Examining Industry Perspectives Related to Legacy Data and Technology Toolset Implementation

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ABSTRACT

This paper outlines past and present issues related to product data management (PDM) technologies and their implementation within organization. Included are the results from interviews with representatives from ten companies regarding their implementation processes related to PDM and PLM technologies. Results from these interviews are detailed in aggregate form related to four different areas: implementation timelines and mitigating factors, chosen PLM toolsets, data archival and migration strategies, and training. Conclusions are made in the final sections relative to industry implications and graphics curricula within a larger body of technology education.

HISTORICAL IMPACTS OF CAD AND PDM TECHNOLOGIES

In the design of complex products, a variety of data exist from multiple disciplines, which at times makes digital communication and collaboration difficult within a design environment. Making data and information available to those that need it, when they need it and in an accurate fashion are critical. This typically includes information from planning, design engineering, job costing and production all coming together through a variety of software programs and platforms: CAD systems, various databases, mainframes, minicomputers, workstations, PCs, and all operating systems that this may entail (Dickerson, 1997).

As CAD systems developed and became more sophisticated, there was a need to manage digital models and drawings, just as their paper-based counterparts had been managed in the past (Foster, 2001). However, due to the dissimilarities in much of this data, this task was not as simple to accomplish as first thought. Companies did not always use the same CAD, analysis, or manufacturing software, nor did they always update that software according to similar schedules. In doing so, they created scenarios where eventually certain parts of their global businesses could no longer communicate with each other. To address this issue, companies invested in product data management (PDM) systems to manage this transportation and translation of CAD data. This enables visualization of product data, collaboration amongst team members, and the integration of product design applications (CIMData, 2001). PDM systems impact the manner in which a corporate design group functions by controlling data security and archival, workflow and process management, product structure management, and classification management (CIMData, 2001). Due to their nature, PDM systems control access to data and the manner in which it is accessed. PDM systems also enable the relatively free exchange of information otherwise embedded into detail drawings, and more recently, 3D models. In doing so, companies have had an impact on the culture that exists within their organizations (Jha & Matthew, 2002).

At one time, CAD tools required very specialized training in order to be effectively used. Information embedded in those drawings and models was only accessible by the individuals that created them. This created a sense of job security within the working group. Currently, CAD tools are taught within nearly all engineering and technology curricula within the U.S., and quite possibly the world. They have been for nearly twenty years – 2D or 3D or both. While the depth and breadth of coverage varies widely, many employers expect engineering and technology students to be hired with some understanding of CAD technology. As companies have begun outsourcing design and modeling work, it suggests that the use of CAD tools has become a commodity activity (MacNaughton, 2005).

As CAD tools were adopted by industry, they were eventually adopted by educational institutions. Students who graduated and joined the workforce were accustomed to using CAD tools and considered them to be mainstream technologies. However, PDM technologies have not been readily adopted by educators, even though they have been available for nearly as long as commercial CAD tools (CIMData, 2006). PDM systems began to emerge in the mid-1980s as a means by which to mange CAD data, but by the mid-1990s, they were being used to manage other information within the design cycle: change controls, resource planning, production planning, and bills of materials (CIMData, 2001). Information that was traditionally contained within disparate electronic systems was now being managed by a tool set produced by the same vendor that supplied an organizations' CAD system. This meant that the potential existed to seamlessly extract information here-to-fore locked within the CAD model and distribute that to other functional groups within the company to increase throughput and decrease product development and production time. In doing so, many of the traditional job roles and titles have changed by the increased ability to access design and product information (Jha & Mattew, 2002).

PDM has also provided the basis for Product Lifecycle Management (PLM). PDM supplies the core functions that create and deploy successful PLM strategies; therefore growth in the PLM market directly expands the opportunities in the PDM market (CIMData, 2006). The overall PLM market in 2002 was up slightly compared to 2001 at approximately $13.5 billion, with 33% of that total defined by to collaborative product definition management (CPDM). "While the tools segment remained flat in 2002 at $9.3. billion, CPDM grew by 8% to reach $4.2 billion" (Amann, 2004). According to Daratech (2004), the implementation of PLM as a strategy for doing business in the manufacturing and design sector will increase the need for PDM and related technologies. Daratech's August 2004 technology assessment predicts that end-user spending on product data management technology is expected to increase a moderate 1% in 2004 to $1.73 billion, but is projected to rebound strongly in 2005. Eventually by 2008, end-user spending on PDM technologies will expand at a compound annual growth rate of 12% through 2008 (Daratech, 2004). These statistics suggest the adoption of a set of tools that will have an impact on how engineers and designers, as well as managers and production analysts, communicate within the company of the future. The figures also suggest the development and growth of a technology that is becoming (or has become) a staple in the way digital product design data is managed and communicated within a company.

However, these systems are typically created by the same vendors that develop CAD systems, which means that companies are being forced to use the same tools from one vendor or a few vendors due to the inherent inability of differing vendors' systems to communicate with each other. This also means that a company's options for organizing, managing, and archiving their product data are limited to that vendor's toolset. To change vendors in an effort to find a better price or better technology often means losing functional access to years or decades worth of CAD models, drawings, analysis files and manufactur-

ing plans, because the new system could not read and interpret a company's legacy data. Given this potential loss of millions of dollars and countless hours of time, the product design and discrete manufacturing companies of the world have continued to invest in CAD and PDM technologies at a steady rate. However, this investment is not without consequence. The dynamics of selecting and implementing PDM tool sets, migrating from one tool set to another, and the impact on job roles within the organization has become an everyday issue to the engineering staff that is expected to use these tools in the design of their products and to the IT staff that is hired to support and facilitate this process. In an effort to determine whether or not current PDM and PLM technologies continue to create the same challenges and problems for product design organizations, a study was conducted during Summer 2005 which examined ten large companies (or divisions of large companies) and their efforts in selecting and implementing various technology tool sets.

METHODOLOGY AND PARTICIPANT DESCRIPTIONS

In an effort to better understand the selection, implementation, and migration of PDM data and tool sets within a corporate environment, ten companies were selected to participate in this project. They were U.S. companies, although all of them have multiple divisions within this country and abroad. The participant companies represented the following product sectors: aircraft manufacturing (commercial, corporate, and military), aircraft engine manufacturing, heavy equipment, agricultural equipment, automotive manufacturing, automotive manufacturing suppliers (Tiers 1 and 2), and aerospace defense (Miller, 2005). Representative companies within these groups were selected based primarily on their ability to represent the collaborative environment necessary to derive full benefit from a PDM system – they have multiple divisions and suppliers that continuously share digital information in the creation of a product. They were also selected based on their size (workgroups

and numbers of corporate divisions) and their availability and willingness to participate. Each participating organization had over 100 users of their CAD and PDM technologies in various job capacities. In this research study, participants at each company were selected based on their knowledge and experience with their company's specific CAD, PDM, enterprise resource planning (ERP), and manufacturing data systems, as well as the implementation and configuration strategies and plans surrounding these systems. Typically these were people that held managerial or senior staff positions in engineering and/or IT departments (Elliott, 2006b). Below is a brief description of the ten companies that participated in this study:

- Company 1 is a multi-national corporation that designs and manufactures construction and heavy equipment and agricultural equipment. The participating individual in this study is an IT manager.

- Company 2 is a multi-national corporation that designs and manufactures agricultural equipment. The two participants in this study are designated CAD and PDM "super users" within the company.

- Company 3 is a multi-national corporation which designs and manufactures power tools and automotive components. The participant in this study is a designated CAD and PDM manager within the company.

- Company 4 is a multi-national corporation that designs and manufactures commercial aircraft and other aerospace vehicles. The three participants in this study are designated CAD and PDM managers and technical support personnel within the company.

- Company 5 is a multi-national corporation that designs and manufactures military aircraft and other aerospace defense systems. The participating individual in this study is an IT manager.

- Company 6 is an aerospace defense contractor. The participating individual in this study

is an IT manager.

- Company 7 is a multi-division company, and the division participating in this study designs and manufactures aircraft engines and other aerospace propulsion systems. The participating individual in this study is an engineering manager.

- Company 8 is a multi-division company that designs and manufactures general aviation aircraft and aircraft component systems. The two participants in this study were technical support and engineering personnel.

- Company 9 is a multi-national corporation which makes many different products to supply the automotive and heavy truck industry. The two participants in this study were IT managers and technical support staff.

- Company 10 is a division of a multi-national company. This division designs and manufactures heavy trucks for on-highway hauling and agriculture. The participant in this study was an engineering manager.

Given the open-ended nature of selecting, implementing, and configuring a PDM system within a large environment and migrating data between systems, a long interview format was chosen to gather information relative to these companies. Long interviews comprise one of the major knowledge elicitation methods in an exploratory study (Creswell, 1998; Moustakas, 1994; McCracken, 1988) and for acquiring knowledge and information from assumed experts in a given discipline (Firlej & Hellens, 1991; Cordingley, 1989; Olson & Biolsi, 1991). The term "interview" in this sense is meant to describe a technique and not an event. In an interview, the researcher asks a person with domain knowledge specific questions related to that domain in an attempt to gain insight into concepts that are not readily available (Cordingley, 1989). Interviews potentially allow for a great deal of expansion on the part of the participant depending on the type of interview that is conducted, although the researcher generally approaches the situation with some type of guide so as to avoid becoming disorganized.

Cordingley (1989) also suggests three styles: structured, semi-structured, and unstructured. The semi-structured interview was the method used for this study. It combines the structure of a few prepared questions, but it does not require the researcher to ask them in a specific order and gives the liberty to add or remove questions as necessary.

The interview questions were developed according to the structure of PDM applications suggested by Cornelissen (1995) and CIMData (2001): structure management, retrieval management, release management, change management and work flow management. In addition, the interview format also gave the researchers the opportunity to probe deeper into the reasoning behind the selection of a particular strategy or decision. The interview guide consisted of twelve questions that covered the following four major areas: PLM implementation timelines and mitigating factors, selected PLM toolsets, data archival and migration strategies, and training. Table 1 at the end of this paper includes the specific interview questions. Through conversation analysis suggested by Creswell (1998), Cordingley (1989), and Olson and Biolsi (1991), the transcripts of the interview notes were analyzed for common terms, attitudes, experiences, and themes between the participating companies. Notes were taken during the interview sessions and the sessions were not recorded. The commonalities (and a few differences) between the companies relative to the selection and implementation of PDM tool sets within a PLM environment, and the use of legacy data, are presented in the next section.

FINDINGS

An emergent theme from this study is that the PLM implementations for these 10 companies first involved the selection and implementation of CAD technologies (both 2D and 3D). PDM technologies were implemented next once the volume of CAD data became unmanageable using only operating system functions, and that it became necessary to be secured, stored, and able to be retrieved for reuse. Finally (and most re-

cently), global enterprise-wide PLM technologies are being rolled out in an effort to enable digital collaboration and communication across the entire corporation. This has become possible by extremely powerful and economically feasible computer hardware at the desktop level and mature software tools, coupled with the growth of the Internet.

It is impossible to go through a major process like migrating to a new PDM system and PLM toolset without acquiring a set of "lessons learned". Each participating company had a wealth of these lessons, which are summarized in this section. The conclusions that come from a study like this can be numerous and wide-ranging. However, it is important that they be kept in perspective, which is to say they should not be generalized too far past the companies that participated in this study. When generalizing these conclusions, it is important to make sure that the company of interest is similar to the companies that participated in this study. Not all companies are large or have multiple divisions or have hundreds or thousands of people that may eventually use the new PLM toolsets.

In general, the selection, implementation, and configuration of PDM systems, as well as the migration of data between PDM systems, requires the development of a good process, the necessity for a champion at the upper levels of management, the need to organize and prepare your data before the migration starts, and the necessity to change corporate culture and the mindset of the users to accommodate the use of these new tools. When it comes to the actual migration process itself, the biggest point to be made is not to try everything at once. Form a set of "early adopters" who can help with the rollout, who can test various functions before recommending them to all users, and who can act as mentors within the different engineering groups once the toolset is released to everyone. In addition, it is important to communicate results of the migration to everyone involved, especially upper management. Finally, dedicated and consistent internal funding is critical to the success of this type of endeavor.

Having framed these conclusions in that sense, the following points are what the authors have gleaned as important conclusions based on the analysis of the interview transcripts from the participating companies:

- PLM toolset implementations typically began with the installation of solid modeling-based CAD systems. From there, the migration was to PDM tools and on to enterprise-wide PLM environments. This move occurred over a period of years if not decades. On average for the ten participating companies, this process took four to five years. However, at least two companies stated that this process has been ongoing for at least ten years in various stages. This time frame was most significantly impacted by software and hardware maturity and the level of planning done by the personnel involved. This process takes consistent funding and resources.

- The PLM toolset implementation must coincide with business processes. If not, it will be seen as inconsistent with corporate plans and will likely not be supported – by rank and file employees or by management.

- Communication is critical regarding the successes and failures of the implementation, and existence of a champion of these new tools is critical, especially at the executive level.

- Develop corporate standards (if they do not exist already) for the creation and input of data into the PDM and PLM systems. This will make future migrations and upgrades happen more quickly and consistently.

- The adoption of these new toolsets typically occurred during one of two times: a new product release or a major revision to an existing project. It is often necessary for these scenarios to leverage the new and improved functionality of the toolsets to accomplish the goals of the new project. Morale is often high and the project is visible at the corporate level.

- The new PLM toolsets are often implemented in two ways according to organizational structure – either by product group or by workgroup. If it was by product group, there were occasional issues about people moving from project to project with regard to security issues, but these were eventually overcome.

- The archival process of new design information as it moves through the PDM tool often follows the typical engineering releasing process. In order to accommodate this massive amount of data, sufficient resources need to be devoted to storage and hardware capabilities.

- All of the companies that participated in this survey currently use one of the following vendors and their tools for their primary PLM toolset functionality: UGS, Dassault Systemes, or PTC. While software maturity is always an issue, it is highly recommended that customization of these tools be kept to a minimum because new software releases can require future customization and customization is very expensive. If customization is chosen, it should be done in concert with the vendor.

- The actual migration of data from one system to another (whether it is with the same vendors tools or not) should be methodical and well planned. Consensus should be reached between all constituent groups, independent of the IT staff, as these individuals know their work processes best.

- A systematic testing process must be developed to verify the migration (or import) of data into the new PLM toolset. Do not simply take the claims of the vendor at face value. The vendor must be able to verify data compatibility from one version to the next.

- When moving data from one system to another, it should never be done all at once. Small (relatively speaking) groups of files should be prepared, imported, and results examined before attempting a larger migration of data. The process of importing entire data base instances should be avoided unless absolutely necessary. Most companies typically did it on a folder-by-folder basis. Most of the participants to date have moved a significant percentage of their new product or major revision files to the new PDM toolset, which generally accounts for terabytes of data.

- Do not short-change the training of personnel who will use these tools. It is critical that they have job-specific training in a timely fashion. Avoid falling into the trap of training everyone – this is typically unnecessary. Bring people up to a basic level of proficiency in most areas of the new toolsets, but after that point, training should be specific to their job. The difficult part is determining the "basic level" of proficiency, because this often varies by corporate processes and by the type of product being designed. To accomplish this, the companies typically spent hundreds of thousands or millions of dollars.

DISCUSSION AND IMPLICATIONS

In examining the literature relative to PDM, two trends have emerged. PDM has evolved into being known as the centerpiece of product lifecycle management (PLM), and a new paradigm called engineering data management (EDM) has emerged relative to small- and medium-sized businesses (SMB) (Waxler, 2006a & 2006b; Elliot, 2006a., b, & c; CIIMData, 2001; Goggin, 1999; Gould, 1997). These trends have also made it obvious that the issues mentioned in the previous section of this paper are still significant and real for many companies, and they are the same issues that have surrounded PDM since its widespread adoption nearly fifteen years ago (CIMData, 2001 & 2006). Cummings (2006) has suggested the following seven steps, when applied in earnest by companies, will lead to effective engineering and product data management:

1. Analysis of existing corporate procedures is critical to account for the needs of users at all levels of the system.

2. Maintaining and tracking legacy data from CAD systems is critical due to the incorporation of design intent into product geometry.

3. Setup digital "vaults" for data storage at remote locations as necessary.

4. Integrate product data management systems with other corporate systems to propagate design intent from CAD geometry to other constituents within the organization.

5. Train users and administrators with the proper level of information to perform their job duties.

6. Make sure that adequate technical support is in place to enable users to implement skills learned during their training.

7. Limit the use of custom-programmed routines so that engineering processes are not tied unnecessarily to a vendor's legacy software code.

So why do the aforementioned items in a recent article match the results from the research study described in this article? Why conduct such a study if the answers are already known? Why have companies not been able to master product data management systems (and ultimately PLM tools) in the same fashion they have mastered CAD systems? In the end, don't these systems just manage CAD and other associated files? Unfortunately the answers to these questions are not quite that simple. CAD data are comparatively easy to manage since they typically have fewer file types to be concerned with. Once an organization begins digitally linking their design data with other areas of the company, it creates a level of access to information that some people are not used to having. It breaks down the barriers of "ownership" to some degree, because one of the goals of product lifecycle management tool vendors and users is to make available product information any time and anywhere it is needed. Also, the fact that CAD systems have been available to educational institutions for nearly twenty years, there is a generation of employees who have "grown up" using these tools. The same cannot be said of PDM tool sets.

While the reasons for academic institutions not adopting PDM technologies within the classroom to the extent they have adopted CAD technologies are varied and often valid, this has left a void in the number of graduates entering the workforce that have been exposed to this technology, let alone those that are versed in its use. It can be argued that this lack of understanding of PDM technologies has contributed to the issues in corporate culture that are being experienced today relative to the implementation and use of these technologies (Jha & Matthew, 2002; Waxler 2006a &b; Cummings, 2006)).

One of the most significant implications for educators related to the use of PDM tools in the classroom is exposure. It is very likely that students leaving a university setting for an engineering or technology position at a design- or manufacturing-related company will have to use some form of a PDM tool to manage their design data on the job. In the past, students could be instructed to use the file management functions within the computer operating system, but that does not provide a sense of security or stability when it comes to editing files associated with a design. It is critical for students to understand contemporary data management issues associated with the design of a product and the corporate personnel structure into which that fits.

A second implication for educators is one of technological literacy. PDM tools have become nearly commonplace within engineering design environments. Even at small-to-medium sized businesses, who may not have the available funding of a global corporation, software vendors have supplied mid-range solutions to at least handle the management of CAD data, if not additional file types. It will also be critical that students understand how to develop CAD models such that information can be extracted from the model and be communicated via the PDM system. A working knowledge of embedded parameters, parent/child references at the assembly model level, product configurations within the CAD tools, and top down modeling are critical to the effective communication of design information

which drives the product lifecycle. While the cost of PDM technology is not as low as CAD tools in terms of educational discounts, it can be had at a reasonable cost if it is made a priority.

A third implication for educators is the impending commodity status that the use of CAD tools has now achieved. Early in its development, CAD technology required specialized training and expensive workstations to operate it. With the advent of Windows workstations and powerful, relatively inexpensive graphics processors, CAD tools have become a staple in most engineering and technology programs. It is the use of PDM tools and other higher-order technologies that will enable students to develop new paradigms of thought about the design process. It will also require faculty to develop more creative instructional opportunities and to change their focus from a production mindset to one of technological integration. While the creation of geometry will always be important, a secondary focus of engineering design graphics education is now developing – a view towards leveraging the 3D database within the larger context of the design environment. To facilitate that process, literacy in the use of PDM tools as a communication and dissemination backbone will be required.

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Table 1

Interview Question Used with Participating Companies

1. What year did your PLM implementation start?
2. How long did it take?
3. Which factors had the most influence on this time frame?
4. Which PLM tool set(s) has your company recently implemented? Specifically, which of the following have been implemented and which vendor was used:
   a. CAD tool(s)?
   b. CAM tool(s)?
   c. Data Manager and vault?
   d. Computer-aided Process Planning (CAPP) tool(s)?
   e. Analysis tool(s)?
   f. Enterprise Resource Planning (ERP) tool(s)?
5. What were your company's prior capabilities in the aforementioned toolsets, including vendor:
   g. CAD tool(s)?
   h. CAM tool(s)?
   i. Data Manager and vault?
   j. Computer-aided Process Planning (CAPP) tool(s)?
   k. Analysis tool(s)?
   l. Enterprise Resource Planning (ERP) tool(s)?
6. If there is a difference in vendors between Question 4 and Question 5, how did that come about? What were the issues that had to be dealt with? Have they been resolved? If not, what is delaying that resolution?
7. If there was no change in vendors (as implied in Question 6), was there a change in version of the aforementioned PLM tools? If so, what issues had to be resolved? Has that process been successful? What were the factors that made it successful, or that have kept it from being successful?
8. Have you continued to use your prior PLM tool sets? If so, why and in what capacity? Is there a plan to eventually stop using them altogether? Can you share the details of that plan?
9. What type of archiving strategy was employed during the implementation of your PLM tools and strategy? Which internal groups were represented in the planning process? How were workgroups determined for PDM configuration? What strategies were used for establishing permissions, security, and design control within the database?
10. How was the data archival process determined? What were the critical factors used in the decision making process?
11. Describe the overall data migration process from the prior set of PLM tools to the current (new) set of PLM tools:
    a. How was the process determined that controlled the migration of legacy into the new PLM tool set? What were the major steps of that migration process? How much data was moved?
    b. How was the process determined that controlled which files were converted to the new file type (if applicable)? What were the major steps of the conversion process? How much data was converted?
    c. How was the process determined that controlled the creation of new data within the new PLM tool set? How much new data was created and archived?
    d. What was the timing of the new PLM tool implementation? Was it strategic or did it happen at the first available time?
    e. What lessons has your company learned throughout this process? How have you taken advantage of those new insights? What would you do differently if you could do this PLM implementation over again?
12. How was the training strategy developed to train people in the use of the new PLM tool set?
    a. How many people were trained? Which workgroup(s) was (were) given priority?
    b. Is there a 1-to-1 ratio of PDM seats to CAD seats? If not, what is the ratio? What was the rationale behind this ratio?
    c. Was this training created and administered by in-house personnel or from the PLM tool vendor? How was this decision made?
    d. How was the training budget determined? What was the overall amount allotted? Did that prove to be enough? Too much? Too little?