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Specifications for an Application Protocol Development Environment

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1 Introduction

The emerging international Standard for the Exchange of Product Model Data (STEP[1]) comprises five distinct types of specifications[2]. “Implementation Specifications” provide descriptions of mechanisms for the actual exchange of STEP data (e.g., a clear text exchange file format [4]). “Description Methods” provide techniques for specifying STEP (e.g., the EXPRESS information modeling language [3]).“Integrated Resources” provide information models describing generic constructs which are useful in a wide variety of product descriptions (e.g., geometry [5]). “Application Protocols” are the Parts of STEP which combine components of Integrated Resources, select implementation mechanisms, and use the Description Methods to specify what product data is to be exchanged and the meaning of that data in a particular industrial context (e.g., associative drafting [6]). In essence, Application Protocols (APs) are the Parts of STEP which are implementable. Thus it can be expected that CAx[3] vendors will provide mechanisms in their products which will facilitate data exchange according to particular APs. A thorough introduction to STEP and its constituent specifications can be found in “Overview and Fundamental Principles” [2].

The National PDES Testbed program at the National Institute of Standards and Technology is focused on the development and implementation of STEP. Principal funding for the National PDES Testbed program comes from the Department of Defense Computer-aided Acquisition and Logistic Support (CALS) office. There are several projects within the National PDES Testbed; among these is the effort to establish an Application Protocol Development Environment (APDE), a software environment supporting the development of APs.

1.STEP is being standardized under the auspices of the International Organization for Standardization (ISO) Technical Committee 184 (TC184) Subcommittee 4 (SC4). The term PDES (Product Data Exchange using STEP) refers to the United States’ effort contributing to this standardization process.

2.STEP will be released as a collection of specifications; each individual specification is known as a “Part” of STEP.

3.The term “CAx” refers to any type of engineering, manufacturing, or operations software application system, e.g., Computer-Aided Design (CAD), Computer-Aided Process Planning (CAPP), etc.

This report documents the specifications for the APDE. These specifications describe the planned functional capabilities of the software environment. Requirements derived from the experiences of current AP developers [1] form the basis of the specified functionality. Those requirements have been collated into a form which can be used to compare candidate implementation approaches and thereby assist with design of the APDE (see Appendix B).

2 AP Development Process

The purpose of this section is to give an overview of the AP development process. For complete details of the process the reader is urged to consult the AP Guidelines document [11]. It is important to note that no commercial software tools are currently available which are specifically intended to facilitate the AP development process. AP developers currently use an ad hoc collection of document processing software, information modeling software, and virtually anything else available which may make their task easier.

The relationships among the components of an AP are many and complex. A large part of the work of an AP developer is making sure that the pieces of the AP are consistent with one another. Changes to one portion of an AP will often impact several other sections. AP components are also related to the Integrated Resources (IRs). AP developers rely on information and documentation in the IRs to produce the AP documentation. Figure 1 shows the relationships between AP components and the Integrated Resources that must be maintained in the APDE.

The bold boxes in Figure 1 represent the conceptual components of an AP. The small boxes in the shaded areas represent documentation sub-components of the conceptual components. Boxes with dashed edges represent documentation that is informative (supplemental explanatory information) to the AP, while boxes with solid edges represent normative documentation (constituting directives of the standard). The arrows show dependencies. Arrows are drawn to components that depend on the originating component. The bold arrows indicate the flow of information between the high level components.

2.1 AP Project Definition

An AP development project is initiated by documenting, in English prose, an industry need for the AP, thereby establishing the requirement for the proposed AP in STEP. A high-level statement of scope is agreed upon (and updated as the AP becomes better defined). In order to further document and clarify the industry need, the AP developers produce an Application Activity Model (AAM), which specifies the processes that use and produce product data in the application context to be addressed by the AP. The AAM is documented using IDEF0 [7] methodology. Once a comprehensive AAM is developed, each element of the AAM is examined and a determination is made whether the element is in or out of scope, based on the intended use of the AP. The scope statement, the completed AAM, and a Candidate AP Summary sheet are submitted for approval as an ISO AP project.

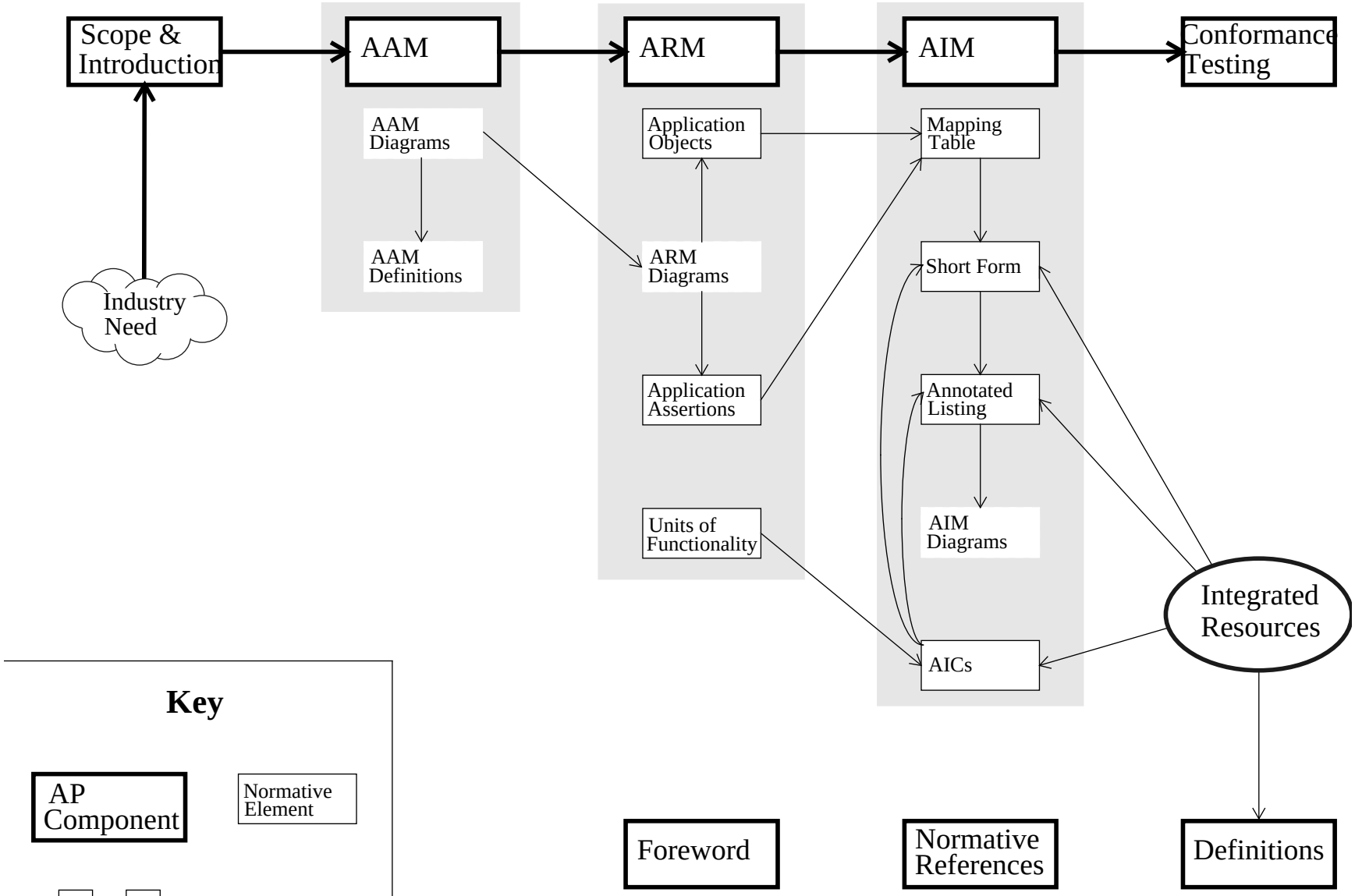

Figure 1: AP Component Relationships

Once the AP project is approved, the scope, requirements and AAM are evaluated by experts in the application area who were not involved in the initial modeling effort. These experts should reflect the breadth and depth of the application scope. The AAM is modified to ensure that it accurately represent industry processes and practices, accurately reflects the desired scope, and is correct and complete. The results of the industry review are documented in a separate document, the AP Validation Report.

2.2 AP Information Requirements

When the scope has been defined and evaluated, the information requirements of the AP are defined through the development of an Application Reference Model (ARM). The ARM is documented in one of three graphical data modeling languages (EXPRESS-G[1], IDEF1X [8], or NIAM [10]). The model diagrams are a required informative annex of the AP, and the information requirements are normatively described in text. Each element in the ARM diagrams is defined as an Application Object in the AP. Each relationship between elements in the ARM diagram is documented as an Application Assertion. The concepts in the ARM are organized into Units of Functionality (UoF). A UoF is a grouping of constructs which reflect one or more distinct concepts within the ARM, possibly corresponding to an application process. The UoFs are potentially useful for evaluating areas of commonality between APs.

The ARM must be evaluated by industry experts as was the AAM. The objective of this ARM validation is to provide a high degree of confidence that the model supports industry practices correctly and robustly. It is impractical to conduct a comprehensive review of the ARM due to its complexity. ARM validation is done with the use of representative test pieces and usage scenarios. The model may be validated by several methods. One method is to build a prototype database that replicates the structure of the ARM, while another method is to perform “paper populations” of the structure and requirements. The method used to perform ARM validation is documented in the AP Validation Report, along with the results of the validation.

2.3 AP Interpretation

The Application Interpreted Model (AIM) is developed by mapping elements from the STEP Integrated Resource Parts to meet the information requirements described in the ARM. This process, known as Interpretation, may result in further constraints on IR constructs and the creation of new constructs in the AIM when an appropriate Integrated Resource construct is not available for a particular ARM requirement.

The Interpretation process requires the cooperation of those who developed the ARM and those who have extensive knowledge of the Integrated Resources. Interpretation is typically carried out in a workshop-style meeting. Detailed notes from this workshop are compiled into an Interpretation Report that becomes part of the AP Validation

1.EXPRESS-G is a graphical subset of EXPRESS. See Annex D of [3] for a description.

Report. Another output of the interpretation workshop is a Mapping Table that shows the correspondence between elements of the ARM and those Integrated Resource constructs which are interpreted to support these elements.

The AIM is documented by an EXPRESS information model known as the Short Listing. The Short Listing consists of references to Integrated Resource elements and definitions of all new elements and constraints added during interpretation, e.g. specializations of Resource elements and rules that further constrain Integrated Resource elements.

An AP also contains an expanded form of the Short Listing, known as the Annotated Listing. The Annotated Listing includes the complete documentation of the AIM. This includes textual descriptions of all of the Resource elements used and other constructs added during interpretation, as well as the EXPRESS definitions of these elements. During the development of the Short and Annotated Listings, the AP developers must also develop a high-level graphical model of the information using EXPRESS-G.

Finally, as with the ARM, validation of the AIM must be performed and documented in the AP Validation Report. AP usage information formulated as part of the validation process may also be provided as an informative portion of the AP document itself.

2.4 Complete AP

Once the AP developers have completed the documentation and validation of the AIM, the remainder of the AP development work involves defining conformance requirements, other implementation-oriented requirements, and completing the AP documentation. This ensures that there are metrics available against which vendor implementations of the AP can be tested for conformance. The information requirements and assertions defined in the ARM and all characteristics defined in the AIM are the starting points for the development of such conformance requirements. Test Groups are defined from the structure of the ARM and Test Purposes are defined for all constructs of the AIM and documented in an Abstract Test Suite. Review and evaluation of the AP's Conformance Requirements and Abstract Test Suite is performed by application experts and AP methods experts. The results of this evaluation are included in the AP Validation Report.

AP developers are responsible for compiling all of the requisite components of the AP specification into a document according to established style guidelines [12]. In addition to the components discussed above, these include a Foreword, Normative References, and English definitions of terms used within the AP. At several stages of AP development the document is submitted to various committees and representatives of voting members (countries) in ISO for review and comment. These reviews result in the submission of issues against the AP. Throughout the development and balloting process, AP developers must maintain logs of issues raised against the AP and the team's responses to these issues.

3 Functional Specifications

The APDE will provide a user with four primary functional units, corresponding to the four major components of the AP development process identified in section 2, namely AP project definition, AP information requirements definition, AP interpretation, and production of the complete AP document. Although a certain amount of functionality will be shared among all of these functional units, it is envisioned that the user will interact with the APDE primarily in one of these modes at any given time.

In the following sections, to provide traceability back to the individual requirements, the elaborations of the functional specifications include references back to the requirements supported by these specifications. For example, the notation "(2.1.A)" indicates that the particular functionality is derived from requirement 2.1.A in [1]

3.1 AP Project Definition

This section describes the functional aspects of the APDE supporting the activities described in section 2.1 and the corresponding requirements documented in [1].

3.1.1 Scope and Requirements Development

At the outset of an AP project, AP developers need to be able to easily review the scope and requirements of existing APs to accurately assess STEP coverage of their industry need. As the number of APs increase, this task will become more important and more time consuming. For this reason, users of the APDE will be able to browse and perform keyword searches over the scope and requirements portions of existing APs. If overlap with an existing AP is desired, portions of the text may be imported into the new AP.

Fundamentally, the APDE will support the collection of requirements (2.1.A). These requirements will come from application experts. The APDE will be able to import and export requirements in a variety of formats. It will provide for the dissemination of these requirements to team members and application expert reviewers across various locations.

The APDE will support requirements gathering (and requirements validation) through the use of electronic questionnaires. The APDE will support the development of the questionnaire, its distribution, and the collection and collation of results.

The APDE will foster interaction between team members as if they were in a meeting. The free exchange of ideas will allow the development of consensus within the team on the development of the initial scope statement of the AP.

The APDE will be able to produce a report of the requirements in a format that can be browsed. It must be possible to establish connections between the requirements and particular constructs in the AAM to facilitate the validation of the AAM (2.1.H).

The APDE will also provide for version control of scope and requirements to keep corresponding versions of the different components (i.e., scope, requirements and AAM) synchronized (2.1.I).

3.1.2 Application Activity Model Development

The main focus of the Application Activity Model (AAM) development functional unit will be a graphical IDEF0 model editor (2.1.D). Various IDEF0-specific functionality and other general AAM manipulation capabilities will be built around this editor.

The AAM unit will be capable of evaluating the decomposition of the AAM and enforcing all IDEF0 modeling rules, although the degree of enforcement will be user selectable, to allow partial models to be saved (2.1.C, 2.1.D, 2.1.E). In addition to its graphical component, this unit will allow textual definitions to be associated with the various terms introduced in the AAM. These definitions will ultimately form the AAM glossary (2.1.F, 2.1.G).

It will be possible to browse the AP scope and requirements information described in section 3.1.1, in order to provide for traceability of requirements throughout the AP development process. In addition, it will be possible to establish connections between particular constructs in the AAM and these previously established requirements. The AAM unit will be capable of ensuring that all AP requirements have been represented in the AAM, and that all AAM constructs are traceable to some AP requirement (2.1.H). The AAM model editor will be capable of documenting the results of this validation for use in the AP Validation Report.

While an AAM is being developed, it will also be possible to browse the AAMs of other APs, in order to facilitate the identification of areas of overlap and to promote consistent activity modeling style (2.1.B).

All of the information captured in the AAM development process will be available to the other APDE functional units as well (2.1.F). In particular, the AP document production unit will be able to produce from this information a fully documented AAM, complete with its glossary, in a standard form which complies with the directives in [11] and [12] (2.1.B, 2.1.F, 2.1.G).

3.2 AP Information Requirements

This section describes the functional aspects of the APDE supporting the activities described in section 2.2 and the corresponding requirements documented in [1].

3.2.1 Application Reference Model Development

The central facilities of the Application Reference Model (ARM) development functional unit will be graphical information model editing tools. These editing tools will provide for creation, maintenance, and browsing of ARMs in IDEF1X, NIAM, and EXPRESS-G. Each of the editors will be capable of enforcing the consistency and constraints particular to the information modeling methodology it supports, although the degree of enforcement will be user selectable (2.2.E). Each of the editors will also be capable of creating printed representations of an ARM diagram in a variety of output sizes (e.g., US Letter, A4, B size drawing, etc.). These printing capabilities will support intelligent diagram layout features such as off-page references (2.2D). The APDE will provide the ability to translate application models between the above mentioned information modeling languages (2.2.C).

Since the information contained in the AP scope, requirements, and AAM drives the development of the ARM, the facilities described in section 3.1 must be easily available to the user during ARM development. Since the AAM is a logical starting point for ARM development there will be a capability for maintaining links from designated AAM elements to the ARM. In addition to providing access to other components of the current AP under development, this unit will also permit examination and extraction of components from other existing APs (2.2.H).

The ARM development functional unit will also assist with identification of Units of Functionality (UoFs). Features will be available which allow the user to select ARM elements and tag them as those which comprise a particular UoF. Names from the tagged elements will then be available to the AP Documentation functional unit for documentation of the UoFs (2.2.B).

An AP development team may choose from a variety of methods to perform ARM validation, depending on the type of information the AP is intended to support [12]. Validation of the ARM will be supported through features which allow the ARM developers to link UoFs with documentation of Test Purposes, test methods, test data, test results and coverage analysis (2.2.I).

3.3 AP Interpretation/AIM Development

This section describes the functional aspects of the APDE supporting the activities described in section 2.3 and the corresponding requirements documented in [1].

3.3.1 AP Interpretation

The primary facility of the AP interpretation functional unit is a software component allowing for the search, examination, and retrieval of candidate EXPRESS entities from the Integrated Resource specifications. Candidate entities will be presented to the user based on the user's specification of search criteria, e.g., finding entities which have keywords in common with ARM element names, finding entities which are related in some specific way to other entities, etc. (2.3.A, 2.3.C). The user will use these retrieval facilities to find EXPRESS entities (if they exist) which correspond to the ARM element being interpreted. When an appropriate EXPRESS entity is selected, this functional unit of the APDE will allow the user to link the EXPRESS entity with the ARM element, and thereby form the basis for documenting the mapping between the two (2.3.G). Finally, this functional unit will also allow the user to verify that all ARM elements have been mapped to EXPRESS entities (2.3.K).

The mapping between the ARM and the Integrated Resources is documented in the Mapping Table. The generation of the Mapping Table lends itself very nicely to software support. To support this, the APDE will manage formatting details of the Mapping Table (2.3.I). In addition, this functional unit will assist in the creation of the Mapping Table by maintaining links between the Integrated Resource constructs and their interpretations in the AIM (2.3.J).

The Mapping Table will be automatically generated from the Application Objects and Application Assertions in the AP.

3.3.2 AIM Development

The result of the AP interpretation process is the AIM Short Listing. The functional unit supporting this process will be a textual information model editor specialized for EXPRESS (2.3.H). This editor will provide features which can ensure that correct language syntax is used and will also help with the incremental development of the AIM. For example, when a selected EXPRESS entity must be further constrained to satisfy the intent of its corresponding ARM element, the editor will provide templates for the definition of various common classes of constraints in EXPRESS (2.3.D).

In addition to the Short Listing, the AIM must be documented in an Annotated Listing and an EXPRESS-G diagram. The APDE will be able to automatically generate the Annotated Listing, including all associated text, from the Short Listing and the Integrated Resources (2.3.L, 2.3.M). In addition, this functional unit will provide a graphical EXPRESS-G editing facility which is able to maintain links between EXPRESS-G constructs and corresponding constructs in the Short and Annotated Listings, using these links to verify the isomorphism of the textual and graphical forms of the AIM (2.3.O, 2.3.P).

An AP development team may choose from a variety of methods to perform AIM validation, depending on the type of information the AP intends to support [13]. Validation of the AIM will be supported through features which allow the AIM developers to link EXPRESS entities with documentation of Test Purposes, test methods, test data, test results and coverage analysis (2.3.O).

After the AIM is completed, an AP developer generates a list of abbreviated names for the entities and types in the AIM. These short names are used in STEP exchange files and must be unique across all AIMs. The AIM Development unit will include a facility which generates these abbreviated names based on a given algorithm and checks an information base of existing AIMs to verify that the names are unique.

3.4 AP documentation

This section describes the functional aspects of an APDE supporting the activities described in section 2.4 and the corresponding requirements documented in [1].

3.4.1 Document Production

As much as possible, the APDE will insulate users from ISO and STEP documentation guidelines, allowing them to focus instead on the information content of the AP. To this end, the APDE will provide functionality to compile AP documentation from the various components built using other functional units. While other functional units will provide some of the text processing functionality described herein, this functionality will be incidental to the units' focus on the information content of the AP. In contrast, the document production unit will focus on the AP as a document, providing such functionality as clause templates, document previewing, and overall layout.

Each functional unit described above requires some text processing capabilities. For example, entering and modifying AAM definitions requires some form of text editor. The same text processing interface will be used in all such instances throughout the

APDE. In addition, some document components are largely textual in nature (e.g., Normative References, Conformance), and are not addressed by any functional unit. These components will be edited using the text editing facilities of the document production unit.

The APDE will provide templates for the various sections in AP documents (2.4.A). A significant part of these templates will be the boilerplate text which is provided in [12] for various clauses in AP documents (2.4.D). In most cases, boilerplate text and user-provided text must be mixed within clauses, so there must be a mechanism for inserting and then maintaining this boilerplate within an active text segment. In other cases, such as the document Foreword, an entire clause may be dictated by STEP directives, in which case this boilerplate text will simply be inserted at the time of document production. In both cases, the APDE will allow these templates to be modified as documentation guidelines evolve, and will migrate these template changes into APs under development (2.4.A, 2.4.D).

Because the rest of the APDE focuses on the information content of the AP independent of its final presentation, the document production unit will provide functionality to view portions of the document itself in its final form, both on-screen and on paper. In addition, it will be possible to manipulate the layout of the document as a whole (2.5.B).

To aid in tracking the status of APs under development, the APDE will also provide bookkeeping functions allowing individual clauses or information components to be marked as being complete or not, or to be marked for special attention. This bookkeeping will be available at varying levels of detail (2.4.C).

In order to ease the labor-intensive task of document editing, facilities such as spell checking and English grammar and style analysis will be provided (2.4.B).

Two document processing systems are currently recommended for use by AP developers. These are LaTeX[1] and WordPerfect[2]. The APDE will provide the ability to easily translate text between the two formats (2.5.A).

3.5 Support Functions

This section describes the functional aspects of the APDE supporting the AP development cycle as a whole and the corresponding requirements documented in [1].

3.5.1 Methodological Support

The AP developer is provided guidance from a variety of currently evolving documents (e.g., [11], [12]). It is difficult for an AP developer to find guidance on development methods for all components of an AP and to be sure that the documentation found is the most current. Although it is anticipated that the AP development methods will become more stable as the first APs and other related documentation (AP Validation Report, Abstract Test Suites, etc.) are completed, the problem of not having the current versions of the pertinent documents in one place will persist (2.3.E, 2.5.I). For this reason, the

1.LaTeX is a freely available document processing system [9].
2.WordPerfect is a registered trademark of WordPerfect Corporation.

APDE will provide an information base of the methodology documents that will support queries for information and provide browsing capabilities for the resulting documentation.

3.5.2 Workflow and Version Control

Since development of an AP is accomplished over a period of time by a group of people, workflow and version management supporting AP development will be available from any functional unit (2.2.A, 2.2.F, 2.2.G, 2.2.J, 2.5.H). Workflow and version control features will include:

- Ability to designate individuals who are permitted to edit and modify particular components of an AP and designation of individuals who are only permitted to browse the AP components;
- Ability to designate individuals who are to be informed when updates are made to an AP component, who made them, and what the changes are;
- Ability to designate release status of the AP component, i.e., whether it is still under development by its owners, whether it is ready for review and comment by designated groups of people, whether it is finished, etc.;
- Ability to establish linkages at various levels of detail between the AP components, e.g., between individual ARM elements and elements of other AP components so that changes to the ARM automatically flag potential changes to other AP components and between a particular version of an ARM and particular versions of other AP components so that one version of an ARM can used to retrieve the corresponding versions of other components in the AP.

3.5.3 Issue Management

Issues documentation and resolution is an ongoing process with AP developers. The APDE will provide the following features in support of this process: a uniform format for issues documentation which includes all pertinent information (2.5.D); the ability to perform keyword searches of the issues (2.5.C); and the ability to distribute issues and resolutions to all interested parties (2.5.G).

To facilitate the tracking of issues, the APDE will be able to establish linkages between issues and specified targets, e.g., document text, entity definitions, rules, etc. (2.5.E). Version control mechanisms will also be provided between particular issues and particular versions of STEP specifications (2.5.F).

4 Conclusion

The functional specifications presented in this paper constitute the second step in the specification of an Application Protocol Development Environment. This report only seeks to identify the functionality of the APDE. Architectural decisions and formulation of technical solutions will be the topic of the next report in this series.

These functional specifications are based primarily on the requirements received from AP developers as presented in [1]. Not all aspects of the AP development process have yielded requirements. For example, delivery of conformance requirements and test criteria are necessary tasks, yet we received no requirements for tools or techniques to assist with these tasks. Unfortunately, the lack of requirements is probably not due to the simplicity of the activity or the availability of existing tools. Instead the absence of requirements is attributed to a lack of experience with these tasks. When all aspects of AP development are exercised, it can be expected that there will be additional requirements for the APDE, which will cause modifications to the functional specification. Until that time, the authors have included in this paper functional specifications in these areas to the degree that the process is understood and/or documented.

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B Functional Requirements

Several representatives of current STEP Application Protocol development projects provided the authors with descriptions of capabilities desirable in an APDE. The input obtained from these potential users of an APDE has provided the authors with a better understanding of the AP development process and the difficulties facing developers. The information obtained from the AP developers is documented in the initial requirements document for the APDE [1].

The requirements described in [1] have been further abstracted and analyzed using a process known as “Quality Function Deployment” or QFD [14]. The QFD process facilitates the analysis of customer requirements, prioritization of customer needs, and determination of how well proposed solutions satisfy customer needs.

B.1 APDE Customers

There are numerous people or organizational units which could be considered as customers of the APDE. The most obvious group, and the one which is considered to be the primary customer, are AP development teams. These teams are typically composed of representatives from industry, government, special consortia, etc., working together through the organizational structure of the U.S. IGES/PDES Organization (IPO) and/or ISO TC184/SC4. The QFD results described here reflect the emphasis that was placed on this customer group.[1]

B.2 Customer Requirements

The initial requirements described in [1] have been categorized into three broad areas: those which deal with how users interact with an APDE, those which describe desired AP validation features, and those which describe desired communication features. High-level requirements have been identified within each of these categories based on a collation of the requirements in [1]. The collated requirements were then given a weighting factor which indicated their relative importance to the customer. The weighting factors were assigned based on the original information provided to us by AP

1.The other customer groups considered as potential users of an APDE are comprised of much fewer people than the AP developers. One such group is referred to as AP interpreters. AP interpreters are a small number of individuals participating in ISO TC184/SC4 who are experts in the philosophy of STEP, the methodologies used for STEP development, and the contents of the STEP Integrated Resources. The job of AP interpreters is to transform AP information models described using application-specific terms (specifically the Application Reference Model) into information models based on the STEP Integrated Resources. Another such group is referred to as Abstract Test Suite developers. They are a small number of individuals participating in ISO TC184/SC4 whose role is to specify the conformance criteria for APs.

developers. The collation of the high-level requirements is shown in Table 1; note that within each category the requirements are listed in descending order of importance to the customer.

Table 1: High-Level Customer Requirements for an APDE

INTERACTION
Produce correct models without thinking about syntax, modeling, and layout
Produce correct documents without thinking about ISO & STEP guidelines
Easy to interact with
Avoid redundant entry of redundant information
Control degree of rule enforcement
Present information content in various forms
VALIDATION
Track relationships among document components with varying granularity
Verify coverage of upstream information requirements
Validate AP requirements
Verify existence of requirements for information elements
Validate models against requirements
COMMUNICATION
Exchange and use others' information
Facilitate intra-team communication
Enforce consistency among corresponding components across APs

B.3 Predictive Metrics

The QFD methodology specifies that for each requirement identified, one or more predictive and quantifiable measures must be established. The metrics must be quantifiable in the sense that one must be able to assess how well any particular implementation would satisfy the metric based on the implementation's design (rather than on the implementation itself). The metrics can also be used against competing implementations to measure how well a competitive product satisfies the customer requirements. In the case of the APDE, there are no competitive products, though there are commercial products which satisfy small subsets of the requirements.

Table 2 shows the APDE metrics which, like the high-level requirements, are listed in order of importance within each category. A (+) after a given metric indicates that its value is to be maximized, while a (-) indicates that the metric's value is to be minimized.

Table 2: Predictive Metrics for High-Level APDE Requirements

INTERACTION
Number of ISO & STEP guidelines checked (+)
Average number of presentation forms per information type (+)
Number of modeling conventions checked (+)
Average number of times particular information input (-)
Average number of modeling conventions whose enforcement configurable (+)
Percentage of user features supported in graphical user interface (+)
VALIDATION
Time to find information element(s) fulfilling requirement (-)
Time to find requirement(s) for information element (-)
Time to identify impact of proposed change to AP scope or AP requirements (-)
Time per model construct for validation (-)
Time per requirement for requirement validation (-)
Time to identify impact of proposed change to Integrated Resource (-)
COMMUNICATION
Number of steps to send/receive others' information in usable form (-)
Percentage of expected communication modes supported (black board, e-mail) (+)
Percentage of deviations between corresponding AP components (-)

B.4 QFD Results

The metrics which have been selected for the high-level APDE requirements will be used to help with the selection of commercial products for the APDE implementation. In addition, the metrics will help determine how well the overall implementation satisfies the customer requirements.