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Information Resource Dictionary System: An Integration Mechanism for Product Data Exchange Specification

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U.S. DEPARTMENT OF COMMERCE
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INTRODUCTION

This paper discusses the need for a mechanism that allows various views of product data to interface with various techniques for managing product data. The Information Resource Dictionary System (IRDS) [ANSI Standard X3.138-1988] is proposed as an integration and configuration management mechanism for the Product Data Exchange Specification (PDES).

BACKGROUND

The design of manufacturable products is an increasingly complex process for industry. Advances in technology have resulted in compartmentalized life-cycle product development activities. This has led to the isolation of the product designer from others participating in product development. Those isolated from access to the designer are: (a) the sponsor who has the need for the product, (b) the process planner who understands how the product can be produced in the factory, (c) the manufacturing manager who understands the operation and performance of the shop floor equipment, (d) the quality assurance inspector who understands how to measure the functionality of the product, (e) the service engineer who is responsible for repair and preventive maintenance of the product, and (f) the reliability engineer who is responsible for tracking the performance of the product over its lifetime.

At each stage of the life-cycle, important knowledge about the product is acquired. Unfortunately, this information is seldom available to staff working on other stages of product development. Specifically, the designer may not understand the impact of his design on the creation of a true 'world-class' product -- one built to minimum cost with highest quality and greatest functionality, in the shortest time span. To integrate the isolated activities of product development, more attention needs to be paid to the information exchange that occurs during the product life-cycle.

With sophisticated and ever evolving technologies, users of product data are faced with the need to exchange information across diverse and dissimilar systems. At the same time, these users must maintain the various contexts within their organization and functional responsibility. The integration of systems as well as the integration of information within this technological heterogeneity is the "core" of the developing Product Data

Exchange Specification (PDES). Recognition of the need to organize the integration and exchange of this information has resulted in a major effort within the PDES community to define an architecture for this purpose.

TOPICAL MODELS

The PDES community has been seeking solutions to manage and exchange information about products as opposed to the graphical exchange of drawings of products. The IGES/PDES Organization, the voluntary standards organization, has been developing the product information descriptions (called conceptual models) across a broad industrial base (e.g. mechanical, electrical, etc.). These descriptions, some common to many industries and some unique to particular industries, form a "core of information" about products. As application activities are defined, committees have been formed to formalize the necessary information shared between product development activities. This effort has resulted in conceptual models which provide the framework for the product information to be exchanged.

When a consensus has been reached on an individual topical model, the model is then voted out of committee as a draft specification. The various models have then been considered for integration, when they contain common information. The PDES Integration Committee was formed to find the overlaps and intersections between different applications. Identification of the integration elements needed to connect individual application models has resulted in a "core" model called the Integrated Product Data Model (IPDM). This model is used to describe how the topical models can be merged into the complete PDES conceptual model.

The urgency to produce a PDES standard that is useful to the industrial community has forced the decision to define PDES as a collection of versions. Each new version enhances the product data definition available in the previous version. In addition, each new version will expand the scope of PDES to incorporate more life-cycle activities. As these versions are released, the techniques for representing the conceptual models may vary because of the new complexity and richness of the specified information. In addition, only the later versions will specify sufficient product data to allow database and knowledge base implementations to be efficiently built.

A conceptual model contains the fundamental objects and concepts managed by an enterprise. The conceptual model also depicts the relationships among the fundamental data objects of the enterprise. Fundamental data objects are combined to create useful collections of data which are subsets of the conceptual model, called external views. An "external view" consists of user-specific data and the structural organization of that data. The procedures for creating the collections are unique recipes or instructions for manipulating the fundamental data. These procedures require management in their own right. They are not part of the conceptual model. The rules for deriving external views are user-specific and unique to each application.

Since the conceptual model includes all the important facts about an enterprise, it can be thought of as a detailed "database" containing vital constructs which can be extracted and viewed in various ways. Extracts can provide a mechanism to validate the content and intent of the conceptual model.

Once the first sharable topical product models were generated and integrated, the PDES group had to consider the following technical issue. How could the product model be represented in a totally unambiguous manner? The answer was to represent the information using a database design technique called "data modeling." The various PDES application subcommittees then implemented the specific topical data model in a variety of data modeling formats. This caused a problem at integration, as different data modeling techniques were used by different application subcommittees. As with all technologies, there are a range of tools, each of which is best for solving specific problems. Improved and extended data modeling techniques, as well as the tools to implement them, will continue to appear in the future. Because PDES will be an ever evolving standard, it is appropriate to allow the different topical data models to be defined using a variety of data modeling techniques.

To be able to tolerate and integrate multiple modeling techniques, a mechanism is needed for transferring specific data models between the competing data modeling techniques. An ideal candidate for this mechanism is a "data dictionary system" that can save the product data model in a neutral specification. Using a data dictionary system as this mechanism, it is then necessary to implement only one pair of translators for each data modeling technique. This allows for the translation of one data modeling representation into the neutral format, and the translation of the neutral format back into another data model representation. The data dictionary system also becomes an effective and efficient configuration manager for the development of the IPDM.

PRODUCT DATA MANAGEMENT

The IPDM, resulting from the integration of the merged topical models, abstractly defines the way in which the product data elements interrelate. In addition, the "physical level" defines the way the actual product data is represented, organized and stored (such as on a disk or in memory). [Figure 1] The PDES community is currently defining levels of implementation for PDES. These levels define the "road map" for how product life-cycle activities (e.g. design, process planning, etc.) will interface to the PDES implementation.

This leads to the second major issue: the development of a mechanism that can manage the enterprise data and data semantics for use in PDES implementations. This information management capability can be supported by a data dictionary system that has adequate functionality. The data dictionary system must be able to interact with a variety of data storage techniques, such as relational databases, file systems, object oriented databases, etc. The data dictionary system must be able to describe the data structures (e.g. strings, numbers, dates, tables, geometric entities) that exist in the product information representation and be able to cross-reference the associations among these data structures. This PDES information must then be accessible to the life-cycle systems through a neutral language that may be dependent on the level of implementation but should not be dependent on the actual system implementation (i.e., the language of a given relational database management system (DBMS) or file management system).

APPROACH

The storage and management of all the components of PDES development information in one logical, standard, data dictionary system is the cornerstone for automation and reusability in the future. Such a data dictionary system is required to manage the numerous PDES topical and application models, model integration, the validation process and the necessary documentation.

The Information Resource Dictionary System (IRDS) standard being developed by the American National Standards Institute (ANSI) and the National Institute of Standards and Technology (NIST) can meet this need. The IRDS can be used to identify and control all of the "pieces" that make up PDES and to evaluate the effect of needed changes that will occur as the PDES standard emerges. With the use of the extensibility feature, the IRDS provides a stable platform for development and maintenance even when the underlying technology is changing. [Figure 2]

The IRDS can support system integration by merging development and maintenance tools into one environment. PDES development requires the use of data modeling tools, data dictionaries, DBMS, and, eventually, knowledge base systems to support all its functions. Commercial and public-domain products exist in all these areas. They can be easily obtained, but not easily interfaced. The IRDS can provide the mechanism by which these tools can be interfaced and replaced as new technologies emerge.

The IRDS can support the 3-schema architecture (i.e., the external view of the user, the logical conceptual model, and the physical or implementation view of the internal model). [Figure 3] Another way to visualize the three-schema architecture is as a 3-dimensional space, with the three axes representing use, processing and universality. Each of the three schemas-- external, internal and conceptual -- can be represented as a point in this space. The major component of each of the schema points projects on a different axis: external projects on the use axis, internal projects on the processing axis, and conceptual projects on the universality axis.

This architecture permits the relationships between levels to be independently defined, permitting some changes to be made to the specifications at one level without affecting the specifications at the other levels. Major changes, such as expansion of scope, discovery of additional relationships, etc., will impact all levels. Therefore, it is important to know how each level is with the other through cross-referencing relationships. The IRDS is the <u>only</u> recognized information management standard in this area.

The IRDS provides a basic Functional Schema which directly supports much of the information that an organization needs to keep about implemented software systems. For example, the ability to describe the data elements that make up a record and how records are organized into a file is part of the IRDS BAsic Functional Schema. Further, the IRDS provides a general schema extensibility mechanism for tailoring and adding types of information resources that need to be managed within an organization. Schema extensibility is provided since the IRDS does not intend to describe all of the types of resources that enterprises may need to manage with a data dictionary. What is provided by the standard is a schema with a minimum set of information resource types, to be used as an example, along with building blocks for extending the schema to meet each organization's needs. It is this extensibility feature which makes the use of IRDS so attractive.

What are the major categories of product data information resources that must be managed if the full potential of an information resource dictionary is to be realized for PDES? PDES information resources can be grouped into three categories:

1) implemented systems and data organizations,
2) conceptual models and business rules, and
3) data usage and external views of data.

If the data types provided by the IRDS Basic Functional Schema are examined, most of them fall within the first category of information resources. The IGES/PDES Organization has spent almost all its effort defining the second category of resource types. Major efforts are still needed in the third category to define industry and activity specific views of PDES or application protocols.

To be a more complete and effective tool for the PDES community, the IRDS schema structures must be modeled with an Information Resource Dictionary (IRD) to store and access the conceptual IPDM. The schema of this IRD must be extended to capture and document the meaning of the entities, relationships and attributes which comprise the integrated conceptual model.

Once a neutral conceptual model is developed, the IRDS can be used to effect change control over existing applications and databases. Currently, IRDS provides facilities for recording, storing, and processing descriptions of data. It can create and store schemas for all types of data management systems. Thus, application programs will not need to incorporate the schemas into their code; programs can obtain the necessary information from the IRDS, resulting in a true data-driven system. The PDES dictionary can also serve as the access control point for all current models. The activities described below provide directions to pursue to support specific PDES needs. We are not attempting to address more general problems.

ACTIVITIES

1. Build a schema for a PDES Information Resource Dictionary, using the IRDS schema extensibility feature to support the storage and management of the diverse conceptual models built by the PDES committees.

   The extensibility feature of IRDS will be used to define a set of information resource types, called metatypes, which correspond to each of the fundamental constructs found within the conceptual modeling techniques used by PDES. This new schema definition will allow IRDS to support the storage and retrieval of conceptual models. Automatic dictionary loading and version-controlled updates must be added to the existing IRDS prototype to support management of the conceptual models.

2. Extend the PDES Information Resource Dictionary schema to support a full three-schema architecture, and populate the IRD with PDES information.

   Initially this repository will hold the conceptual models, supporting entity definitions, and scoping statements, as well as related, but unresolved, issues. The IRDS Basic Functional Schema supports only information describing the internal schema, specifically physical databases and files, computer hardware, and user profiles. Therefore, the PDES

IRD schema will be expanded to support a full three schema dictionary. When application subsets, testing criteria, test cases, and implementation guidelines are developed, the PDES dictionary can then be populated with relevant information. This will permit evaluation of the effects of changes and expansions in the PDES standard. These resources can then be brought into alignment with the standard.

3. Develop automated or assisted translation between diverse data models and represent these data models in the IRDS.

There are three types of data models being produced by PDES activities. PDES Version I will contain both EXPRESS and IDEF1X, two types of data models. In addition, some committees are formalizing their work in NIAM, a third type. A NIAM model must be translated into both IDEF1X and EXPRESS before it can be incorporated into the PDES standard. Equivalent concepts between these models must therefore be identified and formally represented to ensure that the different types are consistent. Translating these data models into the IRDS can provide PDES with a unified representation of this information, and permit consistency checking among the data models.

4. Interface the PDES Information Resource Dictionary to available software.

The IRDS provides for integration between data modeling tools, database and system design aids, and application development. As the repository for dictionary metadata describing functions, data, and objects that compose an application, the IRDS becomes the key integration tool for PDES application development. In addition, it provides the IRDS Export/Import Facility to control moving IRD schema and metadata definitions from one site to another. The IRDS Export/Import Facility is currently under development at NIST.

4.1 Utilize conceptual modeling tools.

These tools are used in the requirements analysis and system design phases. They provide quality controls in the definition of both data models and functional design. Most will also generate a prototype database schema in one or more relational data definition languages. Most also have an interchange form. This interchange form is the most likely method for interfacing these tools to the IRDS. No standardization efforts are active within ANSI to develop a standard conceptual modeling language that could be used for this purpose.

4.2 Support IRDS information interchange with DBMS.

DBMS provide a general purpose capability for storing, accessing, and managing actual instances of data. The Structured Query Language (SQL) standard and the Network Database Language (NDL) standard are expected to be the first of the DBMS related standards to be interfaced to the IRDS standard. Remote Data Access (RDA), an International Organization for Standardization (ISO) standards effort, is not yet mature enough for an interface to IRDS to be designed. RDA also supports less capability than a distributed PDES database implementation needs. However, ISO has done enough work in the distributed area to identify the minimum information requirements that a data dictionary/directory must manage to support this distributed aspect. The IRDS Service Interface, which is currently under review, is an addendum to the IRDS standard that will support the use of the IRDS in an active mode. The Services Interface is expected to be formally accepted as part of the IRDS standard in 1990-91.

5. Develop Relationships to Physical Design.

The PDES organization is not heavily concerned with how PDES is physically implemented because many of these issues fall under the domain of implementors. There are aspects of physical design, however, that must be managed to maintain consistent versions of PDES; PDES will produce an exchange format and testing suites which must conform to the conceptual models defined in the standard. Therefore the elements of the conceptual models must be associated with those of the exchange format and testing libraries. Further, there must be an ability to document the decisions made in the physical design of these modules and to detect changes required to keep these modules consistent with newer versions of PDES. These types of cross-referencing information can be captured and stored in the IRDS.

GLOSSARY

Application Model

A data model which addresses the information requirements for a specific industry or vital business objective such as electrical design or structural analysis.

Conceptual Model

An abstraction of the real world that conveys the concepts, meaning and semantics of information for an organization. It forms the basis for a dialogue between systems and users and is based on a common understanding of the information it represents.

Data Attributes

Properties of product data which describe the data objects.

Data Dictionary

A repository for data definitions, system documentation, data representations, and requirements descriptions of information managed within the automated or manual systems of an organization. This resource is then available over the life-cycle of developing and existing systems.

Enterprise

May be a corporation, a unit or division of a corporation, government unit, or group of cooperating organizations, etc., which is the source or owner of information.

External View

That set of information which is sufficient to support the performance of a particular function or business objective.

Fundamental Constructs

Defines the basic constructs used to create the data model. Each data model technique will have a set of primitive elements that are used to formally describe an actual data model.

Heterogeneity

Use of dissimilar computer hardware and software in support of a common objective.

Implementation Model

A design of the data organization for a system. For database systems this would be a database schema in the definition language of the database management system selected to implement the system. For applications, this would be the data structures in the computer language used to write the application and for object oriented systems, this would be the object class definitions.

Integration

The process of merging together independently developed models into a cohesive and consistent model which reflects a common understanding of information resources used within an enterprise.

IRD Data Layer

The layer of the information resource dictionary that manages the actual descriptions of information resources.

IRD-IRD Interface Facility

A method of exchanging information resource dictionaries to additional sites which may have processing responsibilities.

IRD Schema Description Layer

Provides the basic framework on which to build the types of information resources to be managed within an information resource dictionary.

IRD Schema Layer

Defines the types of information resources to be managed within an information resource dictionary; these are called metatypes.

IRDS

The Information Resource Dictionary Standard is a draft proposed ANSI and FIPS data dictionary standard.

Knowledge Base

A system which is capable of persistent data management and can actively enforce the business rules defined against the data. A knowledge base is capable of evaluating requested functions and performing constraint checking on the data.

Level I Implementation

A passive file interchange implementation of PDES.

Level II Implementation

An active file interchange implementation of PDES.

Level III Implementation

A database implementation of PDES.

Level IV Implementation

A knowledge base implementation of PDES.

Life-Cycle

The distinct phases into which every system may be divided such as requirements, design, implementation, production, and maintenance. Each phase may require different support from the data dictionary which is used to administrate it.

NDL

The Network Database Language is the ANSI standard for data definition and access for network databases.

Physical Design

The process of evaluating an implementation model or design and factoring in performance characteristics and data access to optimize the design.

PDES

Product Data Exchange Specification is a developing standard which will provide for the unambiguous interchange of life cycle product data from concept, to engineering design, to manufacture, and to support.

RDA

The Remote Data Access protocol is an ISO standards activity which is developing a standard for distributed system access.

SQL

The Structured Query Language is the ANSI standard data definition and access for relational databases.

Topical Model

A data model which incorporates the requirements of many users into a data model of limited scope. The scope defines the topic of the data model (e.g. geometry data model).

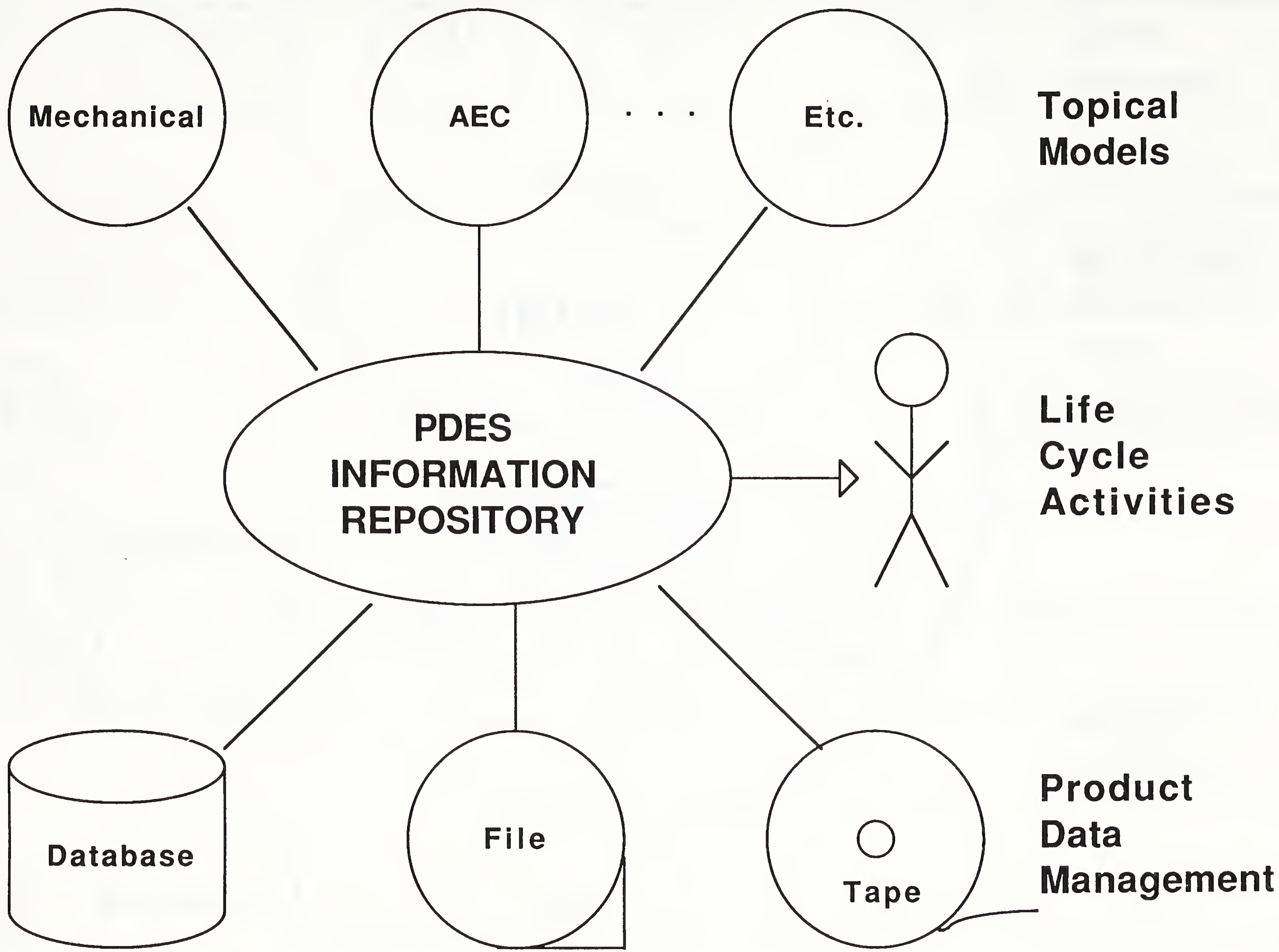

Mechanical
AEC
. . .
Etc.
Topical Models
PDES INFORMATION REPOSITORY
Life Cycle Activities
Database
File
Tape
Product Data Management

Figure 1

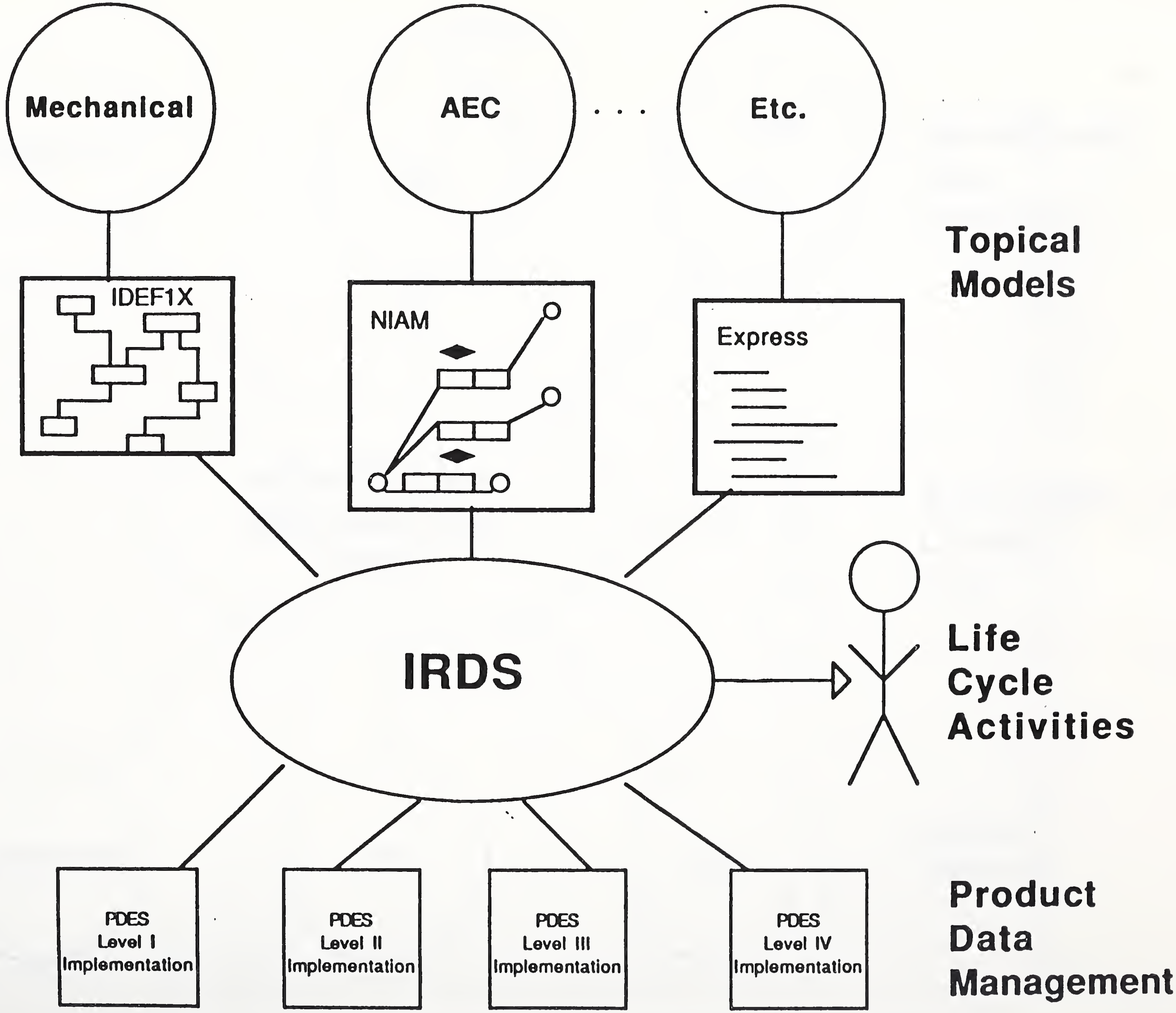
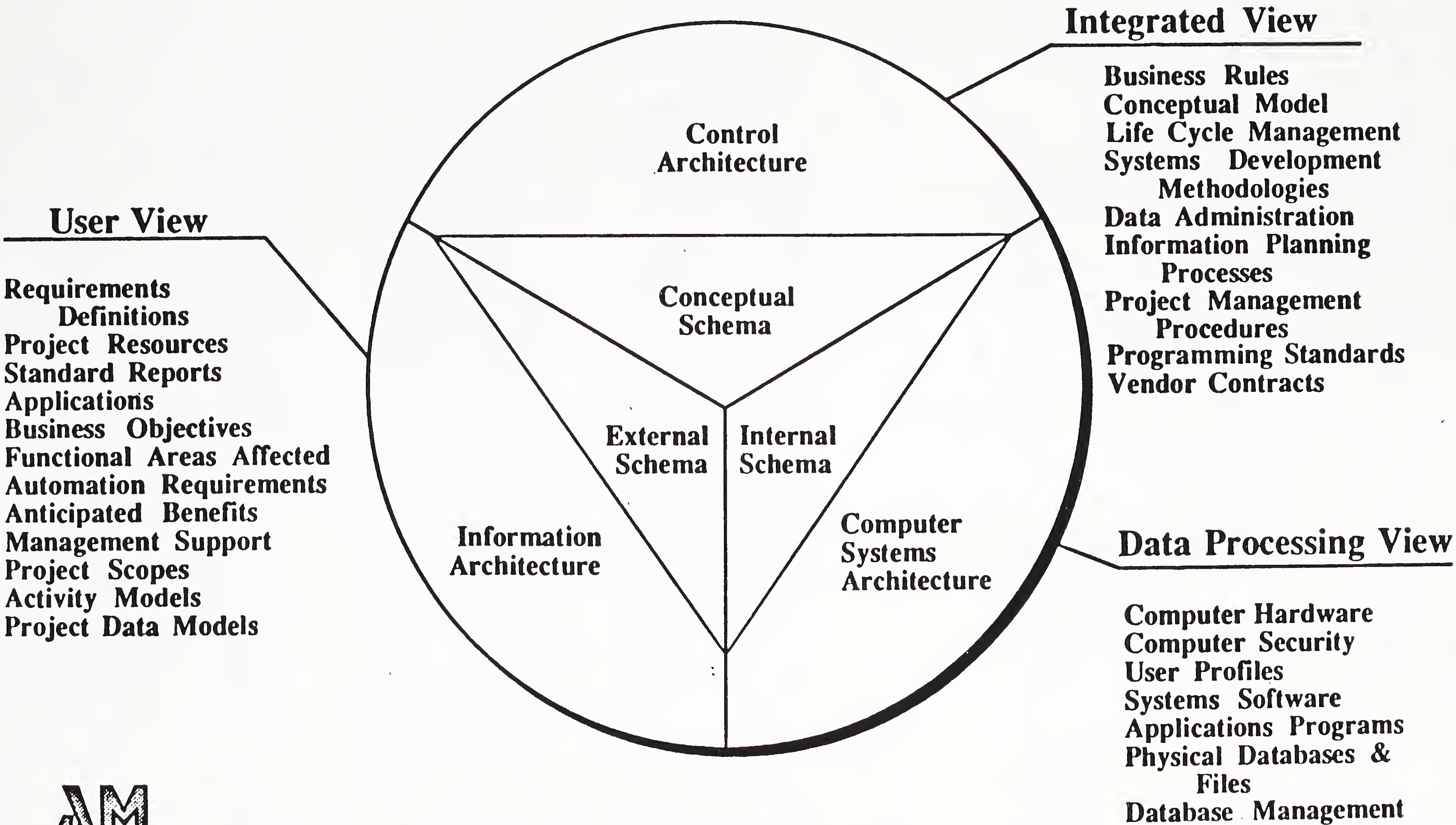

Mechanical
AEC
. . .
Etc.
Topical
Models
IDEF1X
NIAM
Express
IRDS
Life
Cycle
Activities
PDES
Level I
Implementation
PDES
Level II
Implementation
PDES
Level III
Implementation
PDES
Level IV
Implementation
Product
Data
Management

Figure 2

ENTERPRISE STRUCTURE



AMRF

Components of the Three Architectures

Figure 3

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11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

With sophisticated and ever evolving technologies, users are faced with the need to exchange information across diverse and dissimilar systems. At the same time the users must maintain the various contexts within their organization and functional responsibility. The integration of systems as well as the integration of information within this technological heterogeneity is the "core" of product data exchange specification. The need to organize the integration and exchange of this information has been recognized.

A way to store and manage all the components of PDES development in one logical, standard, dictionary system is the cornerstone for automation and reusability in the future. The complexity of the integration task, the validation process, the numerous topical and application models, and the necessary documentation, require the use of a dictionary tool to manage and track the model integration stage of the PDES life cycle. The Information Resource Dictionary System (IRDS) standard being developed by ANSI and NBST can meet this need. The IRDS can be used to identify and control all of the "pieces" that make up PDES and to evaluate the effect of needed changes that will occur as the PDES standard emerges.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

CAD, Computer Integrated Manufacturing, conceptual models, Data Dictionary, data modeling, factory automation, IRDS, PDES, product data, product data exchange

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