Distributed Object Environment for Manufacturing

Federal Manufacturing & Technologies

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Project Accomplishment Summary

Background:

This project was initiated as a joint effort between the Department of Energy (DOE) and Ford to accelerate the development of integrated manufacturing systems through the use of emerging object-oriented software integration architectures and international product data standards. The project adopted the Object Management Group (OMG) Common Object Request Broker Architecture (CORBA) as the formal model for system integration and the ISO Standard for Exchange of Product Model Data (STEP) as the formal model for product data integration. No project at the time had brought the combined strengths of CORBA and STEP together to create an integrated system. Because CORBA technologies were just emerging when this project was started in September 1994, a reasonably high risk was assigned to this project.

The object-oriented paradigm is a computing paradigm that models a complex software system as a set of intercommunicating software objects. Each software object is a complete computing entity in its own right having a self-contained data structure and set of programs that determine how the object will respond to services asked of it. A system is built by creating a client-server environment in which objects serve other objects by exchanging messages. CORBA is a standard vendor-independent description of object messaging and interfacing that isolates the system designer from knowledge of the actual physical location of objects.

STEP is an international standard that allows designers and manufacturers to express product information such as geometric shape and configuration in a standard vendor independent three-dimensional format and share this information via computer. This allows geographically dispersed manufacturers to integrate design, manufacturing, and support processes. On September 1, 1993, engineers at the DOE Kansas City Plant (KCP) machined a prototype automobile connecting rod using STEP. Ford Powertrain Operations earlier had transmitted STEP-based specifications for the part via computer to the DOE Kansas City Plant. The experiment was the world's first use of the STEP draft international standard, approved in February of 1993, to manufacture a machined part. That experiment precipitated this project.

This project attempted to elevate the act of manufacturing system integration from hand craft to systematic practice using the fundamentals of CORBA and STEP. The project made significant progress in validating STEP through the exchange of production power steering pumps with a Ford supplier and developing a CORBA-based approach to integrating Ford's in-house configuration management system. The completion of the CORBA project was cut short and this project terminated shortly after a major reorganization at Ford. Ford and KCP parted amicably with a strong desire to continue the project some time in the future. Knowledge gained in this project has been put to use in the DOE's Technology Enabling Agile Manufacturing (TEAM) and Advanced Manufacturing National Information Infrastructure (AM-NII) projects. Development of the CORBA and STEP technologies that were to be accomplished in the DOE/Ford project have been transferred nearly intact to the TEAM and AM-NII projects without loss of continuity. Advancements in CORBA and STEP, upon which the DOE/Ford project was predicated, have indeed taken place throughout the world. CORBA is becoming the object-oriented approach of choice for creating large-scale integrated systems, and STEP is becoming the specification of choice for neutral exchange of large production solid models. To date every major CAD vendor in the world supports the STEP standard.

Description:

The first objective of this project was to build confidence in the STEP standard by exchanging a STEP description of a power steering pump with a Ford supplier and validating the exchange. This part was successfully exchanged. The second objective was the integration of the Ford in-house configuration management system with a STEP repository using CORBA-based technology. The repository chosen was the KCP Advanced Manufacturing Development System (AMDS), a development repository. This report will describe the power steering pump exchange and CORBA/STEP integration experiences.

Power Steering Pump Exchange:

The principle objective in this phase of the project was to use off-the-shelf software to provide data translation capability for sharing solid models using STEP to transfer a solid model of a power steering pump from GM Saginaw Division (using EDS Unigraphics CAD system) to Ford Motor Company (using Ford in-house PDGS/ACIS). The power steering pump, while specific to this project, is an example of an important generic problem facing large U.S. corporations and their supplier base: rapid exchange of product design early in the design and development cycle. Ford provided a thorough study of its design process (in a proprietary report) indicating the role of STEP exchange. The study looked at the Ford design process that would be in effect when a supplier to Ford has major design/manufacturing responsibility, as in the case with the GM Saginaw power-steering pump.

Based on the preliminary work that has been done to understand the design process with heavy supplier design involvement and an analysis of the information requirements and the STEP capabilities demonstrated by the pump transfer, the following conclusions and recommendations were drawn.

- STEP Application Protocol 203--Configuration of 3D Parts--cannot currently replace the need for Ford's internal PDGS CAD data. AP203's boundary representation solid would be useful for exchanging solid geometry of components that were created by different CAD systems for packaging studies. This technology could be used to exchange solids between Ford and Suppliers or between Ford Divisions.

- More analysis of data types is needed. The drawing notes and engineering specification information are also of primary importance to the engineers and designers. The vehicle program requires early exchange of this information. More analysis of the different types of specifications and engineering requirements that are currently conveyed by means of the part drawing needs to be performed. The current capabilities of the specification exchange capabilities of AP203 also require further analysis and testing.

- Engineering specifications need to be exchanged. The engineering specifications associated with a part need to be accessed by various design, testing, or manufacturing engineers as well as CAE applications. The encapsulation of specifications into computer-readable form has benefit not only to supplier data exchange but also for enabling concurrent engineering within Ford.

- AP203 configuration management is very complete. Most of the configuration management information defined in AP203 is also used throughout the Ford product life cycle. The exchange of configuration management data through AP203 would be valuable additional capability.

- The greatest deficiency is the inability to exchange all of the information associated with the drawing or CAD file by means of STEP. Not only is detailing and tolerance information required for this, but also the pictures contained in the CAD files need to have a specific format. Further study is required to determine if STEP AP201 Explicit Draughting and AP202 Associative Draughting will cover the required detailing information.

Ford and GM were disappointed that manual changes had to be made to the pump STEP transfer file in order to exchange it. Both were expecting a completely automated exchange. Unfortunately the quality of STEP translation software at the time and the completeness of understanding of and agreement on the STEP specification did not allow automatic transfer. Significant progress was made in the year following the pump transfer (September 1994 to September 1995) in other STEP exchange pilots to permit automatic exchange of complex parts. The final conclusion reached at the end of the pump transfer phase of the project, September 1994, was that STEP had strong possibilities but was not yet ready for production usage.

Ford and KCP shared project management roles for this phase of the project. KCP provided significant expertise in troubleshooting STEP file problems. The DOE-developed Advanced Manufacturing Development System was used as a major troubleshooting tool. Ford and GM provided significant motivation for the STEP translator vendors involved in the pump transfer. KCP came away from the pump transfer exchange with a very good working relationship with the STEP vendors: EDS, Grumman Data Systems, and STEP Tools Incorporated. Ford and GM provided the necessary automotive-industry clout to bring the steering pump exchange off on time. STEP exchange technology validated during this phase of the project was instrumental in accelerating STEP exchange within the DOE TEAM project.

Ford Motor Alpha site provided a computing site as a staging area for data exchange between GM Saginaw and Ford. AP203 STEP data was communicated to the staging area by Ford and GM Saginaw. KCP developed the intersite administration software used at the staging area. This software was created to automate, as much as possible, the mechanics of exchanging data over the Internet using File Transfer Protocol. The intersite administration software includes capability to send mail notification to appropriate parties when files have been transferred and are available for use. Technology similar to the intersite file administration was used as the heart of the DOE TEAM Intersite File Manger (IFM). The DOE/Ford technology transfer project provided a useful proving ground for this essential administrative software and provided motivation to develop similar software within the DOE TEAM project. The DOE TEAM Intersite File Manager was successfully demonstrated in March 1996.

CORBA/STEP Integration:

The objective of this phase of the project was to set up a minimum CORBA/STEP environment and provide an integration service for one or more applications. It was desired by both KCP and Ford that this phase of the project have a narrow technical scope to get early results. Both parties wanted to avoid developing general purpose integration tools. Instead it was decided that the project would start with commercially available, general purpose integration tools such as CORBA-based object brokers and relational and object-oriented databases to engineer a specific solution to an enterprise problem. KCP and Ford both wished to get early buy-in and visibility. Each party desired to leverage its best technology. Integration of a legacy system was considered a plus. The Ford configuration management system was the legacy system chosen since it sat in the middle of most of Ford product definition data. The proposal was to let the Ford configuration management system manage STEP data in the KCP Advanced Manufacturing Development System--a STEP data repository developed at KCP. This project would force both companies to progress up the CORBA learning curve while keeping in close touch with STEP technology. KCP liked the project because it allowed Ford to prove-in STEP product data management prior to DOE doing the same within the weapons complex.

Statement of application: Using the Ford configuration management system, locate a STEP solid model part, by part number and revision, in the KCP AMDS STEP repository and display it.

The following functionality was needed to bring the above application to fruition.

1. Couple the relational database of the Ford configuration management system with the object-oriented database of the KCP AMDS STEP repository using CORBA technology.

2. Develop a suitable graphical query interface to the CORBA integration environment that queries the Ford configuration management database and the KCP AMDS STEP repository in a uniform way. The user of the query interface would "see" a single database and would not be aware that it was broken into relational and object-oriented components.

3. Distribute the Ford configuration management database and the KCP AMDS STEP repository across a local area net.

4. Modify an existing data browsing and viewing system to interact with the CORBA software so that the system can retrieve and display a part.

Ford planned to copy a major portion of its configuration management database into a smaller computer so that it would not impact its production system. Ford required that none of the Ford configuration management database schemas be changed as a result of integration. Ford was already trained on the DEC CORBA system, and KCP had training on the Expersoft XSHELL CORBA system. It was originally planned to make these two CORBA systems interoperate.

Major responsibilities for Ford:

1. Map the Ford configuration management data schema to STEP AP203.

2. Procure and extend data browser and solid model display tools.

3. Connect the Ford configuration management database to Ford CORBA software.

4. Develop demonstration.

Major responsibilities for KCP:

1. Upgrade AMDS to International Standard version of STEP.

2. Determine a minimum subset of the STEP AP203 schema that would be useful.

3. Connect the KCP AMDS STEP repository to the Ford CORBA software.

4. Develop demonstration.

KCP and Ford worked diligently to create a mutual project that would benefit both organizations and permit an equal contribution of labor. A detailed project plan and project architecture were completed, and the Cooperative Development Statement of Work was rewritten to reflect this phase of the project.

Accomplishments:

1. Project architecture, detailed project plan, and new statement of work (both)
2. Extensive training in the use of CORBA (both)
3. A common understanding of the STEP AP203 Application Protocol (both)
4. Upgrading of KCP AMDS to STEP International Standard status (KCP)
5. Purchase and installation of CORBA software (both)
6. Agreement on application requirements (both--50% complete)
7. Selection of a commercial browser and display tool (Ford)
8. Mapping of AP203 data types to Ford configuration management database (Ford--30% complete)
9. Creation of software to automatically generate CORBA interfaces (KCP--30% complete)
10. Establishment of minimum AP203 schema (KCP)
11. Upgrading of KCP AMDS to support very large parts (KCP)
12. Linking of Grumman and EDS STEP translators to KCP AMDS (KCP)
13. Extension of AMDS to support International identifiers (KCP)

It should be noted that many of the KCP accomplishments were carried over directly into the DOE TEAM and AM-NII projects. These two DOE projects are using STEP as the basis for CAD data exchange and advanced repository technology and CORBA as the principal software integration technology.

Project Challenges:

1. Immaturity of CORBA implementations (not fully CORBA compliant)
2. Immaturity of CORBA specification (no database or interoperability support)
3. Availability of Ford personnel
4. Lack of real working knowledge of CORBA (anywhere)
5. Lack of DEC and Expersoft CORBA interoperability
6. Lack of object-oriented programming staff

7. Lack of CORBA LISP language interface (AMDS written in LISP)

8. Complexity of integrating with CORBA in the general case

9. Few CORBA successes in the USA at the time of project initiation

10. Difficulty in maintaining communication between Ford and KCP

11. Lack of fine-grain data support from CORBA

The DOE/Ford technology transfer project was terminated in September 1995 due to a reassignment of human resources at Ford. Ford redirected its energies away from the DOE/Ford project to day-to-day operational tasks. An amicable agreement was reached to terminate the project.

Benefits to DOE:

Cooperation between DOE and Ford on this project has accelerated the testing of the STEP standard and has given STEP greater credibility within the automotive industry. This project encouraged other STEP pilot projects within the United States, most notably the Automotive Industry Action Group Auto STEP pilot. DOE will reap the advantage of more mature CAD vendor STEP translators as a result of this project. In the time period January 1995 to January 1996 STEP translations have generally improved to the point where 90% of STEP files can now be translated without human intervention.

With respect to the CORBA/STEP phase of this project, KCP has come to a greater understanding of the problems encountered in integrating relational and object database technology. This phase of the project helped KCP to accelerate its understanding of CORBA implementations and the CORBA specification itself. In the time that DOE and Ford have been working on this cooperative project, CORBA has become the leading object-based integration approach in the world. It is clear that DOE and Ford picked the right technology road and, if sufficient resources had been available, could have been quite successful. The Intersite File Manager designed and implemented for this project (UNIX based) motivated the design and implementation of a very successful Internet NT-based PC version of the Intersite File Manager for the DOE TEAM project.

Economic Impact:

In a prototype experiment Ford was able to reduce the time it takes to transfer a complete power steering assembly from five days to two hours by translating its solid model CAD files to STEP. Real economic impact will come when STEP is used pervasively throughout design/manufacturing organizations. More significant impact will come when major manufacturers can communicate with their suppliers using STEP. It is expected that DOE will reap significant economic benefit through reduced cycle time and universal access to product data through CORBA/STEP-based integration.

Project Status: Terminated

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