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Siemens Digital Industries Software

Electronics production planning

Make manufacturing part of your organization's enterprise digitalization strategy

Executive summary

Having a digital enterprise strategy is required to remain competitive. Traditionally, electronics manufacturing has been a separate part of the overall product development process. Electronics assembly manufacturing has predominantly been siloed with disjointed ecosystems, organizations and processes. This white paper focuses on the business challenges of original equipment manufacturers (OEMs) and vertically integrated manufacturers that design large and/or complex products. We will address the challenge of designing, planning and manufacturing a product that is both mechanical and electronic.

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Abstract

We will discuss how one can manage manufacturing data, manufacturing process planning, electronic work instructions (EWIs) and production optimization, along with process validation tools for electronics manufacturing, as part of the overall product realization process. Furthermore, we will demonstrate how having a single source of truth for both mechanical and electronic content with strong governance can bring electronics manufacturing into the digital thread of the product design lifecycle and improve an organization's competitiveness in the marketplace.

This white paper focuses on how electronics manufacturing can be part of an organization's enterprise digitalization strategy, what steps to take and how to close the digital gap from product design to production execution.



Establishing a foundation

Manufacturers must connect to and enrich the digital thread from design to execution and beyond, not only to relieve the pressures of today but also establish the required foundation for tomorrow. Traditionally, electronics manufacturing has been a separate part of the overall product development process. This is especially true for automotive, aerospace and industrial and heavy equipment companies. These companies must deal with highly complex products, with many layers of mechanical and electronic designs that need to work as designed. However, in today's paradigm, mechanical and electronic parts are designed, managed, planned, and manufactured in completely different ecosystems, with different organizations or departments, and potentially different partners or external suppliers. How can one control, manage and govern the design content, intent or quality?

Manufacturing planning

To stay competitive in the digitalization age of manufacturing, design organizations of complex products must author, analyze and manage manufacturing process plans efficiently and effectively and communicate them throughout their organization and the extended enterprise.

By introducing manufacturing process planning during the design-to-manufacturing phase allows manufacturers to take an engineering bill-of-materials (eBOM) and create an effective manufacturing bill-of-materials (mBOM) to then configure the product bill-of-process (BOP) and the plant BOP independent of each other. These stages bridge the connection between the

product-centric and plant-centric views of building a product, allowing one to standardize and re-use assembly processes across multiple plants and balance production lines. A product bill-of-process contains components and subassemblies and the recipe for the operations and resources needed to build the product. A plant BOP consists of stations and cells with the list of operations that can be performed by them.

With the right tools in place, a manufacturing planner or process planner will know the exact context of their tasks so they can make faster decisions. They can visualize and resolve conflicts between the product and multiple-plant BOPs.

Maintaining engineering and manufacturing BOMs in disparate systems can cause inefficiencies when product designs are frequently updated and launch schedules are constantly squeezed. With an integrated product and process development platform, manufacturing engineers can quickly update process plans according to any design changes.

As described in figure 1, after the manufacturing hand-off there are several stages to ensure the manufacturing of a product design can be done in shorter innovation cycles, with more flexible production at quality and cost. In addition, during the process planning and production planning stages, engineers must have the capabilities to perform front-end design for assembly (DFA) analysis, BOM validation, manufacturing and support tooling design (for example, stencil, part definition, etc.), machine programming and line balancing for both mechanical and electronics manufacturing.

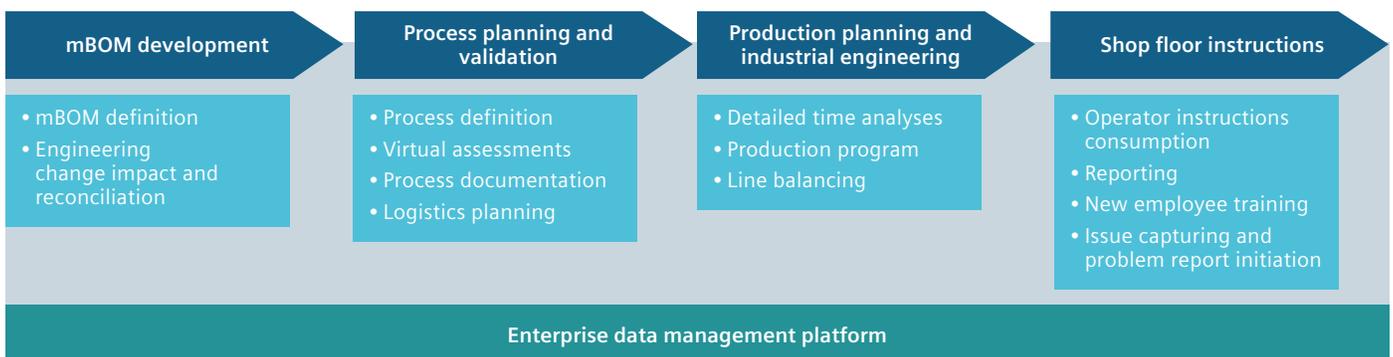


Figure 1. Product realization process (post design).

Business challenges

Production challenges

Almost all manufacturing companies are facing similar challenges:

1. Disconnected data ecosystems and workflows:

- Mechanical design validation, planning and simulation
- Circuit board assembly validation, planning and simulation

2. More products/variants on the same line:

- The need to manage the growing complexity of production systems
- The need to add production of new variants into existing production lines with minimal disruption

3. Growing number of projects:

- Drive the need to increase planning efficiency
- Drive the need to increase success rate to win deals while making sure the promises (cycle time, availability) can be met
- Drive the need to ensure smooth and quick introduction of changes into production to minimize disruption

4. Global production:

- The need for standardization
- The need to easily share and re-use data across engineering and production sites
- The need to include the supply chain (line builders/equipment suppliers)

5. Planning to accurately meet cost, throughput and availability targets.

6. Gut feeling and experience of planners is no longer going to be good enough and scale and efficiency will require systemization of the know-how.

7. Need to track cost from early concept throughout the process.

8. Continuous validation to check throughput and availability.

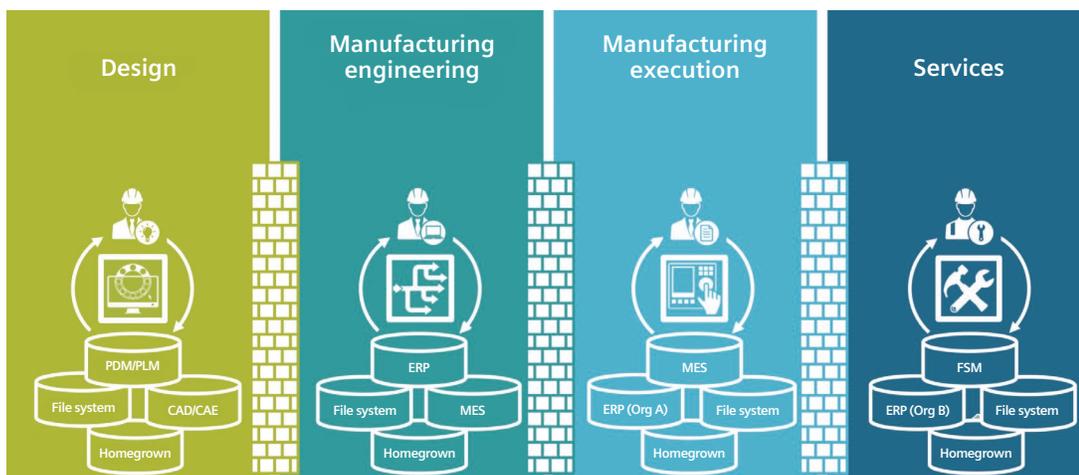


Figure 2. Silos of systems and processes within departments.

Departmental challenges

Silos of systems and processes with manual handoffs and redundancy that are created when departments are not integrated into an enterprise data management system or product lifecycle management (PLM) system can drive additional synchronization issues with engineering changes, revision updates, unmanaged production instructions and many others.

In addition, the specific roles in the manufacturing environment have various challenges when planning is not harmonized between design and manufacturing and when there is no formal manufacturing planning for the entire product. These are further described in figure 3 below.

Integrated production planning

In the age of digital manufacturing, having an integrated production planning environment that leverages the same enterprise data management infrastructure with PLM systems is of critical importance. Siemens Digital Industries Software finds that moving production planning closer to the design infrastructure, or “shifting left,” provides the opportunity for developing an mBOM directly from the source design or eBOM. This provides the opportunity for designers to have visibility into the

processes that will be required to complete manufacturing, the same source computer-aided design (CAD) and BOM to run simulations on both the mechanical assembly process and the electronic printed circuit board (PCB) assembly process. This enables the user to synchronize revision spins, engineering changes and design changes for the purpose of coordinated manufacturing planning and effective model-based quality.

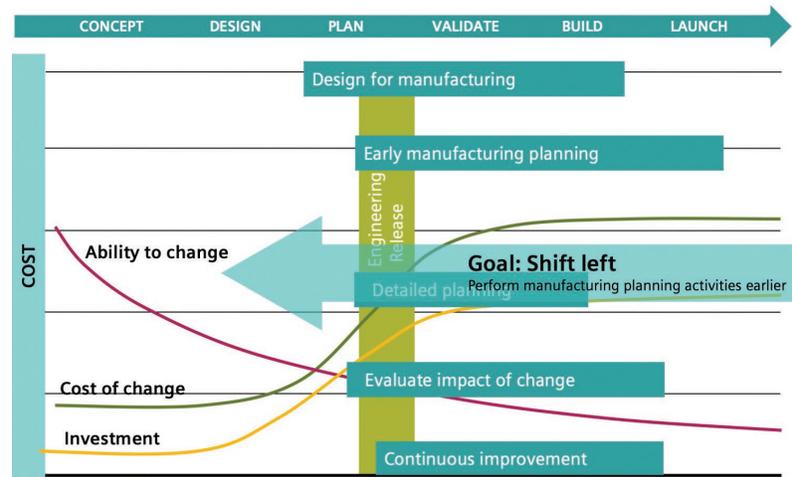


Figure 4: Shifting production planning closer to design.

| Supply chain manager | Quality engineer | Process planner | Shop floor operator | IT |
|--|--|--|--|--|
| <ul style="list-style-type: none"> • Low material turnover • High scrap rate • Low predictability | <ul style="list-style-type: none"> • Test plan not in sync with assembly plan and product changes • Difficult to assess quality of the entire product • No single traceability record | <ul style="list-style-type: none"> • Product data is complex, outdated, hard to access • No standardization across sites | <ul style="list-style-type: none"> • Different machine interfaces • Work instructions are not up-to-date | <ul style="list-style-type: none"> • Outdated legacy information systems • Multiple interfaces to maintain |

Figure 3. Manufacturing role's challenges.



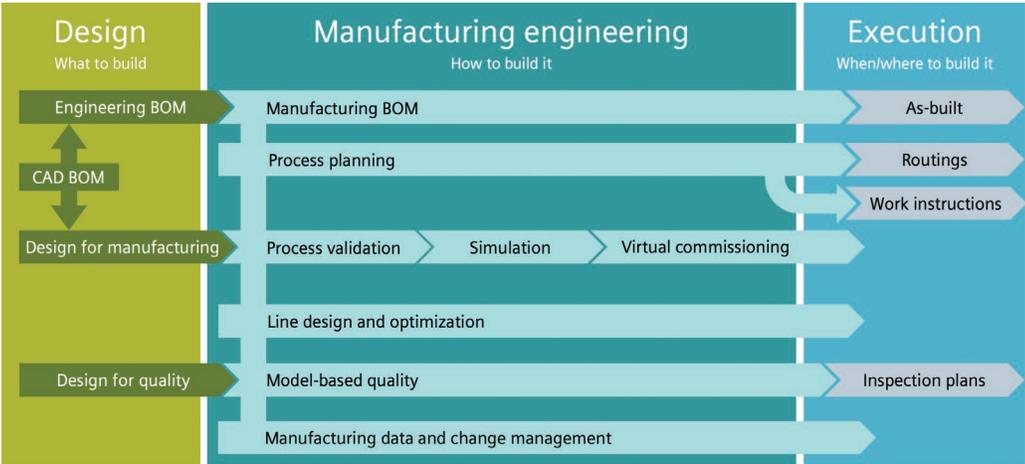


Figure 5. Benefits of moving production planning into enterprise data management systems.

Some of the functional activities an enterprise production planning environment can provide as it synchronizes with both design and execution (manufacturing) are included in figure 5.

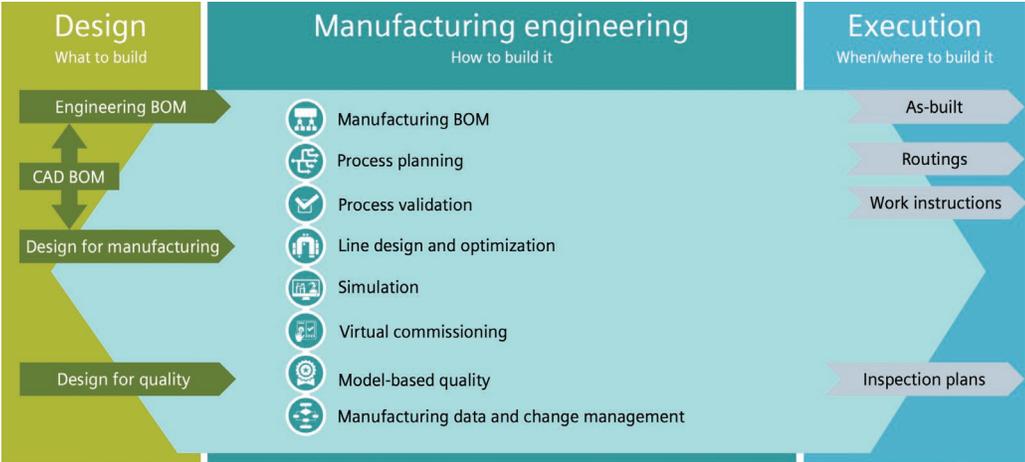


Figure 6. Functional activities that benefit from shifting left.

Why create an mBOM

Abstracting a design BOM into producible allocations is normally a critical initial step in production planning. Many single eBOM lines may require multiple manufacturing steps, each requiring BOM lines of their own. This abstraction based on required producibility is the basis for why a manufacturing BOM is needed. In addition, the mBOM is the main input for enterprise resource planning (ERP) systems. It is the mBOM that determines the true costs, labor and producibility of the product. In

most cases designers are not aware or do not have the knowledge of the required manufacturing steps, subassembly steps or additional manufacturing processes and parts needed to produce a single engineering BOM line. In addition, eBOMs represent the product architecture, thus it is built according to the organizational systems and functions, while the mBOM is organized according to the manufacturing assemblies sequence. That is when it can be used as the basis for a BOP.

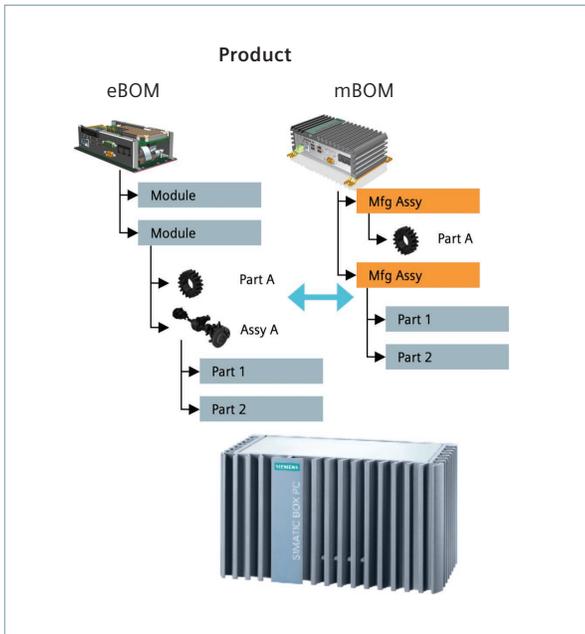


Figure 7. eBOM to mBOM abstraction.

What is a BOP

The eBOM and related mBOM are a list of parts and materials needed to make a product. It shows what to make, not how to manufacture it, leaving the rest up to the BOP.

A product BOP contains components and subassemblies and the recipe for operations and resources needed to build the product. A plant BOP consists of stations and cells with the list of operations that can be performed by them. This capability bridges the connection between the product-centric view of building a product – the product BOP – and the plant-centric view of building a product – the plant BOP – while maintaining the important connection to the manufacturing BOM under revision control throughout the manufacturing planning process. The bill-of-process combines the design data, manufacturing data and shop floor data into a coherent structure. The BOP links parts, tools, plant data, assembly sequences, various types of operations (robotics, human, machines), process collateral (attachment), detailed instructions and more.

The use of a BOP has become a standard in many industries in which operations are repeated and dependence on resources (tools, fixtures) is critical. The introduction of a BOP has significant value, providing an ultimate connection to the shop floor while manufacturing

execution systems (MES) are process driven and require detailed operation descriptions. The BOP allows change management at the level of a single operation.

Traditionally, companies with many plants and processes may have only had informal BOPs. If there were any changes that needed to be communicated to the rest of the enterprise, it was typical for the process to take a long time. The lack of efficiency, scalability and visibility in this methodology can be easily seen.

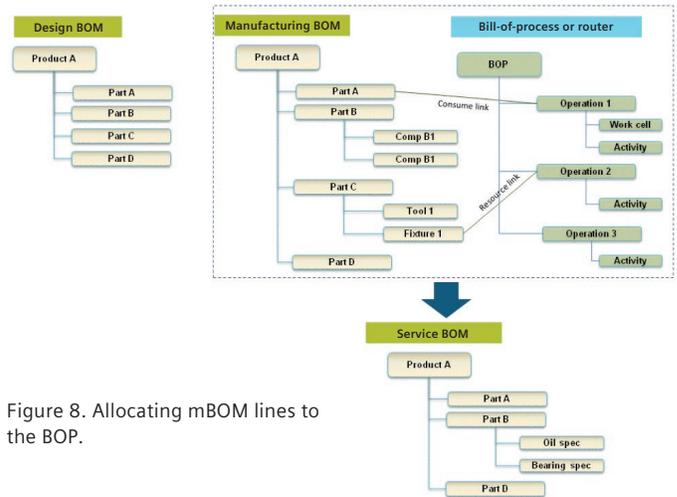


Figure 8. Allocating mBOM lines to the BOP.

Circuit board assembly manufacturers, mechanical parts assembly manufacturers and system assembly manufacturers all create a bill-of-process in the initial planning stages in their ERP system, then create a modified version on the factory floor using other systems, travelers, online documentation, etc.

Moving the function of production planning into an integrated enterprise data management solution allows mass synchronization across the design to manufacturing planning and simulation. In figure 9, one can see how changes in the design and the related eBOM can propagate through planning, simulation and into manufacturing.

The mechanical and electronic divide

It is abundantly clear the skills, know-how and domain expertise required for mechanical and electronic manufacturing are quite different. However, it is also clear there are few products in the world that are only electronic. Also, the drive to create more smart products are driving more electronics into traditionally mechanical-only products.

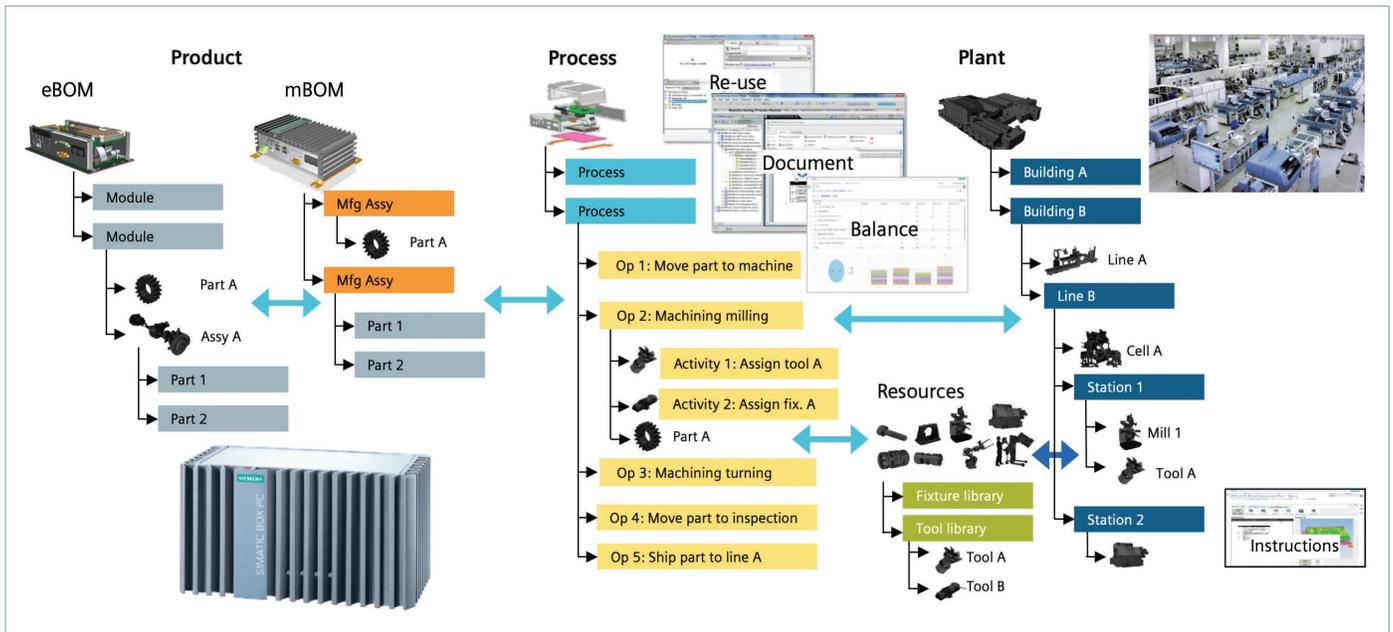


Figure 9: Design change propagated through to manufacturing.

Most enterprise data management vendors, with their related PLM solution, already provide capabilities to manage, author, plan and simulate (to some degree) mechanical manufacturing. However, what is needed is to include the electronics manufacturing domain. This is desperately needed for complex product manufacturers to remain competitive.

In PCB assembly specifically, surface-mount technology (SMT) machines and processes present a unique challenge to generic manufacturing planning tools. The performance of SMT placement machines, no matter how efficient and effective, is directly influenced by the layout of materials on the machine, which is related to the sequence of work orders. SMT performance overall is strongly linked to the size of work orders and the degree of product mixing. Most PCB manufacturing equipment has been designed to be efficient for high-volume manufacturing, but the trend is toward a higher mix of products and variants with reduced quantities per discrete work order. The entire factory planning model has become significantly more complex with this higher mix because every element in the factory must be configured to allow interleaved production of smaller batch sizes.

At the other end of the spectrum are tools provided by SMT machine vendors that are obligated to provide software that can create optimized programs for their machines. This software provides support for creating common feeder setups to reduce changeover time between products. The scope of these functions is limited, however, because vendors focus on line-level solutions within their own set of machines, without considering product sequences based on customer demand, work orders, cross-line product allocations, or processes ahead of or beyond the SMT area.

The cost to the operation due to such mixing comes from the significant time it takes for the changeover between products, which can be substantial given the sheer number of different materials that go into each product, typically numbering in the thousands. Companies that have made the transition from stable, consistent, high-volume production toward more volatile, higher mix production have recorded reduced productivity of 50 percent or more. Whereas high-volume lines can be expected to make several products every few minutes, in an extreme case a high-mix line will make the same quantity of products over an entire day. The production cost of each PCB produced, which includes the fixed costs of the production facility, SMT machine investment, direct and indirect labor costs,

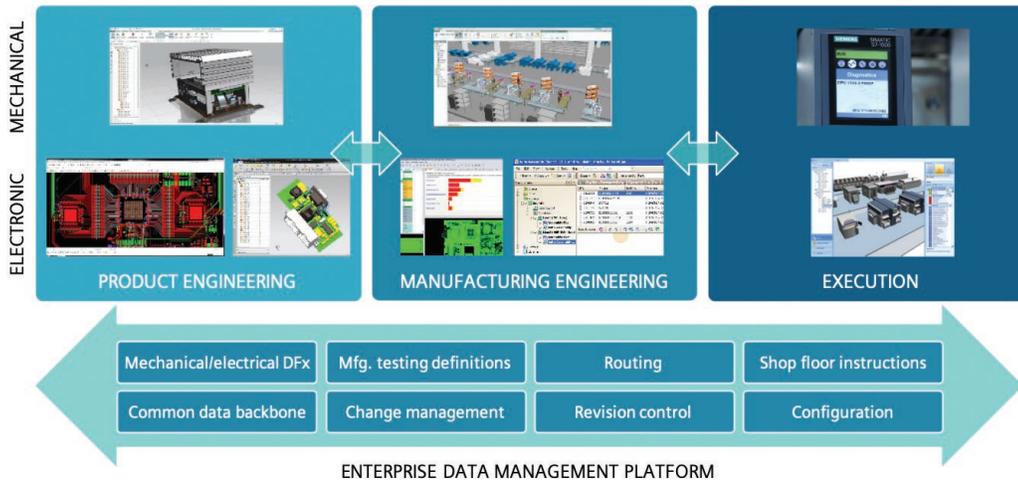


Figure 10. The mechanical and electronic manufacturing divide.

etc., in the low-mix situation can be more than 250 times higher than for high volume. The goal for anyone managing an operation faced with this increasing mix of products should be to find a way to minimize this cost so they can achieve comparable levels of productivity regardless of the product mix or volume. This is essential for the survival of most electronics assembly companies today. Effectively planning a factory operation that can respond to changing customer needs without reducing operational performance requires the entire factory operation to be optimized with a single engine, which caters to PCB assembly manufacturing.

The time required for testing, using in-circuit testers and functional testers are also product-dependent because the number and nature of tests require different processing times, which depends on the part. In most cases, optical inspection times are dependent on the physical layout of the product. The time needed for manual assembly and building the final product by manual operators is also closely linked to the specific engineering information of the product. A production planning tool must be able to account for all these sets of process modeling.

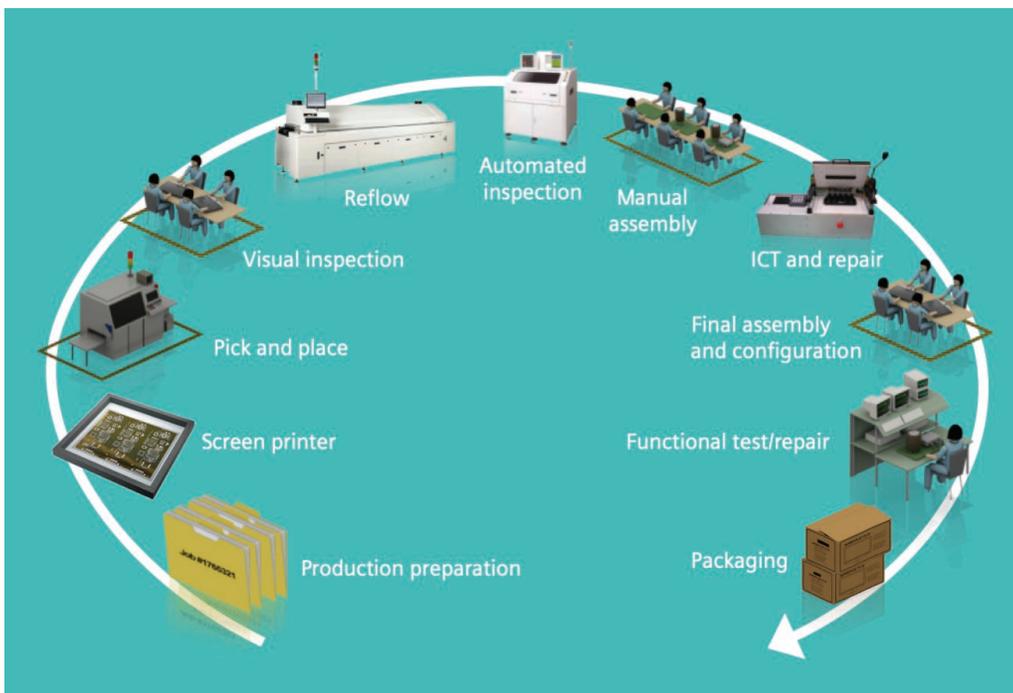


Figure 11. Integrated solution for PCB assembly.

PCB assembly manufacturing

In addition to providing expertise, the integrated solution to any enterprise data management solution must support all the related functions needed (as described in figure 11) so it can enable production planning, simulation and optimization of both mechanical and electronics mBOMs and BOPs in one integrated environment, synchronized with the source design data.

The advantages to having a single planning platform is:

Accelerated new product introduction:

- Increase engineering efficiency by using a single tool for all process engineering tasks
- Eliminate redundant preparation work with learning libraries (machine shapes, rotation, etc.)
- Increase efficiency with automation and use of templates (for work instructions, data import parsers, etc.)

Preserve manufacturing know-how:

- Consolidate organizational best-practice flows
- Centralized part libraries including rotation neutralization and machine shapes, process steps and re-usable cell definitions
- Custom data preparation flows can be defined, enforced and re-used

Product portability:

- Leverage a single source of data to seamlessly move production between lines and factories – eliminate engineering time and increase quality of the product

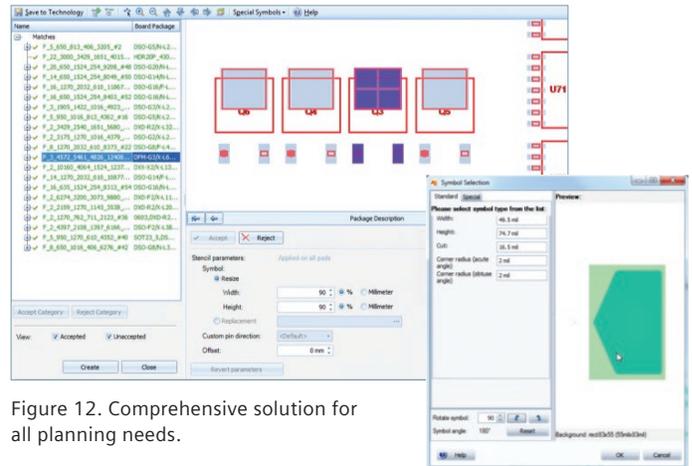
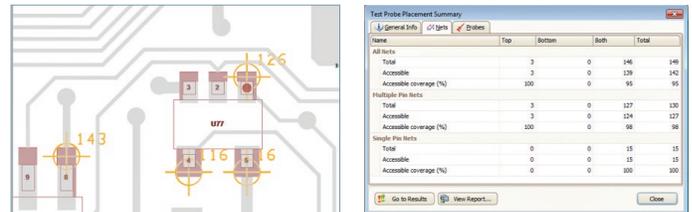


Figure 12. Comprehensive solution for all planning needs.



The functionality required for an integrated solution should include BOM management (parsing, allocation of parts and validation), SMT program portability with automated SMT machine shape generation, simulation of production machines to enable virtual sticky tape functionality, line takt time simulation and load balancing, electronic documentation and creating tooling programming. This includes stencil, fixtures, conformal coat programs and jigs, and a comprehensive test and inspection programming environment that details feasibility and what-if analysis of test programs specific to the type of equipment and strategy.

Conclusion

Manufacturers must connect and enrich the digital thread from design to execution and beyond, not only to relieve the pressures of today but also establish the required foundation for tomorrow. Most enterprise data management vendors with their related PLM solution already provide capabilities to manage, author, plan and simulate mechanical manufacturing. However, none have yet to include the electronics manufacturing domain. This is desperately needed for complex product manufacturers to remain competitive.

For OEMs and vertically integrated manufacturers of complex products in industries such as automotive, aerospace and industrial and heavy equipment, synchronizing what is to be produced, how it will be produced and in which plant, cell or with which process, would create huge efficiencies and add a tremendous competitive edge. Streamlining and managing the

supply chain, especially in the increasingly aggressive nationalistic geopolitical climate, ensure some level of control and assurance. Traditionally, electronics manufacturing has been a separate and siloed part of the overall product development process. Electronics assembly manufacturing has predominantly been siloed, with disjointed ecosystems, organizations and processes. With the right tools, such as Siemens' Teamcenter® software, Manufacturing module, one can manage enterprise-wide product, process, plant and resource data for mechanical and electronic design and manufacturing in a single integrated environment. Furthermore, having a single source of truth for both mechanical and electronic content with strong governance can bring electronics manufacturing into the digital thread of the product design lifecycle and improve an organization's competitiveness.

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