

# STEP DATABASES FOR PRODUCT DATA EXCHANGE

Vinícius Medina Kern  
Virginia Tech and PPGE/UFSC  
vkern@cadserv.cadlab.vt.edu

Jan Helge Bøhn  
Virginia Tech, Department of Mechanical Engineering  
Blacksburg, VA 24061-0238, USA

## Abstract

*Product data exchange is a key factor in achieving the goals of concurrent engineering. STEP is an international standard for product data exchange under development by ISO. This paper presents the architecture adopted for STEP development and discusses the implementation of STEP databases using database management systems. Recent work on STEP and object oriented databases is summarized.*

## Keywords

Product Data Exchange, STEP, PDES, EXPRESS, SDAI, Engineering Databases, Object Oriented Databases, ISO

## 1. Introduction

Global competition favors companies that are able to develop and market their products faster and with higher quality than their competition. Product data exchange promises to provide better and faster communication of design changes and releases, and to allow different groups of engineers to work simultaneously on a product's different design and manufacturing tasks.

Several important national standards for partial product data exchange have been developed, however, they remain incomplete. Hence, the development of STEP (STandard for the Exchange of Product model data), an international standard for product data exchange, was launched by the International Standards Organization (ISO) to unify past work and to better prepare industry for international exchange.

This paper presents the motivation for product data exchange, the architecture of STEP, and a discussion of its implementation using database management systems. Limitations of conventional databases and data management needs for engineering applications are outlined, and recent efforts using object oriented databases as data repositories for STEP models are summarized.

## 2. Background

The need for product data exchange arises when product data has to be moved between different applications. This need can exist within or between different engineering teams, departments or companies.

Basic informal solutions to this problem are: faxing drawings, re-entering original data in the destination format, or restricting use to a single software system. These solutions are acceptable in some cases. For instance, partial re-entering of data may be acceptable if the purpose is to assess the external measures for packet design or to build a basic wireframe

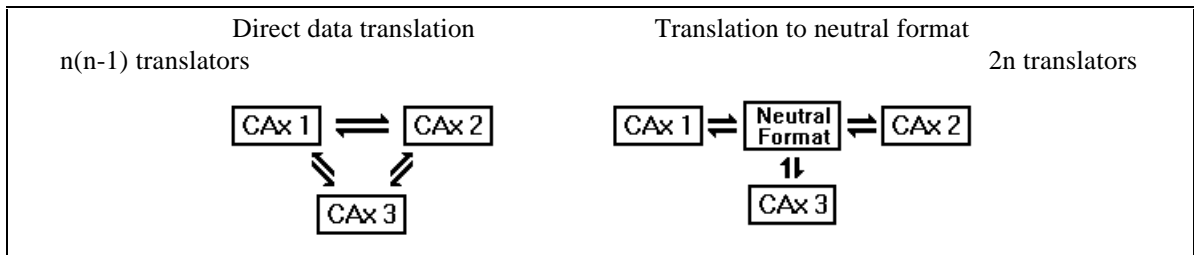


Figure 1 - Direct translation of product model data and translation to a neutral format

Direct translation	Neutral, intermediate format translation
Proprietary formats	Public domain neutral format
n(n-1) translators are needed (n = number of CAx systems)	2n translators are needed (n = number of CAx systems)
A new version of a CAx system requires that all translators involved with that system be updated	A new version of a CAx system requires that a pre and a post-processor be built for that system
One (direct) translation	Two translations (passing through the neutral, intermediate format)

Table 1 - Characteristics and implications of direct and neutral format translation

for finite element analysis. In most cases, however, such *ad hoc* solutions are too constrained.

There are two approaches to data translation from one system to another (Figure 1): direct translation, which implies building a pair of translators for each pair of systems in use, and translation to a neutral format, which implies having a pair of translators, a pre- and a post-processor, for each CAx (CAD, CAM, CAE, CIM) system used. Direct translators tend to be easy to build but costly to maintain. Neutral formats, on the other hand, take time and effort to develop, and carry the risk of being ambiguous or missing features of the existing CAx systems. Even so, this approach is widely accepted as the best solution for product data exchange because it reduces the cost of translator maintenance. The main characteristics and implications of the two approaches are outlined in Table 1.

The first neutral format standards dealt mainly with geometrical data. At the time these standards were published in early 1980's, the existing CAD/CAM systems concentrated on geometry and topology since they often lacked resources for handling the necessary non-shape data, for instance, for analysis or fabrication planning purposes. The most successful among these geometry-only exchange standards were IGES, SET and VDA/FS. In addition to the standards, proprietary specifications were created with the same intent (e.g., DXF).

### 3. An international standard for product data exchange

STEP is the unofficial name of ISO 10303, an international standard for product data representation and exchange. Several national projects are involved in the technical work. It was proposed in 1984 that the existing standards IGES and PDDI (United States), SET (France), VDA/VDMA-FS (Germany), and NEDO (United Kingdom) should form the basis of STEP [1], and PDES, an early proposed successor to IGES, was later realigned in support of STEP.

STEP is intended to handle a product's information throughout its entire life cycle (i.e., from its conception through its retirement). It contains several documents organized in an architecture inspired by the three level architecture for database management systems, i.e., external, conceptual, and internal level:

Introductory	Integrated resources
Part 1 - Overview and fundamental principles	Part 41 - Fundamentals of product description and support
Description methods	Part 42 - Geometric and topological representation
Part 11 - The EXPRESS language reference manual	Part 43 - Representation structures
Implementation methods	Part 44 - Product structure configuration
Part 21 - Clear text encoding of the exchange structure	Part 46 - Visual presentation
Conformance testing methodology and framework	Part 101 - Draughting
Part 31 - General concepts	Application Protocols
	Part 201 - Explicit draughting
	Part 203 - Configuration controlled design

Figure 2 - The first release of STEP as an International Standard (May 1994)

- Application layer: Documents 201 through 1199, known as Application Protocols (APs), are information models prepared by experts for specific application areas. Each of these models is intended to cover the representation of all data for a given application.
- Logical layer: Documents 41 through 199, or Integrated Resources (IRs), are information models for generic purposes such as geometry or topology, or for general application areas such as draughting or finite element analysis. These documents provide the basic constructs used to build the APs.
- Physical layer: Documents 21 through 29, or Implementation Methods, deal with the implementation of the schemata represented by APs and their affiliated product models using a specific technology: physical files, work in memory, databases, or knowledge bases.

In addition, there are introductory documents (Parts 1-9), description methods (Parts 11-19), and a methodology and framework for conformance testing of implementations (Parts 31-39). The first release of STEP (May 1994) comprises 12 International Standards (Figure 2).

Express is a data definition language (DDL) for conceptual schema specification in STEP. Its syntax is Pascal-like and allows the specification of inheritance between constructs.

The separation between product representation (IRs and APs written in Express) and implementation methods is fundamental to STEP [2]. It enables developers to focus on the semantics of data representation without being concerned with physical implementation. For instance, the IRs, Parts 41-99 (generic) and 101-199 (application), provide an unambiguous representation for basic constructs, which can be shared by other IRs or APs. APs make use of the IRs and add specific constraints and relationships to build a conceptual schema for an application area.

#### 4. Implementation of STEP

Current database technologies have been integral to the development of STEP. Its standard parts are organized into a three-level database-like architecture. This is a logical choice since STEP contains vast amounts of information, similar to that of a database. Burkett [3] comments on similarities and differences between STEP development and database design.

The *implementation* of STEP databases, however, differs greatly from the *development* of STEP. STEP implementation involves only APs and implementation methods. The Application Interpreted Model (AIM), the ultimate conceptual schema in an AP, is written in Express. However, unlike a conceptual schema for a database management system (DBMS), Express schemata are not to be translated directly into data dictionaries (DD). Instead, the implementation methods define particular formats and strategies for using the schemata and may include [2] file exchange, application

<pre>(a) ENTITY point ;     x : REAL ;     y : REAL ;     z : REAL ;     END_ENTITY ;</pre>	<pre>(b) ENTITY line ;     p0 : point ;     p1 : point ;     END_ENTITY ;</pre>	<pre>(c) #21 = POINT (1.0, 3.0, -4.5) ; #22 = POINT (1.0, -3.0, -4.5) ; #23 = LINE ( #21, #22 ) ;</pre>
---	---	---

Figure 3 - Entity definitions (a,b) and instances in an exchange file (c) [1]

programming interfaces, and database implementations. The specification of Express is concerned only with the formal aspect of a schema.

The file exchange method defines a mapping from the Express schema to a text file format where each entity occurrence is assigned a unique number #N. For instance, in Figure 3, (a) and (b) are definitions of entities in an AP, and instances of these entities, embedded in an exchange file, have the format specified in (c).

The Standard Data Access Interface (SDAI), which currently is a draft international standard (Part 22), is an interface aimed at isolating the product data from the specific data storage technology. It contains low-level operators to create, delete and retrieve objects, and to insert, modify, and delete object attributes [4]. Language-specific bindings are being developed for C, Fortran, C++, Ada and Pascal. This permits SDAI functions to access a schema and its associated product data models independently of the underlying data storage system.

There are a number of software tools for STEP file exchange [5]. In general, these tools provide an environment for file exchange and check the compliance of an exchange file against an Express schema. However, file exchange is not well suited for full product data sharing. If product data is to be shared in an integrated environment, there must be some way to store and access these data in a common repository, like a database. The next section approaches the implementation of STEP databases using relational and object oriented database technology.

## 5. Using STEP with DBMSs

Relational databases is a well established technology and has a standard query language (SQL). Express schemata have been translated into SQL [5], though this approach has been shown to cause a loss of features [6]. Other flaws of the relational databases, when used to manage engineering data, are [7]: lack of expressive modeling power, impedance mismatch, lack of support for long transactions, and problems with performance, schema evolution, and versioning. In essence, relational DBMSs exert a strict control over the data, implied in the constraints expressed in its DD. This causes a high initial cost for queries. The UPDATE-COMMIT/ROLLBACK mechanism for transactions is adequate for short transactions typical in a business database, but it is not practical for long transactions as is the case with engineering data.

Object oriented databases (OODBs), on the other hand, is an evolving technology which seems to be more appropriate to meet the needs of engineering applications [7]: rich data modeling, sharing of objects among systems, support for object and class evolution, transaction appropriate for cooperative design work, and distributed and platform independent object storage. There is no universal agreement about what an OODB is, but according to Wood [8], these systems seem to be converging towards similar products. He analyses and compares several OODBs in terms of their features for engineering database management.

Organization / Authors	Tool / Functionality / OODB
Arizona State University, USA [4]	SDM (Shared Design Manager) is a blackboard environment using the Itasca object oriented database to support activities associated with design.
CSTB, France [9] [5]	XP-SDAI is an implementation platform supporting the Part 21 format. It allows the storage in persistent repositories (OODBs).
DEC (Digital Equipment Corporation), USA [10]	“STEP Implementation Prototype Package for Level III Database Prototype using Object Oriented Database Technology” is reported. Resources used include Objectivity/DB and languages C++, C and Fortran.
EPM Consultants, Norway [9] [5]	Express Data Manager (EDM) is a multi-user, client-server database management system to maintain Express schemata and models. There is a data manipulation language called EDM, an extended version of SDAI.
Gopas Software GmbH, Germany [9] [5]	ExpressLab compiles an Express schema into an object (C++ based) model. It has a code generator for Ontos DB.
Nanyang Technological University, Singapore [11]	A SDAI implementation on object oriented databases is reported. Versant and Ontos OODBs are used.
NIST (National Inst. of Standards and Technology, USA [9] [5]	Development of a set of test cases with the NIST STEP Class Library (SCL), allowing import/export of STEP files from the database. Open OODB, a Texas Instruments research database, is used.
Rolls Royce Inc., USA [6]	A data sharing architecture and prototype implementation of mechanical part design processes using the OODB ObjectStore is described.
Sema Group Benelux, Belgium [9]	Implementation of an EXPRESS model using the ObjectStore OODB in an ESPRIT project.
STEP Tools, Inc., USA [9] [5]	AP203 Database Manager is a system aimed to manage STEP databases for configuration controlled design. There are database adaptors for ObjectStore, OpenODB, Oracle and Versant.
University of Leeds, England [9] [5]	Implementation of Express models to support engineering applications in DEC Object/Db.
West Virginia University / DARPA Initiative in Concurrent Eng., USA [12]	ISS (Information Sharing Server) enables access to distributed information stored in different repositories. Enterprise (not only STEP) modeling is done in Express. Implementation using Oracle and Versant is reported.

Table 2 - Recent STEP/databases implementations and research initiatives

Table 2 reports recent research and commercial efforts involving STEP and databases. With respect to this work, three points should be emphasized: (1) Since text file exchange is the only standardized method, it is widely supported and frequently is the only format for archiving; (2) Most of the systems on Table 2 use some OODB as data repository; and (3) Different OODBs use different techniques for database management [8]. The appropriate techniques to manage issues such as data integrity, concurrent access, and versioning have yet to be established.

## 6. Conclusion

In this paper, we have presented STEP and the motivation for product data exchange. The basics of implementing STEP are discussed, with emphasis on the utilization of DBMSs, especially OODBs. Recent work using STEP and databases was summarized.

Database implementation of STEP is the most promising aspect of the standard, but its success is still uncertain. Laurance [13] poses the question “Will STEP work?” and states that the answer is “Yes” if it is considered purely as a replacement for IGES (and other previous standards). Unfortunately, the answer is less clear when it comes to sharing product information from “cradle to grave.” This is particularly true when it comes to combining two or more APs in one database.

However, it is expected that the usage of OODBs will prove to be the most effective way to manage engineering data.

## Acknowledgements

This work has been supported in part by the Brazilian National Research Council (CNPq), under process number 200951/94-7. Mr. Kern is a Ph.D. candidate at PPGEP/UFSC, Brazil, under the advising of professor Ricardo Miranda Barcia, Ph.D.

## References

- [1] J. Owen, *STEP - An Introduction*, Information Geometers Ltd., Winchester, UK, 1993.
- [2] ISO TC184/SC4, *STEP Part 1: Overview and Fundamental Principles*, ISO Committee Draft, 15 September 1992.
- [3] W.C. Burkett, "The implementation of STEP schemas," in: K.H.Law (ed.), *Engineering Data Management: Key to Success in a Global Market*, Proceedings of the 1993 ASME International Computers in Engineering Conference and Exposition, San Diego, CA, 1993, pp.25-38.
- [4] S.D. Urban, J.J. Shah, M. Rogers and P. Ravi, "A Heterogeneous, Active Database Architecture for Engineering Data Management," *International Journal of Computer Integrated Manufacturing*, 7, 1994, pp.276-293.
- [5] P.R. Wilson (ed.), *EXPRESS Tools and Services*, National Institute of Standards and Technology, September 1990, Revised December 1993.
- [6] E.A. Edwards-Iwe, "A Client/Server Implementation of the Design Process using PDES/STEP 'Level 3' Data Sharing Architecture," in: K.H.Law (ed.), *Engineering Data Management: Key to Success in a Global Market*, Proceedings of the 1993 ASME International Computers in Engineering Conference and Exposition, San Diego, CA, 1993, pp.15-23.
- [7] J.V. Joseph, S.M. Thatte, C.W. Thompson and D.L. Wells, "Object-Oriented Databases: Design and Implementation," *Proceedings of the IEEE*, 79(1), 1991, pp.42-64.
- [8] C. Wood, "Choosing an Engineering Object Data Management System", in: T.R.Chase (ed.), *Engineering Data Management: Key to Integrated Product Development*, Proceedings of the 1992 ASME International Computers in Engineering Conference and Exposition, San Francisco, CA, 1992, pp.1-14.
- [9] S.P. Reid, Personal communication, 20 April 1995.
- [10] C.R. Whitehead, *STEP Implementation Prototype Package for LEVEL III Database Prototype using OODB Technology*, Digital Equipment, Digital's Prototype Report Draft 1.1, issued 21 November 1991.
- [11] A. Goh, S.C. Hui, B. Song and F.Y. Wang, "A Study of SDAI Implementation on Object-Oriented Databases", *Computer Standards & Interfaces*, 16(1), 1994, pp.33-43.
- [12] R. Karinathi et al., "Modeling Enterprise Information and Enabling Access using Information Sharing Server", in: K.H.Law (ed.), *Engineering Data Management: Key to Success in a Global Market*, Proceedings of the 1993 ASME International Computers in Engineering Conference and Exposition, San Diego, CA, 1993, pp.251-258.
- [13] N. Laurance, "A High-level View of STEP," *Manufacturing Review*, 7, 1994, pp.39-46.