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INTERNATIONAL STANDARD

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OPC Unified Architecture – Part 10: Programs

Architecture unifiée OPC – Partie 10: Programmes

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FOREWORD

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International Standard IEC 62541-10 has been prepared by subcommittee 65E: Devices and integration in enterprise systems, of IEC technical committee 65: Industrial-process measurement, control and automation.

This second edition cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Based on NIST review, security considerations have been included as 4.2.2;
b) Fixed the definition of the Program Diagnostic Type into a data type (5.2.8) and added missing data type for the Program Diagnostic Variable in the ProgramType in Table 5.
c) Corrected the BrowseName of the audit events for Program Transitions in Table 7.

The text of this standard is based on the following documents:

FDIS	Report on voting
65E/383/FDIS	65E/409/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62541 series, published under the general title *OPC Unified Architecture*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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OPC UNIFIED ARCHITECTURE –

Part 10: Programs

1 Scope

This part of IEC 62541 is part of the overall OPC Unified Architecture (OPC UA) standard series and defines the information model associated with *Programs*. This includes the description of the *NodeClasses,* standard *Properties, Methods* and *Events* and associated behaviour and information for *Programs*.

The complete address space model including all *NodeClasses* and *Attributes* is specified in IEC 62541-3. The services such as those used to invoke the *Methods* used to manage P*rograms* are specified in IEC 62541-4.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TR 62541-1, *OPC Unified Architecture – Part 1: Overview and Concepts*

IEC 62541-3:2015, *OPC Unified Architecture – Part 3: Address Space Model*

IEC 62541-4:2015, *OPC Unified Architecture – Part 4: Services*

IEC 62541-5:2015, *OPC Unified Architecture – Part 5: Information Model*

IEC 62541-7, *OPC Unified Architecture – Part 7: Profiles*

3 Terms, definitions and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TR 62541-1, IEC 62541-3, as well as the following apply.

3.1.1
function
programmatic task performed by a server or device, usually accomplished by computer code execution

3.1.2
Finite State Machine
sequence of states and valid state transitions along with the causes and effects of those state transitions that define the actions of a *Program* in terms of discrete stages

3.1.3
ProgramType
type definition of a *Program* and is a subtype of the *FiniteStateMachineType*

3.1.4
Program Control Method
Method having specific semantics designed for the control of a *Program* by causing a state transition

3.1.5
Program Invocation
unique *Object* instance of a *Program* existing on a *Server*

Note 1 to entry: A *Program Invocation* is distinguished from other *Object* instances of the same *ProgramType* by the object node's unique browse path.

3.2 Abbreviations

DA Data Access
FSM Finite State Machine
HMI Human Machine Interfaces
PCM Program Control Method
PGM Program
PI Program Invocation
UA Unified Architecture

4 Concepts

4.1 General

Integrated automation facilities manage their operations through the exchange of data and the coordinated invocation of system functions as illustrated in Figure 1. *Services* are required to perform the data exchanges and to invoke the functions that constitute system operation. These functions may be invoked through Human Machine Interfaces, cell controllers, or other supervisory control and data acquisition type systems. OPC UA defines *Methods* and *Programs* as an interoperable way to advertise, discover, and request these functions. They provide a normalizing mechanism for the semantic description, invocation, and result reporting of these functions. Together *Methods* and *Programs* complement the other OPC UA *Services* and *ObjectTypes* to facilitate the operation of an automation environment using a client-server hierarchy.

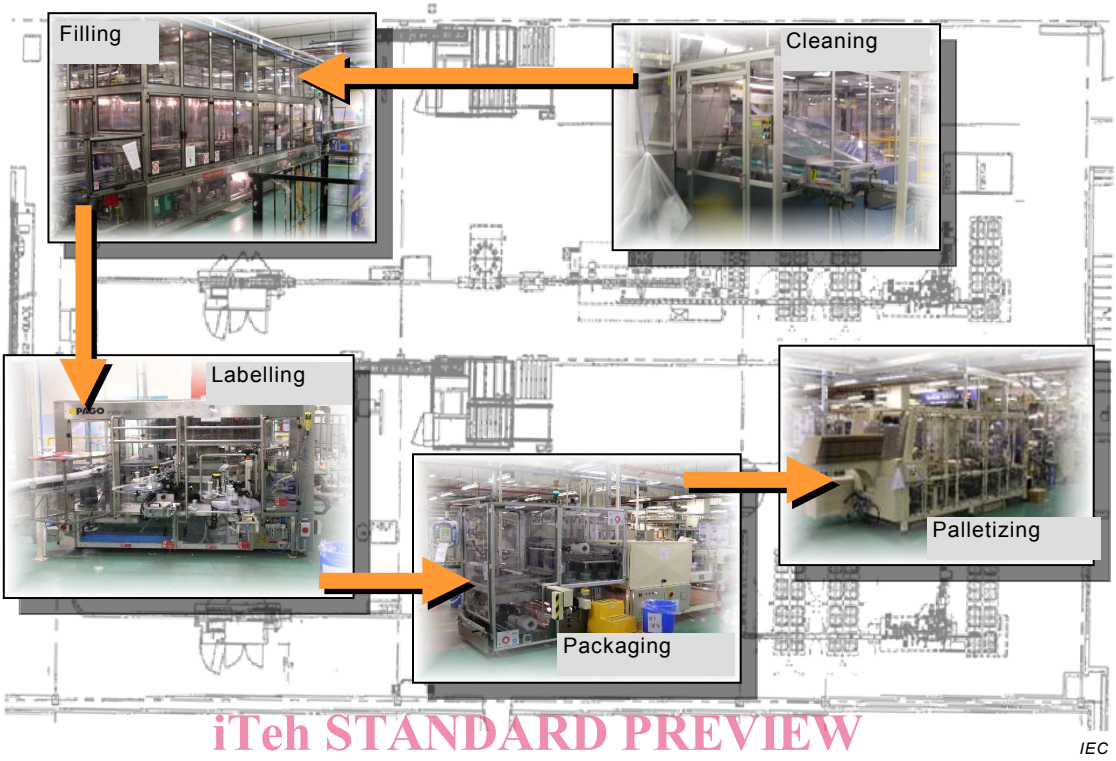

Figure 1 – Automation facility control

Methods and *Programs* model functions typically have different scopes, behaviours, lifetimes, and complexities in *OPC Servers* and the underlying systems. These functions are not normally characterized by the reading or writing of data which is accomplished with the OPC UA A*ttribute* service set.

Methods represent basic functions in the *Server* that can be invoked by a *Client*. *Programs,* by contrast, model more complex and stateful functionality in the system. For example, a method call may be used to perform a calculation or reset a counter. A *Program* is used to run and control a batch process, execute a machine tool part program, or manage a domain download. *Methods* and their invocation mechanism are described in IEC 62541-3 and IEC 62541-4.

This standard describes the extensions to, or specific use of, the core capabilities defined in IEC 62541-5 as required for *Programs*.

4.2 Programs

4.2.1 Overview

Programs are complex functions in a server or underlying system that can be invoked and managed by a *Client*. *Programs* can represent any level of functionality within a system or process in which client control or intervention is required and progress monitoring is desired. Figure 2 illustrates the model.

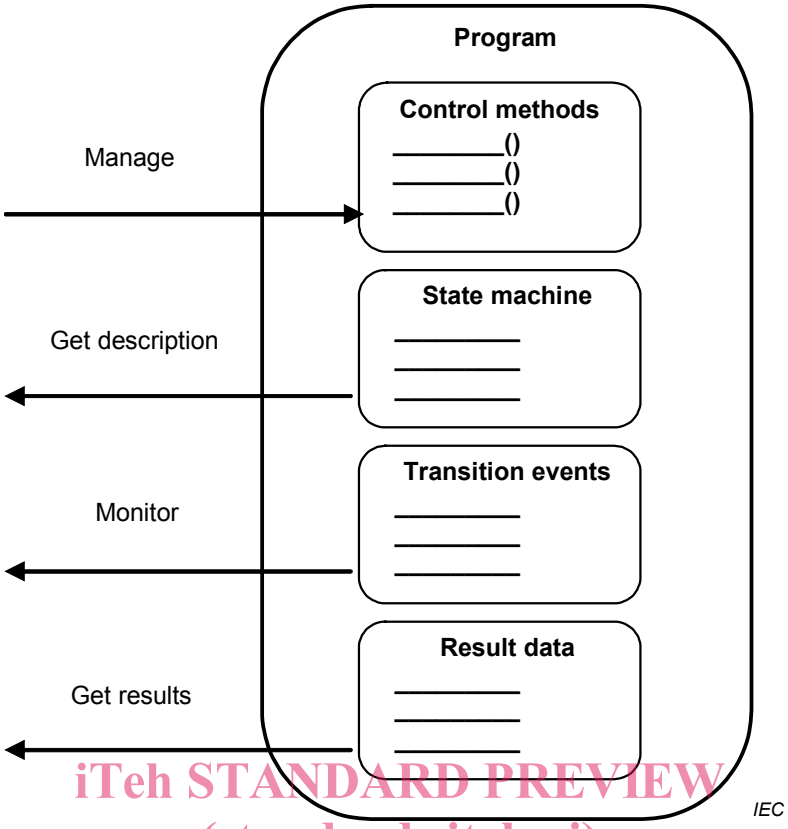

Figure 2 – Program illustration

Programs are state full and transition through a prescribed sequence of states as they execute. Their behaviour is defined by a *Program Finite State Machine (PFSM)*. The elements of the PFSM describe the phases of a *Program's* execution in terms of valid transitions between a set of states, the stimuli or causes of those transitions, and the resultant effects of the transitions.

4.2.2 Security considerations

Since *Programs* can be used to perform advanced control algorithms or other actions, their use should be restricted to personnel with appropriate access rights. It is recommended that *AuditUpdateMethodEvents* are generated to allow monitoring the number of running *Programs* in addition to their execution frequency.

4.2.3 Program Finite State Machine

The states, transitions, causes and effects that compose the *Program Finite State Machine* are listed in Table 1 and illustrated in Figure 3.

Table 1 – Program Finite State Machine

No.	Transition name	Cause	From state	To state	Effect
1	HaltedToReady	Reset Method	Halted	Ready	Report Transition 1 Event/Result
2	ReadyToRunning	Start Method	Ready	Running	Report Transition 2 Event/Result
3	RunningToHalted	Halt Method or Internal (Error)	Running	Halted	Report Transition 3 Event/Result
4	RunningToReady	Internal	Running	Ready	Report Transition 4 Event/Result
5	RunningToSuspended	Suspend Method	Running	Suspended	Report Transition 5

No.	Transition name	Cause	From state	To state	Effect
					Event/Result
6	SuspendedToRunning	Resume Method	Suspended	Running	Report Transition 6 Event/Result
7	SuspendedToHalted	Halt Method	Suspended	Halted	Report Transition 7 Event/Result
8	SuspendedToReady	Internal	Suspended	Ready	Report Transition 8 Event/Result
9	ReadyToHalted	Halt Method	Ready	Halted	Report Transition 9 Event/Result

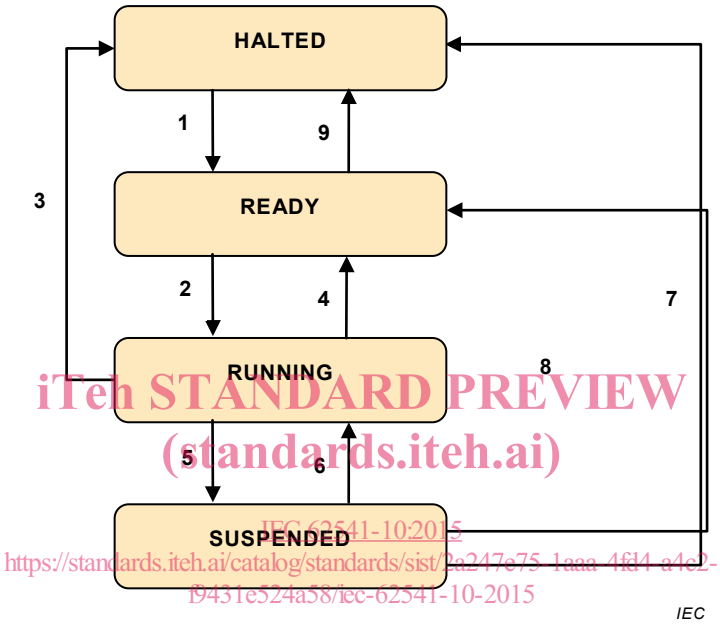

Figure 3 – Program states and transitions

4.2.4 Program states

A standard set of base states is defined for *Programs* as part of the *Program Finite State Machine.* These states represent the stages in which a *Program* can exist at an instance in time as viewed by a *Client*. This state is the *Program's* current state. All *Programs* shall support this base set. A *Program* may or may not require a *Client* action to cause the state to change. The states are formally defined in Table 2.

Table 2 – Program states

State	Description
Ready	The *Program* is properly initialized and may be started.
Running	The *Program* is executing making progress towards completion.
Suspended	The *Program* has been stopped prior to reaching a terminal state but may be resumed.
Halted	The *Program* is in a terminal or failed state, and it cannot be started or resumed without being reset.

The set of states defined to describe a *Program* can be expanded. *Program* sub states can be defined for the base states to provide more resolution of a process and to describe the cause and effect(s) of additional stimuli and transitions. Standards bodies and industry groups may extend the base *Program Finite State Model* to conform to various industry models. For example, the Halted state can include the sub states "Aborted" and "Completed" to indicate if

the function achieved a successful conclusion prior to the transition to Halted. Transitional states such as “Starting” or “Suspending” might also be extensions of the Running state, for example.

4.2.5 State transitions

A standard set of state transitions is defined for the *Program Finite State Machine.* These transitions define the valid changes to the *Program's* current state in terms of an initial state and a resultant state. The transitions are formally defined in Table 3.

Table 3 – Program state transitions

Transition no.	Transition name	Initial state	Resultant state
1	HaltedToReady	Halted	Ready
2	ReadyToRunning	Ready	Running
3	RunningToHalted	Running	Halted
4	RunningToReady	Running	Ready
5	RunningToSuspended	Running	Suspended
6	SuspendedToRunning	Suspended	Running
7	SuspendedToHalted	Suspended	Halted
8	SuspendedToReady	Suspended	Ready
9	ReadyToHalted	Ready	Halted

4.2.6 Program state transition stimuli

The stimuli or causes for a *Program's* state transitions can be internal to the *Server* or external. The completion of machining steps, the detection of an alarm condition, or the transmission of a data packet are examples of internal stimuli. *Methods* are an example of external stimuli. Standard *Methods* are defined which act as stimuli for the control of a *Program*.

4.2.7 Program Control Methods

Clients manage a *Program* by calling *Methods.* The *Methods* impact a *Program's* behaviour by causing specified state transitions. The state transitions dictate the actions performed by the *Program*. This standard defines a set of standard *Program Control Methods*. These *Methods* provide sufficient means for a client to run a *Program*.

Table 4 lists the set of defined *Program Control Methods.* Each *Method* causes transitions from specified states and shall be called when the *Program* is in one of those states.

Individual *Programs* can optionally support any subset of the *Program Control Methods.* For example, some *Programs* may not be permitted to suspend and so would not provide the *Suspend* and *Resume Methods.*

Programs can support additional user defined *Methods.* User defined *Methods* shall not change the behaviour of the base *Program Finite State Machine*.

Table 4 – Program Control Methods

Method Name	Description
Start	Causes the *Program* to transition from the Ready state to the Running state.
Suspend	Causes the *Program* to transition from the Running state to the Suspended state.
Resume	Causes the *Program* to transition from the Suspended state to the Running state.
Halt	Causes the *Program* to transition from the Ready, Running or Suspended state to the Halted state.
Reset	Causes the *Program* to transition from the Halted state to the Ready state.

Program Control Methods can include arguments that are used by the *Program.* For example, a Start *Method* may include an options argument that specifies dynamic options used to determine some program behaviour. The arguments can differ on each *ProgramType*. The *Method Call* service specified in IEC 62541-4:2015, 5.11 defines a return status. This return status indicates the success of the *Program Control Method* or a reason for its failure.

4.2.8 Program state transition effects

A *Program's* state transition generally has a cause and also yields an effect. The effect is a by product of a *Program* state transition that can be used by a *Client* to monitor the progress of the *Program*. Effects can be internal or external. An external effect of a state transition is the generation of an *Event* notification. Each *Program* state transition is associated with a unique *Event*. These *Events* reflect the progression and trajectory of the *Program* through its set of defined states. The internal effects of a state transition can be the performance of some programmatic action such as the generation of data.

4.2.9 Program result data

4.2.9.1 Overview

Result data is generated by a running *Program.* The result data can be intermediate or final. Result data may be associated with specific *Program* state transitions.

4.2.9.2 Intermediate result data

Intermediate result data is transient and is generated by the *Program* in conjunction with non-terminal state transitions. The data items that compose the intermediate results are defined in association with specific *Program* state transitions. Their values are relevant only at the transition level.

Each *Program* state transition can be associated with different result data items. Alternately, a set of transitions can share a result data item. Percentage complete is an example of intermediate result data. The value of percentage complete is produced when the state transition occurs and is available to the *Client*.

Clients acquire intermediate result data by subscribing to *Program* state transition *Events*. The *Events* specify the data items for each transition. When the transition occurs, the generated *Event* conveys the result data values captured to the subscribed *Clients*. If no *Client* is monitoring the *Program*, intermediate result data may be discarded.

4.2.9.3 Terminal result data

Terminal result data is the final data generated by the *Program* as it ceases execution. Total execution time, number of widgets produced, and fault condition encountered are examples of terminal result data. When the *Program* enters the terminal state, this result data can be conveyed to the client by the transition *Event*. Terminal result data is also available within the *Program* to be read by a *Client* after the program stops. This data persists until the *Program* Instance is rerun or deleted.

4.2.9.4 Monitoring Programs

Clients can monitor the activities associated with a *Program's* execution. These activities include the invocation of the management *Methods*, the generation of result data, and the progression of the *Program* through its states. *Audit Events* are provided for *Method Calls* and state transitions. These *Events* allow a record to be maintained of the *Clients* that interacted with any *Program* and the *Program* state transitions that resulted from that interaction.

4.2.10 Program lifetime

4.2.10.1 Overview

Programs can have different lifetimes. Some *Programs* may always be present on a *Server* while others are created and removed. Creation and removal can be controlled by a *Client* or may be restricted to local means.

A *Program* can be *Client* creatable. If a *Program* is *Client* creatable, then the *Client* can add the *Program* to the *Server*. The *Object Create Method* defined in IEC 62541-3:2015, 5.5.4, is used to create the *Program* instance. The initial state of the *Program* can be Halted or Ready. Some *Programs*, for example, may require that a resource becomes available after its creation and before it is ready to run. In this case, it would be initialized in the Halted state and transition to Ready when the resource is delivered.

A *Program* can be *Client* removable. If the *Program* is *Client* removable, then the *Client* can delete the *Program* instance from the *Server*. The *DeleteNodes Service* defined in IEC 62541-4 is used to remove the *Program* instance. The *Program* shall be in a Halted state to be removed. A *Program* may also be auto removable. An auto removable *Program* deletes itself when execution has terminated.

4.2.10.2 Program instances

Programs can be multiple instanced or single instanced. A *Server* can support multiple instances of a *Program* if these *Program* Instances can be run in parallel. For example, the *Program* may define a *Start Method* that has an input argument to specify which resource is acted upon by its functions. Each instance of the *Program* is then started designating use of different resources. The *Client* can discover all instances of a *Program* that are running on a *Server*. Each instance of a *Program* is uniquely identified on the *Server* and is managed independently by the *Client*.

4.2.10.3 Program recycling

Programs can be run once or run multiple times (recycled). A *Program* that is run once will remain in the Halted state indefinitely once it has run. The normal course of action would be to delete it following the inspection of its terminal results.

Recyclable *Programs* may have a limited or unlimited cycle count. These *Programs* may require a reset step to transition from the Halted state to the Ready state. This allows for replenishing resources or reinitializing parameters prior to restarting the *Program*. The *Program Control Method* "*Reset*" triggers this state transition and any associated actions or effects.

5 Model

5.1 General

The *Program* model extends the *FiniteStateMachineType and* basic *ObjectType* models presented in IEC 62541-5. Each *Program* has a *Type Definition* that is the subtype of the *FiniteStateMachineType.* The *ProgramType* describes the *Finite State Machine* model supported by any *Program Invocation* of that type*.* The *ProgramType* also defines the property