Considerations for Seamless Integration of Automated Machining Systems

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Automated machining systems have become the new standard for competitive suppliers and are a key component to the success of U.S. manufacturing. They have been applied and configured to meet a variety of needs across nearly all industries. Die/mold, aerospace, and aero-engine, which traditionally have been extremely labor-intensive manufacturing environments, are now able to incorporate automation.

Whereas automation was previously utilized for eliminating manual tasks, the reasons to consider automation have evolved. The intelligence of software is improving as the IoT initiatives continue to develop and the connectivity of systems advances. Suppliers are seeking the ability to analyze data and make decisions based on the available data. Many manufacturers are now looking to apply multiple engineering disciplines in order to develop the optimum solution for improving their operating efficiencies; whether that be through factory automation or data collection and analysis.

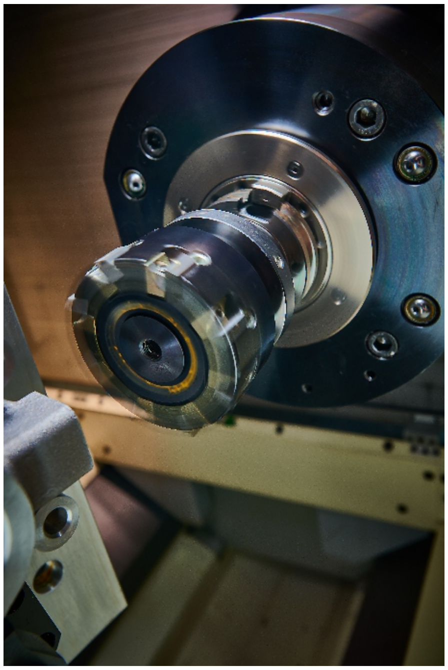
Other advantages include automation systems that are designed to boost general production capacity and to improve flexibility of the production system. No matter the system's configuration or the parts being produced, the reason companies are turning to these automation technologies remains the same: global competitiveness.

Though despite the many benefits of automated manufacturing systems, their complexity is oftentimes intimidating to first-time investors. To effectively define, plan, justify, select, implement and execute a full system integration can be a daunting task for those who are unfamiliar with the process. However, partnering with an automation expert—one who can guide manufacturers through this complex development—can not only provide financial benefits, but allow for a seamless integration.

Advantages of Automation

Businesses that have employed automation systems typically enjoy many efficiencies. Robotic automation enables a single operator to more efficiently handle several machines at once. The benefits associated with this automation are reduced manufacturing costs that result from lower direct labor costs.

Machine efficiencies for manually operated systems are typically less than 70-percent utilization, while the machine efficiencies for an automated system are typically above 85 percent, approaching 95-percent utilization. Machine counts required for known part production volumes may be reduced due to the increased efficiencies realized from automated systems. Improved part quality can also arise when transitioning from manual to automation since the manufacturer is removing the potential for human error from the part or tool setup.



One of the challenges nearly all manufacturers across all industries are facing is a decrease in technically capable workers. Consistent lack of labor availability has been a huge driver for manufacturers in every industry to facilitate automating their production process. While automation doesn't necessarily replace workers, it can help businesses handle more machines and setups with less people.

Ergonomic issues that result from workers carrying heavy parts can also be addressed with automation. This can help manufacturers avoid unnecessary medical expenses and unplanned downtime. Automating parts handling can provide increased flexibility of shop resources, with production hours growing through unattended machining or with 24/7 operation.

For job-shop types of environments—which have many part types and low part counts—automating the machining operations often bring higher productivity due to the faster part turnaround resulting from the elimination of direct setups on the machines. With less time between part setups and multiple jobs running concurrently, there is more throughput generating additional revenue. Customers enjoy shorter lead-times. Ultimately, the business is able to react quickly to market opportunities and can better compete globally due to reduced labor and part expenditures.

Increased revenue potential also comes from additional machining capacity. Imagine the profitability potential if the machine utilization is improved by only one hour a day. While the number sounds small, it can have a significant impact on the shop's profitability.

With the shop running more efficiently, the business is able to accept more jobs and diversify applications. Because the company can do a better job of tracking the work that comes through the shop with an automated system, the machines can run faster, longer and with improved turnaround. A shop that is reorganized for upgraded tracking and flow of work can also see a more efficient manufacturing process.

Finally, many customers also have an improved perception of the business when it employs state-of-the-art machining. Modernization through automation shows a company's commitment not only to their own growth, but to their customer's growth as well.

Successful Automation Blueprint

The following blueprint provides an overview of the requirements for a successful implementation of an automated system. The details of the blueprint are provided to assist you in the planning and implementation of the automated machining system that best fits the requirements of your application.

Planning for Automation	Justifying Automation	Company-wide Acceptance	Scope and Content	Production Types	Execution Planning
Increased machining efficiencies?	Increase machining efficiencies	Operations: Refine the roles	Product to be machined	High-mix and low-volume	Choose internal champion
Reduce direct labor costs?	Decrease labor costs	Quality: Monitor and maintain	Production processes	Pallet-based automation	Engage all aspects of program
Reduce production scrap?	Decrease production scrap	System maintenance and support	Operational processes	Low-mix and high volume	Define scope of work
Eliminate work-related hazards?	Decrease lost work time	Engineering: Process and systems support		Part-based automation	Single-point of contact
	Improve work environment	IT: Network management, remote access			Define request for quotation

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Justifying Automation

It is crucial for any owner or employee driving the automation process to develop a strong business case defining the ways automation can benefit the company. This business case is especially critical if the company is new to automation. These goals can often include efforts to increase machining efficiency and capacity in order to gain extra revenue potential, to save direct labor costs and setup times or improve quality by eliminating scrap.

Potential justifications for the transition to automation systems:

- Improved Machine Efficiencies: As stated in the introduction, typically, companies have seen an increase in machine utilizations from in the 70-percent range to the low 90-percent range.
- Reduction in Labor: Automation provides the potential to reduce the direct labor costs associated with the production of a part or family of parts. The reduction can be realized in the direct elimination of labor, an increase in the number of machines assigned to operators, and an increase in the unattended operation of the machining centers.
- Reduction in Production Scrap: Elimination of operator mistakes such as incorrect part loading into the fixture, running of the wrong machining programs, setup of the wrong fixture for the part number, and defects caused by improper part handling after machining can be addressed by automation systems.
- Reduction in Lost Work Expenses: Automation can improve the operating environment resulting in a reduction in injuries and hazards to the work force.

Drive Systems Manufacturer

- By automating the machining of a family of parts, the customer **increased their machine utilization to 90% over a 24-hour period** and increased their production output ten-fold in a 10-year period, with only a 10-percent increase in labor.
- One operator is currently responsible for maintaining the operation of 12 machining centers.
- Robot automated cells are producing at least a 20-percent uptick over the previous pallet automation systems.

Hydraulics Components Manufacturer

Implementing automation helped this customer run approximately **two months ahead of their normal production schedule based on manual operation of the machines.**

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Implementing Automation

Company Wide Acceptance

The company—from the leadership through to the individual team members in all departments, needs to understand and accept the changes required to support the automation, along with the new responsibilities that the implementation of automation will bring to their roles within the organization.

All concerns should be addressed at this point to ensure the company is committed and capable of executing the implementation of the automated systems and the changes that are required for the successful implementation. Many times, employees who go through the implementation of automation say they have become energized by the process improvements that automation brings, and they are excited to learn new skills.

For example, many operator roles are redefined or re-tasked to other areas. Many times, when the new automation project is completed, operators ask specifically to work on the automated cell because of its additional capabilities. The operators typically appreciate that automation handles the repetitive tasks, providing them with time to do more productive duties, such as checking parts or maintaining the equipment or production area or improving the operations in the area. Automation can be the component which rejuvenates stale morale as well as outdated or mundane processes; breathing new life into the manufacturing environment.

Critical to the successful implementation of an automation system, the following disciplines/organizations play key roles in this process.

- Manufacturing and Process Engineers: Integration of the machining process into the automation systems.
- Operations Personnel: Redefining the roles of the operations staff responsible for operating the automated system and operations.
- Production Maintenance Staff: Planning for the maintenance of the automation system, such as preventative maintenance routines and easy system recovery, to maintain the intended high rate of system utilization.
- Quality Systems: Monitoring and maintaining part quality within the automated operation.
- Facility Safety Organizations: Ensuring that the automation system meets all of the facility's safety and ergonomic requirements.
- IT – Network management, data collection, remote access to automation system controls.

It's crucial that all disciplines understand the company's goals and each of the individual roles that play into supporting the project.

Implementing Automation

Defining the Automation Requirements

Manufacturers must first know what they would like to accomplish through automation in order to determine how their system should best be configured. In other words, what benefits would the company like to experience as a result of automation? Manufacturers should determine whether the goal is to obtain increased machining efficiencies, unattended operation or reduced labor costs, better ergonomics, or the elimination of hazardous work conditions.

One of the first and foremost steps for planning automation integration is to define the part-mix and volume requirements for the automated machining system.

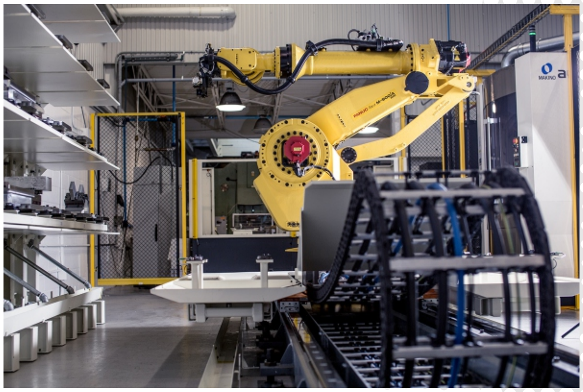
High-Volume, Low-Mix Production

A low-part mix with high-volume production runs (mass production) typically is employed in an automotive parts machining environment, where the same part is being manufactured over and over in quantities by the thousands. There is a need for automation and elimination of the direct handling of parts. Automation for high-volume production typically is a highly customized system, where each one of the systems is unique for the part or process, and usually involves a robot or gantry system that services the machining center. Parts are passed between machining centers for operations.

Makino has an engineering team that is dedicated to the design, engineering, installation, and commissioning of custom automated machining systems that satisfy the requirements of the high-volume, low-mix machining systems. Over 200 automated machining systems have been engineered and installed by this organization over the past 20 years.

High-Mix, Low-Volume Production

High-mix, low-volume production machining is typically found in the medical or aerospace industries and often include standardized automation with a system controller to control the flow of parts production. This typically includes manufacturers with the need for: small batch runs, multiple part types, quick changes between jobs, and manual handling of parts. Automation for these types of manufacturers will incorporate a transport mechanism that may move fixtures between machines or move a fixture plate between tombstones. These automation systems usually include a flexible system that accommodates multiple part types moving across the same machining center. EDM automation typically falls into this type and includes graphite electrode handling with a single (often Cartesian-style) robot servicing these machines.



Makino provides a complete line of automated system products that can be appropriately applied to the high-mix, low-volume systems. The product offerings include large pallet automation systems (MMC2), fixture-plate based automation systems (MMC R), and small pallet automation systems (Erowa/System 3R). Makino's MAS-A5 cell control system provides control of the flow of production through these systems that is developed and supported by Makino.

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Implementing Automation

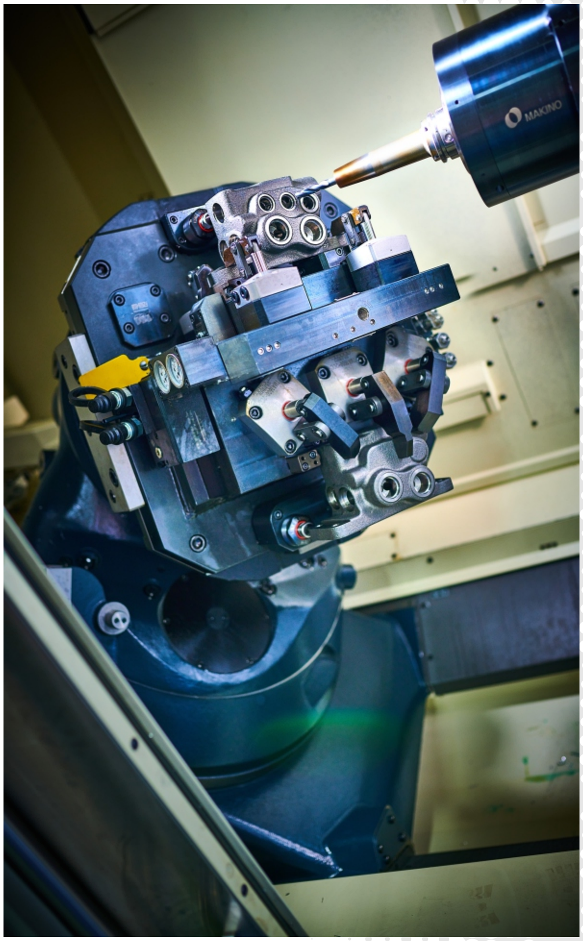
Definition of Automation Details

The next step in planning automation is to examine:

- Which machine platforms are required (horizontal/vertical, 4-axis or 5-axis machining)?
- How parts and raw materials move through the process (manual labor, pallet, conveyor, robots)?
- What auxiliary processes are required to be part of the automation system?

An essential step is to outline the complete production process for the part type or the groups of parts to ensure all aspects of the part production process are accounted for in the automation system plan. Automation can be applied to only a small portion of the production process or to the complete production process. The extent of the automation is usually dependent on application and the ability to undertake complex automation. A parts manufacturer may decide to start simple with a small portion in order for the company to become comfortable with the method of automating the machining process. However, simple or complex, the requirements of the automation must be understood in order to meet all the objectives of the automation. For example, defining what's to be done manually vs what can transition to being automated, can assist with ensuring no step has been overlooked.

From this analysis, the benefits of the automation can be better defined, such as the potential reduction in labor costs, elimination of costly work hazards, unplanned downtime and medical expenses. This calculation is crucial to understanding the potential ROI that can be achieved from automation and deciding whether automation is a sensible decision for the manufacturer.



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Considering Automation/ Integration Partners

At this point, manufacturers have the option to manage the integration process themselves or seek a single-source provider. If the decision is to use internal resources, one pitfall that can prevent a successful implementation of the automated system is when the internal resources are too busy maintaining the current day-to-day operations to execute the implementation of automation. Many times, the day-to-day operations take precedence over the development of the automation.

If internal resources cannot be dedicated to the implementation of the automation, a partnership with an automation company that can take lead in the development of the automation system that best fits their application, while working closely with the manufacturer, is a great option. The selection of the automation partner is critical and can determine how smoothly the next phases proceed.

Given the interdependence of the modern automated systems with the other systems, it is highly recommended that manufacturers work with a supplier that is able to coordinate all aspects of the integration process, including third-party equipment. A single-source supplier should be able to handle all facets of the project, enabling the company to focus its attention on larger objectives—such as the next customer opportunity, internal continuous improvement processes or optimizing business continuity. After all, time is money.

When selecting an automation partner, the products and solutions offered by each supplier should be carefully considered. Whether or not the company has advanced expertise is highly important. Past manufacturing experience with automated systems is essential, and the supplier should be able to share examples of automated machining systems successfully facilitated.

Here are some of the areas of focus in which a single-source supplier should be experienced:

- Project management with a single point of contact
- Specification/design reviews
- Drawing approvals
- Mechanical engineering
- Robot EOAT design
- Layout design
- Controls engineering
- Programming of robot/cell control
- System runoff support at customer site
- Installation/start-up support
- Final documentation
- Site supervision
- Post-installation support
- Parts tracking
- Cell management
- Scheduling
- Resource management
- System monitoring
- Maintenance programs
- Integration of equipment

Manufacturers should evaluate whether or not all equipment to be included in the automation systems can be integrated by a single supplier. A single-source supplier that has knowledge of integrating auxiliary process and equipment can provide recommendations for the entire system; streamlining the system design and purchasing process.

Early in the project, be sure to determine the criteria to be used to accept and approve the automated system. All of these expectations should be dealt within the supplier agreements to ensure successful implementation at the end of the program.

Makino offers production ready solutions that increase performance.

With Makino's expert engineers guiding every step of automation process—from exploring system requirements to reviewing current processes, to planning and developing automation to delivering and setting up machines—there won't be any surprises.

Makino's discovery process is extensive. They ask questions that most suppliers don't even consider until further in the process; when overlooked information could pose a costly roadblock. It's also not uncommon to hear that Makino proposals are the most detailed and thorough proposals submitted.

With Makino as a single-source supplier, manufacturers have a trusted partner. Makino's experts formulate a comprehensive plan for automation integration; overseeing the entire process, developing automation layouts and necessary platforms, reviewing floor space restrictions and refining the concept.

Makino's Comprehensive Process from Start to Finish

I. Define the scope of the request:

- Reasons for considering automation: reduction in labor, safety issues, improve throughput and unattended operation
- Planned labor support after automation is implemented
- Part types, part mix
- Part processing information:
    - Cycle times
    - Number of machining operations
    - Fixture configurations: number of parts, operations, manual/automatic
- Other processes required aside from the machining: i.e. wash, inspection, assembly, testing, marking.
- Current operations that the operator is completing manually while servicing the machines, such as blowing off parts, 100% inspection, etc.
- Delivery of raw material to the system
- What happens to the finished product
- Floor space restrictions
- Part tracking/data collection requirements

II. Define the appropriate automation platform

- Level of cell control required for the application

III. Develop concept automation system including layouts and present to customer

- Provide a concept of plan prior to fully developing the concept and proposal

IV. Refine the concept and present initial proposal

V. Update concept and proposal based on feedback

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System Implementation

Design of the Automation

As you work through the process of justifying and determining how to execute an automation program, the configuration and design of the automation will have to be considered. This will be intertwined with the previous steps, as the process will depend on your knowledge of automated systems and your plan for executing.

From a design standpoint, there are numerous factors for consideration:

- Floor space: The automation cell should be designed in a way that optimizes the use of floor space.
- Operator involvement: Consideration will need to be given to the involvement of the operators in the automated machining system, such as part inspections, tooling replacement, pack-out, deburring, etc.
- Material input/output: The flow of material through the cell must also be decided—such as where the raw material is introduced into the cell and where the finished product exits the cell. What will be the method of buffer in the cell to accommodate unattended operation, if necessary? How much buffer is necessary for input, output, and in-process part buffers?
- System capacity: Specifications for the production volumes should be known, as should requirements for additional capacity. If additional capacity is a possibility, a plan for future expansion should be in place. This plan should include the needs for future machining centers, material handling and additional part types.
- Material tracking: Outlining the materials tracking process will help with designing the automation. Some questions to consider are:
  - Will parts need to be automatically marked, identified and tracked?
  - Will secondary operations such as deburring be an automated feature managed robotically?
  - Is online inspection necessary to ensure the quality of all parts leaving the cell?
- Process Management: How will the machining processes be monitored to ensure the process is still in control? What will happen with rejected parts within the system? How will process checks be handled. Without an operator running the machine during unattended operation, then the machining process should incorporate automated features that monitor the machining process, such as tool-life monitoring and tool-breakage functions.

With the proper monitoring functions, the machining equipment could detect when a tool is becoming dull (reached the end of its life), and if a tool has broken during the machining process. Many shops employ other functions, such as part probing, to monitor the process and to find the exact location of the part before the machining process begins. Shops can also utilize part-seat detection to ensure that the part is loaded properly in the fixture. Both help to safeguard that the automated system is producing quality parts.

In an unattended environment, process checks should be conducted to manage the quality of the part. If the process is capable enough, a company can ultimately reduce its costs on part inspection within the automated system.

Makino machining centers offer a significant number of standard machine options that are either required or can greatly enhance the reliability of an automation system, such as Tool Break Detection, First Tool Used Detection, Data Collection Support. In addition, Makino offers the cell control systems (MAS-A5, Robot Cell Controller) that can schedule and monitor the operation of the automated machining system with standard interfaces defined for each of the Makino machine control systems. This provides a seamless integration of the machining centers with the automation systems.


Makino MAS-A5

System Implementation

Executing the Automation Plan and Integration

Managing the execution can be broken down into the following steps: design/engineering, installation, start-up/runoff, and productization.

At the beginning of program execution, a program schedule should be created to identify the required resources and the timing of their involvement. Also, significant milestones for the program should be identified and monitored during the course of the program to ensure that it is progressing on schedule. Makino has a team of Project Managers that specialize in the execution of these types of programs.

During the design/engineering phase, the progress of this phase is monitored via design reviews and approvals. For each component of the automated system, i.e. robot End-Of-Arm Tooling (EOAT), design reviews should be conducted which include all engineering disciplines that are either directly involved or indirectly effected by the design of the component. This is very important as the automated system typically involves the integration of several pieces of equipment into a single cohesive system.

Early in the design/engineering phase, a Safety Risk Assessment must be executed. This assessment identifies all safety hazards that the automated system will present to the work force during operation and provides a mechanism to evaluate and eliminate those hazards to operate and maintain a completely safe system.

Prior to installation, a single point of responsibility for the installation of the system needs to be identified. This individual will coordinate and monitor the day-to-day activities during the installation to ensure that all milestones are being met, all necessary resources are available, and that installation issues are being resolved. Makino identifies a Site Coordinator for each project who assumes the responsibility for the installation and the day-to-day activities.

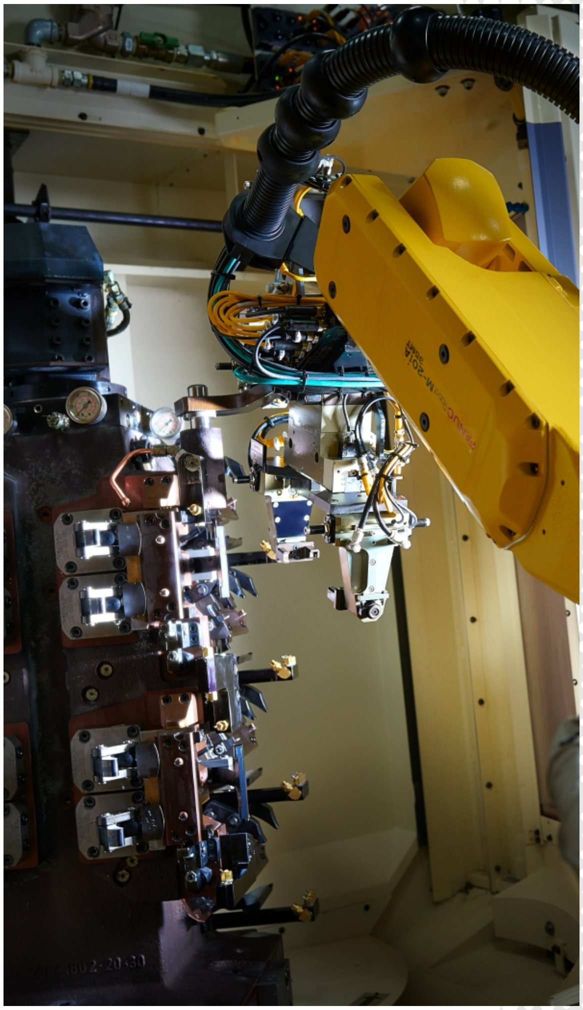
Once the installation is completed, the system must be fully tested. Makino provides a System Test Checklist which is used to fully test an automated system, including the abnormal conditions that will be encountered during the production operation of the system. A checklist is essential to identify and test as many scenarios as possible prior to beginning to run production through the system.

The next step is the system acceptance event which typically includes confirming the automated system is capable of producing at the targeted throughput rate reliably over an extended period of time, typically 8 hours. This step is important to identify the potential weak points of the system that may not perform during normal production operation and to confirm the pacing operation in the system, typically ensuring that the automation is not the pacing operation.

The final step is productization. This step consists of fine tuning the automation system by correcting those reoccurring nuisance issues and implementing improvements that allow the system to consistently produce at the expected throughput rate. Depending on the complexity of the automated system, this step may require 3 to 6 months.

Conclusions

- Seamless integration of automated systems must begin with proper upfront planning. Expectations must be set in terms of production volume and part variety before a proper system type can be identified.
- Investments in automated systems affect more than just the shop floor. During the planning process, it is important to involve leadership from all areas of an organization to ensure the correct decision is made and that all facets of the business are prepared for the shift in production.
- Selecting the right suppliers and integration partners is critical and can simplify all aspects of the project. This is especially important for first-time investors in automation.
- Determining automation technologies and auxiliary processes must be accomplished during layout procedures to ensure efficient workflow. Be sure to verify all requirements for a completed part.
- Execution begins with a thorough review of all project designs, as well as establishing milestones. Take time in the scheduling process to ensure that all components are set to arrive at the appropriate times and adhere to established milestones.



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