INTERNATIONAL STANDARD

ISO 15746-2

First edition
2017-10

Automation systems and integration — Integration of advanced process control and optimization capabilities for manufacturing systems —

Part 2: Activity models and information exchange

Systèmes d'automatisation et intégration — Intégration de contrôles de processus avancés et capacités d'optimisation des systèmes de fabrication —

Partie 2: Modèles d'activité et échange d'informations

Reference number
ISO 15746-2:2017(E)

Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration and architectures of enterprise systems and automation applications*.

A list of all parts in the ISO 15746 series can be found on the ISO website.

Introduction

As a crucial part of manufacturing systems with increased complexity, the automation and control applications enabled by the advanced process control and optimization (APC-O) methodology and solutions perform the operations directed by production planning and scheduling. This work will initially deal with the specific use of APC-O to enable integration of manufacturing operations management (MOM) with the automation and control of manufacturing processes and equipment.

Automation solutions composed of software and hardware components are provided by different suppliers to accomplish APC-O functions. Due to the diversity of development environments and the variety of demand focus, the automation solutions from various suppliers are isolated and relatively independent. These differences make the integration of automation solutions difficult. Consequently, the customers could purchase different automation solution components with redundant and duplicated functions, resulting in a waste of resources and limited interoperability. The proposed standard offers a reference interoperability framework for advanced process control and optimization. It is intended to maximize the integration and interoperability of automation solutions.

This document provides a consistent framework for integration and interoperability between APC-O systems, parts of an APC-O system, Level 2 automated process control systems, and Level 3 manufacturing operations management systems. It builds on the functional models defined by ISO 15746-1 by defining activity models for APC-O systems and the information exchange requirements needed to support those activity models. The modelled activities operate within Level 2 and Level 3 with interaction between each level.

It is not the intent of this document to suggest that there is only one way of implementing APC-O or to force users to abandon their current way of implementing APC-O.

The target users of this standard include: users and providers of advanced process control and optimization solutions, such as, project solution suppliers, automation systems integrators, production departments of companies, process engineers, independent software testing organizations, implementation and consulting service organizations of advanced process control and optimization software, and relevant government and academic organizations.

Automation systems and integration — Integration of advanced process control and optimization capabilities for manufacturing systems —

Part 2: Activity models and information exchange

1 Scope

This document defines:

— activity models to describe the dynamic aspects of the APC-O modules;

— information exchange requirements of the dynamic aspects of the APC-O modules;

— workflows and lifecycles of APC-O elements;

— service definitions to support the following information exchanges between:

  — Level 3 and APC-O components;

  — Level 2 and APC-O components;

  — APC-O components within one or more APC-O systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15746-1, *Automation systems and integration — Integration of advanced process control and optimization capabilities for manufacturing systems — Part 1: Framework and functional model*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15746-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org

3.1
alarm
notification regarding an abnormal condition of special significance to an *APC-O component* (3.2)

EXAMPLE A temperature controlled by an APC module exceeds a high limit or an input to a Soft Sensor module is outside the valid range.

3.2
APC-O component
procedural object in an APC-O system that is an instantiation of an APC-O functional module

Note 1 to entry: An APC-O component can execute various functions involving reasoning and communication with other APC-O components, interaction with simulation and optimization, diagnostic and forecasting, and control.

3.3
APC-O package
group of commercial software products supplied by a single vendor to deliver one or more APC-O functional modules

3.4
APC-O platform
computer-based system capable of managing and executing an APC-O system comprised of one or more *APC-O components* (3.2)

3.5
bias
adjustment made to a calculated value to force it to match actual measurements

Note 1 to entry: A bias is normally applied to account for unmeasured disturbances.

3.6
controlled variable
variable that a controller maintains either at a target or within minimum and maximum limits

Note 1 to entry: It accomplishes this by adjusting the *manipulated variables* (3.11).

3.7
disturbance variable
variable that a controller considers as influencing the *controlled variables* (3.6) but is not adjustable by the controller

3.8
event
detectable change or occurrence that changes the state of an *APC-O component* (3.2) or requires action by an APC-O component

EXAMPLE The mode of a PID loop associated with a *manipulated variable* (3.11) in an APC module changes to REMOTE or a process managed by an APC-O system changes state from “Producing” to “Shutdown”.

3.9
final control element
physical equipment that is actually moved to accomplish control of a process

EXAMPLE Valves, dampers, and variable speed drives.

3.10
hard limit
limit that a controller is not allowed to exceed under any circumstances

3.11
manipulated variable
variable that a controller adjusts

Note 1 to entry: These are typically setpoints of PID loops but could also be direct manipulation of a *final control element* (3.9).

3.12
performance baseline
evaluation and assessment of a set of key performance indicators for a process prior to implementing an APC-O system

Note 1 to entry: The intent is to evaluate performance of the APC-O system against the performance baseline.

3.13
rate of change limit
limit placed on the amount a value is allowed to change over a defined period of time

3.14
recipe
set of ingredients, product specifications, and process settings that define how to produce a product

3.15
soft limit
limit a controller should attempt to respect but may exceed if necessary

3.16
tracking
action of making the value of one parameter the same as the value of another parameter

EXAMPLE A PID controller may track the setpoint to the process value when it is in MANUAL mode.

3.17
trajectory
set of values, typically an array, representing expected behaviour over a defined time horizon

Note 1 to entry: In APC applications, the trajectory of a *manipulated variable* (3.11) is the set of moves planned by the controller and the trajectory of a *controlled variable* (3.6) is the expected changes based on those planned moves and recent history of process changes.

3.18
watchdog
function to determine if a component of the control system or an external system is functioning properly

Note 1 to entry: Typically, a watchdog function will perform some set of instructions if it determines the watched component is not functioning properly.

3.19
workflow
sequence of activities with explicit starting and ending points to describe a task

Note 1 to entry: Workflows may also have branches, decision points, and *events* (3.8). A workflow is a type of activity model.

4 Abbreviated terms

APC	advanced process control
APC-O	advanced process control and optimization
CV	controlled variable
DV	disturbance variable
KPI	key performance indicator
MPC	model predictive control

MV manipulated variable

OP output of a PID controller

OPC open platform communications

OPD object-process diagram

OPL object process language

OPM object process methodology

PID proportional, integral, derivative

SP Setpoint

5 APC-O workflow

5.1 Lifecycle concepts

The lifecycle of an APC-O system consists of the following phases:

a) Requirements Analysis

b) Design

c) Development

d) Execution

e) Support

Figure 1 illustrates the workflow of an APC-O system as it relates to the phases of the lifecycle. This and all subsequent illustrations are depicted using the object process methodology (OPM). Table 1 defines the OPM notations used in this document. Object process language (OPL) is the textual counterpart of the graphic OPM system specification. Example of OPL can be seen in Annex B.

Table 1 — OPM notation used

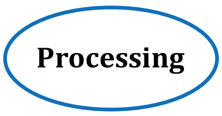
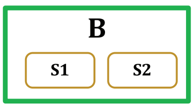
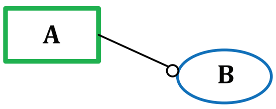
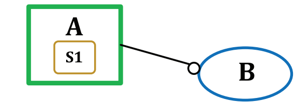
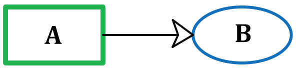
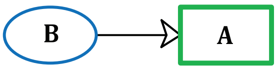
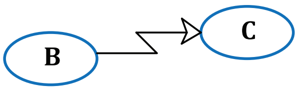
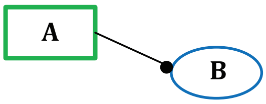
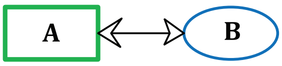
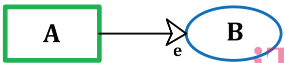
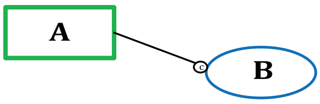
Symbol	Name	Description
	Object	An object is an item that exists or can exist once constructed, physically or informatically. Associations among objects shall constitute the object structure of the system being modelled, i.e. the static, structural aspect of the system.
	Process	A process is an item that expresses the behavioural, dynamic system aspect: how processes transform objects in the system and how the system functions to provide benefit. Processes complement objects by providing the dynamic, procedural aspect of the system.
	State	A state is a situation or position at which an object can exist for a period of time. Object B can be at states S1 or S2.
	Instrument Link	An instrument link is a procedural link that connects a process with an enabler of that process where the enabler is tools, data, etc. Object A enables Process B and Process B cannot happen if Object A does not exist.

Table 1 *(continued)*

Symbol	Name	Description
	Condition Link	A condition link is a procedural link that connects a process with an enabler of that process where the enabler is the state of an object. The process executes if and only if the object is in the certain state.
	Consumption Link	A consumption link is a link that connects a process with an object that is used by, or consumed, as a result of the occurrence of that process. Process B consumes Object A
	Result Link	A result link is a link that connects a process with an object that is constructed as a result of an occurrence of that process. Process B creates Object A.
	Invocation Link	Invocation links are procedural links between invoking processes and invoked ones. The invoking processes activate the invoked processes. Process B invokes Process C.
	Agent Link	Denotes that the object is a human operator. Activating the link triggers the process B.
	Effect Link	Process B changes the state of Object A; the details of the effect may be added at a lower level.
	Consumption Event Link	Existence or generation of object A will attempt to trigger process B. If B is triggered, it will consume A. Execution will proceed if the triggering failed.
	Condition Link	Existence of object A is a condition to the execution of B. If object A does not exist, then process B is skipped and regular system flow continues.

Note the Requirements Analysis and Design phases generally exchange information manually rather than making use of computer based or electronic interfaces. Therefore, this standard only addresses the Development, Execution, and Support phases as illustrated in Figure 1. Figure 1 indicates out of scope processes and objects with a dashed line and in scope processes and objects with a solid line.

Different tools are typically used for each phase due to the different functional requirements of the separate phases. Therefore, this document will describe the Development, Execution, and Support lifecycle phases as separate systems with integration interfaces between them.

ISO 15746-1 identified four functional modules within an APC-O system as Soft Sensor, Advanced Process Control, Optimization, and Performance Assessment. The workflow for any phase is similar for these four functional modules, but not identical. As a result, some commercial APC-O products include completely separate software tools for developing, executing, and supporting the four functional modules while others are well integrated internally. The integration interfaces defined in this standard will facilitate integration between different commercial APC-O products and between APC-O and non-APC-O systems. It does not intentionally favour any particular level of internal integration.

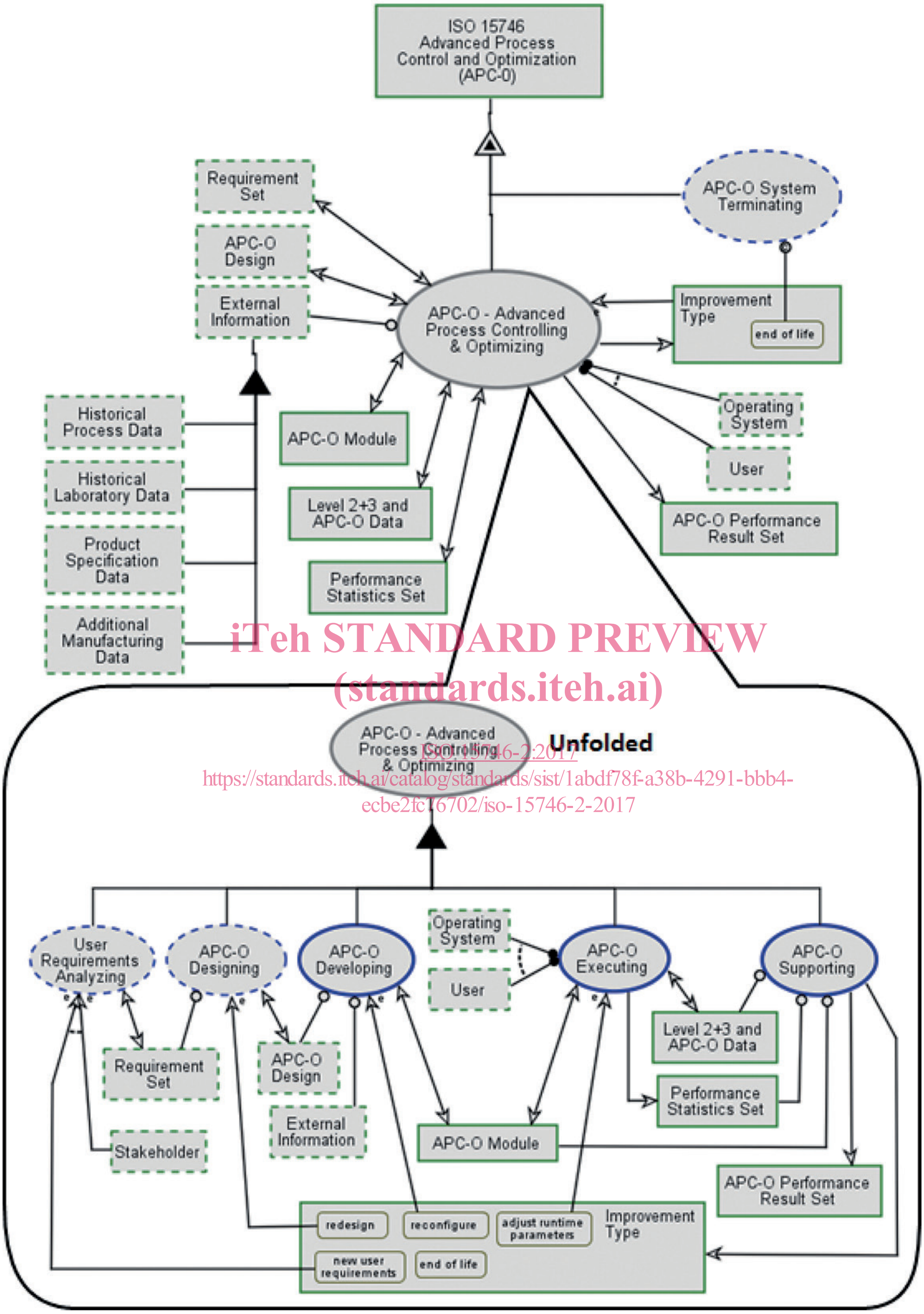


Figure 1 — APC-O Lifecycle Workflow

5.2 Development phase

The Development phase consists of the workflow illustrated in Figure 2. APC-O modules are comprised of one or more components performing specific functions, or jobs. These individual components may be constructed individually then assembled to create the complete APC-O module.

External interfaces used by the Development phase include non-APC-O information models. These could be global resource locators for any level or manually transferred information describing the various systems the APC-O application is expected to interface with in the Execution and/or Support phases.

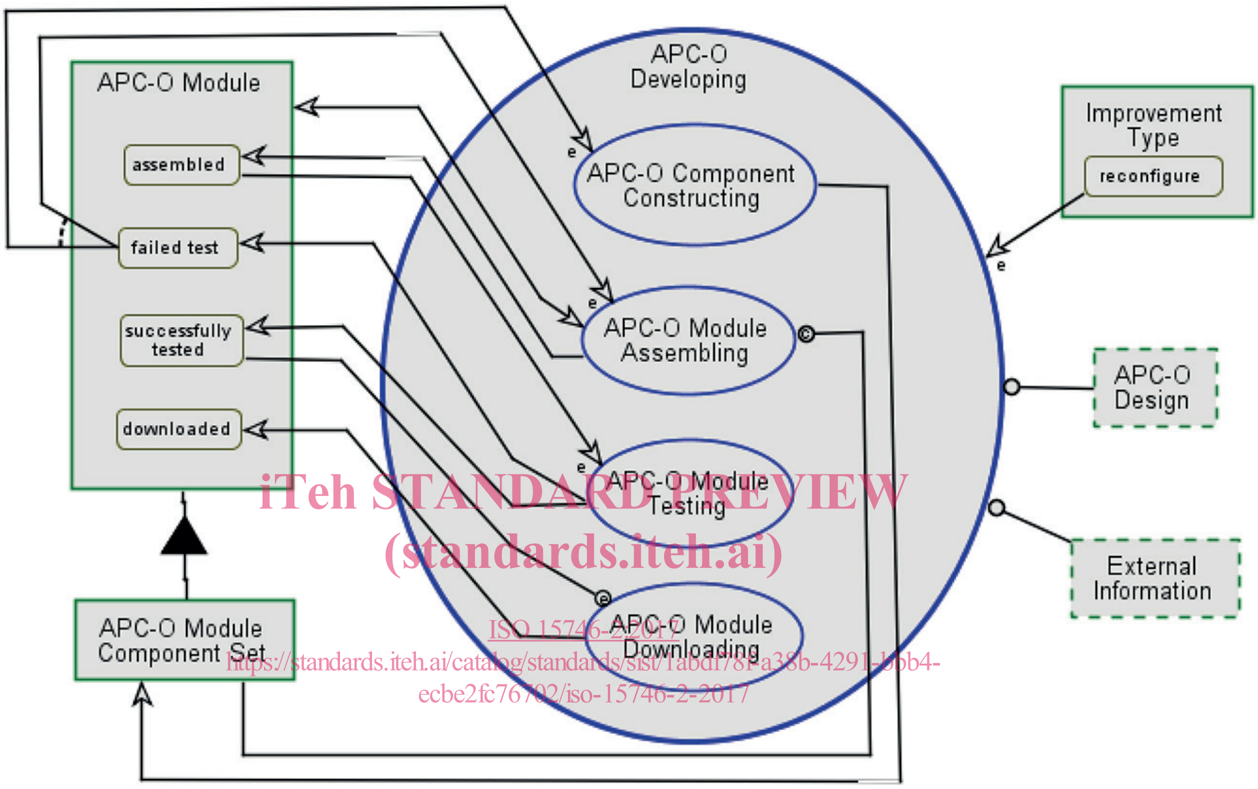


Figure 2 — Workflow of the Development Phase

The Development phase also interacts with historical data from various levels, for example:

— Product specifications

— Historical process data

— Historical laboratory results

— Manufacturing costs

The Development phase shall interact with APC-O systems in the Execution and Support phases by providing APC-O module definitions. These could be new definitions or modifications of existing definitions. Activities in the Development phase may be initiated by completion of the Design phase or by the Support phase signalling improvement of an APC-O system is needed.

5.3 Execution phase

5.3.1 Execution workflow

The Execution phase consists of the workflow illustrated in Figure 3.

Generic activities are defined rather than detailing each functional module separately. While there are differences between the modules as to how these activities are performed, those differences are not relevant to this standard. Furthermore, the details of the Execution phase workflow will differ from one commercial APC-O package to another but those differences are not relevant to this standard. For simplicity, a simple, single-threaded system is used to illustrate the Execution phase workflow. Some commercial packages are designed this way but there are also commercial packages that use fully asynchronous processing and even highly distributed processing.

Figure 3 illustrates APC-O components executing in a continuous loop controlled by a “schedule tasks” process that is only activated if the runtime state of the APC-O module is “running”. As shown in the Development phase, an APC-O module comprises one or more component. In the Execution phase, APC-O components may be updated individually as shown in Figure 3 or the entire module could be updated at one time.

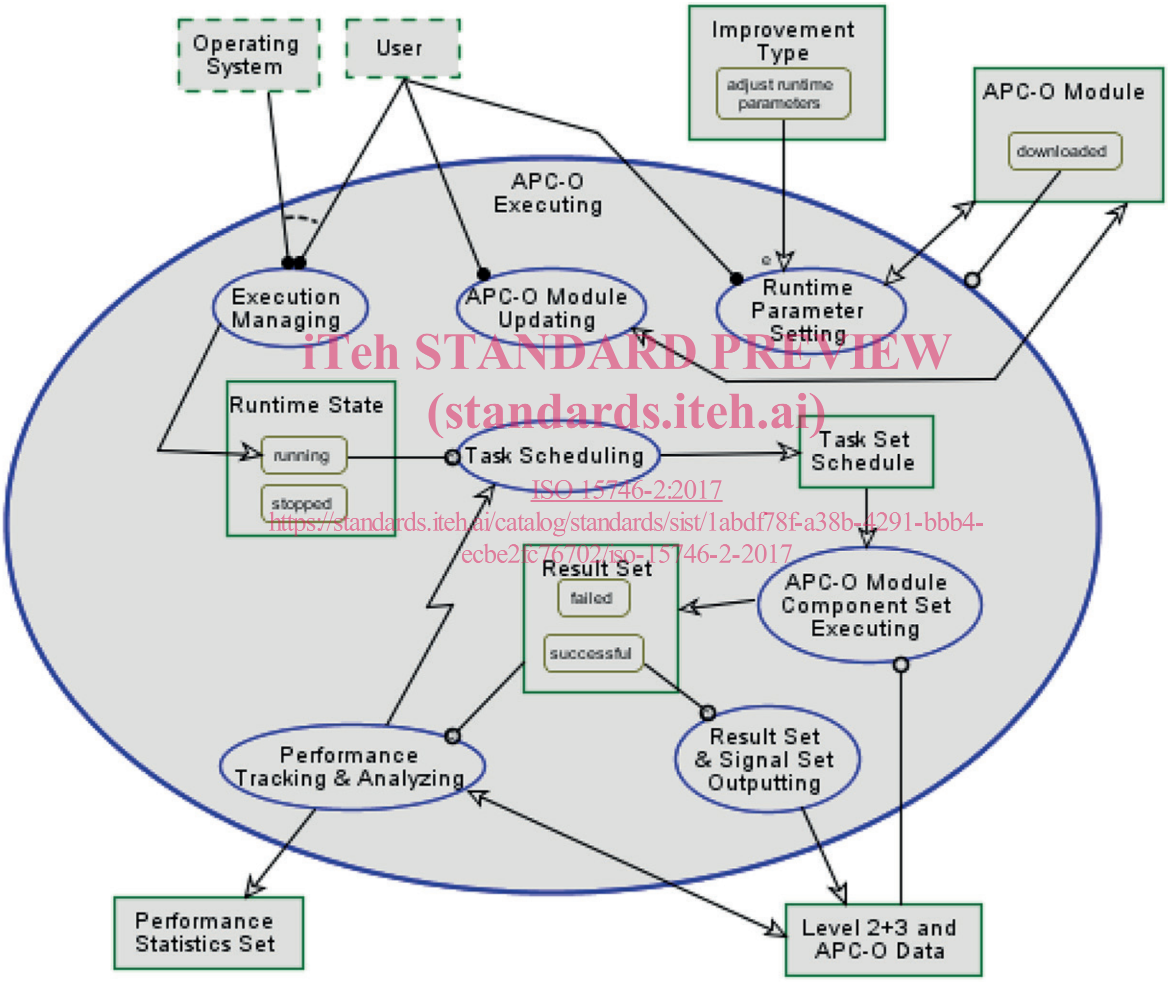


Figure 3 — Workflow of the Execution Phase

The following non-APC-O interfaces to the Execution phase are identified here and described in detail in Clause 6:

a) Level 2 Information Exchange for data such as:

   1) PID Loop parameters

   2) Final control elements settings such as valve positions and drive speeds

   3) Process measurements from instruments such as flow and temperature sensors

4) General control system tag values

5) Alarm and event signals

b) Level 3 Information Exchange for data such as:

1) Product specifications

2) Recipe based process settings

3) Laboratory results

4) Manufacturing costs

The following interfaces between APC-O Components are also identified here and described in detail in Clause 6:

a) APC-O Information Exchange, for example:

1) APC-O data, alarms, and events

2) APC-O performance statistics

3) Execution requests and results

4) APC-O Module Definitions

5.3.2 Distributed APC-O system

Figure 4 illustrates how distributed APC-O components interact. In the example system, six APC-O modules interact to perform several interrelated functions. The six modules are identified as:

— Module 1 – a soft sensor providing one or more data elements for Module 3

— Module 2 – a second soft sensor, different from Module 1, providing one or more data elements for Module 3

— Module 3 – an APC module performing advanced control functions on a manufacturing process wholly within a level 2 environment

— Module 4 – an APC module performing advanced control functions on a manufacturing process in a way that affects the manufacturing process itself in level 2 and also one or more MOM functions in level 3

— Module 5 – an optimization module performing process optimization functions wholly within a level 3 environment

— Module 6 – a performance assessment module analysing, tracking, and reporting performance of modules 1 - 5

Various interactions between modules are illustrated in Figure 4. Modules 1 and 2 simply provide data for Module 3 in a similar manner as physical instruments installed on the manufacturing process. Module 3 also consumes one or more outputs from Module 4. These outputs could be setpoints written from manipulated variables in Module 4 and used as targets for controlled variables in Module 3. Likewise, Module 4 consumes one or more outputs from Module 5. Since Module 5 is an optimization module, a good example would be targets for controlled variables in Module 4 where these targets are determined by Module 5 to be the optimum targets based on business objectives as gathered from various MOM systems at level 3.