Background Statement for SEMI Draft Document 4848
New Standard: GENERIC EQUIPMENT MODEL FOR THIN FILM PHOTOVOLTAIC MANUFACTURING (GEM-PV)

Note: This background statement is not part of the balloted item. It is provided solely to assist the recipient in reaching an informed decision based on the rationale of the activity that preceded the creation of this document.

Note: Recipients of this document are invited to submit, with their comments, notification of any relevant patented technology or copyrighted items of which they are aware and to provide supporting documentation. In this context, “patented technology” is defined as technology for which a patent has issued or has been applied for. In the latter case, only publicly available information on the contents of the patent application is to be provided.

What is the problem being solved?

SEMI standard has a set of specifications, so called “SEMI GEM300” for semiconductor manufacturing and it has been improving industry efficiency.

For PV factory, “SEMI PV-02” has already been defined by reusing lower layers of “GEM300” – i.e. definitions of messages and the message transport level (SEMI E5, E30, E37) – with additional definitions for PV application.

Meanwhile, there has not been defined higher layer of the equipment operation as standards for semiconductor has defined – i.e. Process Job and Control Job Management (SEMI E40 and E94) , Carrier Management (SEMI E87) and Substrate Tracking (SEMI E90) that are playing major role in converging variation in the specifications.

To give similar efficiency as GEM300 does to semiconductor factory, a set of equipment operation standard for PV factory is necessary.

SEMI Draft 4848 is proposing to improve the efficiency for PV manufacturing.

The proposal will define all functions required for the PV manufacturing in one document so that definition of process, transfer and tracking of the substrate will be consistent while GEM300 has separate standards to define those functions to make the integrity throughout entire standard detracted.

PV manufacturing is characterized as;

- More single substrate oriented in nature
- Less process steps and less iterative process in comparison to semiconductor manufacturing
- Substrate mostly becomes final product in the form without cutting
- Need 10~20 years of quality guarantee and traceability

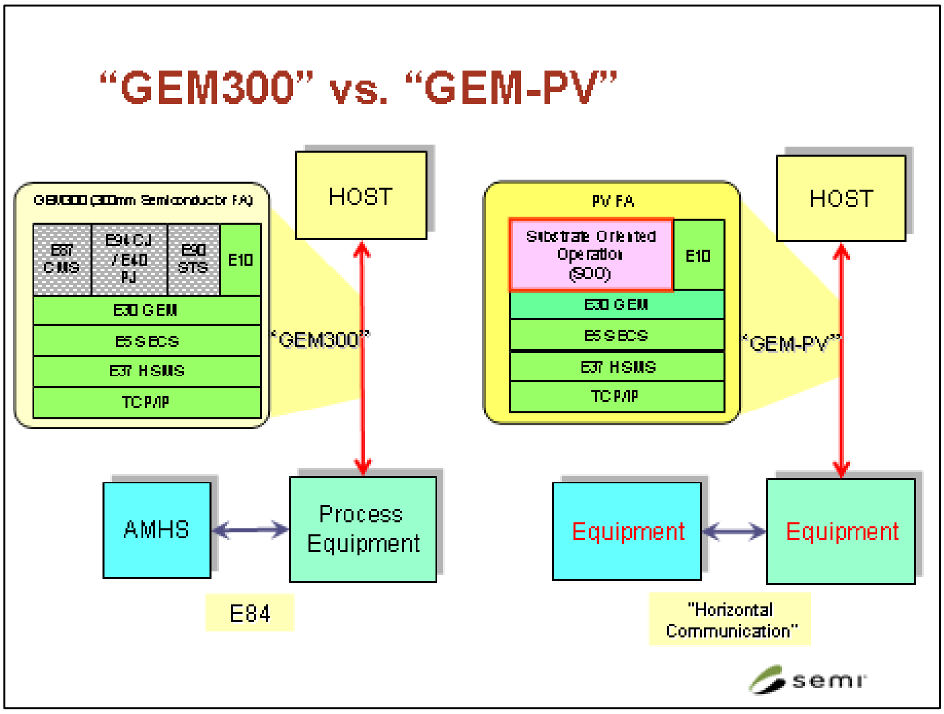
Also, it is necessary to accommodate to;

- Single Substrate transfer and Batch transfer.
- Single Substrate processing and Batch processing.

It is not easy to manage single substrate under lot management. Meanwhile, it is rather easy to compose batch under single substrate management. According to those PV manufacturing characteristics, substrate should be identified and managed by the substrate itself not depending on the group of substrates transferred or processed.

Moreover, full traceability of every single substrate is required.

As the consequence of those requirements, ”Substrate Oriented Operation” is proposed in the 4848.



What is the history of this issue and ballot?

This is first draft of Blue Ballot to get feedback from world wide committees before issuing formal proposal of the standard.

So the Blue Ballot is not completed document that there are sections that need more work.

To indicate the status of a description, parenthesis ***/…/*** is used.

Text in the parenthesis ***/text/*** is not a part of the draft but to indicate the status.

Whom will this affect? How? Why?

This standard will not conflict with existing standards or with existing implementations.

Is this a change to an existing solution, or, is it a new activity?

This is a new activity.

Revision Control

This revision control records activity within the task force as well as formal submit and resubmit dates and results per SEMI. Entries have been made by the task force.

Date	Version	Name	Edits
01/06/2010	0.1	Mitch Sakamoto	First draft for review by PV-EIS TF

SEMI Draft Document 4848
NEW STANDARD: GENERIC EQUIPMENT MODEL FOR THIN FILM PHOTOVOLTAIC MANUFACTURING (GEM-PV)

1 Purpose

1.1 The purpose of this standard is reducing implementation costs and improving product traceability by the definition of automated equipment operation concept and rules to support it in PV manufacturing system.

2 Scope

2.1 This standard defines outline of fab control system (hereafter GEM-PV) to be used for the PV device manufacturing on relatively large size solid substrate.

- This umbrella standard defines concept and macro specification
- Details to be defined in child standards

2.2 GEM-PV includes following aspects of information and control;

- Procedure for Material Transfer (handoff mechanism, rout switching, Batch Composition, Substrate ID association)
- Recipe transaction between host and process equipment
- Information management for Substrate Traceability, Equipment Health Management

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.

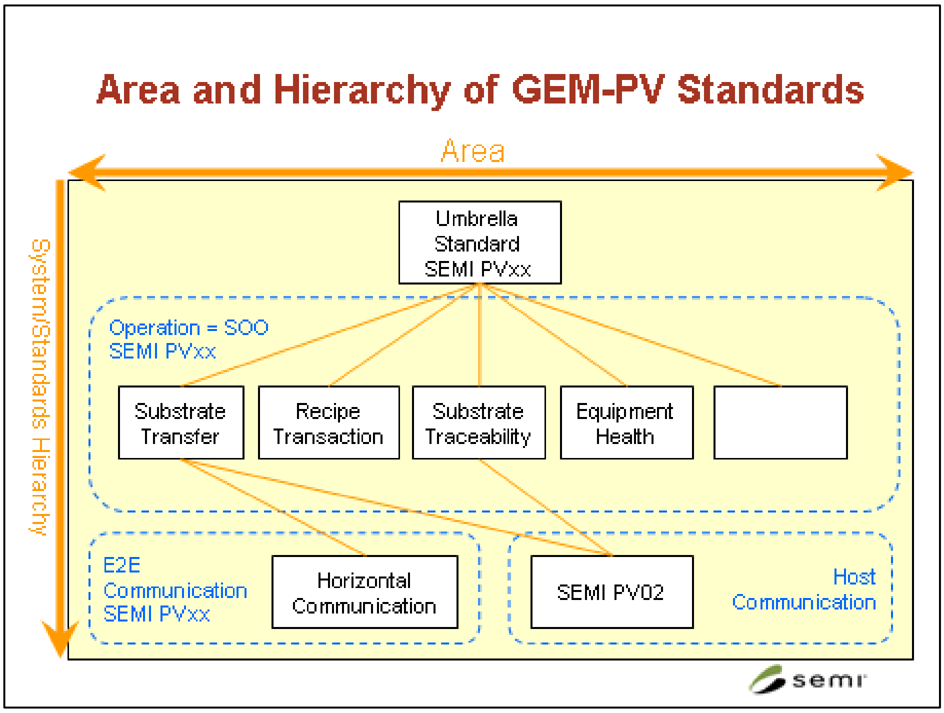


Figure 1
Area and Hierarchy of GEM-PV Standard

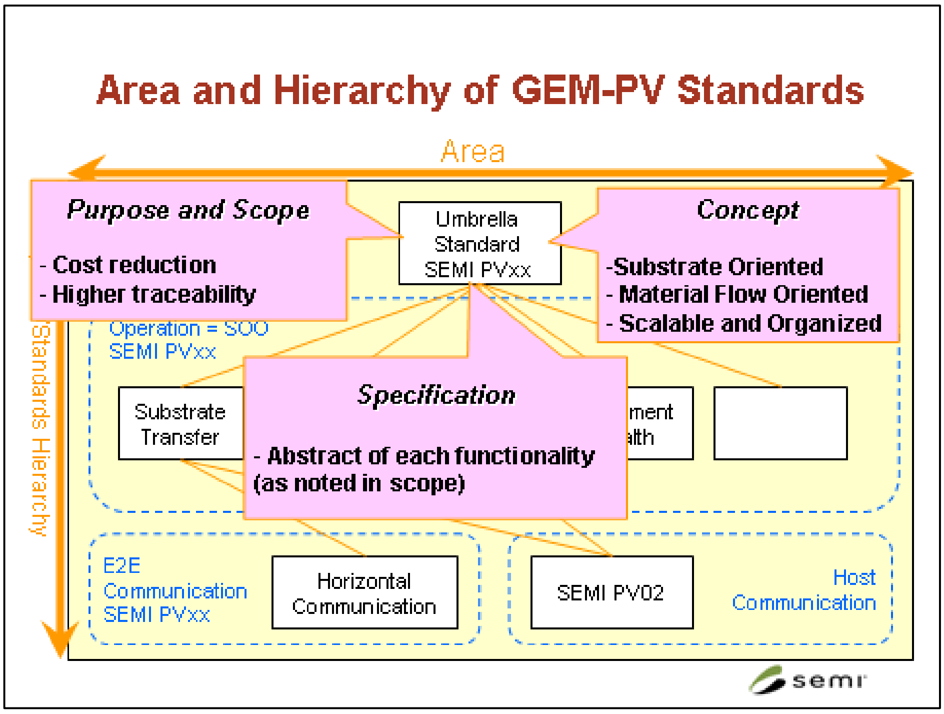


Figure 2
Coverage of Umbrella Standard

3 Limitations ***/ to be completed later /***

4 Referenced Standards and Documents ***/ to be completed later /***

4.1 *SEMI Standards*

SEMI PV2 — Guide for PV Equipment Communication Interfaces (PVECI)

XXXX — Substrate Oriented Operation for PV Manufacturing

XXXX — Horizontal Communication

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

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

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

5 Terminology ***/ to be completed later /***

5.1 *Abbreviations and Acronyms*

5.1.1 SOO — Substrate Oriented Operation

5.1.2 SCA — Service Component Architecture

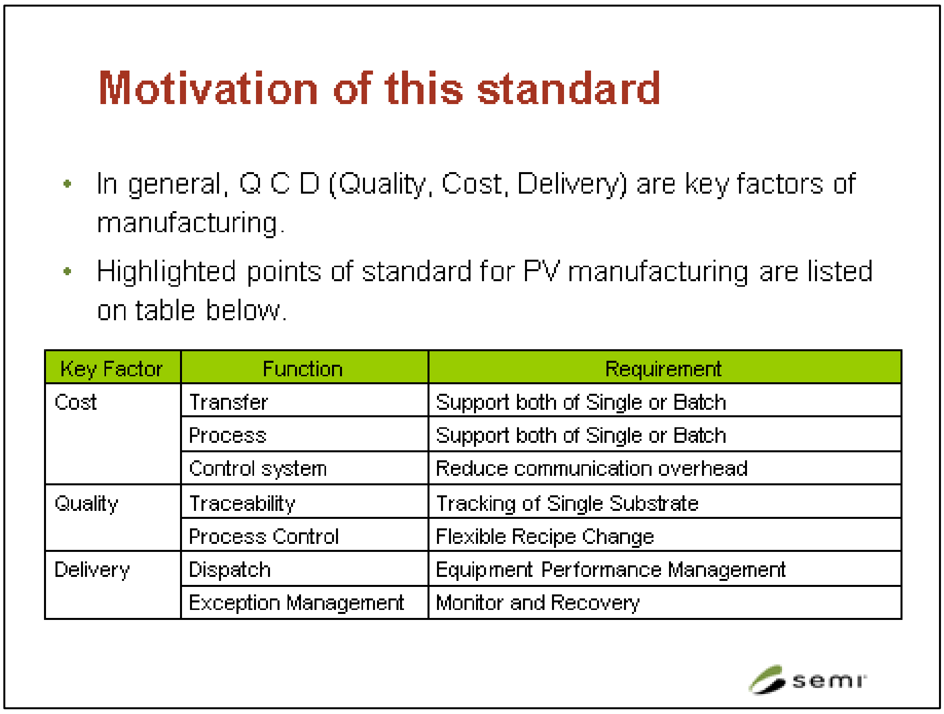
5.2 *Definitions*

None.

6 Conventions ***/ to be completed later /***

7 Concept

7.1 *Motivation of this standard* — Figure 3 describes motivation of this standard. Concepts to deal with those requirements in the figure are discussed in the following sections.



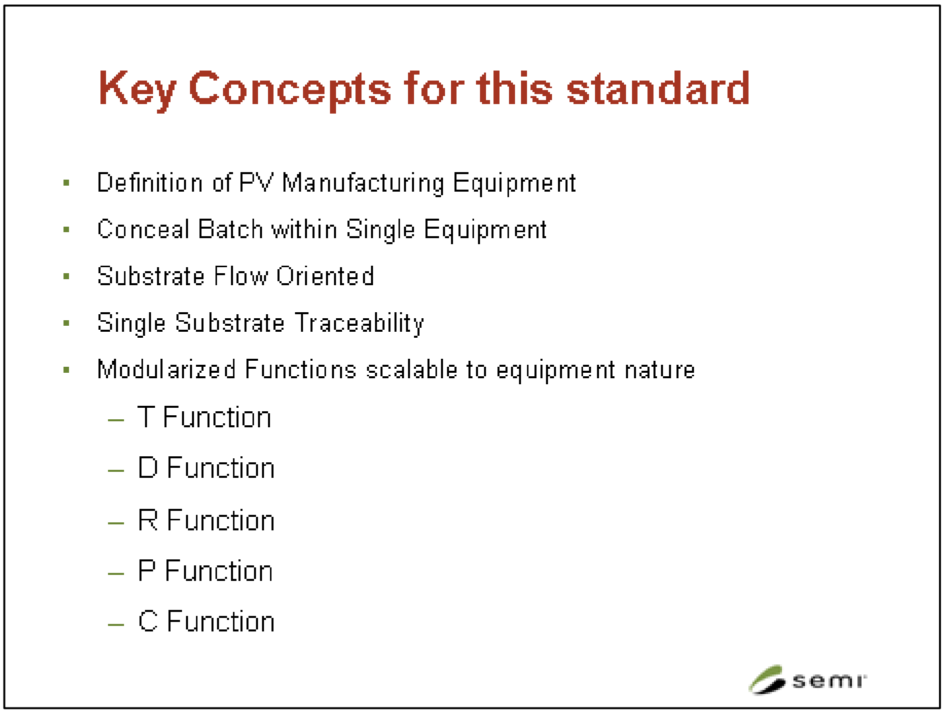
Motivation of this standard

- In general, Q C D (Quality, Cost, Delivery) are key factors of manufacturing.
- Highlighted points of standard for PV manufacturing are listed on table below.

Key Factor	Function	Requirement
Cost	Transfer	Support both of Single or Batch
	Process	Support both of Single or Batch
	Control system	Reduce communication overhead
Quality	Traceability	Tracking of Single Substrate
	Process Control	Flexible Recipe Change
Delivery	Dispatch	Equipment Performance Management
	Exception Management	Monitor and Recovery

Figure 3
Feature of PV Manufacturing

7.2 *Key Concepts for this standard* — Figure 4 describes key concepts defined in this standard. More detail of those concepts will be addressed in the following sections.

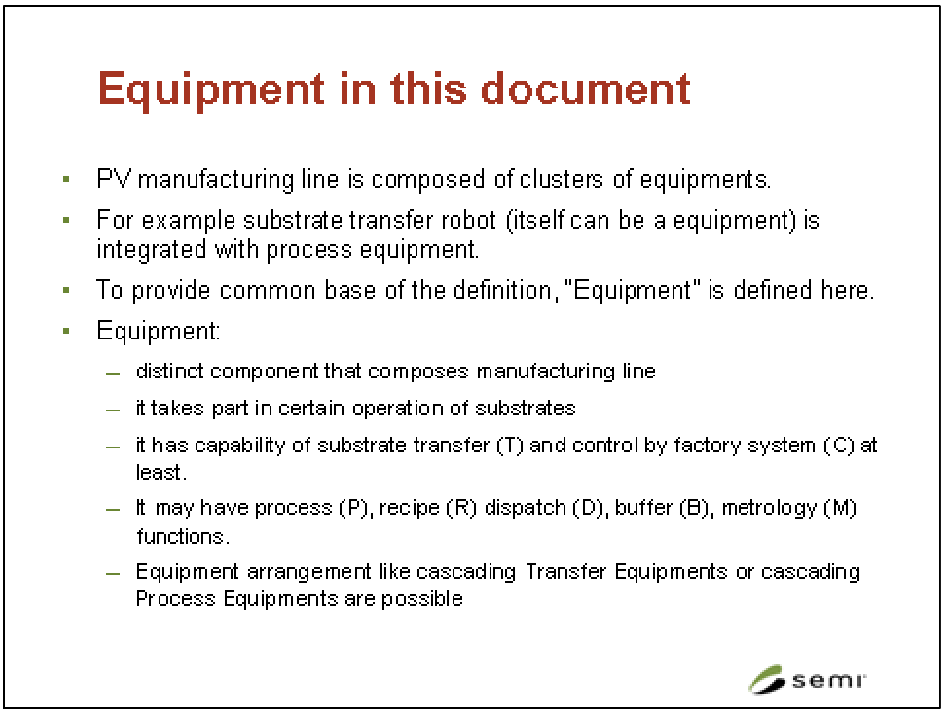


Key Concepts for this standard

- Definition of PV Manufacturing Equipment
- Conceal Batch within Single Equipment
- Substrate Flow Oriented
- Single Substrate Traceability
- Modularized Functions scalable to equipment nature
  - T Function
  - D Function
  - R Function
  - P Function
  - C Function

Figure 4
Concepts for PV Manufacturing Operation

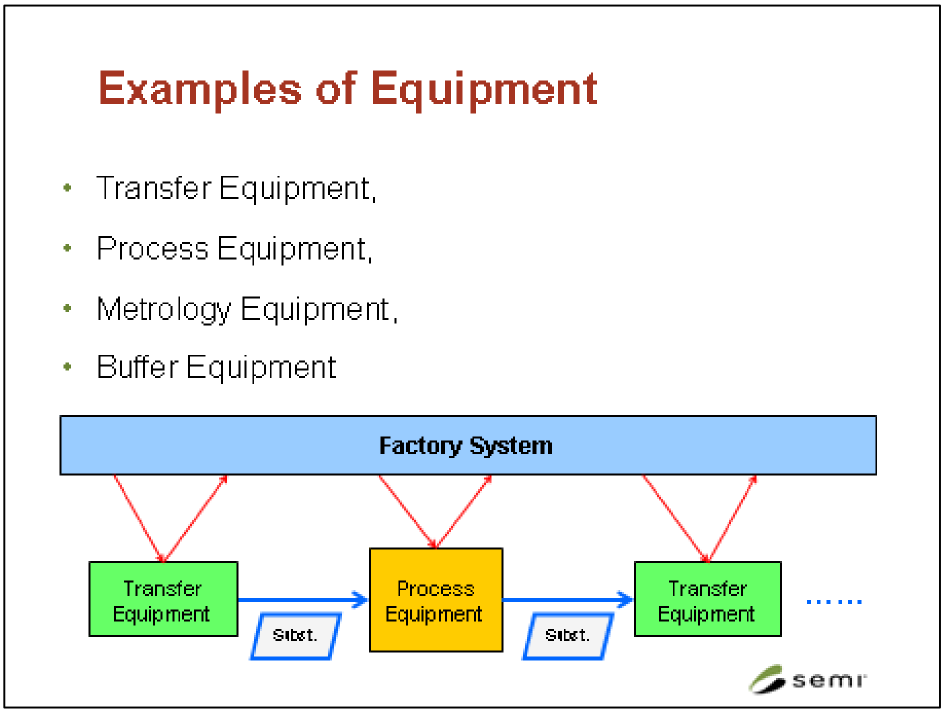
7.2.1 *Definition of PV Manufacturing Equipment* — Figure 5 describes definition of equipment for GEM-PV. Figure 6 is for example of equipment. Figure 7 and Figure 8 show examples of line configuration with those equipments to provide the user of this standard common image of the manufacturing line.



Equipment in this document

- PV manufacturing line is composed of clusters of equipments.
- For example substrate transfer robot (itself can be a equipment) is integrated with process equipment.
- To provide common base of the definition, "Equipment" is defined here.
- Equipment:
  - distinct component that composes manufacturing line
  - it takes part in certain operation of substrates
  - it has capability of substrate transfer (T) and control by factory system (C) at least.
  - It may have process (P), recipe (R) dispatch (D), buffer (B), metrology (M) functions.
  - Equipment arrangement like cascading Transfer Equipments or cascading Process Equipments are possible

Figure 5
Definition of Equipment



Examples of Equipment

- Transfer Equipment,
- Process Equipment,
- Metrology Equipment,
- Buffer Equipment

Figure 6
Example of Equipment

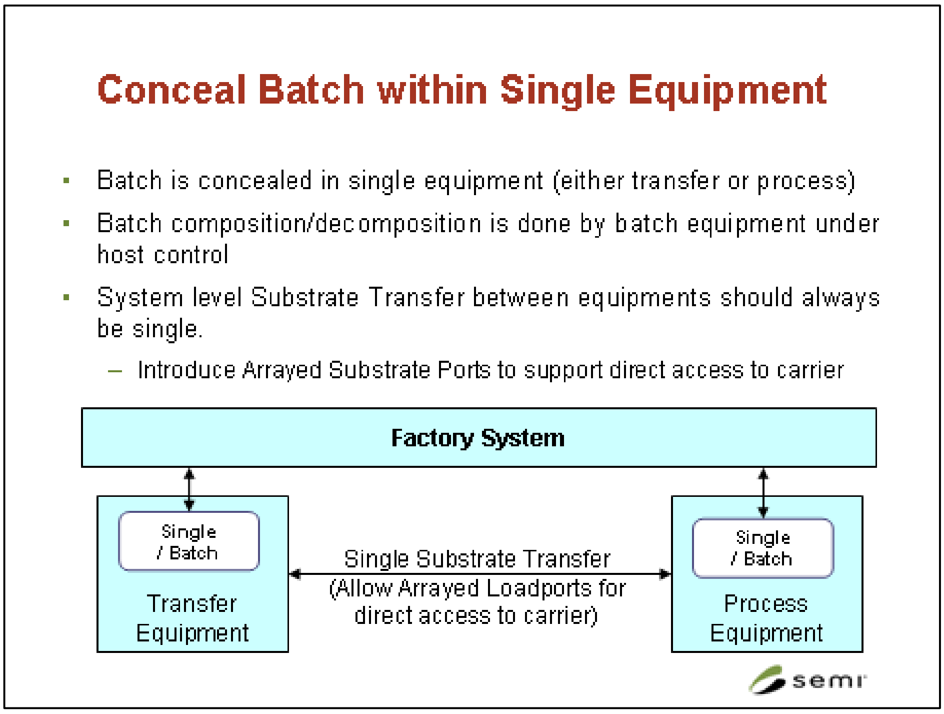
/ figure will be posted later /

Figure 7
Example of Line Configuration – Transfer by Backbone Equipment

/ figure will be posted later /

Figure 8
Example of Line Configuration – Transfer by Conveyers

7.2.2 *Conceal Batch within Single Equipment* — Figure 9 describes the concept of how to deal with batch transfer/process. Figure 10 describes detail of how to deal with batch transfer. Figure 11 describes about discussion of substrate transfer at carrier. Figure 12 describes detail of how to deal with batch process.



Conceal Batch within Single Equipment

- Batch is concealed in single equipment (either transfer or process)
- Batch composition/decomposition is done by batch equipment under host control
- System level Substrate Transfer between equipments should always be single.
  - Introduce Arrayed Substrate Ports to support direct access to carrier

Factory System

Single / Batch

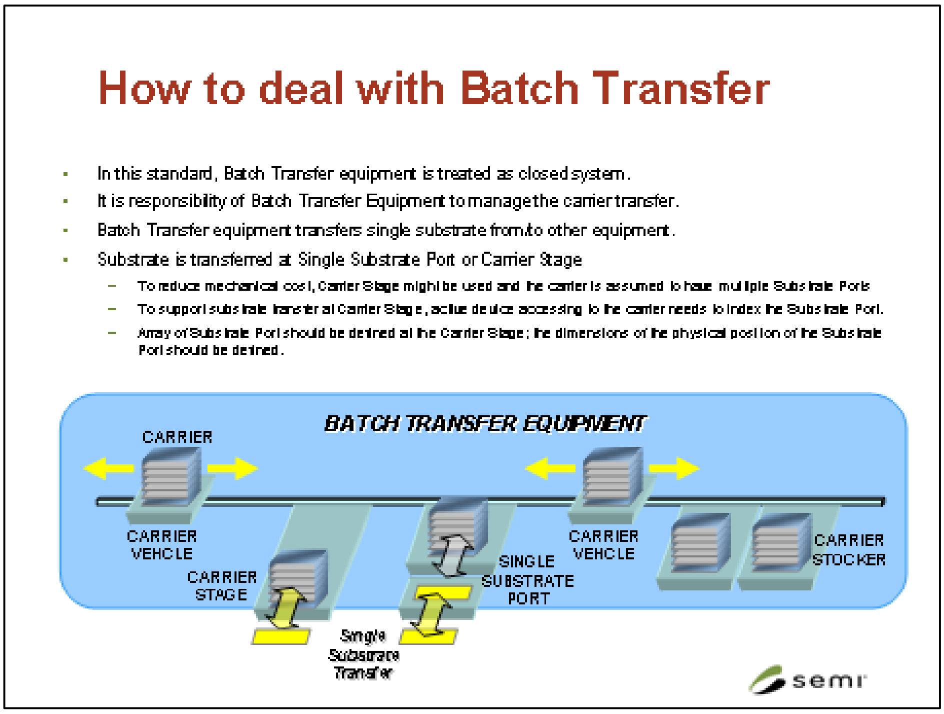
Transfer Equipment

Single Substrate Transfer (Allow Arrayed Loadports for direct access to carrier)

Single / Batch

Process Equipment

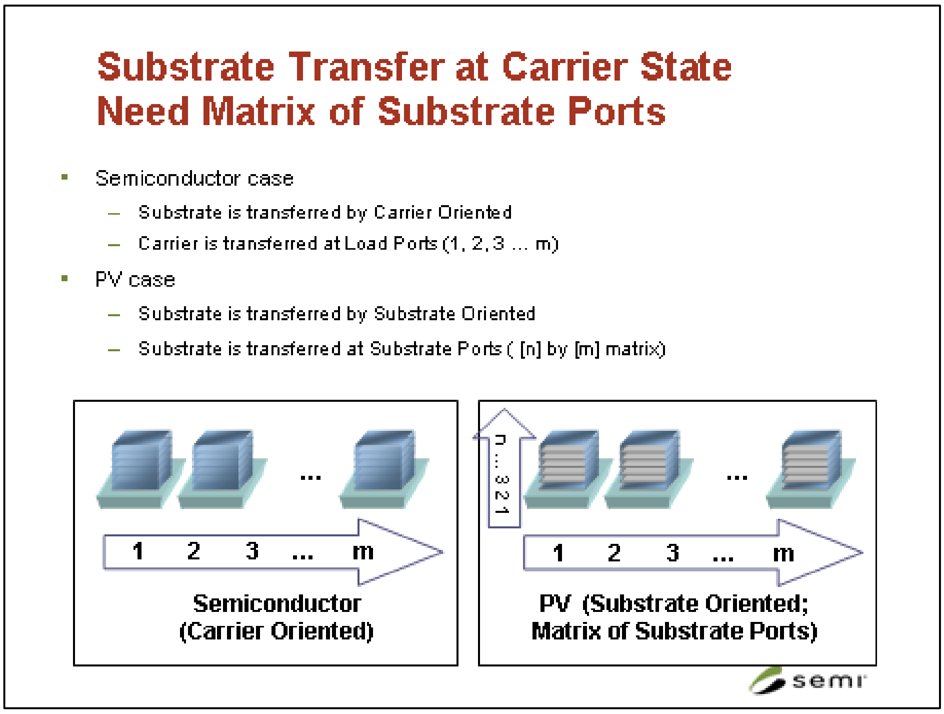
Figure 9
Conceal Batch within Single Equipment



How to deal with Batch Transfer

- In this standard, Batch Transfer equipment is treated as closed system.
- It is responsibility of Batch Transfer Equipment to manage the carrier transfer.
- Batch Transfer equipment transfers single substrate from/to other equipment.
- Substrate is transferred at Single Substrate Port or Carrier Stage
  - To reduce mechanical cost, Carrier Stage might be used and the carrier is assumed to have multiple Substrate Ports
  - To support substrate transfer at Carrier Stage, active device accessing to the carrier needs to index the Substrate Port.
  - Array of Substrate Port should be defined at the Carrier Stage; the dimensions of the physical position of the Substrate Port should be defined.

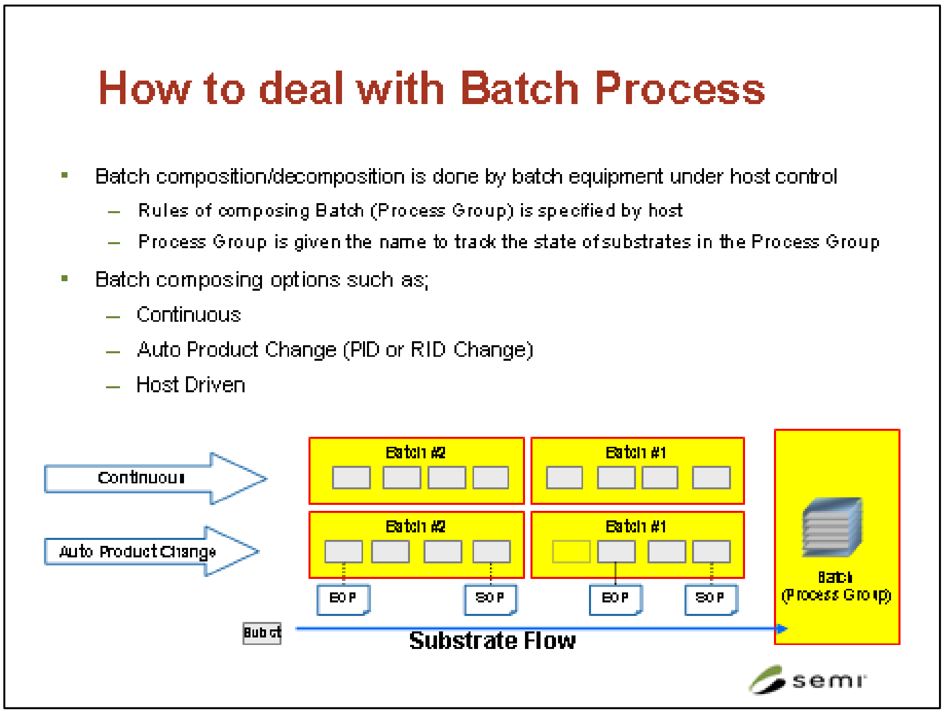
Figure 10
How to deal with Batch Transfer



Substrate Transfer at Carrier State
Need Matrix of Substrate Ports

- Semiconductor case
  - Substrate is transferred by Carrier Oriented
  - Carrier is transferred at Load Ports (1, 2, 3 … m)
- PV case
  - Substrate is transferred by Substrate Oriented
  - Substrate is transferred at Substrate Ports ([n] by [m] matrix)

Figure 11
Substrate Transfer at Carrier Stage – Need Matrix of Substrate Ports

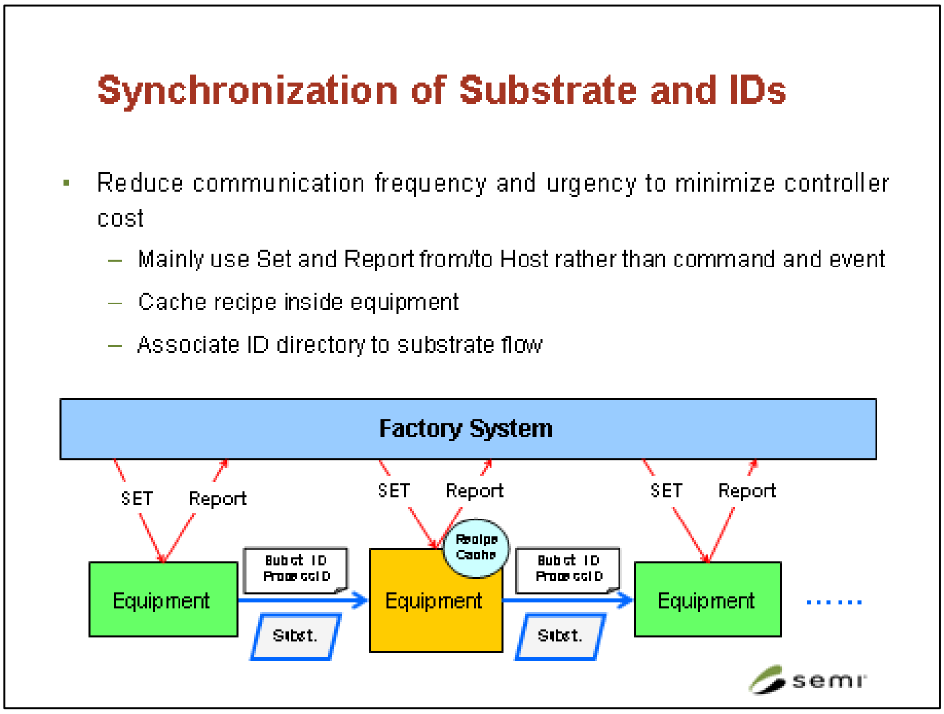


How to deal with Batch Process

- Batch composition/decomposition is done by batch equipment under host control
  - Rules of composing Batch (Process Group) is specified by host
  - Process Group is given the name to track the state of substrates in the Process Group
- Batch composing options such as;
  - Continuous
  - Auto Product Change (PID or RID Change)
  - Host Driven

Figure 12
How to deal with Batch Process

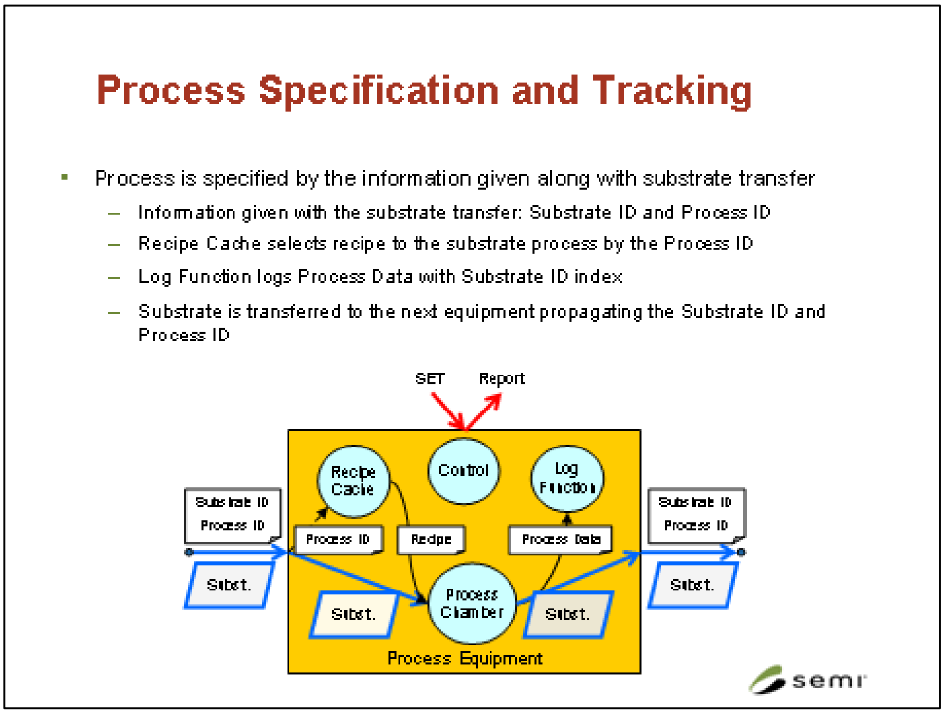
7.2.3 *Substrate Flow Oriented* — Concept of Substrate Flow Oriented is introduced to reduce communication overhead. Substrate ID and Process ID is transferred synchronously with substrate transfer to the next equipment. The equipment receives substrate operates the substrate based on the Substrate ID and the Process ID. Figure 13 illustrates the synchronization of substrate and the information. Figure 14 illustrates detail of how to specify and track the process.



Synchronization of Substrate and IDs

- Reduce communication frequency and urgency to minimize controller cost
  - Mainly use Set and Report from/to Host rather than command and event
  - Cache recipe inside equipment
  - Associate ID directory to substrate flow

Figure 13
Synchronization of Substrate and IDs

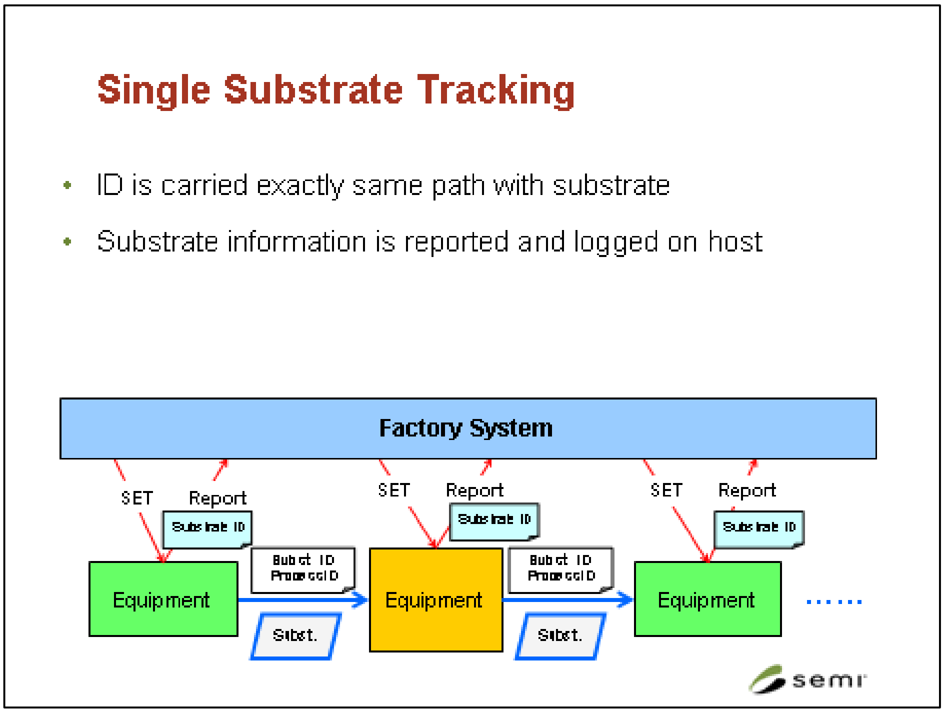


Process Specification and Tracking

- Process is specified by the information given along with substrate transfer
  - Information given with the substrate transfer: Substrate ID and Process ID
  - Recipe Cache selects recipe to the substrate process by the Process ID
  - Log Function logs Process Data with Substrate ID index
  - Substrate is transferred to the next equipment propagating the Substrate ID and Process ID

Figure 14
Process Specification and Tracking

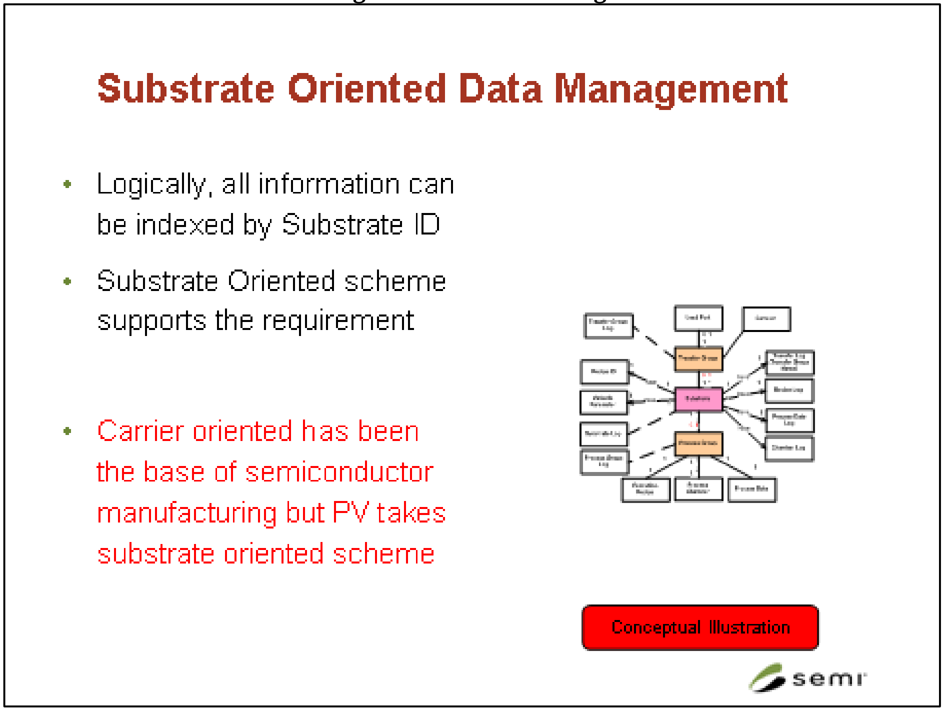
7.2.4 *Single Substrate Traceability* — Figure 15 illustrates the concept of the substrate tracking in the manufacturing line. Equipment reports Substrate ID to factory system. The report can have additional data with Substrate ID.



Single Substrate Tracking

- ID is carried exactly same path with substrate
- Substrate information is reported and logged on host

Figure 15
Single Substrate Tracking

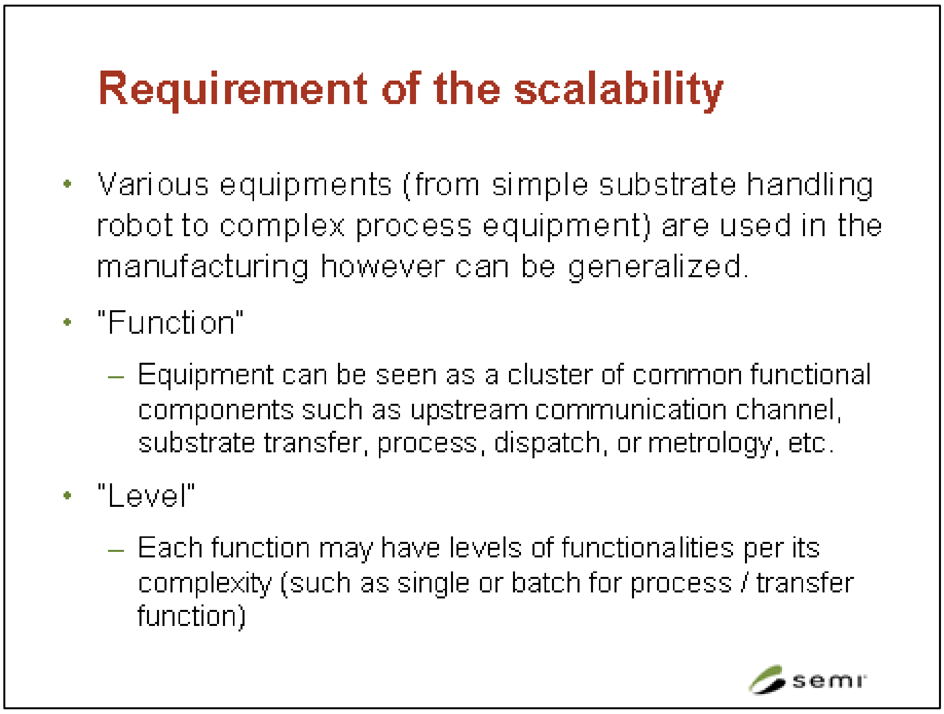


Substrate Oriented Data Management

- Logically, all information can be indexed by Substrate ID
- Substrate Oriented scheme supports the requirement
- Carrier oriented has been the base of semiconductor manufacturing but PV takes substrate oriented scheme

Figure 16
Substrate Oriented Data Management

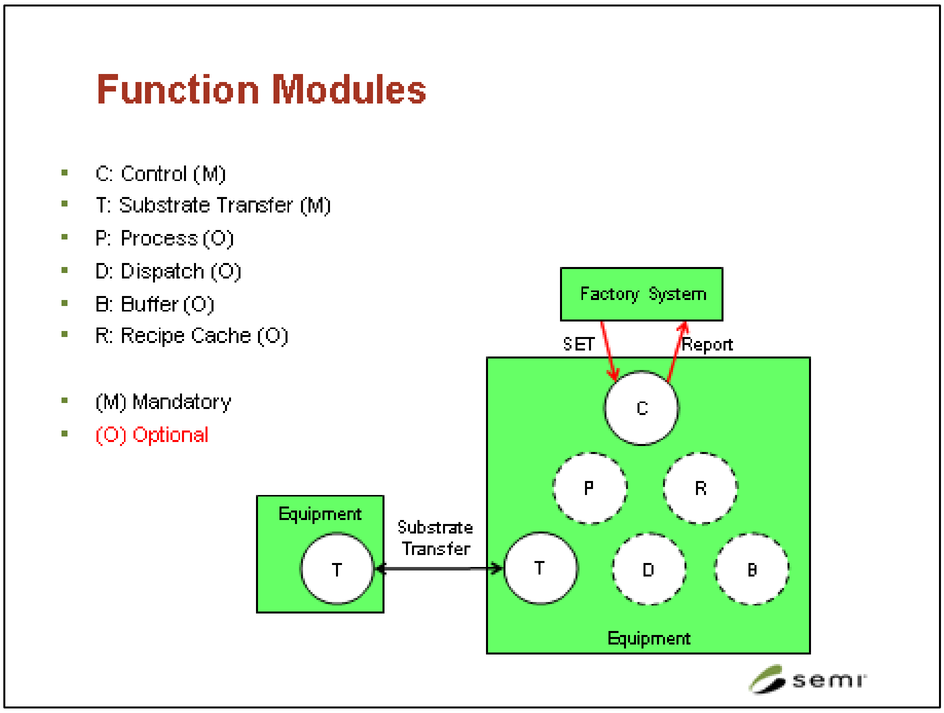
7.2.5 *Modularized Functions scalable to equipment nature* — Figure 17 describes requirement of the scalability. Modularized “Function” and “Level” are defined. Definition of generic equipment model with the function modules is described on Figure 18 and Figure 19. Some examples of function modules on equipment types are illustrated on Figure 20 and Figure 21.



Requirement of the scalability

- Various equipments (from simple substrate handling robot to complex process equipment) are used in the manufacturing however can be generalized.
- "Function"
  - Equipment can be seen as a cluster of common functional components such as upstream communication channel, substrate transfer, process, dispatch, or metrology, etc.
- "Level"
  - Each function may have levels of functionalities per its complexity (such as single or batch for process / transfer function)

Figure 17
Requirement of the scalability

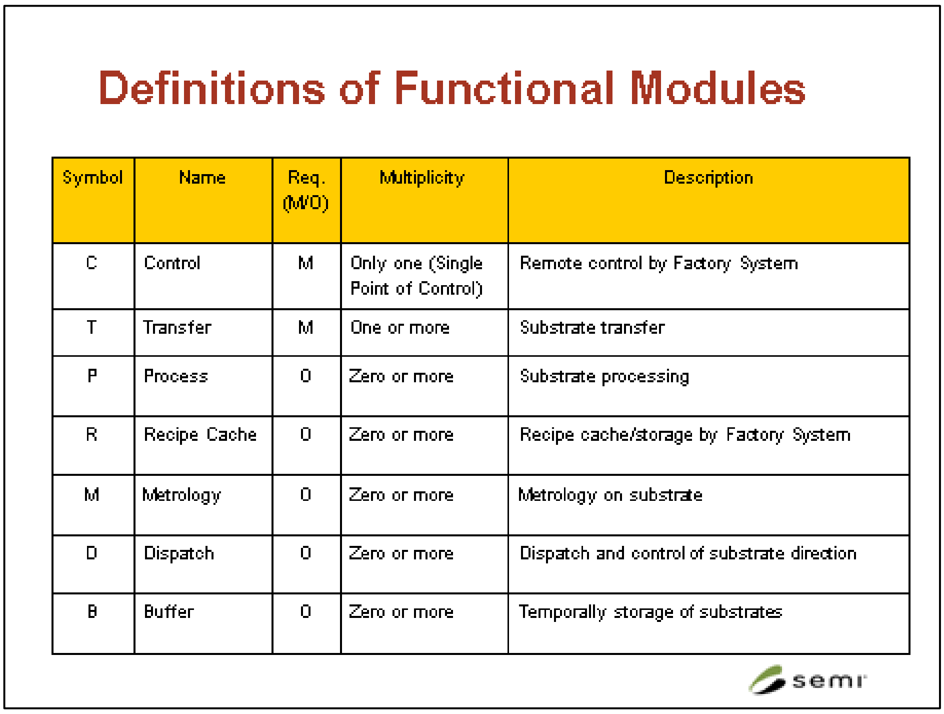


Function Modules

- C: Control (M)
- T: Substrate Transfer (M)
- P: Process (O)
- D: Dispatch (O)
- B: Buffer (O)
- R: Recipe Cache (O)

- (M) Mandatory
- (O) Optional

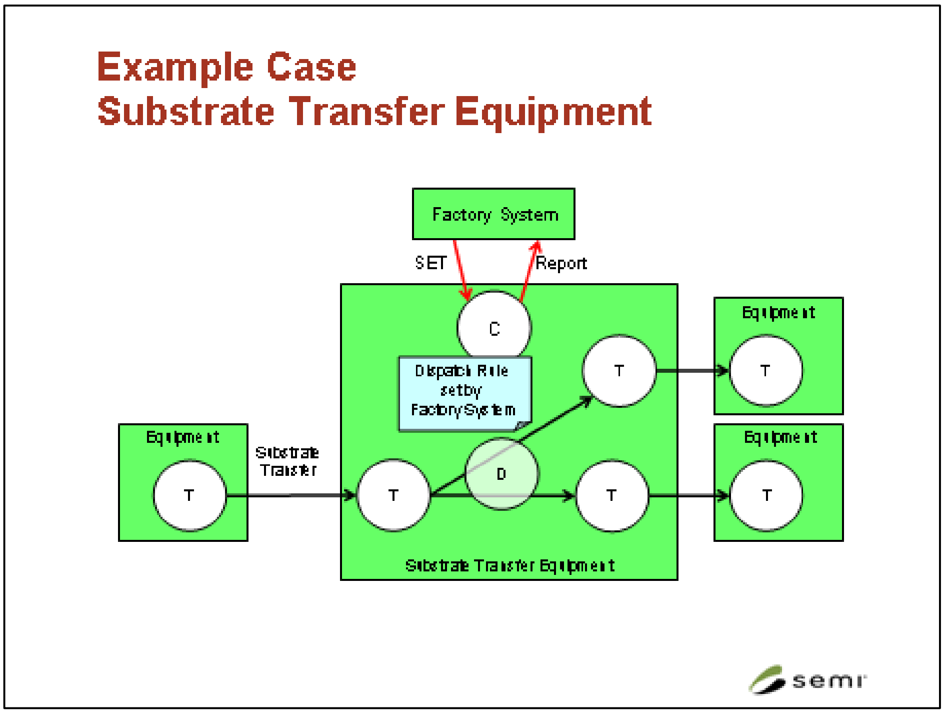
Figure 18
Function Modules



Definitions of Functional Modules

Symbol	Name	Req. (M/O)	Multiplicity	Description
C	Control	M	Only one (Single Point of Control)	Remote control by Factory System
T	Transfer	M	One or more	Substrate transfer
P	Process	O	Zero or more	Substrate processing
R	Recipe Cache	O	Zero or more	Recipe cache/storage by Factory System
M	Metrology	O	Zero or more	Metrology on substrate
D	Dispatch	O	Zero or more	Dispatch and control of substrate direction
B	Buffer	O	Zero or more	Temporally storage of substrates

Figure 19
Definitions of Function Modules



Example Case
Substrate Transfer Equipment

Figure 20
Example Case – Substrate Transfer Equipment

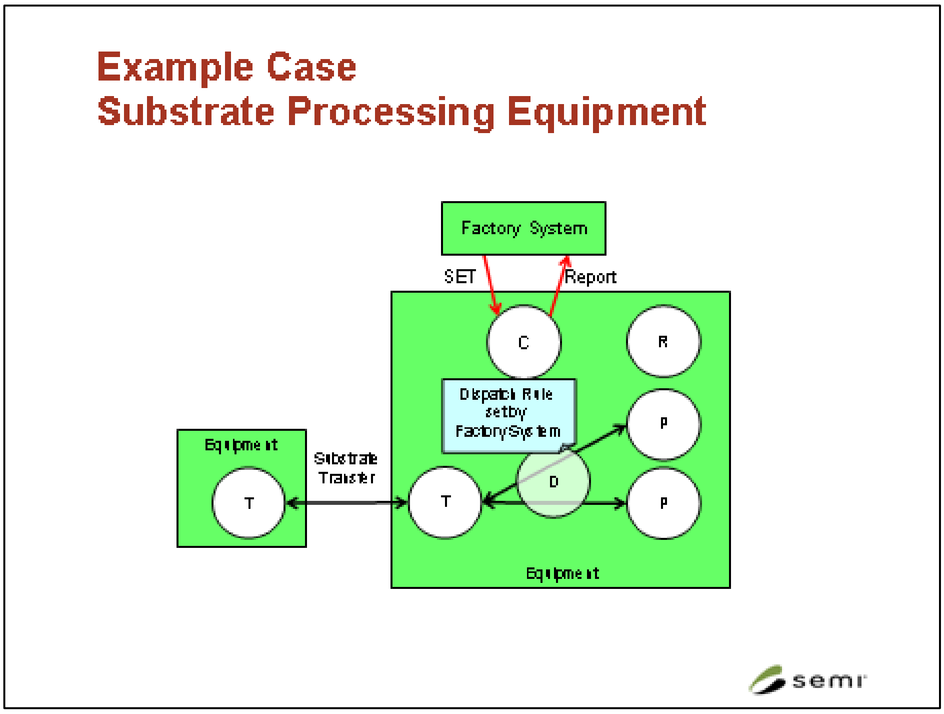
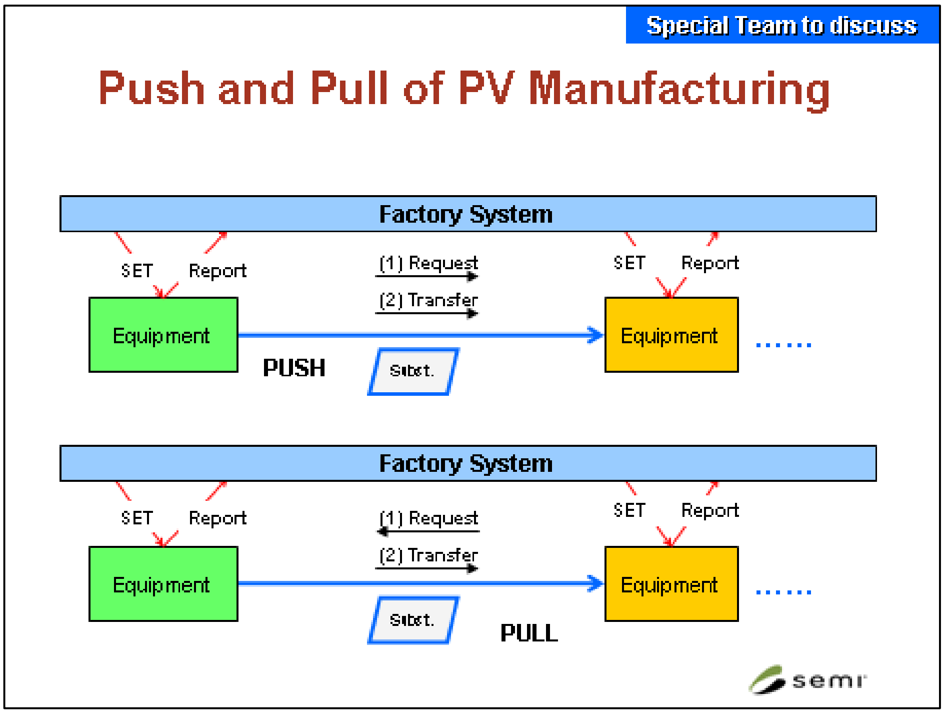

Example Case
Substrate Processing Equipment

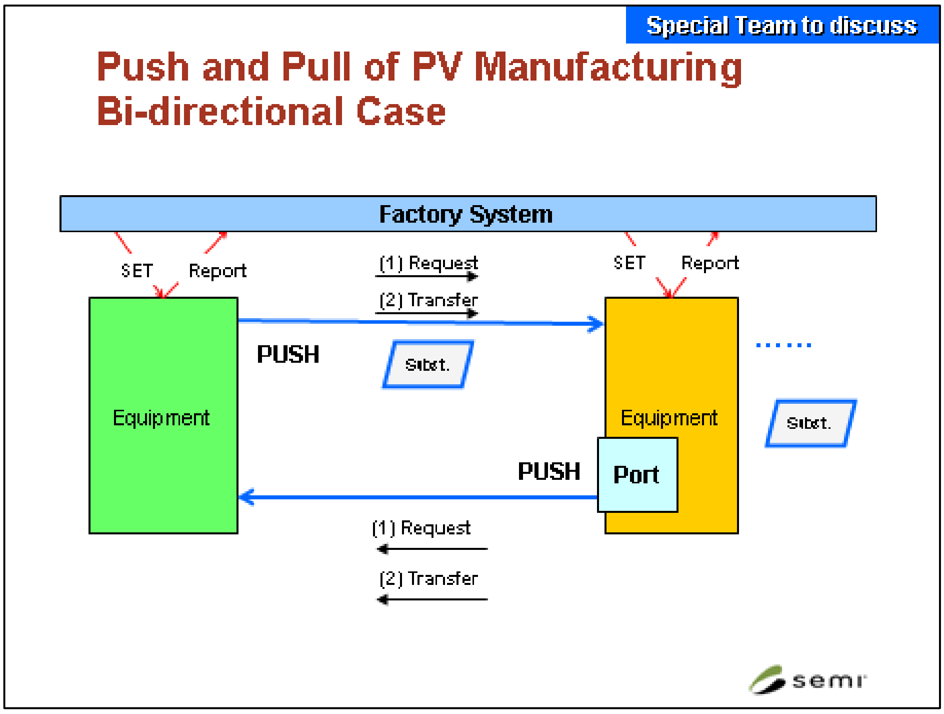
Figure 21
Example Case – Substrate Processing Equipment

7.2.5.1 *T Function* — */ under discussion by T Function Special Study Team; to be completed later /*


Special Team to discuss

Push and Pull of PV Manufacturing

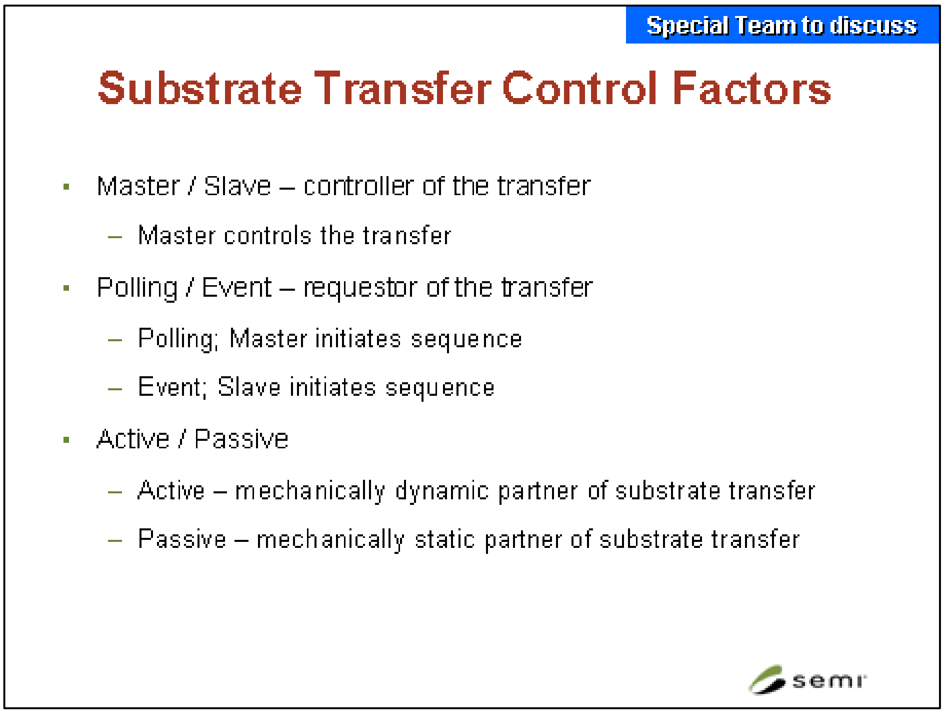
Figure 22
Push and Pull of PV Manufacturing



Special Team to discuss

Push and Pull of PV Manufacturing
Bi-directional Case

Figure 23
Push and Pull of PV Manufacturing – Bi-directional Case



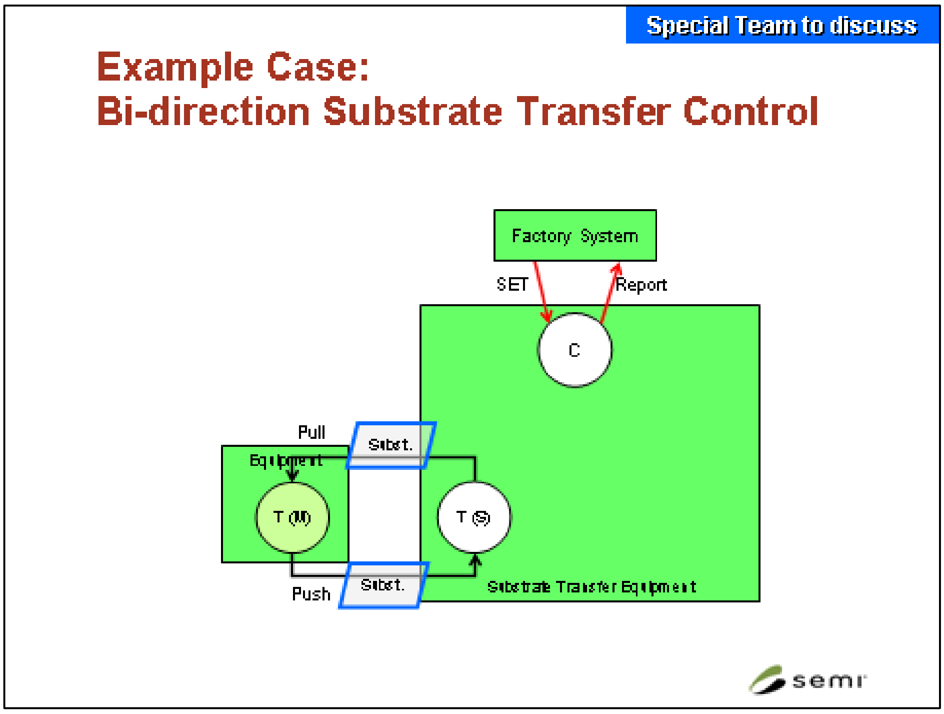
Special Team to discuss

Substrate Transfer Control Factors

- Master / Slave – controller of the transfer
  - Master controls the transfer
- Polling / Event – requestor of the transfer
  - Polling; Master initiates sequence
  - Event; Slave initiates sequence
- Active / Passive
  - Active – mechanically dynamic partner of substrate transfer
  - Passive – mechanically static partner of substrate transfer

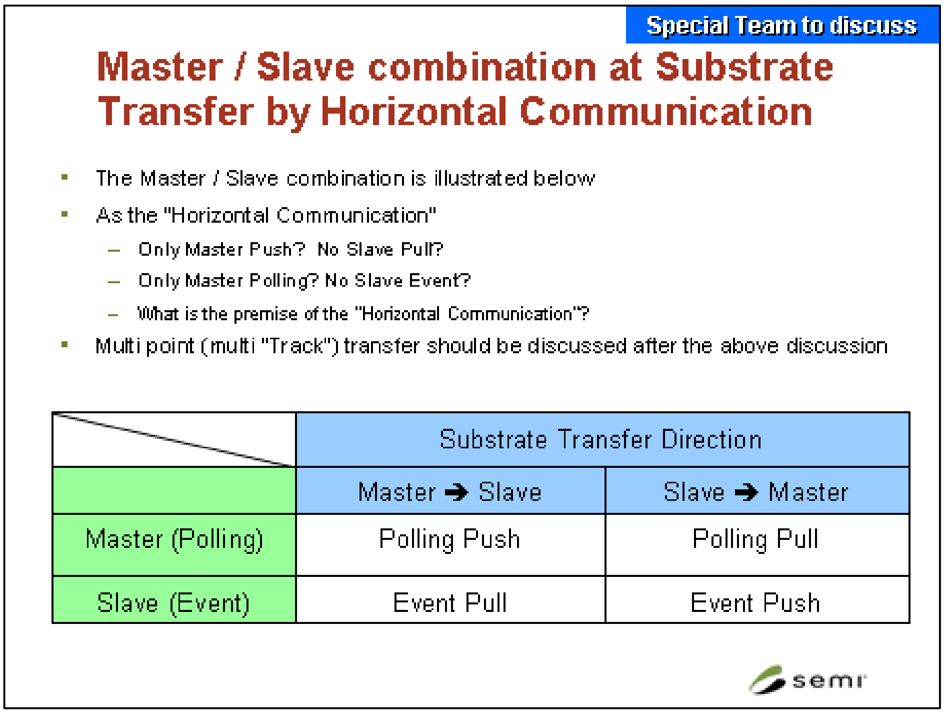
Figure 24
Substrate Transfer Control Factors

INFORMATIONAL (BLUE) BALLOT


Special Team to discuss

Example Case: Bi-direction Substrate Transfer Control

Figure 25
Example Case – BI-directional Substrate Transfer Control


Special Team to discuss

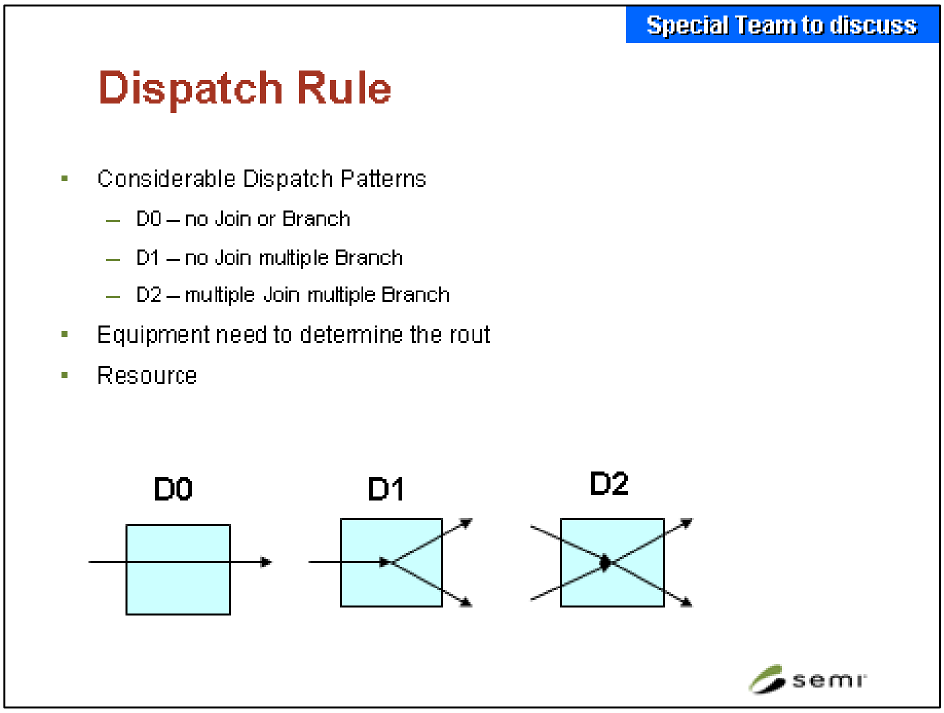
Master / Slave combination at Substrate Transfer by Horizontal Communication

- The Master / Slave combination is illustrated below
- As the "Horizontal Communication"
  - Only Master Push? No Slave Pull?
  - Only Master Polling? No Slave Event?
  - What is the premise of the "Horizontal Communication"?
- Multi point (multi "Track") transfer should be discussed after the above discussion

	Substrate Transfer Direction	
	Master ➔ Slave	Slave ➔ Master
Master (Polling)	Polling Push	Polling Pull
Slave (Event)	Event Pull	Event Push

Figure 26
Master / Slave combination at Substrate Transfer by Horizontal Communication

7.2.5.2 *D Function* — ***/ under discussion by T Function Special Study Team; to be completed later /***

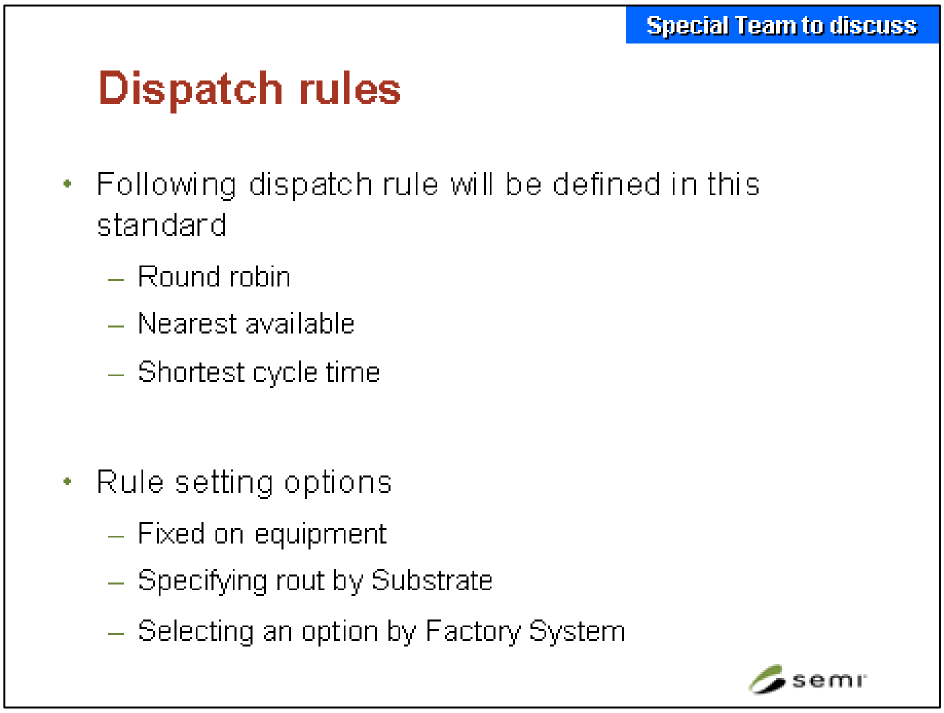


Special Team to discuss

Dispatch Rule

- Considerable Dispatch Patterns
  - D0 – no Join or Branch
  - D1 – no Join multiple Branch
  - D2 – multiple Join multiple Branch
- Equipment need to determine the rout
- Resource

Figure 27
Dispatch Rule

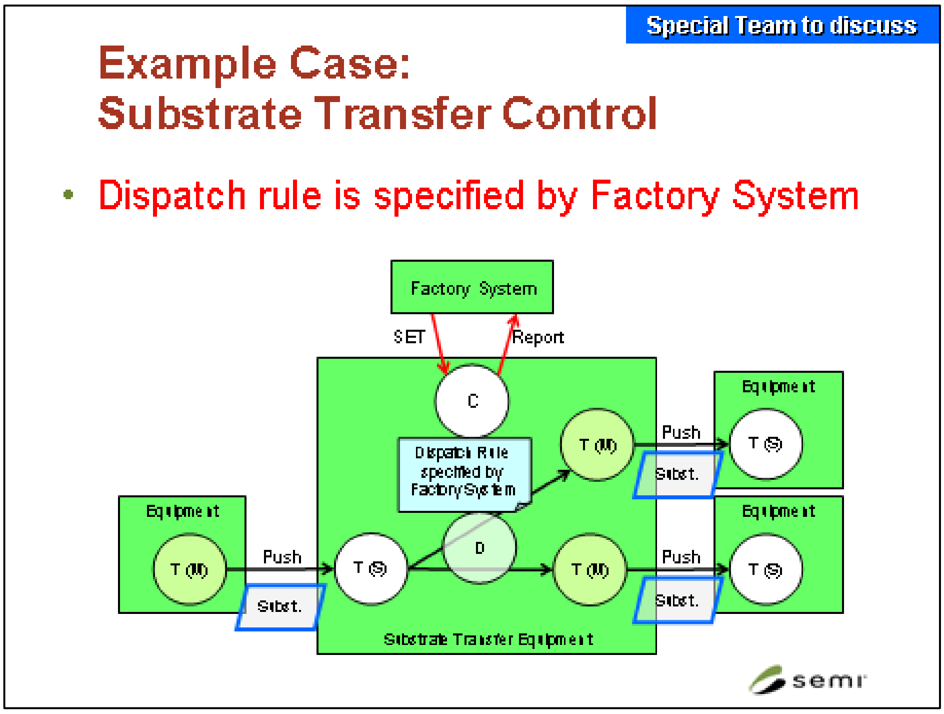


Special Team to discuss

Dispatch rules

- Following dispatch rule will be defined in this standard
  - Round robin
  - Nearest available
  - Shortest cycle time
- Rule setting options
  - Fixed on equipment
  - Specifying rout by Substrate
  - Selecting an option by Factory System

Figure 28
Dispatch Rules



Special Team to discuss

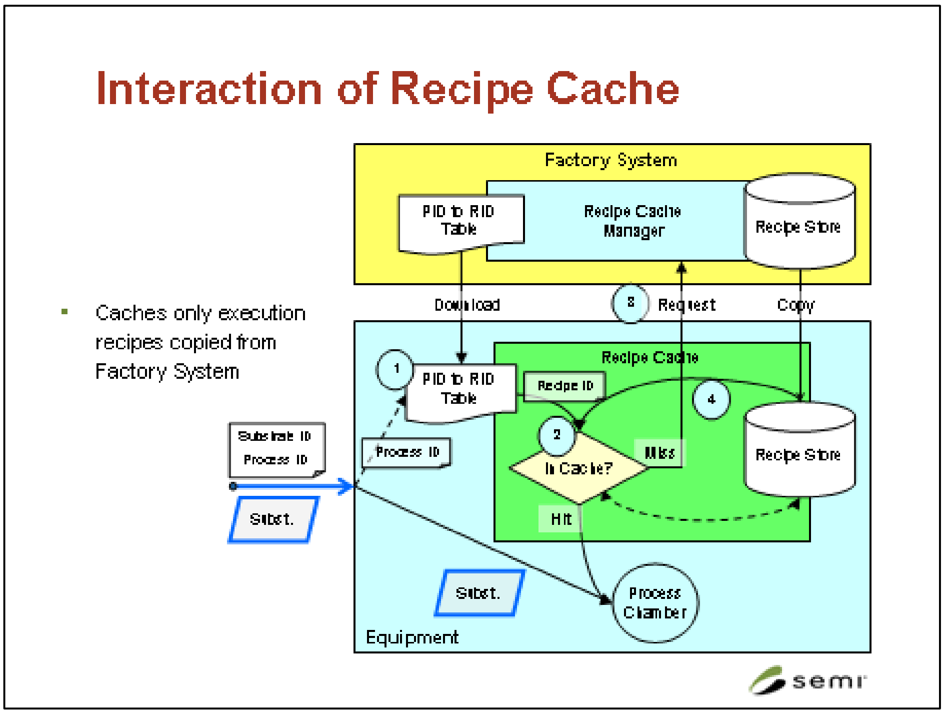
Example Case:
Substrate Transfer Control

- Dispatch rule is specified by Factory System

Figure 29
Substrate Transfer Control

7.2.6 *R Function* — R (Recipe) Function: Recipe Cache concept is applied. For the Recipe Cache, equipment provides Recipe Storage. The Recipe Storage stores only recipes copied from the factory system (host). Process ID (PID) to Recipe ID (RID) correspondence table is given by Factory System. When a substrate is transferred, equipment is informed Substrate ID and Process ID. Equipment determines Recipe ID by looking up PID/RID Table. Recipe Cache checks if the recipe of the Recipe ID is stored in Recipe Storage on equipment. If the Recipe ID hits the stored recipe, the recipe is applied to the substrate process. If the Recipe ID misses (not stored on equipment) the equipment request factory system to give the copy. After copying, the recipe is applied to the substrate.

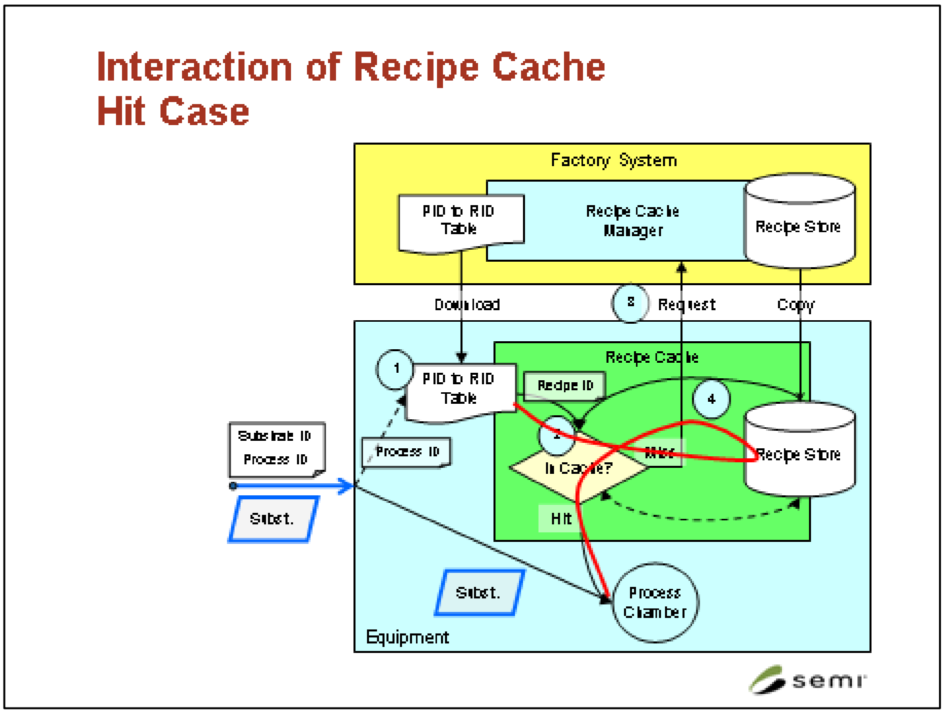
INFORMATIONAL (BLUE) BALLOT



Interaction of Recipe Cache

- Caches only execution recipes copied from Factory System

Figure 30
Interaction of Recipe Cache



Interaction of Recipe Cache
Hit Case

Figure 31
Interaction of Recipe Cache – Hit Case

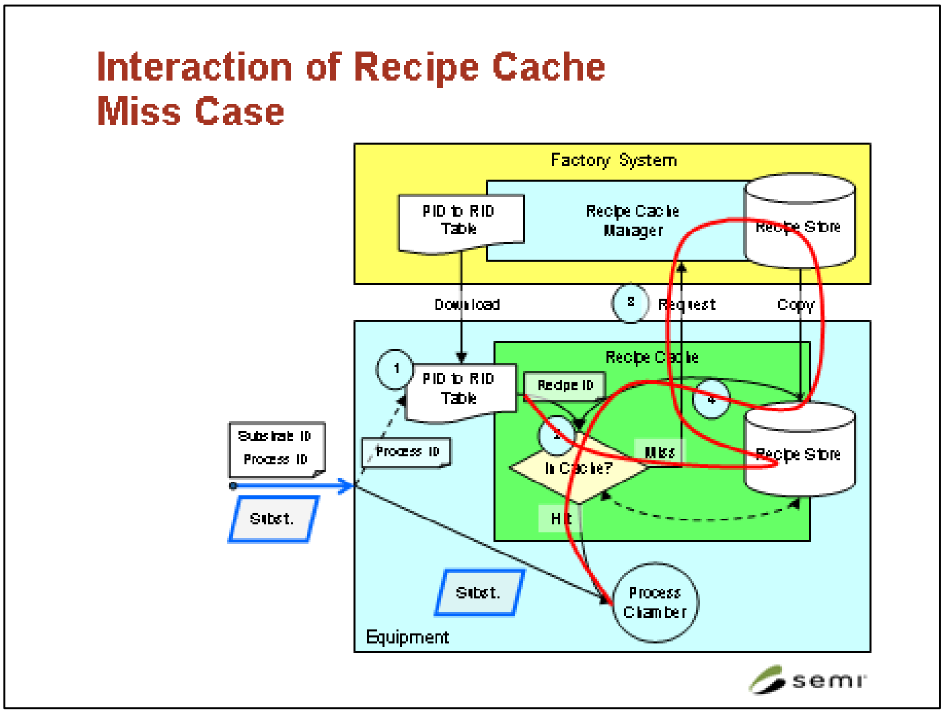


Figure 32
Interaction of Recipe Cache – Miss Case

7.2.6.1 P Function   */ to be defined later /*

7.2.6.2 C Function   */ to be defined later /*

8 Requirements to Related Standards   */ to be defined later /*

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

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