

# **SEMI E58-0703**

## **AUTOMATED RELIABILITY, AVAILABILITY, AND MAINTAINABILITY STANDARD (ARAMS): CONCEPTS, BEHAVIOR, AND SERVICES**

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## SEMI E58-0703

# AUTOMATED RELIABILITY, AVAILABILITY, AND MAINTAINABILITY STANDARD (ARAMS): CONCEPTS, BEHAVIOR, AND SERVICES

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## 1 Purpose

1.1 This document provides standards for implementing and collecting SEMI E10 state changes at the equipment level per SEMI E10.

1.1.1 SEMI E10 defines various terms and equipment states but was not written specifically for application by automated equipment. This document is intended to provide a consistent interpretation of these equipment states through formal state model methodology.

1.1.2 ARAMS defines concepts, behavior, and message services to support the integration of automated systems within a semiconductor factory.

1.1 *Background and Motivations* — To implement the integration of SEMI E10 states on automated equipment, integration of definitions and requirements must be detailed and precise to ensure interpretations are consistent across equipment suppliers. This provides an opportunity to automatically retain information at the equipment itself.

1.1.3 Both equipment supplier and equipment user benefit from the automation of SEMI E10 data collection at the equipment through application of a consistent state model.

1.1.4 SEMI E10 defines specific states but does not address transitions between states. The ARAMS standard specifies the triggers for state transitions made by automated equipment. Extensions to SEMI E10 described in this document apply to decisions made by automated equipment only.

## 2 Scope

2.1 This standard is applicable to the following relationships: traditional host/equipment, operator/equipment, and cluster tool controller/attached module. The scope of this document is to define standards which facilitate equipment-level capture and communication of SEMI E10 related data. Specifically, this document provides the following:

- An equipment state model that defines the rules for equipment state changes,
- A set of standard equipment codes for representing substates of the six basic equipment states defined in SEMI E10,
- Definition of equipment-generated data,
- Concepts and messages required to exchange information, and
- Requirements for fundamental compliance to ARAMS
- Additional optional specifications.

2.2 This standard is intended as a supplement to SEMI E10 to be used for equipment support of SEMI E10. Formal definitions of all terms common to both documents are provided solely by SEMI E10.

2.3 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 3 Referenced Standards

### 3.1 SEMI Standards

SEMI E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E30 — Generic Model for Communications and Control of SEMI Equipment (GEM)

SEMI E38 — Cluster Tool Module Communications (CTMC)

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E41 — Exception Management (EM) Standard

SEMI E42 — Recipe Management Standard: Concepts, Behavior, and Message Services

SEMI E53 — Event Reporting

### 3.2 Other Document

Harel, D., “Statecharts: A Visual Formalism for Complex Systems,” *Science of Computer Programming* 8 (1987) 231–274

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

## 4 Terminology

4.1 *Acronyms* — The following acronyms are used in this document.

4.1.1 *ARAMS* — Automated Reliability, Availability, and Maintainability Standard, as defined by this document.

4.1.2 *CTMC* — Cluster Tool Module Communications [SEMI E38].

4.1.3 *EMS* — Exception Management Standard [SEMI E41].

4.1.4 *ERS* — Event Reporting Standard [SEMI E53].

4.1.5 *GEM* — Generic Equipment Model [SEMI E30].

4.1.6 *OSS* — Object Services Standard [SEMI E39].

4.1.7 *RAM* — Reliability, Availability, and Maintainability.

4.2 *General Terms* — The following definitions for general terms are used in this document. References are given in brackets.

4.2.1 *alarm* — Related to any abnormal situation on the equipment that may endanger people, equipment, or material being processed [SEMI E30, SEMI E41].

4.2.2 *collection event* — An event (or grouping of related events) on the equipment that is considered to be significant to the host [SEMI E30].

NOTE 2: A state transition in a formal state model always represents a collection event unless explicitly stated otherwise.

4.2.3 *equipment production criteria* — The set of conditions and operating specifications that must be satisfied for the equipment to consider itself as performing its intended function. This includes basic requirements for information, material to process, and the absence of any detectable exception conditions (e.g., no alarms). It also includes criteria specific to the equipment model, such as a required level for vacuum pressure and availability of consumables and support tools required for its process.

4.2.4 *event* — A detectable occurrence significant to the equipment.

NOTE 3: Within the context of ARAMS, an event may be detected by either the equipment or the user.

4.2.5 *event report* — A message the equipment sends to the host on the occurrence of a collection event.

4.2.6 *exception* — An alarm or error that is reported to the user and that may or may not be recoverable.

4.2.7 *fault* — An exception.

4.2.8 *host* — The intelligent system that communicates with the equipment, acts as a supervisory agent, and represents the factory and the user to the equipment.

4.2.9 *intended function* — A manufacturing function that the equipment was built to perform. This includes transport functions for transport equipment and measurement functions for metrology equipment as well as process functions such as physical vapor deposition and wire bonding. Complex equipment may have more than one intended function.

4.2.10 *interrupt (interruption)* — A failure [SEMI E10].

4.2.11 *operator* — Any person who communicates locally with the equipment through the equipment’s control panel.

4.2.12 *state* — A static set of conditions and associated behavior. While all of its conditions are met, the state is current (active). Behavior within a given state includes the response to various stimuli.

NOTE 4: Within the scope of this document, the term “state” generally refers to one of the six equipment states defined by SEMI E10 and used in the ARAMS State Model: productive, standby, engineering, scheduled downtime, unscheduled downtime, and non-scheduled time.

4.2.13 *state model* — A collection of states and state transitions that combine to describe the behavior of a system. This model includes a definition of the conditions that delineate a state, the activities possible within a state, the events that trigger transitions to other states, and the process of transitioning between states.

4.2.14 *state transition* — A change from one state to another state.

4.2.15 *standby condition* — Any condition during manufacturing time when the equipment’s production criteria are not satisfied, and it is fault free and otherwise able to perform its intended function.

4.2.16 *substate* — A refinement of a state.

NOTE 5: States may be subdivided into substates to facilitate more concise definition of behavior. Thus, a hierarchy is defined whereby any state may be a substate of some parent state and in turn be the parent of its own substates [SEMI E30, Appendix].

4.2.17 *superstate* — The parent state of two or more states.

4.2.18 *symptom* — A user-detected event (e.g., smoke observed).

4.2.19 *timestamp* — The notation of the date and time of the occurrence of an event [SEMI E42].

4.2.20 *timestamp format* — A text string of the form “YYYYMMDDhhmmsscc”, where:

YYYY = year (e.g., 1995)

MM = month (01–12)

DD = day (01–31)

hh = hour (00–23)

mm = minute (00–59)

ss = second (00–59)

cc = centisecond (00–99)

4.2.21 *trigger* — An event that causes a change in the state of the equipment. Examples are changes in sensor readings, alarms, messages received from the host, and operator commands.

4.2.22 *user* — Any entity interacting with the equipment, either locally as an operator or remotely via the host. From the equipment’s viewpoint, both the operator and the host represent the user.

4.3 *data types* — The following terms are used to represent valid types of data.

4.3.1 *form* — Type of data: positive integer, unsigned integer, integer, floating point (float) enumerated, Boolean, text, formatted text, structure, list, ordered list.

4.3.2 *positive integer* — May take the value of any positive whole number. Messaging protocol may impose a limit on the range of possible values.

4.3.3 *unsigned integer* — May take the value of any positive integer or zero. Messaging protocol may impose a limit on the range of possible values.

4.3.4 *integer* — May take on the value of any negative or unsigned integer. Messaging protocol may impose a limit on the range of possible values.

4.3.5 *floating point (float)* — May take on any single (real) numeric value, positive or negative. Messaging protocol may impose a limit on the range of possible values.

4.3.6 *enumerated* — May take on one of a limited set of possible values. These values may be given logical names, but they may be represented by any single-item data type.

4.3.7 *boolean* — May take on one of two possible values, equating to TRUE and FALSE.

4.3.8 *text* — A character string. Messaging protocol may impose restrictions, such as length or ASCII representation.

4.3.9 *formatted text* — A character string with an imposed format. This could be by position, by use of special characters, or both.

4.3.10 *structure* — A specific set of items, of possibly mixed data types, in a specified arrangement.

4.3.11 *list* — A set of one or more items that are all of the same form (one of the above forms).

4.3.12 *ordered list* — A set of items in specific sequence.

## 5 Basic Requirements

5.1 An ARAMS-compliant implementation requires provision of certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and provision of an internal time-and-date clock. These requirements may be satisfied through compliance to one of the following sets of requirements:

- The Generic Equipment Model (GEM):
  - Clock Services
  - Event Notification
  - Status Data Collection
  - Equipment Constants
  - Alarm Management
- The following set of standards:
  - Object Services Standard
  - Clock Services, Cluster Tool Module Communications
  - Event Reporting Standard
  - Exception Management Standard

5.2 The developer is expected to be familiar with the appropriate documents before attempting to implement ARAMS (see Section 16.1).

## 6 Conventions

This document follows the conventions for state model methodology and service definitions used by the SEMI standards referenced in Section 3.

6.1 *State Model Methodology* — This document uses the state model methodology in SEMI E30 to describe the behavior of equipment. A state model has three elements: definitions of each state and substate, a

diagram of the states and the transitions between states, and a state transition table. The diagram of the state model uses the Harel State Chart notation. An overview of this notation is presented in an appendix of SEMI E30. The formal definition of this notation is presented in *Science of Computer Programming 8*, “Statecharts: A Visual Formalism for Complex Systems”, by D. Harel, 1987.

6.1.1 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A **transition table** contains columns for Transition #, Current State, Trigger, New State, Action(s), and Comment. The “trigger” (column 3) for the transition occurs while in the “current” state. The “actions” (column 5) includes a combination of 1) actions taken upon exit of the current state, 2) actions taken upon entry of the new state, and 3) actions taken which are most closely associated with the transition. No differentiation is made between these cases.

| #            | Current State | Trigger | New State | Action(s) | Comment |
|--------------|---------------|---------|-----------|-----------|---------|
| Transition # |               |         |           |           |         |

6.2 *Object Attribute Representation* — The object information models for standardized objects will be supported by an **attribute definition table** with the following column headings:

| Attribute Name                         | Definition                                | Access   | Reqd   | Form        |
|----------------------------------------|-------------------------------------------|----------|--------|-------------|
| The formal text name of the attribute. | Description of the information contained. | RO or RW | Y or N | (see below) |

6.2.1 The Access column uses RO (Read Only) or RW (Read and Write) to indicate the access that users of the service have to the attribute.

6.2.2 A ‘Y’ or ‘N’ in the Required (Reqd) column indicates if this attribute must be supported in order to meet fundamental compliance for the service.

6.2.3 The Form column is used to indicate the format of the attribute (see Section 4 for definitions).

### 6.3 Service Message Representation

6.3.1 *Service Resource Definition* — A **service definition table** defines the specific set of messages for a given service resource, as shown in the following table:

| Message Service Name | Type | Description |
|----------------------|------|-------------|
|----------------------|------|-------------|

| Message name | N or R | The intent of the service |
|--------------|--------|---------------------------|
|--------------|--------|---------------------------|

6.3.1.1 Type can be either N = Notification or R = Request.

6.3.1.2 Notification type messages are initiated by the service provider and the provider does not expect to get a response from the service user (consumer/subscriber).

6.3.1.3 Request messages are initiated by a service user. Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

6.3.2 *Service Parameter Dictionary* — A **service parameter dictionary table** defines the parameters for one or more services, as shown in the following table:

| Parameter   | Description                     | Form       |
|-------------|---------------------------------|------------|
| Parameter X | A parameter called X is B in A. | Data type. |

6.3.2.1 A row is provided in the table for each parameter of the service. The first column contains the name of the parameter. This is followed by columns describing the form and contents of the corresponding parameter.

6.3.2.2 The Form column is used to indicate the type of data contained in a parameter (see Section 4 for definitions).

6.3.2.3 The Description column in the Service Parameter Dictionary table describes the meaning of the parameter, the allowed values, and any interrelationships with other parameters.

6.3.2.4 To prevent the definition of numerous parameters named “XxxList”, this document adopts the convention of referring to the list as “(List of) Xxx”. In this case, the definition of the variable Xxx will be given, not of the list. The term “list” indicates a collection (or set) of zero or more items of the same data type.

6.3.2.5 Where a list is used in both the request and the response, the list order in the request is retained in the response. A list must contain at least one element unless zero elements are specifically allowed.

6.3.3 *Service Message Definition* — A **service message definition table** defines the parameters used in a service, as shown in the following table:

| Parameter   | Req/Ind     | Rsp/Conf    | Description                     |
|-------------|-------------|-------------|---------------------------------|
| Parameter X | (see below) | (see below) | A description of the parameter. |

6.3.3.1 The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message. The message sent by the initiator is called the “Request”. The receiver terms this message the “Indication”. The receiver may then send a “Response”, which the original sender terms the “Confirmation”.

6.3.3.2 The following codes appear in the Req/Ind and Rsp/Conf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

“M” - *Mandatory parameter* — Must be given a valid value.

“C” - *Conditional parameter* — May be defined in some circumstances and undefined in others. Whether a value is given may be a completely optional or may depend on the value of other parameters.

“U” - *User-defined parameter*

“-” — The parameter is not used.

“=” — (For response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

## 7 Overview

7.1 This section provides an overview of how ARAMS will be applied and the capabilities that ARAMS defines.

7.2 Systems that are used to track equipment performance should be based on SEMI E10’s definitions of the six basic equipment states. The tracking systems typically rely on factory personnel to manually enter SEMI E10 state changes. Individual factories may have further company-specific and/or facilities-specific refinements of the states. For example, the basic equipment state may be “unscheduled downtime” with a refinement of “waiting for parts”. In addition to entering a state change, the operator (who may be the production operator, a process engineer, an equipment engineer, or a supplier field service engineer) may select from a pre-defined set of behaviors (symptoms) that prompted the change of state, such as “smoke observed”.

7.3 Specifications provided by ARAMS are intended to support the integration of equipment systems with factory tracking systems. For this purpose, equipment needs to be cognizant of the ARAMS states and substates, must know its current state, and must follow common rules for determining if equipment-initiated transitions can be made. In addition, the user needs to be able to interact with the tracking system at either the host system’s console or the equipment’s operator

console. This requires that the operator be able to enter certain information at the equipment’s console: a new state or substate request, and specific observed behavior that prompted the request. The host system is then notified that a change in state has occurred.

7.4 Integrated systems are able to provide more accurate data for those state changes than the equipment alone is able to detect. While the user is still required to initiate state changes for other conditions, this can be accomplished either directly at the equipment’s console or remotely at the host tracking system terminal.

7.5 Exchange of information is accomplished through standardization of the meaning and form of data and the specification of the message services for the exchange. ARAMS provides generic definitions for the common substates described in SEMI E10. ARAMS also defines two tables and the message services required for the equipment and host to exchange tables. The first table contains a set of ARAMS substate definitions (an ARAMS code identifying the substate) and a corresponding description. The second table defines a set of symptoms with a numeric symptom identifier and a corresponding description.

7.6 While the above discussion assumes that the equipment is interacting with host systems, the ARAMS state model only requires interactions with a “user”, which might be either a local operator or a host system.

## 8 State Models

8.1 This section defines the formal state model for ARAMS, called the ARAMS State Model, which is required for ARAMS compliance. To clarify the relationships between this state model and the equipment’s operations, it introduces a second state model, called the General Equipment Operations Model, which is used for purposes of illustration. The General Equipment Operations Model is assumed to exist in some form but is not required for ARAMS compliance.

8.1.1 This document follows the convention of using upper-case to denote the formal names of states. Informal references may use lower case. For example, the ARAMS states SCHEDULED DOWNTIME and UNSCHEDULED DOWNTIME may be referred to as downtime states.

8.1.2 Detailed requirements for equipment behavior are provided in Section 16.

NOTE 6: Although the equipment is unable to detect a condition of no power, it is able to detect when the INITIALIZING state has been entered and is able to differentiate between a hard reset (Transition 6) and a soft reboot (Transition 5).

8.2 *SEMI E10 Equipment States* — Figure 1 contains a diagram of SEMI E10 equipment states using the Harel notation. SEMI E10 divides total time into six basic states: PRODUCTIVE, ENGINEERING, STANDBY, SCHEDULED DOWNTIME, UNSCHEDULED DOWNTIME, and NON-SCHEDULED TIME. These six states are shown in Figure 1 with solid lines.

8.2.1 OPERATIONS TIME, UPTIME, DOWNTIME, and MANUFACTURING TIME are derived by grouping states defined in SEMI E10 and are useful for classification purposes, but formally they are not considered as SEMI E10 equipment states. Time in these groupings can be derived by summing the time in their corresponding states, based on Figure 1.

NOTE 7: Figure 1 uses shadings to show derived states. It is not intended as a formal state model.

8.2.2 MANUFACTURING TIME includes time spent in PRODUCTIVE and STANDBY. UPTIME includes the time spent in MANUFACTURING TIME and ENGINEERING. DOWNTIME includes the time spent in SCHEDULED DOWNTIME and UNSCHEDULED DOWNTIME.

8.2.3 In SEMI E10, precise rules governing state transitions are not required. The ARAMS model, in contrast, is intended to be used by automated equipment capable of detecting internal conditions. Conditions for

each valid state transition are defined, both those initiated by equipment and those determined by interactions between the user and the equipment.

8.3 *ARAMS State Model Definition* — This section contains the formal definition of the ARAMS State Model, consisting of three parts:

- A diagram of the ARAMS State Model (Figure 2), using Harel notation,
- a description of each state and the behavior of the equipment within that state, and
- a table of transitions (Table 1) showing the previous state before the transition, the trigger for the transition, the new state after the transition, a description of any actions to be taken upon entry, and comments concerning the new state.

8.3.1 *ARAMS State Model Diagram* — Figure 2 contains the diagram of the ARAMS State Model.

8.3.2 *Descriptions of ARAMS States* — This section provides brief descriptions of the basic states for model completeness.

NOTE 8: These are informal descriptions included for the completeness of the ARAMS State Model. They do not replace the formal definitions in SEMI E10.

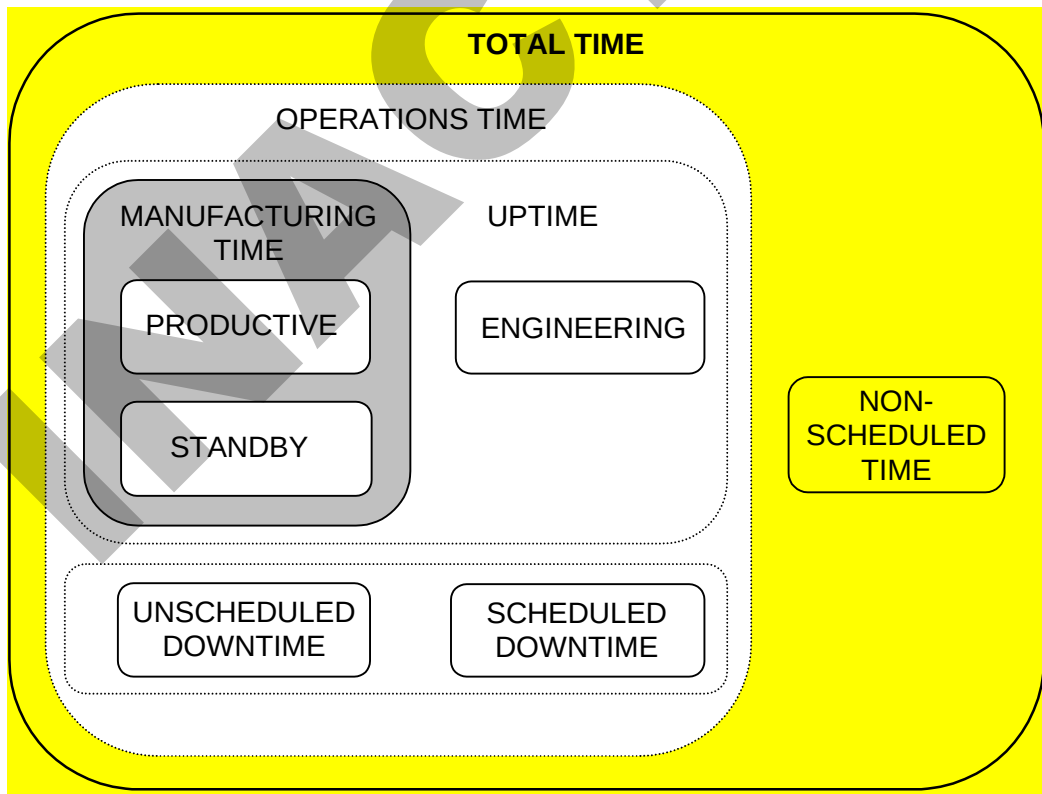


**Figure 1**  
**SEMI E10 Equipment States in Harel Notation**

**8.3.2.1 TOTAL TIME** — The TOTAL TIME state includes 100% of real time; the sum of the time in the six basic SEMI E10 states, including time when the equipment is powered down. PRODUCTIVE, STANDBY, and ENGINEERING are called *uptime*, and SCHEDULED DOWNTIME and UNSCHEDULED DOWNTIME are called *downtime*.

**8.3.2.2 MANUFACTURING** — The ARAMS State Model includes MANUFACTURING as a user-selectable superstate of PRODUCTIVE and STANDBY. When the user selects MANUFACTURING, the equipment automatically transitions to either PRODUCTIVE or STANDBY, depending upon its internal status at the time.

**8.3.2.2.1** Equipment is fault-free during MANUFACTURING.

NOTE 9: MANUFACTURING is not a SEMI E10 equipment state.

**8.3.2.3 PRODUCTIVE** — The PRODUCTIVE state covers the time spent by the equipment in performing its intended function. This also includes time spent loading and unloading product. PRODUCTIVE is an uptime manufacturing state.

**8.3.2.3.1** The equipment is in PRODUCTIVE when, and only when, it is in MANUFACTURING, its equipment production criteria are satisfied, and it is busy performing its intended function.

NOTE 10: Although by definition, the equipment is only considered to be “performing its intended function” in the PRODUCTIVE state, equipment processing cycles may occur in any of the basic SEMI E10 states except STANDBY.

**8.3.2.4 STANDBY** — The STANDBY state is an uptime manufacturing state that covers the time the equipment is waiting to enter the PRODUCTIVE state.

**8.3.2.4.1** The equipment enters this state automatically from the PRODUCTIVE state whenever it is in the MANUFACTURING superstate and the requirements for PRODUCTIVE do not apply. This includes periods during which it detects a normal standby condition, such as no work, no operator, etc. During STANDBY, the equipment monitors conditions for PRODUCTIVE. When all requirements for PRODUCTIVE are satisfied, then it transitions automatically to PRODUCTIVE.

**8.3.2.5 ENGINEERING** — The ENGINEERING state is an uptime state that is selected by the user for process and equipment engineering purposes, such as process development or characterization.

**8.3.2.5.1** Because the equipment may be pushed deliberately outside of its normal operating conditions, faults that may occur in the ENGINEERING state do

not trigger equipment-initiated transitions to UNSCHEDULED DOWNTIME. The equipment may also be powered off while in ENGINEERING.

**8.3.2.6 UNSCHEDULED DOWNTIME** — The UNSCHEDULED DOWNTIME state is used for unplanned downtime activities, such as maintenance, setups, conversions, change of consumables, factory-related problems, etc.

**8.3.2.6.1** Any transition from PRODUCTIVE to UNSCHEDULED DOWNTIME, whether equipment or user initiated, counts as a SEMI E10 failure. In some cases, where the equipment has detected an alarm condition and has transitioned to UNSCHEDULED DOWNTIME, the equipment is able to recover and return to PRODUCTIVE.

**8.3.2.7 SCHEDULED DOWNTIME** — The SCHEDULED DOWNTIME state is used for planned downtime activities, such as preventive maintenance, setups, conversions, change of consumables, factory-related events, etc.

**8.3.2.8 NON-SCHEDULED TIME** — The NON-SCHEDULED TIME state is used to account for time outside of the normal factory production schedule. This includes time when the factory itself is not operating and time when the equipment is being used for purposes other than production, engineering, or maintenance. Examples of such time include unworked shifts, holidays, plant shutdowns, installation, and off-line (outside of normal factory operations) training of personnel.

**8.3.3 ARAMS Substates** — Each of the six basic ARAMS states have refinements defined in SEMI E10. These refinements are captured by the ARAMS Substate Codes in Section 9. The host requests an ARAMS state change by specifying an ARAMS Substate Code directly, while the operator selects a state and substate combination, through the human interface, that results in an ARAMS Substate Code. The equipment then determines the appropriate ARAMS state/substate based on this code.

**8.3.4 State Transitions** — The user may ask the equipment to go to any ARAMS state at any time by specifying a new ARAMS Substate Code (see Section 9) or by specifying a code of “0000” to request a change to the MANUFACTURING superstate.

NOTE 11: A user-initiated ARAMS state change is not intended to initiate a change in the equipment’s operation. For example, if the operator puts the equipment in UNSCHEDULED DOWNTIME while the equipment is completing a process cycle of material, the equipment shall complete its normal cycle. If the operator intends to abort the process, then the process must be specifically aborted.

8.3.4.1 Table 1 defines the triggers for each transition shown in Figure 2.

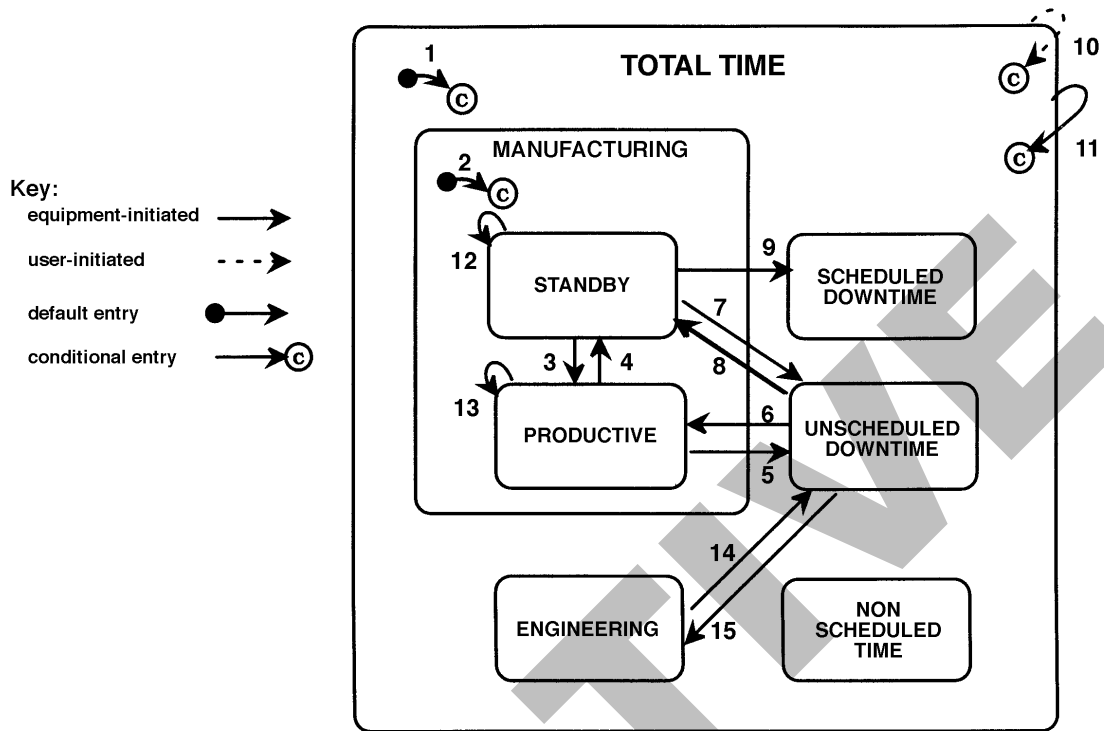


Figure 2  
ARAMS State Model

Table 1 Transitions for ARAMS State Model

| # | Current State                                                     | Trigger                                                           | New State                                                                   | Action(s)                                           | Comment                                                                                                                     |
|---|-------------------------------------------------------------------|-------------------------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| 1 | (Either undeterminable or any state except PRODUCTIVE or STANDBY) | Powerup/reset                                                     | Depends upon the state in which Transition 11 occurred (see Section 8.5.2). | None                                                | Entry state is dependent upon previous state (see NOTE 1) where this can be determined. May not generate an event report.   |
| 2 | (any state)                                                       | User selects a manufacturing state.                               | PRODUCTIVE or STANDBY, depending upon the status of the equipment.          | Determine the new ARAMS state/substate.             | Equipment determines if production criteria are satisfied. If not, it transitions to STANDBY. No event report is generated. |
| 3 | STANDBY                                                           | Equipment detects that all its production criteria are satisfied. | PRODUCTIVE                                                                  | Set ARAMSState to value in PrdState (Section 11.2). | May begin or resume processing.                                                                                             |
| 4 | PRODUCTIVE                                                        | Equipment detects a standby condition.                            | STANDBY                                                                     | Monitor all production criteria.                    | Equipment may detect a standby condition at any time.                                                                       |
| 5 | PRODUCTIVE                                                        | Equipment detects an exception.                                   | UNSCHEDULED DOWNTIME                                                        | Increment InterruptionPrd (Section 11.5).           | Alarm or exception report generated by same trigger.                                                                        |

| #  | Current State                 | Trigger                                                | New State                                                        | Action(s)                             | Comment                                                                                                                                                                                                       |
|----|-------------------------------|--------------------------------------------------------|------------------------------------------------------------------|---------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6  | UNSCHEDULED DOWNTIME          | All fault conditions have been cleared.                | PRODUCTIVE                                                       | Resume processing                     | Transition 6 can only follow Transition 5. Automatic recovery without operator direction may be disabled by the user. (See NOTE 2.) May resume processing. Process should be recoverable without degradation. |
| 7  | STANDBY                       | Equipment detects fault condition.                     | UNSCHEDULED DOWNTIME                                             | None                                  | Alarm or exception report generated by same trigger.                                                                                                                                                          |
| 8  | UNSCHEDULED DOWNTIME          | All fault conditions have been cleared.                | STANDBY                                                          | Monitor all production criteria.      | Transition 8 can only follow Transition 7 and may be disabled by the user. (See NOTE 3.)                                                                                                                      |
| 9  | STANDBY                       | A monitored parameter has reached a pre-defined limit. | SCHEDULED DOWNTIME                                               | None                                  | Preventive maintenance may require reset of the monitored parameter.                                                                                                                                          |
| 10 | (Any ARAMS state/substate)    | User selects a new ARAMS Substate Code.                | (Based on state/substate selected by user)                       | Depends upon state/substate selected. | The user may select a new ARAMS state or substate at any time.                                                                                                                                                |
| 11 | (Any of the six basic states) | Powerdown                                              | UNSCHEDULED DOWNTIME, SCHEDULED DOWNTIME, or NON-SCHEDULED TIME. | None                                  | On powerup, the equipment assumes this transition has occurred. This state transition does not represent a collection event.                                                                                  |
| 12 | STANDBY                       | Equipment detects a change in standby conditions.      | STANDBY                                                          | None                                  | Transitions 12 and 13 are optional and may be disabled by the user. (See NOTE 4.)                                                                                                                             |
| 13 | PRODUCTIVE                    | Equipment detects a change in productive conditions.   | PRODUCTIVE                                                       | None                                  | Transitions 12 and 13 are optional and may be disabled by the user. (See NOTE 4.)                                                                                                                             |
| 14 | ENGINEERING                   | Equipment detects a fault condition.                   | UNSCHEDULED DOWNTIME                                             | None                                  | Transitions 14 and 15 may be disabled by the user. (See NOTE 5.)                                                                                                                                              |
| 15 | UNSCHEDULED DOWNTIME          | All fault conditions have been cleared.                | ENGINEERING                                                      | None                                  | Transition 14 shall only follow Transition 15. (See NOTE 6.)                                                                                                                                                  |

NOTE 1: See the variable ARAMSState in Section 11.2.4.

NOTE 2: See PrdRecovery variable in Section 11.4.5.

NOTE 3: See SbyRecovery variable in Section 11.4.6.

NOTE 4: See SubstateSelect variable in Section 11.4.7.

NOTE 5: See EngInterrupt variable in Section 11.4.1.

NOTE 6: EngRecovery variable in Section 11.4.2 required for automatic recovery.

**8.4 General Equipment Operations Model** — The equipment has various state models that it maintains in addition to the ARAMS State Model. The state model presented in this section (Figure 3) is provided as a high-level example of one such model to clarify the relationship between ARAMS and the equipment's operations. For purposes of ARAMS, it is referred to as the General Equipment Operations Model.

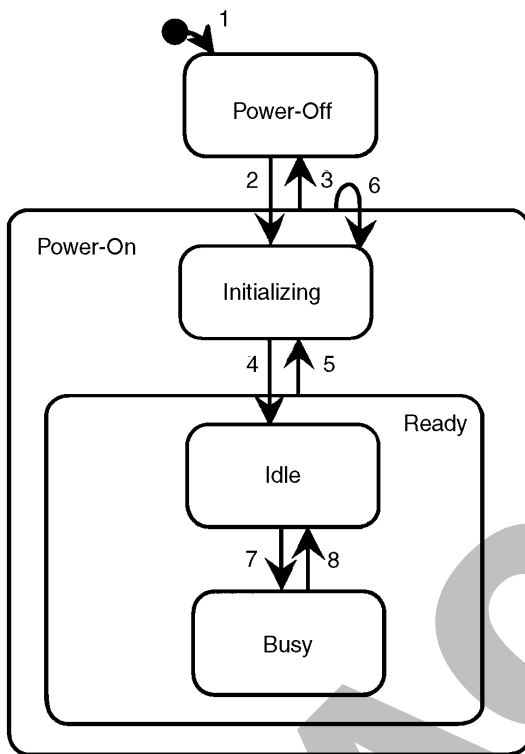


**Figure 3**  
**Example of General Equipment Operations Model**

8.4.1 ARAMS assumes that a similar model, either formal or implicit, exists, although it may differ in detail depending upon the equipment type and the application. Formal implementation of the General Equipment Operations Model is not required for ARAMS compliance.

8.4.1.1 The states of the General Equipment Operations Model are not SEMI E10 states or substates.

NOTE 12: To minimize confusion between references to states and events, the events of losing power and recovering power are termed *powerdown* and *powerup* respectively.

**8.4.2 State Definitions** — The General Equipment Operations Model uses the following states:

**8.4.2.1 POWER-OFF** — The equipment has no power and is unable to function. While this state is only valid from a view external to the equipment, it is required to cover all periods of time to match the ARAMS model.

**8.4.2.2 POWER-ON** — The POWER-ON state includes all the functions of the equipment. It has two substates, INITIALIZING and READY.

**8.4.2.3 INITIALIZING** — When equipment is first powered on or recovers from a reset, it must initialize its hardware and software subsystems and components, including its different internal state models. This process takes time, which is represented by the INITIALIZING state.

**8.4.2.4 READY** — When all initializations are complete, the equipment enters the READY state and is able to interact with the user. The READY state has two substates, IDLE and BUSY.

**8.4.2.5 IDLE** — In the IDLE state, the equipment is inactive and able to accept a command for automatic processing or manual operations.

NOTE 13: IDLE is not the same as the SEMI E10 STANDBY state. (See Section 8.5.3.)

**8.4.2.6 BUSY** — In the BUSY state, the equipment is active. BUSY includes all operations of the equipment.

NOTE 14: BUSY is not the same as the SEMI E10 PRODUCTION state. (See Section 8.5.3.)

**8.4.3 General Equipment Operations Model Table of Transitions** — Table 2 defines the triggers for each transition shown in Figure 3. The second column, labeled Table 1, shows the corresponding transition in the ARAMS state model.

**Table 2 Table of Transitions for General Equipment Operations Model**

| # | Table 1 | Current State | Trigger                          | New State    | Action(s)                    | Comment                                  |
|---|---------|---------------|----------------------------------|--------------|------------------------------|------------------------------------------|
| 1 | None    | (undefined)   | Equipment is installed.          | POWER-OFF    | None                         | New equipment                            |
| 2 | None    | POWER-OFF     | Power is turned on (powerup).    | INITIALIZING | Begin system initialization. | Initialization of hardware and software. |
| 3 | 11      | POWER-ON      | Power is turned off (powerdown). | POWER-OFF    | None                         | Equipment does not function.             |