SEMI E94-0312
SPECIFICATION FOR CONTROL JOB MANAGEMENT

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1 Purpose

1.1 This Specification describes equipment provided services to the factory that supports a high level of factory automation. These services provide capabilities for the host to coordinate processing and disposition of materials on production equipment.

2 Scope

2.1 This Specification may be applied to equipment that is compliant to SEMI E30 (GEM).

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 presents a model of the ControlJob. The model delineates the services (messages) and behavior of the ControlJob. The model is protocol independent. Thus, an ancillary standard must be selected in order to provide a complete implementation.

3.2 This Standard should not be applied to non-production equipment, such as, material transport systems or facilities (environmental) controllers.

3.3 This Specification applies to equipment for which the atomic unit of material is the same for all input and output carriers on the equipment. It may not apply to equipment which would perform operations such as slicing or assembly that would require or result in different input and output material objects. This Specification may not apply to equipment or equipment configurations where the equipment does not handle carriers, as in the case of a stepper or scanner in a linked photolithography cell.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

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

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

5 Terminology

5.1 *Definitions*

5.1.1 *control job* — defines a unit of work on equipment for one or more carriers. The work is described by a set of one or more process jobs to be applied to the material contained in the carriers.

5.1.2 *de-queue* — the act of removing an item from a queue. The de-queue implies nothing about the status of the item after removal.

5.1.3 *equipment* — the intelligent system that communicates with the host.

5.1.4 *host* — the intelligent system that communicates with the equipment.

5.1.5 *life cycle* — the processes and activities of something from its beginning (creation) to its ending.

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5.1.6 *Material Redirection Mode* — term for an equipment mode of operation in which substrates are redirected to a carrier slot other than the source carrier slot.

5.1.7 *multi-module equipment* — equipment that has more than one distinct processing resource (e.g., chamber).

5.1.8 *production equipment* — equipment that measures or adds value to the product.

5.1.9 *protocol independent* — for software, this means that the message descriptions are independent of delivery mechanisms.

5.1.10 *Randomization* — process of moving material from a carrier source location to a carrier destination location in a mathematically random pattern.

5.1.11 *set-up* — a description of the current process capability of an equipment.

5.1.12 *Slot Integrity Mode* — term for an equipment mode of operation in which all substrates are returned to the same source carrier and source slot after processing.

5.1.13 *substrate* — basic unit of material on which work is performed to create a product. Examples include wafers, lead frames, CD's, die, flat panel displays, circuit boards, and disks.

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

5.1.15 *user start* — activities that are initiated on a system by another system or operator.

6 Conventions

6.1 *Object Models*

6.1.1 This Standard uses object models to specify the control job interface.

6.1.2 *Object Services Standard*

6.1.2.1 This Document conforms to the conventions established by SEMI E39.

6.1.3 *Formal Name of an Object*

6.1.3.1 The text capitalizes formal object name references, similar to the way capitalization is normally used when discussing entities. When describing something in the general (like cities) lower case is used, but when a specific entity is of interest (New York City), then first letters are capitalized.

6.2 *State Model Methodology*

6.2.1 This Document uses the Harel state chart convention for describing dynamic operation of defined objects. The outline of this convention is described in an attachment of SEMI E30. The official definition of this convention is described in "State Charts: A Visual Formalism for Complex Systems" written by D. Harel in Science of Computer Programming 8, 1987.[1]

6.2.2 The Harel convention does not have the concept of state models of 'creation' and 'extinction' for expressing a temporary entity. The 'job' described in this Document is such an entity, and a copy of the same state model is used for an independent job newly created. In this Document, a circle with a black circle inside is used for expressing extinction of an entity. A filled, black circle denotes the entry to the state model (the entity creation).

6.2.3 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:

1. Actions taken upon exit of the previous state.
2. Actions taken upon entry of the new state.
3. Actions taken which are most closely associated with the transition.

6.2.3.1 No differentiation is made between these cases.

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

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6.2.4 The state models included in this Standard are a requirement for Control Job Management compliance. A state model consists of a state model diagram, state definitions, and a state transition table. When using collection events, all state transitions in this Standard, unless otherwise specified, shall correspond to collection events.

6.2.5 A state model represents the host's view of the equipment, and does not necessarily describe the internal equipment operation. When using collection events, all Control Job Management 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 Control Job Management state models for transition to another state. In the case, the equipment makes the required transition without any additional actions in this situation.

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

6.3 *Service Message Representation*

6.3.1 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.

6.3.2 *Service Definition*

6.3.2.1 A service definition table defines the specific set of messages for a given service resource, as shown in the following table:

Message Service Name	*Type*	*Description*

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

6.3.2.3 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).

6.3.3 *Service Parameter Dictionary*

6.3.3.1 A service parameter dictionary table defines the description, format and its possible value for parameters used by services, as shown in the following table:

Parameter Name	*Description*	*Format: Possible Value*

6.3.3.2 A row is provided in the table for each parameter of a service.

6.3.4 *Service Message Definition*

6.3.4.1 A service message definition table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Res/Cnf*	*Comment*

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6.3.4.2 The columns labeled REQ/IND and RSP/CNF 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' or the request. The receiver may then send a 'Response' which the original sender terms the 'Confirmation'.

6.3.4.3 The following codes appear in the REQ/IND and RSP/CNF 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 value of the other parameter.
U	User-Defined Parameter.
-	The parameter is not used.
=	(For response only) Indicates that the value of this parameter in the response must match that in the primary (if defined).

7 Overview

7.1 This section provides an overview of the control job functionality. It does not contain the specifications which define that functionality.

7.1.1 Control jobs provide a supervisory level of control for process jobs on material processing equipment. They can be used to reduce the amount of host level interaction required for material processing. A factory host is provided with methods for instructing the equipment to provide only significant factory level events, such as, a carrier complete. The ControlJob also supplies methods for the disposition of material after processing.

7.2 *User Requirements*

7.2.1 To handle the complexity required for manufacturing, equipment must support the ability to coordinate its processing services with the factory's needs. The ControlJob provides the services that the factory needs to accomplish this coordination. The requirements that the ControlJob satisfies include: (1) a method by which the equipment coordinates related work, for instance, all process jobs associated with a carrier, and (2) a method by which the equipment can be informed of material destination after processing. The ControlJob is not a type of process job. It is not responsible for the coordination of the processing resource and the material to be processed.

7.2.2 *Initiate and Monitor Process Jobs*

7.2.2.1 ControlJobs are queued. ProcessJobs are not queued by equipment that supports control jobs, rather they are pooled waiting to be scheduled by their respective ControlJob. The ControlJob specifies the order for process jobs. The equipment follows that order as the equipment's resources become available (and when material is available).

7.3 *Supplier Requirements*

7.3.1 *Management of Process Materials*

7.3.1.1 Suppliers need to implement an operational model for managing material and processing in a manner consistent with factory expectations. For instance, the equipment must know when it is finished with a carrier so that it can either allow or signal the factory for the removal of the carrier. This Standard provides mechanisms to meet this requirement. While the model implies some implementation it is only the external events that are required by this Standard.

7.3.2 *Control Job Events*

7.3.2.1 Control jobs supply information to host systems as either responses to request messages or as events which are sent to the host. Typically the equipment can implement the event mechanisms in GEM (SEMI E30).

7.3.2.2 All state transitions defined for state models in this Document must be able to be reported by separate collection events as defined in ¶ 6.2, State Model Methodology. The state model is the Control Job State Model (Figure 2). The data required for each state model transition event is defined per the following. This data is the minimum required per event. The host may assign other variable, as applicable, from § 13, Variable Data, of this Document, or from other equipment variable data.

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7.3.2.2.1 The following data is required to be available for the Control Job State Model transition collection events: CtrlJobID.

7.4 *Operational Descriptions*

7.4.1 The ProcessJob as referenced in the specification of the control job model is the SEMI E40 process job. Within a ProcessJob the material processing order is managed by the equipment. For some equipment types, the user may be able to configure the material processing order. If available, this feature shall be fully documented by the supplier (see SEMI E40).

7.4.2 To support a simpler interface for single substrate processing, it is suggested to use the PRJobMultiCreate (see SEMI E40) service.

7.4.3 The use of control jobs restricts some SEMI E40 functionality. In particular, the equipment's queue management functionality for process jobs is superseded by the job order as defined in the control job.

7.4.4 The relationship between control jobs and process jobs varies by equipment type. The equipment supplier should document this relationship.

7.4.5 This section describes the behavior of a control job in the ACTIVE state if some or all referenced process jobs are stopped or aborted. The host can use the control job attribute PRJobStatusList to determine the way in which each process job has finished.

7.4.5.1 Transition 11 of the control job state model shall be taken only if the control job itself is stopped as described in the trigger column of Table 3, Transition #11.

7.4.5.2 Transition 12 of the control job state model shall be taken only if the control job itself is aborted as described in the trigger column of Table 3, Transition #12.

7.4.5.3 If the control job itself has not been stopped and has not been aborted, then transition 10 of the control job state model shall be taken when all of the referenced process jobs have reached the POST ACTIVE state or have been deleted; these process jobs may have completed normally or they may have completed as part of the process job being stopped or aborted.

8 ControlJob Object Model

8.1 This Specification only standardizes the ControlJob object's interface. The other objects provide a context for the ControlJob interface. Since only the interface is standardized, it is not a requirement for equipment to implement a control job object, it is only required that the equipment provide an external interface that provides the services and behavior defined for the ControlJob.

8.2 *Material to Job Linkage*

8.2.1 The equipment has relationships with many other components not illustrated in Figure 1. In particular, from its knowledge based on substrate and carrier tracking capabilities, the equipment shall connect the process job material list to the materials in the carriers that it has. It is the responsibility of the factory host to make sure that the description or identifiers of material contained in carriers can be mapped to the material identifiers in the process job definition.

8.3 *Control Jobs and Carriers*

8.3.1 A control job may specify work for several carriers. The supplier shall document the behavior of the equipment in the case where a carrier is specified for use in more than one control job.

8.4 *Attribute Definitions*

8.4.1 The attributes in Table 1 shall be accessible using the Object Services Standard (SEMI E39). Object Services is a set of messages which may be required of any service provider which is modeled by objects. An object model for a service provides a consistent naming convention for exchanging information between the service provider and user. Object Services implementations shall be consistent with the service's object and state models. For instance, if an attribute can only be modified in a certain state, then a request to set that attribute when the model is in the wrong state shall be rejected (fail).

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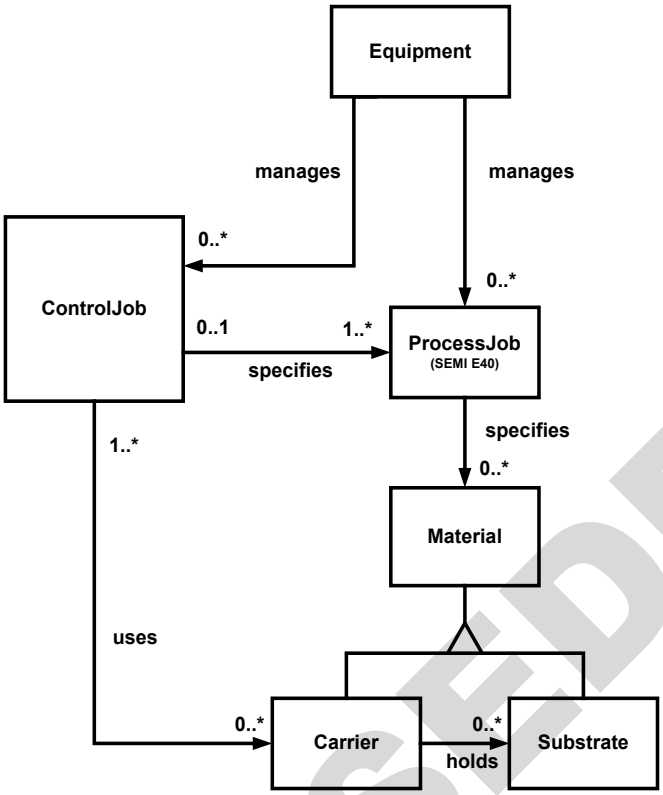

Figure 1
ControlJob Object Model

Table 1 ControlJob Attributes

Name	*Definition*	*Rqmt*	*Access*	*Form*
ObjID	Host defined identifier of the control job.	Y	RO	Text
ObjType	Object type.	Y	RO	Text = 'ControlJob'
CurrentPRJob	Holds the identifiers of any process job in the active state (i.e., in the Executing, Stopping, Aborting or Pause states).	Y	RO	(list of) PRJobID (see SEMI E40)
DataCollectionPlan	Identifier for a data collection plan to be used during execution of the control job.	N	RW	Text
CarrierInputSpec	A list of carrierID for material that will be used by the ControlJob. An empty list is allowed.	Y	RW	(list of) CarrierID
MtrlOutSpec	Maps material from source to destination after processing. In Slot Integrity Mode the list shall be empty.	Y	RW	List of Structure: SourceMap DestinationMap
MtrlOutByStatus	List structure which maps locations or Carriers where processed material will be placed based on material status.	N	RW	List of structure: MaterialStatus DestinationMap
PauseEvent	Identifier of a list of events on which the Control Job shall PAUSE.	N	RW	(list of) EventID
PRJobStatusList	A list of all process jobs managed by this Control Job and their associated status.	Y	RO	(list of) PRJobID PRJobState (see SEMI E40)

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Name	*Definition*	*Rqmt*	*Access*	*Form*
ProcessingCtrlSpec	A list of structures that defines the process jobs and rules for running each that will be run within this ControlJob.	Y	RW	(list of) Structure: PRJobID ControlRule OutputRule
ProcessOrderMgmt	Define the method for the order in which process jobs are initiated.	Y	RW	Enumeration: LIST ARRIVAL OPTIMIZE
StartMethod	A logical flag that determines if the ControlJob can start automatically. A user start may come through either the host connection or the operator console.	Y	RO	Boolean: TRUE – Auto FALSE – UserStart
State	The current state of the ControlJob.	Y	RO	Enumerated: per State Model

8.4.2 A number of the ControlJob attributes are composite data types. The constituent data is defined in Table 2.

Table 2 Attribute Data Definitions

Data Identifier	*Description*	*Form*
CarrierID	The identifier of a carrier that is the source or destination for substrates.	Text
ControlRule	Provides additional job control functionality. It is equipment type dependent. It may be used to modify processing based on processing results. Use of this attribute is not required for equipment, which does not support it. Suppliers shall document the use of this attribute when supported.	(list of) Structure: RuleName RuleValue
Destination	The identifier of a substrate location at which material can be placed (Identifier should conform to standards for substrate tracking).	Text
DestinationMap	Describes carrier positions into which the finished material will be placed. If the list of SubstrateLocation is empty, then follow sequential order of source. Optionally, equipment suppliers may choose to allow DestinationMap be an empty structure in a MtrlOutSpec.	Structure: CarrierID List of SubstrateLocation
MaterialStatus	ControlJob processing assigns this value to finished material. The association of MaterialStatus to Destination enables ControlJob processing to put material at the desired destination.	Equipment dependent enumeration
OutputRule	Defines the MaterialStatus (such as Good, Reject, Aborted, Monitor, etc.) based on results of the process job.	Equipment dependent
PRJobID	A process job identifier as defined by SEMI E40. Host must supply same name in the ProcessingCtrlSpec as when it requested creation of process job. NOTE: SEMI E40 process jobs link material to a recipe.	See SEMI E40
Rule Value	The value used by the equipment for execution of a control rule.	Equipment dependent
RuleName	Identifier of a control rule.	Text
SourceMap	Describes the locations from which material is taken for processing. If the list of location is empty, then assume the default of ascending order.	Structure: CarrierID List of SubstrateLocation
SubstrateLocation	A substrate position at a source and a destination. A carrier is an example of a multi-location destination. For a wafer carrier the SubstrateLocation is a slot number.	Numeric

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8.4.3 *ControlRule*

8.4.3.1 For equipment that supports this attribute (field), the host sets this in order to achieve better host processing control capabilities. For example, the host may have previously measured characteristics of the material to be processed. A standard recipe is used based on the product and process step, but based on the measured characteristics, the application of the recipe is biased by the specified rule and the value that is passed to the rule (RuleValue). However, use of ControlRule should not be considered to be limited to only this type of application.

8.4.4 *DataCollectionPlan*

8.4.4.1 The DataCollectionPlan is a name given by the host to associate data collection activities to a specific control job. In general, it provides a way for the equipment to then inform and coordinate with the host to receive data collection requests. A DataCollectionPlan is generic and will be applied to many control jobs. The variable itself, DataCollectionPlan, will hold no significance for the equipment. It is simply a label the equipment reports back when requested by the host. Normally, the host upon receiving the ControlJob START event would include DataCollectionPlan as a data variable to be reported. The host then knows that the time is appropriate to set up various trace reports and event reports on the equipment. Potentially, all jobs that specify the same product type and process capability could specify the same DataCollectionPlan.

8.4.5 *MtrlOutSpec*

8.4.5.1 The MtrlOutSpec attribute shall be used to map source locations of material to be processed within a ControlJob to destination locations where the processed material shall be placed. The value of this attribute determines whether the equipment is to operate in Slot Integrity Mode or Material Redirection Mode.

8.4.5.2 *Slot Integrity Mode (Mandatory)*

8.4.5.2.1 If MtrlOutSpec is empty, material shall be returned to its source location in its source carrier after processing.

8.4.5.2.2 The only exception to this requirement is in the case of wafer sorters, where jobs such as Randomization are permitted to change the destination locations even though MtrlOutSpec is empty.

8.4.5.3 *Material Redirection Mode (Optional)*

8.4.5.3.1 The equipment may optionally support Material Redirection Mode by allowing the MtrlOutSpec attribute to be non-empty (i.e., if it contains at least one SourceMap and DestinationMap pair). In order to avoid conflict, Carrier ID's specified in SourceMaps shall match Carrier ID's if specified in SEMI E40 PrMtlNameLists.

8.4.5.3.2 If the equipment does not support Material Redirection Mode, it shall reject any request to set a value for MtrlOutSpec.

8.4.5.3.3 To avoid conflicts when the MtrlOutSpec is not empty, every source location in a SourceMap shall only be referenced once in the SourceMaps of a MtrlOutSpec and every destination location in a DestinationMap shall only be referenced once in the DestinationMaps of a MtrlOutSpec.

8.4.5.3.4 If the MtrlOutSpec is not empty, material shall be redirected to the specified destination location(s) when it leaves the equipment. When the equipment is ready to return the material to the carrier(s), the equipment shall determine if the material's designated destination location provided in the MtrlOutSpec is unoccupied and accessible and if so, the equipment shall move the material to that location.

8.4.5.3.5 When the equipment is ready to return the material to its destination but the MtrlOutSpec specifies a non-accessible or occupied destination location for the material, the equipment shall issue (set) a 'SubstrateDestinationNotAccessible' alarm. The equipment shall clear this alarm when a DestinationMap referring to an accessible destination has been provided by the host or operator intervention.

8.4.5.3.6 If the equipment supports incomplete MtrlOutSpecs (i.e., MtrlOutSpecs containing SourceMaps and empty DestinationMaps) it shall allow updates of the DestinationMaps via the SEMI E39 (OSS) SetAttr service request before or after the ControlJob enters the EXECUTING state. Requests in the EXECUTING state shall only be accepted if the SourceMaps contained in the MtrlOutSpec remain unchanged and material whose destination location is changed by the update has not yet been placed into a destination carrier and is not currently moving into a destination carrier.

8.4.5.3.7 If the equipment supports incomplete MtrlOutSpecs and the DestinationMap is empty on completion of processing, the equipment will be unable to determine a destination location from the MtrlOutSpec. In this case, the equipment shall issue (set) a 'SubstrateDestinationUnknown' alarm and shall remain capable of accepting updates of

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the MtrlOutSpec as described in ¶ 8.4.5.3.6 above to enable this exception to be handled by the host in an automated fashion. When the material has been successfully moved to its destination location, the equipment shall automatically clear the 'SubstrateDestinationUnknown' alarm.

8.4.6 *OutputRule*

8.4.6.1 This attribute can only be supported by equipment that has some means to determine the status of material that it has processed. For equipment with that ability, the rule will usually take the form of a list of name value pairs. The names will be material status and the values will be measurement thresholds that correspond to the status category (such as, Good, Reject, Rework, etc.). Substrate (material) status changes should be recorded in substrate histories created by the equipment.

8.4.6.2 Equipment which also supports the MtrlOutbyStatus shall use the status determined by the OutputRule to place substrates at the Destination associated with MaterialStatus.

8.4.7 *PauseEvent*

8.4.7.1 For equipment which can support it, this attribute contains a list of equipment events, specified by the host, at which the host expects the equipment to PAUSE the ControlJob. Equipment suppliers shall document any events that can be used for the pausing of control jobs. Pausing a control job causes it to stop initiating process jobs. The host might use this to stop processing after one or more process jobs has started in order to await results before processing the rest of the material in the control job.

8.4.8 *ProcessOrderMgmt*

8.4.8.1 This is an enumerated attribute that defines the order in which processing will occur. This Standard defines three enumerations. For some equipment other enumerations may be possible. If they are the supplier shall document them.

8.4.8.2 *LIST*

8.4.8.2.1 When ProcessOrderMgmt is set to this value, process jobs shall be initiated in the order of the list in ProcessingCtrlSpec.

8.4.8.3 *ARRIVAL*

8.4.8.3.1 When ProcessOrderMgmt is set to this value, process jobs shall be initiated as the material for the job arrives. Any jobs that do not require material will be initiated first.

8.4.8.4 *OPTIMIZE*

8.4.8.4.1 When ProcessOrderMgmt is set to this value, process jobs shall be initiated in an order to be determined by internal equipment algorithms, that optimize the throughput of material in the equipment.

9 Control Job State Model – Behavior

9.1 The following state chart defines the behavior of the ControlJob.

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