

**F**or the past five years, fabs have been automated by integrating a variety of disparate systems. It seemed

like such a simple recipe:

- 1 - Manufacturing Execution System
- 1 - Overhead track delivery system
- 15 - Stockers
- 1 - Material Control System
- 50 - Equipment types (250 total pieces)
- 375 - SMIF arms/mini-environments
- Bolt loader to the front of the equipment.
- Bolt Stepper to tracks.
- While installing equipment, write:  
100,000 lines of custom code
- Plug in CIM system
- Plug in Cell Controllers and equipment interfaces.
- Process Wafers.

Easy, right? Well, not quite. As we all know, from too many late nights spent in the fab, this is twelve months of hard work – or more if not managed properly.

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*Compaq*

# Pre-Engineered CIM/Enterprise Systems

## The Next Generation of CIM Systems

**T**he reason this pain could be endured was that CIM systems in the semiconductor industry were new. They had not been done before, sharing this data with other companies (your competitor) would give away the competitive advantage. Today, integrated CIM systems are a given. The goal now is to reduce the cost of the integration and expand that integration to be easily modifiable and more pervasive throughout the fab. In practice, many fabs did this by employing the copy exact methodology in building newer fabs.

However, as with the entire industry, this was bound to change. With technologies improving, geometries continually shrinking and wafer sizes increasing, a new generation in CIM system is required. The next generation is the pre-engineered solution. Components of the best of breed vendors are pre-integrated for deployment in the new fab. In this article, some of the major additions and considerations of a pre-engineered solution will be discussed. A brief discussion will follow that will touch on some of the major areas. The items that will be covered are scope and some of the required components and tools that are used to facilitate extensibility of the system.

### System Scope

The key here is scope. How big does this system get? The answer is “How big would your customer like it to get”. Maybe today’s concern is simply the IC fabrications facility or the Assembly/Test area. But, tomorrow it may be tying these two facilities together. They may not even be owned by the same company. Quick expansion of the CIM/Enterprise System in directions that may not be apparent or a high priority today may be required by a customer next month. To accommodate this, a flexible system must be in place to allow additions to the enterprise system. By using a pre-engineered solution, many of these issues have already been addressed.

To look at this in more detail, a quick definition of the levels (refer to Figure 1 – CIM Components ) of a solution must be explored, followed by a deeper discussion of some of the more critical systems.

### Corporate Systems

To speak of CIM systems is difficult. First, everyone has a different definition of what is or is not in a CIM system. Second, the line that divided the CIM and ERP used to stop just below the ERP system (SAP, Baan,

Oracle, etc.). This is becoming very fuzzy. However, regardless of the definition, there is no doubt that execution systems must be integrated into the ERP system. Orders need to be monitored and controlled from the ERP system giving downstream systems, customers and facilities the much-needed view of what is in the production pipeline. Any pre-engineered solution includes the standard interfaces to the common ERP systems.

In addition to this requirement, other systems throughout the enterprise may need information. Figure 2 - Example of Data Usage Requirements, shows some of the systems that may need information throughout the enterprise.

Corporate systems require data to move within a facility or out to customers and vendors. The role of the supply chain is becoming increasingly more important for all companies. This includes processing and engineering data.

Date warehouses and data marts are part of this level of systems. Being able to determine the effect of initial wafer manufacturing data on fab yield, comparing final test data to implant data, design vs process issues are all part of the information exchange requirement.

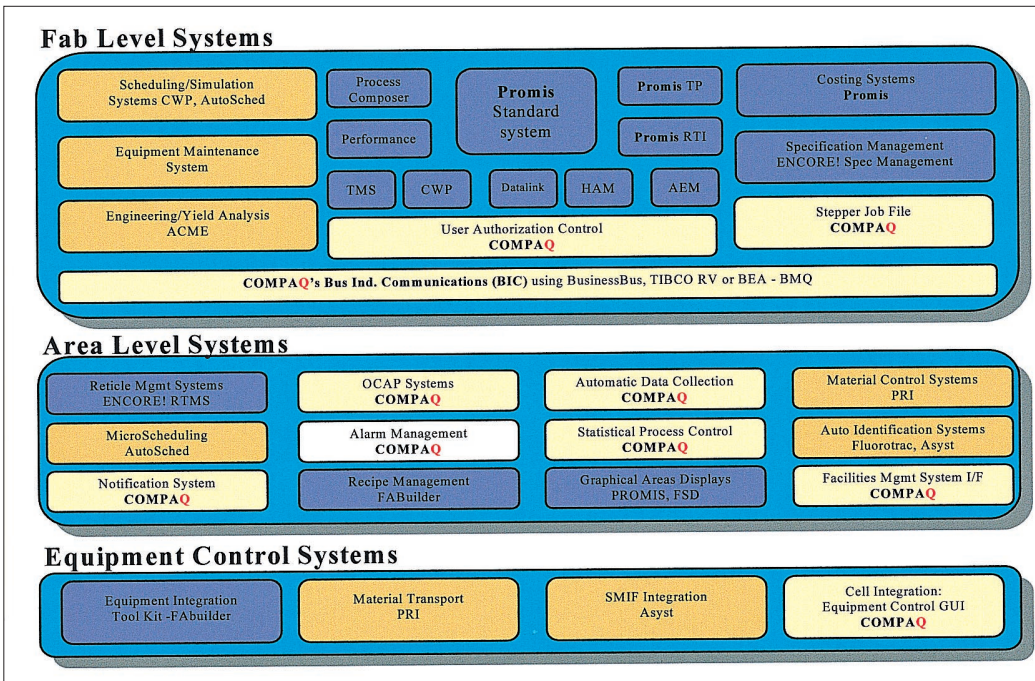


Figure 1. CIM Components

**Figure 2. Example of Data Usage Requirements**

System	Information	Recipient
MES	Lot status	Resource Planning Supply chain Second MES
Resource Planning	Lot Release Information	Scheduler MES
MES	Lot Completion	Downstream MES Supply Chain Resource Planning

#### Fab Level Systems

Fab level systems consist of components that control or affect a single facility. The manufacturing execution system (MES), scheduling, engineering data analysis (EDA) are examples of these systems. These systems affect multiple areas in a fab. They are critical in ensuring that material flows through the facility smoothly. Data is input from the corporate systems to guide the process, and data is received from area level systems to

indicate what has been done. New customer or product requirements mean new systems must be added to accommodate the information. The solution must be agile to accommodate the addition of new systems or data requirements at this level.

A prime example discussed later is the scheduling system. New requirements for proper scheduling are being added continuously to ensure the best algorithm for optimizing the line.

All of these systems need more than to be integrated. The integration must be flexible enough to handle the addition of new systems and new data flows.

#### Area Level

Area level systems require a more specific level of data. These systems translate the raw information from the shop floor level to data that can be disseminated to operators, technicians, supervisors, and fab level systems. Among the responsibilities are resource management modules, alarm and notification systems and data collection and usage components.

Resource Management, as will be discussed later, encompasses a group of components that are required to determine if the capabilities are present to do the processing that is required for an operation. Systems that monitor recipes, reticles, down holder, and crucibles, for example, are part of this group of systems.

#### Equipment Integration

The lowest level of the CIM system is the shop floor, or equipment integration level. It interacts directly with the equipment and the material handling system.

Here, interfaces to each piece of equipment, support equipment (robot arms, mini-environments, tag readers, loaders, etc) and the material handling system must be accommodated. The wide and varied equipment protocols must be converted and the messages and control information must be manipulated into a usable form by the CIM system.

In addition, the ever-growing list of equipment types must be

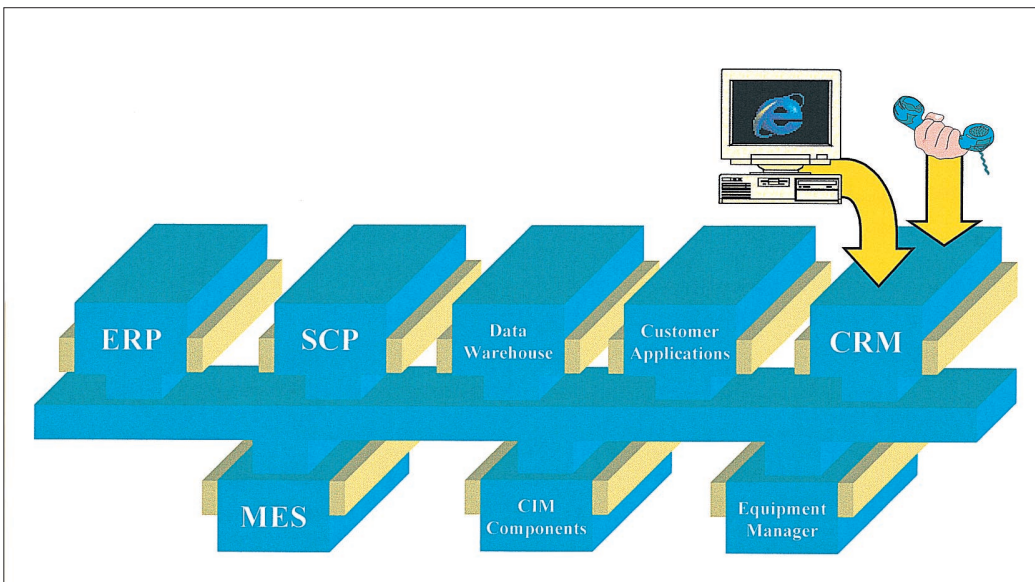


Figure 3. Bus Structure.

accommodated. Figure 4 – Example of Equipment Types, enumerates some examples of equipment types and the related equipment.

With new process technologies and larger wafer diameters, new systems must be implemented that facilitate direct material delivery to the equipment. This process, intra-bay delivery, will require more complete area and fab level systems to ensure proper utilization of equipment.

The Engineered Solution

The engineered solution requires that all systems work together and configuration is all that is required to make the system usable. Although this is the ideal goal, in reality this is difficult to achieve. Nevertheless, significant portions of the engineering can be accomplished. This was the goal of Compaq Computer (formerly Digital Equipment Corporation) and PRI (formerly Promis Systems Corporation) when the groundwork was laid for the SemiSuite product. Collaboration between numerous vendors was required to achieve the product. Following are some of the important issues that were addressed and learned through this effort.

Integration Flexibility

The key to pre-engineering a system is the communication method. As mentioned before these systems are not static. They are continually being changed to get the proper data to the right place at the right time. To do this the middleware must be able to allow data to dependably move throughout the system and allow easy modification to give flexibility in the future. There are four basic requirements of the middleware layer.

First, it must be flexible, preferably independent of transport layer. The middleware must equally be able to use BEA's MessageQ, Microsoft's MSMQ or TIBCO's Rendezvous. The actual bus being used must be transparent to the components using it. This requires an additional layer of obstruction

above the transport medium. A variety of products assist in this process (e.g. Compaq's BusinessBus, CrossWorld's InterChange Server and Vitria's BusinessWare).

Second, it must be able to perform data element mapping. This allows two systems with dissimilar data structures to be able to share information. This data should be stored in text tables that may be edited and changed with no need for recompiling or restarting applications. In this manner, SAP's MATNR can be understood in the CIM system as being equivalent to PROMIS's partId.

Third, it must allow transaction mapping. Transaction mapping allows a transaction from one system to be mapped to one or more transactions in one or more other systems. As an example, to perform a split lot transaction in a MES is simple. However, to ensure that all of the other steps are properly taken is more complex. Specifications must be retrieved and read by the operator. After acknowledgment of that, the ERP system may split the lot. In SAP's case, the Process Planning module does not support a split lot transaction; therefore a set of transactions similar to those listed in Figure 5 – Possible Split Lot Transaction Set – may need to be executed. Instead of these transactions being hard coded, they should be able to be maintained in a configuration table that will allow for easy modification of such mapping.

Lastly, the middleware must be capable of multi-site deployment and interfacing. Implied is the middleware being fully Internet enabled. As shown in Figure 3 – Bus Structure,

access by, and to, customers and suppliers is essential. Interfacing to systems that can safely and securely transfer data between sites allows for fast and efficient communication of information. Orders can be processed and status delivered, further increasing the cost effectiveness of the enterprise system.

Scheduling

One of the original requirements for an automated system was to decrease the cost of manufacturing. It has done through decreasing in rework and scrap. In addition, it has gone a long way in improving the efficiencies stemming from product not being in the right place at the right time. With proper look ahead and resource management, scheduling can be greatly improved. This is a critical part of a pre-engineered solution. Without a proper design, the components making up the solution will be unable to supply the information needed to properly schedule product on the floor.

Besides the requirement to see the material in the "production pipe", a scheduler needs far more informa-

tion from the floor equipment. Equipment capabilities and resource availability are required.

Equipment, being very complex, has a variety of configurations. This is especially evident in multi-chamber pieces of equipment. Depending on the configuration, some multi-chambered equipment can look and function like more than one piece of equipment. The scheduler requires access to this information to have the data required to properly schedule material across the production floor.

To insure that all of the required resources are available for the material to be processed, the scheduler must have access to some systems that are classed as resource systems. Recipes, reticles, probe cards, down holders and qualified personnel are a few examples of some of the information required to determine if a lot may be processed at the estimated time that it will arrive at a operation. To accomplish this task, components like the Recipe Management System, Reticle Tracking Management System and the User Authorization and Control system must be accessible and integrated with the scheduler

Figure 4. Example of Equipment Types

Equipment Type	Example
Single Lot	Ashers
Linked Equipment	Track/Stepper
Batch	Furnaces
Cascading	Wet Benches
Chambered	Oxide Deposition, Metal Deposition
Chambered multi-process	Oxide systems capable of running two processes simultaneously

Figure 5. Possible Split Lot Transaction Set

MES	Integration Manager	ERP	Specification Management	Operator Station
Split Lot →	Step 1 →		Determine Specification Requirements	
			Retrieve Sec. for operator →	Display Specification
	Step 2 ←			Operator Acknowledgement
	Step 3 →	Create new lot		
	Step 4 →	Assign route to new lot		
	Step 5 →	Move Material to be split to new lot		
	Step 6 →	Start new lot		
Commit Lot Split ←	Step 7 ←			



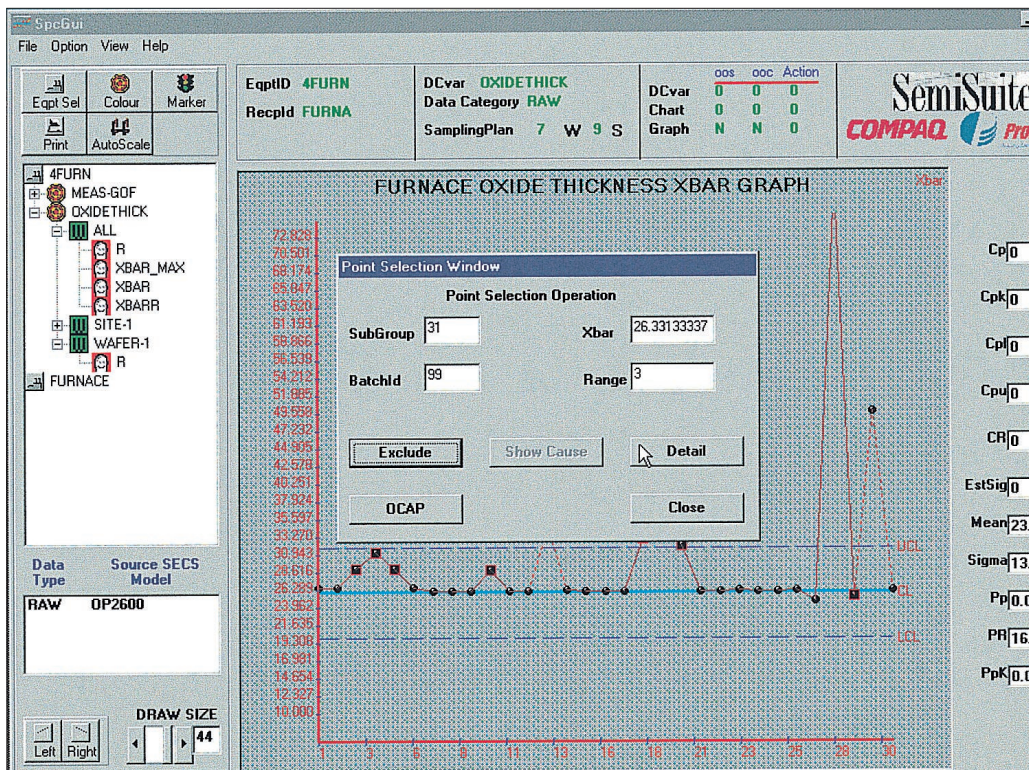


Figure 6. SPC Display.

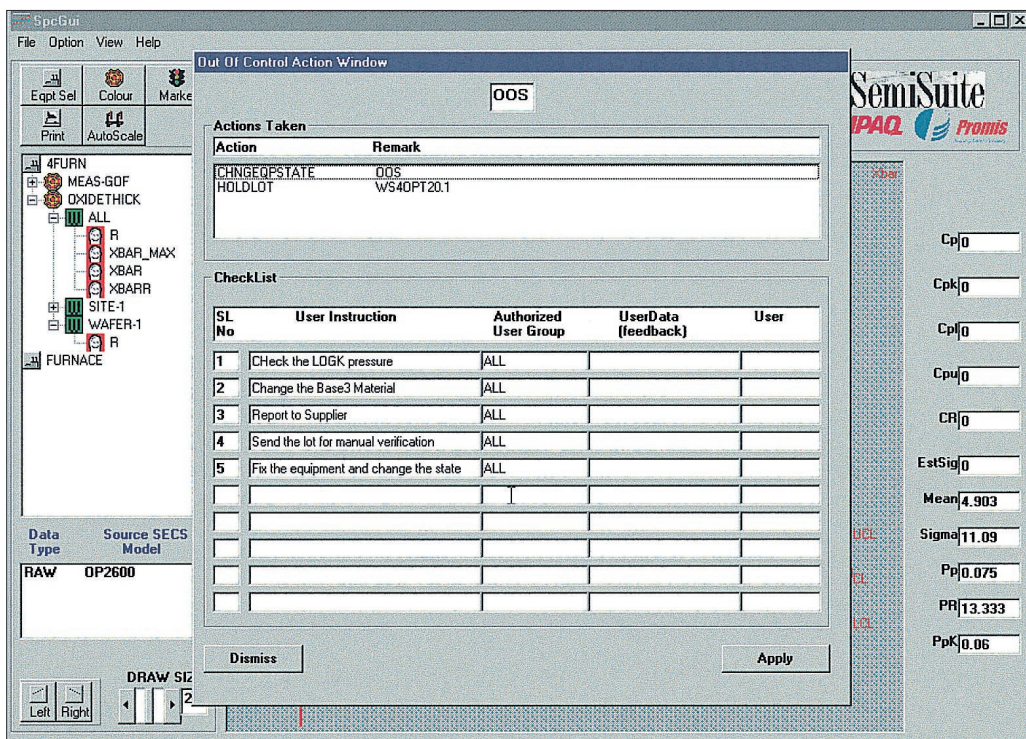


Figure 7. Operation Corrective Action Porcedure Screen

to provide this data.

As silicon manufacturing facilities and IC fabs move to their next level of automation for 300mm, and TAP facilities move to complete automation, automated delivery to the equipment is going to be more critical. Without properly insuring the resources are available for an operation, delivery to the equipment will be impractical. Errors in delivering material to a piece of equipment that does not have the proper resources will negate any added efficiency improvements.

### Data Collection and Usage

An IT manager at a wafer manufacturing facility once said, "We give them the wafer, we sell them the data." This statement underscores the importance of data collection, not just to the facility where the manufacturing is being done but to the customer. Key to the next generation system is data collection and usage.

Of course, the root of this is the equipment. Equipment must have methods of reporting data back to the CIM system. However, this is not enough. The data reporting schemes must be standard. Anyone who has attempted to automate the data collection process from any type of fab will testify that this can be a nightmare. Although some very flexible systems can be designed and written to acquire the information and report it to EDA systems, there are too many "imaginative" engineers to ever allow one to produce the infinitely flexible equipment interface. To help, a pre-integrated solution must have an extremely configurable equipment interface. The solution cannot rely on re-compiling every time a equipment controller is modified.

As the data is collected, it must have some level of automated analysis performed. Determining if the data is simply out of specification is not enough. To ensure automated exception handling, the system should be able to determine if a value being returned from a process is reasonable. If possible, "unreasonable" data should be re-acquired from the equipment – without operator/technician interaction.



As the data is presented to the fab personnel, it should be in a manner that they may be quickly drilled down to determining the source of the problem. Figure 6 – SPC Display – shows some of the data that should be available to fab personnel for their use in determining the cause and solution of a problem. As will be discussed later, this data should be available throughout the facility, not just on the shop floor. Mechanisms should be in place for this information to be accessed or routed to the appropriate personnel regardless of time of day or their location.

To this end, data needs to be available through a data warehousing solution. Data marts are required to properly support the data analysis tools for the fab. These data marts must be “Multi-site data marts”. Whether your manufacturing facility is captive or not, the data generated by the system has an effect on subsequent processing by your customer. Wafer flatness data relates to CDs, CDs relate to turn-on voltages, turn-on voltages relate to final test results, and all are affected by design. In smaller geometries the dividing line between facilities data, process data and design become far more obscure.

#### **Shop Floor Interfaces**

As already mentioned, the shop floor equipment integration level is crucial. It must be flexible, allowing for changes in the equipment’s capability and the desires of production and engineering. The interface must not require recompilation or drastic reconfiguration to enable or disable a feature. Equipment interfacing products must be able to accommodate changes through configuration files.

To simplify procedures all functionality should be contained in a single place. One user interface

should be capable of displaying all the information required about a process of equipment. This requires user interfaces that are highly configurable and are capable of displaying information based on the users’ requirements.

#### **Alarm, Notification and Resolution**

Classical CIM systems determine a problem and present the issue to the operator or equipment GUI. Flexibility is required to ensure the information may be presented to anyone. In addition, corrective action procedures must be supplied. In some cases, corrective action procedures may be able to be executed automatically by the system.

Alarm situations may occur from a variety of sources. Alarms may be generated by equipment, from process data (via an SPC system) or from other systems that supply data about the facilities.

When an alarm occurs, action must be taken. These situations are often called “exception processing” or “anomaly handling”. To handle these an Operations Corrective Action Procedure (OCAP) must be executed. The key is to properly model the facility to ensure as many exception-handling procedures are captured at initial design. By definition, pre-engineered solutions are already “aware” of many of the common process problems. It is simply up to the facility to enter the appropriate business process to take.

Corrective action need not be taken just by people on the factory floor. Some situations do not require the physical interaction of a person and may be handled remotely. Although remote execution of procedures may not be employed

immediately, the system should be capable of providing the functionality.

Figure 7 – Operation Corrective Action Procedure Screen, is an example of a manual OCAP screen. In this example, a corrective action procedure is triggered by a process that has not met specification. The attendant to this action is presented with a list of actions to take and must complete each action and enter a result before the lot may proceed to the next step.

These procedures are not necessarily intended for an operator. The corrective actions should be presented to the appropriate people in the facility to correct the problem. This implies intelligent routing of data to a variety of output media. Although the example shows a Windows NT based display, this data may be displayed on variety of devices, including PDAs.

#### **Conclusion**

Pre-engineered CIM solutions are required to decrease the cost and installation time in a facility. In addition, the solution must think beyond just the Shop Floor CIM system. This requires that the system be designed to accommodate the flexibility of fabrication facilities. To do this a solid architectural framework must be in place. At the root of this design is the method of transporting data within and without the system. Completely adaptable transport methods must be in place and able to be quickly modified.

To facilitate new processing schemes, a complete scheduling system must be in place. Beyond what is done today, the scheduling system must be able to “look” further into other systems, (e.g. resource handling systems) to determine the

proper scheduling.

Data is ever more important to a growing number of people in the supply chain. Data must be used both internally and externally to your facility and your company. All solutions should have a complete data collection and usage system.

Exception handling is the capability that will allow the facility to react in a quick, consistent and thorough manner to situations that are not part of the normal process. A fully engineered solution is the only way to ensure that these situations are understood and accounted for.

#### **BIOGRAPHY**

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