



CHAPS

Construction History and ParametricS:

Improving affordability
through intelligent CAD data exchange

CHAPS Program Final Report

January 2, 2004

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TABLE OF CONTENTS

<i>1. Executive Summary</i>	4
<i>2. The Problem</i>	5
Current Exchange Standard Provides A Partial Solution	5
Smart CAD Translation Solution Requires Construction History, Parametrics And Constraints	6
<i>3. The CHAPS Smart CAD Translator Solution</i>	7
SPANS Program	7
CHAPS Objectives	8
Leveraging Previous Efforts	8
CHAPS Pilot Team	8
Developing An Enhanced Data Model	10
CHAPS Translators	12
<i>4. CHAPS Pilot Activities</i>	15
<i>5. CHAPS Business Case</i>	16
Benefits of CHAPS Technology	21
Deployment and Commercialization	22
<i>6. Conclusions</i>	23
<i>Appendix A: JACG Memorandum</i>	A1
Joint Aeronautical Commanders Group Chairman Memorandum: “Strategy for Product Data throughout the Life Cycle”	A1

TABLE OF FIGURES

Figure 1. CAD Model Exchange Results in “Dumb” Solid.	6
Figure 2. Construction History and Parametrics Explained.	7
Figure 3. CHAPS Pilot Deployment Scenario.	10
Figure 4. Example Production Models Used to Define CHAPS Features.	11
Figure 5. ANSI/ANC101 Test Part Translated Using CHAPS.	12
Figure 6. Production Part CAD Model Translated with CHAPS Technology.	13
Figure 7. Parametrics and Constraints Translated with CHAPS.	14

TABLE OF TABLES

Table 1. CAD Data Exchange Statistics.	15
Table 2. Potential Annual Savings at Raytheon Using CHAPS.	17
Table 3. Annual Savings to MRAS With 100% CHAPS Translation Success.	18
Table 4. Annual Savings to MRAS - 71.4% CHAPS Translation Success Rate.	18
Table 5. Summary of Business Case for CHAPS Pilot Team.	21

1. Executive Summary

Complex weapon systems are frequently designed and manufactured in a collaborative environment between a prime contractor and a distributed supply chain, with 70% or more of manufacturing taking place downstream from the prime. These supply chains frequently use different CAD systems that are unable to exchange complete CAD model information due to differences in features, modeling techniques, and geometry format representation. This CAD incompatibility problem has been partially addressed by point-to-point CAD translators that use proprietary translation technology. Neutral standards have also been developed to enable primes to deliver CAD data in a format that is readable by most modern CAD systems. But in either case the current state of practice typically yields a solid structure that is not easily modified, a so-called “dumb” solid which has lost its underlying construction history, parametric relationships and design constraints.

The Construction History and ParametricS (CHAPS) project began in mid 2002 with the objective of providing an initial business case for smart CAD exchange using an emerging ISO 10303 standard, AP203-E2 (scheduled for approval in 2004). CHAPS translators provide a new method of exchanging CAD information that maps the construction history, parametric relationships and constraints of the delivering system into a neutral format, then translates these parameters into the receiving system, essentially rebuilding the CAD model as a intelligent native file. The project was managed by ATI and included supply chains from Raytheon Missile Systems (RMS) and Northrop Grumman Electronic Systems (NG). Sponsored by the Office of Naval Research under the Supply-chain Practices for Affordable Navy Systems (SPANS) program, CHAPS piloted technology that enabled Raytheon and Northrop Grumman to exchange intelligent CAD data with their supply chains using three different CAD systems, Pro/ENGINEER® (Pro/E), CATIA® V4, and Unigraphics®.

The project verified that it was possible to exchange enhanced CAD information between different CAD systems using international standards for data exchange. The original goal for the pilot was a 50% translation success rate. CHAPS pilot translators successfully translated 67% of the team’s CAD models, 47% with complete accuracy and 20% requiring minor rework. CHAPS pilot metrics demonstrated that using smart CAD translators can dramatically reduce labor and cycle times. Assuming perfect translations, three CHAPS team members reported business cases that would save over 4 man-years of labor, for a cost avoidance of \$744,476. Using the actual pilot exchange success rates, savings would still equal 2.24 man-years and \$412,598. Annual labor savings ranged from \$138k to \$198k per supplier, and for one supplier a savings of over \$400k for a single CAD migration project. CHAPS will continue development as an official PDES, Inc. pilot project to continue development and deployment. Commercial translators will improve translation success rates dramatically and should yield labor and cycle time savings and improved product quality for any DoD supply chain that requires model exchange between different CAD systems.

2. The Problem

Complex weapon systems are frequently designed and manufactured in a collaborative environment between a prime contractor and a distributed supply chain, with 70% or more of manufacturing taking place downstream from the prime. These supply chains frequently use different CAD systems that are unable to exchange complete CAD model information due to differences in features, modeling techniques, and geometry format representation. This problem also occurs in different versions of the same CAD system.

This CAD incompatibility problem has been partially addressed by creating point-to-point CAD translators that are not entirely satisfactory, in that they must be revised with every new CAD revision and cannot handle a model from another CAD system. Most suppliers provide manufacturing services for multiple primes, which often requires exchanging multiple CAD formats (requiring translators for each CAD pair). Furthermore, point-to-point translators use proprietary internal model representations, increasing the risk of obsolescence if the developer goes out of business.

Current Exchange Standard Provides A Partial Solution

ISO 10303, commonly known as STEP (STandard for the Exchange of Product model data)¹, is an International Standard for representing the physical and functional characteristics of a product throughout its life cycle in computer interpretable form. The development of STEP is a multi-national effort, with worldwide participation from industry, government, and academia. STEP provides the capability for organizations with diverse software tools to represent, exchange, and archive data for CAD, Computer Aided Manufacturing (CAM) and Engineering (CAE), and Product Data Management (PDM), in a neutral and openly documented format.

STEP is endorsed (and even required) by leading organizations in aerospace, the automotive industry, shipbuilding, and DoD, such as Boeing, Lockheed Martin, Raytheon, IBM, BAE Systems, Newport News Shipbuilding, Electric Boat Corporation, Rockwell, and NASA. DoD has recently acknowledged that STEP is now the standard of choice and is to be accommodated throughout DoD².

ISO 10303-203 (STEP AP203) has been instrumental in enabling primes to deliver CAD data in a neutral format that is readable by most modern CAD systems. However, the current state of practice yields a solid structure that is not easily modified, a so-called “dumb” solid which has lost its underlying construction history, parametric relationships and design constraints (Figure 1).

¹ STEP is a neutral format for computer data exchange. See <http://pdesinc.atiacorp.org>.

² Memorandum for the Air Force, Navy, and Army Acquisition Executive: “Strategy for Product Data throughout the Life Cycle”. Richard V. Reynolds, Lieutenant General, USAF. Joint Aeronautical Commanders Group Chairman. May 8, 2002 (see Appendix A).

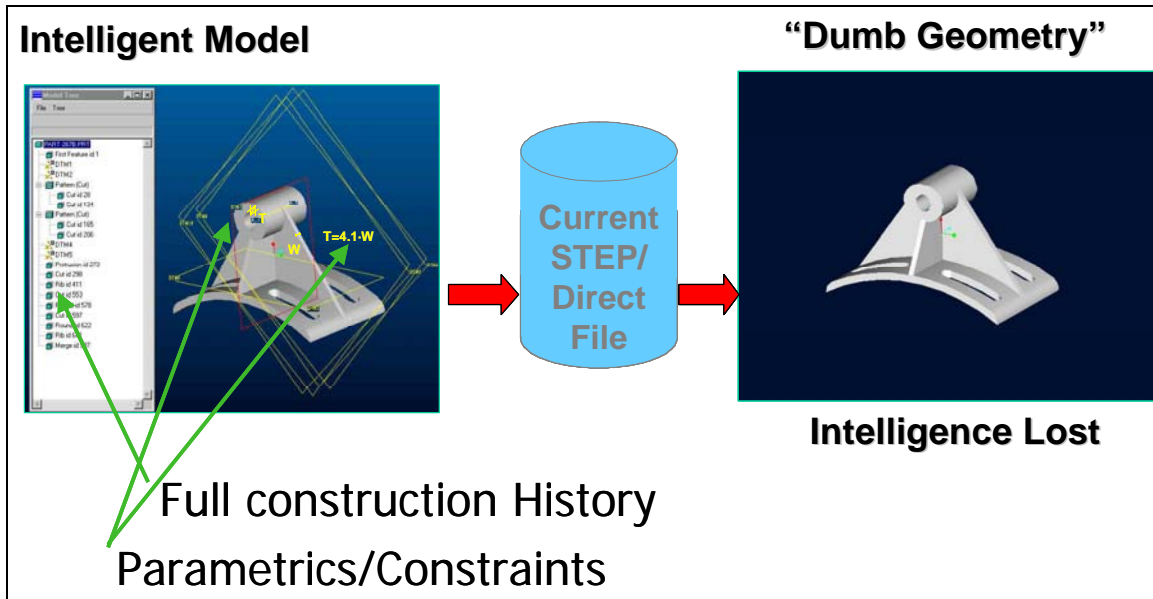


Figure 1. CAD Model Exchange Results in “Dumb” Solid.

Engineers must often modify these dumb solids during downstream activities such as CAM programming for machining processes or to facilitate engineering analysis, a process that is time-consuming and labor intensive. This data compatibility issue costs the aerospace industry at least \$253M annually (in 2001 dollars) as determined by a December 2002 Research Triangle study sponsored by NIST³.

Smart CAD Translation Solution Requires Construction History, Parametrics And Constraints

Construction history, parametrics and constraints combine to create a smart CAD model, and these elements are what are currently missing from both neutral file and most point-to-point translators. Figure 2 shows a representation of a CAD model that demonstrates both construction history and parametrics/constraints.

Construction History is the series of steps required to build a model in CAD. The first construction step in creating the CAD model pictured in Figure 2 is to create a 2 dimensional cross-section of the part. The next step is to create a solid by revolving the cross-section 360 degrees. Each successive step adds to the model, ultimately creating the part. By creating a data model that captures that construction history in a generic form, translators can be developed that map those construction history steps into virtually any other CAD system.

³ Planning Report 02-05, Economic Impact Assessment of the International Standard for the Exchange of Product Model Data (STEP) in Transportation Equipment Industries, prepared December 2002 for National Institute of Standards and Technology by the Research Triangle Institute, Health, Social, and Economics Research, Research Triangle Park, NC 27709

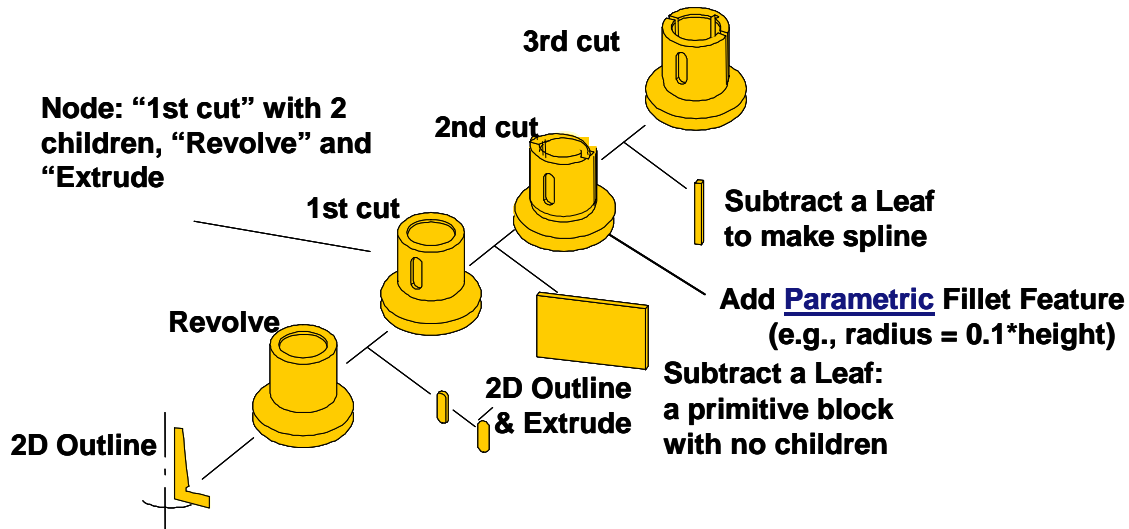


Figure 2. Construction History and Parametrics Explained.

Parametrics and constraint relationships enable designers to specify explicit relationships between entities that make up CAD models. For example, in Figure 2 we have defined a relationship between the radius of a fillet and the height of our model. Constraints are used to constrain or restrict features in a useful way. A typical constraint would explicitly define two surfaces as parallel or perpendicular, or holes as round or oblique, depending on design requirements. Parametrics and constraints are methods of including additional design information within a CAD model.

3. The CHAPS Smart CAD Translator Solution

SPANS Program

The Construction History and Parametrics (CHAPS) project was funded by the Supply-chain Practices for Affordable Navy Systems (SPANS) program. Sponsored by the Office of Naval Research, the SPANS Program mission is to move promising new technology into deployment in one or more Navy weapon system programs, resulting in improved affordability. SPANS focuses on the development and deployment of supply chain management technologies and best practices to provide a foundation for affordability benefits throughout the weapon system life cycle. By working with commercial industry and DoD, the SPANS Program fosters the creation of new technology suppliers that enables the Navy to increase innovation, as well as improve affordability.

The SPANS Program identifies potential supply chain technologies and commercial practices to satisfy Navy requirements⁴. These technologies are evaluated and projects initiated to adapt them to the Navy supply chain environment. Working with Navy programs such as F/A-18, Standard Missile, and JSF, the SPANS team leads pilot deployment projects to validate the benefits and transition the solutions into a product environment. In mid 2002, SPANS funded the CHAPS Project to validate the feasibility

⁴ For more information on the SPANS Program, see www.SPANS.org

of using an enhanced version of STEP for CAD data exchange, so called “smart translators” to provide a more complete CAD model to the receiving system.

CHAPS Objectives

The CHAPS project had several objectives, all of which contribute to an overall objective of bringing smart CAD translators into the DoD supply chain:

- Leverage past research and emerging standards technology for improved CAD data exchange to improve chances of widespread deployment
- Conduct a pilot with a representative supply chain for testing the efficacy of improved translators in a production environment
- Based on the pilot team requirements, enhance the data model and implement bidirectional CAD translators that provide the capability of exchanging construction history (steps required to build a CAD model) as well as parametrics relationships and constraints embedded in the model
- Document pilot exchange metrics that validate the business case for smart translators

Leveraging Previous Efforts

In the mid 1990s, the DARPA Enabling Next GENERation mechanical design (ENGEN) Program concentrated on exchange of CAD model constraints. Based on this research an initial Construction History Data Model (CHDM) was developed by PDES⁵, Inc. using the STEP standard. Functionality included construction history and features (fillets, rounds, holes, extruded and rotated solids). Parametric representations were not developed.

To accelerate deployment of CHAPS technology, the PDES organization agreed to make CHAPS a PDES, Inc. deployment pilot, providing resources to enhance the previously developed CHAPS data model based on member company CAD systems and requirements and to move the model through the standards process as part of AP203 Edition 2 and promote it to PDES, Inc. members and CAD vendors. In addition to construction history, the model would contain parametric and constraint relationships.

CHAPS Pilot Team

CHAPS was managed by ATI⁶ (Charleston, SC). ATI is also the managing contractor for the PDES organization. Raytheon Missile Systems (Tucson, AZ) and Northrop Grumman Electronic Systems (Baltimore, MD) are PDES, Inc. members and were interested in participating in CHAPS activities and piloting CHAPS on the STANDARD Missile and

⁵ The mission of PDES, Inc. is to accelerate the development and implementation of ISO 10303, also known as STEP. For more information see <http://pdesinc.aticorp.org>.

⁶ For more information on ATI, see <http://www.aticorp.org>

JSF weapons systems, respectively. Raytheon uses the Pro/E CAD system on STANDARD Missile, and Northrop Grumman uses Unigraphics on JSF.

Based on the exchange requirements of these large primes, the CHAPS team decided to develop three bidirectional STEP translators, one each for Pro/E, Unigraphics, and CATIA. Note that writing STEP translators for three CAD systems requires three translator pairs, one for each CAD system. This is the same number of translator pairs required for a point-to-point solution. However, to add another CAD system to the group would require writing only a single translator pair for STEP (into/out of the STEP format), but three additional translator pairs for point-to-point interoperability. This is an important advantage of using a common neutral format. Each additional CAD system requires a single translator pair to be interoperable with every other CAD system that employs a STEP translator. As the number of CAD systems (N) increases, the number of translators required for point-to-point solutions increases exponentially ($N \times (N-1)$), whereas the number of translators for neutral formats is $N \times 2$.

To create a representative supply chain for pilot efforts, two suppliers were selected for each prime. These suppliers used different CAD systems to ensure 3-way compatibility testing would take place during pilot exchange activities. Raytheon suppliers included Moog, which manufactures high performance actuators, and Rocketdyne, which manufactures propulsion systems. Northrop Grumman suppliers were GE Middle River Aircraft Systems, which manufactures high precision machined parts, and Bechdon, also a high precision manufacturer (see Figure 3).

Theorem Solutions, another PDES member that provides both STEP and direct CAD translators, was selected to develop the advanced CHAPS translators required for this effort. PTC, which creates the Pro/E line of CAD software was contracted to assist Theorem, primarily in Pro/E import translator activities.

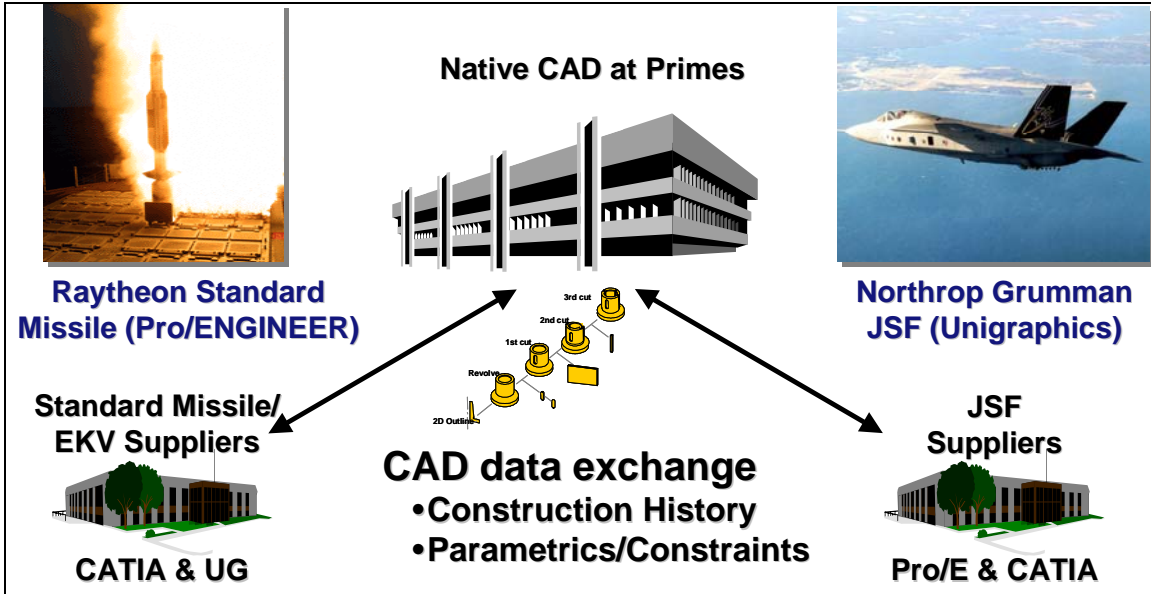


Figure 3. CHAPS Pilot Deployment Scenario.

Developing An Enhanced Data Model

To enhance the previously defined construction history data model, Raytheon and Northrop Grumman submitted typical production files for feature analysis. Figure 4 shows examples of these production models and a list of features documented for these models.

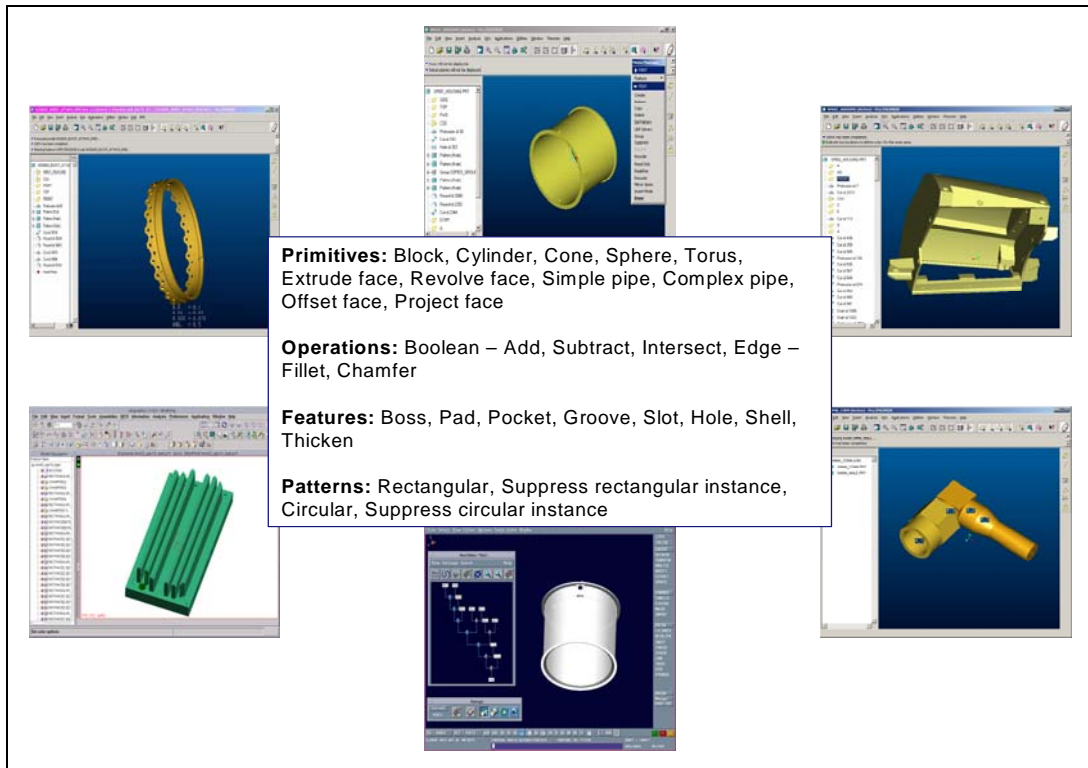


Figure 4. Example Production Models Used to Define CHAPS Features.

While these features do not represent 100% of the modeling capability of the supply chain's CAD systems, they cover most of the features used by Raytheon and Northrop Grumman.

Dr. Bill Anderson of ATI worked with Theorem Solutions to enhance and formalize the CHAPS construction history data model and begin the approval process required to make the model an ISO 10303 standard. The model is defined as ISO 10303 Part-111, *Construction History Features*, which is currently moving through the standards process and will ultimately become part of ISO 10303 AP203⁷, the 3D geometry exchange standard for STEP.

In addition to construction history features the CHAPS team identified parametrics and constraints commonly used by both primes. The CHAPS data model for these CAD features is being promoted through ISO 10303 Part-108, *Parameterization and constraints for explicit geometric product models*⁸.

⁷ For an overview of AP203, see <http://pdesinc.aticorp.org/aps/203ovw.ppt>

⁸ ISO 10303 Part 108 overview: http://www.nist.gov/sc4/wg_qc/wg12/n919/WG12N919.ppt

CHAPS Translators

Based on the enhanced STEP construction history data model and the requirements of the CHAPS pilot supply chain, the team built bidirectional translators to support the following CAD systems:

- Unigraphics 18 or NX (19) on either Windows or Unix
- Catia 4.2.3 or later (but not Version 5) on Unix
- Pro/ENGINEER 2001 Data code 2002350 or later on Windows

CHAPS was originally devised as a 2-phase project, initially targeting construction history only, then enhancing CHAPS translators by adding parametric and constraint information. Due to technical issues the team ultimately piloted construction history translators only. The team was not able to create a CATIA parametrics and constraints translator due to the lack of an application programming interface (API) for version 4 of that CAD system. Draft parametrics and constraints translators were developed for Unigraphics and Pro/E, but not in time to conduct pilot activities. Screen shots of parametrics and constraints translations are shown later in this section.

Construction History Translators

The development team extensively tested both production models and test files to prove out the CHAPS translators. Figure 5 shows an ANSI/ANC101 test part translated from Unigraphics and Imported into CATIA. This test part is commonly used to evaluate CAM and rapid prototyping software and was a good test part for demonstrating the CHAPS software due to its wide variety of features and familiarity in the CAD community. This part, along with its construction history, was successfully translated between all three CHAPS translators.

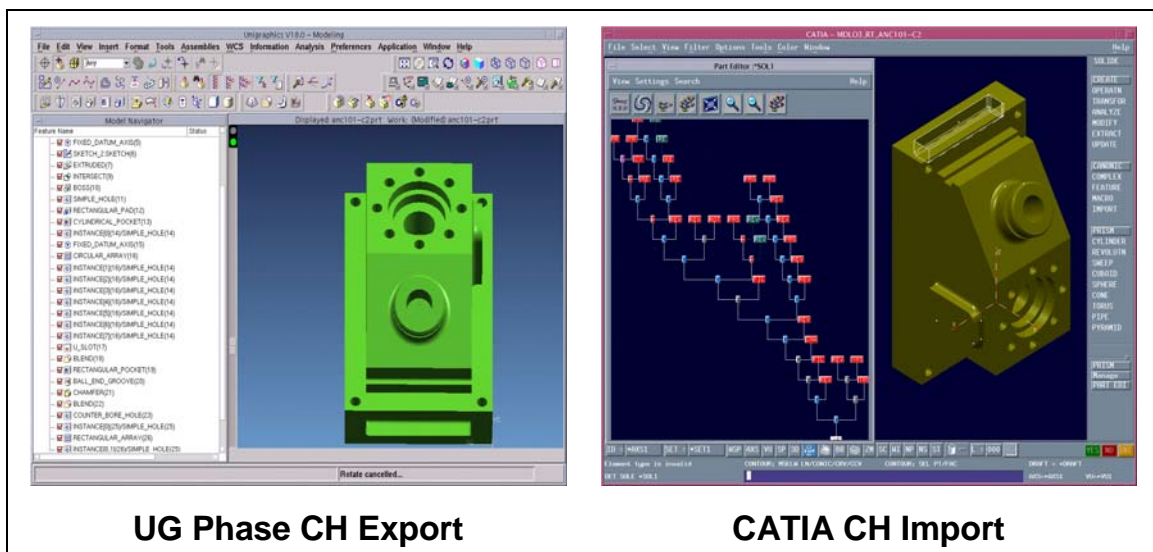


Figure 5. ANSI/ANC101 Test Part Translated Using CHAPS.

Figure 6 shows a production part translated between all three CHAPS team CAD systems. The construction history for each system is clearly displayed in each figure. Note that the construction history for each system may be different. By mapping these unique features to/from a neutral standard, the design intelligence is interpreted and maintained when translated into the receiving CAD system.

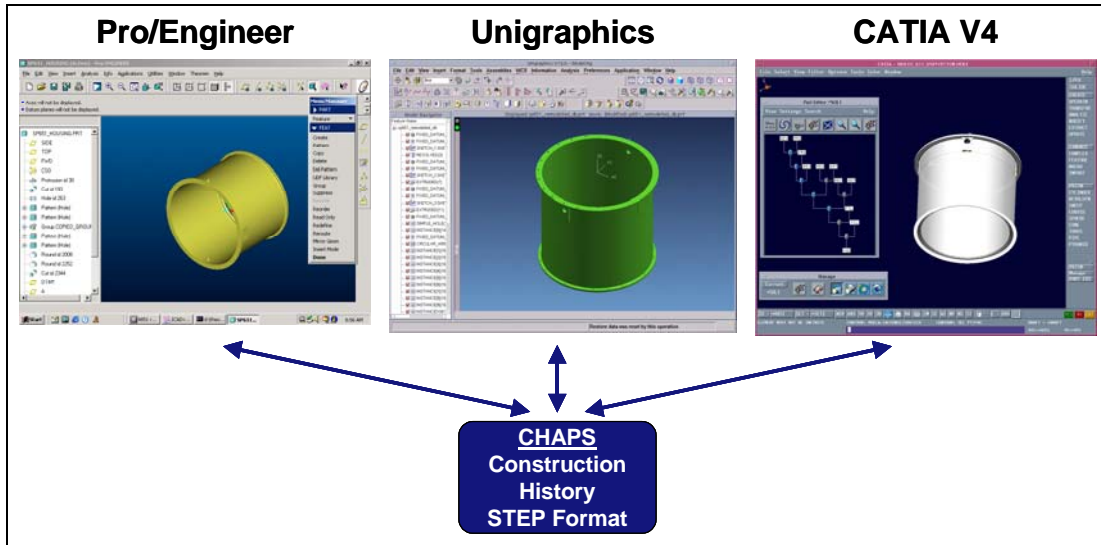
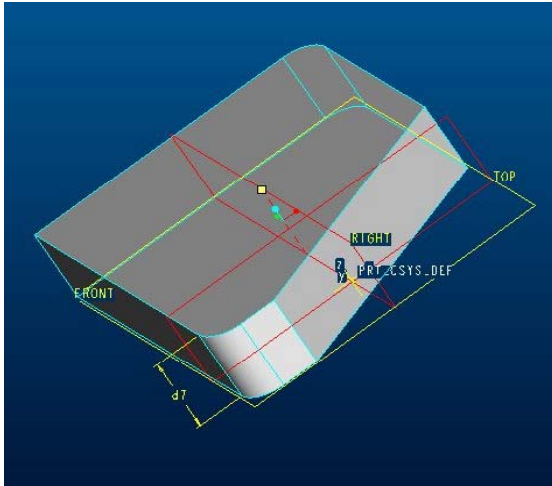


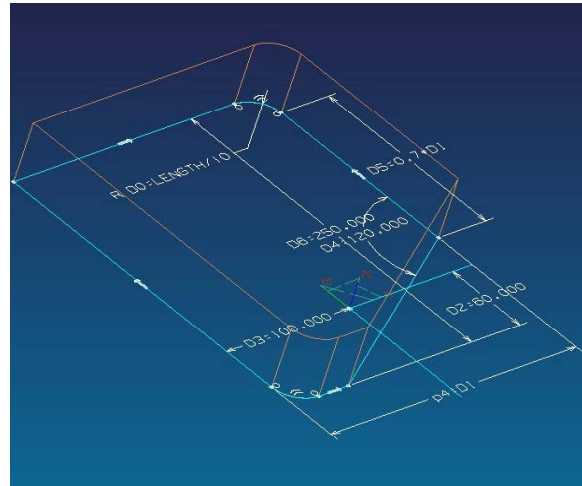
Figure 6. Production Part CAD Model Translated with CHAPS Technology.

Parametrics and Constraints Translators

Due to the unavailability of an API for CATIA's parametric and constraint features, the CHAPS team did not develop a translator for CATIA that provided those features. Without access to the API, the team could not interface with the code used to generate parametrics and constraints. However, the team did develop draft translators for Unigraphics and Pro/E to demonstrate this functionality. Due to time constraints the team did not pilot these translators. Figure 7 shows two screen captures of a part that contains both parametrics and constraints. The figure shows a part in Pro/E that was exported to CHAPS, then imported into Unigraphics.



Pro/E Parametrics Export



UG Parametrics Import

Figure 7. Parametrics and Constraints Translated with CHAPS.

Several parametric relationships and constraints are included in the translated model:

- LIMITS
 - P8 and P7 taper angle = 0 max
 - D7 Length = 50.000000 max
- LINEAR AND ANGULAR RELATIONSHIPS
 - $D5 = 0.7 * D1$, Vertical Dimension between Line5 and Line4
 - $D3 = 100.000000$, Perpendicular Dimension between Line1 and Line7
 - $P4 = D1$, Perpendicular Dimension between Line4 and Line7
 - $D2 = 60.000000$, Perpendicular Dimension between Line2 and Line6
 - $D6 = 250.000000$, Perpendicular Dimension between Line3 and Line6
 - $D4 = 120.000000$, Angular Dimension between Line4 and Line5
 - $D0 = LENGTH/10$, Radius Dimension on Arc1
- EXPRESSION REFERENCES
 - $D1 = LENGTH$
 - $LENGTH = 200$

While the CHAPS beta translators do not yet meet all the production requirements defined by our primes, they nevertheless provide a basis on which to build a viable solution. It is important to note that all our supplier participants said they would not require the exchange of parametric and constraint data with other companies, except in cases of dedicated collaborative design. With this in mind, we believe construction history only translators will meet the immediate requirements of supply chain CAD exchange, with a building requirement to include parametric information as companies improve their collaborative teaming. However, internal exchange of parametrics and constraints remains a critical need for companies that require internal exchange between different CAD systems. This was the basis of the Raytheon business case detailed later in this report.

4. CHAPS Pilot Activities

The CHAPS team piloted file exchange by first selecting weapon system CAD files at the primes, translating these files, and distributing them to their suppliers. Validation properties for these files were provided to enable the supplier to verify successful translations. These properties included part surface area and volume, as well as screen shots of the expected shape. These were then compared with the resulting solid in the receiving system.

Translated CAD models often require minor repairs to close surfaces or otherwise “clean up” the model. For example, one CHAPS supplier uses a point-to-point translator in production that requires minor translated model repair 66% of the time, with an average repair labor requirement of 2 hours. Some CHAPS translations required rework to complete the model translation. For models that were translated but did not completely translate all features, suppliers evaluated time required to repair the model.

Translator Deployment Issues

While all three construction history translators ran well in the development environment, numerous issues were encountered when attempting to deploy these translators with the CHAPS pilot team. CAD software is highly complex, with a variety of variables that range from deployment operating system to various licensing schemes and environment variable differences. One supplier changed computer platforms and operating systems late in the program. This supplier was using Pro/E and receiving UG CAD files. We were not able to update our Pro/E translator in time to pilot UG to Pro/E exchange with this supplier. The CHAPS team was ultimately able to deploy and pilot CAD file exchanges at 5 of our 6 participant sites, 2 with Unigraphics, 2 with CATIA, and one with Pro/E. Additionally we were able to deploy Pro/E at one of our CATIA sites (Rocketdyne) for additional testing.

Pilot Exchange Statistics

Table 1 shows the statistics for pilot CAD model exchange during the CHAPS pilot. While the team exchanged numerous test and production models in preparation for the pilot, we officially evaluated 49 parts of varying complexity. Pilot translators successfully translated 67% of the team’s production models, 47% with complete accuracy and 20% requiring minor rework (our goal for the pilot translators was a 50% success rate). This is not unusual for pre-beta software, and commercial versions of the CHAPS translators will dramatically improve translation success rates.

Table 1. CAD Data Exchange Statistics.

Sending System	Receiving System	Total Files	"Perfect"	Percent	Rework Necessary	Percent	Failed	Percent	% usable
Raytheon Pro/E	Moog Unigraphics	11	6	55%	2	18%	3	27%	73%
Raytheon Pro/E	Rocketdyne CATIA	17	8	47%	2	12%	7	41%	59%
Northrop Grumman UG	MRAS CATIA	21	9	43%	6	29%	6	29%	71%
Program Totals	All CAD Systems	49	23	47%	10	20%	16	33%	67%

Although our production exchange success rates were low compared to currently available traditional translators, the results are actually quite good when compared to past experience in the STEP community for initial translators based on a new standard. Based on success rates and requirements for CAD data exchange, three team members submitted business cases for deploying CHAPS. Additionally, a fourth supplier, Bechdon, provided estimates regarding savings when CHAPS is used as a collaboration tool early in the design process.

5. CHAPS Business Case

Raytheon Business Case for CHAPS: *CAD requirements for international trade*

“At Raytheon, we originally felt that there was a minimal need for CHAPS functionality; however, after participating in the pilot we realized the cost of 1320 hours per year could be avoided if a robust CHAPS translator were developed and available.” Dave Stephens, Section Manager Mechanical Applications, Raytheon Missile Systems.

An internal study at Raytheon by Dave Stephens quickly revealed a compelling need for CHAPS translators. Raytheon’s present international partners use CATIA, Ideas and Unigraphics. Raytheon expects even greater international partnering in the future due to offset agreements⁹. With this in mind Raytheon determined the major usage of CHAPS translators would be in the following two areas:

1. **Interface Control** – Most assemblies Raytheon subcontracts have on the order of 100 – 500 part models per assembly. For most of the part models, a standard AP203 translation would be adequate. However, models that interact with the primary weapon structure would benefit from CHAPS. These parts are typically any shell or mounting structure parts. On a representative subcontracted assembly this would be about 12 models that would require the CHAPS translation. If the translator were not available, labor to remodel these parts would average 10 hours per part. This would result in a cost of 120 hours for each project that needed to remodel interface models. It is estimated that approximately 8 projects per year will need translation services, which will result in an annual labor requirement of 960 hours.
2. **Detailed Analysis** – Raytheon conducts several different types of analysis on partner designs. These types are: verification of vendor results; complete analysis for vendors with minimal analysis capability; and addition of vendor’s configuration to system simulations. The standard input for Raytheon’s analysis systems is a Pro/E model. On a typical analysis requirement, the need would be for about 5 models that would require CHAPS translation. If the translator were not available, the labor to remodel these parts would be an average of 14 hours per part. This would result in a cost of 70 hours for each project that needed to remodel

⁹ http://www.cfr.org/public/GeoEcon_Military/Geo_Report.html#1 (Clause F)

analysis models. It is estimated that 6 projects per year will need analysis translation services, which will result in a yearly cost of 420 hours.

In this case, construction history translators would suffice, as there is not a requirement for significant redesign for these parts. For other programs where multiple CAD systems were used for collaboration, or when migrating programs from one CAD system to another, the need for parametrics and constraints would be more significant.

Table 2 shows possible cost avoidance using CHAPS technology to translate necessary files from Raytheon international partners to Pro/E. A conservative burdened labor rate of \$100 per hour was applied which resulted in an annual savings of \$138k. Savings assumes 100% success rate for translation. Raytheon’s pilot success rate was approximately 50% (all files tested, perfect translation), which would yield a current savings of approximately \$69k.

Table 2. Potential Annual Savings at Raytheon Using CHAPS.

	Annual Labor Hour Savings with CHAPS	Annual Cost Savings with CHAPS
Interface Control	960	\$96,000
Detailed Analysis	420	\$42,000
Total Labor Hour Savings with CHAPS:		1,380
Total Cost Avoidance with CHAPS:		\$138,000

Middle River Aircraft Systems (MRAS) Business Case for CHAPS: Wedgetail AWACS CAD data import

Middle River Aircraft Systems conducted a business case analysis based on their CAD data exchange requirements on the Wedgetail AWACS. They received an average of approximately 58 AWACS CAD models per month over the last 20 months. MRAS translates these files into CATIA using a point-to-point translator that does not include construction history or parametrics capability. The result is a dumb solid model in CATIA, essentially identical to the types of CAD models produced by current STEP translators.

Metric 1: The resulting CAD files tend to be extremely large, requiring approximately 15% more time to manipulate than native CATIA files based on interviews with CAM programmers at MRAS. In preparation for manufacturing, these files averaged 11 hours of CAM programming time, on which 15% was added time due to using a none native translated model. Because CHAPS files are actually rebuilt as native files in the receiving

system, MRAS would realize a reduction of 15% in CAM programming time if CHAPS-translated models were used. Table 3 shows MRAS’ estimated savings of over \$100k per year from this savings alone by using CHAPS.

Table 3. Annual Savings to MRAS With 100% CHAPS Translation Success.

	Per Year	Range (hours)	Average	Annual Labor Hour Savings with CHAPS	Annual Cost Savings with CHAPS
Files Received	694				
Tool Path Programming Time:		3 to 36	11		
15% Reduction in Tool Path Programming With CHAPS Files:		0.5-5.4	1.65	1145	\$114,543
Tool Path Rework	84		1.5	95	\$9,450
Percent "Dumb" Translations Requiring Rework:	66%	0.5 to 16	2	744	\$74,379
Total Labor Hour Savings with CHAPS:				1984	
Total Cost Avoidance with CHAPS:					\$198,372

Metric 2: Table 3 also shows potential annual savings for reducing tool path reprogramming time. MRAS estimates they average 1.5 hours of labor to reprogram parts that change during the CAM programming process. They estimate that approximately 7 parts per month are affected by such changes. MRAS estimates that using CHAPS-translated files would reduce reprogramming time by 75%. Applying an estimated \$100 per hour labor rate, CHAPS would save approximately \$10k per year for tool path reprogramming due to model changes on the AWACS program alone.

Metric 3: Rework of point-to-point translations required an average of 2 hours due to the resulting solid losing construction history. CHAPS models used for MRAS pilot exchange averaged approximately 30 minutes of rework. Only 28% of CHAPS successfully translated files required rework, and based on those statistics MRAS estimated an annual savings of almost \$75k using CHAPS technology.

MRAS projected a total annual savings from all three AWACS program metrics of almost \$200k. This estimate assumed “perfect” translations. They also estimated savings based on pilot exchange success statistics (Table 4). Middle River estimated time required repair models that required rework and subtracted this time from overall savings. The resulting savings still equaled approximately \$141k per year.

Table 4. Annual Savings to MRAS - 71.4% CHAPS Translation Success Rate.

Pro/E to CATIA 71.4% success rate	Per Year	Range (hours)	Average	Annual Labor Hour Savings with CHAPS	Annual Cost Savings with CHAPS
Files Received	496				
Tool Path Programming Time:		3 to 36	11		
15% Reduction in Tool Path Programming With CHAPS Files:		0.5-5.4	1.65	818	\$81,816
Tool Path Rework	60		1.5	68	\$6,750
Percent "Dumb" Translations Requiring Rework:	66%	0.5 to 16	2	531	\$53,128
Total Labor Hour Savings with CHAPS:				1417	
Total Cost Avoidance with CHAPS:					\$141,694

Rocketdyne Business Case for CHAPS: *Space Shuttle Main Engine CAD data migration*

We were fortunate to have Dr. Charles Chen as a member of the CHAPS pilot team. Dr. Chen is an Associate Technical Fellow at Boeing Rocketdyne and editor of Boeing's Product Data Exchange Newsletter. Dr. Chen worked with the team to define a business case for CHAPS based on Rocketdyne's Space Shuttle CAD exchange requirements.

"We are currently moving SSME (Space Shuttle Main Engine) from CATIA V4 to Pro/E. We need 1000 CHAPS-style conversions." Dr. Charles Chen.

To establish a baseline for developing the CHAPS business case, Dr. Chen leveraged the results of a Rocketdyne CAD modeling study he conducted prior to joining the CHAPS team. Dr. Chen assembled 12 diverse production models as a representative sample of CAD models at Rocketdyne. He then assembled a team of CAD designers from different Rocketdyne divisions and asked them to completely rebuild these CAD models and document their labor. Modeling time ranged from 15 minutes to 15 hours, with an average modeling time of 4.4 hours.

Based on these metrics and the success rates for CHAPS pilot exchange, Rocketdyne could then define a potential business case for translating 1000 models from CATIA V4 to Pro/E for their SSME program. Figure 8 shows the resulting metrics for all 12 models. Labor reduction was based on eliminating remodeling time, minus five minutes for CHAPS translation, which was typical for Rocketdyne during the pilot.

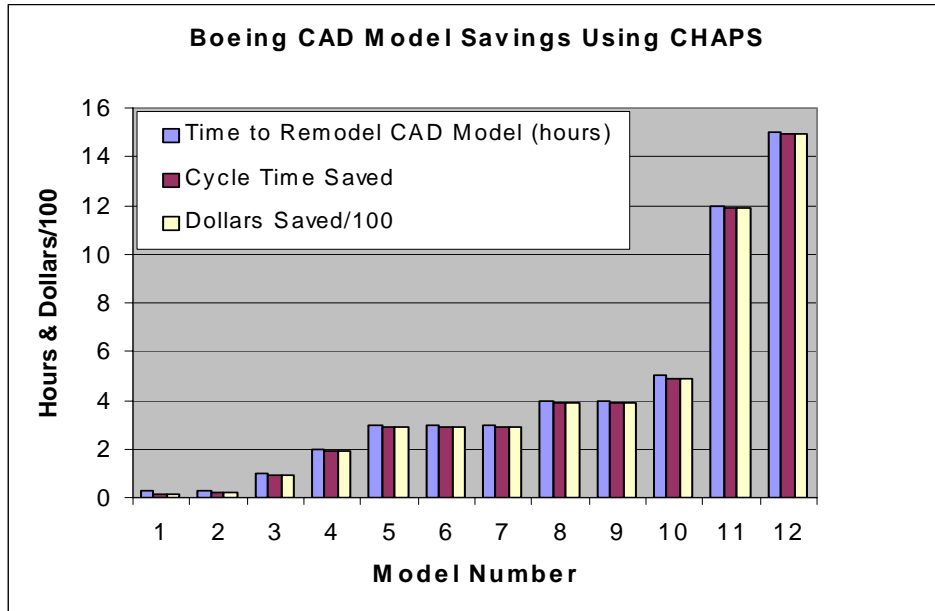


Figure 8. Cycle Time/Cost Savings Using CHAPS for SSME CAD Translation.

By applying our conservative \$100/hour savings to the 4.3 hour average labor savings, Rocketdyne estimated a potential savings of \$408K for 1000 SSME files (assuming a 95% success rate). Rocketdyne’s actual success rate for “perfect” translations during the pilot was approximately 47%, which would equal a savings of \$201k.

Bechdon Business Case for CHAPS: *Early Design Collaboration*

Bechdon did not participate in pilot exchanges during the project due to technical issues, but they did provide a high-level business case. Bechdon manufactures a wide range of actuators, many of which can be modified and reused on multiple product lines. Bechdon analyzed a typical process of moving from pre-proposal (early design) activities to manufacturing prove-out for a new weapon system and provided an estimate of labor and cycle time savings using CHAPS for design collaboration with their customer during this process.

Bechdon’s problem is that their customers typically freeze their design envelopes very early in the design phase. If their customer could use existing Bechdon product envelopes in their early design phases, it would enable Bechdon to use an existing product shell for that product, incorporating internal changes if necessary to meet performance and other requirements of the new product. CHAPS would enable collaborative design changes with customers that use a different CAD system than Bechdon. Without this early collaboration, Bechdon must redesign their actuator envelope and develop new tooling to build an entirely new actuator. Based on this analysis, Bechdon estimated savings of 6 man-months of labor and 3 man-months of cycle time if CHAPS was used to enable collaboration very early in the design process.

CHAPS Business Case Summary

Table 5 summarizes the results of the CHAPS team business cases. The pilot demonstrated significant potential savings, even though based on relatively few deployment examples. Assuming perfect translations, the three CHAPS team members that reported business cases would save over 4 man-years of labor, for cost avoidance of \$744,476. Even using the much lower pilot exchange success statistics, savings would equal 2.24 man-years and \$412,598.

Table 5. Summary of Business Case for CHAPS Pilot Team.

	Annual Labor Hour Savings with CHAPS (ideal)	Potential Annual Cost Savings with CHAPS (ideal)	Annual Labor Hour Savings with CHAPS (pilot)	Annual Cost Savings with CHAPS (pilot)
Raytheon	1,380	\$138,000	690	\$69,000
Middle River	1984	\$198,372	1417	\$141,694
Rocketdyne	4081	\$408,104	1976	\$201,904
Total Labor Hours:		7,445	4,083	
Total Cost Avoidance CHAPS:		\$744,476	\$412,598	

To establish a return on investment will require additional information, especially cost of translators and estimates for user training. Theorem Solutions is committed to commercial development of CHAPS translators, but they have not yet established a cost model.

Benefits of CHAPS Technology

In addition to financial considerations, there are other benefits to deploying STAMP technology, some of which may result in considerably more savings over the life of a product than those realized through labor reduction. One obvious benefit is compressed cycle times. Our CHAPS team business cases showed a potential labor reduction of over 7000 hours. Based on an 1800-hour man-year, labor savings alone equates to over 4 man-years of effort. While the team did not precisely evaluate cycle time using CHAPS, this labor savings would inherently translate to reduced cycle time.

Specific benefits of CHAPS technology include:

- Captures design intent more completely
- Simplifies analysis of features, reducing labor and cycle time for downstream analysis (CAE) and manufacturing processes (CAM)
 - Simplifies definition of fillet radius analysis & hole centerlines for example
- Enables parametric editing of features which is critical in a dynamic design environment
 - Bulk diameter resizing of holes

- Change “all”
- De-featuring for analysis/manufacturing
- Reduces requirements to remodel part during tool path programming
- Automates identification of dimensions (difficult and time-consuming with inarticulate CAD model)
- During the pilot, translation files were typically 12% the size of current translator files, resulting in faster model exchange for distributed teams

These advantages translate into real cost and cycle time savings and improved product quality.

Finally, using the STEP international standard for CAD data exchange enables the supplier to process digital data from multiple primes that use different CAD systems without requiring the supplier to deploy multiple CAD systems in house. This results in savings due to reduction in software costs and training costs and enables suppliers to use CAD systems based on their modeling needs while still fulfilling the needs of their customers.

Deployment and Commercialization

The PDES organization has agreed to make CHAPS a PDES, Inc. deployment pilot, providing resources to enhance the CHAPS data model based on member company CAD systems and requirements and to move the model through the standards process as part of AP203 Edition 2 and promote it to PDES, Inc. members and CAD vendors. As PDES, Inc. members, Northrop Grumman, Rocketdyne and Raytheon have committed to continued participation in CHAPS activities, specifically concentrating on providing requirements and validating CHAPS translators in their production environments.

During each phase of the CHAPS pilot, progress was reported and demonstrated at various PDES, Inc. meetings. As members of the PDES, Inc. CAx Implementor Forum, a group dedicated to STEP CAD interoperability, the manufacturers of all three CHAPS pilot CAD systems have tentatively committed to developing CHAPS translators internally. This combination of software vendor development and user community testing has been used on every successful STEP effort thus far and should prove invaluable for accelerating the deployment of CHAPS technology.

Theorem Solutions (also a member of PDES, Inc.) is continuing development of commercial versions of their CHAPS translators. These will likely find a market with large primes, especially those requiring internal data exchange between different CAD systems. These requirements are becoming more common as companies migrate to different CAD solutions or acquire other companies that use different CAD systems. If costs can be minimized, CHAPS translators are also expected to be deployed by small and medium size aerospace suppliers.

6. Conclusions

CHAPS successfully demonstrated the feasibility of incorporating construction history and parametrics into the next generation of standards-based translators. The project also showed opportunities for significant cost reduction through reduced labor and software requirements, as well as reduced cycle time and improved product quality in the Raytheon and Northrop Grumman supply chains. However, deployment is not limited to the aerospace community. Any industry that requires 3D CAD translation will benefit from CHAPS technology.

More development and piloting are required to move translators to production quality, but CAD modeling practices can be optimized to improve exchange success for CHAPS “Alpha” software, and the CHAPS pilot showed that significant savings are possible using even these early version translators. Once commercially viable translators are developed, installation and training for entire supply chain should be minimal. While the benefit derived from cost savings is obvious, cycle time reduction provides less tangible but perhaps even more important benefits, especially in the case of an urgent need for replacement weapons, as was observed during the wars in Iraq and Afghanistan.

Appendix A: JACG Memorandum, May 8, 2003

Joint Aeronautical Commanders Group Chairman Memorandum: "Strategy for Product Data throughout the Life Cycle"




JOINT LOGISTICS COMMANDERS
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8 MAY 2003

MEMORANDUM FOR THE AIR FORCE ACQUISITION EXECUTIVE
NAVY ACQUISITION EXECUTIVE
ARMY ACQUISITION EXECUTIVE

SUBJECT: Strategy for Product Data throughout the Life Cycle

1. Last year, we evaluated the benefits of standardizing on common product data exchange requirements. In particular, we were interested in standards that would allow engineering data developed under one automated design tool to be read and manipulated by design teams using different automated tools. We determined the existing ISO 10303 (STandard for Exchange of Product model data – STEP) met our military aeronautical requirements and that it was widely used by the commercial aerospace community. As a result, we have approved the use of STEP throughout our commands. Since STEP is a standard with many applications beyond aerospace (e.g., it is required in Navy shipbuilding), we encourage you to consider its use in other sectors.
2. Our implementation approach will be to use STEP in new aerospace system designs and major modifications to existing systems unless either the cognizant PEO or Systems Commander approves a waiver. The services have agreed and hence its use should be considered mandatory. Where a business case supports this, we are also encouraging the use of STEP for legacy systems.
3. The use of STEP will give us the greatest flexibility to take advantage of new computer design and support tools, but the real benefit to our services will be seen in reduced cost and cycle time, and in improved supportability. I would be pleased to arrange a briefing on STEP and our intended implementation, if you would like.
4. My point of contact for this subject is Mr. James Arnold, ASC/ENSM, DSN 785-9883, email: James.Arnold@wpafb.af.mil.


RICHARD V. REYNOLDS
Lieutenant General, USAF
JACG Chairman

Attachment:
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