MANUFACTURING EXECUTION AND OPERATIONS MANAGEMENT AUTOMATION

BRUCE ISBELL, MENTOR GRAPHICS

Make or Buy?
A discussion of the pros and cons
The core value of automation for Manufacturing Execution Systems (MES), or Manufacturing Operations Management (MOM), is to enable on-time delivery of a quality product at the lowest cost. This value is a competitive necessity shared by all electronics manufacturers and as a result, many companies have taken and or now taking the challenge to deploy automation for this purpose.

Very often, the decision to shift to MES or MOM automation is accompanied by considerable management debate over whether to invest upfront capital into a third-party software solution, or have the organization’s highly skilled employees put time and effort into the development of an internal software. This is the first cycle of the “make or buy” conflict. Management faces a tough decision here, as critical business factors such as capital expenditure and dedication of human resources come into sharp focus and discussion.

If a homegrown automation solution is chosen, this first development cycle is only the beginning. In the natural course of software development and platform upgrades, routine maintenance and often complete rewrites are required continually as business needs and technologies change. Since human resources and expenditures are again required, additional cycles of “make or buy” are encountered. Although it might seem as though the decision parameters on these secondary cycles are different, in fact they remain exactly the same as in the first cycle: invest more in internal efforts or purchase a solution from a third party.

In this document, we review the advantages and disadvantages of making or purchasing a MES or MOM automation solution (henceforth referred to simply as MES Automation).

WHY MES AUTOMATION?

Let’s begin by positing the main purpose for creating this automation in the first place. MES automation is desired to improve competitive differentiation and to advance the company’s goals to continuously improve new product introductions (NPI) and production process efficiency. Four main factors either stand in the way of achieving these goals, or form the gateway to success:

**Product Quality** - the highest possible quality must be maintained, to fulfill the customer demand and safeguard the brand name. In all cases, quality is untouchable.

**Time to Market** - the shortest possible time-to-market is fundamental to overcome any competition and to leverage short product life cycles common to many electronic products, especially in the consumer markets
Operational Expenditures - these are expected to be minimized, without impacting quality or performance, especially in the area of on-time delivery. The primary drivers of operational cost in electronics assembly manufacturing are materials (i.e. inventory), labor, capital equipment and facilities.

Compliance and Audit Trail - organizations must comply with current industry standards and be able to present clear audit trails. Many OEMs also require conformance demonstrated via audit trail or device history record, in addition to industry standards or regulations, to ensure customer specific requirements are followed.

In the electronics assembly manufacturing world, the classic business terms noted above break down into several elements. The make or buy decision should be made through a lens focused on how the end product will affect competitive differentiation defined via improved performance in the following business elements:

- Process development
- Test development
- Production optimization
- Asset Utilization
- Inventory Management
- Material Verification
- Product Traceability
- Quality Management

Each of these factors has a different impact and implication regarding the core business values among different companies. However, even within different departments of the same organization many different implications can be seen. For example, in the high-volume production line, a reduction in per unit cycle time of only a few seconds may translate to millions of dollars in additional revenue. In the high mix production area, reducing changeover time between work orders relieves additional capacity for more production and more revenue. In procurement and inventory management, eliminating excess inventory can create millions of dollars of cost savings which directly impacts the bottom line. In the engineering departments responsible for introducing new products, the quality and time required for process and test development, creating production recipes such as SMT programs, test and inspection programs and fixture designs have an impact in every area. If manufacturing development for new product introductions can be reduced from several days to just a few hours, without errors, the direct impact on time to market, product quality and brand loyalty can mean success or failure for the business. In addition, even before production contracts are signed, program managers need the ability to provide immediate objective manufacturability feedback to their customers with clear DFM analysis of the product design.

WHAT SHOULD MES AUTOMATION INCLUDE?

The make or buy decision starts with a clear understanding of the intended scope of the solution. The broader the integration into each area of manufacturing, the more leverage the solution has to achieve its goals. In order to translate into cost-effective business values, MES Automation should address each of these areas, and offer a variety of configurations and tuned capabilities based on the most critical challenges and obstacles in manufacturing operations of the enterprise. Here we review each of these elements one by one offering these as a guide to the components of world class MES automation. Following these descriptions we will then take a detailed look at the pros and cons of in-house development vs. outside purchase.
1 PROCESS DEVELOPMENT

Achieving fast process development without errors at a lower total cost is the goal of this automation element. Process development includes all recipe, documentation and data requirements to introduce a new product into production with perfect quality from the very first PCB. We call this Right-First-Time manufacturing. This can be accomplished by incorporating the following characteristics:

- Automation modules for DFM, machine programming, test engineering, documentation and stencil design, each of which can leverage a central component library containing the physical attributes and shapes of each component part number used in production.
- BOM management, error checking and comparisons, including verification of AVL (Approved Vendor List) components for correct equivalent attributes.
- BOM centric machine programming for production including ability to auto-generate new part data for specific SMT machines used in the production lines.
- Centralized product data model that is used in parallel for SMT programming, test and inspection development, documentation and stencil design.
- Direct link linkage of machine programs and digital work instructions to the BOM data for automated updates upon new revisions and ECNs.
- Centralized libraries which learn new part numbers and attributes every time a new product is started.
- Precise machine models and line configurations for accurate offline production simulation to calculate and optimize cycle times, and solve complex line balancing and product grouping challenges, even between different machine platforms.
- Offline verification of each production ready SMT program to ensure correct rotation and placement of all components, “as built” in a virtual world before production starts.

2 TEST DEVELOPMENT

The speed of a new product introduction development cycle can only be as fast as the readiness of last development segment. This is often on the test engineering side of the house. Keeping this critical function in parallel with Process development is the goal, so that neither becomes the bottleneck to the start of production. Robust automation for DFT is necessary and should include the following characteristics:

- The ability to create machine specific tester programs for ICT and Flying Probe based on a common product data model.
- The ability to create machine specific inspection programs for AOI and AXI based on a common product data model.
- Include physical design for test (DFT) analysis.
- Include ability to analyze fixtures designs for reuse, determining which test probes can be altered based on a new revision of the PCB design.
3 PRODUCTION OPTIMIZATION

Improved production flow with minimal time lost for changeover between work orders, or capacity losses due to ineffective production planning are both crucial concerns to achieve on-time delivery, every time. This is a fundamental goal of MES Automation and should include the following characteristics:

- Auto-assignment of work orders (or groups of work orders) to production lines to achieve “best fit” using real constraints of actual machine placement rates, material availability, feeder capacity, line configurations, previous setups and static feeder setups.
- Optimize the production sequence of all work orders based on the current delivery schedule according to customer priorities, using the above real constraints plus, planned downtime for maintenance and working hours of the factory.
- Ability to choose as many production work orders as necessary, without limit, to automate best possible product groupings and line assignments to achieve best delivery schedule or best utilization of capacity, depending on goals.

4 ASSET UTILIZATION

The goal of this module is to enable the enterprise to do more with what they have. Real-time and historical analysis of factory performance is required to find and eliminate areas of waste. Combining operational performance data with an understanding of the work orders, production routings and schedules, this automation will yield the business intelligence needed to maximize utilization and put to use every advantage possible. The following characteristics of this element are required to achieve this goal:

- Remote or on-demand graphical display of real-time machine performance including machine status, actual cycle time, machine errors, feeder performance and Pareto view showing which feeders are next in line for splicing or replenishment and how many more panels can be produced before the feeder reaches exhaust point.
- Remote or on-demand graphical display of machine and line performance in a factory wide view 24/7, including machine status, bottle neck location, change over time, beat rate, and all machine or feeder errors.
- Data collected through a robust machine interface, using one centralized system regardless of machine platform or model, and a common graphical user interface for all control actions and displays.
- Identify machines and feeders by individual IDs so that individual performance histories are used for trend analysis, preventative maintenance and audit trails.
- Machine interface must also integrate with other elements such as material verification, material management and traceability.
- Centralized data that is shared between asset utilization functions, quality management and material verification to create a rich source of information for business intelligence.

Designing in-house MES software from scratch is extremely time-consuming and becomes a burden on the R&D team.
5 INVENTORY MANAGEMENT

The operational goal of inventory management is to get the right material to the right place at the right time to keep production moving according to the production plan. All this needs to be accomplished without excess inventory used as a hedge against poor planning. This element of MES automation can accomplish these logistical goals and eliminate excess inventory using the following characteristics:

- Use Lean principals to streamline the flow of material from the stock room to each line on the shop floor on a Just In Time (JIT) basis.
- Use the aggregate of all real-time demand signals (low warnings from each feeder position on each machine) from each machine interface to guide the generation of pick lists as needed for each line on a recurring interval, such as every 30 minutes. This prevents over-supply and therefore more material remains freed up for use on other work orders. This also eliminates the need for buffer stock.
- Use the machine interface to keep an accurate count of components remaining on every reel during production, per individual reel ID. This eliminates the need to manually count parts on the reel and improves the accuracy of the overall inventory.
- Report material transactions such as scrap, consumption and Return-to-Stock back to ERP in order to improve the effective application of ERP.
- Track movement of inventory in and out of the stock room based on reel or tray ID and bin locations.
- Use a pick list logic that pulls material from the most efficient location first, including dry storage locations and area stock rooms located near the production lines.
- Utilize the ability to split reels and therefore allocate material efficiently to multiple work orders where the same material is needed in different locations.

6 MATERIAL VERIFICATION

Perfect quality can never be achieved without automation to accurately and objectively enforce the correct manufacturing recipe in the execution of the production work order. Two of the most crucial parts of this enforcement are 1) lock out production unless the correct program is being used per the requirement of the work order 2) lock out production unless the correct materials are used for each machine feeder as dictated in the machine program. The successful application of this MES automation element requires the following characteristics:

- All verification is based on a unique ID applied to every reel and tray at incoming inspection. Material attributes such as internal part number, vendor part number, vendor name, vendor lot code, quantity, purchase order, MSD status, RoHS status are captured to the database for each reel ID
- When loading a reel onto a feeder the reel ID and feeder ID are compared to ensure the correct feeder type, then joined in the database. In this way all the material attributes are now connected to the feeder ID
- When setting up production, either on offline mobile feeder units (trolleys) or on the machine itself, the graphical user interface, must guide the operator to load the feeders into the correct slot. Production is locked out until every position is verified.
- MSD (Moisture Sensitive Device) countdown timers are tracked for each MSD device per reel ID, including countdown suspension while in dry storage and tracking the number of re-bake cycles to ensure full compliance. Production is locked out unless each feeder with an MSD part is in compliance.
AVL (Approved Vendor List) is enforced by locking out production if a feeder containing a part number violates the AVL requirement.

Enforce correct production routing by locking out production if a Work Order is loaded onto the incorrect line.

**PRODUCT TRACEABILITY**

Most segments of the electronics manufacturing industry require some level of material traceability for each work order or for each individual PCB ID within the work order. In the most strict case, traceability compliance may require that material lot codes be traced to each individual reference designator on each PCB ID and that traceability reports be instantly available on demand. Whatever level of the material traceability is needed, success with this element depends on the following:

- Use of central database connecting material verification data, machine performance data and work order tracking along the production route.
- Automation maintains an integrated data chain during normal production, splicing events, feeder changes, part substitutions, line changes and unit repairs where a defective component is replaced with another part.
- Trace data can be supplemented with quality data and WIP tracking data throughout the production routing to create a complete device history record.
- Compliance reports are available at the push of a button.
- Use of diagnostics performed on trace data to turn manufacturing problems into opportunities for improvement by drilling into the data to find the root cause of a problem and fixing it quickly.

**QUALITY MANAGEMENT**

Quality management ensures that manufacturing is correctly executed and drives the manufacturing operation toward the goal of zero defects. This element must achieve its goals without adding to the overall cost of production, therefore a great deal of incentive is placed on preventing defects. This element can achieve its goal using the following characteristics:

- Abstraction of tests results from resources and test stations are used to identify the location of the work station, materials and program data used in the creation the defect, with direct feedback sent to that work station as an alert. This is the heart of a preventative approach to quality.
Test or Inspection cycle is linked to the repair function so that this element has a closed loop which cannot allow a failed product to advance in the routing until successful repair is validated by re-test or re-inspection.

Repair station includes visual instructions and guided diagnostics to quickly determine an actual failure vs. a false failure.

Visual work stations based on a rich graphical display of the PCB board including logical connections via the net list, component attributes and work instructions created by process engineering team. The work stations have a roles based purpose, so that the user interface changes as needed for Visual Inspection, Test and Repair, or Work Instruction display with active feedback, or simple pass through stations used in wip tracking.

Additional related characteristics to achieve this element purpose:

- Maintain hierarchical product genealogy as subassembly serial numbers are added into a higher level assembly
- Parsing of result data and aggregation to a central repository
- Statistical results analysis
- Data querying
- Report generation
- Dashboards, trend analysis, and automatic alert mechanisms

**PROS AND CONS**

Both “homegrown” and “off the shelf” solutions have benefits and downsides. When the organization must take a decision whether to MAKE or BUY an MES Automation solution - the above list is a useful tool for assessment of the long-term financial and technical values that the two options offer. As you can see from the eight elements described above, a full MES Automation solution touches almost every aspect of production from initial design review all the way to finished goods.

Here is the list of the most significant pros and cons for each option, as we learned from our customers’ management and technical teams.

**HOMEGROWN DEVELOPMENT**

**Pros**

- Tailored to the department requirements
- Direct internal control of features and timelines

**Cons**

- Requires considerable internal effort in developing a product which is not the company’s core business
- High cost — many resources are invested (human resources, management, QA/verification)
- Continual, expensive maintenance
- Knowledge base is dependent on specific personnel
The design may tailored to a specific department’s needs, and not flexible enough to support other groups

- Limited performance and scalability
- Full deployment is time-consuming
- High risk of an unsuccessful implementation
- Successful deployment may require extensive training or upgrading the skill sets of the user, depending on the level of intuitive nature of the solution.

- Support availability- usually limited and lagging behind need, especially in manufacturing operations that run 24/7 or with multiple sites in different regions, possible using different languages
- Documentation is usually lacking or unprofessional and “word of mouth” based
- The software life span is usually shorter than expected

PURCHASING A MES AUTOMATION SOLUTION

Pros

- Automation deployment duration is reduced
- Expenses over a medium-to-long timeframe (2-5 years) are much lower
- A stable, market-tested and mature product is used
- “Living” product, with cutting-edge technology based on a professional roadmap and lessons learned from numerous users around the world
- Guaranteed, on-demand professional customer support
- Verification of the software’s value can be undertaken in stages prior to implementation
- High usability of the software makes training easier and less expensive
- System scalability can be pre-assessed
- Full professional documentation is provided, and is updated with product changes
- Methodology, knowledge and experience are gained through a framework developed for the needs of multiple companies and departments
- Readymade sets of built-in components available for use immediately
- Additional Pros of the Valor® MSS Solutions Suite
  - An end-to-end solution comprising all necessary components for automation
  - Powerful scalability built on a solid, integrated database and many API are include to help with connections to other 3rd party or internal systems
  - Built-in domain expertise in each module dramatically reduces the implementation effort compared to more generic MES tools
  - Modular and scalable architecture makes it easy “add as you need”
  - Full deployment of a complete system includes robust Business Intelligences module with a high level of domain expertise built into the software. Dash boards and queries can begin adding value of actionable information and decision support almost immediately.
Cons

- The modules of the MES solution may not meet 100% of specific needs, therefore some customized automation in the form of special scripts or APIs may be needed.
- Additional features or new machine coverage are dependent on the source company
- Up front capital investment required
- Continuing annual maintenance fees required to stay current with new updates and 24/7 support

WHAT’S THE ANSWER?

Assessing whether to build or buy an MES Automation solution is often resolved with the understanding that designing an in-house solution from scratch is extremely time consuming and usually becomes an exhausting burden for the company’s R&D team. The most important advantage of a “Homegrown” solution — that it is custom-designed to meet a company’s unique requirements — is losing ground to innovative new technologies that can be quickly configured and deployed, such as the Valor MSS solution suite from Mentor Graphics.

Valor MSS is a flexible, scalable solution that is easily configured for any PCB manufacturing environment. Companies can maintain R&D efforts where they are mostly needed — in product development — while reducing manufacturing costs, improving on-time delivery, and assuring product quality.