STandard for the Exchange of Product Model Data (STEP)

Why DoD Should Have an ISO 10303 (STEP) Migration Plan

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The DoD needs to implement a plan for assuring that the engineering data associated with procurement, distribution, and repair of its weapons systems will support interoperability and data reuse. The STandard for the Exchange of Product model data (STEP) structure is an emerging international standard that enables interoperability resulting in large cost savings.[1] This article provides some history on engineering data, reports on STEP development progress, and provides recommendations on implementing STEP within the DoD.

Today, all of the major CAD vendors are quick to offer the capability to import and export STEP data files.

Evolution of the Engineering Environment And Associated Data

In the late 80s, DoD undertook an effort to convert engineering data into an electronic media to not only physically preserve this data, but also make it universally available. The approach taken by DoD was that of basically scanning existing drawings into electronic pictures called raster images.[2] While this approach is acceptable for preserving legacy data, it is not sufficient for helping create new or reengineering weapons systems using the computer-aided design/computer-aided manufacturing (CAD/CAM) tools available today.

CAD/CAM systems have experienced a tremendous growth in capability. Many of these systems initially started out as computer-aided drafting tools, offering essentially automated line and curve manipulation capabilities, which facilitated producing the conventional three-view

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(front, top, side) orthogonal parts drawings used by machinists.

Today's CAD/CAM systems provide many capabilities that speed up the parts design process. The biggest speed contributor is the ability to build solid models of parts as a composite of other solids like cubes, cylinders, or cones. Composite solid model structuring is accomplished by pick-and-place operations; the CAD/CAM user picks a basic solid shape out of a library of shapes, dimensions it to match the size of the feature on the new part being created, and then appropriately places it on the other composite features already structured for the new part. Solid modeling also provides a capability to freely roll the part around on the computer screen so it can be viewed from any angle. This facilitates adding new part features and checking part integrity.

Parts'designing is an iterative "trial-and-error process." The engineer is usually trying to minimize weight to enable meeting airlift constraints. In the typical partsdesign scenario, engineers develop an initial design, which they then test using simulation, stress, and fatigue analysis. These tests typically indicate a need to change some key feature, which often requires other modifications on the part, plus modifications of mating parts.

To aid the modification process, most CAD/CAM systems offer a capability to set up parametric relationships among key design parameters such as a constant hole size or a constant ratio between two or more dimensions on a part or among parts on mating assemblies. A change in a dimension on a part then automatically drives changes on mating parts within an assembly of parts. Additionally, design constraints can be applied so when the bumping effect of a change in a dimension occurs, the CAD/CAM user will be notified if a spatial constraint has been violated.

Today's CAD/CAM systems are rich in capability to support manufacturing operations. The most supportive manufacturing role is that of providing the input file required to drive automated Numerical Controlled (NC) processes. Additionally, most of these systems provide a capability to simulate conventional cutting operations to assure part manufacturability, i.e., some part surfaces may not be accessible for some cutting tools. These CAD/CAM capabilities, coupled with automated manufacturing layouts, have in many applications eliminated the need for a machinist.

CAD/CAM systems store their data in a variety of formats, collectively known as vector formats. Vector data are often referred to as intelligent data because they embody all the CAD/CAM background structure needed to rapidly change a design. Raster data unlike vector data are essentially a bit map picture of the part generally shown in the conventional 3-view format. They essentially require the engineer to start from ground zero and develop the solid models needed to change the design or do the changes by hand. For these reasons, raster data are often referred to as dumb data.

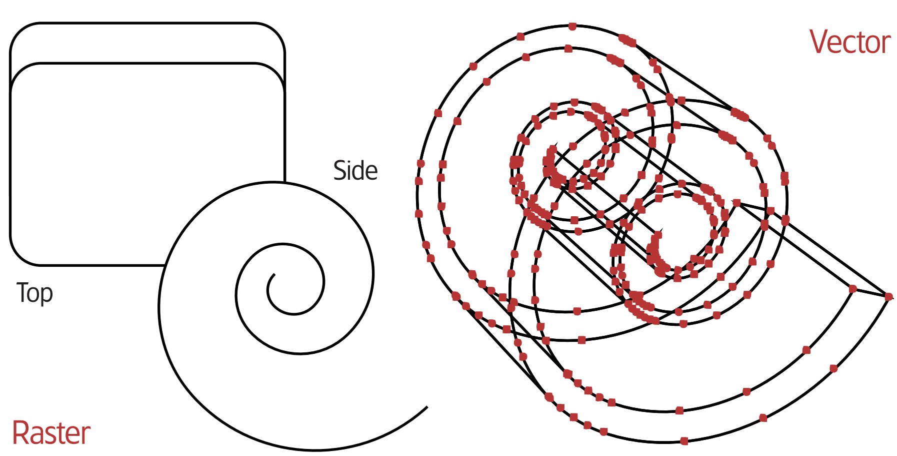
All the CAD/CAM vendors offering products in the marketplace today have their own proprietary format for creating and storing vector data. These proprietary formats make it very difficult to move the engineering data associated with the design of a part or assembly from one CAD/CAM vendor's system to another. Complex DoD weapons system designs today are frequently done in a collaborative distributive environment among a team of designers using heterogeneous CAD/CAM systems.[3] As design complexities increase and designers are becoming increasingly distributed throughout an expanding virtual enterprise, the quantity and quality of collaborative vector data exchanges become critical elements for effective, efficient design and manufacturing.

Origin of STEP

Considerable progress has been made in vector data exchange over the recent past. Initially, some CAD/CAM vendors offered direct translator software. There are several disadvantages to this approach, which include:

- A unique pair of translators is needed for every version of every combination of CAD/CAM systems available in the marketplace.
- The user is dependent on software vendors to maintain this almost infinite combination of version applications.
- The maintenance of all these combinations of transfer capabilities is costly, and that cost is ultimately passed on to the user.
- As a general rule, these translators passed low-quality solid geometry that was not adequate for driving NC operations without the CAD/CAM user having to aid the transfer process by doing a lot of geometry clean-up. Also, no attempt was made to transfer parametric model dependencies/constraints. As a result of these problems, most major weapons system developers and many large-scale commercial vendors such as Boeing, Ford, and GM

Raster/Vector Comparison



as well as many CAD/CAM vendors have abandoned or are phasing out direct translators. Rather, big business is helping to grow and is using an emerging neutral file – an international standard approach known as ISO 10303 (also known as STEP).[4]

The STEP community is in the process of defining and standardizing a number of domain-specific (mechanical or electrical) Application Protocols (AP) that will define neutral files readable by any CAD/CAM system. These neutral files will carry all the information needed for the development and life cycle maintenance of a new product. The neutral file structure will provide the much-needed standardization of DoD's technical data, thus enabling rapid and efficient modification, storage, and retrieval of the technical data.

Today, all of the major CAD vendors are quick to offer the capability to import and export STEP data files as the underlying STEP APs attain the ISO standard acceptance level.[5] Additionally, many large manufacturers who have their own CAD modeling systems to conduct special product studies and design efforts use STEP. The Army, for instance, has its Ballistics Research Laboratory (BRL) CAD system, which is used for conducting ballistics studies. At present, no one CAD/CAM vendor has the wherewithal to support all the CAD analytical requirements of an organization as complex as DoD. There is a need to integrate the "best" analytic point solutions together to develop the "best" affordable weapon systems. STEP can help DoD fulfill this need.

Industry-Developed STEP Capabilities

AP-203, Configuration Control for 3D Design of Mechanical Parts and Assemblies, provides a very robust mechanical parts product model geometry transfer capability. This capability has been slow in coming. The solid model capabilities and high numerical geometric precision possible in AP 203 (and all STEP models) required many of the CAD/CAM vendors to push the technology edge of their system's capabilities. CAD vendor's AP-203 geometry transfer capability quality level is now high enough that translated solid models are readily being used to construct NC operations driver files.

AP-203, along with AP-224, Mechanical Parts Definition for Process Planning Using Machining Features, has had a significant cost savings impact on mechanical parts manufacturing.[6] AP-224 defines a set of basic solids used for pick-and-place composite solid model structuring, which greatly facilitated parts design and generative process planning (GPP). GPP uses the underlying basic solid shapes of the composite solid to conduct extensive cost-reduction trade-off analysis over the many processing options typically available within a given machine shop.

Cost-reductions of 30 percent are fairly commonplace for GPP process planning relative to the traditional variant process planning. Variant process planning basically consists of using a process plan for a similar old part. Most old parts in DoD's inventory have not been run through a GPP trade-off analysis or anything close to its cost optimization process.

AP-203 and AP-224 provide the necessary capability for low-cost generation of mechanical parts CAD/CAM models and rapid transfer of the vector data among disparate CAD/CAM systems. STEP's transfer capabilities will result in creating more private sector competition for manufacturing weapons systems components, i.e., many 2nd and 3rd tier parts manufacturers will not bid on a job if the vector data are not compatible with their CAD/CAM system. DoD needs to develop a strategic plan for capturing this manufacturing benefit, especially for its legacy systems where the technical data reside in a wide variety of formats if, in fact, they exist.

A common complaint voiced in the end-item management and DoD parts manufacturing communities is that no technical data for many repair parts exist, especially for some of those weapons systems procured via the performance specifications method of acquisition. Engineering data tend to become a lost child in the merger, acquisition, and business failure environment of the private sector economy. It is costly to reengineer a part, but that is the only solution remaining once the technical data are lost. However, the combination of AP-203 and AP-224 provides a low-cost redemption option for mechanical parts.

STEP Capabilities Being Developed

STEP has made significant inroads in transferring some of the vector data, especially the data supporting NC manufacturing. However, a major roadblock to collaborative design in the defense industry exists today in the inability to exchange all the vector data, especially the construction history data.[7] There is a critical need in industry for a designer using one (native) CAD system to be able to transfer an "intelligent solid" model in a standard way to a different (target) CAD system, so that it is still an intelligent solid (modifiable) model in the target system. Currently, intelligent solids generally become "dumb solids" (non-modifiable) after exchange.

STEP data transfer today uses Boundary representation (B-rep) of the part geometry, i.e., B-rep uses boundary intersections and faces to define the CAD objects. B-rep is a necessity for high-precision manufacturing operations requiring exact boundary locations needed to drive NC cutting and quality checking processes. However, intelligent solid exchange will require CAD vendors to be able to exchange model tree data. The model tree is essentially the log of the construct steps used to develop the part. It carries all the parametric relationships, constraints, primitive solids, and each placement step used in making the composite solid model.

Composite solid modeling is often referred to as Constructive Solid Geometry (CSG) modeling. CSG is, computationally, several orders of magnitude faster than B-rep in performing the ray tracing needed for BRL CAD lethality analysis and is deemed a necessity for lethality work. It is relatively easy to convert from CSG to B-rep, but it is nearly impossible to do the reverse. Construction history/model tree/CSG transfer capability is a paradigm shift for the STEP community. However, being able to efficiently move CAD data between lethality and manufacturing environments will provide significant labor savings and greatly speed up the process of conducting design/lethality/manufacturing trade-offs.

Leading e-commerce software providers and the auto/aerospace firms are pushing for intelligent solid model transfers. The ISO Parametrics Group has been working on developing the information model needed to exchange intelligent models as characterized by construction history. An ability to transfer construction history will greatly facilitate front-end lethality studies and provide the missing link for STEP being able to support data interoperability for the entire weapons system life cycle.

STEP in the 21st Century

Evolutionary CAD applications supporting design can be categorized into three types – traditional, knowledge-based, and immersive.[8] The present day traditional CAD system grew out of a need to automate drafting. These systems provide comprehensive tools for generating geometric forms, which encourages designers to come up with a form first and think about function later (i.e., form-to-function transformation). Knowledge-based tools that help a designer think in terms of function are now starting to evolve. In this paradigm, form results from function (i.e., function-to-form transformation). In immersive CAD applications, the human being becomes part of the design by using various immersive interfaces, including visual, speech, and haptic (special mechanical gloves, boots, etc.) devices. This evolutionary CAD development path will make great strides toward design optimization.

Interoperability among these evolving CAD systems, however, will continue to be an issue in our competitive free market environment that rapidly generates proprietary solutions. But, the most significant contribution STEP will provide

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is a bridge between the old and the new. Knowledge-based design tools concentrate on the generation of a symbolic structure, using various types of objects and relationships. Mapping from this symbolic structure to traditional CAD requires appropriate interface specifications. Immersive CAD systems generate certain process constraints such as trajectory and assembly mating constraints. The interface between immersive CAD and traditional CAD systems requires extensions to AP 203 and other STEP standards.

Why DoD Should Use STEP

STEP is not a completely finished product today, and considerable cost savings work remains to be completed.[9] However, STEP has progressed to the point where it has a very strong industrial user/developer base. Major U.S. original equipment manufacturers (OEM) in the Automotive, Aerospace, and Defense industries are jointly developing memoranda of understanding identifying STEP as their standard data exchange approach for domain-specific AP data. These firms, along with major firms around the world, in concert with ISO, are driving STEP development. With DoD having many of the same suppliers as the industrial companies driving STEP implementation, the lowest cost solution for DoD would be that of using this same STEP technology in providing and receiving vector data from its suppliers.

There are basic advantages in structuring an international standard for exchanging and maintaining product data.

- First, a standard format is the long-run salvation for archiving technical data for aging fleets, i.e., proprietary CAD formats come and go as the companies propelling them rise and fall in the marketplace.
- Second, everybody receiving technical data in a standard format immediately knows where to look for specific types of information within the exchange package. Data quality checks are easier to administer, resulting in very high-quality/completeness levels. Software and hardware vendors are quick to recognize they must develop the data transfer capabilities required to accommodate the standard in order to keep their products competitive.
- Third, standards generally spur innovation directly by codifying accumulated technological experience to form a baseline from which new technologies emerge. Standards also spur innovation indirectly because they increase global competitiveness, which, in turn, spurs innovation.[10]

STEP Launching Pad

In closing, to fully capture the benefits STEP offers, DoD needs to establish a STEP implementation plan. That plan should, as a minimum, address the following:

- Installing and/or requiring STEP- based weapons systems and parts manufacturing, i.e., there are immediate cost savings waiting to be captured.

- Establishing the guidance and infrastructure within its weapons system project management and logistics communities for requesting and maintaining technical data in the domain-specific AP formats as the APs mature to the ISO standard level.
- Developing a STEP-based archiving system that assures availability of engineering data in time of CAD/CAM vendor failure or OEM failure, i.e., no more parts reengineering because of a lack of technical data.
- Facilitating future STEP development efforts, especially construction history, to ensure engineering data interoperability over the entire weapons system life cycle.

Initially concentrating on these basic considerations should provide a good launching pad for STEP.

Editor's Note: The author welcomes questions or comments on this article. Contact him at **Moellerg@ria.army.mil.**

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Web-Enabled Courses for Defense Industry Students

In fiscal 2000, the Defense Acquisition University (DAU) developed a plan to offer all Web-enabled (online) courses to students who work for corporations in the Defense Industry. The program began at the start of the new fiscal year in October 2000.

No tuition fee will be charged to students for the online courses. This key feature of the program should encourage defense industry students to enroll in the courses, thereby building upon and enhancing the skills of the Defense Industry professional acquisition workforce. Students will find application for enrollment very easy, since the program will use the same online application form that is currently used by industry students who apply for DAU resident courses – available at **http://www.dsmc.dsm.mil/registrar/industry_applic.htm**.

The following courses will be available to industry students online starting in October 2000:

- Fundamentals of Systems Acquisition Management (ACQ 101)
- Fundamentals of Earned Value Management (BCF 102)
- Basic Information Systems Acquisition (IRM 101)
- Basic Software Acquisition Management (SAM 201)
- Acquisition Business Management (BCF 211)
- Simplified Acquisition Procedures (CON 237)
- Acquisition Logistics Fundamentals (LOG 101)
- Introduction to Acquisition Workforce Test and Evaluation (TST 101)

DAU has put together a high-quality program, and the University is confident the program not only has long-term growth potential, but will also be of great benefit to the Defense Industry as well as the students.

For more information, contact Art McCormick, Registrar for Industry Students:
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