SEMI E87-0921
SPECIFICATION FOR CARRIER MANAGEMENT (CMS)

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NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONs, lists) therein. The paragraph symbol (¶) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and ¶¶) the symbols are used to reference more than one section or paragraph, respectively.

1 Purpose

1.1 This Specification provides a standardized behavior for host view communication with production equipment during the coordination, execution, and completion of automated and manual carrier transfers to and from the equipment and, if it exists, its internal buffer space.

2 Scope

2.1 This Specification covers host and equipment communication for SEMI E15.1, 300 mm load ports.

2.2 This Specification defines standards that facilitate the host's knowledge and role in automated and manual carrier transfers, as well as internal buffer equipment carrier transfers. Specifically, this Specification provides state models and scenarios that define the host interaction with the equipment for the following:

- Carrier transfer between AMHS vehicles and production equipment load ports.
- Carrier transfers to/from production equipment internal buffer space.
- Equipment and load port access mode switching.
- Carrier to load port association.
- CarrierID verification and Carrier slot map verification.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Standard applies to semiconductor equipment with SEMI E15.1 compliant load ports. It may also be applied to other manufacturing equipment that supports automated carrier transfers, and/or contains an internal buffer. This Standard is intended to be used for production equipment. It may or may not be applied to other types of equipment. Also, stocker load ports are not addressed by this Standard.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E15.1 — Specification for 300 mm Tool Load Port

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

SEMI E39 — Specification for SECS-II Protocol for Object Services (OSS)

SEMI E40 — Specification for Processing Management

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SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

SEMI E90 — Specification for Substrate Tracking

SEMI E94 — Specification for Control Job Management

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AMHS* — automated material handling system

5.1.2 *CRTU* — carrier ready to unload

5.1.3 *FIMS* — front-opening interface mechanical standard

5.1.4 *FOUP* — front opening unified pod

5.1.5 *GEM* — generic equipment model

5.1.6 *PIO* — parallel input/output interface

5.2 *Definitions*

5.2.1 *automated material handling system (AMHS)* — an automated system to store and transport materials within the factory.

5.2.2 *automation* — the degree to which activities of machines or production systems are self-acting.

5.2.2.1 *Discussion* — In this Standard, automation provides methods that will reduce the amount of operator intervention required.

5.2.3 *buffer* — a set of one or more locations for holding carriers at/inside the production equipment.

5.2.4 *carrier* — a container, such as a FOUP or open cassette, with one or more positions for holding substrates.

5.2.5 *CarrierID* — a readable and unique identifier for the carrier.

5.2.6 *CarrierID read* — the process of the equipment reading the CarrierID from the carrier.

5.2.7 *carrier ID tag (tag, ID tag)* — a physical device for storing carrier ID and other information. There are two basic types of tags, read-only tags and read/write tags. [SEMI E99]

5.2.8 *carrier ready to unload (CRTU)* — the state in which a carrier is ready to be unloaded from the equipment.

5.2.9 *CRTU Prediction* — the process that detects and reports the CRTU Prediction Event to the host.

5.2.10 *CRTU Prediction Event (Prediction Event)* — the event that a carrier has been estimated to come CRTU within specified time later.

5.2.11 *collection event* — a collection event is an event (or grouping of related events) on the equipment that is considered to be significant to the host.

5.2.12 *docked position* — the position where the carrier is ready for substrate extraction or insertion.

5.2.13 *front-opening interface mechanical standard (FIMS) port* — the substrate access port where the FOUP is opened and closed.

5.2.14 *fixed buffer equipment* — production equipment that has only fixed load ports and no internal buffer for carrier storage. Substrates are loaded and unloaded directly from the carrier at the load port for processing.

5.2.15 *host* — the factory computer system or an intermediate system that represents the factory and the user to the equipment.

5.2.16 *internal buffer* — a set of locations within the equipment to store carriers. These locations exclude load ports.

5.2.17 *internal buffer equipment* — equipment that uses an internal buffer.

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5.2.18 *load* — the operation of placing a carrier on a load port.

5.2.19 *load port* — the interface location on the equipment where carriers are loaded and unloaded.

5.2.20 *object instantiation* — the act of storing of information related to a physical or logical entity so that it can be recalled on demand based on its public identifier.

5.2.21 *on-line equipment* — equipment that is connected to, and able to communicate fully with, the host.

5.2.22 *process equipment* — equipment used to produce product, such as semiconductor devices. This excludes metrology and material handling equipment.

5.2.23 *production equipment* — equipment used to produce product, such as semiconductor devices, including substrate sorting, process, and metrology equipment and excluding material handling equipment.

5.2.24 *properties* — a set of name value pairs assigned to an object or used in a service message to include additional information about the object (i.e., carrier, port, etc.).

5.2.25 *re-initialization* — a process where production equipment is either powered off then on or when some kind of hardware or software reset is initiated to cause the equipment to reset and possibly reload its software. On production equipment that contains some kind of mass storage device this can also be called a 'reboot.'

5.2.26 *read position* — any position on a load port or in an internal buffer from which the tag on a carrier can be read.

NOTE 1: This position may vary on any particular equipment depending on the read technology selected by the end user. Some technology/load ports may allow the carrier to be moved during reading. Equipment may have more than one read position.

5.2.27 *single communication connection* — exactly one physical connection using exactly one logical session and a standard set of messages.

5.2.28 *slot map* — the information that relates which slots in a carrier hold substrates, both correctly and incorrectly.

5.2.29 *slot map read* — the process of the equipment reading the slot map for substrate position and placement within the carrier.

5.2.30 *standard message set* — messages conforming to standard message specifications.

5.2.31 *substrate* — material held within a carrier. This can be product, or durables such as reticles.

5.2.32 *substrate port* — the carrier location from which substrates are accessed by the equipment.

5.2.33 *transfer unit* — maximum number of carriers allowed in a specific transfer service:

- AA is the maximum number of carriers allowed for acquisition at the transfer source.
- BB is the maximum number of carriers allowed for deposit at the transfer destination.
- CC is the maximum number of carriers allowed for transfer in one transport vehicle.

The transfer unit is the minimum of AA, BB, and CC.

5.2.34 *undocked* — the status of a carrier on a load port or in an internal buffer that is not at the docked position.

5.2.35 *unload* — the operation of removing a carrier from a load port.

5.2.36 *write position* — any position on a load port or in an internal buffer from which the tag on a carrier can be written to. This position may vary on any particular equipment depending on the write technology selected by the end user. Some technology/load ports may allow the carrier to be moved during writing. The read position and the write position may or may not be the same position.

6 Requirements

6.1 Carrier Management Standard (CMS) compliant equipment is required to provide certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and equipment control. These requirements shall be satisfied through compliance to the following sets of Standards:

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6.2 *Generic Equipment Model Standard (GEM) SEMI E30*

- Event Notification
- Status Data Collection
- Equipment Constants
- Alarm Management
- Equipment Control

6.3 *Object-Based Standards*

- Object Services Standard (SEMI E39)

7 Conventions

7.1 *Objects*

7.1.1 Whenever the equipment is required to know about specific kinds of entities, and required to manage information concerning these entities, it is useful to treat these entities as objects that comply with the basic requirements of SEMI E39. This is especially true whenever there are a large number of objects of a given type or when the entities are transient rather than permanent. In both cases, it is difficult to describe a general way for the host and equipment to specify which particular entity is referenced and to get information related only to a specific one out of many.

7.1.2 By defining these entities as objects that comply with OSS, it is only necessary for the host to specify the type of object and its specific identifier in order to inquire about one or more properties of the specific entity of interest.

7.1.3 *Object Properties*

7.1.3.1 A property (attribute) is information about an individual object that is presented as a name/value pair. The name is a formally reserved text string that represents the property, and the value is the current setting for that property.

7.1.3.2 Properties shall be accessible to the host via the service GetAttr for the Carrier object. Using SEMI E39, for example, it is possible to:

- get the list of IDs for the current carriers at the equipment, and
- get the specified properties for one or more individual carriers.

7.1.4 *Rules for Object Properties*

- Attributes with RO access cannot be changed using SetAttr service as defined in OSS.
- Attributes with RW access can be changed using SetAttr service as defined in OSS.
- Additional attributes may be specified by the user or the equipment supplier by using an attribute name starting with 'UD' (User Defined). Care should be taken to ensure the name of the attribute is unique.

7.1.5 *Object Attribute Table*

7.1.5.1 The object attribute table is used to list all the attributes related to the defined object as shown below the Access column is defined as Read Only (RO) or Read/Write (RW). The Reqd column is used to specify whether the attribute is required for implementation. A 'Y' in the Requirement (Reqd) column indicates if this attribute is supported in order to meet fundamental compliance for the service. 'N' in the Requirement (Reqd) column indicates when this attribute is supported in order to meet Optional Requirements. Finally, the Form column is used to specify the format of that particular attribute.

Table 1 Object Attribute Table

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
ObjType	Object type	RO	Y or N	Text = 'Carrier'

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7.2 *State Model Methodology*

7.2.1 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 Related Information 1 of SEMI E30. The definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems" by D. Harel, 1987.[1]

7.2.2 *State Model Requirements*

7.2.2.1 The state models included in this Standard are a requirement for CMS compliance. A state model consists of a state model diagram, state definitions, and a state transition table. All state transitions in this Standard, unless otherwise specified, shall correspond to collection events. More explicitly, there must be a unique collection event for each state transition.

7.2.2.2 Equipment must maintain state models for each of the required state models as defined in this Standard. Equipment shall maintain individual and unique state models for each logical entity instantiated or physical entity in the equipment that has state models associated with it. The event identifier reported during a particular state transition change for each of these state models shall be shared for all associated state models but unique for each transition. For example, if the equipment has two load ports and the load port state model defines 10 transitions, there must be exactly 10 event identifiers for each load port transfer state model but not 10 for each physical load port. The information identifying the physical entity or logical entity undergoing the transition will be contained within the associated event report.

7.2.2.3 A state model represents the host's view of the equipment, and does not necessarily describe the internal equipment operation. All CMS state model transitions shall be mapped sequentially into the appropriate internal equipment collection events that satisfy the requirements of those transitions. In certain implementations, the equipment may enter a state and have already satisfied all of the conditions required by the CMS state model for transition to another state. In this case, the equipment makes the required transition without any additional actions in this situation.

7.2.2.4 Some equipment may need to include additional substates other than those in this Standard. Additional substates may be added, but shall not change the CMS defined state transitions. All expected transitions between CMS states shall occur.

7.2.2.5 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 number, Previous State, Trigger, New State, Actions, and Comments. The 'trigger' (column 3) for the transition occurs while in the 'previous' state. The 'actions' (column 5) includes a combination of:

- Actions taken upon exit of the previous state,
- Actions taken upon entry of the new state, and
- Actions taken which are most closely associated with the transition.

7.2.2.6 When a state model is defined with multiple AND substates, the equipment may report all state entry events with only one collection event. When conditional paths are defined in the state model, it is not necessary to report any state transition(s) until a terminal state is reached at which time each transition used to reach that state is reported.

Table 2 State Transition Table

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*

[1] Elsevier Science, P. O. Box 945, New York, NY 10159-0945, USA; http://www.elsevier.nl/homepage/browse.htt

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7.3 *Services*

7.3.1 Services are functions or methods that may be provided by either the equipment or the host. A service message may be either a request message, which always requires a response, or a notification message that does not require a response.

7.3.2 *Service Message Description*

7.3.2.1 A service message description table defines the parameters used in a service, as shown in the following table:

Table 3 Service Message Description Table

Service Name	*Type*	*Description*

#1 Type can be either 'N' = Notification or 'R' = Request & Response.

7.3.2.2 Notification type messages are initiated by the service provider (e.g., the equipment) and the provider does not expect to get a response from the service user. Request messages are initiated by a service user (e.g., the host). Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

7.3.3 *Service Message Parameter Definition*

7.3.3.1 A service parameter dictionary table defines the description, range, and type for parameters used by services, as shown in the following table:

Table 4 Service Message Parameter Definition Table

Parameter Name	*Form*	*Description*

#1 A row is provided in the table for each parameter used on a service.

7.3.4 *Service Message Definition*

7.3.4.1 A service message description table defines the parameters used in a service message. It also describes each message and its cause/effect to the equipment. The columns labeled Req/Ind and Rsp/Conf link the parameters to the direction of the message.

Service Parameter	*Req/Ind*	*Resp/Conf*	*Description*

7.3.4.2 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'.

7.3.4.3 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 completely optional or may depend on the values 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).

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7.4 *Alarm Requirements Definition*

7.4.1 An alarm requirements definition table defines the specific set of alarms required by CMS. The table is divided up by equipment configuration, and then by alarm. The danger and affected columns are marked with 'X' characters to show each alarm and its possible impact to operators, equipment, and material. The table format is shown in the following example:

Equipment		*Danger*		*Affected*		
Configuration	*Alarm Text*	*Potential*	*Imminent*	*Operator*	*Equipment*	*Material*
Configuration 1	Alarm 1	X		X	X	X
	Alarm 2		X			X
Configuration 2	Alarm 3	X		X	X	
	Alarm 4	X			X	X

8 Overview

8.1 CMS defines the behavior, data, and services required for equipment supporting automated carrier transfer. This Specification provides a standard interface for host/equipment communications regarding the transfer of carriers. The standardized carrier transfer host interface includes not only transfers to and from the external load ports, but also transfers to and from the internal buffer positions on internal buffer type equipment.

8.2 *Single Connection Requirement*

8.2.1 The expectation of the production equipment supplier is that this Standard be implemented in conjunction with the generic equipment model (GEM) interface to their production equipment and without the use of a separate communication connection.

9 Load Port

9.1 A load port (port) is used by the factory to load and unload carriers to and from production equipment. A load port may be used as an input load port, an output load port, or as an input/output load port, depending upon equipment type, configuration and/or factory practices. This classification may be fixed or it may be programmable by the user. A load port is generally designed to handle one specific carrier type, such as substrate cassettes, leadframe magazines, SMIF pods, or front opening unified pods (FOUPs).

9.2 *Load Port Numbering*

9.2.1 The load port number shall be assigned incrementally from the bottom left to bottom right, then top left to top right when facing the front of the equipment. The load port numbering requirement is to provide a common reference base to external entities, such as humans.

9.3 *Carrier Slot Numbering*

9.3.1 The slot numbers for a carrier shall be assigned incrementally from the bottom, starting with '1'.

9.4 *Load Port Resource Sharing*

9.4.1 A model of a load port must account for any mechanical assemblies that are either active during carrier transfer or are capable of interacting with the transfer. The load port is responsible for such mechanisms when the load port is in the TRANSFER READY state. If these mechanisms are shared with other load ports, then the sharing must be coordinated.

9.5 *Load Port Transfer State Model*

9.5.1 The purpose of the Load Port Transfer State Model is to define the host view of a carrier transfer, which includes the host interactions with the equipment necessary to transfer carriers to and from equipment load ports. Each load port on the equipment shall maintain an independent instance of this state model.

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9.5.2 *Load Port Transfer State Model Diagram*

9.5.2.1 Figure 1 is the diagram for the Load Port Transfer State Model.

9.5.3 *Load Port Transfer State Definitions*

9.5.3.1 *LOAD PORT TRANSFER* — The super state for the IN SERVICE and OUT OF SERVICE states.

9.5.3.2 *OUT OF SERVICE* — Transfer to/from this load port is disabled. A transition to IN SERVICE is required to continue using this load port for transfers.

9.5.3.3 *IN SERVICE* — Transfer to/from this load port is enabled. A transition to OUT OF SERVICE disables the load port for transfer use.

9.5.3.4 *TRANSFER READY* — A substate of IN SERVICE. The load port is available for carrier transfer. The transfer can either be manual or automated, and can be a load or an unload. This state contains two substates, which are used depending on whether or not a carrier is present on the load port (READY TO LOAD and READY TO UNLOAD).

9.5.3.5 *READY TO LOAD* — A substate of TRANSFER READY. When transitioning to the TRANSFER READY state, if a carrier is not present on the specified load port, this is the active substate. In this state, the load port is available to be loaded with an external carrier, or with a carrier that is currently located inside the equipment (i.e., internal buffer).

9.5.3.6 *READY TO UNLOAD* — A substate of TRANSFER READY. When transitioning to the TRANSFER READY state, if a carrier is present on the specified load port, this is the active substate. In this state, the load port is available for unloading of a carrier from the load port to material handling equipment. When the load port is being used by the equipment, the state shall transition to TRANSFER BLOCKED.

9.5.3.7 *TRANSFER BLOCKED* — The carrier transfer state is neither READY TO LOAD nor READY TO UNLOAD. Because of load port related activity being performed, transfer is not available to/from this load port at this time.

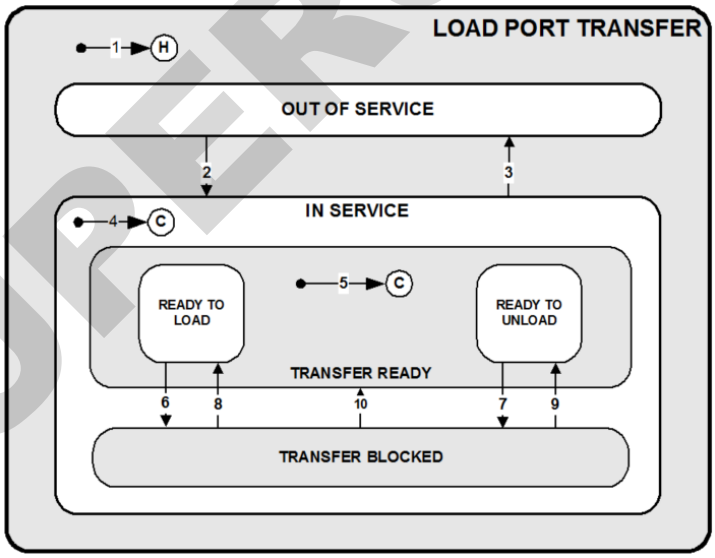

Figure 1
Load Port Transfer State Model Diagram

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9.5.4 *Load Port Transfer State Transition Table*

Table 5 Load Port Transfer State Transition Definition

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
1	(no state)	System reset.	OUT OF SERVICE or IN SERVICE (History)		This transition is based on what the current transfer status was prior to system reset. Data required to be available for this event report: PortID PortTransferState
2	OUT OF SERVICE	The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE.	IN SERVICE		Load port is now usable for transfer. Data required to be available for this event report: PortID PortTransferState
3	IN SERVICE	The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of OUT OF SERVICE.	OUT OF SERVICE		Load port is now rendered unusable for transfer. Attempted usage of the load port for carrier transfer after the state transition results in an alarm. Data required to be available for this event report: PortID PortTransferState
4	IN SERVICE	*Service:* The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE. *System Reset:* This transition can be activated by an equipment re-initialization.	TRANSFER READY or TRANSFER BLOCKED		This is the default entry into IN SERVICE. The state is TRANSFER BLOCKED if the carrier, or load port, is not available for carrier transfer. Otherwise, the state is TRANSFER READY. Data required to be available for this event report: PortID PortTransferState
5	TRANSFER READY	*Service:* The host or an operator has invoked the ChangeServiceStatus service for this load port with a value of IN SERVICE. *System Reset:* This transition can be activated by an equipment re-initialization. *Failed Transfer:* If a transfer fails, this transition is activated by transition #10.	READY TO LOAD or READY TO UNLOAD		When entering the TRANSFER READY state, if a carrier is present, the substate is READY TO UNLOAD, else the substate is READY TO LOAD. If the state is READY TO LOAD, data required to be available for this event report: PortID If the state is READY TO UNLOAD, data required to be available for this event report: PortID CarrierID PortTransferState

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#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*
6	READY TO LOAD	*Manual*: The equipment recognizes the logical indication of the start of a manual load transfer. This trigger is configurable by the user, examples are included in Table 8. *Automated*: The PIO load transfer is beginning and the PIO 'READY' signal is activated (see SEMI E84). *Internal Buffer:* A CarrierOut service has started for this load port.	TRANSFER BLOCKED		When a CarrierOut service is queued and the equipment load port is currently in the TRANSFER BLOCKED state, the equipment shall keep the load port in the TRANSFER BLOCKED state. Data required to be available for this event report: PortID PortTransferState
7	READY TO UNLOAD	*Manual*: The equipment recognizes the logical indication of the start of a manual unload transfer. This trigger is configurable by the user, examples are included in Table 8. *Automated*: The PIO unload transfer is beginning and the PIO 'READY' signal is activated (see SEMI E84). *Internal Buffer:* A CarrierIn service has started for this load port. *By CarrierReCreate Service:* A CarrierReCreate service command has been issued by host or operator.	TRANSFER BLOCKED		When a CarrierOut service is queued and the equipment load port is currently in the TRANSFER BLOCKED state, the equipment shall keep the load port in the TRANSFER BLOCKED state. Data required to be available for this event report: PortID PortTransferState
8	TRANSFER BLOCKED	*Manual:* The carrier unload transfer has completed, and the load port is now empty and ready for load transfer. This is indicated when two conditions are met, the presence signal indicates that no carrier is present and the operator has logically indicated that the transfer is complete. *Automated:* The PIO unload transfer ends with the PIO 'COMPT' signal (see SEMI E84). *Internal Buffer:* The carrier has finished its move from the load port into the internal buffer, and no CarrierOut services are queued for this load port.	READY TO LOAD		A carrier can now be loaded onto the load port from either an external entity, or by the equipment's internal material handling resource. Data required to be available for this event report: PortID PortTransferState

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#	Previous State	Trigger	New State	Actions	Comments
9	TRANSFER BLOCKED	*Manual:* Processing for substrates contained within the carrier has completed, or a CancelCarrier/ CancelCarrierAtPort service has been issued, and the carrier has returned to the load/unload position on the load port. *Automated:* Processing for the substrates belonging to the carrier has completed, or a CancelCarrier/CancelCarrier-AtPort service has been received, and the carrier has returned to the load/unload position. *Internal Buffer:* A carrier has completed its move from the internal buffer to the load port.	READY TO UNLOAD		The carrier on the load port can now be unloaded from the load port to an external entity. Data required to be available for this event report: PortID CarrierID PortTransferState
10	TRANSFER BLOCKED	The transfer was unsuccessful, and the carrier was not loaded or unloaded.	TRANSFER READY		The substate of TRANSFER READY which is decided by transition #5. Data required to be available for this event report: PortID PortTransferState

10 Carrier Object

10.1 Information about a carrier is encapsulated as an object. This allows the host to exchange information with the equipment about one or more specific carriers using services defined in SEMI E39. A carrier has properties (attributes) that are defined in Table 6, Carrier Attribute Definition.

10.2 *Object Instantiation*

10.2.1 The carrier object is a software representation of the carrier in the equipment. Under normal circumstances this object is instantiated by the equipment when the host uses the Bind or Carrier Notification service or when the equipment successfully reads the CarrierID from the carrier. A carrier object is instantiated by CarrierID read only if there are no currently existing objects with the CarrierID just read. A carrier object can also be instantiated by either the ProceedWithCarrier or CancelCarrier Services on an NOT ASSOCIATED port. (This implies a failed CarrierID read event.) The ContentMap attribute will be an empty list (a list of zero) when the instantiation is done by CarrierID read. The SlotMap attribute should be a list consisting of all slots enumerated as 'UNDEFINED' when the carrier object is instantiated by CarrierID read.

10.2.2 From the host point of view, an object is instantiated if the host is able to query the equipment about that object, its current state, and other attributes. Once instantiated, the object is considered destroyed (no longer instantiated) if the response to such queries is 'unknown object'.

10.2.3 Summary of carrier object instantiation:

1. Bind or Carrier Notification or CarrierReCreate (with PropertiesList) service;
2. CarrierID read with no currently existing carrier objects having the carrierID just read; and
3. ProceedWithCarrier or CancelCarrier Service on an NOT ASSOCIATED port with a carrier.

10.2.4 *Carrier Object Identifier (ObjID)*

10.2.4.1 The purpose of an Object Identifier is to allow references to an object within the system. The object identifier is created when an object is instantiated and should be unchanged or persistent until the end of the object lifecycle. The Object Identifier shall be unique at the equipment during lifecycle of the object. The CarrierID is the

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Carrier Object Identifier. The equipment is responsible for ensuring uniqueness of the CarrierID prior to instantiation by the bind service.

10.2.5 *Carrier Object Destruction*

10.2.5.1 Normally, the Carrier Object reaches the end of its lifecycle when the carrier is unloaded from the equipment. Abnormally, the Carrier Object reaches the end of its lifecycle when a CancelBind or CancelCarrierNotification service is executed prior to the carrier being loaded, or when an equipment based carrier verification fails following carrier instantiation by the bind service.

10.2.5.2 Summary of carrier object destruction:

1. A carrier is unloaded from the equipment;
2. A CancelBind or CancelCarrierNotification service is received;
3. An equipment based CarrierID verification fails after a carrier object was previously instantiated with a 'Bind' service (Equipment initiated CancelBind); and
4. The host or operator has issued a CarrierReCreate service.

10.3 *Carrier Attribute Definitions*

10.3.1 The following table contains the attributes that are of importance to the host and/or the equipment in order to manage the history and the reports about the carrier object.

10.3.2 *Reqd Column*

10.3.2.1 All attributes marked 'Y' in the 'Reqd' column in the Carrier Attribute Definition (Table 6) are required to be associated with the carrier object and are always maintained and updated by the equipment.

10.3.2.2 Attributes marked 'N' in the 'Reqd' column in the Carrier Attribute Definition (Table 6) can be omitted if it is not used. Those attributes are used only in the case the capability is implemented.

10.3.3 *ACCESS Column*

10.3.3.1 Even though a value may be marked as RO (read only), the initial value for the attribute may be provided by the host when attached to either the Bind or ProceedWithCarrier services.

10.3.4 *Carrier Attribute Definition Table*

Table 6 Carrier Attribute Definition

Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
Capacity	Maximum number of substrates a carrier can hold.	RO	Y	Positive integer.
CarrierIDStatus	Current state of the carrier ID verification.	RO	Y	Enumerated: ID NOT READ, [ID] WAITING FOR HOST, ID VERIFICATION OK, ID VERIFICATION FAILED.
CarrierAccessingStatus	The current accessing state of the carrier by the equipment. The current substate of the CarrierAccessingStatus state model.	RO	Y	Enumerated: NOT ACCESSED, IN ACCESS, CARRIER COMPLETE, CARRIER STOPPED.

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Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
CaRTUPStatus	State of the CRTU Prediction of the carrier. This attribute is required only when CRTU Prediction is implemented.	RO	N	Enumerated: PREDICTION DISABLED, WAITING FOR CARRIER, WAITING FOR PREDICTION, PREDICTED, PREDICTION ABORTED, PREDICTION COMPLETED.
CaRTUPSettingTime	CRTU Prediction Setting Time. This attribute is required only when CRTU Prediction is implemented. This attribute specifies the lead time (in seconds) for detecting the CRTU Prediction Event. The CRTU Prediction Event is detected when the current time reaches within the lead time to CRTU time of the carrier estimated by equipment. If this attribute is set to 0 (zero), the CRTU Prediction is disabled (i.e., goes into PREDICTION DISABLED state).	RO	N	Non-negative integer. Default value = 0.
CaRTUPTimeOut	CRTU Prediction Time Out. This attribute is required only when CRTU Prediction is implemented. This attribute specifies the maximum time allowed to wait the CRTU after the predicted CRTU time. If this time elapses after the predicted CRTU time and the carrier is still not ready to be unloaded, the carrier object shall be into 'PREDICTION ABORTED' state to inform the prediction is no longer effective. If this attribute is set to 0 (zero), the abort condition is not checked, and the carrier stays in PREDICTED state until unloaded.	RO	N	Non-negative integer. Default value = 0.
ContentMap	Ordered list of lot and substrate identifiers corresponding to slot 1,2,3,…n.	RO	Y	Ordered list of n structures, where n is equal to the value of 'Capacity' above, and each structure consists of a LotID and SubstrateID. List of Structure LotID SubstrateID When no Lot ID is provided by the host, the LotID value should be null. When a slot has no substrate or the host does not know substrate identifier, the LotID and SubstrateID value should be null.
LocationID	Identifier of current location.	RO	Y	Text 1–80 characters.
ObjType	Object type.	RO	Y	Text 1–40 characters equal to 'Carrier'.
ObjID	Object identifier.	RO	Y	Text 1–80 characters equal to the CarrierID.

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Attribute Name	*Definition*	*Access*	*Reqd*	*Form*
SlotMap	Ordered list of slot status as provided by the host and corresponding to slot 1,2,3…n until a successful slot map read, then as read by the equipment.	RO	Y	Ordered list of n, where n is equal to the value of 'Capacity', each value in the list is from the following enumeration: UNDEFINED, EMPTY, NOT EMPTY, CORRECTLY OCCUPIED, DOUBLESLOTTED, CROSS SLOTTED. (NOT EMPTY provided for equipment that cannot detect incorrectly slotted substrates).
SlotMapStatus	Current state of slot map verification.	RO	Y	Enumerated: SLOT MAP NOT READ, [SLOT] WAITING FOR HOST, SLOT MAP VERIFICATION OK, SLOT MAP VERIFICATION FAILED.
SubstrateCount	The number of substrates currently in the carrier.	RO	Y	Non-negative integer less than or equal to the Capacity.
Usage	The type of material contained in the carrier (i.e., TEST, DUMMY, PRODUCT, FILLER, etc.).	RO	Y	Text as defined by the equipment.

#1 NOT EMPTY is included to indicate presence for equipment that is only able to detect substrate presence but not correct positioning of the substrate slot. For equipment that can detect incorrect positioning such as cross-slotted or double slotted, NOT EMPTY may not be applicable.

10.3.5 *Rules for Carrier Attributes*

- The equipment shall change object attributes, Capacity, ContentMap, SlotMap, Substrate count and Usage, provided by the host. All other attributes, such as LocationID, shall be set and maintained by the equipment.
- The attributes, Capacity, ContentMap, Substrate count and Usage, shall be provided with Bind, CarrierNotification, or ProceedWithCarrier service before or when SlotMap is provided.
- The SlotMap shall be provided with Bind, CarrierNotification, or ProceedWithCarrier to verify CarrierID, when the SlotMap verification is equipment based. And it shall not be provided when the SlotMap verification is host based.
- Carrier properties may be provided before the carrier arrives as part of the Bind service and should be retained until either a CancelBind service is received or the carrier is removed.
- Carrier properties may also be provided by the ProceedWithCarrier service. The carrier properties that are provided by the ProceedWithCarrier service may differ based whether or not the object is instantiated by the service.
- Carrier properties that are required shall be actively updated by the equipment.

10.3.6 *Carrier Location*

10.3.6.1 A carrier location, signified by LocationID, is used for tracking carriers as they move through the equipment. A carrier location is any physical area that is capable of holding a carrier. It is not intended to represent entire mechanisms, which may have a variety of other properties of interest, but only that portion where a carrier may rest.

10.3.7 *Carrier Location Examples*

10.3.7.1 Carrier locations include load port locations, substrate port locations, internal buffer locations, as well as grippers, conveyors, and elevators that are used internally for moving the carrier from one fixed location to another.

10.3.8 *Rules for Carrier Ready To Unload Prediction Attributes*

10.3.8.1 Rules in this section apply to the optional attributes, additionally to the rules in § 10.3.5, when the CRTU Prediction is implemented.

- The equipment shall maintain and update the object attribute CaRTUPStatus.

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- Carrier attributes CaRTUPSettingTime and CaRTUPTimeOut may be provided before the carrier arrives as part of Bind or CarrierNotification service. Those attributes should be retained until either CancelBind or CancelCarrierNotification service is received or the carrier is removed.
- Carrier attributes CaRTUSettingTime and CaRTUPTimeOut may also be provided by the ProceedWithCarrier or CarrierReCreate service.
- If an attribute of CaRTUSettingTime or CaRTUPTimeOut is not specified, the default value applies to the attribute.

10.4 *Carrier Location Naming*

10.4.1 Carrier locations shall be assigned a unique name. Information about the carrier location can be obtained by querying the CarrierObject for the LocationID or by asking the equipment for the CarrierLocation-Matrix. The text form of the LocationID shall be descriptive of the location. For example, LocationID form for load port load/unload location might be 'LPn', where 'n' equal is equal to the load port number (the load port number is determined through the numbering rule in ¶ 9.1). The LocationID form for the FIMS port location might be 'FIMSn'. The LocationID form for a buffer location might be 'BUFn'.

10.5 *Load Port Carrier Locations*

10.5.1 For fixed buffer equipment configured to handle FOUPs, a load port has two different carrier locations. One represents the place where a carrier is delivered and picked up, while the other represents the place where the carrier is docked and can be opened.

10.6 *Carriers Between Locations*

10.6.1 When the carrier is traveling from one location to another, the location attribute remains equal to the source location until the carrier movement is complete and the carrier is resting at the new carrier location (the destination location).

10.6.2 *Usage*

10.6.2.1 The Usage parameter indicates the type of substrate the carrier contains. All Usage values are equipment specific values. Some internal buffer equipment manages carriers by establishing logical partitions. This type of equipment shall use the Usage parameter to determine which logical partition where the carrier is held.

10.6.3 *SubstrateCount*

10.6.3.1 The SubstrateCount parameter can be sent to the equipment by the host in either the Bind service or the ProceedWithCarrier service. However the equipment shall update this parameter based on the results of the read slot map operation. Furthermore, the equipment shall update the parameter based on its own actions of adding and removing a substrate to and from a carrier. If the equipment does not know the value of SubstrateCount prior to instantiation, the equipment shall instantiate the carrier object with the value of null for SubstrateCount.

10.6.4 *Lot information for ContentMap*

10.6.4.1 Lot is defined in SEMI E90 as a group of one or more substrates of the same type. It is organized external to the equipment. The Lot ID is the identifier of this group. If the equipment is informed of the Lot ID to which a substrate belongs, the equipment must maintain this information.

10.6.5 *Carrier Accessing Status*

10.6.5.1 The CarrierAccessingStatus is used by the host to know whether or not the carrier owned by the equipment can be moved out. If the carrier is within the internal buffer equipment, this status may be used by the host to issue CarrierOut service.

10.7 *Carrier State Model*

10.7.1 The purpose of the Carrier State Model is to define the host's view of a carrier. The equipment shall maintain a separate and independent state model for each carrier in/at the equipment.

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10.7.2 *Carrier State Model Diagram*

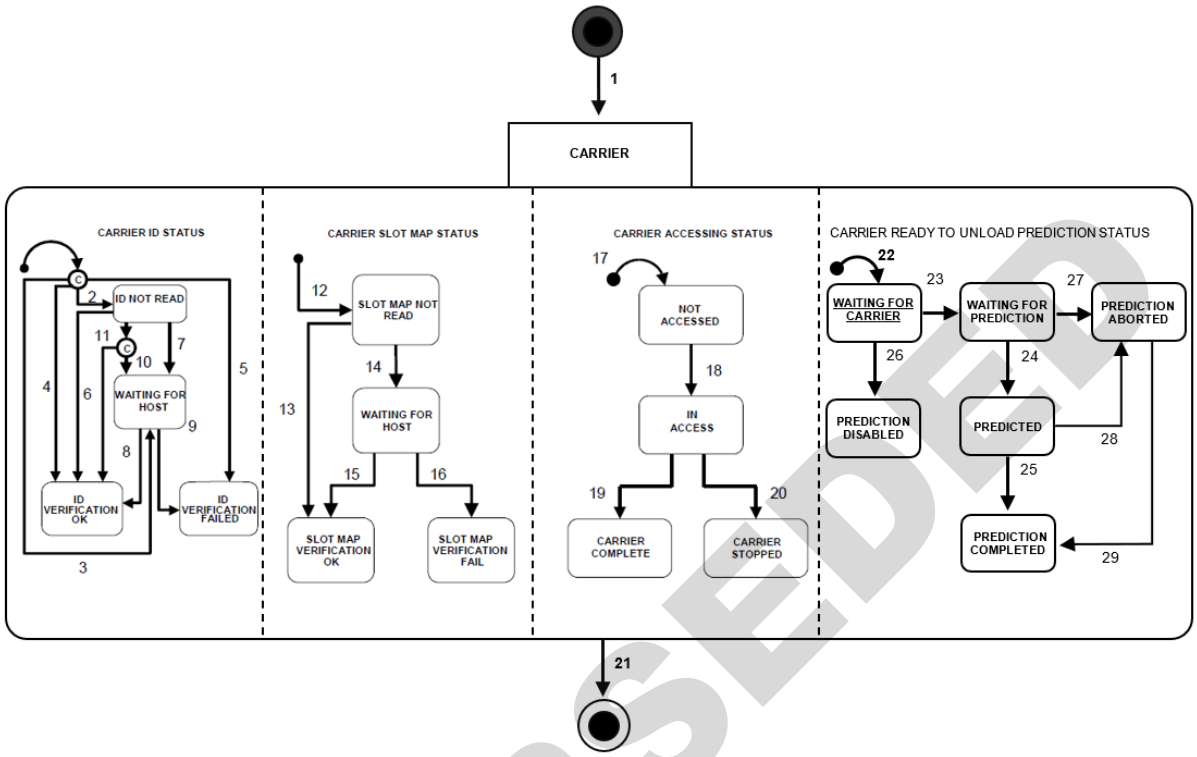

Figure 2
Carrier State Model Diagram

10.7.3 *Carrier State Definitions*

10.7.3.1 *CARRIER* — The CARRIER state has three fundamental states of CARRIER ID STATUS, CARRIER SLOT MAP STATUS and CARRIER ACCESSING STATUS, and an additional state CARRIER READY TO UNLOAD PREDICTION STATUS. The Additional state is required only when the CRTU Prediction is implemented.

10.7.3.2 *CARRIER ACCESSING STATUS* — This is a substate of CARRIER and indicates the current accessing status of the carrier. It has four substates, NOT ACCESSED, IN ACCESS, CARRIER COMPLETE, and CARRIER STOPPED. The initial default entry substate is NOT ACCESSED.

10.7.3.2.1 *NOT ACCESSED* — This is a substate of CARRIER ACCESSING STATUS and is active when access by the equipment to the carrier has not been started. The carrier can be moved out.

10.7.3.2.2 *IN ACCESS* — This is a substate of CARRIER ACCESSING STATUS and is active when access by the equipment to the carrier has been started but has not been finished, and the carrier should not be moved out.

10.7.3.2.3 *CARRIER COMPLETE* — This is a substate of CARRIER ACCESSING STATUS and is active when the access by the equipment to the carrier has been finished, and the carrier should be moved out. This is a final state.

10.7.3.2.4 *CARRIER STOPPED* — This is a substate of CARRIER ACCESSING STATUS and is active when the access by the equipment to the carrier has been stopped abnormally, and the carrier should be moved out. This is a final state.

10.7.3.3 *CARRIER ID STATUS* — This is a substate of CARRIER and indicates the current status of the carrier with respect to its identifier. It has four substates, ID NOT READ, WAITING FOR HOST, ID VERIFICATION FAILED, ID VERIFICATION OK. The initial substate is conditional based on information the equipment has about the carrier. When the carrierID is provided by the Bind or the Carrier Notification service, the carrier object shall be instantiated

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in the ID NOT READ substate. When the carrierID is provided by the carrier ID reader, the carrier shall be instantiated in the WAITING FOR HOST substate. When the Carrier is instantiated by the ProceedWithCarrier service, the carrier shall be instantiated in the ID VERIFICATION OK substate. Finally when the carrier is instantiated by the CancelCarrier service, the carrier will be instantiated in the ID VERIFICATION FAILED substate.

10.7.3.3.1 *ID NOT READ* — This is a substate of CARRIER ID STATUS. This state is active whenever the CarrierID has not been read by the equipment.

10.7.3.3.2 *ID VERIFICATION FAILED* — This is a substate of CARRIER ID STATUS and is active when the carrierID has failed verification by the host following the CancelCarrier service. This is a final state.

10.7.3.3.3 *ID VERIFICATION OK* — This is a substate of CARRIER ID STATUS and is active as soon as the CarrierID has been accepted. The ID is determined to be accepted by either successful verification by the equipment or the host, or by bypassing ID read because a carrier ID reader is not available and the BypassReadID variable is set to true. This is a final state.

10.7.3.3.4 *WAITING FOR HOST* — This is a substate of CARRIER ID STATUS and is active during the period of time when the CarrierID has been read by the equipment successfully or unsuccessfully and has not yet been verified by the host.

10.7.3.4 *CARRIER SLOT MAP STATUS* — This is a substate of CARRIER and indicates the current status of the carrier with respect to its slot map. It has four substates, SLOT MAP NOT READ, WAITING FOR HOST, SLOT MAP VERIFICATION FAILED, SLOT MAP VERIFICATION OK. The initial default entry substate is SLOT MAP NOT READ.

10.7.3.4.1 *SLOT MAP NOT READ* — This is a substate of CARRIER SLOT MAP STATUS and is the default entry state. It is active when the Carrier is first loaded at the equipment until the Slot Map has been read successfully by the equipment at the Substrate Port.

10.7.3.4.2 *SLOT MAP VERIFICATION FAIL* — This is a substate of CARRIER SLOT MAP STATUS and is active when the Slot Map has been read by the equipment and has failed verification by the host. This is a final state.

10.7.3.4.3 *SLOT MAP VERIFICATION OK* — This is a substate of CARRIER SLOT MAP STATUS and is active as soon as the slot map has been verified. This is a final state.

10.7.3.4.4 *WAITING FOR HOST* — This is a substate of CARRIER SLOT MAP STATUS and is active when the equipment is waiting for input from the host.

10.7.3.5 *CARRIER READY TO UNLOAD PREDICTION STATUS* — This is a substate of CARRIER, to indicate current status of the carrier with respect to its prediction for READY TO UNLOAD. It has six substates, WAITING FOR CARRIER, WAITING FOR PREDICTION, PREDICTED, PREDICTION ABORTED, PREDICTION COMPLETED, PREDICTION DISABLED.

10.7.3.5.1 *WAITING FOR CARRIER* — This is a substate of CARRIER READY TO UNLOAD PREDICTION STATUS and is active when the carrier object is created.

10.7.3.5.2 *WAITING FOR PREDICTION* — This is a substate of CARRIER READY TO UNLOAD PREDICTION STATUS and is active when the equipment is waiting for the condition (refer to ¶ 10.7.8.4) to be satisfied. For carriers in this state, the equipment estimates the time that the carrier is ready to be unloaded, and checks for the possible abort condition (refer to ¶ 10.7.8.5).

10.7.3.5.3 *PREDICTED* — This is a substate of CARRIER READY TO UNLOAD PREDICTION STATUS and is active when the condition (refer to ¶ 10.7.8.4) is already satisfied. For carriers in this state, the equipment estimates the time that the carrier is ready to be unloaded, and checks the condition of prediction to be aborted.

10.7.3.5.4 *PREDICTION ABORTED* — This is a substate of CARRIER READY TO UNLOAD PREDICTION STATUS and is active when the abort condition (refer to ¶ 10.7.8.5) is satisfied. For carriers in this state, the equipment no longer calculates the time until READY TO UNLOAD.

10.7.3.5.5 *PREDICTION COMPLETED* — This is a substate of CARRIER READY TO UNLOAD PREDICTION STATUS and is active when the carrier is in the state that the carrier can be unloaded. This is a final state.

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10.7.3.5.6 *PREDICTION DISABLED* — This is a substate of CARRIER READY TO UNLOAD PREDICTION STATUS and is active when CARRIER READY TO UNLOAD PREDICTION capability is disabled. This is a final state.

10.7.4 *Carrier State Transition Table*

10.7.4.1 Table 7 indicates the triggers and the expected behavior of the instantiated carrier object.

Table 7 Carrier State Transition Definition

#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
1	(no state)	A carrier is instantiated.	CARRIER	None.	No event is required for this transition
2	(no state)	*Normal:* A Bind or Carrier Notification service is received.	ID NOT READ	None.	Data required to be available for this event report: CarrierID CarrierIDStatus
3	(no state)	*Normal:* A CarrierID not currently existing at the equipment is successfully read. *Abnormal:* A CarrierID is read successfully but an equipment based verification failed.	WAITING FOR HOST	None.	Data required to be available for this event report: CarrierID PortID CarrierIDStatus Normally, this transition will happen after a successful ID read if a bind service has not been issued (host based verification) or abnormally if a bind service is followed by a successful ID read and an unsuccessful equipment based verification.
4	(no state)	*ID Read fail or UnknownCarrierID Events*: ProceedWithCarrier service is received.	ID VERIFICATION OK	A carrier is instantiated having the CarrierID provided by the Proceed WithCarrier service.	Data required to be available for this event report: CarrierID CarrierIDStatus This transition can happen only if a bind service has not been received.
5	(no state)	*ID Read fail or UnknownCarrierID Events:* A CancelCarrier service is received.	ID VERIFICATION FAIL	A carrier is instantiated having the CarrierID provided by the Cancel Carrier service.	Data required to be available for this event report: CarrierID CarrierIDStatus This transition can happen only if a bind service has not been received.

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#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
6	ID NOT READ	*Normal*: CarrierID is read successfully and the equipment has verified the carrierID successfully. *Abnormal:* The carrier was instantiated via a CarrierNotification service and upon carrier placement the equipment has sent a CarrierID Read Fail Event or UnknownCarrierID Event. Subsequently the host has issued a ProceedWithCarrier service. The ProceedWithCarrier service must provide the PortID parameter as well as the CarrierID parameter in order to unambiguously identify the physical carrier.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
7	ID NOT READ	CarrierID is read unsuccessfully.	WAITING FOR HOST	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
8	WAITING FOR HOST	A ProceedWithCarrier service is received.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
9	WAITING FOR HOST	A CancelCarrier service is received.	ID VERIFICATION FAIL	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
10	ID NOT READ	BypassReadID variable is set to FALSE, and a carrier is received when the ID reader is not in service or not installed.	WAITING FOR HOST	Wait for ProceedWith-Carrier.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
11	ID NOT READ	BypassReadID variable is set to TRUE, and a carrier is received when the id reader is not in service or not installed.	ID VERIFICATION OK	None.	Data required to be available for this event report: PortID CarrierID CarrierIDStatus
12	(no state)	A carrier is instantiated.	SLOT MAP NOT READ	None.	No event is required for this transition.

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#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
13	SLOT MAP NOT READ	Slot Map is read and verified successfully by the equipment.	SLOT MAP VERIFICATION OK	None.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID CarrierAccessingStatus SlotMapStatus
14	SLOT MAP NOT READ	*Normal host based verification:* Slot Map is read successfully and the equipment is waiting for host verification. *Equipment based verification fail:* Slot Map is read successfully but equipment based verification has failed. *Slot map read fail:* Slot Map cannot be read. *Abnormal substrate position within the carrier:* The Slot Map read has indicated an abnormal substrate position.	WAITING FOR HOST	Save new slot map in the SlotMap attribute.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID SlotMap (if valid) Reason SlotMapStatus
15	WAITING FOR HOST	A ProceedWithCarrier service is received.	SLOT MAP VERIFICATION OK	Proceed with the carrier as instructed.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID SlotMapStatus
16	WAITING FOR HOST	A CancelCarrier service is received.	SLOT MAP VERIFICATION FAIL	Prepare the carrier for Unload.	Data required to be available for this event report: PortID (if valid) CarrierID LocationID CarrierAccessingStatus SlotMapStatus
17	(no state)	A carrier object is instantiated.	NOT ACCESSED	None.	No event is required for this transition
18	NOT ACCESSED	The equipment starts accessing the carrier.	IN ACCESS	None.	Data required to be available for this event report: CarrierID CarrierAccessingStatus
19	IN ACCESS	The equipment finishes accessing the carrier normally.	CARRIER COMPLETE	None.	Data required to be available for this event report: CarrierID CarrierAccessingStatus
20	IN ACCESS	The equipment finishes accessing the carrier abnormally.	CARRIER STOPPED	None.	Data required to be available for this event report: CarrierID CarrierAccessingStatus

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#	Previous State	Trigger	New State	Actions	Comment
21	CARRIER	*Normal:* The carrier is unloaded from the equipment. *Abnormal by service:* CancelBind or CancelCarrierNotification service is received prior to the carrier load. *Abnormal by equipment:* An equipment based verification fails and the equipment performs a self-initiated CancelBind service.	(no state)	The equipment destroys the instance of this carrier object.	Data required to be available for this event report: CarrierID
22	(no state)	A carrier object is instantiated.	WAITING FOR CARRIER	None.	Data required to be available for this event report: PortID (if valid), CarrierID
23	WAITING FOR CARRIER	The CARRIER ACCESSING STATUS is "IN ACCESS" and the Carrier attribute CaRTUPSettingTime is not set to 0 (zero).	WAITING FOR PREDICTION	Start estimation of the CRTU time (Tp) to detect the Prediction Event	Data required to be available for this event report: PortID (if valid), CarrierID
24	WAITING FOR PREDICTION	The estimated CRTU time is within the specified lead time (CaRTUPSettingTime) from the current time.	PREDICTED	Stop updating Tp to preserve the value, and start estimation of CRTU time (Te) to detect the abort condition	Refer to § 10.7.8.4 for the detail condition for the Prediction. Data required to be available for this event report: PortID, CarrierID
25	PREDICTED	The carrier is ready to be unloaded.	PREDICTION COMPLETED	Stop the estimation of CRTU time (Te).	Data required to be available for this event report: PortID, CarrierID, CaRTUPActualTime
26	WAITING FOR CARRIER	The CARRIER ACCESSING STATUS is 'IN ACCESS' and the Carrier attribute CaRTUPSettingTime is set to 0 (zero).	PREDICTION DISABLED	None.	Data required to be available for this event report: PortID (if valid), CarrierID
27	WAITING FOR PREDICTION	(1) CRTU Prediction is not available for any reason with the equipment or, (2) For internal buffer equipment, the load port for the unload is changed.	PREDICTION ABORTED	None.	Refer to § 10.7.8.5 for the detail condition of the PREDICTION ABORTED. Data required to be available for this event report: PortID (if valid), CarrierID, CaRTUPAbortedReason
28	PREDICTED	(1) The estimated CRTU time (Te) in this state exceeded CaRTUPTimeOut after the predicted CRTU time (Tp), or (2) For internal buffer equipment, the load port associated to the carrier is changed.	PREDICTION ABORTED	None.	Refer to § 10.7.8.5 for the detail condition of the PREDICTION ABORTED. Data required to be available for this event report: PortID, CarrierID, CaRTUPAbortedReason

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#	*Previous State*	*Trigger*	*New State*	*Actions*	*Comment*
29	PREDICTION ABORTED	The carrier is ready to be unloaded.	PREDICTION COMPLETED	None.	Data required to be available for this event report: PortID, CarrierID

#1 Only one collection event report is required when entering the Carrier State Model (instantiating a carrier object). This event report shall include the entry state of the all the substates of Carrier State Model, (including CARRIER ID STATUS substate and the CARRIER SLOT MAP STATUS substate).

10.7.5 *Slot Map Read Details*

10.7.5.1 The Slot Map shall be read on all production equipment prior to removal of substrates from the carrier.

10.7.6 *Carrier Read Failure* — A carrier read failure occurs when the carrier ID reader is present, in service, and reports that it is unable to read the ID of a carrier. This represents a transient random failure rather than a steady condition.

10.7.7 *Bypass Read ID* — A carrier ID reader may be unavailable: either out of service, not installed, or otherwise malfunctioning and unable to execute a read operation. This represents a steady condition that often is known in advance. The equipment shall provide a user-configurable variable BypassReadID used to bypass verification of the carrier ID when the carrier ID reader is unavailable or not installed and the load port is ASSOCIATED. BypassReadID is not used to bypass the carrier ID reader. In this case, the carrier object is instantiated in the ID NOT READ state, and when the carrier is received, the state model transitions to either WAITING FOR HOST or ID VERIFICATION OK, depending upon whether BypassReadID is FALSE (the default value) or TRUE. When TRUE, then the Carrier ID received in the Bind is used automatically. Otherwise, the carrier transitions to WAITING FOR HOST and waits for the host to send a ProceedWithCarrier. The ID used will be the ID included with the ProceedWithCarrier.

10.7.8 *Carrier Ready To Unload (CRTU) Prediction Details*

10.7.8.1 The purpose of the CRTU Prediction functionality is to provide a factory host with sufficient pre-notification before a carrier can be unloaded. This makes it possible for the factory system to schedule an AMHS vehicle for early carrier pick-up. This will allow the factory to reduce carrier exchange time and therefore potentially improve equipment productivity.

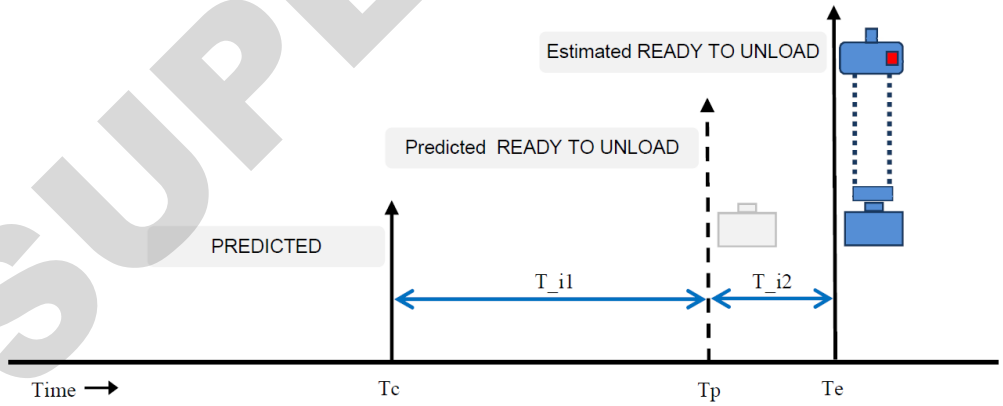

Figure 3
Carrier Ready To Unload Prediction Behavior

10.7.8.2 Figure 3 shows how the equipment predicts the time when a certain carrier can be unloaded. In the figure, the Tc represents the time at which the equipment is predicting the event that a carrier will be 'READY TO UNLOAD' on a load port. At the Tc, the equipment calculates the predicted time Tp at which the carrier will be ready for pickup to determine the Prediction Event. After this time Tc, the equipment calculates continually the estimated time Te at

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which the carrier can be picked up after the Tp. T_i1 represents the time difference between the current time Tc and the predicted time Tp for the detection of the Prediction Event. T_i2 represents the time difference between predicted time Tp and the time Te estimated after the Tp.

- Tc: The time of the condition calculation.
- Tp: The predicted time when the carrier's load port will be READY TO UNLOAD at Tc.
- Te: The estimated time when the carrier's load port will be READY TO UNLOAD after Tc.
- T_i1: The time interval in seconds between Tc and Tp(T_i1 = Tp – Tc)
- T_i2: The time interval in seconds between Tp and Te(T_i2 = Te – Tp).

10.7.8.3 *Carrier Attributes for Carrier Ready to Unload Prediction* — Different factories have different AMHS installations, therefore the required pre-notification time depends on the equipment user. It is therefore important that the factory host can configure the pre-notification time. It is also important to be able to configure a maximum delay time between predicted time and actual time the carrier is ready to unload, after which the equipment will no longer consider its prediction valid. The factory host can configure the condition to optimize the carrier transfer time by using as following carrier attributes.

10.7.8.3.1 *CaRTUPSettingTime — Carrier Ready To Unload Prediction Setting Time.* This attribute describes the time difference (in seconds) between host notification (through transition to the PREDICTED state) and the anticipated readiness for carrier unload.

10.7.8.3.2 *CaRTUPTimeOut — Carrier Ready To Unload Prediction Time Out.* This attribute specifies the maximum time difference between originally anticipated time for the carrier's ready to unload and the current time. If this time elapses and the carrier is still not ready for unloading, the carrier object shall transition from the PREDICTED to the PREDICTION ABORTED state. If this time is set to 0 (zero), the equipment does not check T_i2 for the condition of the PREDICTION ABORTED state.

10.7.8.4 *Condition for the PREDICTED* — This state shall be assumed, when ALL of the following conditions have been fulfilled:

- T_i1 ≤ CaRTUPSettingTime, that is, the CARRIER READY TO UNLOAD PREDICTION state model shall transition to the PREDICTED state whenever the equipment determines that the currently predicted time at which the carrier is ready to unload is smaller than or equal to the CaRTUPSettingTime later than the current time.
- The equipment has determined the load port at which the carrier will be ready for unload.

For internal buffer equipment, the equipment is required to predict one carrier per load port at one time. Each of the carriers queued to a load port shall remain in the WAITING FOR PREDICTION state until the carrier currently in the load port is removed.

10.7.8.5 *Condition for the PREDICTION ABORTED* — this state shall be assumed, when at least one of the following conditions is fulfilled:

- If the CARRIER READY TO UNLOAD PREDICTION status is WAITING FOR PREDICTION and the equipment can't estimate the time for READY TO UNLOAD caused by a problem on the equipment.
- T_i2 ≥ CaRTUPTimeOut, i.e. In the PREDICTED state, the estimated time of the carrier getting ready for unloading is greater than or equal to the time specified in CaRTUPTimeOut past the predicted time.
- For internal buffer equipment, the equipment has changed the load port at which the carrier will be ready for unload.

11 Access Mode

11.1 *Access Mode State Model*

11.1.1 The Access Mode State Model defines the host view of equipment access mode, as well as the host interactions with the equipment necessary to switch the access mode. Each load port has its own Access Mode State Model. There are two access mode states: MANUAL and AUTO. These are defined in ¶ 11.3.3.

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11.1.2 The access mode for a load port may be switched at any time by the host or the operator, except when the Load Port Reservation State Model for that load port is in the RESERVED state or during carrier transfer. Carrier transfer boundaries, for determining when access mode may be changed, are designated by Table 8, Carrier Transfer Boundaries.

Table 8 Carrier Transfer Boundaries

Transfer Type	*Transfer Method*	*Starting Boundary*	*Ending Boundary*
LOAD	MANUAL	This starting boundary is specified by the user. Known examples of the starting boundary include but are not limited to; the presence sensor detecting a carrier, a load port door opening, input to the equipment by the operator through a switch at the load port or the equipment console.	This ending boundary is specified by the user. Known examples of the ending boundary include but are not limited to; a preset configurable time following presence and placement sensor detecting a carrier, a load port door closing, or input to the equipment by the operator through a switch at the load port or the equipment console or a service message.
	AUTO	The PIO signal 'READY' is active for load (see SEMI E84).	PIO signals a transfer complete signal 'COMPT' (see SEMI E84).
UNLOAD	MANUAL	This starting boundary is specified by the user. Examples of the starting boundary include but are not limited to presence and placement sensor no longer detecting a carrier, a load port door opening, or input to the equipment by the operator through a switch at the load port or the equipment console or a service message.	This ending boundary is specified by the user. Examples of the ending boundary include but are not limited to a preset configurable time following presence and placement sensor no longer detecting a carrier, a load port door closing, or input to the equipment by the operator through a switch at the load port or the equipment console, or a service message.
	AUTO	The PIO signal 'READY' is active for unload (see SEMI E84).	PIO signals a transfer complete signal 'COMPT' (see SEMI E84).

11.2 *Manual Carrier Transfer Confirmation Trigger*

11.2.1 For a manual transfer completion confirmation, the production equipment supplier must implement a software or hardware mechanism for an operator to inform the equipment that the carrier transfer is complete.

11.3 *Access Mode Initial Value*

11.3.1 Also, when equipment re-initialization occurs, the access mode(s) must be remembered, and used as the initial value when initializing. Since the access mode is remembered through re-initializations, the initial value that is used the very first time the software is ever loaded is not important. The equipment supplier is free to set this default value.

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11.3.2 *Access Mode State Model Diagram*

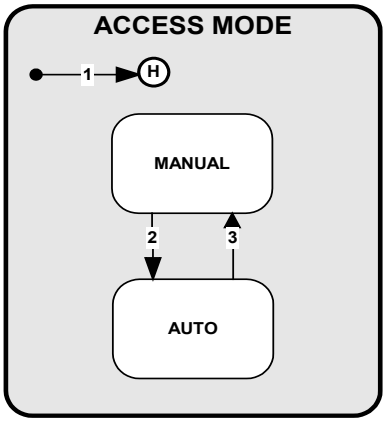

Figure 4
Access Mode State Model Diagram

11.3.3 *Access Mode State Definitions*

11.3.3.1 *ACCESS MODE* — The parent state for the MANUAL and AUTO substates.

11.3.3.2 *MANUAL* — A substate of ACCESS MODE. When the production equipment or specified load ports are in this mode, only manual (non-AMHS) carrier transfers are allowed. The production equipment may generate an alarm if an automated (AMHS) transfer is attempted, but this capability is not required. If a ChangeAccess service with the value of MANUAL is received in this state, the equipment shall accept the service and no event is sent for this action.

11.3.3.3 *AUTO* — A substate of ACCESS MODE. When the production equipment or specified load ports are in this mode, only automated (AMHS) carrier transfers are allowed in normal operation. The production equipment shall have the capability of generating an AccessModeViolation alarm if a manual transfer is attempted. If a ChangeAccess service with the value of AUTO is received in this state, the equipment shall accept the service and no event is sent for this action.

11.3.3.3.1 The passive equipment shall behave as follows if a manual transfer occurs in AUTO mode:

11.3.3.3.1.1 If an operator removes a carrier from a load port in access mode AUTO and transfer state READY TO UNLOAD, the equipment shall raise an AccessModeViolation alarm. After the load port transfer state finally transitioned to the READY TO LOAD state the AccessModeViolation alarm shall be cleared automatically. The load port access mode shall remain in AUTO.

11.3.3.3.1.2 If an operator places a carrier on a load port in access mode AUTO and transfer state READY TO LOAD the equipment shall raise an AccessModeViolation alarm. The equipment shall treat the transfer as incomplete but provide means for the operator to continue or cancel the manual carrier delivery (see ¶ 11.3.3.3.1.2.2 for restrictions on continuing).

11.3.3.3.1.2.1 Removing the carrier shall be treated as the cancellation of the manual carrier delivery. The load port shall transition to READY TO LOAD and the AccessModeViolation alarm shall be cleared automatically. The load port access mode shall remain in AUTO.

11.3.3.3.1.2.2 If the operator selects the continue option, the equipment shall treat the transfer as normally completed. The AccessModeViolation alarm shall be cleared automatically. Some IC makers have a policy against accepting a carrier manually placed onto a load port in access mode AUTO. Therefore, in order to prevent the operator who placed the carrier from continuing the manual carrier delivery, the equipment shall provide a configuration to disable the continue option.

11.3.4 *Access Mode State Transition Table*

11.3.4.1 Table 9 defines the transitions for the Access Mode State Model.

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