Acorn Technology Systems, Inc.

Getting Started With SEMI 300mm Standards

The purpose of this document is to allow a manager/engineer to visualize the scope of a project that would integrate your 300mm capital equipment software with third-party SEMI 300mm standards software such that your 300mm equipment will be compliant with current SEMI standards for 300mm factory automation. This article begins with an overview of the standards and then describes the sequence of steps necessary to bring your application and equipment to 300mm compliance from a software perspective.

The Standards

Semiconductor Equipment and Materials International (SEMI, www.semi.org) is an industry research and standards group that, with industry representation, maintains a series of hardware and software standards which are adhered to by semiconductor capital equipment vendors. The Manufacturing Execution Systems (MES or just 'factory host') in most 300mm foundries now expect nearly uniform compliance to these standards, especially for inline tools. This article describes a procedure to follow in integrating the software portion of the SEMI standards into your software application. The information found here will be most useful to capital equipment vendors seeking to place their equipment in or near a 300mm semiconductor fab. Hardware changes are also briefly discussed.

The following table describes the current set of SEMI 300mm software standards for factory automation. Note that other standards, such as 'Interface a' are being developed and will be added to this document soon.

E4	SECS-I (Semiconductor Equipment Communication Standard) This is a low-level serial communications protocol which is implemented using RS-232 (known as JIS C 6361 in Japan). This is a still-supported, but rarely used communications protocol which has mostly been replaced by E37 (HSMS, see below).
E30	GEM (Generic Equipment Model) This is an older specification which represents a first pass at equipment and factory host cooperation. GEM provides standards for data and event reporting to a factory host. Optional capabilities provide for the upload/download of recipes and for the factory host to start a job (normally the purview of E40/94 in a 300mm plant). GEM represents the lowest or first level of factory automation. It is commonly found in 200mm fabs and is required of

	all 300mm equipment when SEMI 300mm factory automation standards apply.
E5	SECS-II (SEMI Equipment Communications Standard 2 Message Content) Represents a message protocol that is used by all the SEMI software standards. The E5 message layer can use a E4 or E37 communications link.
E37	HSMS (High Speed Message Service) Uses TCP/IP protocol to establish a connection and is therefore not limited to speed except by the physical connection limitations. HSMS is the communications protocol most in use for SECS-II messaging. It is typically implemented over Ethernet.
E39	Object Services Standard Provides a common object model and common object services used by several of the SEMI Exx standards. Provides a common way to manage data via objects defined in various SEMI standards.
E40	Standard for Processing Management Manages a process job on your capital equipment. This standard allows for the automated control of material processing at your equipment. E40 optionally manages process job queuing when E94 is not in use.
E58	Automated Reliability, Availability, Maintainability (ARAMS). Monitors equipment reliability through data collection and user input.
E84	Enhanced parallel Interface for Cassette Transfer. A hardware specification allowing for cassette handoff in automated material handling systems (AMHS). This is the accepted transfer hardware protocol and is mandated by most fabs when AMHS is in use.
E87	Carrier Management System Defines standards for wafer carrier transfer. Provides a standardized behavior of communication between host and equipment during the coordination, execution and completion of automated and manual carrier transfers.
E90	Specification for Substrate Tracking Specifies standards and services to provide for equipment substrate tracking.
E94	Specification for Control Job Management Specifies equipment services to the factory to support a high level of factory automation. E94 provides for material arrival at the equipment and process job (E40) invocation.
E116	Equipment Performance and Tracking E116 is similar to ARAMS (E58), but differs in that it focuses on information known only by the equipment. E116 specifies standard methods for equipment to report when it is IDLE, BUSY, or BLOCKED, as well as the time spent in each of these states. If the equipment transitions to a BLOCKED state, it reports the reason it is blocked from processing. The semiconductor manufacturer can utilize this information to identify key reasons why the equipment is blocked from processing, and eliminate these issues to decrease equipment downtime. Note that although E116 and E58 can be implemented together, it is becoming more frequent that E116 alone is the typical requirement.

Steps to SEMI 300mm Compliance

In the following steps the software integration team and the equipment application programmers are referenced as separate software groups. The software integration team is the group which gathers the SEMI standards requirements, designs an integration model and plan, and develops a set of API's and software modules which will be used by the equipment application programmers. The equipment application programmers are those responsible for the equipment application software and will therefore have to be involved in the SEMI standards integration project, but it is the job of the integration team to minimize this involvement. In other words, if your software application team does not want to be bothered with factory automation standards, then hiring a good software integration team from the outside may be the best choice.

Step 1
Choose a software integration team. If you are doing this project using only in-house staff, then Step 1 is complete. Go on to Step 2.

If you choose to outsource your integration project to a company like Acorn Technology Systems, you will realize several advantages.

- Having SEMI 300mm software integration experience enables the integration team to quickly debrief factory MES managers to discover the minimum set of standards requirements for your tool. Understanding typical fab environments will speed the requirements phase of the project.

- Your costs will be known up front and be containable. Having integrated several capital equipment platforms into a 300mm environment allows the integration team to develop methods and software which are re-useable, which results in a low-risk project with no upside surprises.

- Your equipment application programmers may be primarily concerned with the function and data of their tool. To have to consider integrating its functionality into a fab environment is both uninteresting and may be a waste of time that can be used to develop the tool further.

- An experienced integrator knows the third-party software well and can guide you through the choices available to you.

- It is the job of the integration team to arrive at a design for use by the application programmers such that its implementation will be as close to plug 'n' play as possible. In other words, if the integration team has designed a minimal set of API's, has a concise and comprehensive set of requirements, and has several key state models defined for your tool, then the job of the application programmers will be straight forward as they integrate the new API's into their code. An experienced team of integrators will have this all thought out ahead of time and be ready to put into action a plan of integration that is simple to follow and involves the application programmers in as minimal a fashion as possible.

Step 2
Choose a software vendor for the SEMI Exx standards. Nobody should write this code for themselves since it has already been written several times and there is a lot of code to write. In our opinion it makes sense to purchase a development license from one of the vendors of SEMI Exx standards software. There is still a lot of work to do in integrating the purchased software into your application. Your software integration team should research the products available and come back with a recommendation.

Step 3
You must now begin the requirements phase of the project. With which standards will your equipment comply? It is not always necessary to comply with them all, especially if your tool is not inline. Your integration team must be able to effectively communicate with the fab's MES managers to discover the automation level to which your equipment must comply. The diligent completion of this phase of the project will avoid many headaches down the road and will help to speed the design phase.

Let's look at some of the standards more closely with a view to developing project requirements:

1. E5 (SECS-II), E30 (GEM), E37 (HSMS)
   These are the standards common to all further SEMI standards requirements. You will always be required to implement these standards where any SEMI software standards apply. E4 (SECS-I) is not likely to be used, but is generally available with any implementation of SECS-II.

   HSMS is the High Speed Message Service which is most everywhere used in place of SECS-I messaging. It is a TCP/IP protocol standard typically implemented using Ethernet hardware.

   GEM integration involves modifications to the equipment application software. The application is responsible for signaling material arrival/departure, login/logout, software version, model number, etc. In addition the equipment may wish to define several variables and events that will be useful to the factory host. Optionally your application can support GEM remote commands, although this is not often a requirement in 300mm fabs, since E40/94 were designed with this in mind and have much greater flexibility.

   Note that if your interview with the fab's MES managers is thorough, then the GEM implementation will be straight forward and uncomplicated. GEM integration is a big first step as it lays the communications foundation for the later standards.

   Application Involvement: MEDIUM
   The integration team will have developed a minimal set of API's for the application to use in signaling events and setting variables. It should be a straight forward task for the applications programmers to take these API's and apply them at the appropriate points of processing.

2. E39 (Object Services)
   Most upper level SEMI standards rely on object services in order to acquire and manipulate data. Where any upper-level standards are required, such as E87, E40, E90, E94, then E39 is also a requirement. E39 is a 'for free' service in that integrating it in requires no direct action from the application.

   Application Involvement: NONE

3. E87 (CMS)
   Carrier Management provides a way for the factory host to view the flow of material into and out of your tool. It is difficult to imagine, that in a 300mm environment, this would not be required. With this standard the factory is able to associate a substrate carrier with your load port and know its processing status. E87 also monitors the access mode (auto or manual) of your load port. It is likely that your tool will allow both automated and manual carrier delivery, but it is possible that only manual delivery will be required, if your tool is not inline. Carrier ID verification and slot map verification are also covered by E87.

   A full E87 implementation often requires a modern 300mm load port which can accept a FOUP (front opening unified pod), dual or single. Such a load port may have Carrier ID and E84 (AMHS) built in along with software support. The load port can be thought of as a 'turn-key' device from a hardware perspective, but it is still the job of the integration team to present its functions to the application programmers in as minimal a fashion as possible. It is also possible that an older 300mm load port be used and then additional hardware such as Carrier ID and E84 devices purchased as required by the fab. In either case it is the job of the integration team to find and recommend the best path to E87 compliance.

So what does this require of your application? A lot. Your carrier handling software must have several calls into the E87 API's supplied by the integration team. Every movement of the carrier must be tracked and errors must be handled. In addition your software has to consider how a manual versus an automated load is handled. E87 must know when you begin and end a process on a carrier. Your software must understand and handle the load port in service and out of service transfer states, auto vs. manual access mode, port reservation status. These are just some of the connections between your application and the E87 software.

Application Involvement: HIGH
Although the application involvement is high, since the application is wafer transfer and not the actual wafer processing and data crunching, it is conceivable that the application work here be off loaded to the integration team. This is an area where a thorough design tested against several cassette round trip scenarios will speed implementation.

4. E90, Substrate Tracking
Substrate tracking allows the fab MES to keep information about substrates (wafers). E90 provides a set of services to the fab MES in order to do this effectively. As a substrate is moved through its processing, the MES system is kept apprised by the E90 services. Substrates are tracked with regards to location, state of processing and history. This is a very likely requirement, but is simple to implement from an application standpoint. An application merely has to indicate a substrate's location and state of processing when either changes.

Application Involvement: MEDIUM
E90 capability is very often handled by the same software module as the E87 capability, from the application perspective. This is so because carrier transfer and wafer transfer are related functions. Therefore, as with E87, it is conceivable that this application work be off loaded to the integration team since it is, like E87, not considered too strongly linked to the work of the equipment application itself.

5. E40, Processing Management
Through E40, the factory host controls the process on your tool. For inline tools it is essential to have an E40 capability in a 300mm fab. For non inline tools or 'near fab' tools, its usefulness may be marginal or not required at all. Tools that are not inline are often run manually and may not need to support the higher levels of the SEMI standards. There does however seem to be a move toward tighter integration as the 'near fab' concept is developed. A trend to move laboratory and analytical tools closer to the fab (aka ‘near fab’) requires that they have higher levels of SEMI standards integration.

E40 controls material processing by initiating processes using a state model which applies to all fab substrate processing equipment. Process jobs are queued and then one at a time are set to the executing state (by E94) in which they traverse any or all of the following states: setup, waiting, processing, completing, stopping, pausing, and aborting. In the setup state, recipe information and recipe tuning information is downloaded (where applicable). Hence an application needs to be modified to support the E40 process job state model.

Application Involvement: HIGH to LOW
There can be a fair amount of work in matching one's application to the process job state model and then calling the various API's to indicate state changes and implementing the various callback routines which implement recipe parameters and tuning and job commands. It is here that the application team will experience the most work in the integration project. But, if your tool's processing model is simple or even completely manual (again, not an inline tool), then you may get by with a very simple E40 implementation where your application simply passes through most of the states without

action such that your application is either 'processing' or not. A thorough requirements investigation will make E40 integration a straight forward project.

6. E94, Control Job Management
   With this specification, the factory host uses material location and process knowledge to coordinate process jobs. E94, with E87 and E40, allows the fab MES system to know where its materials are (E87), know how to process the substrates (E40) and can coordinate the processing of material with material arrival (E94). E94 therefore represents the highest level of factory MES control and view.

   Application Involvement: MEDIUM to LOW
   The application's involvement with E94 can be very little. This is true mainly because the application conducts most of its business with the factory host via E87, E90 and E40. However, it is likely to want to have E94 status and control available at the equipment, which would mean a set of E94 API's to get status, create E94 style control jobs and accept material management parameters from the factory host.

7. E116, Equipment Performance Tracking
   The factory host may want to keep track of a process equipment's running, paused, etc. status in order to gauge the tool as regards up time/down time. It is then a straightforward matter to indicate to the host whether or not the equipment is processing and why or why not. This is the purpose of E116. If a tool is always BLOCKED because there is no material to process, then clearly the factory managers know where to go to solve the problem. Or if equipment is frequently idle for operator intervention or maintenance, then clearly the problem needs further investigation at the tool. E116 is simply a reporting of operating states and reasons for those states.

   Application Involvement: MEDIUM to LOW
   Depending on the nature of the equipment the variety of scenarios for which a tool could be blocked or idled may be large or small. Either way, it is still a straight forward task to indicate tool status and reasons.

Step 4
Design/Implementation phase begins. With a rash of requirements fresh on paper, the design phase of the project will have a natural beginning. This is the longest phase of the project and involves a series of communications (either in meetings, teleconference or email), each meeting bearing down on the design and its implementation.

It is now the job of the application programmers and integration team (collectively the ‘design team’) to examine each of the Exx standards. Each standard describes various state models and data objects. At this point, it may work best for the integration team to present and drive the discussions by explaining each standard and its state model(s) in brief. The application team can respond by describing how they may fit into the models presented. Once a model is conceived which matches the standard, the design team will test it against several test scenarios on the white board. The model is adjusted and tested, adjusted and tested.

These first design sessions should be a series of presentations, adjustments and test scenarios. The integration team will keep a record of these design sessions and use them to begin development of software modules. The application team, keeping its own notes will begin to work with the application code to see how it can be adjusted to fit state models presented in the discussions.

The teams will return to discuss the various efforts made. The integration team will present candidate API's, configuration management solutions (your equipment won't be running the same way in every situation), and installation options.

Soon, candidate software modules will be made available to the application programmers for insertion into their code. The integration team will have a tool configuration and installation method available and very quickly the equipment can be up and running the SEMI standards in a 'rough draft' fashion. The following weeks will serve to tune, re-work and finalize the software.

Step 5

Documentation. Each equipment, to comply with the 300mm SEMI standards, must come with a GEM/SECS/300mm Standards manual. It is written to assist the fab MES programmers in creating a factory host interface to your tool. This manual states in clear terms the level of compliance to the SEMI standards. The various state models, variables, messages are all laid out clearly and in detail. This final piece of documentation is the responsibility of the integration team. Although a long and detailed document, it is the result of all the designs and notes taken during requirements and design phases and can be produced in a short amount of time.

Step 6

You are done. How long did it take? If you had an experienced integration team and the team had no familiarity with your equipment and you needed full SEMI Exx compliance, with automated material handling, wafer ID, Cassette ID, etc., and then if your hardware team could keep up, it took about 4 months. If you had a much slimmed down implementation, with minimal E40/94 involvement, no automated cassette delivery, you might have finished in less than 3 months.

If you chose to do it in house, it probably took longer, but you now have the experience and if you have other tools to do maybe you're glad you did it this way. Acorn Technology Systems would be glad if you called us. We think we'd save you time and money.