

SEMI D54-0709

SPECIFICATION FOR SUBSTRATE MANAGEMENT OF FPD PRODUCTION (SMS-FPD)

This standard was technically approved by the global Flat Panel Display – Factory Automation Committee.
This edition was approved for publication by the global Audits and Reviews Subcommittee on May 13, 2009.
It was available at www.semi.org in June 2009 and on CD-ROM in July 2009.

1 Purpose

1.1 At the production line of FPD, an automation evolution is underway; however, the reality is that each fab controls its equipment with its own specification. Because of this, a huge loss has been created in terms of the automation cost and lead time of equipment. Also, due to the migration to large substrate sizes in FPD production, the necessity to meet new demands such as single substrate transfer has been increasing. This document describes standard behaviors for automated transfer of substrates among automated material handling systems (AMHS) and equipment at FPD fabs.

2 Scope

2.1 The scope of this document is to standardize communication between host and equipment at the transfer points where substrates are transferred into /out of the equipment at FPD fabs.

2.2 This document defines standards that facilitate the host's knowledge and role in automated and manual substrate transfers. Also, it is intended to be useful for controlling material processing by equipment. Specifically, it covers the followings:

- Object definition of transfer points on the equipment
- Object state model of transfer points on the equipment
- Service commands to objects for transfer points on the equipment
- Behavior of transfer points on the equipment

2.3 This document clearly defines transfer positions for substrate transfer at the equipment and describes the interface useful for controlling substrate transfer, which is also applicable to AMHS installed in the FPD fabs. However, this should be implemented considering the applicability by facility manufacturers if it is to be applied to AMHS other than equipment.

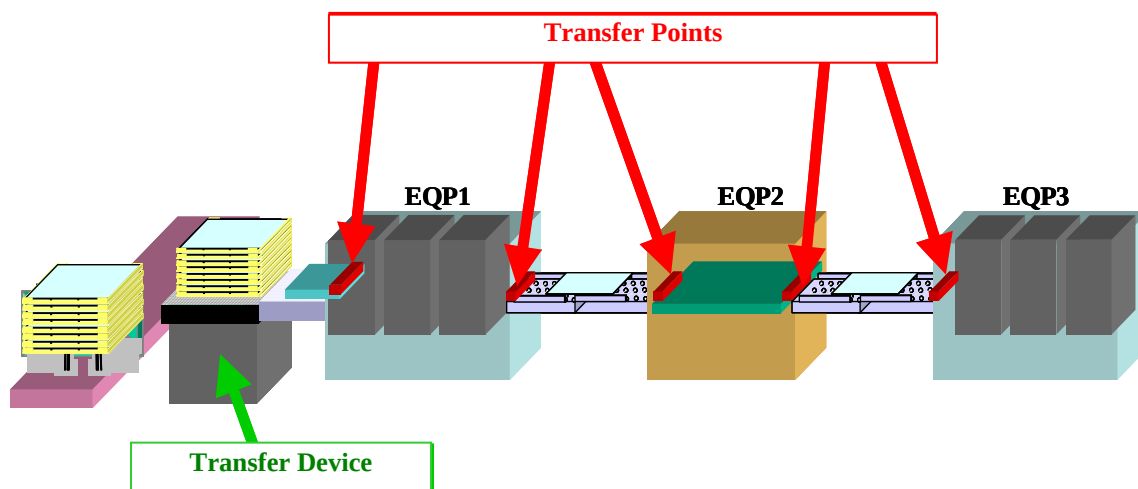


Figure 1
Transfer Points Example

NOTICE: 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 or other limitations prior to use.

3 Limitations

3.1 This standard only applies to transfer points on the equipment that transfer substrates with external equipment and does not cover the positions of substrate transfers within the same equipment.

3.2 This standard indicates modeling of substrate transfer positions on the equipment and substrate information entered in the equipment. This model indicates the substrate transfer service and behavior profile but does not depend on the protocol. Therefore, to fully implement, a complementary standard must be used.

3.3 In order to use this standard, the followings must be implemented:

- Implementation of transfer point objects
- Implementation of status management function of transfer points
- Substrate transfer management function at transfer points
- Information reporting function of transfer point objects

3.4 *Priority of Substrate Transfer Requests*

3.4.1 Equipment may become incapable of planned substrate transfer due to faults within the equipment or reject transfer-in as the transfer-out becomes priority depending on the equipment internal processing status. Priority is set by the equipment and the host should determine the substrate transfer information from the equipment and give appropriate information and instructions to the AMHS, etc.

3.4.2 Substrate transfer refusal/preference scheme during fault is not specified as it needs to consider the particular equipment structure for substrate transfer to/from the equipment. However, it needs to be studied and considered when this standard is implemented.

4 Referenced Standards and Documents

4.1 *SEMI Standards*

SEMI D51 — Specification for Handshake Protocol of Single Substrate for Handling off/on Tool in FPD Production

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

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

SEMI E40 — Standard for Processing Management

SEMI E41 — Exception Management (EM) Standard

SEMI E53 — Event Reporting

SEMI E90 — Specification for Substrate Tracking

5 Terminology

5.1 *Definitions*

5.1.1 *direction of substrate viewed from the transfer point* — direction of substrate at the transfer point refers to the direction of transfer-in/-out against the transfer point and not left/right of the equipment or upstream/downstream of the processing sequence.

5.1.1.1 *input* — direction of transfer-in to the transfer point.

5.1.1.2 *output* — direction of transfer-out from the transfer point.

5.1.2 *host* — factory automation system.

5.1.3 *inline controller* — controller that controls overall inline equipment, which integrates multiple units.

5.1.4 *inline equipment* — equipment that connects multiple equipment units.

5.1.5 *transfer point* — substrate transfer position that exists on the equipment.

5.1.6 *transfer device* — AMHS for transferring substrates.

6 Requirements

6.1 Substrate Management of FPD Production (SMS-FPD) compliant equipment is required to provide certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and equipment control. These standards shall be satisfied through compliance with the following sets of standards:

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

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

6.3 *Object-Based Standards*

- Object Services Standard (SEMI E39)
- Event Reporting (SEMI E53)
- Exception Management (SEMI E41)

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 Object Services Standard (OSS). 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 Object Services Standard, for example, it is possible to:

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

7.1.4 *Rules for Object Properties*

- Attributes with RO access can not 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 is defined as Read only (RO) or Read/Write (RW). The REQD column is used to specify whether the attribute is required for implementation. 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	Text = "Carrier"

7.2 State Model Methodology

7.2.1 A state model has three elements: definitions of each state and sub-state, 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 definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems," by D. Harel, 1987.

7.2.2 State Model Requirements

7.2.2.1 The state models included in this standard are a requirement for SMS-FPD 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 document. 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 SMS-FPD 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 SMS-FPD 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 sub-states other than those in this standard. Additional sub-states may be added, but shall not change the SMS-FPD defined state transitions. All expected transitions between SMS-FPD 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 sub-states, 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

<i>Num</i>	<i>Previous State</i>	<i>Trigger</i>	<i>New State</i>	<i>Actions</i>	<i>Comments</i>

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

<i>Service Name</i>	<i>Type</i>	<i>Description</i>

#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

<i>Parameter Name</i>	<i>Form</i>	<i>Description</i>

#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 definition 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.

Table 5 Service Message Definition Table

<i>Service Parameter</i>	<i>Req/Ind</i>	<i>Rsp/Conf</i>	<i>Description</i>

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).

8 Explanation

8.1 High Efficiency of Substrate Transfers

8.1.1 This standard provides the specification for substrate transfer to the equipment; however, it also deals with predictive transfer which can be enabled when substrate information is provided to the equipment including substrate processing conditions prior to the processing. It uses the ProcessJob queue management function specified by SEMI E40 as a method to provide information including the substrate processing conditions prior to the processing. Therefore, Create service of ProcessJob shall be used for the host to inform the processing conditions to the equipment.

8.2 Reserving Substrates

8.2.1 This standard is characterized by the host providing substrate information to the equipment before the processing, the equipment puts that substrate information into the queue, and starts processing the substrate transfer-in requests from the top of the queue, and when the substrate transfer is complete, runs the substrate processing using the substrate information processing conditions previously obtained.

8.2.2 The equipment shall retain the substrate information provided by the host within the equipment as the substrate objects.

8.3 Substrate Transfer

8.3.1 When substrates are transferred to the equipment using this standard, the substrate corresponding to the substrate information at the top of the queue in the equipment shall be securely transferred to the equipment. In order to conduct a smooth substrate transfer, the AMHS can be arranged to recognize which substrate must be transferred to the equipment beforehand, to ensure preliminary transfer work is completed. Therefore, the host shall also consider providing the substrate sequence information which is provided to the equipment, to the AMHS. The host may be able to conduct more efficient material transfer by understanding the ProcessJob sequence that the equipment puts into the queue and informing the process sequence to the AMHS. This operation must be applied by thoroughly considering the AMHS and method.

8.3.2 In the case of inline equipment, the host can regard the inline equipment as one unit and provide the same substrate sequence information to all the equipment connected to it, provided there is no bypassing or alteration of sequence within the equipment. Also, when the inline controller is connected or different equipment units are communicating with each other, the host can set all the equipment conditions into the process conditions within the substrate information allowing each production equipment unit to retain the necessary information for itself as substrate objects.

9 Overview

9.1 SMS-FPD defines required behavior, data and services for the equipment that supports substrate transfer along with automation. This document describes the standard interface for host/equipment communication concerning substrate transfer.

9.2 Single Connection Requirement

9.2.1 Equipment suppliers are expected to implement this standard only by connecting the equipment through the GEM interface, without requiring individual connection for communication.

10 Definitions of Transfer Point Objects

10.1 Transfer Points

10.1.1 Transfer points are the locations where the equipment transfers substrates and can be used as input, output or both input/output depending on equipment type and configuration. This classification may be fixed or it may be programmable by the user. However, the host shall be able to obtain the classification.

10.1.2 Transfer points shall be numbered for easier reference. The numbering may be fixed or programmable by the user; however, it shall start with 1 as the minimum number with increments of 1. The host shall be able to obtain these numbers.

10.1.3 The information regarding transfer points shall be capsuled as objects and the host shall be able to exchange individual information of one or multiple transfer points with the equipment using services defined by SEMI E39, Object Services Standard. Transfer point objects are permanent objects as equipment resources. Transfer point objects have attributes defined in Table 6 Transfer Point Attribute Definition.

Table 6 Transfer Point Attribute Definition Table

Attribute Name	Definition	Access	Reqd	Form
ObjType	Object Type	RO	Y	Text 1 to 40 characters equal to "TransferPort"
ObjID	Object ID	RO	Y	Equivalent to Transfer Point Numbering String 1 – n Increments of 1
TPType	Operation Type of Transfer Point	RO	Y	LOAD, UNLOAD, UNI
TPStatus	Transfer Point State	RO	Y	Enumerated: OUT OF SERVICE, IN SERVICE, TRANSFER READY, NOT REQUEST, REQUEST, TRANSFER BLOCKED
TPActTime	Guideline of Processing Tact of the Equipment (Accuracy is not required)	RO	Y	xxxx Sec
TPReqTime	Guideline of cycle time for substrate transfer at the transfer points (Accuracy is not required)	RO	Y	xxxx Sec
TPReqType	Substrate Transfer Request Type	RO	Y	Enumerated: INPUT, OUTPUT

Attribute Name	Definition	Access	Reqd	Form
TPActMaterialList	Material list of cassettes and substrates, etc. which exist at transfer points	RO	Y	List L,n (n=number of materials) 1. L,2 (Material 1) 1. Cassette ID1 2.L,m (m=Number of substrates) 1. Substrate object ID 1 : m. Substrate object ID m 2. L,2 (Material 2) 1. Cassette ID2 2.L,m (n=Number of substrates) 1. Substrate object ID 1 : m. Substrate object ID m n. L,2 (Material n) 1. Cassette IDn 2.L,m (m=Number of substrates) 1. Substrate object ID 1 : m. Substrate object ID m *When a single substrate is requested L,1 1. L,2 (Material 1) 1. A[0] no cassette ID 2.L,1 1. Substrate object ID
TPReqMaterialList	Material list of cassettes and substrates, etc. which is requested by transfer points	RO	Y	List Same as TPActMaterialList
TPMtlType	Material in question	RO	Y	Substrate/Cassette
TPAccessStatus	Transfer Point Access State	RO	Y	Enumerated: MANUAL AUTO

10.2 Transfer Point Substrate Transfer State Model

10.2.1 The objective of the Transfer Point Substrate Transfer State Model is to define the substrate transfer requests and states viewed from the host. This includes communication interaction required to transfer substrates between the host and the equipment. Each of the equipment transfer points has an individual instance in this state model.

10.2.2 Transfer Point Transfer State Model Diagram

10.2.2.1 Figure 1 shows dynamic behavior of the transfer point described using Harel state chart notation.

10.2.3 Transfer Point Transfer State Definition

10.2.3.1 **TP TRANSFER STATUS** — The upper most state of IN SERVICE state and OUT OF SERVICE state.

10.2.3.2 **OUT OF SERVICE** — No transfer-in/-out is possible in this state. In order to use this transfer point for continuous operation, transition into IN SERVICE is required.

10.2.3.3 **IN SERVICE** — Transfer into/out of this transfer point is possible. By transitioning into OUT OF SERVICE, transferring in/from this transfer point will be disabled.

10.2.3.4 **TRANSFER READY** — Substrate of IN SERVICE in which this transfer point is ready to transfer substrates, whereas the substrate transfer operation is not underway. This state has two substrates which can be selected depending on whether the transfer request exists or not (NOT REQUEST and REQUEST).

10.2.3.5 **NOT REQUEST** — Substrate of TRANSFER READY. State where substrate transfer request does not exist when transitioned to TRANSFER READY state.

10.2.3.6 **REQUEST** — Substrate of TRANSFER READY state. State where substrate transfer request exists when transitioned to TRANSFER READY state. In this state, the substrate with the substrate ID requested from the equipment can be transferred at this transfer point.

10.2.3.7 **TRANSFER BLOCKED** — State where substrate is transferred or moved at this transfer point. In this state, this transfer point is in operation and no substrate transfer request can be executed.

10.2.4 Transfer Point Transfer State Transition Table

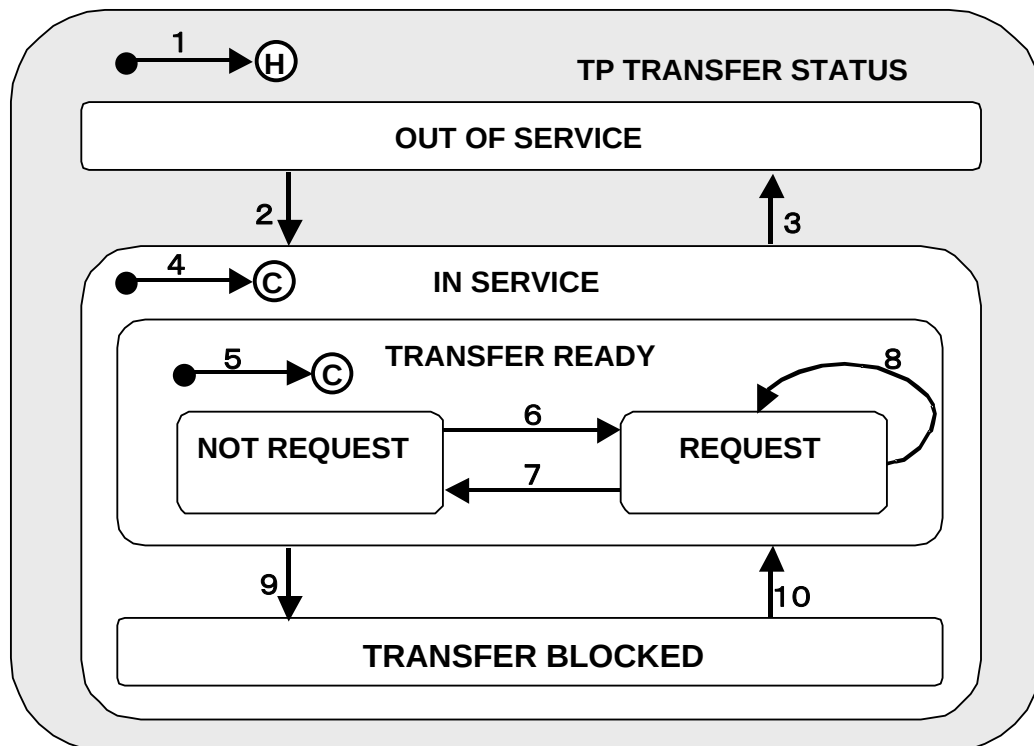


Figure 2
Transfer Point Dynamic Behavior Model

Table 7 Transfer Point Transfer State Transition Definition

Num	Previous State	Trigger	New State	Actions	Comments
1	(no state)	System Reset.	OUT OF SERVICE or IN SERVICE (History)		This transition is based on the transfer status before system reset occurred. Data required to be available for this event: TPID TPStatus
2	OUT OF SERVICE	The host or an operator has requested ChangeServiceStatus service with a parameter value of IN SERVICE to this transfer point.	IN SERVICE		The transfer point becomes available for substrate transfer at this point. Data required to be available for this event: TPID TPStatus
3	IN SERVICE	The host or an operator has requested ChangeServiceStatus service with a parameter value of OUT OF SERVICE to this transfer point.	OUT OF SERVICE		The transfer point becomes unavailable for transfer. An alarm will be issued by an attempt to use this transfer point for substrate transfer after the state transition. Data required to be available for this event: TPID TPStatus
4	IN SERVICE	Service: The host or an operator has requested ChangeServiceStatus service with a parameter value of IN SERVICE to this transfer point. System reset: this transition can be invoked by equipment re-initialization.	TRANSFER READY or TRANSFER BLOCKED		Default state of transition into IN SERVICE. If the transfer point is not available because it is in operation with substrate or transfer, the state becomes TRANSFER BLOCKED. Otherwise, it will become TRANSFER READY. Data required to be available for this event: TPID TPStatus TPActMaterialList TPReqType TPReqMaterialList
5	TRANSFER READY	Service: Host or operator requested ChangeServiceStatus service with a parameter value of IN SERVICE to this transfer point. System reset: this transition can be invoked by equipment reinitialization. When substrate transfer is completed or transfer motion is completed at the transfer point, transition #10 will trigger this transition.	NOT REQUEST or REQUEST		When becoming TRANSFER READY state, if substrate transfer request exists, the substrate is REQUEST and otherwise, NOT REQUEST. Data required to be available for this event: TPID TPStatus TPActMaterialList TPReqType TPReqMaterialList
6	NOT REQUEST	Automated: The equipment requested substrate transfer, identifying the target substrate ID recognizing the need for transfer.	REQUEST		At this point, substrate can be transferred with external entity at the transfer point. Attribute data: Transferring in is possible when Req.Type is INPUT, transferring out is possible when it is OUTPUT. Data required to be available for this event: TPID TPStatus TPActMaterialList TPReqType TPReqMaterialList

Num	Previous State	Trigger	New State	Actions	Comments
7	REQUEST	Automated: The equipment released the need for substrate transfer and cancelled transfer request.	NOT REQUEST		At this point, the substrate cannot be transferred. The transferring mechanism which has been transferring the substrate to the transfer point must immediately halt substrate transfer. Data required to be available for this event: TPID TPStatus
8	REQUEST	Automated: The equipment changed the substrate ID or transfer request type in the substrate transfer request.	REQUEST		At this point, the substrate can be transferred with external entity at the transfer point. Attribute data: Transferring in is possible when Req.Type is INPUT, transferring out is possible when it is OUTPUT. Data required to be available for this event: TPID TPStatus TPActMaterialList TPReqType TPReqMaterialList
9	TRANSFER READY	Automated: The PIO substrate transfer is beginning and the PIO READY signal is activated. Internal operation: The substrate begins to move at this transfer point.	TRANSFER BLOCKED		At this time, the substrate is being transferred from an external entity or moved within the equipment by material transfer mechanism. Data required to be available for this event: TPID TPStatus TPActMaterialList
10	TRANSFER BLOCKED	Automated: Substrate transfer by PIO has been completed. Internal operation: The transfer operation of the substrate on the transfer point has been completed.	TRANSFER READY		At this time, substrate transfer from the external entity or transfer within the equipment by the material transfer mechanism has been completed and the transfer point is ready to accept the substrate transfer request. Data required to be available for this event: TPID TPStatus TPActMaterialList TPReqType TPReqMaterialList

10.2.5 Transfer Point Access Definition

10.2.5.1 **MANUAL** — Substrate transfer to the transfer point is not controlled by the host but manually by operation of a member of staff.

10.2.5.2 **AUTO** — Substrate transfer to the transfer point is conducted by the automatic AMHS controlled by the host.