Automatic Data Collection Baseline Requirements: Levels 1 and 2 Events and Variables

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Abstract: This document from Project MODA007 consists of guidelines for equipment suppliers to promote an initial automatic data collection (ADC) baseline. It is targeted at 150 mm and 200 mm toolsets. It defines the minimum data required for performance tracking in a semiconductor manufacturing factory, defines the compliance testing goals and methodologies, and provides guidelines for software documentation and compliance testing reporting.

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1 INTRODUCTION

1.1 General Note

This document is sponsored by the International SEMATECH Tool Performance Tracking Platform (TP2) Steering Committee. The guidelines in this document resulted from a number of formal studies [1] [2] [3] and include data collected from the customers of the Tool Performance Tracking Platform (TP2) project. The TP2 software [4] is currently installed in 15 facilities and 400 tools. Further information about the TP2 project can be obtained from International SEMATECH through the authors of this document.

To remain consistent, this document uses definitions (including Figure 1) from the Object-Based Equipment Model (OBEM), SEMI E98-0600.

Equipment communication capabilities are an important consideration when purchasing equipment for an integrated manufacturing environment. Automatically collected data has been found to be significantly more accurate than data collected from manual input. To collect data automatically, the equipment must be capable of tracking and reporting changes in states and equipment variables. Equipment that cannot meet these guidelines cannot provide the basic necessary data collection capabilities needed today by the semiconductor industry; hence, this capability has been designated as baseline.

1.2 General Document Assumptions

This document is based on the following assumptions:

- To effectively operate semiconductor manufacturing factories, the equipment must provide accurate messages to allow the measurement of the manufacturing and tool processes. To accomplish this, the needs of the semiconductor-manufacturing community must be successfully conveyed to the equipment suppliers. To reduce cost and confusion, requirements should represent a consensus of the needs of a significant number of the manufacturing factories.
- Effective requirements for automatic data collection (ADC) should include a standard methodology for describing tools and their elements, a minimum list of the event messages needed, and a test for message completeness and accuracy. To encourage implementation of the requirement, the list of events should be the minimum necessary and should be as generic as possible.
- To maintain consistency, other standards should be leveraged where appropriate.

1.3 Purpose of the Document

The purpose of this document is to

- Define the minimum (baseline) data required for performance tracking
  - Level 1 Objective: to list the minimum amount of data needed to allow the user to calculate performance metrics for the primary process modules

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[1] Section 2.2, reference 1

[2] Section 2.2, reference 2

[3] Section 2.2, reference 3

[4] Section 2.2, reference 4

  - Level 2 Objective: to list the data needed to allow the user to calculate performance metrics and to perform analyses of all the modules
- Define the compliance testing goals and methodologies for Levels 1 and 2
- Provide the guidelines for software documentation and compliance testing reporting

1.4 Scope of the Document

This document consists of guidelines for equipment suppliers to promote an initial ADC baseline. It is targeted at 150 mm and 200 mm toolsets with a 300 mm update expected. Requested data will include only that information that the tool "knows" about itself, including information that it may have obtained from the Manufacturing Execution Systems (MES), wafer ID readers, or operator input.

The document has two separate sets of requirements:

- Those that address module task measurement pairs and associated variables
- Those that address product-material task measurement pairs and associated variables

1.5 Intended Usage of Data

Data collected by ADC is used by the semiconductor manufacturing factory to create a "picture" of the states of the equipment modules and the flow of wafers through the tool in real-time.

A few of the possible uses of the data gathered using ADC are as follows:

- Input into overall equipment effectiveness (OEE) calculations
- Input into SEMI E10 calculations
- Input into an elemental criticality analysis (ECA)
- Input into equipment productivity loss calculations
- Input into an analysis of events associated with non-standard product

1.6 Industry Usage

Below are a few of the metrics derived from ADC data currently being tracked by some of the semiconductor device manufacturers:

- Productive time
- Standby time
- Engineering wafer processing time
- Qualification wafer processing time
- Rework-wafer processing time
- Unscheduled downtime (alarm triggered)
- Interrupt time that occurs during productive time
- The number of interrupts
- The number of cycles or wafers
- Process recipe-step duration
- In situ chamber clean time
- Lot waiting for unload

- Wafer processing time by wafer ID, by recipe, by lot, and by module
- Average wafer processing time by recipe, by lot, and by module
- Loadlock pumpdown time
- Loadlock vent time
- Wafer transfer time

2 REFERENCE DOCUMENTS

2.1 SEMI Standards

The following standards are applicable to this document.

SEMI E5-0600 – SEMI Equipment Communications Standard (SECS-II)

SEMI E10-0600 – Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAMS)

SEMI E30-0600 – Generic model for Communications and Control of SEMI Equipment (GEM)

SEMI E37-0298 – High-speed SECS Message Services (HSMS) Generic Services

SEMI E40-0200 – Process Management (PM)

SEMI E41-95 – Exception Management Standard (EMS)

SEMI E42-0299E – Recipe Management Standard (RMS)

SEMI E53-1296 – Event Reporting Standard

SEMI E54-0997 – Sensor/Actuator Network Standard

SEMI E58-0697 – Automated Reliability, Availability, and Maintainability (ARAMS)

SEMI E79-0200 – Standard for Definition and Measurement of Equipment Productivity

SEMI E98-0600 – Object-Based Equipment Model (OBEM)

2.2 Other References

1. Leachman, Robert C., Editor, *Third Report on the Results of the Main Phase*, Competitive Semiconductor Manufacturing Report Series, CSM-31, Engineering Systems Research Center, University of California, Berkeley, August 1996.
2. Aardal, Marv, *Benchmarking Study Report: Equipment Data Collection and Use of Data*, SEMATECH Technology Transfer # 95052835A-TR, June, 1995.
3. Busing, David P., “Automated Procedures for Characterizing Specific Equipment Productivity Losses with Applications in the Semiconductor Manufacturing Industry,” *Competitive Semiconductor Manufacturing Program*, CSM-45, ESRC 99-01, Engineering Systems Research Center, University of California, Berkeley, February 1998.
4. Deller, Clete, “Automatic Data Collection For Operational And Equipment Performance, A Perspective From International SEMATECH,” published on ISMT TP2 webpage, September 1999.

5. Leachman, Robert C., Busing, Cruikshank, Lui, Moore, Woo, “Models of Theoretical and Average Process Times for Selected Semiconductor Fabrication Equipment,” *Competitive Semiconductor Manufacturing Report Series*, CSM-44, Engineering Systems Research Center, University of California Berkeley, December 1998.
6. Moder, Philips, David, *Project Management and CPM, PERT and Precedence Diagramming*, Third Edition, Blitz Publishing Company, Middleton, Wisconsin, 1983.

3 TERMINOLOGY

3.1 Acronyms and Abbreviations

ADC – Automatic Data Collection

ALID – Alarm Event Identifier

AMHS – Automated Material Handling System

APC – Advanced Process Control

ARAMS – Automated Reliability, Availability, and Maintainability Standard. (SEMI E58)

CEID – Collection Event Identifier

Ch – Process Chamber

ECA – Elemental Criticality Analysis

EPT – Equipment Performance Tracking

LL – Loadlock

MES – Manufacturing Execution Systems

OEE – Overall Equipment Efficiency

RAMS – Reliability Availability Maintainability Standard (SEMI E10)

SEMI – Semiconductor Equipment and Materials International

SECS-II – Semiconductor Equipment Communications Standards (SEMI E5)

SVID – System Variable Identifier

TP2 – Tool Performance Tracking Platform

3.2 Definitions

actuator — An analog or digital output device used to effect changes in the physical environment. Examples of actuators include mass flow controllers (MFCs) and open/closed valves. [SEMI E98-0600 (OBEM) Sec. 5.2]

advanced process control (APC) — Techniques covering both feed-forward and feedback control and automated fault detection, applied both by the equipment (in situ) and by the factory (ex situ). [SEMI E98-0600 (OBEM) Sec. 5.2]

carrier — This includes the cassette, SMIF pod, or FOUP used to transport product-material through the factory.

clock — A device that is used to provide real-time date and time information. [SEMI E98-0600 (OBEM) Sec. 5.2]

elemental criticality analysis or algorithm (ECA) — An elemental criticality algorithm uses critical path calculations based on network models to calculate elemental losses that affect equipment productivity. [5]

equipment — Equipment (manufacturing equipment) performs one or more of the following manufacturing functions in the factory: material process, material transport, or material storage. Equipment is made up of various parts: modules, subsystems, and sensors/actuators. Equipment has at least one carrier port. Equipment communicates with the factory. [SEMI E98-0600 (OBEM) Sec. 5.2]

equipment element — A component of the equipment that behaves as a unit, performs work, and may or may not contain lower-level components. [SEMI E98-0600 (OBEM) Sec. 5.2]

equipment performance tracking (EPT) — On-tool performance tracking implementation that is similar to E58, but does not require user input. Standard is currently under development by the SEMI EPT task force.

event timestamp — Time and date from the equipment that it assigns to an event when it occurs.

fault detection — Analysis of data for early detection of process faults before yield loss becomes significant. [SEMI E98-0600 (OBEM) Sec. 5.2]

I/O device — A general term for any type of sensor or actuator or aggregation of sensor and/or actuator. [SEMI E98-0600 (OBEM) Sec. 5.2]

linked equipment — Two or more equipment physically and logically connected and functioning as a single installation of equipment. In this case, the individual component equipment is modeled as a high-level module of the linked equipment. [SEMI E98-0600 (OBEM) Sec. 5.2]

lot ID — A unique designation that is used by the factory for identifying and tracking product-material through the factory.

Manufacturing Execution System (MES) — The factory system responsible for managing the manufacturing process, including logistics and process flow. [SEMI E98-0600 (OBEM) Sec. 5.2]

material — (1) Any material used in, or required by, the manufacturing process. Material is classified as consumable, durable, or product. (2) An abstraction of the various types of things used during manufacturing, such as wafers, reticles, carriers, or chemicals, that require some management. [SEMI E98-0600 (OBEM) Sec. 5.2]

material location — A reference to a place within the equipment of an equipment component that can hold material, such as the top surface of an indexer or substrate chuck or the end effector of a substrate handler. [SEMI E98-0600 (OBEM) Sec. 5.2]

measurement equipment — Equipment whose intended function is to measure or inspect the product and to report results. Measurement of the product is the factory's means of gaining feedback on the manufacturing process. [SEMI E98-0600 (OBEM) Sec. 5.2]

module (equipment module) — A major component of equipment that contains at least one material location and performs some task on material. Equipment modules may be aggregates of

---

[5] Section 2.2, reference 5

equipment subsystems, I/O devices, and other modules. [SEMI E98-0600 (OBEM) Sec. 5.2] It is responsible for handling, storing, and/or processing product-material in one of the following manners:

1. Module's sequence of steps or actions is fixed and does not vary by product or recipe
2. Module has a fixed sequence of steps that allows varying settings by recipe
3. Module's process can have a variable sequence of steps and the module's recipe controls the step parameters and duration

process equipment — Equipment whose intended function is to process product, that is, adding value to the product. [SEMI E98-0600 (OBEM) Sec. 5.2]

process flow name — The designation given to the set of instructions that control the product-material's movement through the equipment and the process recipe IDs to be executed at designated modules.

product (product-material) — (1) From the equipment's perspective, product is a synonym for substrate and includes non-product substrates such as test substrates and send-ahead substrates; (2) From the factory perspective, product is the material being processed and produced by the factory. [SEMI E98-0600 (OBEM) Sec. 5.2]

recipe ID — The designation given to a particular recipe that is used to identify and track that recipe.

recipe step ID — An ID that describes the order of the recipe steps.

recipe step name — A name given to each recipe step.

run-to-run control — Techniques for varying settings in one run based on analysis of either incoming product (feed-forward) or product from an earlier run. [SEMI E98-0600 (OBEM) Sec. 5.2]

sensor — A component that responds to changes in the physical environment and provides an analog or digital input value. [SEMI E98-0600 (OBEM) Sec. 5.2]

sensor/actuator device — A device consisting of one or more sensors and/or actuators on the physical tool. See SEMI E54 for a precise definition of "sensor or actuator" and for a description of the internal structure of a sensor/actuator network Common Device Model Definition. [SEMI E98-0600 (OBEM) Sec. 5.2]

setup — 1. (verb) The performance of one or more steps that puts the equipment into a known state in which it is ready to perform a specific process; 2. (noun) The state of the equipment once it has been set up. [SEMI E98-0600 (OBEM) Sec. 5.2]

subassembly — A component of equipment that provides some limited functionality. [SEMI E98-0600 (OBEM) Sec. 5.2]

subsystem — An intelligent aggregate that behaves as a unit. A subsystem is made up of sensors and/or actuators and may contain mechanical assemblies. Multiple modules may share subsystems. [SEMI E98-0600 (OBEM) Sec. 5.2]

task — EPT task force is developing exact definition. It is used in this document in two ways: (1) as an action performed by an equipment module other than those actions necessary (which do not require a recipe) to maintain environmental requirements such as background temperature,

pressure, particle monitoring, etc.; (2) to describe the duration of each unit of product-material being handled and processed through the equipment.

wafer ID — The identifier from the “ID reader.” If no ID reader is present, then it is an integer value used to identify from which slot in the carrier the wafer originated.

4 MODELING INTERNAL COMPOSITION OF EQUIPMENT

4.1 SEMI E98-0600 (OBEM) Model

“The physical makeup of equipment is of interest to the factory, particularly for equipment that is complex, multi-module, and/or multi-process. Productivity and maintenance tracking, for example, requires that the factory be able to specify individual subsystems and/or modules for maintenance activities, where it is possible to do so without removing the entire equipment from manufacturing scheduling. Efficient and effective product processing requires that the appropriate equipment elements and subsystems are capable of reporting their states and variables on a real-time basis.” [6]

Figure 1 shows a high level example of the internal composition of equipment using the SEMI E98-0600 standard. “Equipment is made up of elements (units or parts) of different levels of intelligence and complexity, such as modules, subsystems, and I/O devices. Each of these elements may be made up of several smaller subsystems, some of which may also be intelligent, and this allows the complexity of the equipment to be distributed to smaller functional units. Many of these elements may be of interest to the factory. In particular, the process modules, which are intelligent and may be independently operable, are very interesting to the factory, since these are the units where the product is actually processed. The factory requires processing modules to be highly visible and individually addressable and to support certain of the same remote commands that are required of the equipment. Other elements of interest include subsystems for material handling, alignment, and measurement.” [7]

[6] SEMI E98-0600 (OBEM) section 8.5

[7] SEMI E98-0600 (OBEM) section 9.1

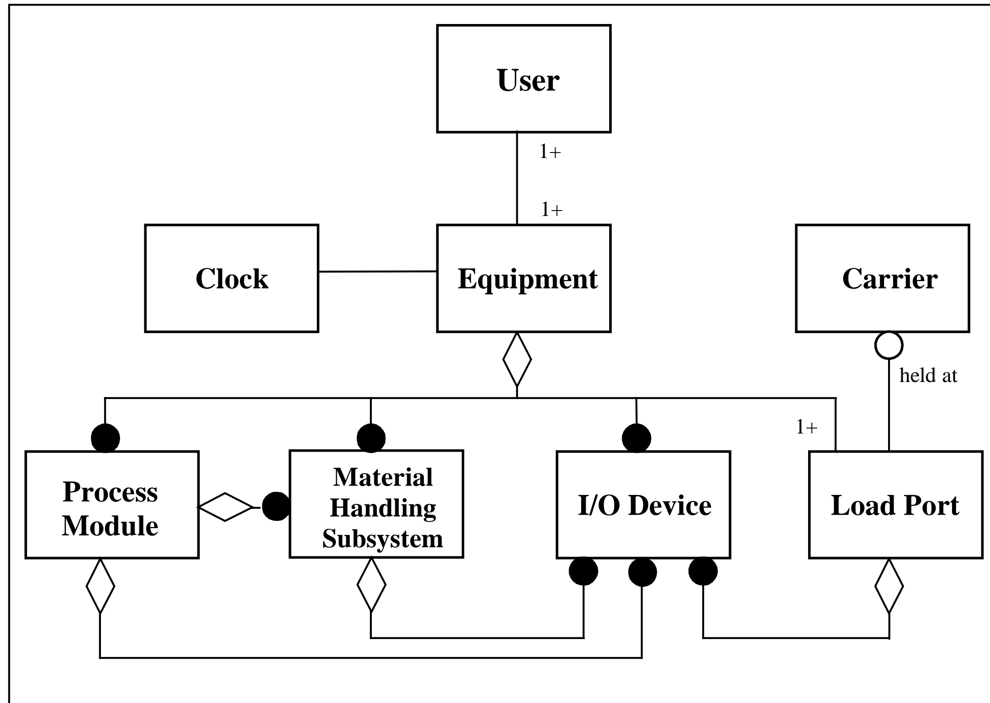

Figure 1 An Example of Equipment Internal Composition [8]

[8] Reprinted with permission from SEMI E98-0600 (OBEM) © SEMI 2000 Semiconductor Equipment Materials International. All rights reserved.

4.2 Tool Element Examples

Figure 2 is an example of tool elements for a wafer polisher.

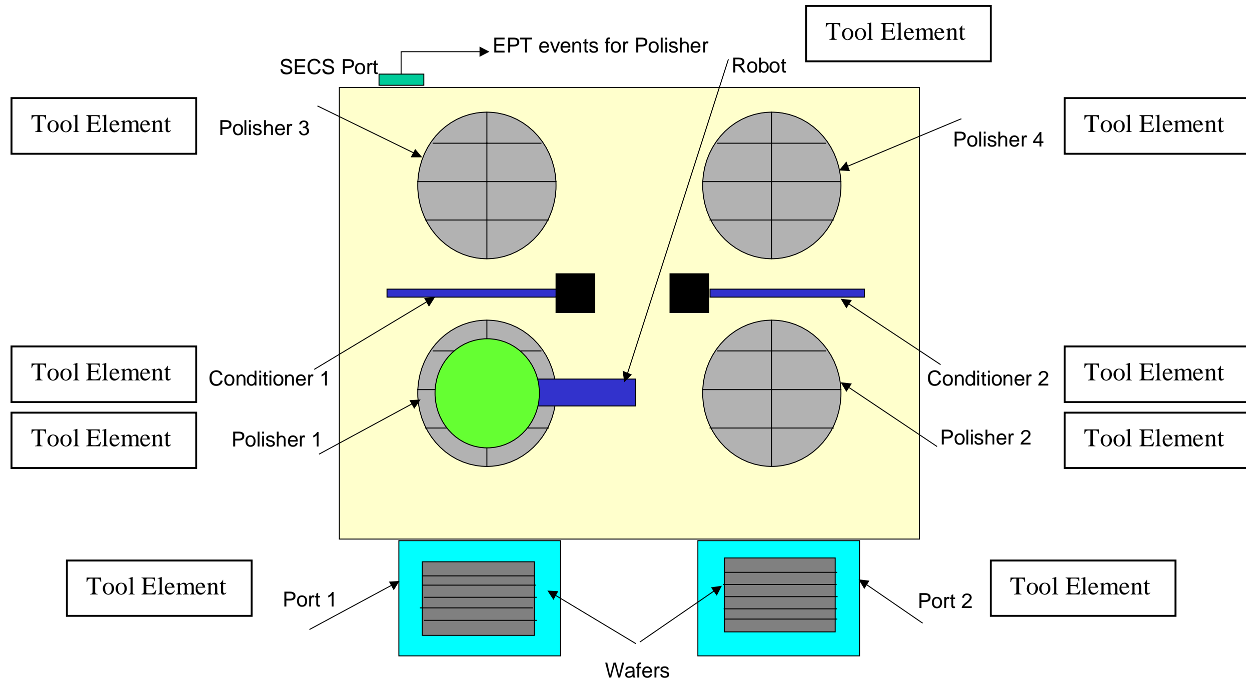

Figure 2 Example of Wafer Polisher Elements

Table 1 gives further examples of some tool elements for additional tool types.

Table 1 Examples of Tool Elements

CMP	Linked Litho Track	Linked Litho Expose	Thin Film Deposition	Vertical Reactor
Alignment Stage	Load ports	Expose Stage	Central Wafer Handler	Quartz Loading Station
Polish Table	Spin Cup	Wafer Transfer	Cool Down Module	Reactor Module
Wafer Handler	Central Wafer Handler Module	Link Transfer Station – In port	PVD Module	Wafer Transfer System
Slurry Flush	Link Transfer Station	Link Transfer Station – Out port	Loadlock Module	Gas-Panel
Rinse/Scrub Station	Resist Delivery System	Laser Assembly	Argon Sputter Etch Module	
Transport Table	Vapor Prime	Reticle Management	TEOS Cabinet	
	Chill Plate		Degas Module	
	Soft Bake		CVD Module	

5 EVENT/ALARM REPORTING – TRACKING EQUIPMENT AND PRODUCT-MATERIAL TASKS

5.1 Equipment Elements and Modules

From the factory's perspective, an equipment element is a component of the equipment that behaves as a unit, performs work, and may or may not contain lower level components. [9] An equipment module is an equipment element that contains at least one product-material location. [10] The requirements in this document are focused on gathering information on the states of these modules. Updates will address the requirements for equipment elements that do not contain product-material locations.

5.2 Basic Assumptions

This document is based on the following assumptions relative to modules and the tool process:

- A module is assumed to be in one of three states: busy, blocked, or idle.
- A module is "idle" when it is not performing any active, finite task and able to start a new one. It is idle when it is maintaining environmental requirements such as particle monitoring, background temperature, etc., which do not require a recipe. Idle is the Default State of the module.
- A module is "blocked" when it has a critical fault or interrupt condition that prevents it from being "busy" or when it is waiting for input to resume its previous "busy" state.
- A module is considered "busy" when it is performing a "task" or a set of tasks. Material does not need to be present in the module when these tasks are occurring.
- In this document, "task" is also used to describe the duration of each unit of product-material being handled and processed through the equipment.
- Every task has a beginning/start event and an end/complete event. If these events are SECS-II enabled, an "event report" will be transmitted. An "event report" is referred to as a "message" or "event message" in this document.
- Each event or alarm will generate a single message with all the required information.
- Each task will have its own corresponding message pair.
- If the equipment possesses more than one main process capability, as in cluster tools, then each module will have its own message pairs.
- Transport modules will have the capability of issuing event message pairs with "Pick" and "Place" information.
- Every severe alarm "set" has an associated alarm "clear."
- Severe alarms are defined as those with severity codes 1, 2, 4, and 5 and that result in the equipment or module's process stopping (see SEMI E5-0600, section 7.9).
- The tool process (module tasks and product-material flow through the tool) can be described and depicted using simple Gantt charts [11] (see Figure 3 and Figure 4).

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[9] SEMI E98 -0600(OBEM) Section 5.2.13

[10] SEMI E98-0600 (OBEM) Section 5.2.14

[11] Section 2.2, reference 6

5.3 Modules

Modules can be described by the level of input they require. Typically, the more user input the module requires, the more data collection is required to successfully monitor the process. Table 2 contains the definitions for three module types that will be used in this document.

Table 2 Module Types

Type #	Module Type Name	Type Description
1	Fixed Algorithm	The module's sequence of steps or actions is fixed and does not vary by product or recipe. *Examples: Central Wafer Handler, Wafer Orienter*
2	Fixed Process	The module has a fixed sequence of steps that allows varying settings by recipe. *Examples: Bake Oven, Loadlocks*
3	Step Process	The module's process has variable sequence of steps and the module's recipe controls the step parameters and duration. *Examples: CVD, PVD, Etch, and Spin-coat chambers*

5.4 Basic Measurement Categories

The need for information falls into two basic categories:

- Message pairs and associated variables used to capture the duration and performance aspects of an module task
- Message pairs and associated variables used to capture the duration of a product-material task

An example of module task and product-material task messages on a sequential process tool is given in Figure 3.

The number of tasks per tool can vary based on different tool configurations. Figure 4 depicts the tasks for a cluster tool processing three wafers through parallel modules, chamber A and chamber B, with two wafer transfer systems and a four-wafer batch loadlock. Chamber A processes wafers 1 and 3, and chamber B processes wafer 2.

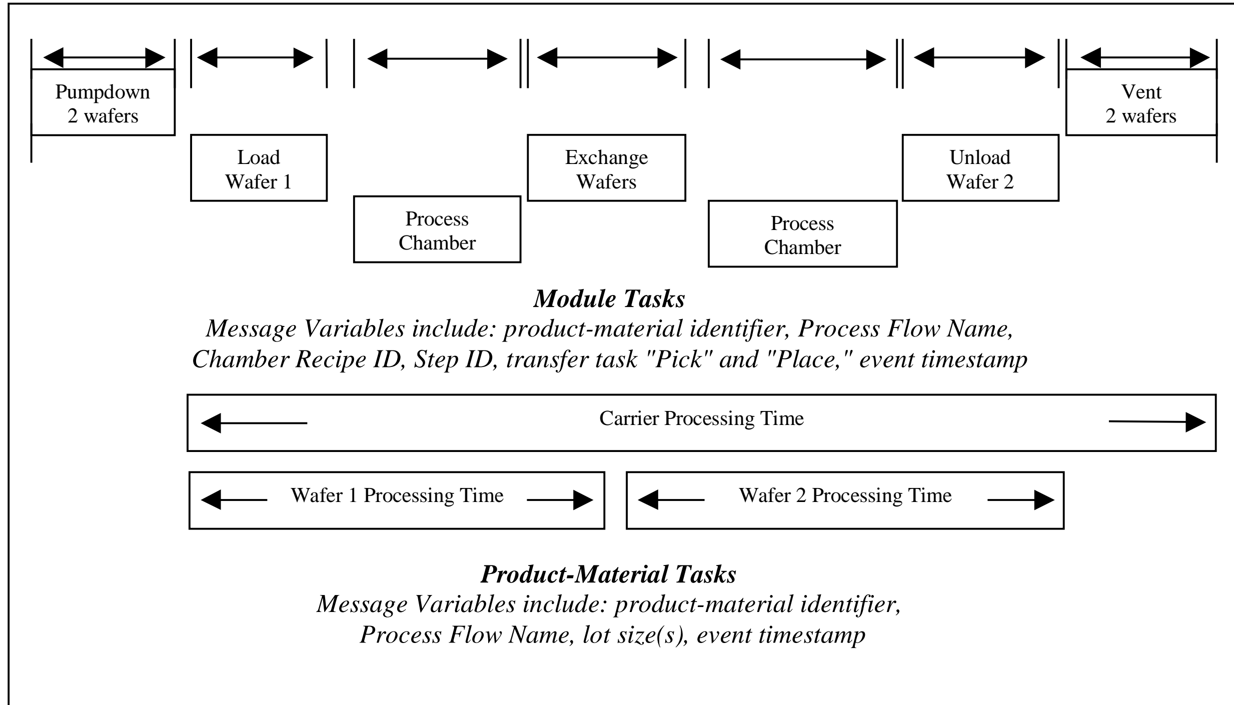

Figure 3 Tasks for Sequential Processing Equipment

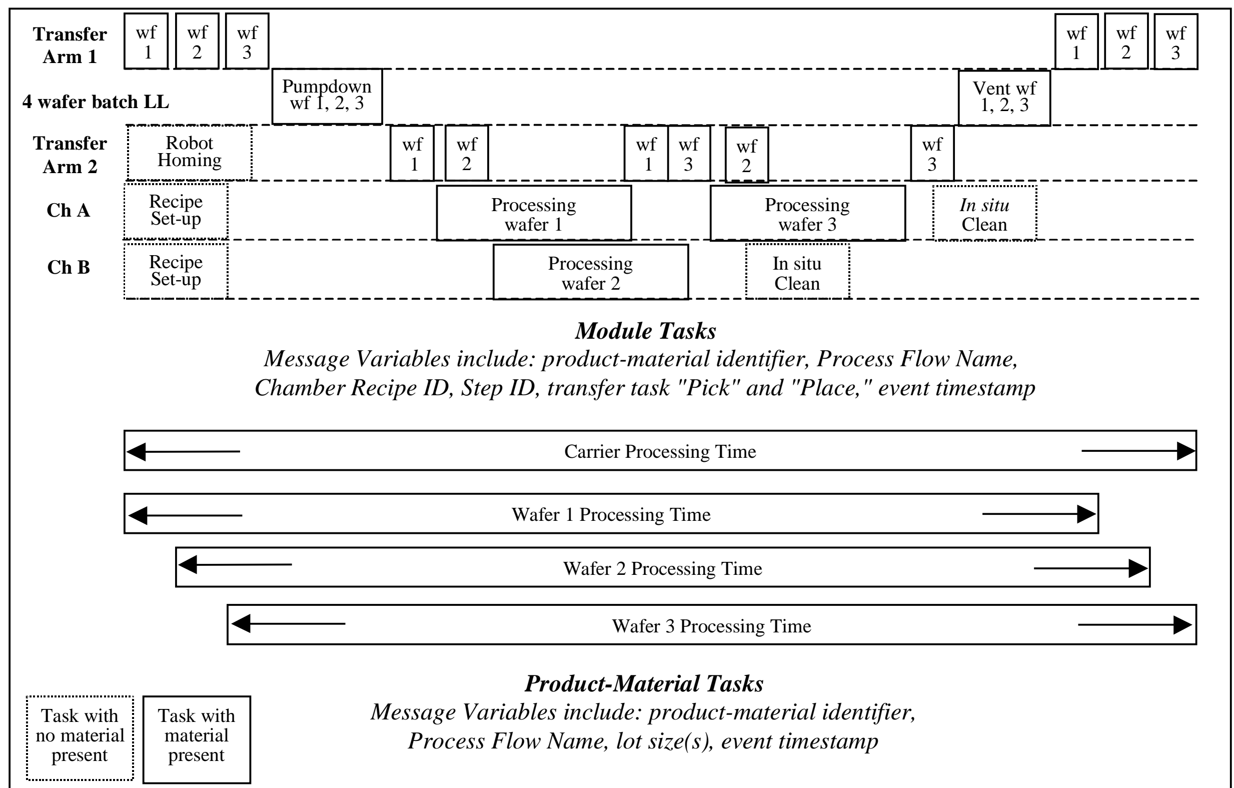

Figure 4 Tasks for Parallel Processing Equipment

6 REQUIREMENTS FOR LEVELS 1 AND 2

6.1 Overview

Table 3 is a summary by equipment element type of the data collection scheme described in sections 6.3 (Level 1) and 6.4 (Level 2) for module tasks.

Table 3 Module Task Messages by Equipment Element Type

<table>
<tr><th colspan="3">Equipment Element Categories</th></tr>
<tr><th>Elements Without a Location for Product-Material Processing</th><th colspan="2">Elements With a Location for Product-Material Processing (Modules)</th></tr>
<tr><td rowspan="4">Messages to be determined in a future ADC version</td><th>Product-Material Present In Module</th><th>Product-Material's Presence In Module <u>Not</u> Required</th></tr>
<tr><td>Fixed Algorithm Module:
Level 2 module messages</td><td>Fixed Algorithm Module:
Level 2 "Additional Task" messages</td></tr>
<tr><td>Fixed Process Module:
Level 2 module messages</td><td>Fixed Process Module:
Level 2 "Additional Task" messages</td></tr>
<tr><td>Step Process Module:
Levels 1 & 2 module messages</td><td>Fixed Algorithm Module:
Level 2 "Additional Task" messages</td></tr>
</table>

6.2 Background

Table 4 through Table 8 contain the messages and variables required for Levels 1 and 2. These requirements assume the equipment has enabled the SECS-II standard. (See Appendix A for typical SECS-II messages and variables.) Product-material processing for wafers is considered to have started when the wafer leaves the source carrier; it is considered complete when the wafer is returned to the destination carrier. Product-material processing for a carrier is considered to have started when the first wafer leaves the source carrier and is considered complete when the carrier is ready for removal by the factory AMHS or operator.

It is assumed that the Lot ID, Process Flow Name, and/or Recipe ID(s) have been provided to the equipment by automation from the MES system or from manual input. Wafer ID(s) may have been obtained by a wafer ID reader. If no ID reader is available, then Wafer ID is an integer value representing the wafer's carrier-slot of origin.

It is important for the user to be able to associate each of the events with the product-material affected by that event. The definition of product-material will vary by the module's processing mode. That is, a module may be designed to process single wafers, single carrier, or various sized batches of wafers that may or may not include wafers from multiple lots and carriers. Therefore, the start and complete event messages for tasks in these processing modules need to include the appropriate product-material identifiers in their event reports as defined in Table 4. Event reports for batch processing modules should also include the location of the material in the processing module, for example, the position of a lot on a wet-bench transfer arm or the position of a wafer on an implant wheel.

If a factory allows multiple lots in one carrier or multiple carriers for one lot, then an additional product-material identifier (carrier ID) will be required.

Table 4 Product-material Identifiers by Module's Processing Mode

Processing Mode	Description	Product-material Identifiers
Single-wafer	The module processes or handles a single wafer at a time.	Wafer ID, Lot ID, carrier ID (optional)
Multiple-wafer-batches	The module processes or handles multiple wafers (less than 25) at a time. The wafers may come from more than one Production Lot and from more than one carrier.	Wafer ID(s), Lot ID(s), carrier ID(s) (optional)
Single-carrier	The module processes or handles one carrier at a time.	Lot ID, carrier ID (optional)
Multiple-carrier-batches	The module processes or handles multiple whole carriers at a time.	Lot ID(s), carrier ID(s) (optional)

6.3 Level 1 Message Pairs

Table 5 and Table 6 contain Level 1 message pairs and associated variables. These will provide the user with the minimum information needed to calculate some of the inputs into OEE and SEMI E10 metrics.

Table 5 Level 1 Module Task Messages Pairs and Variables

Description	Data ID	Used For	Associated Variables
Process Step Module (Table 2, type 3) Start Message	CEID	Start measurement of a type 3 module	Recipe ID, Product-material identifiers, Module ID
Process Step Module (Table 2, type 3) Complete Message	CEID	Complete measurement of a type 3 module	Recipe ID, Product-material identifiers, Module ID
Alarm Set – Severe Alarms	ALID	Start measurement of alarm downtime	Alarm Severity Code, Alarm Text
Alarm Clear – Severe Alarms	ALID	Complete measurement of alarm downtime	Alarm Severity Code, Alarm Text

Table 6 Level 1 Product-material Task Message Pairs and Variables

Description	Data ID	Usage	Associated Variables
Wafer Start Message	CEID	Start measurement of wafer processing time	Product-material identifier, Process Flow Name
Wafer Complete Message	CEID	Complete measurement of wafer processing time	Product-material identifier, Process Flow Name
Carrier Start Message	CEID	Start measurement of carrier processing time	Product-material identifier, Process Flow Name, lot size(s), loadport name
Carrier Complete Message	CEID	Complete measurement of carrier processing time	Product-material identifier, Process Flow Name, lot size(s), loadport name

6.4 Level 2 Message Pairs

Table 7 and Table 8 contain Level 2 message pairs and associated variables. These will provide the user with additional information for calculating Level 1 metrics as well as the ability to perform ECA and equipment productivity loss calculations.

Additional Tasks messages are module-specific. These messages should capture the time that the module spends performing other "busy" tasks. Examples are included in Table 25 of Appendix C. If no product-material is present in the module at the time of the task and at least one of the following conditions is true, then the product-material identifier must be included in the additional task's event message.

- The task is initiated because of the product-material's presence elsewhere in the equipment
- The execution of the task will affect the product-material's total processing time

Table 7 Level 2 Module Task Messages Pairs and Variables

Description	Data ID	Usage	Associated Variables
All Level 1 message pairs from Table 5	–	–	The same as Level 1 plus the Event Timestamp
Module Start Message (Table 2, types 1 & 2)	CEID	Start measurement of a type 1 or 2 module task	Recipe ID, Product-material identifier, Module ID, Event Timestamp, "Pick" and "Place" information for transport modules
Module Complete Message (Table 2, types 1 & 2)	CEID	Complete measurement of a type 1 or 2 module task	Recipe ID, Product-material identifier, Module ID, Event Timestamp, "Pick" and "Place" information for transport modules
Recipe Step Start Message(s)	CEID	Start measurement of recipe step(s) for process step module (Table 2, type 3)	Recipe ID, Step ID, Product-material identifier, Module ID, Event Timestamp
Recipe Step Complete Message(s)	CEID	Complete measurement of recipe step(s) for process step module (Table 2, type 3)	Recipe ID, Step ID, Product-material identifier, Module ID, Event Timestamp
Additional Task(s) Start Message(s) (product-material's presence is not required)	CEID	Start measurement of module's additional busy task(s) (for Table 2, type 1, 2, or 3)	Product-material identifier (if applicable), Module ID, Event Timestamp
Additional Task(s) Complete Message(s) (product-material's presence is not required)	CEID	Complete measurement of module's additional busy task(s) (for Table 2, type 1, 2, or 3)	Product-material identifier (if applicable), Module ID, Event Timestamp
Alarm Set – Severe Alarms	ALID	Start measurement of alarm downtime	Alarm Severity Code, Alarm Text, Module ID, Event Timestamp
Alarm Clear – Severe Alarms	ALID	Complete measurement of alarm downtime	Alarm Severity Code, Alarm Text, Module ID, Event Timestamp

Table 8 contains Level 2 product-material and non-product material message pairs. Non-product-material tasks are module-specific. Examples of nonproduct-material are reticles, ceramic substrates, dummy or filler wafers, calibration material, etc.

Table 8 Level 2 Product-material Task Message Pairs and Variables

Description	Data ID	Usage	Associated Variables
All Level 1 message pairs from Table 6	–	–	The same as Level 1 plus the Event Timestamp
Carrier Waiting for Input Before Starting	CEID	Start measure of blocked time due to waiting for operator, AMHS, or host input	Product-material identifiers, Process Flow Name, lot size(s), loadport name, Event Timestamp
Input Received	CEID	Complete measure of blocked time due to waiting for operator, AMHS, or host input	Product-material identifiers, Process Flow Name, lot size(s), loadport name, Event Timestamp
Carrier Ready for Unload	CEID	Start measure of idle time due to no operator or AMHS available	Product-material identifiers, Process Flow Name, lot size(s), loadport name, Event Timestamp
Carrier Unloaded	CEID	Complete measure of idle time due to no operator or AMHS available	Product-material identifiers, Process Flow Name, lot size(s), loadport name, Event Timestamp
Start of movement of non-product-material	CEID	Start measure of non-product-material transfer and process time	Event Timestamp, material identifier (if applicable)
Completion of movement of non-product-material	CEID	Complete measure of non-product-material transfer and process time	Event Timestamp, material identifier (if applicable)

7 ACCURACY OF SECS-II EVENT MESSAGES

7.1 Historical Perspective

Dr. David Busing (University of California, Berkeley) identified significant errors in the SECS-II messages coming from two semiconductor tools. [12] The experience of the TP2 project on over 400 tools has validated Dr. Busing's study. The problems encountered with the SECS-II messages fall into ten basic categories:

1. Unavailable messages
2. Duplicate events
3. Data in conflict with the known equipment process flow
4. Message missing
5. Missing variables from message

[12] Section 2.2, reference 3

6. Data with incorrect event timestamps
7. Conflicts in timestamps
8. Completion time is earlier than start time
9. Timestamp is missing
10. Equipment alarm message errors

7.2 Definitions of Error Types

Following is a detailed explanation of the ten error types:

1. *Unavailable messages*
   One or more messages required for baseline compliance (see section 6) are not available.
2. *Duplicate Events*
   Identical event messages issued with the same timestamp.
3. *Data in conflict with the known equipment process flow*
   Equipment emits messages that violate the known logical sequence of events for the tool process. For example, if each wafer is supposed to receive 1) a metal etch, 2) a strip, and 3) a cooling recipe, messages are emitted out of order (1, 3, 2, or 2, 1, 3, etc.).
4. *Missing messages*
   Equipment emits messages on an intermittent basis. For example, a normally occurring “wafer complete” message is not received as expected after a “wafer start.”
5. *Missing Variables*
   Information that is normally present in a given event report is absent.
6. *Data with incorrect timestamps*
   Timestamps from the equipment messages deviate from the wafer fab “standard clock.” To obtain an accurate picture of the wafer fab, the clocks for the equipment, the “middleware,” and the factory must be synchronized.
7. *Conflicts in timestamps*
   Data conflicts in timestamps can happen in two different situations:
   a. Timestamps for duplicate messages – Timestamps for duplicate messages for the same event have conflicting times.
   b. Timestamps for different messages that represent the same process step are in conflict. For example, the timestamp for the first processing step start was in conflict with the timestamp for the corresponding module start message.
8. *Completion time is earlier than start time*
   The completion time (either from the event timestamp or from the received timestamp) is before the start time.
9. *Timestamp is missing (sent or received)*
   The message is issued, but it does not contain a timestamp.
10. *Equipment Alarm Message Errors*
    Four basic alarm errors must be addressed:
    a. Alarm messages are not issued in pairs (e.g., both set and clear messages are not issued).

b. Alarm messages with severities 1, 2, 4, and 5 do not stop the equipment process or Alarm messages with severities 0, 3, 6, 7, and 8 stop the equipment process (SEMI E5-0600, section 7.9).
c. Alarm clear does not signify that the alarm condition no longer exists.

7.3 Testing Requirements

Table 9 contains the testing and verification required for Level 1 ADC compliance.

Table 9 Testing Requirements for Level 1 Messages and Variables

Test Number	Test Description
Test 1	Verify the message pairs and variables required in Level 1 are available.
Test 2	Test messages for duplicate events.
Test 3	Test messages to assure that the order that messages are issued is not in conflict with the process flow.
Test 4	Test messages for missing messages (a normally occurring message did not occur as expected).
Test 5	Test messages for missing variables.
Test 6	Test messages to assure there are no conflicts between timestamps (between messages that are different, but represent the same process step).
Test 7	Test messages to assure that completion times are not earlier than start times.
Test 8	Test to assure all Alarm messages with severity codes 1, 2, 4, and 5 are issued in pairs, i.e., for each alarm, both “Alarm Set” and “Alarm Clear” messages are issued.
Test 9	Verify that all Alarm messages with severity codes 1, 2, 4, and 5 stop the equipment or module and verify that all Alarm messages with severity codes 0, 3, 6, 7, and 8 do not stop the equipment or module (SEMI E5-0600, section 7.9).
Test 10	Verify that “Alarm Clear” messages signify that the Alarm condition no longer exists.

Table 10 contains the testing and verification required for Level 2 ADC compliance.

Table 10 Testing Requirements for Level 1 and 2 Messages and Variables

Test Number	Test Description
Tests 1 through 4 & 6 through 10	Test and verify Level 1 and Level 2 messages and variables (Table 9).
Test 5	Test messages for missing variables, including event timestamps.
Test 11	Describe how the equipment's clock may be synchronized with the “middleware” and factory clocks.

8 TESTING AND REPORTING

8.1 How to Use This Document

This document outlines the requirements for equipment upgrades, modifications, and purchases of new equipment. The following steps are suggested for using this document:

1. Read and review this document and appendices B and C (Appendix B contains a sample report and Appendix C contains suggested reporting tables).
2. Develop a process diagram that describes the tasks in the tool process (Figure 3 and Figure 4). If more than one process flow or sequence are possible, the diagram should include the process flow that contains the most possible tasks and modules.
3. Identify the Level (1 or 2) that you plan to meet. Using the process diagram and the tables in Appendix C, define the list of message pairs and variables to meet that Level. List the variables that are required with each message.
4. Using SEMI E10 reliability testing methodologies, develop a test plan to test the messages and variables for completeness and accuracy (for Levels 1 and 2).
5. Apply the methodology to the equipment and product-material task events and variables. Record the results in a format similar to the tables in Appendix C. Note at the top of each table the appropriate compliance level. List and provide details for each message that is not available (based on the diagrams you have developed) and/or does not meet the testing criteria (Table 9 or Table 10).
6. Develop and provide an action plan to address any shortcomings. Provide action plan details in the appropriate table in Appendix C).
7. Submit the diagrams, the test methodology, and the results using the tables in Appendix C, as needed.

8.2 Testing Recommendations

Testing should be rigorous and should be performed for a meaningful period of time. The tool and all its modules should be operated in all of their functions. The testing mode should simulate a production environment. It should include the sending of lot and recipe information through an automation simulator and performing any internal database purging and activities that may occur during normal production. Verify that all alarms adhere to the definitions in SEMI E5-0600, section 7.9. This may be done using a simulator or a mechanical dry cycle mode.

Use SEMI E10 statistical testing methods to design a test for mean cycles between failures (MCBF) at the 80% confidence level. A "cycle" is an event or alarm message. A recommended target is an MCBF of more than 10,000 cycles between failures for single-wafer processing tools. The target should be scaled appropriately for batch processing tools.

Reliability testing methodologies and the statistical tables from SEMI E10 are also available at http://www.nist.gov/stat.handbook, chapter 8 ("Reliability"), section 8.3.1.1 ("Planning Reliability Assessment Tests"), and section 8.4.5.1 ("Fitting System Repair Rate Models"/"HPP/Exponential Model").

8.3 Software Documentation

Using Table 23 through Table 33 in Appendix C, the following documentation should be received to comply with the requirements of this document:

a. A description of the testing methodology used to meet these requirements.
b. Diagrams (similar to a Gantt chart – see Figure 3 and Figure 4) depicting the equipment process.
c. Detailed list of the events and variables available based on the diagram, including a list of events that “trigger” the event messages.
d. Testing results for the appropriate level.
e. All SECS-II logfiles generated during the testing period.
f. Verification that all alarm messages comply with SEMI E5, section 7.9, definitions.

9 ADC COMPLIANCE FOR ADVANCED PROCESS CONTROL (APC) VARIABLE REPORTING

Future software must be expected to support automatic data collection (ADC) of the tool and process health. This includes process parameter data collection, fault detection and classification, diagnosis, fingerprinting, and other related activities that will allow process and equipment engineers to monitor and improve tool performance and to reduce costs. Examples of process parameters (actual and setpoint) that may be of interest to the factory are temperature, chamber pressure, gas flows, etc.

Some of the future requirements will include the following:

- Ability to collect data through the tool's communication port.
  - Collected data values with associated timestamps will include sensors, I/O devices, actuators, process events, internal states, etc.
  - Communication port will need to support High-Speed SECS Message Service (HSMS) per SEMI E37-0298. The minimum data throughput requirement is estimated at 100 data elements with timestamps per second per process module.
- Data must be accurately time-stamped and the timestamp must be synchronized with the factory’s clock.
- Ability to associate collected process data with product-material identifier, recipe name, step name, process-flow, module identifier, wafer orientation, and equipment parts' life.
- A means to externally block processing of wafers and to externally resume processing of wafers.
- When applicable, a means to externally control the process using endpoint detection.
- A means to update process recipe settings based on feed-forward and run-to-run feedback information.
- Support for a method to synchronize information collected from added external sensors with the tool’s internal state.
- The tool’s communication port should support spooling during trace.
- Ability to add and integrate additional sensors into the tool.
- Summary documentation of all process control strategies and their relationship to updateable process recipe settings.

APPENDIX A
SECS-II MESSAGES FROM THE EQUIPMENT – BUILDING BLOCKS FOR ADC

ADC requires the equipment to emit messages that contain information about the equipment, its variables, and its various states. The "building blocks" for compliance are the equipment SECS-II messages. The SEMI E5 SECS-II standard provides a common language for communications between the equipment and the "outside world." SECS-II provides a number of data items and stream-function structures that facilitate ADC. Some of the typical data items are in Table 11, and typical SECS-II stream-functions are in Table 12.

Table 11 Typical SECS-II Data Items Used for ADC

Data ID	Definition	Usage
ALED	Alarm Enable/Disable Code	Select alarms you want to see
ALCD	Alarm Code	Provide Alarm Set/Reset and severity information
ALID	Alarm ID	Identify alarm
ALTX	Alarm Text	Description of alarm
CEED	Collection Event Enable/Disable Code	Select events you want to see
CEID	Collection Event ID	Identify events
DSID	Data Set ID	Pre-defined reports
DVVAL	Data Value	Variable information included in data-sets
MID	Material ID	Identify wafers, lots, or reticles
PPID	Process Program ID	Identify recipe, process-flow, sequence, or process
RCPID	Recipe ID	Identify recipe
RPTID	Report ID	Custom reports defined by user
TIME	Basic Time Format ("yymmddhhmmss")	Record time within 1 second
TIMESTAMP	Basic Time Format ("yyyymmddhhmmss.cc")	Record time within .01 second
V	Variable Data	Variable information included in the custom reports defined by user

Table 12 Typical Stream-Functions Messages Used for ADC

Stream, Function	Name of Function	Usage
S2, F33	Define Reports	Define the variables (V) to be included in custom reports
S2, F35	Link Report to an Event	Decide which custom report will be included with the S6F11 event for each CEID or ALID
S2, F37	Enable/Disable Report	"Turn on" the desired CEIDs or ALIDs to send event reports
S2, F39	Multi-Block Data Send	Request permission to send multiple blocks of data in an S2F33 or F35 report
S5, F1	Alarm Report Send	Send reports when alarms are set or cleared
S5, F3	Alarm Report Disable	"Turn on" the process for sending reports with the selected alarms
S5, F8	List Enabled Alarm Data	Respond to Host's request (S5F7) to send current alarm status after the system is powered down or reset
S6, F3	Discrete Variable Send	Send an event report that is the same as S6F9, except that the data values (DVVAL) are each accompanied by their name (DVNAME)
S6, F5	Multi-Block Data Send	Request permission to send multiple blocks of data in an S6F3, F9, or F11 report
S6, F9	Formatted Variable Send	Sends an event report with a pre-defined data-set report
S6, F11	Event Report Send	Sends an event report that was defined using S2F33 and S2F35 messages

The events and associated variables required by this document are typically sent in the S6F3, F9, and F11 event messages and in the S5F1 alarm message.

APPENDIX B
AN EXAMPLE OF ADC SOFTWARE DOCUMENTATION AND TESTING RESULTS

Table 13 Equipment Configuration and Testing Schema – Level 2

Date:	20-Jan-2001
Supplier:	Amazing Equipment Supplier (AES)
Equipment Type:	Etcher
Equipment Model:	Metal Etch Cluster Model 2000
Hardware Configuration Tested:	3 – Metal Etch "Turbo" Chambers, 2 – Orienter Chambers 1 – Cooldown Chamber 2 – single-wafer "FastCycle" loadlocks 1 – material handling system, cassette-to-loadlock 1 – material handing system, loadlock-to-chamber, chamber-to-chamber
Software Configuration Tested: **Platform Software, Version** **Factory Automation Software, Version**	 AES version 6.01 dated 25-Dec-00 GEM-People's Inc. version 1.2.2 with patch 1.1a
Process/Flow Tested:	*Process Flow/Sequence:* Cassette → TA 1 → LL R or L → TA 2 → Orienter ch D or E → TA 2 → Etch ch A, B, or C → TA 2 → Cooldown ch F → TA 2 → LL R or L → TA 1 → Cassette (LL = loadlock, TA = transfer arm) *Etch Chambers A, B, C Process* (Step Process Module): Step 1. Process gases On, 5 sec Step 2. LF RF On, 5 sec Step 3. HF RF On, 45 sec Step 4. HF RF Off, 3 sec Step 5. LF RF Off, 3 sec Step 6. Process gases Off, N_2 On, 5 sec *Loadlocks R & L* – base pressure 25 mT (Fixed Process Modules) *Orienter Chambers D & E* – (Fixed Algorithm Modules) *Cooldown Chamber F* – 20 sec (Fixed Process Module) *Transfer Arms 1 & 2* – (Fixed Algorithm Modules)
Total Time Measured:	Equipment was exercised continuously from 10-Jan-01 through 16-Jan-01 – Total Productive Time of 6.3 days or 147 hrs. 6,100 wafers were cycled.
Fixed Length Testing Goals from SEMI E10:	Testing goal: MCBF > 10,000 – 80% Confidence Interval, – 192,300 messages,
Total Number of Messages Received:	Actual: 214,255 unique primary messages received

Table 14 Data Items Available to be Assigned to Event Reports (Messages)

Data Item (V or DVVAL)	Description
MID	Lot ID
PPID	Process Flow identifier
RCPID	Module (Table 2, type 3) Recipe identifier
TIME	Event Timestamp
CHID	Supplier created variable for module identifier
PTN	Loadport position
WFRID	Supplier created variable for wafer ID as obtained from ID Reader on Loadport
STEPID	Supplier created variable for Module (Table 2, type 3) Recipe Step identifier

Table 15 Available Module and Product-Material Events

Product-Material Task Events	CEID	Variables Available	Event "Trigger"
Level 1			
Wafer Start	300	MID, WFRID, PPID, TIME	Wafer has been placed on transfer arm 1
Wafer Complete	301	MID, WFRID, PPID, TIME	Wafer is no longer sensed on transfer arm 1
Carrier Start	731	MID, PPID, TIME, PTN	The 1st wafer in the carrier has been placed on transfer arm 1
Carrier Complete	732	MID, PPID, TIME, PTN	The last wafer of the carrier is no longer sensed on transfer arm 1
Level 2			
Carrier Waiting for Input Before Starting	735	MID, PPID, TIME, PTN	SMIF Pod has opened and wafers have been transferred to processing cassette, Message Box on GUI requesting operator input
Input Received	736	MID, PPID, TIME, PTN	Operator input received
Carrier Ready for Unload	733	MID, PPID, TIME, PTN	Load-port door has opened
Carrier Unloaded	734	MID, PPID, TIME, PTN	Cassette no longer detected on load-port stage
Dummy/filler wafer transfer start	501	TIME	Protective substrate used during module plasma-clean has been placed on transfer arm 3
Dummy/filler wafer transfer complete	502	TIME	Protective substrate used during module plasma-clean is no longer sensed on transfer arm 3
Module Task Events			
Level 1			
Etch Module Start (chambers A, B, C)	1123	MID, WFRID, RCPID, CHID, TIME	Chamber's slit-valve is opened
Etch Module Complete (chambers A, B, C)	1124	MID, WFRID, RCPID, CHID, TIME	Last step of recipe (RCPID) is completed
Severe Alarm Set	N/A	ALID, ALCD, ALTX	Refer to AES SECS/GEM manual for a list of available alarms
Severe Alarm Clear	N/A	ALID, ALCD, ALTX	Refer to AES SECS/GEM manual for a list of available alarms

Product-Material Task Events	CEID	Variables Available	Event "Trigger"
Level 2			
Etch Module Recipe Step Start (chambers A, B, C)	2123	MID, WFRID, RCPID, CHID, STEPID, TIME	Step (STEPID) of recipe (RCPID) started
Etch Module Recipe Step Complete (chambers A, B, C)	2124	MID, WFRID, RCPID, CHID, STEPID, TIME	Step (STEPID) of recipe (RCPID) has completed
Cooldown Chamber Start (chamber F)	1125	MID, WFRID, CHID, TIME	Wafer has been transferred to chamber
Cooldown Chamber Complete (chamber F)	1126	MID, WFRID, CHID, TIME	Wafer has been removed from chamber
Orienter Chamber Start (chamber D, E)	1127	MID, WFRID, CHID, TIME	Wafer has been transferred to chamber
Orienter Chamber Complete (chamber D, E)	1128	MID, WFRID, CHID, TIME	Wafer has been removed from chamber
Transfer Arm 1 Start	1129	MID, WFRID, CHID, TIME	Transfer arm picks up wafer, wafer detected
Transfer Arm 1 Complete	1130	MID, WFRID, CHID, TIME	Wafer is no longer on transfer arm
Transfer Arm 2 Start	1131	MID, WFRID, CHID, TIME	Transfer arm picks up wafer, wafer detected
Transfer Arm 2 Complete	1132	MID, WFRID, CHID, TIME	Wafer is no longer on transfer arm
Loadlock Vent Start (modules L , R)	1140	MID, WFRID, CHID, TIME	Isolation valve is closed
Loadlock Vent Complete (modules L, R)	1141	MID, WFRID, CHID, TIME	Loadlock reaches atmospheric pressure
Loadlock Pumpdown Start (modules L, R)	1142	MID, WFRID, CHID, TIME	Roughing pump valve opens
Loadlock Pumpdown Complete (modules L, R)	1143	MID, WFRID, CHID, TIME	Base pressure is achieved
Additional Level 2 Module Tasks (product-material may or may not be present)			
Seasoning Start (Chambers A, B, C)	2100	MID, RCPID, CHID, TIME	1st step of recipe (RCPID) started
Seasoning Complete (Chambers A, B, C)	2101	MID, RCPID, CHID, TIME	Last step of recipe (RCPID) is completed
In situ Clean Start (Chambers A, B, C)	2200	RCPID, CHID, TIME	1st step of recipe (RCPID) started
In situ Clean Complete (Chambers A, B, C)	2201	RCPID, CHID, TIME	Last step of recipe (RCPID) is completed
Process Recipe Set-up Start (Chambers A, B, C)	2300	RCPID, CHID, TIME	Set-pt of parameter(s) changed
Process Recipe Set-up Complete (Chambers A, B, C)	2301	RCPID, CHID, TIME	Designated parameter(s) has stabilized

Table 16 Alarms that Occurred During the Testing Period

ALID	Severity	Number of Occurrences	Adhered to E5 definition	Description
5021	4	1	Yes	Wafer not detected in Chamber A
5028	4	1	Yes	N2 exceed maximum tolerance for set-pt in Chamber B
5030	4	1	No (Table 19)	Timeout – Base pressure not reached in Left Loadlock
5031	4	1	Yes	Gas cabinet exhaust out of range
5040	4	1	Yes	HF:LF ratio out of bounds for Chamber A
5041	4	1	Yes	HF:LF ratio out of bounds for Chamber B
5060	4	1	Yes	Unable to find wafer-flat after 3 tries
5070	2	2	Yes	Elevator not at home, unable to transfer wafer
5094	2	1	Yes	Transfer Arm 1 misalignment
6007	7	3	Yes	Event History file purged
6014	7	2	No (Table 19)	Elevator started homing
6015	7	2	Yes	Elevator completed homing
6075	7	28	Yes	Constant automatically reset to “0”

B.1 ADC NONCOMPLIANCE SUMMARY

Table 17 Unavailable Event Messages – Level 2

#	Event Messages	Product-Material or Module Task Measure	Expected Availability
1	Arm 1 Transport Time Start Message (load, exchange, and unload wafer)	Module	Next s/w release scheduled for 04-Jul-2001
2	Arm 1 Transport Time Complete Message (load, exchange, and unload wafer)	Module	Next s/w release scheduled for 04-Jul-2001
3	Chamber F Recipe Step Start (fixed process module, Table 2, type 2)	Module	No plans at this time
4	Chamber F Recipe Step Complete (fixed process module, Table 2, type 2)	Module	No plans at this time

Table 18 Unavailable Event Variables – Level 2

#	Event Variables	Product-Material or Module Task Measure	Expected Availability
1	Transport Arm 2 Start message “Pick” and “Place” information	Module	Next s/w release scheduled for 04-Jul-2001
2	Transport Arm 2 Complete message “Pick” and “Place” information	Module	Next s/w release scheduled for 04-Jul-2001
3	Lot ID for Recipe Set-up Start messages on Table 2, type 3 modules (chambers A, B, C)	Module	Next s/w release scheduled for 04-Jul-2001
4	Lot ID for Recipe Set-up Complete messages on Table 2, type 3 modules (chambers A, B, C)	Module	Next s/w release scheduled for 04-Jul-2001
5	Event Timestamp for Carrier Start	Product	s/w release scheduled for 04-Dec-2001
6	Event Timestamp for Carrier Complete	Product	s/w release scheduled for 04-Dec-2001
7	Chamber ID for Alarm Set	Module	No plans at this time
8	Chamber ID for Alarm Clear	Module	No plans at this time
9	Event Timestamp for Alarm Set	Module	No plans at this time
10	Event Timestamp for Alarm Clear	Module	No plans at this time

Table 19 Noncompliant Alarms – Level 2

#	ALID	Description of Noncompliance	Expected Availability
1	5012	Alarm should be an attention flag (severity 7), but was sent as a severity 2. Tool did not stop processing. No alarm clear was sent. Alarm occurred 42 times. AES recommends that the user "disable" this alarm until the next s/w release is available.	Next s/w release scheduled for 04-Jul-2001
2	6014	Alarm should have been a parameter control error (severity 4), but was sent as a severity 7. Tool stopped processing and no alarm clear was sent. Alarm occurred 21 times. No workaround is available yet.	Next s/w release scheduled for 04-Jul-2001

B.2 TEST RESULTS FOR ERROR CATEGORIES

The following tables reflect sample information to help you understand how to report test results. A detailed explanation and a corrective action plan should be provided for each error recorded.

Table 20 Testing Results – Level 2

(Not including Unavailable Event Messages and Variables – see Table 17 and 18)

#	Error Type	CEID	Message Type	Number of Expected or Received Messages	Number of Messages in Error
1	Missing messages	731	Carrier Start	244	6
2	Data conflict w/ process	1143 & 1131	Loadlock Pumpdown Complete & Start Wafer Transfer on Arm 2	12,200	3
3	Missing data from event report	2123	Etch Module Recipe Step Start	52,416	12
4	Missing data from event report	2124	Etch Module Recipe Step Complete	52,416	4

Table 21 Summary of Testing Results – Level 3

#	Error Details	Probable Cause	Corrective Action Plans
1	*Missing messages:* 238 Carrier Start and 244 Carrier Complete messages were recorded. In 6 instances, Carrier Complete messages were received, but no corresponding Carrier Start messages were received.	We believe that this problem is most likely associated with the equipment's message buffer. When the number of messages requested overflows the equipment's outgoing message buffer, the messages are dropped. Or it may be due to the automation's recipe download activity interfering with the issuing of the Carrier Start message.	Work with the s/w provider (we contract out this function) to develop a message buffer that can accommodate additional information. We expect to have this corrective action completed in the next s/w version scheduled for 4Qtr 2001.
2	*Data in conflict with process*: 12,200 messages were issued with 3 messages in error. In the 3 cases, the wafer transfer start message preceded the LL pumpdown complete message.	We do not have a probable cause of the errors at this time	Work with the AES s/w staff to determine the cause of the errors. We expect to have this corrective action completed in the next s/w version scheduled for 4Qtr2001
3	*Event report was missing data items:* 12 of the Recipe Step Start event reports were missing the wafer identifier (WFRID). The wafer identifier was "0" in all cases. 9 of the errors were associated with Ch-B	We do not have a probable cause of the errors at this time	Work with the AES s/w staff to determine the cause of the errors. We expect to have this corrective action completed in the next s/w version scheduled for 4Qtr2001
4	*Event report was missing data items:* 4 of the Recipe Step Complete event reports were missing the wafer identifier (WFRID). The wafer identifier was "0" in all cases. 2 of the errors were associated with Ch-B.	We do not have a probable cause of the errors at this time	Work with the AES s/w staff to determine the cause of the errors. We expect to have this corrective action completed in the next s/w version scheduled for 4Qtr2001

Table 22 Testing Results – Level 2

Fixed Length Testing Goals from SEMI E10				Actual		Results		
MCBF Goal	Target # of Cycles	Target # of Failures	Target Confidence Interval	# of Cycles	# of Failures	MCBF Point Estimate	Lower 1-sided Confidence Bound*	Passed (Y/N)
10,000 messages between failures	192,300 messages	<=15	80 %	214,255 messages	25	8,570 messages between failures	7,103 messages between failures	No

* The Lower 1-sided Confidence Bound expresses the value in the distribution of likely results where there is an 80% probability that the mean is equal to or greater than this value.

APPENDIX C
SOFTWARE DOCUMENTATION AND TESTING REPORTING FORMS

Table 23 Equipment Configuration and Testing Schema – Level x

Date:	
Supplier:	
Equipment Type:	
Equipment Model:	
Hardware Configuration Tested:	
Software Configuration Tested: **Platform s/w Version** **Factory Automation s/w Version**	
Process/Flow Tested:	
Total Time Measured:	
Fixed Length Testing Goals from SEMI E10:	
Total Number of Messages Received:	

Table 24 Data Items Available to be Assigned to Event Reports

Data Item (V or DVVAL)	Description

Table 25 Available Module and Product-Material Events – Level x

(Events are included as examples only)

Product-Material Task Events	CEID	Variables Available	Event "Trigger"
Level 1			
Wafer Start			
Wafer Complete			
Carrier Start			
Carrier Complete			
Level 2			
Carrier Waiting for Input Before Starting			
Input Received			
Carrier Ready for Unload			
Carrier Unload			
Dummy/filler wafer transfer start			
Dummy/filler wafer transfer complete			
Reticle transfer start			
Reticle transfer complete			
Module Task Events			
Level 1			
Module X Start (Table 2, type 3)			
Module X Complete (Table 2, type 3)			
Severe Alarm Set		ALID, ALCD, ALTX	
Severe Alarm Clear		ALID, ALCD, ALTX	
Level 2			
Cool-Down Module Start (Table 2, type 2)			
Cool-Down Module Complete (Table 2, type 2)			
Pre-bake Module Start (Table 2, type 2)			
Pre-bake Module Complete (Table 2, type 2)			
Transport Arm 1 Start (Table 2, type 1)			

Product-Material Task Events	CEID	Variables Available	Event "Trigger"
Transport Arm 1 Complete (Table 2, type 1)			
Central Wafer Handler Start (Table 2, type 1)			
Central Wafer Handler Complete (Table 2, type 1)			
Lot Transfer to Quartz Start (Table 2, type 1)			
Lot Transfer to Quartz Complete (Table 2, type 1)			
Module X Recipe Step Start (Table 2, type 3)			
Module X Recipe Step Complete (Table 2, type 3)			
Severe Alarm Set		ALID, ALCD, ALTX, Module ID, TIME	
Severe Alarm Clear		ALID, ALCD, ALTX, Module ID, TIME	
Additional Level 2 Module Tasks (product-material may or may not be present)			
Fault recovery process Start			
Fault recovery process Complete			
Vent Start Loadport X			
Vent Complete Loadport X			
Pumpdown Start Loadport X			
Pumpdown Complete Loadport X			
Seasoning/Conditioning Start Module X			
Seasoning/Conditioning Complete Module X			
Calibration Start			
Calibration Complete			
Recipe Set-up Start			
Recipe Set-up Complete			
In situ Clean Start Module X			
In situ Clean Complete Module X			

Table 26 Alarms that Occurred During the Testing Period

Note: Supplier should substitute "x" for compliance level.

ALID	Severity	Number of Occurrences	Adhered to E5 definition	Description

C.1 ADC NONCOMPLIANCE SUMMARY

Table 27 Noncompliant Event Messages – Level x

Note: Supplier should substitute "x" for compliance level.

#	Event Messages	Product-Material or Module Task Measure	Expected Availability
1			
2			
3			
n			

Table 28 Noncompliant Event Variables – Level x

Note: Supplier should substitute “x” for compliance level.

#	Event Variables	Product-Material or Module Task Measure	Expected Availability
1			
2			
3			
n			

Table 29 Noncompliant Alarms – Level x

Note: Supplier should substitute “x” for compliance level.

#	ALID	Description of Noncompliance	Expected Availability
1			
2			
3			
n			

C.2 TESTING RESULTS – SUMMARY OF ERRORS DETECTED

Table 30 Testing Results – Level x

Note: Supplier should substitute “x” for compliance level.

#	Error Type	CEID	Message Type	Number of Expected or Received Messages	Number of Messages in Error
1					
2					
3					
n					

Table 31 Summary of Testing Results – Level x

Note: Supplier should substitute “x” for compliance level.

#	Error Details	Probable Cause	Corrective Action Plans
1			
2			
3			
n			

Table 32 Clock Synchronization – Level 2

Explanation of Equipment, Factory, and Middleware Clock Synchronization Method

Table 33 Reliability Results – Level x

Note: Supplier should substitute “x” for compliance level.

Fixed Length Testing Goals from SEMI E10				Actual		Results		
MCBF Goal	Target # of Cycles	Target # of Failures	Target Confidence Interval	# of Cycles	# of Failures	MCBF Point Estimate	Lower 1-sided Confidence Bound*	Passed (Y/N)

* The Lower 1-sided Confidence Bound expresses the value in the distribution of likely results where there is an X% (X = the statistical confidence level value) probability that the mean is equal to or greater than this value.

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