ISO TC 184/SC4 STANDING DOCUMENT

**Technical Committee 184 for Industrial Automation Systems and Integration
Subcommittee 4 for Industrial Data**

Guidelines for the development and approval of STEP application protocols

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

This standing document was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC4, *Industrial data*.

ISO/TC 184/SC4 standards are prepared according to guidelines put forth in the following standing documents:

— Guidelines for application interpreted construct development;

— Guidelines for application interpreted model development;

— Guidelines for the development and approval of STEP application protocols;

— Guidelines for the development of abstract test suites;

— Guidelines for the development of mapping tables;

— ISO/TC 184/SC4 organization handbook;

— Supplementary directives for the drafting and presentation of ISO 10303.

Introduction

ISO 10303 is an International Standard for the computer-interpretable representation and exchange of product data. The objective is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product independent from any particular system. The nature of this description makes it suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and archiving.

This International Standard is organized as a series of parts, each published separately. The parts of ISO 10303 fall into one of the following series: description methods, integrated resources, application interpreted constructs, application protocols, abstract test suites, implementation methods, and conformance testing. The series are described in ISO 10303-1.

The purpose of this document is to provide methods and procedures for the development of application protocols for ISO 10303, *Industrial automation systems and integration - Product data representation and exchange*, commonly known as STEP.

A fundamental concept of ISO 10303 is the definition of application protocols (APs) as the mechanism for specifying information requirements and for ensuring reliable communication. An application protocol is a part of ISO 10303 that defines the context, scope, and information requirements for designated application(s) and specifies the STEP resource constructs used to satisfy these requirements.

Background

ISO 10303 has been designed to support an extensive domain of product data communication requirements, i.e., all product data necessary to completely define any product for all applications over the product's entire life cycle. With the broad scope and complexity of ISO 10303, the implementation of the entire International Standard by any one organization is unlikely. At the June 1989 meeting, ISO TC 184/SC4 established the following working policy for developing application protocols:

"The practical implementation of the STEP standard to support data exchange for a particular application shall not require the use of every STEP entity. In addition, STEP entities may be constrained within the context of a particular application context, in terms of use or understanding."

An additional objective of ISO 10303 is to support conformance testing of implementations. A mechanism was needed for specifying: 1) the resource constructs required for information exchange within a defined application and 2) the requirements for conformance testing of implementations of these constructs. Based on the Open Systems Interconnection (OSI) concept of protocols [1] and the information communication methods developed for the Initial Graphics Exchange Specification (IGES) [2], the application protocol methodology was developed.

For the use of STEP within a particular application context, an application protocol shall provide the information required for practical implementation. This shall include:

— the definition of the application context, scope, and functional requirements;

— the definition of the application information requirements;

— the required use of the STEP integrated resource constructs to support the application information requirements;

— the specification of levels of conformance for evaluating implementations of the AP.

The STEP integration framework and the role of application protocols

The STEP integration framework [3] establishes an explicit architecture for the conceptual models that are part of ISO 10303. This architecture provides the structure for the integrated resources and application protocols. The integrated resources provide constructs that are independent of a specific product data application context. These constructs are used for developing the application interpreted models of application protocols [4] [5].

Application protocols employ three types of information models: an application activity model, an application reference model, and an application interpreted model. The models are application context-dependent.

— Application activity model (AAM): A model that describes the activities and processes that use and produce product data in a specific application context. The AAM shall be defined in IDEF0, a formal activity modelling language [6].

— Application reference model (ARM): A model that defines terminology within the application context and specifies conceptual structures and constraints used to describe the information requirements of an application. The ARM shall be documented in a formalized modelling, either EXPRESS-G [7] or IDEF1X [8]. An EXPRESS-G model may be supplemented with the corresponding EXPRESS listing. Each information requirement shall be documented as a normative definition.

— Application interpreted model (AIM): A model of selected integrated resources which are constrained, specialized or completed to satisfy the information requirements of the ARM. The AIM shall be defined in EXPRESS and EXPRESS-G (a graphical subset of EXPRESS) [7].

Principles of application protocols

The following principles guide the AP development process:

— ISO 10303 is defined in a collection of parts that include integrated resources, application protocols, application interpreted constructs, and abstract test suites. The integrated resources are available for conforming implementations through an AP. Integrated resource constructs are interpreted in an AIM by:

a) specifying global rules, for example, to modify optional attributes of entities to be non-existent or mandatory, or to constrain entity behavior and entity interactions;

b) specifying subtypes of an entity to specialize the meaning of an attribute, localize a constraint on an entity within the reference path defined by an attribute or define a behavioral constraint on the subtyped entity.

— The AIM specifies implementable constructs of a specific AP. The AAM and the ARM provide the context and requirements for the AIM. The AIM is a required normative clause of an AP. The AAM and the ARM are required informative annexes of an AP.[1] This principle of specifying the application semantics in the ARM and mapping the application semantics to the integrated resources is explained in clause 5 of this document.

— The definition of an AIM is consistent with the semantics of the integrated resources and maintains the application semantics documented in clause 4 of the AP.

— APs specify the data content and levels of conformance for standardized implementations of ISO 10303. This is explained in 5.5.

— There will inevitably be some overlap between APs. Whenever a resource construct(s) is interpreted to represent the same information requirement in different APs, the same interpretation of the resource construct(s) is used.

— APs shall be developed, documented, reviewed and approved in accordance with the specifications provided in the *SC4 quality handbook* [9].

— The AP development process will deliver APs with the following characteristics:

a) Appropriate scope of the AP: An AP scope is well-defined, self-contained, and satisfies an international industrial need.

b) Consistent usage of the integrated resource constructs: All APs use the integrated resource constructs consistently. If two APs have the same information requirement, these APs use the same resource constructs for the common requirements. Shared specifications are stored in a library of standardized application interpreted constructs (AICs).

The reuse of interpreted constructs provides the mechanism for ensuring that the relevant product data can be exchanged between APs and allows for interoperable APs. This library of shared application interpreted constructs (AICs) is used as an additional resource for defining the AIMs of APs.

c) Testability: APs specify levels of conformance for conformance testing of AP implementations. A standard abstract test suite for each AP is documented as a Technical Report part of ISO 10303. Requirements of an abstract test suite are specified in *Guidelines for the development of abstract test suites*.

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[1] A normative element of an ISO standard defines provisions with which it is necessary to comply in order to be able to claim conformity with the standard. An informative annex is a supplementary element of an ISO standard that provides additional information intended to assist the understanding or use of the standard.

Guidelines for the development and approval of STEP application protocols

1 Scope

This standing document specifies the components of an ISO 10303 AP and provides the guidelines for developing and approving ISO 10303 APs.[2] The introduction provides a general overview of the STEP project and the fundamental principles of APs. Clause 3 defines the terms relevant to the development of APs. Clause 4 describes the contents of an AP. Clause 5 provides a detailed description of the process and responsible agents for developing and reviewing an AP. Clause 6 explains the process for approving an AP within ISO TC 184/SC4.

The following are within scope of this standing document:

— description of the contents of an ISO 10303 application protocol;

— description of the development and review process for an ISO 10303 application protocol;

— guidance on preparation of an application protocol project proposal;

— description of the application protocol validation process and the contents of an AP validation report;

— description of the application protocol approval process;

— a template for an application protocol development schedule.

The following are outside the scope of this standing document:

— specification of presentation information for the documentation of any portion of an ISO 10303 application protocol;

NOTE 1 - This information is found in *Supplementary directives for the drafting and presentation of ISO 10303*.

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[2] The AP development process is subject to refinement. These guidelines will be updated as these refinements are approved by the SC4 Working Groups and SC4.

— detailed guidance on how to select constructs of the ISO 10303 integrated resources that map to the information requirements of an ISO 10303 application protocol;

NOTE 2 - This information is planned to be covered in greater detail in a forthcoming document entitled *Procedures for application interpretation*[10].

— detailed guidance on the development of mapping tables for ISO 10303 application protocols;

NOTE 3 - This information is covered in greater detail in *Guidelines for the development of mapping tables.*

— guidance on the use of EXPRESS in ISO 10303 application reference models and application interpreted models.

NOTE 4 - The EXPRESS language is described in ISO 10303-11. *Guidelines for application interpreted model development* provides EXPRESS usage guidance in the context of application interpreted model development.

2 Normative references

The following standing documents and standards contain provisions which, through reference in this text, constitute provisions of this standing document. At the time of publication, the editions indicated were valid. All standing documents and standards are subject to revision, and parties to agreements based on this standing document are encouraged to investigate the possibility of applying the most recent editions of the standing documents and standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/TC 184/SC4 N532:1997, *Guidelines for application interpreted model development.*

ISO/TC 184/SC4 N533:1997, *Guidelines for the development of mapping tables.*

ISO/TC 184/SC4 N534:1997, *Guidelines for application interpreted construct development.*

ISO/TC 184/SC4 N536:1997, *Guidelines for the development of abstract test suites.*

ISO/TC 184/SC4 N537:1997, *Supplementary directives for the drafting and presentation of ISO 10303.*

3 Terms, definitions, and abbreviations

3.1 Terms defined in ISO 10303-1

For the purpose of this standing document, the following terms defined in ISO 10303-1 apply [11].

3.1.1
abstract test suite (ATS)

a part of this International Standard (ISO 10303) that contains the set of abstract test cases necessary for conformance testing of an implementation of an application protocol.

3.1.2
application
a group of one or more processes creating or using product data.

3.1.3
application activity model (AAM)
a model that describes an application in terms of its processes and information flows.

3.1.4
application interpreted model (AIM)
an information model that uses the integrated resources necessary to satisfy the information requirements and constraints of an application reference model, within an application protocol.

3.1.5
application object
an atomic element of an application reference model that defines a unique application concept and contains attributes specifying the data elements of the object.

3.1.6
application protocol (AP)
a part of this International Standard (ISO 10303) that specifies an application interpreted model satisfying the scope and information requirements and constraints of a specific application.

> NOTE 1 - This definition differs from the definition used in open system interconnection (OSI) standards. However, since this International Standard is not intended to be used directly with OSI communications, no confusion should arise.

3.1.7
application reference model (ARM)
an information model that describes the information requirements and constraints of a specific application context.

> NOTE 2 - The application reference model employs application-specific terminology and rules familiar to experts in the application.

3.1.8
conformance class
a subset of an application protocol for which conformance may be claimed.

3.1.9
data
a representation of information in a formal manner suitable for communication, interpretation, or processing by human beings or computers.

3.1.10
data exchange

the storing, accessing, transferring, and archiving of data.

3.1.11
implementation method
a part of this International Standard (ISO 10303) that specifies a technique used by computer systems to exchange product data that is described using the EXPRESS data specification language [7].

3.1.12
information
facts, concepts, or instructions.

3.1.13
information model
a formal model of a bounded set of facts, concepts, or instructions to meet a specified requirement.

3.1.14
integrated resource
a part of this International Standard (ISO 10303) that defines a group of resource constructs used as a basis for product data.

3.1.15
interpretation
the process of adapting a resource construct from the integrated resources to satisfy a requirement of an application protocol. This may involve the addition of restrictions on attributes, the addition of constraints, the addition of relationships among resource constructs and application constructs, or all of the above.

3.1.16
PICS proforma
a standardized document in the form of a questionnaire, which, when completed for a particular implementation, becomes the protocol implementation conformance statement (PICS).

3.1.17
product
a thing or substance produced by a natural or artificial process.

3.1.18
product data
a representation of information about a product in a formal manner suitable for communication, interpretation, or processing by human beings or by computers.

3.1.19
product information
facts, concepts, or instructions about a product.

3.1.20
protocol implementation conformance statement (PICS)
a statement of which capabilities and options are supported within an implementation of a given standard. This statement is produced by completing a PICS proforma.

3.1.21
resource construct
a collection of EXPRESS language entities, types, functions, rules and references that together define a valid description of an aspect of product data.

3.1.22
unit of functionality (UoF)
a collection of application objects and their relationships that defines one or more concepts within the application context such that the removal of any component would render the concepts incomplete or ambiguous.

> NOTE 3 - UoFs are a mechanism for modularising the information requirements of the AP into primary concepts. The UoFs are also used as modules for defining conformance classes.

3.2 Terms defined in ISO 10303-31

For the purpose of this standing document, the following terms defined in ISO 10303-31 apply [12].

3.2.1
abstract test case (ATC)
a specification, encapsulating at least one test purpose, that provides the formal basis from which executable test cases are derived. It is independent of both the implementation and the values.

3.2.2
abstract test method
the description of how an implementation is to be tested, given at the appropriate level of abstraction to make the description independent of any particular implementation of testing tools or procedures, but with sufficient detail to enable these tools and procedures to be produced.

3.2.3
conformance testing
the testing of a candidate product for the existence of specific characteristics required by a standard in order to determine the extent to which that product is a conforming implementation.

3.2.4
test purpose
a precise description of an objective which an abstract test case is designed to achieve.

3.3 Terms defined in ISO 10303-202

For the purpose of this standing document, the following terms defined in ISO 10303-202 apply [13].

3.3.1
application interpreted construct (AIC)
a logical grouping of interpreted constructs that supports a specific function for the usage of product data across multiple application contexts.

3.4 Other definitions

For the purpose of this standing document, the following terms apply.

3.4.1
application context
a frame of reference based on a group of one or more processes that create or use product data.

3.4.2
application protocol validation
the process of evaluating a candidate AP and its components, e.g., ARM and AIM, to determine whether these satisfy the specified scope and requirements for the AP.

3.4.3
construct
a data modelling structure that represents the semantics of a concept.

3.4.4
data planning model
a model that describes the primary concepts of an application domain and the relationships among the concepts.

3.4.5
fitness testing
the determination of whether or not a model, e.g., AAM, ARM, or AIM, is useful in a particular context.

3.4.6
integrity testing
testing that demonstrates when a model, e.g., ARM or AIM, is syntactically correct and self-consistent.

3.4.7
planning model
a model that illustrates the primary concepts of the application domain and the general relationships among the major concepts. The planning model does not describe the relationships, e.g. meaning, cardinality, or direction. The planning model provides an overview of the scope of the AP.

> NOTE 4 - The planning model included in the Introduction of an AP shall illustrate the general relationships among its major concepts or units of functionality and shall not be used to fully describe the relationships.

3.4.8
test model
a specification of an example product model, e.g., design and surface finish specification for a gear, which is structured to support the incremental testing of the information models of an AP, e.g., ARM, AIM, and implementations of the AP. The test model shall include sufficient detail to populate the relevant objects, attributes, relationships, and assertions of an information model.

3.4.9
usage scenario
a specification of a sequence of industry events which create, access, modify, or exchange some portion of the product data considered for inclusion in the scope of an application protocol. The usage scenario includes the description of the types of information used in the events, the tasks and objectives of each event, and the roles executed by software tools and humans before, during or after the events.

3.4.10
usage test
a specification of the usage scenario, test model, test purposes, test queries, and verdict criteria for assessing an information model or an implementation of an AP.

3.4.11
validation
the process of evaluating a system or component to determine whether it satisfies specified requirements.

3.5 Abbreviations

For the purposes of this standing document, the following abbreviations apply.

AAM	application activity model
AIC	application interpreted construct
AIM	application interpreted model
AP	application protocol
ARM	application reference model
ATC	abstract test case
ATS	abstract test suite
Cax	computer-aided systems, including computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), computer integrated construction (CIC), and computer integrated manufacturing (CIM)
CD	Committee Draft
DIS	Draft International Standard
FDIS	Final Draft International Standard
ICAM	integrated computer-aided manufacturing
IDEF0	ICAM definition language 0

IDEF1X   ICAM definition language 1 extended

IS   International Standard

ISO   International Organization for Standardization

IUT   implementation under test

JWG9   Joint Working Group 9, Electrical/Electronics Applications [14]

NWI   New Work Item

OSI   Open Systems Interconnection

PICS   protocol implementation conformance statement

PPC   Policy and Planning Committee (for ISO TC 184/SC4) [14]

QC   Quality Committee

SC   ISO Sub-committee

SC4   Sub-committee 4 of ISO Technical Committee 184 [14]

STEP   Standard for the Exchange of Product Model Data (ISO 10303)

TC   ISO Technical Committee

TC 184   ISO Technical Committee 184

UoF   unit of functionality

WG   working group

WG2   Working Group 2, Part Libraries [14]

WG3   Working Group 3, Product Modeling [14]

WG8   Working Group 8, Industrial Manufacturing Management Data [14]

WG10   Working Group 10, Technical Architecture [14]

WG11   Working Group 11, EXPRESS Language, Implementation Methods, and Conformance Methods [14]

WG12   Working Group 12, Common Resources [14]

4 Contents of a STEP application protocol

This clause provides an overview of the contents of an application protocol. The contents for a STEP AP are given in Table 1 and are explained in the subsequent subclauses. The four major components of an AP are: 1) the scope, application activity model, and functional requirements; 2) the application reference model as a representation of the application domain information requirements; 3) the application interpreted model that specifies the required use of the STEP integrated resource constructs, and 4) conformance requirements for implementations of the AP.

Table 1 - Contents of a STEP application protocol

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The AP development process starts with the definition of the application context, the proposed scope of the AP, and an application activity model. The application context is defined by the types of products and types of product information to be supported by the AP, the business process activities and functions that create, use or modify relevant product information, the stages in the life cycle of the product(s) to be investigated, and the disciplines, e.g., mechanical engineering, that create, use or modify relevant product information.

The application context, the scope of the AP, and the application activity model are used for identifying the information requirements of the application protocol and documenting them in an application reference model. The semantics of the application reference model are documented in clause 4 of the AP as definitions for application objects and application assertions. The application reference model and clause 4 are then used to select constructs from the integrated resources and identify constraints or specializations of entities for describing the application information in an application interpreted model.

An AP issues log and an AP validation report shall be maintained by the AP project and are required for the successful qualification of the AP and the approval of the AP by SC4. The issues log summarizes the discussions and resolutions of technical issues raised during the development of the AP. The validation report documents how the components of the AP were successfully validated to ensure that the AP fulfills the documented scope and requirements. The issues log and validation report are used in the AP review and ballot process, but they do not become part of the International Standard. Insights and explanations includedin the issues log and validation report are used to develop the AP implementation and usage guide. There shall be no open technical issues in the issues log when the AP is submitted to QC for approval for DIS ballot. There shall be no open issues (technical or editorial) in the issues log when the AP is submitted to QC for approval for FDIS ballot. An abstract test suite (ATS) shall be available for each application protocol of ISO 10303.[3] Each standard abstract test suite shall be a separate part of 10303 and shall be referenced by the corresponding application protocol as a normative reference.[4]

Detailed requirements for documenting APs, including any required text, are provided in the Supplementary directives for the drafting and presentation of ISO 10303. Detailed assessment criteria for evaluating the quality of an AP are provided in the *SC4 procedures for internal review* [15].

The Introduction for the AP shall provide an overview of the technical content and explain how the AP can be used for industrial activities. The Introduction should include a planning model that provides a high level description of the concepts supported by the AP. This model shall have boxes with the concepts named and lines connecting those concepts that have some relationship. The planning model does not describe the relationships, e.g. meaning, cardinality, or direction. For APs which are designed as part of a suite of harmonized APs, the Introduction shall explain the overlaps and interfaces between the APs. The planning model may be used to illustrate these overlaps and interfaces.

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[3] Refer to *Guidelines for the development of abstract test suites*.

[4] For the committee draft (CD) ballot(s) of an AP, the ATS is not required.

4.1 Scope

Clause 1 of an AP shall define the domain of the AP and summarize the fundamental concepts and assumptions of the scope, the functionality of the AP, and the types of information that are accommodated by the AP. A description of the functionality and information that are specifically outside the scope of the application shall be defined to clarify the domain of the AP.

This clause shall define the following characteristics of the scope of the application:

— type of product;

— types of product data;

— stages in the product life cycle supported;

— uses of the product data, e.g., functional processes, supported;

— discipline views of the product supported;

— exclusions from scope for the purpose of clarification.

The scope definition shall be supported by an application activity model (AAM), provided as annex F and may reference a planning model provided in the Introduction. The scope description shall reference the application activity model (annex F).

4.2 Normative references

All normative references shall be listed in clause 2 of an AP. The minimal required set of normative references are:

ISO 10303-1:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles.*

ISO 10303-11:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual.*

ISO 10303-31:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 31: Conformance testing methodology and framework: General concepts.*

ISO 10303-41:1994, *Industrial automation systems and integration — Product data representation and exchange — Part 41: Integrated resources: Fundamentals of product description and support.*

4.3 Definitions and abbreviations

Clause 3 of an AP shall include definitions of all concepts necessary to understand the Introduction, Scope, and Information requirements clauses. This clause may include concepts that are defined further in the Information requirements clause. The concept definitions provided in this clause shall be consistent with the complete definitions provided in the Information requirements clause.

This clause shall contain at least three subclauses: list of terms defined in ISO 10303-1 and used in the AP, terms defined in the AP, and abbreviations and symbols used in the AP. This clause shall not include the definitions of objects defined in the application interpreted model. This clause shall list the terms defined in other ISO standards that are necessary for understanding the AP.

4.4 Information requirements

Clause 4 of an AP shall describe the functionality and information requirements of the AP. The first paragraphs of this clause provide a high level description of the information requirements that are supported by the AP and a summary of the structure used to partition the information requirements. This clause may include a description of the types of products supported by the AP, any restrictions on product classes supported, and the supported uses of the defined information. These information requirements may be organized by the product types, life cycle phases, or application views supported by the AP. This clause shall provide all additional information on the fundamental concepts and assumptions (initially introduced in clauses 1 and 3) which is necessary for complete understanding of the information requirements and the scope boundaries.

This clause may include a data planning model which describes the primary concepts of the ARM and the relationships among the concepts. The planning model is at a high level of abstraction and does not include details such as cardinalities of relationships. The planning model follows no specific methodology. The data planning model may include the UoFs of the AP and is used to introduce the detailed requirements provided in clause 4. This clause shall include a note that refers the reader to the application activity model (annex F) and to the application reference model (annex G) to explain the relevance and roles of the required information.

This clause shall include subclauses for units of functionality (UoFs), application objects, and application assertions.

4.4.1 Units of functionality

Clause 4.1 of an AP shall specify a list of the UoFs defined in the AP and the definition of each UoF. A UoF is a grouping of data constructs which is important in the application context. A UoF specifies the set of application objects that constitute one or more concepts of the application reference model. UoFs are a mechanism for modularising the information requirements of the AP into primary concepts. The UoFs are used to organize and summarize the functionality of the ARM. The UoFs are also used as modules for defining conformance classes. Each UoF definition shall include the scope of the UoF, a description of the function(s) that the grouping of data is intended to support, and a list of the application objects and assertions that are included in each UoF.

4.4.2 Application objects

Clause 4.2 of an AP shall include the definitions for all application objects and attributes supported by the AP. An application object is an atomic element of an application reference model that defines a unique application concept and contains attributes specifying the data elements of the object.

4.4.3 Application assertions

Clause 4.3 of an AP shall specify all relationships among application objects, the cardinality of the relationships, and the rules required for the integrity and validity of the application objects and UoFs (see 5.3).

4.5 Application interpreted model

Clause 5 of an AP shall specify the application interpreted model. The AIM shall be defined in the EXPRESS language and is constructed from the resource constructs using the EXPRESS interfacing mechanism (USE FROM) defined in ISO 10303-11. Needs for refinement of the resource constructs arises from the information requirements supplied by the particular application.

4.5.1 Mapping table

Clause 5.1 of an AP shall specify the mapping table. The mapping table documents the correspondence between the information requirements and the constructs of the AIM. This mapping table shall specify a complete and unambiguous mapping between the application objects and assertions defined in the information requirements clause and the constructs of the AIM. The mapping shows how the integrated resource constructs are used to meet the information requirements of the application.

4.5.2 AIM EXPRESS short listing

Clause 5.2 of an AP shall specify the AIM EXPRESS short listing. The AIM EXPRESS short listing shall consist of USE FROM statements that select resource constructs and AICs, AP specific declarations, and any appropriate modifications to textual material that applies to constructs imported into the AIM schema from the integrated resource parts of ISO 10303. The declarations include TYPE declarations, ENTITY declarations that create subtypes of resource entities, and any necessary RULES, FUNCTIONS, and PROCEDURES that are required to satisfy the information requirements. Any declarations of entities, rules, functions, and procedures specific to the AP are fully documented in the AIM EXPRESS short listing. Textual modifications include:

— clarification of application specific interpretation of the meaning of a generic entity definition;

— clarification of application specific interpretation of the meaning of one or more attributes;

— specification of application specific informal propositions;

— specification of all associated global rules defined in the AP;

— addition of application specific examples and notes;

— specification of text in the resource part that is to be rendered inapplicable in the AIM.

4.6 Conformance requirements

Clause 6 of an AP shall specify the conformance requirements an implementation shall satisfy. Only those aspects that are stated as conformance requirements in this clause, or referenced through this clause, are requirements for conformance to this part of ISO 10303.

A subclause describing conformance classes shall be included for APs that specify conformance classes. Conformance to a particular conformance class requires that all AIM entities, types, and associated constraints defined as part of that class shall be supported.

4.7 Annexes

A AIM EXPRESS expanded listing (normative)

This annex shall contain the AIM EXPRESS expanded listing. The AIM EXPRESS expanded listing is based on the AIM EXPRESS short listing (5.2) and contains the complete listing of the AIM EXPRESS. The expanded listing contains the results of the application of all USE FROM statements in the short listing with copies of the corresponding EXPRESS specifications from the integrated resources and the AICs.

B AIM short names (normative)

This annex shall contain a correspondence list between the entities used in the AIM and the short names. This list is derived from the short names specified in the integrated resources together with the short names for entities introduced in the AP.

C Implementation method specific requirements (normative)

This annex shall contain additional requirements for the specified implementation methods. For example, an AP to be used with ISO 10303-21, requires the schema name of the AP to be specified in the header section of a file. The required schema name for the header section would be specified in annex C of the AP.

The implementation method specific requirements shall be in addition to those listed in the AP's conformance requirements clause. This annex may specify the meaning of values not given in the normative clauses. If no implementation specific requirements are specified, this fact shall be stated in this annex.

D Protocol Implementation Conformance Statement (PICS) proforma (normative)

This annex shall contain the PICS proforma that explicitly defines the implementation flexibility, if any, allowed by the application protocol specification. The PICS proforma is given in the form of a questionnaire to be completed by the supplier or implementor of an implementation of the AP before it undergoes conformance testing. The PICS proforma shall cover all optional functions, preparation procedures for the conformance assessment process, parameters, and other capabilities identified in the AP. The completed questionnaire shall be used by conformance testing laboratories for abstract test case selection and parameterization.

E Information object registration (normative)

This annex shall specify the information object identifiers (as defined in ISO 8824-1) for the application protocol. This shall include identifiers for the AP document and for the AIM schema.

F Application activity model (informative)

This annex shall contain the application activity model (AAM) that provides a representation of the application context of the AP and of the activities which use product data in the application context. AAMs are mechanisms for scoping the information requirements for individual APs and for planning the development of nested APs. The AAM shall be represented in IDEF0 [6].

The AAM includes the definition of the inputs, controls, outputs, and some of the mechanisms of those activities. Only those mechanisms that are organization and enterprise independent shall be included.

The first paragraphs of this annex shall explain the context of the AAM and summarize the assertions on which the AAM is based. The definitions for all activities and information flows in the AAM shall be provided in annex F.1, and the IDEF0 diagrams shall be provided in annex F.2.

G Application reference model (informative)

This annex shall contain the application reference model (ARM) that is a formal model of the information requirements and constraints of the application context as defined by the scope and the AAM. The ARM provides the basis for specifying the application objects and assertions in clause 4 of the AP.

The first paragraphs of this annex shall summarize the scope of the ARM. The ARM uses application-specific terminology and rules familiar to an expert from the application context. The ARM is independent of any physical implementation. The ARM shall be documented by use of a formal modelling language, i.e., EXPRESS [7], EXPRESS-G, or IDEF1X [8]. The ARM, together with the AAM and the scope statement, shall be sufficient for a person familiar with the application to understand the AP domain.

H AIM EXPRESS-G (informative)

This annex shall contains the EXPRESS-G representation of all entities in the AIM. This representation shall be documented in accordance with annex D of ISO 10303-11 and the *Supplementary directives for the drafting and presentation of ISO 10303*.

J Computer interpretable listings (informative)

This annex shall contain a URL referencing the entire AIM EXPRESS listing without comments or embedded references. Tail comments identifying the source parts of ISO 10303 shall be included. There shall also be a URL provided that references the short names.

K ARM EXPRESS listing (optional and informative)

This annex, if provided, contains the EXPRESS listing corresponding to the ARM diagrams and to clause 4 of the AP.

L Application protocol implementation and usage guide (optional and informative)

This annex, if provided, contains informative guidance on implementing and using the AP. This annex provides guidance to two different audiences, i.e., implementors and end users of AP compliant implementations. Example product descriptions that are supported by the AP and the corresponding AP exchange files may be included in this annex. If exchange files are included in this annex, the annex should explain the primary data structures and the logic and meaning of the values used in the exchange file.

M Technical discussions (optional and informative)

This annex, if provided, contains a summary of relevant technical discussions and the resolution of issues raised during the development of the AP. This annex provides background information for potential users of the AP and for developers of similar or related APs. The material given should not cast doubt or self justify. Only material which supports the normative text shall be given.

N Bibliography (informative)

This annex lists all informative references relevant to the AP. At a minimum, it shall contain references to the IDEF0 activity modelling format, to the *Supplementary directives for the drafting and presentation of ISO 10303* and to the format used for annex G if EXPRESS-G has not been used.

5 Development and qualification of a STEP application protocol

This clause specifies the requirements and process for developing and qualifying an AP. Figure 1 illustrates the overall STEP development process and shows "Plan & Execute STEP AP Projects" as activity A4. Figure 2 decomposes A4 into three activities: "Plan & Develop Application Protocol" as activity A41, "Develop Abstract Test Suite" as activity A42, and "Develop Prototype AP Implementation" as activity A43. Figure 3 decomposes A41 to the next level of detail. The tasks and objectives included in activity A41 are described in this clause.

The ISO/IEC Directives define seven stages in the development life cycle of an international standard:

Preliminary Stage   Collaborative planning on technical subjects for possible standardization projects, e.g., within an SC4 AP planning project

Proposal Stage   SC4 P-members ballot starting a new project, e.g., an SC4 AP project

Preparatory Stage   Project develops a Working Draft

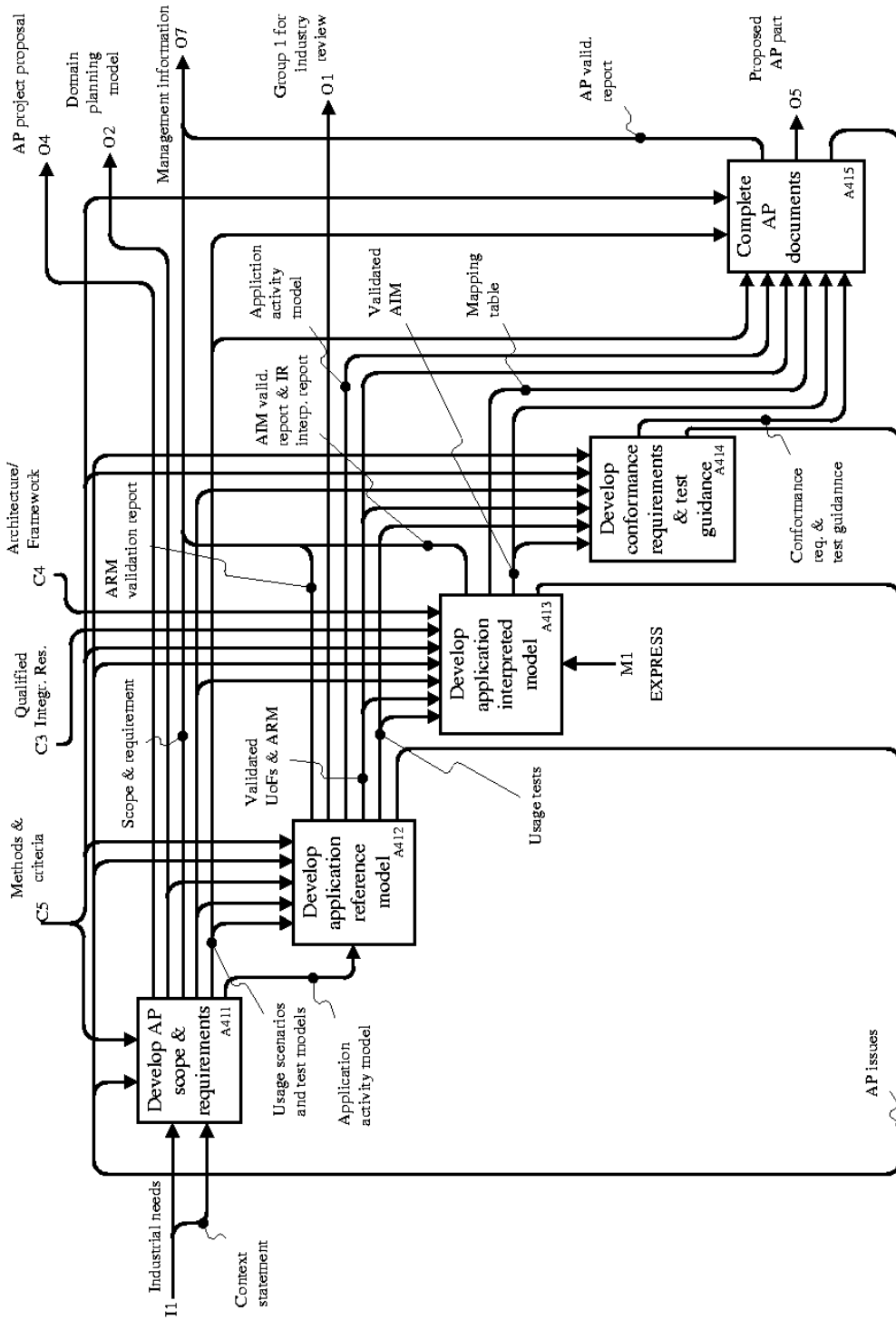Committee Stage   Consensus is achieved on a Committee Draft (CD)

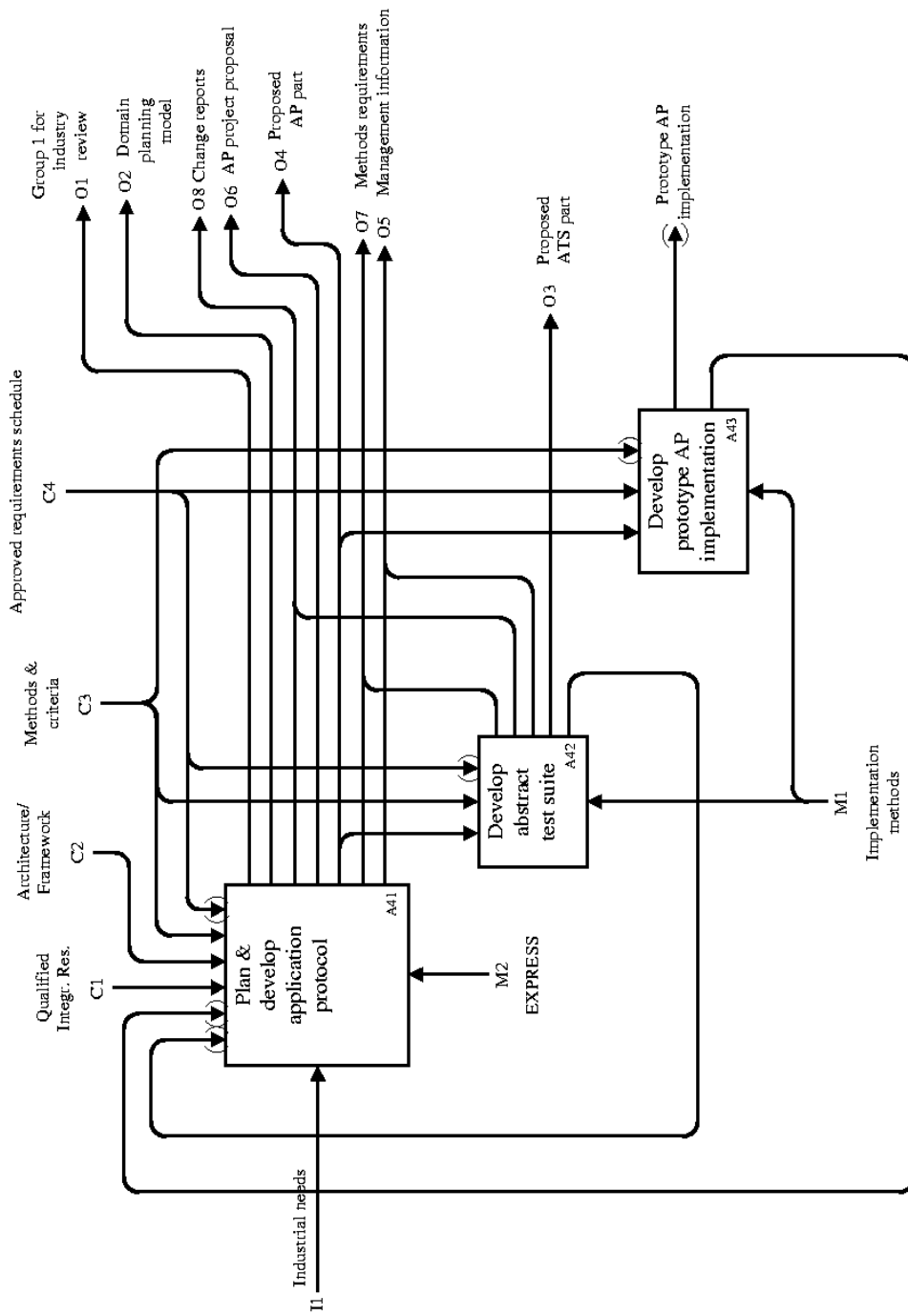**Figure 1 - Activity A0, Develop STEP**

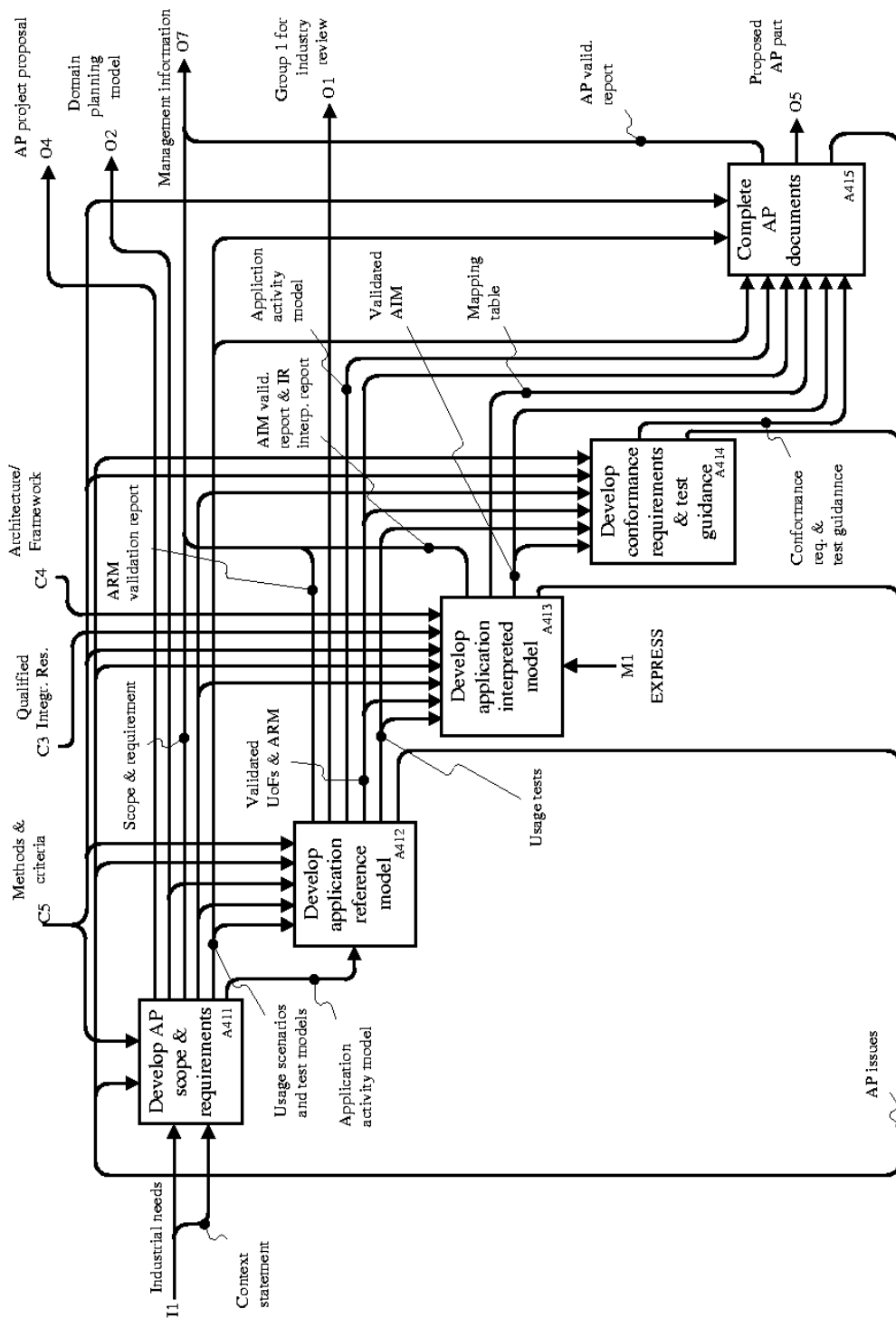**Figure 2 - Activity A4, Plan & Execute STEP AP Projects**

Figure 3 - Activity A41, Develop Application Protocol

Enquiry Stage   National Bodies vote on a Draft International Standard (DIS)

Approval Stage   National Bodies vote on a Final Draft International Standard (FDIS)

Publication Stage   ISO publishes the International Standard

The Preliminary Stage is used by SC4 to convene a group of experts in an application protocol planning project to investigate the need for APs within a specified domain. The use of the Preliminary Stage is optional. To start an AP planning project, an AP planning project proposal (see clause A.1) is submitted to the SC4 Secretariat. The Preliminary Stage is begun when a simple majority of the P-members vote to approve the AP planning project. The AP planning project focuses on documenting requirements for APs in the specified domain and can prepare one or many AP New Work Item Proposal(s). AP planning projects work with industry to define and coordinate AP projects.

An AP planning project provides an international forum for defining the scopes and requirements of specific AP projects. The AP planning project provides oversight and coordination for AP projects within its application domain and works to ensure effective harmonization with other, relevant AP projects. AP planning projects shall conduct broad outreach activities to identify and contact organizations and experts that can contribute to defining the scope and requirements of needed APs. Industry organizations and programs should collaborate in AP planning projects to define a common, industry-wide activity model, information exchange requirements, priorities for developing APs, long-range priorities for AP development, and AP New Work Item Proposals. The definition of high-value, product data exchange scenarios in conjunction with the common activity model provides a useful baseline for defining the industry priorities for the delivery of APs. For industry sectors or large product information domains, it is beneficial to develop a planning model for defining needed APs for the entire domain.

The ISO/IEC Directives specify dates after the approval of a New Work Item for when a project must advance to the next stage:

— Working Draft within six months, or

— Committee Draft within two years, or

— Final Draft International Standard within three years.

The AP project leader is responsible for reporting to the SC4 Secretariat updates to the AP project schedule whenever there are significant changes and the reasons for any delays in meeting the ISO development schedule. The maintenance of accurate schedules for all projects is essential to effectively manage the resources and work of SC4. The SC4 Secretariat monitors the progress of AP projects and reports to the ISO Technical Management Board all delays in AP projects. The ISO Technical Management Board reviews the status of all AP project which have not attained the required progress and may decide to cancel projects. This decision will be based on information provided by the SC4 Secretariat and the AP project leader.

An AP shall be developed and reviewed incrementally as components of the AP documentation are completed. The objectives of the incremental development and review process are twofold. First, the review of an AP's scope and information requirements, prior to developing the AIM, provides the opportunity to establish international consensus on the detailed requirements and to identify requirements common with other applications for the purpose of AP integration planning. Second, a comprehensive

review at each stage improves the quality of the AP and provides to the STEP project useful feedback on the AP development and quality review process [15] [16]. APs shall be documented in accordance with the *Supplementary directives for the drafting and presentation of ISO 10303*.

At the beginning of each AP project, the AP project team shall meet with representatives of the Quality Committee and receive training on the process and criteria for AP qualification. The objectives of these meetings are to instruct the AP project team on how to efficiently and correctly develop and document APs and to ensure that the teams have all necessary supporting documents. AP project leaders shall review and use the Project Leader Approval Check List for ISO 10303 while developing the AP. The Check List summarizes the important tasks and quality criteria for a AP project leader to approve a working draft for release from the AP project. AP project leaders shall ensure all team members are provided sufficient training to understand and contribute to the AP development process. Without this training, AP teams often make mistakes that must be corrected, and this re-work delays the completion of the AP project. The Quality Committee will answer questions on documenting an AP and will provide informal reviews of components of an AP document at any point in the development process.

Each component of an AP and the supporting documents, i.e., AAM, ARM, AIM, conformance classes, annexes, Group 1, and AP validation report, proceeds through three basic steps: 1) define the requirements and evaluation criteria for the component, 2) develop the component, and 3) exercise the criteria to evaluate the component. Each stage in the development process builds upon the precision and documentation of the previous step.

The process for developing an AP is described below (see annex B for an AP development schedule template). The formal qualification of an AP by the Quality Committee and by industry is divided into two stages. The first formal qualification reviews the Group 1 document of the AP. Group 1 of the AP includes the scope, definitions, information requirements, application activity model, usage scenarios, application reference model, initial conformance requirements and conformance classes, the initial issues log, and the initial AP validation report with the scope and requirements evaluation clause and the ARM validation clause completed. The Quality Committee reviews the Group 1 document to ensure that the document is sufficiently complete and understandable to warrant review by all sectors of the industries which may use the AP.

After successful completion of the Group 1 review by the Quality Committee and the resolution of Group 1 technical errors, the AP project distributes the Group 1 document for review by industry and relevant organizations. The review package should include a Reviewers Guide which explains the purpose and objectives of the review, the contents of the Group 1 document, criteria for assessing the document, and the process for submitting comments and participating in the AP project. The AP validation report and issues log should be included in the review package. This review ensures that the scope and requirements are correct, complete, and stable prior to investing resources in the development of the subsequent components of the AP which are based upon Group 1. Group 2 includes all other components of the AP, i.e., the mapping table, the application interpreted model, the revised conformance requirements, all additional annexes of the AP.

<u>Summary of the AP development process</u>

— Industry representatives document requirements for APs and develop a proposal for a STEP AP planning project (see clause A.1). The proposal shall be submitted to the SC4 Secretariat. The AP planning project proposal describes the scope of the project, i.e., type(s) of product, application tasks, discipline views, types of product data, and stages of the product life cycle to be included, an industry

activity model describing the industry context and the scope for the project, evidence of international industry need for APs in this area, committed human resources to the project, overlaps and relationships to other APs, and the schedule for delivering AP project proposals.

— The SC4 Secretariat reviews the AP planning project proposal to ensure that the proposal is complete and distributes each complete proposal to SC4 members for review and approval (see SC4 Secretariat checklist, SC4 N488 [17]). If the proposal is incomplete or ambiguous, the SC4 Secretariat returns the proposal to the submitter with recommendations for improvement.

— SC4 reviews the proposal to ensure that the proposed AP planning project: a) is compatible with existing AP planning projects and AP projects, b) will address industry requirements shared by many organizations and countries, and c) has sufficient human resources to complete the planned work. Based on the results of this analysis and the recommendations of industry and the WG conveners, SC4 votes whether to approve the proposed AP planning project.

— Industry representatives, application experts, and vendors of computer-aided tools document an industry consensus AAM, usage scenarios, example product representations, data exchange requirements, and priorities for APs within a specific application domain. With the assistance of STEP experts, application experts assess the correspondence of the application requirements to: a) existing AP planning projects and AP projects, and b) the scope and architecture of STEP. These analyses provides the basis for an initial definition of the scope of an AP or suite of APs, a data planning model for the application domain, and a development plan.

— The AP planning project meets with the Quality Committee for instruction on how to efficiently and correctly develop and document APs. The AP planning project meets with WG11 for instructions on how to efficiently and correctly develop the conformance classes and abstract test suite for the AP.

— Industry representatives and application experts document an AAM (which decomposes relevant activities of the common industry activity model used by the AP planning project), a representative set of usage scenarios and product representations, the initial data planning model, UoFs, information requirements, and conformance classes and produce the initial Working Draft of the AP. The initial Working Draft may include a complete application reference model. The initial Working Draft and an AP New Work Item (NWI) proposal are submitted to the SC4 Secretariat for a vote for approval by SC4. The AP NWI proposal describes the scope of the project, evidence of international industry need for the AP, committed human resources to the project, the member of the AP project team assigned to work in the Quality Committee, overlaps and relationships to other APs, and the schedule for completing the AP. It is recommended that AP NWI proposals be defined as part of an AP planning project.

— The SC4 Secretariat reviews the NWI proposal to ensure that the proposal is complete and distributes each complete proposal to SC4 for review and approval. If the proposal is incomplete or ambiguous, the SC4 Secretariat returns the proposal to the nominator with a summary of the sections of the AP NWI proposal requiring further development and recommendations for improvement.

— SC4 reviews the NWI proposal to ensure that the proposed AP project: a) is compatible with existing AP projects, b) will address industry requirements shared by many organizations and countries, and c) has sufficient human resources to complete the AP and the corresponding ATS. The SC4 Secretariat summarizes the results of this review and sends the summary to the nominator for the proposal. Using the results of this analysis, SC4 votes whether to approve the project. After SC4

approves an AP NWI proposal, the SC4 Secretariat assigns part numbers for the AP and the corresponding abstract test suite (ATS) and the project leaders for the AP and the ATS.

— The AP project team uses the AAM, scope, usage scenarios, validation testing, and input from industry to refine the ARM, UoFs, and conformance classes.

— The AP project team conducts industry reviews and evaluations of the AAM, scope, usage scenarios, requirements, ARM and initial conformance classes. As part of these reviews, the AP project team maintains a list of industry reviewers and companies that are interested in the development, utility and future use of the AP. The results of these reviews and the basis for industry acceptance of the reviewed components of the AP are documented in the scope and requirements evaluation clause of the AP validation report. Issues defined during these reviews shall be documented in the AP issues log.

— The AP project team conducts an overview of the information requirements, ARM, and UoFs for review and comments with experts on the integrated resources. These experts provide guidance to the AP project on the development of the AIM and determines whether additions to the existing integrated resources are required to meet the information requirements of the AP. If additions to the integrated resources are required, the AP project team defines a plan for developing these additions.

The AP project documents overlaps with other APs and requirements for interoperability with implementations of other APs. The AP project reviews these overlaps and requirements and includes resulting AIM development tasks into the AP development plan. The development of AICs or other forms of AIM alignment may be needed.

— The AP project team validates the ARM and UoFs and produces the ARM validation clause of the AP validation report. The AP project team defines ARM test purposes and usage tests as part of validating the ARM. The ARM test purposes are an important starting point for the development of the AP's abstract test suite.

— The AP project team submits Group 1 of the AP to the Quality Committee for initial quality review.

— The AP project team documents the plan for resolving comments and issues raised in the Quality Committee reviews and completes the Group 1 of the AP.

— The AP project is responsible for establishing effective mechanisms for validating the contents of the Group 1 document and for ensuring industry review and consensus on the contents of the Group 1 document. As a minimum, the AP project distributes the Group 1 document to all industry representatives who have submitted comments or input to the AP project. A simple explanation of STEP APs and instructions on how to effectively review and comment on the AP shall be included with the Group 1 document. The AP project produces a short summary of the Group 1 document, the role of the AP in any defined suite of APs, and instructions for obtaining copies of the document. If extensions to the scope or additional information requirements are planned for the AP, this shall also be explained to the industry reviewers.

The AP project notifies relevant industry organizations, the convener of the parent WG, the SC4 AP Coordinator and relevant standards development organizations that the Group 1 document is complete and available for review and comment. The AP project shall provide to the SC4 Secretariat paper and digital copies of the Group 1 document, and the list of industry reviewers to whom the Group 1

document was distributed. The SC4 Secretariat shall distribute the summary of the Group 1 document and the list of industry reviewers to the P and O members of SC4 and the A and B liaisons of SC4. The AP project is responsible for distributing the Group 1 review packet to industry.

To ensure maximum feedback from this industry review, AP projects should send follow-up inquiries to the reviewers prior to the closing of the review period to encourage the submission of comments.

— The AP project team reviews the comments from industry reviews of the Group 1 document and determines how to resolve the issues.

— The AP project team, working with the AIM development expert, selects and interprets resource constructs for the AIM. With the guidance of experts on the integrated resources, the AP project team documents the rationale for the selection and specialization of IR constructs to support the AP information requirements. This information and summaries of concepts and issues which required extensive discussion or analysis shall be included in the Integrated resources interpretation clause of the AP validation report.

The AP project team produces the mapping table, the AIM (EXPRESS and EXPRESS-G), the AP usage guide, and updates Integrated resources interpretation clause of the AP validation report.

— AP project team compiles and validates the AIM and produces the AIM validation clause of the AP validation report. The AIM compilation shall consist of the use of at least two software tools that accept the AIM EXPRESS short listing as input and produce the AIM EXPRESS expanded listing to be included in annex A of the AP document. The AIM listings shall be checked for errors with at least two software tools. The results of these tests and the name and version of the tools employed shall be included in the AIM validation clause of the AP validation report.

— The AP project team updates the conformance requirements and conformance classes and documents implementation method specific requirements.

— The AP project team completes the AP document and submits the document to the Quality Committee for final qualification approval.

— The AP project team resolves all qualification issues, approves the AP to Committee Draft status, and submits the AP to the convener of the parent WG for approval for distribution as a Committee Draft for ballot. The AP issues log and the AP validation report shall be circulated with the AP for these reviews.

— The AP project team submits to the SC4 Secretariat paper and electronic copies of the AP for review and Committee Draft ballot by SC4.

The AP development process continues according to ISO and SC4 procedures for document balloting and approval [14].

The AP projects should, where possible, utilize the work of existing AP projects in the development of new APs. This requires that AP developers understand the scope and status of other AP projects and the integrated resources and coordinate their work with the necessary WGs and STEP projects.

AP developers shall maintain a comprehensive issues log and shall forward to each WG and AP project issues relevant to their charter. AP projects shall maintain accurate schedules and shall submit revisions to schedules to the SC4 Secretariat for updates to SC4 project management records.

5.1 Development and review of the scope and information requirements

The first phase of developing an AP is the definition of its scope and information requirements. Definition of the scope and information requirements begins with the formulation of a statement of the application context and functional requirements for the AP. The application context statement describes the characteristics of the industries, business processes, products, product information, and information exchange activities relevant to the objectives of the AP project. The detailed scoping and information requirements definition shall proceed from these descriptions.

Scope definition shall be refined via the development of an application activity model (AAM). The AAM describes the input and output information requirements of the processes within the application context. The AAM shall be documented with the activity modelling technique IDEF0 [6]. The AAM shall include a glossary that defines all activities and elements in the model. The AAM for an AP project should be developed in conjunction with an industry wide AAM which covers the complete life cycle for the industry's product(s). The AP's AAM will be a subset of the industry wide AAM. The development of these AAMs will be an iterative process. The detailed analysis of the AAM for an AP project will often provide insights and refinements for the industry wide AAM and for the AAMs of other, related APs.

The descriptions of product data usage scenarios pertinent to the application and example parts or products that will be represented with the AP shall be used as aids to defining detailed information requirements. The AP project shall define usage scenarios that illustrate high value information exchanges relevant to a majority of the industries which could use the AP. Usage scenarios should illustrate major information exchange problems for the target industries and the business value of developing and using the AP. Usage scenarios may describe new ways to use product data exchange to improve work processes.

As the AAM and information requirements become more detailed, the scoping statement prepared at the beginning of the scoping phase shall be updated to correspond.

The AP's scope, AAM, and information requirements shall be carefully defined and documented. This documentation, in addition to the example products and product data usage scenarios, provides the foundation for developing the AP. The usage scenarios are extremely valuable in the subsequent validation of the ARM and the AIM.

At each level of decomposition of the AAM, the activities, inputs, controls, outputs, and mechanisms should be examined, and a determination made as to whether they are in scope for the AP. The inclusion of mechanisms, e.g., resources and tools, in an AAM should be carefully analyzed. Often, mechanisms are organization or enterprise dependent, and those dependencies shall not be included in the AAM. Only those mechanisms that are organization and enterprise independent shall be included. The AP development process is designed to develop organization and enterprise independent models.

An AAM for the existing "as is" processes should be developed before defining an AAM for future "to be" processes. The decision to scope an AP based on future processes rather than existing processes requires careful analysis of the industry need(s), objectives sought by the proposed improved process, the time required to deliver the AP to industry, and the relative costs and benefits.

The AP scope statement shall include a summary of the type(s) of product, the application processes, the types of product data, and the discipline views of the product that are within the scope. For clarification, the scope statement may also identify the type(s) of product, the application processes, the types of product data, and the discipline views of the product that are outside of the scope.

As the scope, requirements, and AAM are further defined, the AP project should develop an initial data planning model which identifies the primary concepts and relationships to be supported by the AP. The data planning model will evolve as the details of the AP are developed. The AP team should conduct fitness testing and evaluations of these AP components by experts in the application. The majority of these expert reviewers should not have participated in the AP development. Representatives from all relevant industries and from a broad spectrum of user organizations should be included to the maximum extent possible.

The objectives of this review are to ensure that: 1) the scope and requirements are accurate, viable, and meet a significant industrial need; 2) the AAM accurately represents all areas which are described by the scope statement, and 3) the documentation is sufficient, unambiguous, and conveys the correct meanings. All issues raised during the review(s) and the resolutions of these issues shall be documented in the AP's scope and requirements evaluation clause of the AP validation report. This report shall include the list of workshops, surveys, and reviews used in the assessment, the identification of the organizations participating in the reviews, the list of the expert reviewers, with their qualifications, summaries of the review(s) and the evaluations, and an issues log with the issues resolved. The report shall be included in the AP validation report.

5.2 Development and review of an application protocol project proposal

Each new AP project must be authorized by the voting members of SC4. A proposal for a new AP may originate from a national body member of SC4, the SC4 Secretariat, another ISO TC or SC, an organization in liaison, the ISO Technical Management Board or the ISO Chief Executive Officer. The ISO New Work Item proposal form (available from the SC4 Secretariat) shall be used for proposing an AP project. An AP NWI proposal should be submitted to SC4 when industry sponsorship, commitment of necessary expertise and funding, and international consensus on the scope and requirements for the AP project have been established.

An AP New Work Item Proposal shall include:

— title of project;

— date of submission;

— nominator;

— purpose and justification;

— target date for publication as an International Standard;

— relevant documents to be considered;

— relationships to activities of other international bodies;

— overlaps with other APs and AP projects;

— STEP resource schemas targeted for use by the AP;

— sponsoring organizations, participants, project plan, and schedule;

— summary of industry reviews of the scope and requirements;

— a partial draft of the proposed document.

The partial draft shall include an outline of the proposed document, a complete statement of scope, and sufficient technical content so that its requirements and position in the SC4 architecture can be understood. The draft document shall comply with the format and table of contents for an AP and shall include:

— scope;

— normative references;

— essential definitions;

— application activity model;

— data planning model;

— assumptions about the application context;

— information requirements;

— units of functionality (UoFs);

— initial definition of conformance classes.

The document may include the initial application reference model (see 5.3.1). This document constitutes the initial Working Draft of the proposed AP.

5.3 Development and review of the ARM and information requirements

When the detailed scope, functional requirements and data planning model have been defined, the information domain of the AP shall be defined by the use of the application reference model (ARM). The ARM shall be developed using a formal graphical data description language, i.e., EXPRESS-G, or IDEF1X. ARMs specified using EXPRESS-G may include an EXPRESS schema as well. Each application information requirement that is within scope in the AAM shall be expressed in the ARM. Conversely, each element of the ARM shall satisfy a documented information need of the application. The ARM shall describe fully the data needs of the application, using the terminology of the application. The ARM shall not use terminology from the integrated resources.

An ARM shall be sufficiently detailed so that the selection and interpretation of the integrated resources (see 5.4) can be done accurately. The ARM documents the required data and relationships. The graphical

presentation of the ARM, i.e., EXPRESS-G or IDEF1X, aids the understanding and review of the information requirements and definitions. The ARM diagrams shall be at a detail level sufficient to present the requirements in a manner that it is understandable to an application domain expert. The information requirements shall be modelled only to the level necessary to convey the information that is important from the application experts' point of view.

A mechanism for modularising the scope of an AP into manageable constructs is to define units of functionality. A UoF is a collection of application objects and assertions that conveys one or more well-defined concepts within the context of an ARM. A UoF usually supports an application function or process. UoFs are used to organize and summarize the functionality of the ARM. For example, if a geometric modelling application has a requirement for wireframe geometry, then a UoF may be defined which provides a grouping of those application objects in the ARM which are intended to support geometric modelling using wireframe geometry.

As the ARM is refined, traceability and consistency shall be maintained between the scope, functional requirements, AAM, and ARM. The AP development team shall ensure that each requirement identified in the AAM is expressed in the ARM.

AP projects shall maintain knowledge of the domain and status of other AP projects and shall investigate possible overlaps with other APs and AP projects. This shall include the analysis for common information requirements, similar units of functionality, and correspondence between ARMs. AP projects which address similar information or application domains should investigate opportunities and benefits of ARM harmonization. Harmonization of ARMs which have overlapping scopes can make the set of resultant APs more useful to industry and less expensive to implement and use. This harmonization may occur for the application objects or for entire UoFs.

APs with similar UoFs or information requirements are compared for semantic overlaps to determine functional equivalence. When two or more APs have equivalent UoFs or common information requirements, the same interpretation of the integrated resources shall be used in the APs' AIMs. This interpretation shall be accomplished by the inclusion of a common module in each of the APs. This common module is called an application interpreted construct (AIC) and its development is described in *Guidelines for the application interpreted construct development*. The AICs are intended to provide for consistency of STEP data representation among APs.

After the ARM is developed it shall undergo validation to ensure that it fulfills the functional requirements, is self-consistent, and covers the scope of the application completely. This validation should be done by both expert modellers for integrity testing and application experts for fitness testing. The functionality documented in the ARM shall meet the requirements expressed in the scope. Additionally, the functionality documented in the ARM shall not exceed the boundaries defined in the scope and the requirements.

The test models and usage scenarios used in the initial scope and requirements definition should be used for building the usage tests for validating the ARM. Usage tests document typical operations for creating or accessing product data. The set of ARM usage tests should be carefully defined to ensure coverage of the application context and functional requirements, the information defined in the ARM, and possible combinations of product representations. Difficulty in defining a meaningful usage test which exercises an application object may indicate that the application object is not needed. To ensure sufficient coverage for validating the ARM, the usage tests should use at least seventy percent of the application objects, attributes, and assertions.

5.3.1 ARM and information requirements documentation

Clause 4 of the AP shall include a high level description of the information requirements, a summary of the structure used to partition the information requirements into UoFs, and subclauses for specifying UoFs, application objects, and application assertions.

The grouping of UoF's into logical sets that aids in the understanding of the information domain is recommended. The logic of these groups of UoFs shall be included in 4.1. The grouping of UoFs should contribute to clarity of the information requirements and the ease of understanding and review by industry and SC4 experts.

The definition of UoFs and groups of UoFs should be reviewed in conjunction with the definition of conformance classes for the AP. UoFs are often useful as modules for defining conformance classes. A table which illustrates the UoFs included in each conformance classes shall be included in clause 6.

Nested or hierarchical structures of UoFs are not recommended. This type of structuring can obscure the semantics of the individual UoFs. Additionally, overlap of UoFs should be minimized. If one or more application objects participate in more than one UoFs, the scope and constituents, i.e., application objects and assertions, of the overlapping UoFs shall be carefully analyzed for logical restructuring which removes the overlap. If an application object does not participate in any UoF, the UoFs and application objects should be re-examined for logical structure and completeness of the UoFs.

The information requirements clause shall define in prose the application objects and application assertions. The elements listed within these subclauses shall be listed in alphabetical order. UoFs, application objects and application assertions shall have unique names within the AP.

The documentation for an AP's ARM and information requirements includes the following five components.

— ARM: The ARM shall be included in annex G of the AP. The ARM uses the terminology of the application and shall be documented with IDEF1X or EXPRESS-G.

— units of functionality: Units of functionality shall be defined in 4.1 of the AP. This subclause provides a list of the UoFs defined for the AP, a description of the functions that each UoF supports, and the list of application objects included in the UoF.

— application objects: The application objects shall be defined in 4.2 of the AP and are derived from the ARM. Each object which exists in the ARM shall be defined.

— application assertions: The application assertions shall be defined in 4.3 of the AP and are derived from the ARM. These assertions define relationships among application objects, the cardinality of the relationships, and the rules constraining one or more relationships among application objects required to maintain their integrity. Usage constraints, and relationships among valid interdependent values within the application domain are specified within the assertion that the AP project team deems most appropriate. These constraints may or may not be possible to be modelled in any graphical representation of requirements.

EXAMPLE 1 - A constraint may be necessary in an enterprise payroll application protocol to ensure the validity of the total salary budget. Such a constraint may be specified in the assertion between an employee

object and a salary object. This constraint may be stated as, "The sum of the salaries of all employees of a department may not exceed the budget of the department."

— ARM validation clause: An ARM validation clause is part of the AP validation report and describes the methods, tests, and verdict criteria which were used to validate the ARM.

5.3.1.1 EXPRESS-G ARMs

If the ARM has been modelled using EXPRESS-G, then the application object definitions and application assertions shall be specified as follows:

— Each entity shall be stated in the application object definitions.

— Each attribute whose data type is either a base data type or a defined data type which is a SELECT data type with a select list that does not contain entity types or, recursively, other SELECT types with select lists that do not contain entity types shall be stated as an ATTRIBUTE attribute of that entity in the application object definition.

— Each attribute whose data type is an aggregate with a type that is either a base type or a defined type which is a SELECT data type with a select list that does not contain entity types or, recursively, other SELECT types with select lists that contain entity types shall be defined as an attribute in the application object definition, with the cardinality specified in the definition.

— Each attribute whose data type is an aggregate of either an entity type or a SELECT type with a select list that contains either entity types or other select types with select lists that contain entity types shall be stated in the application assertions with the cardinality defined by the aggregate bounds.

— Each attribute whose data type is an entity type shall be stated as a relationship between the two entities in the application assertions.

— Each attribute whose data type is a SELECT data type with a select list that contains entity types or other select types with select lists that contain entity types shall be stated as a relationship between the entity containing the attribute and each of the options in the SELECT list in the application assertions.

— The INVERSE statements of referenced entities shall be examined in order to specify the cardinality constraints in the application assertions.

5.3.1.2 IDEF1X ARMs

If the ARM has been modelled in IDEF1X, then the application object definitions and application assertions shall be specified as follows:

— Each entity shall be stated in the application object definitions.

— Each attribute shall be stated as an attribute in the application object definitions.

— The business rule defining each relationship shall be stated in the application assertions.

— The notes which document any additional constraints shall be stated in the application assertions.

5.3.2 ARM validation

The AP team shall summarize its plan for ARM validation and the validation results in an ARM validation clause of the AP validation report. This clause shall include the rationale for the selection of representative test models, usage scenarios, and usage tests and the analysis of the degree of coverage provided by the validation testing. This clause shall summarize the impact that these results had on the ARM and the final scope of the AP. This clause may include a summary of ARM validation issues and how these were resolved. The usage tests shall be included in the AP validation report.

The validation of the ARM is a critical and resource intensive activity. Complete model validation of a complex ARM is impractical. It is usually evident from the development of the AAM that recurring demands for the same information exist. These facts can be used to prioritize the parts of the ARM to be validated. The objective of the ARM validation testing is to provide a significant level of confidence in the correctness and robustness of the model. The AP team shall document the required level of confidence and the steps that were completed to reach that level.

One method for validating an ARM is to build a prototype database which closely matches, if not replicates, the constructs of the ARM. This prototype database is then tested for its ability to accommodate representative example parts or products from the application context. Representative usage tests in the form of queries are posed upon these populations of the database to evaluate whether the "simulated ARM" is sufficient to support the in-scope processes defined in the AAM.

ARM validation shall, at a minimum, include paper populations of the data structure and reference path analyses to check whether the ARM can support the representative example product representations and can support the representative usage tests. Both of these methods will benefit from the use of software tools to control and aid in the development and testing of complex ARMs.

Detailed validation testing of the ARM provides feedback on the structure and requirements defined in the model. There will be iterations between the population and reference path analysis of the ARM and its development. Each iteration shall be documented in the ARM validation report along with a summary of the test coverage, data, and path analyses which were used in the validation, and a summary of the impact of the test results on the model.

5.4 Development and review of the application interpreted model

The application interpreted model (AIM) is an EXPRESS schema which specifies the interpretation of the integrated resources to satisfy the information requirements of the AP. The AIM specifies the implementable constructs of the AP. The AP team shall produce the AIM. The documentation for an AIM includes six components:

— mapping table;

— AIM EXPRESS short listing;

— AIM EXPRESS expanded listing;

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— AIM EXPRESS-G;

— integrated resources interpretation clause;

— AIM validation clause.

5.4.1 Integrated resources interpretation

The AIM is developed by interpreting the integrated resource constructs based on the information requirements. The AIM may specify subtypes of entities imported from the integrated resources or global rules in order to satisfy those application specific requirements which are specified in the ARM. Since the integrated resources are generic in nature, AIMs will take a more specific view of these entities. To restrict the population of particular attributes of an entity, a global rule shall be specified. This rule shall contain constraints on the particular entity or group of related entities.

Subtyping of an integrated resource construct is necessary when an ARM concept is only partially supported by that construct. In this case, a subtype of that integrated resource construct shall be created and those attributes and rules necessary to complete the concept attached to that subtype. Only DERIVED attributes may be specified in the AIM except for the purpose of completion and assignment of product data management resources. When the practice of subtyping is used for the completion and assignment of product data management resources, it specifies the constructs in the AIM to which those product data management resources (such as date_time, person_organization, approval, etc.) are applied. In this case, a SELECT type is created in the AIM which specifies the entities which are required to have product data management resources applied to them. A subtype of the entity in the product data management schema shall be created and an attribute placed in that entity whose type is a SET [1:?] of the newly created SELECT.

The AP team shall document the rationale for each subtype and rule added in the AIM in an integrated resources interpretation report. This report shall be included in the AP validation report.

As the number of APs grows over time, there will inevitably be some overlap in scope between different APs. These areas of overlap may be indicated by commonality in the scope statements or the use of the similar UoFs in their ARMs. These areas may also be indicated by the common use of resource constructs within APs. When two APs contain equivalent information requirements, these APs shall use the same interpretation of the integrated resource constructs. Figure 4 depicts this aspect of the AIM development and integration process.

When interpreting the integrated resources to satisfy the information requirements, the following steps shall be taken [5] [10]:

— Identify integrated resource constructs corresponding to application objects: To represent the required functionality using integrated resource constructs, each of the application objects must be examined to find a corresponding construct or group of constructs in the integrated resources. At this point of interpretation, only those constructs which satisfy an information requirement directly shall be identified. The method by which the integrated resources are interpreted directly by the AIM is described in 5.4.4, AIM EXPRESS documentation.

— Identify requirements for specializing integrated resource constructs: In addition to those constructs
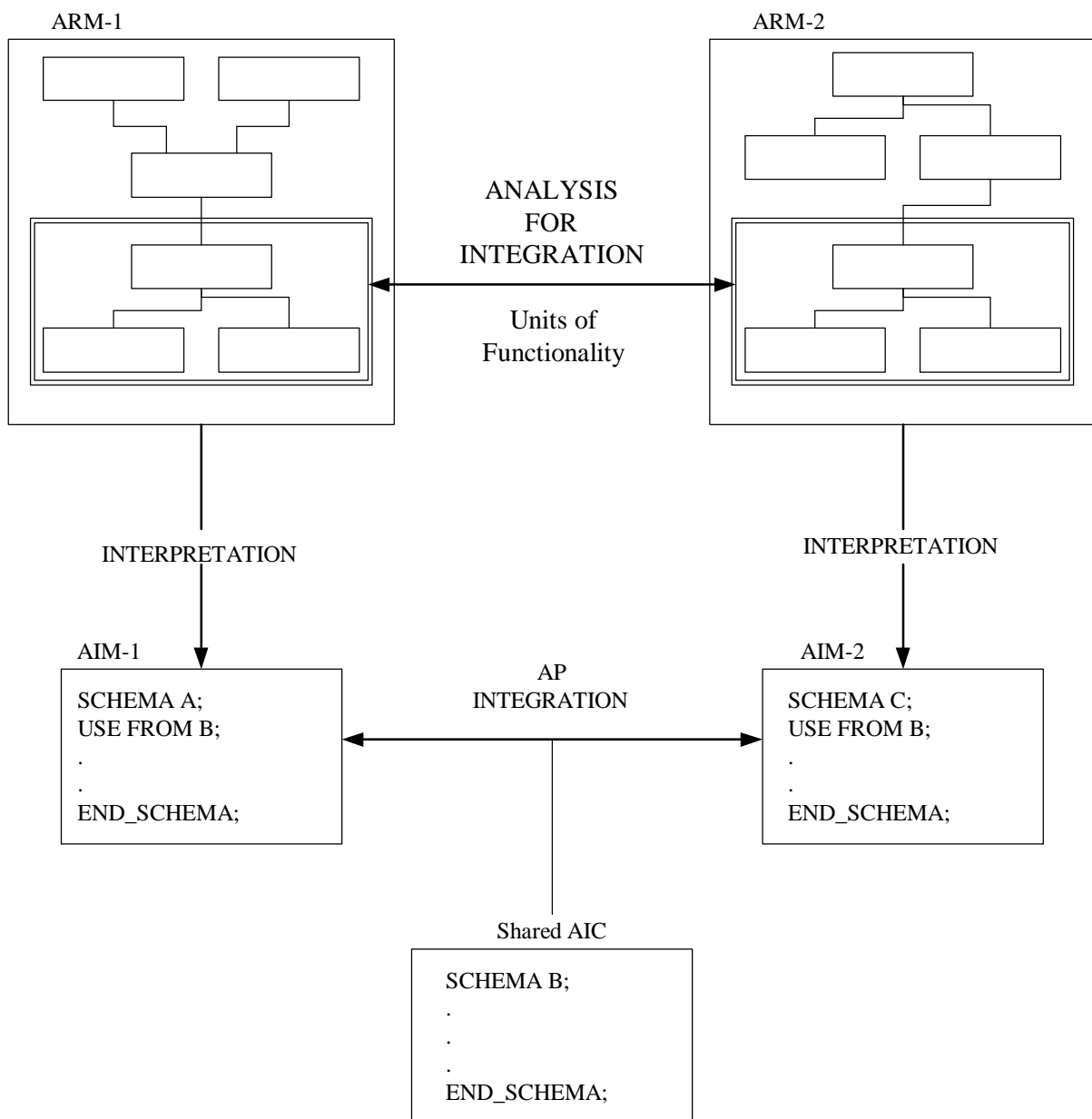

Figure 4 - Analysis for AP integration

in the ARM which have a direct correspondence to constructs in the integrated resources, there may be some constructs which have a partial correspondence. Some constructs in an ARM may correspond to the general intent of an integrated resource construct, yet require the refinement of that construct to attain semantic correspondence. The refining of these concepts is called specialization. At this point in the AIM development process, those constructs requiring specialization in the AIM are identified.

— Specialize constructs with partial correspondence: For those integrated resource entities for which a specialization requirement has been identified, subtypes or global rules are defined in the AIM. The refinement of an entity may be accomplished through the specification of constraints or definition of derived attributes. There are two ways in which specialization may be accomplished in an AIM. The first way to achieve specialization is by defining a new subtype of the integrated resource entity whose semantics are being refined to satisfy a particular requirement of the application context. The subtype entity may contain DERIVED attributes with attribute names that are specialized to be consistent with the semantics of the information requirements or local rules that constrain the use of the specialized entity to be consistent with the information requirements. The second way in which specialization may be accomplished is by constraining an entity that is imported from the integrated resources. This second method is typically used to restrict attribute value population or cardinalities among entities that have relationships to each other. When one these types of constraint needs to be added to the integrated resource in order to satisfy the information requirements, a global rule shall be added to the AIM depending on the use of the construct. See *Guidelines for application interpreted model development* for the specific rules on developing the application interpreted model.

— Develop mapping table (see 5.4.2): While the AIM is developed, the AP team shall record in a table in clause 5.1 of the AP document the selections and specializations made from the integrated resources to establish correspondence to each information requirement. This mapping will list each information requirement and its corresponding AIM construct(s). If a path of entity references in the AIM must be followed to completely satisfy a particular requirement as it is given in the ARM, the mapping table shall indicate the complete reference path which needs to be given to represent the required information in the AIM.

— Develop integrated resource interpretation clause: The AP team shall produce an integrated resource interpretation clause to summarize the rationale with which the AIM was derived and all specializations of integrated resource constructs. In developing the constraints on entities, a number of constraints may be required to constrain different entities for the same purpose. These constraints shall be grouped together in the integrated resource interpretation report with a description of their purpose in the AIM. The integrated resource interpretation clause is included in the AP validation report.

5.4.2 Mapping table

During the interpretation of the integrated resources, the mapping of the correspondence between the application objects and the constructs of the AIM shall be documented and maintained. The resultant mapping table shows the AIM construct(s) required for each application object. See *Guidelines for the development of mapping tables* for details on the development and documentation of mapping tables.

In EXPRESS, a single attribute or entity may not be enough to establish a full understanding of a concept. Although a single attribute or entity may be the AIM construct to which an ARM construct maps, that attribute or entity will not provide all of the information necessary to completely understand the semantic.

The specification of a reference path in the mapping table occurs when an attribute in the ARM and the entity to which it belongs do not correspond to the same entity in the AIM. Often an attribute in the ARM is developed at a higher level of detail than the integrated resources. In this case, the reference path is provided so that the complete semantic (including the relationship of the attribute to the entity in the ARM) is represented in the mapping table. Additionally relationships in the ARM will always have reference paths to show the complete set of entity instances required in the AIM to satisfy the relationship, subtypes created in the AIM will show the supertype from the integrated resources in the reference path and any mapping rules or choices will be specified in the reference path.

The example table below (see Table 2 and 3) illustrates a number of types of mappings that will be found in the mapping table of an application protocol. Two units of functionality are given, Advanced_b_rep and Authorization. The mappings of two application elements, ADVANCED_B_REP and APPROVAL, are provided. The mappings are described as follows:

— The application element ADVANCED_B_REP maps to the AIM entity advanced_-brep_representation. The source column value denotes that the AIM entity advanced_-brep_representation is an AP specialization, originating in ISO 10303-203. This specialization requires a reference path from the integrated resource entity from which it is specialized. The reference path denotes that the AIM entity advanced_brep_representation is a subtype of the integrated resource entity shape_representation.

— The application element APPROVAL maps to the AIM entity cc_design_approval. The source column denotes that the AIM entity cc_design_approval originates in ISO 10303-203. This specialization requires a reference path from the integrated resource entity to the specialized subtype. Rules 1 and 2 which are found at the end of the table constrain the use of the approval structure.

— The application element APPROVAL has an attribute date which maps to the date entity in the AIM. The date entity originates in ISO 10303-41 as indicated in the source column. Since the attribute maps to an entity in the AIM, a reference path is give from the entity cc_design_approval (this is the entity to which the application element APPROVAL was mapped) to the date entity (this is the entity to which the ARM attribute date is mapped). The reference path is to be read as follows:

    a) cc_design_approval is a subtype of approval assignment,

    b) approval_assignment has an attribute named assigned_approval that references the entity approval,

    c) approval is referenced by the attribute dated_approval in the entity approval_date_time,

    d) approval_date_time has an attribute named date_time which references a select type called date_time_select,

    e) in this case, the date_time_select, references the date_and_time entity,

    f) the date_and_time entity has an attribute named date_offset,

    g) the attribute date_offset references the entity date.

Table 2 - Example 1 of a mapping table

Application element	AIM element	Source	Rules	Reference path
ADVANCED_B_REP	advanced_brep_representation	203		shape_representation=> advanced_brep_representation

Table 3 - Example 2 of a mapping table

Application element	AIM element	Source	Rules	Reference path
APPROVAL	cc_design_approval	203	1, 2	approval_assignment => cc_design_approval
date	date	41		cc_design_approval<= approval_assignment approval_assignment.assigned_approval-> approval<- approval_date_time.dated_approval approval_date_time.date_time-> date_time_select=date_and_time date_and_time.date_offset-> date
purpose	approval.purpose	41		cc_design_approval<= approval_assignment approval_assignment.assigned_approval-> approval approval.purpose

1) approval_requires_approval_date_time
2) approval_requires_approval_person_organization

— The application element APPROVAL has an attribu te purpose which maps to the purpose attribute of the approval entity in the AIM. The source of the attribute purpose in the entity approval is ISO 10303-41.

STEP experts and application expe rts shall review the mapping table to ensure that they are complete and correct. The mapping is complete when each ARM construct has an equivalent construct(s) in the AIM.

5.4.3 Application interpreted constructs

During the interpretation process, one or more groups of constructs may be identified for which th e information requirements are equivalent t o another ISO 10303 application protocol. In this case, common interpretations are used and schemas to satisfy the common information requirements are developed fo r inclusion in the application interpreted models. These schemas are referred to as application interpreted constructs. All application protocols which have been identified as sharing a common informatio n requirement shall use the appropriate application interpreted construct schema in its entirety.

5.4.4 AIM EXPRESS documentation [5]

The AIM shall be documented in three formats:

— AIM EXPRESS-G;

— AIM EXPRESS short listing;

— AIM EXPRESS expanded listing.

5.4.4.1 AIM EXPRESS-G

Once an initial correspondence between application elements and the Integrated resources constructs has been established, an EXPRESS-G representation of the AIM should be produced. The EXPRESS- G diagrams are useful in developing the AIM EXPRESS listings, both the short listing and the annotate d listing. The AIM EXPRESS-G diagrams shall include all ENTITY, ENUMERATION and SELECT types. Each ENTITY drawn in the EXPRESS-G diagram shall include its attributes and their names, but not references to base types or defined types other than ENTITY, ENUMERATION or SELECT types. An EXPRESS-G model for all entities in the AIM shall be provided as annex H.

5.4.4.2 AIM EXPRESS short listing

The AIM EXPRESS short listing provides the interface specification between AIM schema and th e resources it uses, i.e., int egrated resources and AICs. There is a single EXPRESS schema for each AIM. This EXPRESS schema specifies the elements from the integrated resources and the AICs that are used in the AP and contains the types, entity specializations, rules, and functions that are specific to the AP.

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[5] Detailed requirements for documenting AP parts of ISO 10303, including any required text, are provided in th e *Supplementary directives for the drafting and presentation of ISO 10303*.

Any entity which is declared in the AIM EXPRESS short listing shall be a subtype of an entity that i s brought into the scope of the schema from using the USE FROM statement. These are the integrate d resource entities which need to be special ized in the AIM. Data types shall be specified in the short listing to specialize the used integrated resources. Rules and functions which are needed to further constrain an entity or relationship shall be included in the short listing.

Rules in the AIM are derived from rules and modeling structure in the ARM. An assessment of the ARM shall made to define the requirements for glo bal rules in the AIM after all of the entities and local rules are completed. This as sessment consists of an analysis of each ARM assertion against the path that satisfies it in the AIM. Requirements for cardinality const raints will follow from that analysis. Rules for dependent instantiability may be derived from the requirement to add an explicit line in the interface specification for a supporting purpose (i.e. so a subtype could be defined). Analysis of the subtypes in the AIM schema against the ARM requirement s will yield subtype relationship rules for entities with a common supertype. Enumerated values in clause 4.2 may require a value restriction rule if a particular enumeration contains a finite set of specific elements.

The AICs shall be incorporated into the AIM schema by the use of the USE FROM <AIC schema > statement. An AIC shall be used in an AIM only in its entirety.

In addition to EXPRESS declarations, documentation modifi cations may be necessary to the understanding of the interpretation of constructs that are imported into the AIM from the integrated resources. Certain documentary functions are requ ired in order to achieve a complete interpretation and certain functions are desirable for clarification of the generic resource constructs in a specific application context. Functions which have been identified for the modification of imported constructs are:

— addition of application specific examples;

— clarification of the interpretation of the meaning of an entity within the context of the application protocol;

— clarification of the interpretation one or more attributes of an imported entity;

— specification of AP specific informal propositions for an entity;

— documentation of associated global rules that are associated with each imported entity for which there is a global rule defined in the AIM.

Each of these functions will be documented in a subclause of clause 5.2 of the AP document. Every textual modification for each imported construct will be d ocumented in a separate subclause specifically dedicated to the documentation of textual modifications for that construct.

5.4.4.3 AIM EXPRESS expanded listing

The AIM EXPRESS expanded listing consists of the EXPRESS specification containing the result of the expanded USE FROM statements and the AP unique EXPRESS declarations. Discrepancy between the short listing and the expanded listing shall be avoided in all cases. If there is a discrepancy between the short listing and the expanded listing, a statement that the expanded listing shall take precedence will be made in annex D of the AP.

5.4.5 AIM validation

Comprehensive validation testing of a complex AIM is resource inte nsive. The objective of AIM validation testing is to provide a significant level of confidence in the correctness and robustness of the model. The AP team shall document the required level of confidence and the steps that were completed to reach that state. The AP team shall document the usage scenarios, test models, AIM test purposes, and verdic t criteria used to validate the AIM.

The AP team shall summarize the AIM validation test plan and test results in the AIM validation clause of the AP validation report. This clause shall include the rationale for the selection of test models, tes t purposes, and usage scenarios. A selection of the ARM validation tests shall be included in the AIM tests. An analysis of the degree of coverage provided by the v alidation testing shall be included. This report may include a summary of AIM validation issues and how these were resolved.

5.4.6 AP implementation and usage guide

During the devel opment and validation of the AP, descriptions of the way in which the AP is to b e implemented and used will be developed. Initially, this information will be included in the AP validation report. This information should be refined with the objective of eventually producing an A P implementation and us age guide which facilitates the implementation and use of the AP by industry. The AP usage guide is an optional and informative annex of the AP.

A subclause in the usage guide may be reserved for each applicable implementation method. Examples of the use of the AP within each implementation method applicable may be explained in these subclauses. For a file exchange implementation, an example exchange file may be included. The inclusion of a n exchange structure with values which are representative of those for which the AP was specified is a n appropriate component of an AP implementation and usage guide. Usage guides may also contain usage scenarios developed for the AP validation report (see 5.6.1).

5.5 Development and review of conformance requirements

Conformance testing is the evaluation of an implementation for all required characteristics, i.e., t o determine whether an implementation conforms to the standard. For an AP, this includes the information requirements, the AIM (entities, types, attributes, functions, proced ures, rules, and the full range of values), and any implementation method specific requirements defined in annex C of the AP.

The AP team shall define the conformance requirements and any conformance classes for the AP afte r careful analysis of the requirements of industry, the objectives of conformance testing, and th e consequences of enforcing or not enforcing completeness. If conformance classes are used, th e conformance requirements for the individual classes shall be explicitly listed in clause 6 of the AP. The definition of a conformance class shall include a table indicating which constructs from the AIM shal l appear in each conformance class.

If completeness is enforced, each implementat ion must be able to process the full range of values for every attribute of every entity identified in a particular conformance class. For example, if widgets have a color attribute which is an enumeration of red, blue, and green, then all conforming processors must be able to produce (preprocessor) or interpret (postprocessor) all three colors of widgets. This does not imply that

all three colors of widgets must appear in each exchange, merely that a system can distinguish widgets of the different colors, if desired.

Using the above example, if completeness of color attributes is not enforced, a "conforming " implementation may be at liberty to lo se all the color information or to change blue and green widgets into red ones. From the perspective of the industrial need to maintain the color information, this condition is unacceptable. AP developers are advised to require completeness of implementation of all AP require d characteristics. A clear statement of the required completeness shall be included in clause 6 of the AP.

A list of high level conformance requirements for an AP implementation is provided below. The A P developers shall consult WG11 on proposed modifications and additions to these conformanc e requirements.

— The information requirements of the AP shall be preserved in the implementation. This includes support for valid combinations of entities and their attributes. Consequently, all application objects and assertions from clause 4 shall be maintained.

— All entities, types, and their associated const raints identified in a particular conformance class shall be supported. Treatment of options and default values shall conform to the AIM.

— Only those constructs specified in the AIM shall be produced or accepted by an implementation.

— An implementatio n of ISO 10303 combines an application protocol with an implementation form. Such an implementation shall satisfy all general requirements applicable to the implementation form (given in the appro priate part of the 20-series class) and any AP-specific options given in annex C of the AP.

Clause 6 of an AP shall reference the implementation specific requirements specified in annex D of that AP. This reference includes the correct use of the AIM mapped by the implementation form an d conformance to the implementation form.

The conformance requirements shall be reviewed and evaluated by experts (application experts , implementa tion experts, and AP methods experts) who did not participate in the original development . These experts and WG11 shall assess the ut ility, practicality, understandability, and coverage provided by this clause of the AP. The results of this review shall be included in the conformance requirement s evaluation clause of the AP validation report.

5.6 Summary of application protocol validation

The basic concept of AP validation is to ensure that the scope and information requirements are completely and unambiguously delivered in the AP. This requires that the scope, requirements, ARM, AIM, an d conformance requirements a re complete and consistent. The components of the AP shall be evaluated for their soundness and for their internal con sistency. Each AP project shall develop and ensure the execution of an AP validation plan. The AP validation plan shall describe the usage scenarios, usage tests, target coverage of the ARM, AIM, and instantiation of the AIM for the validation, and the roles an d responsibilities of each member of the AP team during the validation process.

The AP validation plan and the resulting AP validation report shall be maintained by the AP project as a supporting document during the development of the AP. A well documented AP validation report is   a useful reference for the AP project and reviewers of the AP while the AP is being developed. Th e completed AP validation report shall be sub mitted with the completed Draft AP for review and acceptance by the Quality Committee.

As part of the validation process it is essential to include the viewpoints of many individuals from th e different disciplines that may use the AP. Suggested reviewers of the AP include:

— application experts to determine whether the A P comprehensively and unambiguously describes the application domain;

— experts in t he modeling methodology used for the ARM to determine that the ARM is correctl y specified;

— STEP experts to determine that the AP correctly uses the STEP specification;

— implementation experts to determine the utility and implementability of the AIM and any specified conformance classes.

A summary of the AP validation process for proposed APs is given below, followed by a more detaile d description of the complete methodology:

— Scope and requirements evaluation analyzes the completeness and correctness of the scope , requirements, and AAM.

— ARM validation evaluates the completeness and correctness of the ARM's representation of th e information requirements for the application area and correspondence to the scope and AAM.

— AIM validation evaluates the completeness and correctness of the AIM's representation of the AP information requirements as specified by the ARM.

— Conformance requirements evaluation analyzes the completeness of coverage, correctness, and self-consistency of these requirements with the ARM, AIM, and implementation requirements.

— AP validation through simulated implementations via prototypes   uses test implementations of the AP to evaluate the utility, correctness, and completeness of the AP.

The scope and requirements evaluation activity requires a te am of experts from the subject application area to provide peer reviews of the scope, requireme nts, and AAM. The AP team shall conduct a walk-through and evaluation of these items by these experts. The majority of these expert reviewers should not hav e participated in th e AP modelling effort. The objectives of this review are to ensure that: 1) the scope and requiremen ts are accurate, viable, and complete to meet an important industrial need; 2) the AA M accurately represents all areas which are described by the refined scope statement, and 3) th e documentation is sufficient, unambiguous, and conveys t he correct meanings. Sample instances of product models and the concepts that the AP is intended to support are also used to verify the scope an d requirements statement.

The ARM validation activity e nsures that the ARM satisfies the stated scope and requirements of the AP, is consistent with the AAM, and is syntactic ally and semantically complete and correct. This activity uses experts from the subject application area to provide peer reviews of t he ARM. The sample product models, i.e., test models, and the usage scenarios which were used to define the scope should be used to validate the ARM.

For an optimum model validation of the ARM, the reviewers should not be the same experts tha t participated in the development of the ARM. This portion of the process is manpower intensive. In the future it may be possible to use software tools to evaluate the ARM for completeness or correctness.

The ARM shall be reviewed manually to establish the validity of the semantics of the ARM. The ARM shall be reviewed to verify that the relationships between applic ation objects are understandable and correct and that all required objects appear in the ARM. In addition, the ARM should be loaded into a software tool(s) to check consistency of the ARM and the completeness of the representation.

The definitions of all application objects and relationships shall be checked for completeness an d understandability. The definitions shall be understandable to the prospective users of the AP. The users of the AP will include developers of STEP implementations and application experts. There shall be a definition for every element in the ARM. Some AP developers have been tempted to omit definitions of certain elements on the grounds that they are "self evident" or "standard terms". The problem with thi s approach is that what is self evident to one individual is not self evident to another. When this mode l validation is successfully completed, the AP team shall produce a summary report on the ARM validation.

The AIM validation activity involves the evaluation of the AIM and the specified implementation form(s) for the ability to carry all of the info rmation requirements specified in the AP. This model validation shall check that all items of information defi ned in the ARM can be carried in the AP format as specified by the AIM and any implementation specific requirements. The objective is to ensure semantic correspondence between the ARM and the AIM. The ARM and the AIM shall be checked to verify that they trul y correspond to each other. They shall be checked two ways:

— all ARM constructs map completely to one or many AIM constructs; and

— all AIM constructs map completely to one or many ARM construct.

An important aspect to check is that all the constraints modelled in the ARM are represented in the AIM. The AIM shall be successfully compiled on the EXPRESS compiler(s) designated by the Qualit y Committee. The results of the compilation(s) of the AIM shall be included in the AIM validation report. AIM validation shall require both applica tion area experts and experts in the capabilities and use of STEP to generate populated test pieces and path traversals.

The conformance requirements evaluation activity analyzes the completeness of coverage, correctness, and consistency of these requirements with the ARM, AIM, and implementation requirements. Th e conformance requirements shall be checked to ensure that the y meet industry needs and are useful, testable, and stated clearly. If conformance classes are also specified for the AP, the conformance classes ar e evaluated against these same criteria.

The activity of AP validation by developing and testing AP prototypes is a recommended additional step for providing a higher level of confidence in the implementability and utility of the AP. The creation of a prototype requires AP developers to analyze the AP in ways that probably would not be considered i n

reviews of the AP. If a prototype is not developed it is essential that the AP validation efforts include the development of detailed usage scenarios and test cases to simulate validation checks that a prototyp e software development effort would produce.

The development and validation of a STEP AP is an iterative process of progressive detailing an d refinement. Each step in this process provides critical feedb ack for the next version of the draft AP. While the AP validation effort is underway, new versions of the AP may be released during the review process. It is important to ensure that commen ts generated on previous versions of an AP are addressed by the new version of the AP.

5.6.1 AP validation report

The AP validation report documents: the AP validation process, the results of each validation activity, how these results were evaluated, and how all validatio n problems and errors were resolved. The AP validation report shall be developed in parallel with the development of the AP. The report shall include the following clauses:

1 Introduction

2 AP validation plan

3 Usage scenarios and usage tests

4 Scope and requirements evaluation

5 ARM validation

6 Integrated resources interpretation

7 AIM validation

8 Conformance requirements evaluation

The AP validation report may include an additional clause on AP validation with prototyp e implementations and an annex describing sample test parts, usage scenarios, and success criteria use d during the AP validation activities.

Clause 1 provides an overview of the validation process, problems ide ntified and procedures used to resolve problems, issues, and errors. The Introduction shall also describe market assessments of industry needs for the AP and any metrics u sed to assess industry and application experts confidence in the results of the validation activities.

Clause 2 describes the AP validation plan and the resources and experts used to complete the validation. This clause may also document the relationships between each validation activity and how traceabilit y between activities and results was maintained. Collaboration on validation activities with other STE P projects shall be documented in this clause.

Clause 3 describes the usage scenarios and usage tests. Each usage scenario shall describe a sequence of industry events which use some portion of the product data considered for inclusion in the scope of a n application protocol. An IDEF0 representation which corresponds to the AAM shall be included. Each usage test shall specify a usage scenario, test model, test queries and verdict criteria for assessing a n information model or an implementation of an AP.

Clause 4 describes the analysis performed to determine the accuracy and completeness of the AP's scope, functional requirements, and AAM. This analysis is based on the requirements from industry and th e evaluations by industry and application experts.

Clause 5 describes the validation testin g of the ARM. These tests verify the completeness and correctness of the information requirements modelled in the ARM and the ARM's correspondence to the scope an d AAM. This clause shall document that each "in-scope" information stream of the AAM is supported by the ARM. This clause shall describe the usage scenarios, example product representations, ARM tes t purposes, and verdict criteria used to validate the ARM a nd the percentage of the ARM that was validated.

Clause 6 records the interp retation of the integrated resources to meet the information requirements of the AP and the resolutions to problems identified during the interpretation process. This clause shall include sections of the AP's mapping tables and explanations necessary to clarify the rationale for selections from the integrated resources and modifications to the integrated resources.

Clause 7 describes the validation testing of the AIM. This validation ensures the correlation of th e information requirements in the ARM to the constructs defined in the AIM and verifies that the AIM i s complete and self-consistent. This clause shall describe the usage scenarios, example produc t representations, AIM test purposes, and verdict criteria used to validate the AIM. The results of th e compilations of the AIM and the identification of the software tools used shall be included in this clause. This clause shall describe the percentage of the AIM that was validated. Issues raised during the AI M validation which effect the ARM shall also be included in the ARM validation clause.

Clause 8 describes the assessment of the completeness of coverage, correctness, and self-consistency of the conformance requirements and any specified conformance c lasses with the information requirements, AIM, and implementation requirements.

During the development of the AP, the AP project may choose to distribute a subset of these clauses t o selected reviewers. The AP valid ation report, with all relevant clauses completed, shall be submitted with the AP as part of each review by the Quality Committee.

5.7 Development of the abstract test suite

A standardized abstract test suite (ATS) for each AP shall be developed by the AP developers an d approved by SC4 as a separate 300 series technical report part of ISO 10303. The ATS is the complete set of abstract test cases embodying the application element, i.e., app lication object or application assertion, test purposes, AIM test purposes and verdict criteria necessary to perform conformance testing of A P implementations. The development of the abstract test sui te provides valuable feedback on the correctness, completeness and potential ambiguity of the AP. For this reason, AP projects should start the development of the abstract test suite in parallel with the validation of the AP.

Abstract test cases are independent of implementations and are used to produce comparable results from the conformance testing of d ifferent implementations. An executable test case is derived from an abstract test case in a form which allows it to be run on the implementation under test. *Guidelines for the development of abstract test suites* provides requirements on the structure and content of an ATS an d provides further information to enable the consistent development of the 300 series parts of ISO 10303.

6 Process for approving a STEP application protocol

After an AP is complete and has been approved by the WG convener and the Quality Committee, the AP is submitted to the SC4 Secretariat for review and approval for distribution for committee draft (CD) ballot. The SC4 Secretariat will ensure that evidence of broad industry review and validation of the AP is provided with the submission of the AP and will perform quality checks on the components of the AP, as defined in the ISO directives and SC4 resolutions. If sufficient evidence of review and validation is not provided or if quality problems in the AP are identified, the SC4 Secretariat will require the problems to be resolved by the AP project before approving the document for distribution. After approving th e document for distribution, the SC4 Secretariat forwards the CD to the office of the ISO Chief Executive Officer for registration as a CD, and the SC4 Secretariat begins the ballot process. The ballot is sent to all participating (P-member) and observing (O-member) SC4 member countrie s and also to Class A Liaison organizations. All recipients are asked for comments on the CD. Voting members of SC4 are asked to vote on the acceptance of the CD as a draft International Standard (DIS). All P-members of SC4 have a n obligation to reply. A minimum voting period of four months is prescribed by SC4 resolutions on first CDS. Ballot comments are collected and summarized by the SC4 Secretariat.

Within four weeks after the closing date for submission of replies, the SC4 Secretariat prepares th e compilation of comments and arranges for the circulation to all P-members and O-members of SC4. When preparing this compilation, the SC4 Secretariat indicates its proposal, made in consultation with the SC4 chairman and, if necessary, the project leader, for proceeding with the project, either

  a) to discuss the committee draft and comments at the next meeting; or

  b) to circulate a revised committee draft for consideration; or

  c) to register the committee draft for the enquiry stage

If, within two months from the date of dispatch, two or more P-members disagree with proposal b) or c) of the secretariat, the committee draft shall be discussed at an SC4 meeting. [6]

Once the CD is approved by SC4 ballot and all ballot comments are resolved, the SC4 Secretariat submits the AP to ISO for formal registration as an enquiry dr aft, i.e., DIS. The ISO Central Secretariat circulates the AP to all national bodies of ISO with a formal ballot on the approval of the DIS as a Final Draf t International Standard. All national bodies have an obligation to reply. A five month voting period i s prescribed. Ballot comments are returned to the ISO Central Secretariat. The Central Secretariat sends the comments to the SC4 Secretariat.

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[6] ISO/IEC Directives Part 1, 2.5.3

On receipt of the result s of the voting and any comments, the SC4 chairman, in cooperation with the SC4 Secretariat and, if necessary, th e project leader, and in consultation with the ISO Chief Executive Officer, decides on one of the following courses of action:

a) when a two-thirds majority of the votes cast by P-members of SC4 are in favor, not more than one-quarter of the total votes cast are negative and consensus is reached, to register the enquiry draft as a Final Draft International Standard, or

b) when the above approval criteria are not met:

1) to circulate a revised enquiry draft, i.e., a second DIS, for voting; or

2) to circulate a revised committee draft for comments; or

3) to discuss the enquiry draft at the next meeting. [7]

The last ballot is a two month ballot on the Final Draft International Standard (FDIS) for final proo f review. For an AP to be advanced to FDIS, there shall be proof pr ovided to SC4 that at least three systems have demonstrated implementations of the AP. Any technical comments received from the FDIS ballot are for information only. Additional details on this p rocess are provided in clause 2 of the *ISO/IEC Directives Part 1: Procedures for the technical work*.

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[7] ISO/IEC Directives Part 1, 2.6.4

Annex A

Application protocol planning project proposals

A.1 AP planning project proposal

An application protocol planning project proposal shall be submitted to the SC4 Secretariat for review and approval by SC4. An AP planning project provides an international forum for defining the scopes an d requirements of specific AP projects. The AP plannin g project provides oversight and coordination for AP projects within its application domain. The AP planning project proposal shall include:

1. Application protocol planning project title:

2. Date of submitting the proposal to SC4:

3. Nominator (ISO TC184/SC4 member body or liaison):

4. Proposal advocate:
   Organization:
   Mail address:
   Telephone:
   Facsimile:
   Electronic mail:

5. Scope of the AP planning project:

6. Industry activity model:

7. Evidence of industry need for APs in this domain:

8. Overlap and relationships to other APs or AP planning projects:

9. Required resource schemas:

10. Current participants and committed human resources for the AP planning project:

11. Schedule for delivery of AP project proposals with existing resources:

A.2 Explanations of AP planning project proposal questions

1. AP planning project title: Provide the title for t he application protocol (AP) planning project. The title shall clearly and succinctly state the domain.

2. Date of submission: Provide the date of su bmission of the proposal to the AP Coordinator of the SC4 Secretariat.

3. Nominator: Provide the name of the ISO TC184/SC4 member body or liaison who is sponsoring this AP Planning Project within ISO. Include the name s of the supporting National Standardization Bodies.

4. Proposal advocate: Provide the name and location of the proposal proponent and positions (if any) in ISO committees. Fu rnish organization name to division level, postal address, telephon e number, facsimile number, and electronic mail address.

5. Scope: State the domain of d iscourse of the AP planning project, i.e., type(s) of product, application tasks, discipline views, types of product data, and stages of the product life cycle included. Indicate whether considere d within the scope of approved SC4 work items. If not in the scope o f approved SC4 work items, list P-member countries that are committed to participating in the project.

6. Activity model: Provide the activity model whic h defines the industry context, processes, tasks, and information flows that will be investigated by the project. "In scope" and "out of scope" processes, tasks, and information flows shall be identified. Definitions of all objects in the model shall be provided.

7. Industry need: Provide the evidence of inter national industrial need or potential for APs in this domain.   This may include conclusive international trad e assessments, e.g., inter national auto industry; large national government program requirements, e. g., CALS; international program requirements, e.g., EC M-IT-04; breadth of industry participation in the plannin g project; and funding allocated to support this project.

8. Overlap with other APs or   Define the overlaps and relationships between this AP planning
   AP planning projects: project's scope and requir ements and those of other APs or AP planning projects.

9. Resource schemas: List which integrated resource schemas are targeted to support APs i n this application domain?

10. Participants and plan:

State the level of effort currently d evoted to this AP planning project and the breadth of international expertise assigned to this project. List th e individual s and the companies that will work on this AP. How man y person hours per year are assigned to working on the project outside of ISO committee meetings?

List the vendors of computer-aided tools and information systems tha t will participate in defining the APs and in reviewing the output of thi s project. List the industry associations and other groups of applicatio n experts that will participate in defining the APs and in reviewing th e output of this project.

Provide a summary of the plan for identifying the customers of th e potential APs, assessing the market demand for these APs, completin g an APs planning model, defining the potential APs' scope boundaries , and establishing broader industrial participation and consensus on these results.

11. Schedule:

State the schedule for delivery of AP project proposals to SC4 with the current level of committed resources. A P planning projects shall provide a status report to SC4 within 6 months. At least one AP project proposal shall be submitted within one year from a pproval of the planning project. If no proposal is submitted within one year, SC4 shall review th e viability of the planning project and consider canceling the plannin g project.

Annex B

Application protocol development schedule

As an aid to planning the schedule and human resource requirements for developing a STEP application protocol, this annex provides a template schedule with estimated resource requirements. Any estimation of the time and human resources required for developing a specific AP is dependent upon numerou s variables, some of which are: the maturity, stability, and scope of the application; the skills and abilities to work as a team of AP development project members; the availability and participation of application domain experts; the completeness and stability of the required Integrated Resources; and the availability of reliable tools for developing, validating, and documenting the AP.

The included AP development schedule presumes:

— the application domain is well understood, with common product data and task descriptions used internationally;

— the scope of the AP matches the boundaries of commonly used CAx applications;

— stable standards are avail able for the definition of the application elements and the development of the ARM;

— a sufficient mix of application domain experts, e.g., technical experts from the relevant industries, participate in defining and reviewing components of the AP;

— the AP development project members understand the STEP architecture, the STEP methods, e.g., EXPRESS, and the AP development process;

— a lack of integrated tools for developing and documenting the AP; and

— the AP will not require new schemas to be added to the Integrated Resources.

This schedule does not include resources for developing prototypes of the AP, and it does not include the time and resources required for developing the AP's abstract test suite (ATS). Each AP project shal l produce an ATS. The AP development schedule should only be used as a starting point for defining the schedule and human resource requirements for a specific AP development project.

ID	Task Name	Days	Hours	Year 1				Year 2				Year 3			
				Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
1	Define Project and Develop AP (Template)	738d	4828												
2	AP Project Definition and Approval	738d	1106												
3	Document Industry Commun Rqmts +	30d	80												
4	Define Usage Scenarios and Test Models +	60d	120												
5	Define AAM +	60d	150												
6	Define AP Scope & Requirements +	90d	200												
7	Define AP Development and Validation Plan	50d	60												
8	Document Capabilities and Voids in IRs	4d	16												
9	Document Information Requirements +	112d	440												
10	Define UoFs and Planning Model +	70d	120												
11	Develop ARM +	112d	280												
12	Define Initial Conformance Classes +	41d	40												
13	Prepare AP New Work Item Proposal (NP)	49d	40												
14	Submit AP NP to SC4	0d	0												
15	SC4 Ballot of AP NP	67d	0												
16	SC4 Approves AP Project	0d	0												

+ = Requires Industry Participation

Figure B-1 - AP Schedule Template, Part 1 of 3

ID	Task Name	Days	Hours	Year 1				Year 2				Year 3			
				Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
17	Complete Group 1	153d	792												
18	AP Qualification Preview	1d	16												
19	Update UoFs +	79d	40												
20	Update ARM +	110d	300												
21	Update Appl. Objects and Assertions +	130d	280												
22	Review ARM for AIM Dev. & AP Integr.	3d	16												
23	Document IR and AIC Uses	5d	40												
24	Group 1 Qualification & Revision	11d	100												
25	ARM Validation +	154d	200												
26	Distribute Group 1 to Industry	0d	0												
27	Group 1 Review by Industry +	70d	0												
28	Resolve Group 1 Comments	45d	120												
29	Develop AIM	160d	710												
30	Interpretation and Mapping Table	100d	220												
31	AIM EXPRESS-G & Short Listing	120d	160												
32	Document New Constructs (not always req	65d	180												
33	AIM Expanded Listing	31d	80												
34	AIM Review & Revisions	16d	70												
35	AIM Validation	28d	200												

+ = Requires Industry Participation

Figure B-1 - AP Schedule Template, Part 2 of 3

ID	Task Name	Days	Hours	Year 1				Year 2				Year 3			
				Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
36	Complete AP	105d	400												
37	Conformance Rqmts & Test Guidance	34d	100												
38	AP Implemtation and Usage Guide +	105d	125												
39	PICS Proforma	5d	15												
40	Final AP Qualification	23d	40												
41	Resolve Qualification & Edit Comments	22d	120												
42	Work in Quality Committee	310d	900												
43	Prototype AP Implementation	151d	0												
44	Submit AP to SC4 for CD Ballot	0d	0												
45	SC4 CD Ballot	87d	0												
46	Resolve SC4 CD Ballot Comments	70d	400												
47	Submit ATS to SC4 for TR Ballot	0d	0												
48	Submit AP to SC4 for DIS Ballot	0d	0												

+ = Requires Industry Participation

Figure B-1 - AP Schedule Template, Part 3 of 3

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