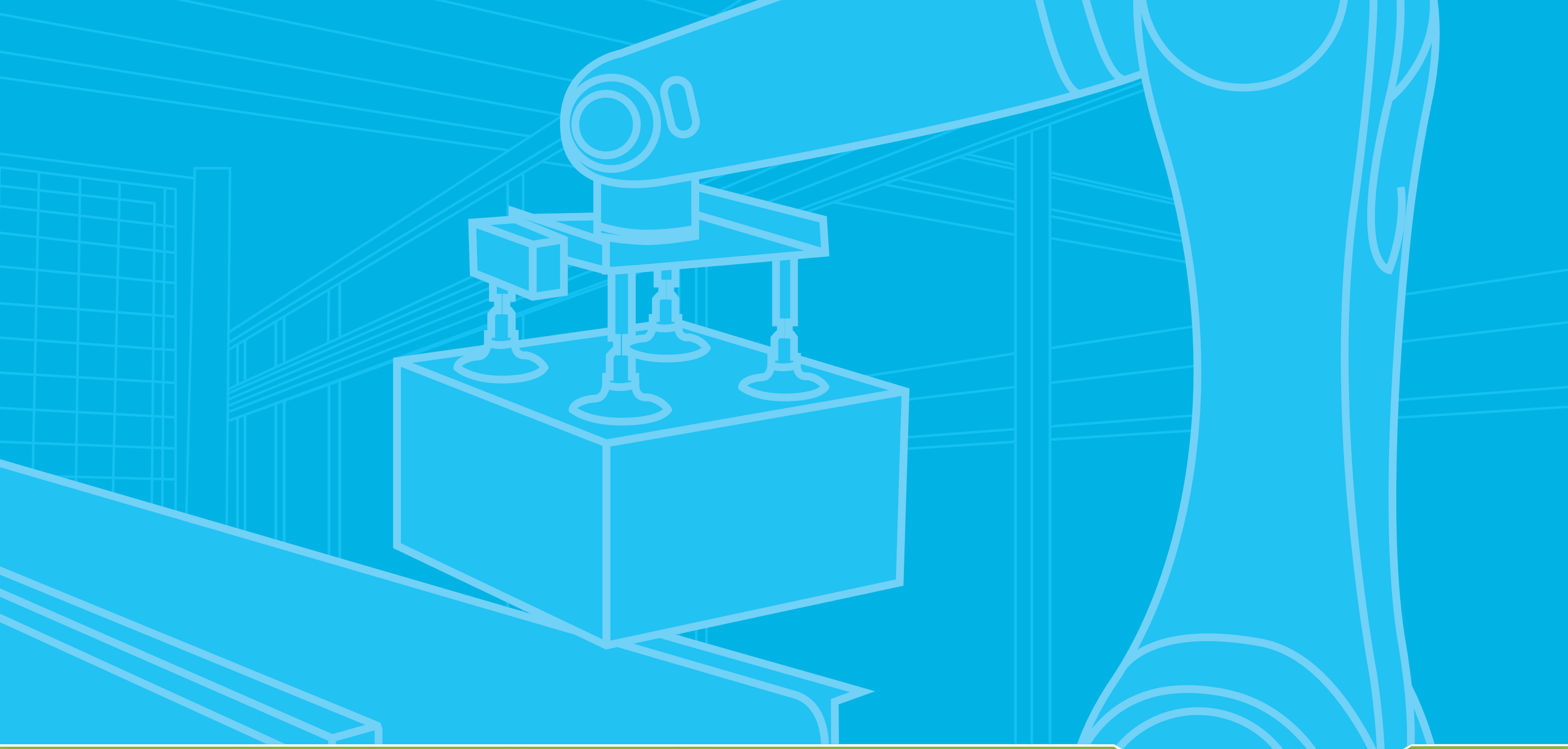
Your Strategic Partner for Manufacturing Growth



PURPOSE OF THIS GUIDE

This guide serves as an introduction to the most common types of robots and robot accessories on the market. It also presents initial steps to help you understand how robotics can add value in your organization. Robotics have traditionally been thought of as a singularly focused and costly system exclusive to large manufacturers with low mix/high volume production. Recent technology advances in sensors, software, vision systems, and more are shifting that paradigm and making robotics implementation accessible and feasible for even the smallest manufacturers.

Robotics have been a key element in improving efficiency and safety in manufacturing, particularly in the automotive and electronics industries, for decades. However, it is estimated that automation potential remains across over 60%[1] of manufacturing tasks, a figure that increases to over 80% for production oriented tasks. This is particularly true for small and medium manufacturers (SMMs), which make up 99%[2] of all manufacturing organizations in the United States. As SMMs grapple with upwards of two million positions unfilled through 2025[3], exploring robotics is a valuable step. While not a "one size fits all" solution, robotics can often help SMMs achieve benefits such as increasing production with the same workforce, eliminating or reducing production bottlenecks, and improving worker satisfaction by redeploying workers to more value-added tasks.

AUTOMATION OPPORTUNITY REMAINS IN 60% OF MANUFACTURING TASKS

AUTOMATION POTENTIAL INCREASES TO OVER 80% FOR PRODUCTION ORIENTED TASKS

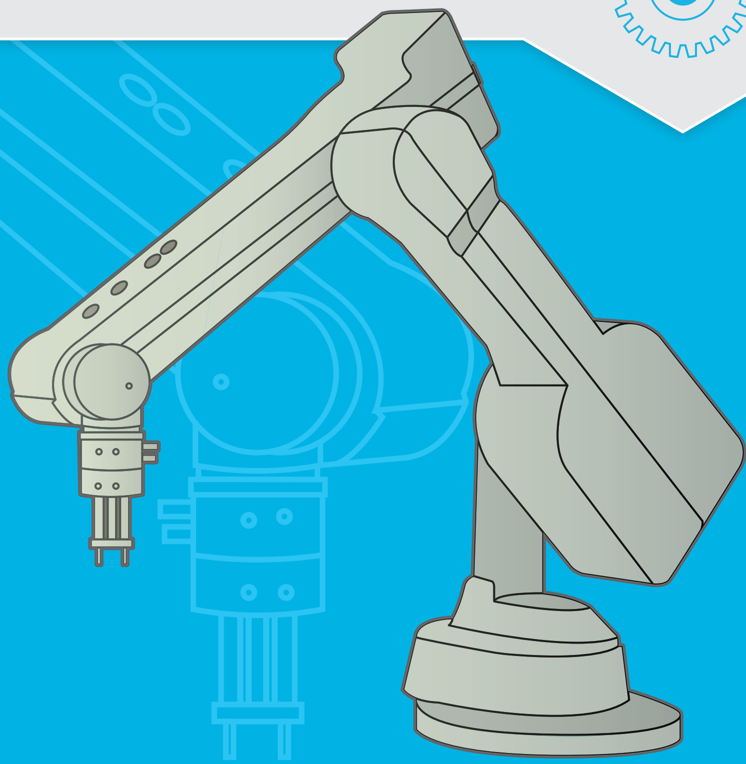
SMMs MAKE UP 99% OF ALL MANUFACTURING ORGANIZATIONS IN THE UNITED STATES

1 https://www.mckinsey.com/business-functions/operations/our-insights/human-plus-machine-a-new-era-of-automation-in-manufacturing

2 Source: U.S. Census Bureau

3 https://www2.deloitte.com/us/en/pages/manufacturing/articles/boiling-point-the-skills-gap-in-us-manufacturing.html

ARTICULATED



- PICK AND PLACE
- MACHINE TENDING
- ASSEMBLY
- WELDING
- PACKAGING
- PALLETIZING
- INSPECTION
- MATERIAL REMOVAL
- DISPENSING

An articulated robot is the type of robot that comes to mind for most people. Similar to a human arm, an articulated robot is classified by the number of points of rotation or axes (joints) such as the most common, the 6-axis articulated robot. There are also 4 and 7-axis units on the market. Key specifications include payload (end of arm tooling + work piece) and reach. This ranges from 1lb (0.5kg) and 10.2” (260mm) on the smallest of articulated units up to 5,000lb (2,300kg) and 181” (4,600mm) on the largest industrial units.

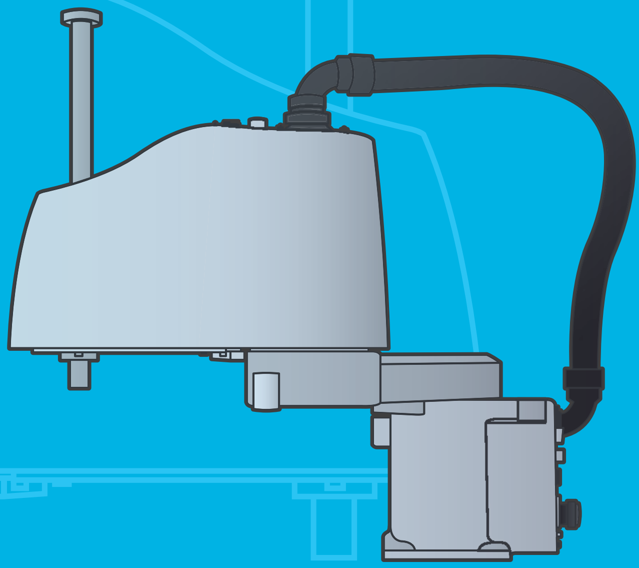
ADVANTAGES

High degree of flexibility, dexterity, and reach makes articulated robots ideally suited for tasks operating between various, non-parallel planes, such as machine tending. It can easily reach into a machine tool compartment and under (or even around with 7th axis) obstructions to gain access to the workpiece. Sealed joints and available protective sleeves allow them to excel in clean and dirty environments alike. Ability to mount on any surface (ceiling, sliding rail, or mobile robot) maximizes working range options.

DISADVANTAGES

Flexibility and dexterity comes at a cost. Higher cost compared with other robot types of comparable payload. Less suited for very high-speed applications due to more complex kinematics and relatively higher component mass than other robot types. Precision degrades on outer limits of payload/working range, although modern control systems can compensate.

SCARA



- PICK AND PLACE
- ASSEMBLY
- INSPECTION
- PACKAGING
- DISPENSING

Selective Compliance Assembly (or Articulated) Robot Arm. Slightly compliant in X-Y, horizontal, plane, but rigid in Z (vertical) direction. Generally a 4-axis unit, with most under 13lb (6kg) payload capacity and 25” (650mm) of reach.

SCARA
(Selective Compliance Articulated Robot Arm)

—

Excels at vertical assembly or operations between two parallel planes (ex. tray to conveyor)

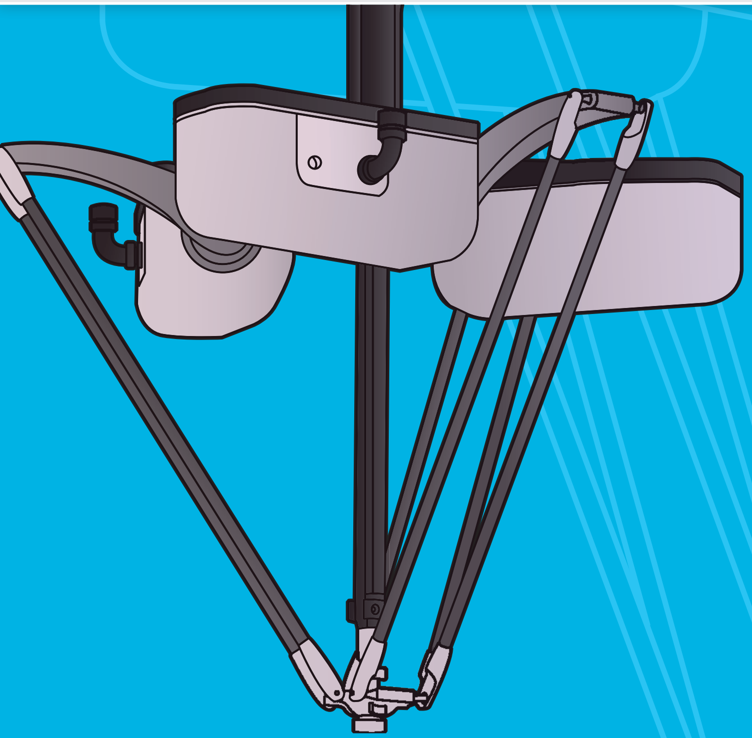
ADVANTAGES

Lightweight, pedestal mounted with small footprint makes them ideally suited to applications in limited space. Good at vertical assembly tasks such as inserting pins without binding due to rigidity in vertical direction. Lower cost option to articulated robot when working between two parallel planes, such as pick and place from a tray to a conveyor. Capable of very fast cycle times.

DISADVANTAGES

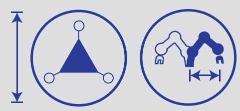
Most models are focused on lower payload and shorter reach applications, although some models up to 110lb (50kg) and 47” (1200mm) are available. Due to the fixed swing arm design, which is an advantage in certain applications, SCARA robots have limited ability to work around or reach inside an object such as fixtures, jigs, or machine tools within the work cell.

DELTA



- PICK AND PLACE
- ASSEMBLY
- INSPECTION

Delta robots utilize three base-mounted motors to actuate control arms in a parallelogram arrangement to position the wrist. They are also referred to as "spider" robots. Basic delta robots are 3-axis units; 4- and 6-axis models are also available that utilize remote actuated wrist designs. By mounting the actuators on, or very close to, the stationary base instead of at each joint as on an articulated robot arm, the moving structure (arm) of the robot can be very lightweight. This allows rapid acceleration which makes delta robots ideal for very high speed operations with light loads. Delta units range in payload from <1lb (0.5kg) to 26lb (12kg), and reach from 15" (420mm) to 63" (1600mm), though they are most commonly implemented on the lower end of the payload/reach range. Use caution when comparing reach specifications to other robot types. Reach for delta robots is typically defined by the circular diameter of the working range, as opposed to the reach on a radius from the base of articulated or SCARA units. For example, a delta unit with a 40" reach would only have half the reach (20" on a radius) of a 40" articulated or SCARA unit.



*REACH

ADVANTAGES

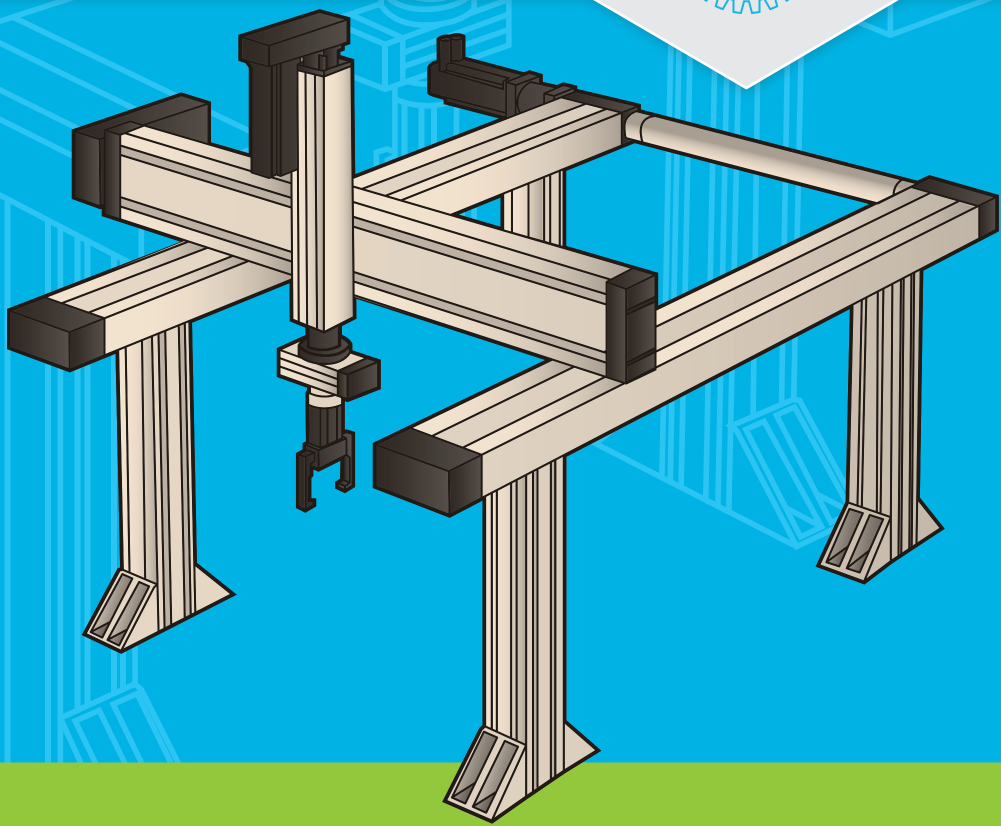
Design of unit makes it excel at high speed operations; in some applications it can reach 200 cycles per minute. Well suited for placement above a conveyor for pick and place operations. Makes quick work of tasks between parallel surfaces. (ex. picking part from passing conveyor and assembling to workpiece)

DISADVANTAGES

Low payload/reach capabilities. Limited ability to work in planes perpendicular to mounting base. Extensive mechanical linkages and gearboxes can have higher maintenance requirements compared to articulated and SCARA units.

CARTESIAN/GANTRY

- PICK AND PLACE
- DISPENSING
- ASSEMBLY
- INSPECTION



Cartesian robots typically consist of 2-3 linear actuators assembled to fit a particular application. By their nature, Cartesian robots are positioned above the intended workspace and can be elevated above to maximize available floor space and accommodate a wide range of workpiece sizes. When placed on an elevated structure suspended over two parallel rails, they are referred to as gantry robots. The work envelope and payload are only restricted by the length and capacity of the structure and actuators. This means they can be small, light payload (<1 lb / 0.5 kg) units or heavy payload (>250lb / 100kg) units that cover an entire production floor when leveraging bridge-crane type structures.

ADVANTAGES

Relatively low cost compared to other types of robots. Use of standard linear actuators and mounting brackets minimizes cost and complexity of "custom" systems. Can cover large work area. Higher capacity units able to integrate other robotic technologies (such as articulated robot) as "end-effector" to increase capabilities of system. High payload capacity when supported at both ends.

DISADVANTAGES

Unable to easily reach into or around obstacles. Exposed sliding mechanisms less suited to operation in dusty/dirty environments, particularly on lighter duty units. Structure spans entire work area.

COLLABORATIVE VS. INDUSTRIAL

COLLABORATIVE

Collaborative robots, also known as “cobots”, operate at lower payloads and speeds and are equipped with safety systems allowing operation together with workers in the same work cell.

- Operate with lower forces/speeds
- Lower payload – typical cobot max of approximately 22lb (10kg), though models up to 77lb (35kg) are available
- Able to operate without extensive safety guarding allows significant flexibility/mobility
  - Operating at highest capable speeds can require safety system integration to reduce to “collaborative” speeds when workers in close proximity
- Ease of programing through teach pendant or physically moving unit to “teach” motion
- Safety standards
  - RIA TR R15.606-2016
  - ISO 15066:2016

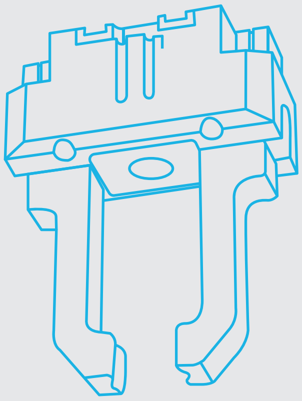
INDUSTRIAL

Traditional robotic systems.

- Significantly higher payload (up to 2,300kg) and speed capabilities (up to 10 m/s)
  - Capabilities far exceed collaborative robotics
- Safety guarding/systems required due to higher speed and force capabilities
  - Increases cost over comparable collaborative robot
- Higher investment due to significant cost associated with safety guarding and systems integration
- Safety standards
  - ANSI/RIA R15.06-2012
  - ISO 10218-1:2011
  - ISO 10218-2:2011

	COLLABORATIVE	INDUSTRIAL
High speed/payload		X
Comparable speed to human worker	X	
Potential to program and setup in-house	X	
High flexibility to redeploy to multiple applications	X	
High accuracy	X	X
High accuracy and speed		X
Operate near or with workers	X	
Lowest implementation cost	X	
Achieve “lights out” operation	X	X

TOOLING & ACCESSORIES



END EFFECTORS*

Grippers – Most common end effector used for manipulation of work pieces

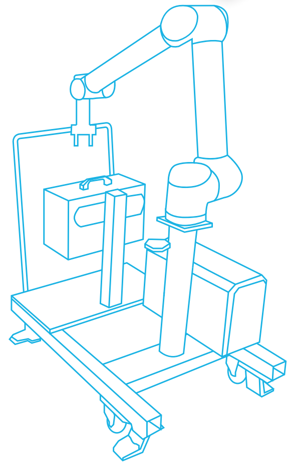
- 2 or 3 finger. Grips wide range of products and shapes
- Compliant/Adaptive. Ability to adjust closure path and force to accommodate different material requirements (ex. fragile items that could be damaged with excessive force)
- Vacuum. Typically used with flat, non-porous materials (ex. sheet metal, boxes)
  - Traditional suction cup designs can be highly customizable – just piece together desired structure
  - "Area grippers" utilize pad to grip large area with control valves to provide vacuum only where needed (ex. perforated surface)

Material Removal – sander, buffer, grinder, etc. Often utilize standard tooling modified for use on robot. Some purpose built robotic tooling available

Assembly – screw/nut driver, welder, dispenser (glue/sealant/etc), paint sprayer

Tool Changers, Dual Grippers – allows multiple tools to be used for improved efficiency.

*ALSO KNOWN AS END-OF-ARM TOOLING (EOAT)



OTHER ACCESSORIES

Force-Torque Sensors. Allows robot to "feel" the workpiece and surrounding area. Integrated into robot or mounted at wrist

Cart/Stand

- Fixed stand for dedicated application
- Wheel mounted with foot jacks to allow flexibility to move to various cells in facility
- Unique mountings possible – ceiling, wall, mobile robot

Jigs/Fixtures (Part Presentation). Highly variable by application, but a critical part of robot integration. Common to encounter issues when inadequate focus placed on how to present parts to robot or how the robot is able to hand off finished goods

Vision Systems

- Robot Guidance
- Quality inspection – feature presence/ location, quantity checks, defect checks
- Measurements/gauging
- Character recognition – recognition (or validation comparing to expected value)
- Print quality inspection

FIRST STEPS

01

IDENTIFY RESOURCES TO GET THE LEVEL OF SUPPORT YOU NEED

Connect with Catalyst Connection or your local MEP center
Connect with vendors and systems integrators through SWPA AR Working group
Engage with ARM

02

IDENTIFY YOUR NEEDS OR PAINPOINTS AND PRIORITIZE

Supporting Tools
Manufacturing Examples

03

BUILD A BUSINESS CASE

Business Case Components
Investment Considerations

IDENTIFY RESOURCES

CATALYST CONNECTION
Your Strategic Partner for Manufacturing Growth

CATALYST CONNECTION AND MEP NETWORK

- Local and Regional support for manufacturing

SOUTHWESTERN PA ADVANCED ROBOTICS (AR) WORKING GROUP

- Learn from experts in the field
- Gain awareness of relevant events and training opportunities in the region
- Share and learn from mutual challenges and exchange best practices
- Expand your network of peers, suppliers, integrators, and academics
- Identify development and implementation assistance to support your projects

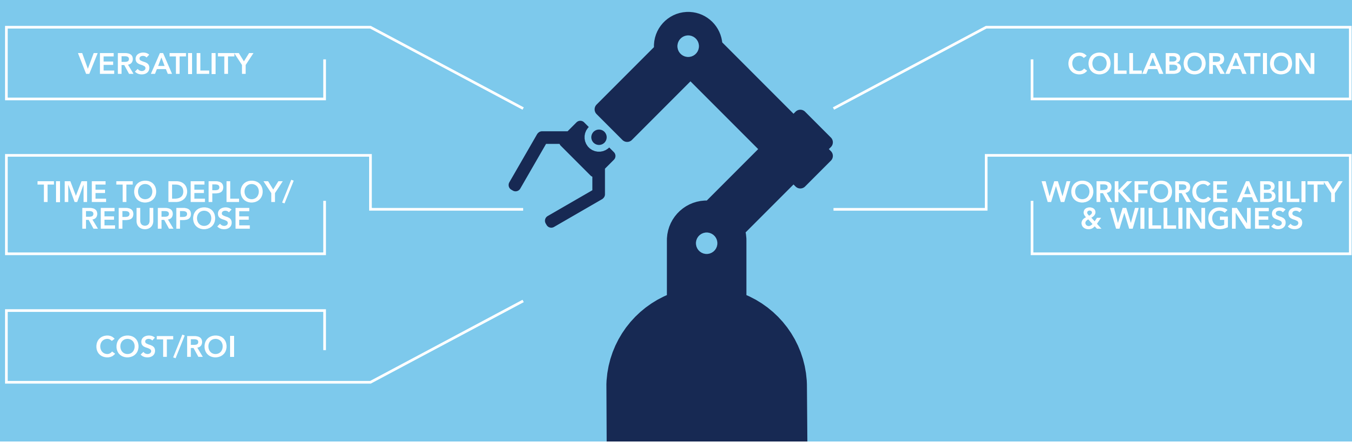
ARM
ADVANCED ROBOTICS FOR MANUFACTURING

ARM (ADVANCED ROBOTICS FOR MANUFACTURING)

- Member-based consortium with national scope
- Project funding and access to project outcomes
- National network of suppliers, partners, potential customers
- Access to physical, knowledge, or talent resources
- Insight into advancements, trends, use cases, and best practices

Catalyst Connection and the MEP Network are working together with ARM to extend national reach and support SMMs in the exploration and potential adoption of robotics.

ARM'S PROJECTS DESIGNED TO ADDRESS TECHNICAL & WORKFORCE CHALLENGES



PAINPOINTS & PRIORITIES

IDENTIFYING NEEDS

The first step before robotics or any new technology is implemented or expanded is identifying the need or painpoint. Sometimes that is identified well in advance through strategic planning or new product introductions, but it is often identified in the moment when it may already have a negative impact on your business. Issues like worker safety concerns, poor delivery performance, or excessive quality returns. Every manufacturing environment is different and there are no "one-size-fits-all" solutions, but identifying your top needs or painpoints is where every manufacturer should start their journey.

TOOLS

- Internal discussions with key business/operations personnel to establish potential needs/painpoints
- Product/process matrix to identify opportunities in high-mix, low volume operations
- Evaluating effort/complexity/impact to start prioritization
    - Combines internal effort required with technology implementation complexity to evaluate priority

EXAMPLE RESULTS AT REAL MANUFACTURERS: CAN YOU IDENTIFY SIMILAR OPPORTUNITIES IN YOUR OPERATION?

INDUSTRY	NEED/PAINPOINT	ROBOTICS CHALLENGE & SOLUTION	RESULT
Custom Engineered, Low Volume Injection Molder	Quality control. Current manual inspection of molded parts often completed offline, increasing cycle times beyond allowable limits. Inspection staff needed elsewhere for value added tasks.	New conveyor supplies ejected parts to cobot with wrist camera; 2-finger gripper identifies part orientation and presents part to inspection camera. Pass/fail quality check completed, then part rejected or delivered to final packaging.	Achieved 100% inspection in-process with cobot implementation. Selected staff trained to identify new opportunities in automation. Inspection staff reallocated to more value-added tasks.
Contract Metal Fabrication (high-mix, low volume)	Maintain workforce level & keep pace with production needs on press brake and stamping operations. Stay ahead of technology curve and fill skills gap.	Flexible solution to service different cells. Implemented 10kg payload cobot on mobile stand with 2-finger gripper and custom vacuum gripper.	Existing staff trained to identify opportunities and program new jobs. Implemented in production in 1 month with payback expected in 12-24 months as utilization ramps up.
Precision Machine Shop	Safety concerns. Move workers from dirty sanding task with small parts and hand proximity to sanding belt to more value added tasks.	Proper part presentation to facilitate operation. Implemented 5kg payload cobot with 2-finger gripper with 3D printed jaws and part presentation trays on stand integrated with belt sander.	Workers happy to work in other areas rather than dirty, dangerous task. Continuing to expand application of system to other sanding operations.
Industrial Component Manufacturer	Reshore production of welded components by reducing production time and maintain/increase quality.	Sense exact location of joint to be welded on cast parts with variations. Implemented industrial welding robot with two rotating fixtures. Integrate laser sensor to determine profile of joint for high quality weld every time.	Successful reshoring of product thanks to 80% reduction in weld process time and high quality finished product. Skilled workers added to support reshored process.

BUILDING A BUSINESS CASE

The discussion of a business case for robotics and automation frequently centers around ROI (return on investment) and payback, which are financial metrics of the success of an investment and can be used to compare competing investment opportunities. These are useful metrics that require tangible, measurable benefits to compare against the total investment as well as investment period.

$$\text{Return on Investment} = \frac{\text{Incremental Gains}}{\text{Total Investment}} \quad \textit{(expressed as \%)}$$

$$\text{Payback Period} = \frac{\text{Total Investment}}{\text{Annual Incremental Gains}} \quad \textit{(expressed as years — multiply by 12 for months)}$$

IDENTIFY BENEFITS

In addition to tangible and financial benefits, a business case should also attempt to include intangible benefits of robotics and automation that could be impractical or challenging to measure. These benefits would be presented in written portions of a business case, providing context to linkages between implementation benefits and company strategy.

Quantitative: increased production, reduced scrap rate (quality), reallocated labor hours, reduced labor hours at process level, safety (workers comp claims reduction/elimination), increased utilization, WIP reduction, cycle time reduction

Qualitative: Employee satisfaction, worker retention, attracting best talent, technology "forward" company, keeping edge over competition, safety (general improvements), production/lot tracking

INVESTMENT COMPONENTS

Your potential investment in implementing robotics is more than just a robot. It is easy to overlook associated costs (internal and external) with the excitement over declining initial cost of some base robotic systems. Make sure to consider ALL applicable costs when evaluating a robotics investment.

Robotics/automation hardware: robot, end of arm tooling, stands, fixtures, trays, vision system, safety systems, accessories (force-torque sensor, protective covers, etc), spare parts, etc.

Integration: design engineering, installation, testing, ongoing support, additional programming needs

Internal costs: Technical and production team time (installation, test/acceptance trials), training, loss of production revenue during installation/ramp up, hiring of additional technical personnel, finance costs

INVESTMENT CONSIDERATIONS

- Maximize return on investment (ROI) by focusing on high utilization applications
    - Collaborative units can accommodate switching between multiple applications/ work cells
- Flexibility in system will facilitate re-tooling as applications evolve or new opportunities arise
- Complexity of integration is primary driver of cost — expect 2-4x hardware cost for complex integrations
- Building internal expertise (implementation champion) can reduce reliance on and expense of 3rd party services for ongoing support needs
- Look for units that provide for a wide range of pre-integrated end of arm tooling and accessories. This allows faster and lower cost (lower risk!) implementation compared with custom tooling integration.
- Don't forget to consider part presentation! Some tasks, like bin picking, are easy for humans, but require additional systems (bowl feeders, fixtures/ trays, vision systems, etc) to automate the process

CALL TO ACTION

JOIN THE SOUTHWESTERN PENNSYLVANIA ADVANCED ROBOTICS WORKING GROUP TO SUPPORT YOUR EXPLORATION OF ROBOTICS

Contact Catalyst Connection to learn more about:

- Service offerings including:
    - Robotics/technology project assistance
    - Assessments
    - Request for Proposal (RFP) development
- Grant funding opportunities
- ARM projects and resources

For more information:
www.catalystconnection.org/advanced-robotics-small-manufacturers

STRATEGIC PARTNERSHIP SERVICES

Catalyst Connection is a private not-for-profit organization headquartered in Pittsburgh, Pennsylvania. We provide consulting and training services to small manufacturers in southwestern Pennsylvania, accelerating revenue growth and improving productivity. Through active collaboration with our clients and the manufacturing community at large, we contribute to the growth, vibrancy, and ongoing robustness of manufacturing in our region.

Catalyst Connection is supported, in part, by the Commonwealth of Pennsylvania, Department of Community and Economic Development, and by the National Institute of Standards and Technology's Hollings Manufacturing Extension Partnership.

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