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A Paradigm Shift towards Personalized and Scalable Product Development and Lifecycle Management Systems in the Aerospace Industry

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***Abstract*—**Integrated systems for product design, manufacturing, and lifecycle management are difficult to implement and customize. Commercial software vendors, including CAD/CAM and third party PDM/PLM developers, create user interfaces and functionality that allow their products to be applied across many industries. The result is that systems become overloaded with functionality, difficult to navigate, and use terminology that is unfamiliar to engineers and production personnel. For example, manufacturers of automotive, aeronautical, electronics, and household products use similar but distinct methods and processes. Furthermore, each company tends to have their own preferred tools and programs for controlling work and information flow and that connect design, planning, and manufacturing processes to business applications. This paper presents a methodology and a case study that addresses these issues and suggests that in the future more companies will develop personalized applications that fit to the natural way that their business operates. A functioning system has been implemented at a highly competitive U.S. aerospace tooling and component supplier that works with many prominent airline manufacturers around the world including The Boeing Company, Airbus, Embraer, and Bombardier Aerospace. During the last three years, the program has produced significant benefits such as the automatic creation and management of component and assembly designs (parametric models and drawings), the extensive use of lightweight 3D data, and changes to the way projects are executed from beginning to end. CATIA (CAD/CAE/CAM) and a variety of programs developed in C#, VB.Net, HTML, and SQL make up the current system. The web-based platform is facilitating collaborative work across multiple sites around the world and improving communications with customers and suppliers. This work demonstrates that the creative use of Application Programming Interface (API) utilities, libraries, and methods is a key to automating many time-consuming tasks and linking applications together.

***Keywords*—**CAD/CAM, CAPP, PDM, PLM, Scalable Systems.

I. Introduction

COMPUTER software applications that help to simplify repetitive tasks and streamline interactions between departments by using centralized databases have become commonplace in companies that want to increase their competitiveness. From automotive, aerospace and electronics manufactures to producers of raw materials like petroleum, wood, and minerals to services like banks, hospitals, and transportation; they all use software to better manage data. Some of the main objectives include improving the allocation of resources, facilitating communication between personnel, customers, and suppliers, and adding collaboration tools for the timely flow of information and products. Maintaining a competitive advantage in today's fast paced and technology-rich global landscape is forcing companies to find new and innovative approaches to address these problems.

Although some larger corporations have had success with implementing systems classified as Enterprise Resource Planning (ERP), Product Lifecycle Management (PLM), Computer Aided Process Planning (CAPP), Supply Chain Management (SCM), and Customer Relations Management (CRM) among many, others have had little or no success for varying reasons. Oftentimes, companies do not take the time or dedicate the resources necessary to fully understand the complexity of their operations or produce good documentation that describes procedures, standards, and best practices. Losses related to these bad investments can be costly in terms of both money and time. There can also be a negative effect on efforts to change how people do their job and their willingness to implement new ideas and software tools in the future.

By focusing this paper on component and tooling manufacturers in the aerospace industry, the authors hope to outline an approach that helps systems planners, engineers, and decision makers to develop more useful and practical software integration strategies. To provide the flexibility and scalability necessary to address the problems that companies are facing with commercial systems, and make systems both web-based and collaboration centered, will require a change to the current paradigm. The change agents, especially engineers and software developers, must work together on this innovative and promising technology. The first step is to collect and study the current processes, tools and methods used by departments and personnel in the company. Subsequently, areas should be identified where immediate benefits can be obtained in critical processes using software automation. Early efforts should focus on gaining credibility with key personnel and management, and on a base system that can be scaled over time. This paper also describes developing "filters" so individuals only see and manipulate data specifically related to their role in product development, production, and order management.

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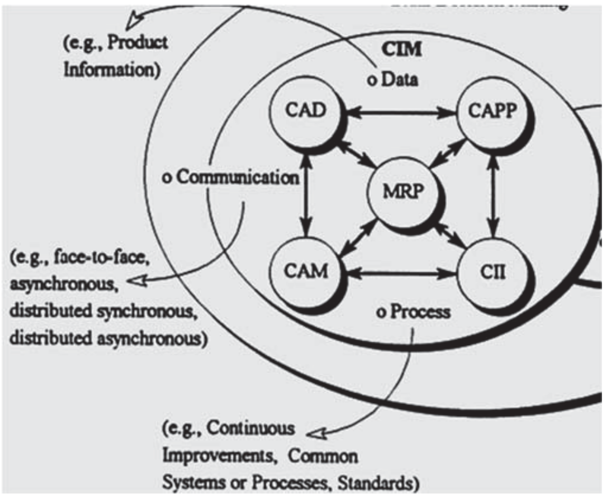

Fig. 1 Components of Computer Integrated Manufacturing

An alternative approach to what is currently done in industry is described in this paper that is based on modern tools for Computer Aided Product Development (CAPD). It looks at the software technology that is available to help companies connect design and engineering applications to business functions and the management of projects and services. The basis of this approach is to focus first on key points related to a particular industry (in this case products, standards, and methods that are common to the aerospace contractors). Next, a detailed study is done on the interactions between departments as well as with both internal and external entities (personnel, product/project tracking, and customers/suppliers). Lastly, and often overlooked, current practices, standards, information (files, terminology and forms/documents), and the software applications utilized must be documented and verified.

The idea behind this strategy is to keep the natural flow of work in place and incorporate "the way we've always done things" in the new system so employees take ownership and are enthusiastic about participating in the development and continuous improvement of new software applications. Other benefits of this approach include:

1) Less disruption to daily operations and a reduction in the time needed to train new engineers and personnel.
2) Engineers and operations managers are not frustrated by having to change their methods to adjust to software,
3) A company can carefully choose which technologies and software need to be purchased, which can be developed using consultants or in-house, and which ones are not needed at all, thereby saving money,
4) Personnel in charge of software development and implementation can use feedback to address issues and propose enhancements over the short, medium, and long term that are in the best interest of the company.
5) A company's best practices, standards and experience can be embedded in the software functionality and applied to all new jobs ("artificial intelligence").

Developing personalized and scalable software solutions that fit to the way a company operates and does not force skilled and experienced personnel to adapt to a software company's "philosophy" just makes sense. Advances in computer software engineering, scalable open systems, information technology, and cross disciplinary education will provide the tools and expertise to make this approach a more viable option in the future for companies of all kinds.

II. Background and Literature Study

A. Fundamental Concepts and Roots in CIM

Computer software to assist companies in product design, process planning, manufacturing, and shop-floor management activities has grown and matured at a similar rate to technology in general over the last three decades. Although new names and acronyms are constantly coming out to better describe specific functionality and categorize computer-aided applications (*often called CAX*) for marketing to engineers and operations managers, much of the progress can be traced back to the theory and vision described in Computer Integrated Manufacturing (CIM) literature from the 1990s. "CIM integrates the total manufacturing enterprise by using integrated systems and data communication coupled with new managerial philosophies that improve organizational and personnel efficiency. Controlling, organizing, and integrating the data that drive the manufacturing process through the application of modern computer technology effectively integrates all the steps in the manufacturing process into one coherent entity" [1]. The focus of CIM is on connecting individual pieces of computer assisted technology such as design, process planning, manufacturing, inspection, scheduling, and resource management so people can obtain the information they need in a timely manner to facilitate Concurrent Engineering (CE) as demonstrated in Fig. 1, which was taken from [2].

Achieving total integration has been difficult for companies and advances in robotics, Programmable Logic Controllers (PLC), CAD/CAM, and vision systems for inspection have added an additional level of complexity to an ever-changing environment. As many companies go beyond CIM to incorporate best practices, standards, collaborative, intelligent, cloud/web-based, cultural differences, and life-cycle concepts into their software systems, the end is "nowhere in sight".

B. Product Data and Lifecycle Management

"Modern enterprises are facing ever increasing challenges of shorter product lifecycles, increased outsourcing, mass customization demands, more complex products, geographically dispersed design teams, inventories subject to rapid depreciation, and rapid fulfillment needs" [3]. Some authors are focused on the link between CAPP and CAM as a critical part of collaboration for modern PLM systems. Although the connections between the system that is described in their work and CAD/CAM and ERP systems are mentioned, they do not refer to specific API functionality that would give the ability to automatically extract, export and process the information that is needed for seamless CAPP/CAM and PLM integration. Instead, textual "messages" are used to pass this information and they do not go to the extent of opening the

CAD/CAM system and passing this information directly into the databases and implement the strategies selected. The system described in this paper (called AITPLM) demonstrates how Windows, CATIA and SQL are connected using custom API programs. This is something that distinguishes AITPLM from other systems presented in the literature. Most of these systems are focused on particular pieces of the PDM/PLM puzzle without adequately describing how collaboration between the pieces will be automated to streamline design to manufacturing, as well as how they are connected to business activities [4]-[6]. Since AITPLM has been implemented in a working aerospace company and has been through a few iterations of feedback/improvements/growth, it demonstrates how a personalized and scalable system composed of pieces of many PLM concepts can be successfully developed "in-house".

Other literature has focused on the use of international standards such as STEP, IGES, and ISO as the basis for product model definition, software interoperability and PLM system development [7]. In the future, continued work on these standards will be important and help companies build integrated solutions but, currently they fall short of providing the level of detail needed for daily operations, multi-site collaboration, and web-based/cloud-based services needed for PLM [8]. Improvements and expansion to Application Protocols (AP) for STEP are promising for reaching a universal standard but interoperability between proprietary systems continues to be a problem today. Often, high level information, like features defined in product or process models, is lost. Such a translation approach also creates a tremendous number of inconsistent copies of data files in processes like the 'snowball' effect observed in day-to-day email attachments. Such discrepancies are great hurdles for collaborative integration among engineering partners. With the penetration of virtual-enterprise business practice in the current engineering collaborations, globally-distributed designers and engineers at different stages of product lifecycles use different semantics and engineering patterns [9]; yet they all work on a common product with different derived 'views' of their relevant working scopes [10]-[12]. Hence, a new level of interoperability has to be investigated to create a solution for pervasive collaboration based on advanced engineering informatics and Web technologies [8].

C. Role of Knowledge, Practices and Standards

Personalizing integrated product development applications for specific industries and individual companies can only be accomplished by incorporating three important components in the fabric of the system: 1) Expertise or Knowledge, 2) Past Experiences and Projects, and 3) Industry and Company Standards. Each of these areas has been the focus of papers and research projects related to Concurrent Engineering, CAD Automation and Computer Aided Process Planning, to mention a few. "Developing products without sufficient expertise in a broad set of disciplines can result in extended product development cycles, higher development costs, and quality problems. Product development is being more often done collaboratively, by geographically and temporally distributed design teams. Designers are no longer merely exchanging geometric data, but more general knowledge about design and the product development process, including specifications, design rules, constraints, and rationale. Furthermore, this exchange of knowledge often crosses corporate boundaries" [13]. This higher level perspective clearly shows typical jobs in product development being enriched by company specific case histories and PDM utilities to facilitate collaboration and improved workflow (Fig. 2) taken from [13].

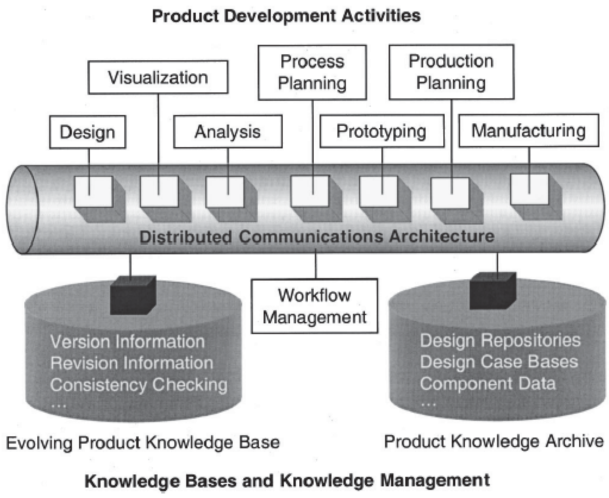

Fig. 2 High-level view of distributed product development

Artificial Intelligence (expert systems, fuzzy logic and Case Based Reasoning) in product development has also been the subject of theoretical and applied research [14]. CAPP systems are classified as Generative or Variant based on whether process plans are generated from scratch or from a similar part or product whose plan is retrieved from a database and then modified to incorporate variations or enhancements to fit the new part [15]. In either case, the importance of archiving knowledge, best practices and the incorporation of industry/company standards is widely accepted as an important part of future integrated product lifecycle systems. Material presented in this paper speaks to how aspects of knowledge and company standards are incorporated into the AITPLM system. In [16], while discussing collaborative product development, the author suggests personalizing software systems and including company practices and personnel in the development process. In the section "It Takes More than Software, Many factors – both technical and cultural – affect attaining a high degree of efficiency in any collaborative relationships, be it group or global. A key to achieve true efficiency is user's confidence in the quality of data flowing through the systems. Lack of confidence among team members may cause continual questioning and correcting data, wasting time, money and user's patience". Although this is more of a management and cultural statement than technical, it is an important consideration that speaks to the practicality of implementation and daily use with highly skilled employees that often work under growing pressure from customers and management.

D. Commercial Systems for PDM/PLM

Solutions for lifecycle management and Collaborative Product Development (CPD) are available in many varieties and prices. Two types of PDM/PLM systems that are commonly found in manufacturing companies are those that are incorporated within a suite of CAD/CAM/CAE modules (CATIA, Siemens NX, Autodesk, CREO are examples) and 3rd party systems that use centralized databases and custom user interfaces. First of all, a product's lifecycle can be divided into five major stages: *plan, design, build, support and disposal*. Although all of these are important, the early stages often define much of the entire product's cost parameters and are a place where organizations can benefit from better data management. The stages that encompass *plan, design, build* are often referred to as the start of the digital lifecycle. In PLM [17], the author Grieves defines CPD as "an approach to capturing, organizing, coordinating, and /or controlling all aspects of product development information, including functional requirements, geometry, specifications, characteristics, and manufacturing processes in order to provide a common, shared view as product requirements are translated into a tangible product and to create a repository of product information to be used throughout the product lifecycle. It begins the core of the PLM model". Since the company/application presented in this paper utilizes CATIA from Dessault Systemes, it will be used here to describe state of the art capabilities available in commercial systems. The following information was taken from the CATIA website [18].

The Systems Engineering solution delivers a unique, open and extensible development platform – a platform that fully integrates the cross-discipline modeling, simulation, verification and business process support needed for developing complex 'cyber-physical' products. It enables organizations to quickly and easily evaluate requests for changes or develop new products or system variants, while utilizing a unified performance based systems engineering approach that reduces the overall cost of system and product development. ENOVIA's Aerospace and Defense PLM Solutions provide capabilities for clients who require Product and Portfolio Management, Program Management, Requirements Management, IP Protection and Materials Compliance to meet their business objectives. DELMIA Digital Manufacturing solutions drive manufacturing innovation and efficiency by digitally planning, simulating, and modeling global production processes. Aerospace & Defense manufacturers and suppliers use SIMULIA solutions as part of their integrated development environment to evaluate design alternatives, collaborate on projects and leverage computing resources for more efficient analysis [18]. CATIA PLM is representative of commercial software capabilities that continue to expand and encompass the stages that make up the product lifecycle. The AITPLM software presented in the next sections uses the CATIA software as the core design, planning, and manufacturing tool and accesses the CATIA interface and databases through the use of custom Application Program Interface programs that will be discussed in depth later in this paper. Many of the advanced capabilities available in ENOVIA, DELMIA, and SIMULIA can also be accessed through the API and macro utilities.

III. Project AITPLM: Company Profile, Concept, Road-Map, and Implementation

A. Advanced Integration Technologies (AIT)

AIT is a leading industrial automation and tooling company that delivers turnkey factory integration to the aerospace industry. AIT designs, manufactures, and installs machines and systems for the automated assembly of aerospace structures. Relying on the strength of a diverse group of engineering professionals, AIT has served as the full-scale integrator to some of the most prominent aerospace companies, including Airbus, Boeing, Bombardier, Embraer, Spirit AeroSystems, and Vought Aircraft. With many years of experience in the aerospace industry, AIT has earned a reputation for providing high quality systems in reduced lead times as well as increased reliability and affordability. Precision-engineered technology and automation has enhanced the industry's ability to manufacture aircraft in less time and with greater flexibility.

Because of AIT's diverse product and service offerings, they are composed of a multi-site, multi-layered group of professionals that rely on the accurate, coordinated, and timely exchange of information between customers, suppliers, designers, manufacturers, managers, testers, and installers at sites around the world [19] (Fig. 3). As the AITPLM software has continued to grow, engineers and operations managers from different sites have requested that the software be made available to everyone, recognized the need for specific capabilities at each site, and given valuable feedback to the developers so that AITPLM becomes more versatile and widely used throughout the company.

- Plano, Texas: Engineering, project management, fabrication, testing, metrology.
- Chesterfield Township, Michigan: Manufacturing, design, fabrication, project management.
- Bothell, Washington and Leganés, Spain: Design.
- Umeå, Sweden: Automated guided vehicles, fabrication.
- Langley, Canada: Fabrication, machining, assembly, metrology.
- Grand Prairie, TX: Aerospace components and services.

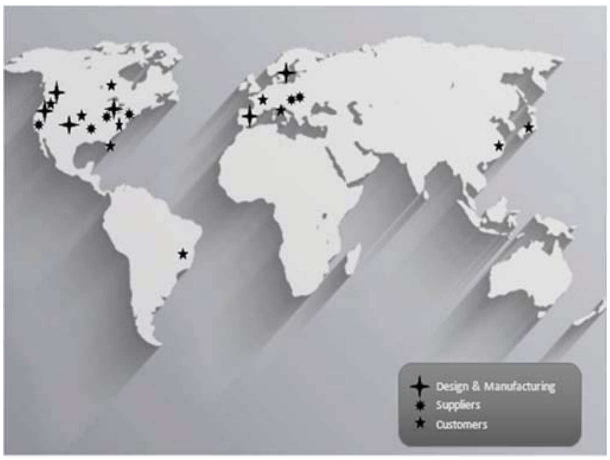

Fig. 3 Map showing global sites involved in AIT business

B. Conceptual Description of AITPLM

Many companies do not need the full capability / portfolio of utilities and modules offered by commercial software. Purchasing a suite of programs that include CAD/CAE/CAM, Product Data Management (PDM), Product Lifecycle Management (PLM), Enterprise Resource Planning (ERP), and Shop Floor Management and Control (SFM&C) can easily add up to $100K USD or more. Once purchased, the learning curve and implementation time can also be very expensive and require not only the hiring of qualified human resources but, also upgrades to make computing / IT infrastructure more robust.

The objective of this paper is to serve as a guide or methodology to determine what a company needs in order to have the biggest impact on operations and productivity as a starting point, and then how to grow and improve the software over time. A generic road-map for using what was learned in this project to develop similar systems for other companies and industries is presented in the following sections. The breakthrough ideas and innovative approach of this work has not only improved the alignment between engineering and data management/distribution but, also resulted in many positive changes to company culture and collaboration between personnel and multi-site offices. The use of Application User Interface (API) tools has enabled programmers to automate routine tasks, manipulate the databases of proprietary programs, personalize user interfaces, incorporate company standards and best practices into new projects, and filter information so people only get what they need to do their jobs.

C. Application Programming Interface (API)

Most commercial software vendors offer the user tools to automate and customize their programs using different programming languages including Visual Basic (standard or .NET), C++, C#. There are even more options these days so that bridges can be used to mix and interface programs written in different languages including Perl, Python, Java and SQL. The power of APIs is not only in the ability to work in a single software but, just as importantly to connect and share information between programs. Thinking about the paradigm of Collaborative and Digital Product Development (CDPD), the new capabilities offered by APIs could provide the key to integrating functions related to design, planning, manufacturing, marketing, finance, and customer / supplier relations.

AITPLM, the application discussed in this paper, is using these programming tools under the umbrella of Microsoft Visual Studio to demonstrate the benefits and possibilities offered by these advances in computer programming. A very important lesson learned in this project is that engineers, operations managers, and programmers/IT specialists must do a better job at crossing the lines between disciplines in order for these projects to be successful. For a long time, there has been a lack of communication and understanding about the contributions and knowledge that personnel in each area use to complete their daily tasks. Only by studying carefully these interactions and documenting the flow of information can a company hope to streamline and simplify operations using software automation tools and custom API programs. The information hierarchy shown in Fig. 4 on the following page and the IDEF0 diagram in Fig. 5 show how the AITPLM system stores and utilizes information as a project is completed. This conceptual framework was used to develop the core functionality and inter-connection of steps used for CDPD at AIT. The API utilities and libraries of commands available with CATIA CAD/CAE/CAM provide very flexible and powerful capability to manage this information effectively.

Repetitive and tedious work can occupy up to 20-30% of an engineer's time throughout the early stages of product development (design, planning, and manufacturing). Although engineers with some computer programming skills and creativity have been using API programs (also known as macros) for years, a higher level of thinking is required to connect many parts of the CAD/CAM and CDPD process together, design an efficient user interface (GUI), and integrate this into the larger context of a company's daily operations. For example, a company could use the API in CATIA to create component models, produce engineering drawings, add Product Manufacturing Information (PMI), combine components together in an assembly file, build a bill of materials and export all this information to .pdf or .xml files for sending to customers, suppliers or manufacturing sites.

By expanding on this "streamlined" approach to CDPD a company can use the API to address bottlenecks and identify opportunities across the entire product lifecycle. Furthermore, if API programs from different software applications are organized into "modules" (ERP, order management, shop-floor control, knowledge / standards archives, SQL databases, Windows programs like Excel and Word, and JAVA/HTMS web applications), information could be distributed efficiently and accurately allowing personnel to focus on value-adding activities and collaboration both internally (between departments and personnel) and externally (geographical sites, customers, suppliers). This is the long range plan and higher level of thinking that is driving the continuous improvement and growth of not only the AITPLM software but, the direction in industry as a whole.

An important point to make in completing the discussion on API programs related to CAD/CAE/CAM systems is that as new capabilities are added by software developers in areas like PDM, PLM, 3D Lightweight Data, Collaboration, and Cloud/Web functionality, that functionality is also added to the API utilities and command library. To maintain a competitive edge in CDPD, companies must take advantage of the new capability and consider integrating this functionality into their processes using API programs. To demonstrate some basic ideas on how to link design and manufacturing planning with CAD/CAM to business and information management systems using API commands, Table I shows the steps of typical project once the customer has submitted all of their requirements. Some of the linkages to systems shown in the table do not exist yet in the AIT system but are planned for future versions. The center column identifies the steps to complete a project, the left-hand columns to show information that is input/output and connections to external programs, and the right-hand column to mention specific API code utilized to complete/automate each step. For purposes of explaining the concepts discussed in this paper, CATIA API commands are used in the table. CAD and CAM software on the market provide API programming functionality including giving users the option of languages like Visual Basic .NET, C++, and C#. Companies could replicate the capability described in the AITPLM system using any of the robust CAD/CAE/CAM applications including CREO, AutoDesk, or Siemens NX.

Fig. 4 Information Hierarchy Showing Typical Project Items Used by AIT

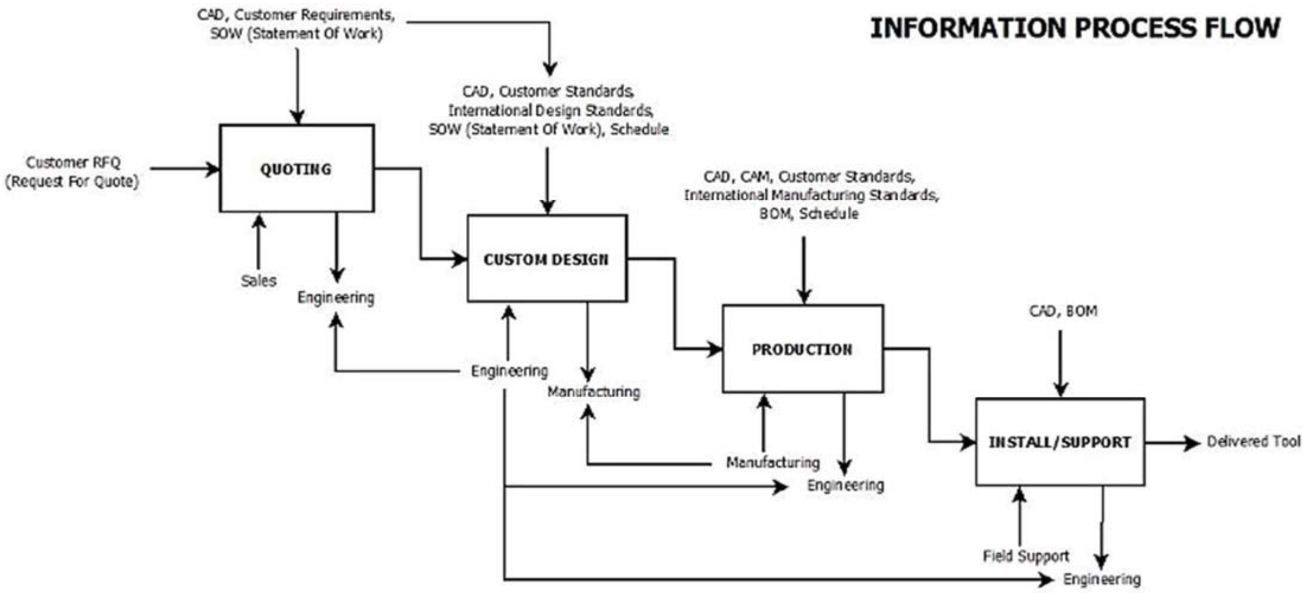

Fig. 5 IDEF0 Diagram for AITPLM Information Flow

TABLE I
APPLICATION PROGRAMMING INTERFACE TOOLS THAT HELP STREAMLINE COLLABORATIVE AND DIGITAL PRODUCT DEVELOPMENT

Programs Utilized for Dbase and Business	Specific Information to Export or Import Support of Product Development	Standard Process for New Projects using CAD/CAM	Application Programming Interface Functionality and Specific Code Examples "Which API Commands Correspond to Each Task?"
CRM System	Customer Information	Create Project	Open Catia Application, New Part/Template, Preferences
Order Mangt.	Project Description	Start New Job	Set CATIAApp = CreateObject("CATIA.Application")
SQL Dbase	Specs / Requirements	Open CAD Sys.	CATIADoc = CATIAap.NewDocument("C:\...\Templates")
			CATIAUserPreferenceOption_e.CATIADetailingDimension
			bRet=CATIAParamName.SetStringValue2(AttName & " - ")
Engr. Dbase	Job Data Files	Configure Work Environment	Set Permissions for Users, Logins, Assign Project
CAD/Project	Personnel Assigned	Set Permissions & Accessibility	value = instance.SetUserPermissions(Name, permissions)
Templates	Roles/Relations		value2 = instance.CreateProject(Name, Description, Parent)
IT Control	Access Codes/Passwd.		conn.Login("pdmwadmin", "pdmwadmin", "localhost")
Job Archives	Customer Standards	Load Standards	Control of Custom Properties Based on Company Standards
Prefer. Dbase	Part/Job Codes	Set Properties,	Dim instance As IRevisionTableAnnotation
Job Number	Set File Structure	Initiate PDM &	Dim value As System.Object
File Storage	Create Folders	Job Tracking	value = instance.GetAllCustomProperties()
Order Mgt.	Assignments Person.		
Part Dbase	Old Part Files	2D/3D Model Components	Insert New Sketch, Extrusion of Feature, Create Drawing
Strategy	Job Experiences	Assemblies	CATIASketchMgr.InsertSketch(True)
Dbase	Best Practices	Drawings	extrudeFeature = CATIADXPart.GetFeature("Pocket1")
	Standards		value = instance.AddComponent4(CompName, X, Y, Z)
			va= instance.CreateDrawViewFromView3(ModelName
Web Site	Mass Properties	Export Results	Commands to insert BOM, Assign Center of Mass, Analysis
MS Word	Bill of Materials	3D lightweight	CATIABOMAnnotation = CATIAView.InsertBomTable4
Excel	Finite Element Anal.	Collaboration	MyMassProp = Extn.CreateMassProperty
XML/JAVA	Collab / Design Rev.	Design Review	params = MyMassProp.CenterOfMass
	Marketing/Manuals		Set utThicknessAnalysis = utAddIn.ThicknessAnalysis
Order Mgt.	Text Files	Release Job	Track Orders and Release Data for Customer, Suppliers
MRP Sys.	Spreadsheets	Resource Allocation	Set connection = CreateObject("PDMWorks.PDMWks")
Suppliers	Schedules	Materials Order	value=instance.SaveAs(Name,Version,Options,ExportData)
ERP Sys.			dmExtRefOption = swDocMgr.GetExtRefOptionObject
Tool Dbase	Tooling Lists	Computer Aided Process Planning	
Machine List	Fixture Lists	Mfg. Expertise	CAPP and CAM are currently being implemented.
Knowledge Database	Machine Capabilities		
& Methods Mgr	Operator Input		
Report Writer	Routing Sheets	CAM / CNC	
Word	Operator Instructions	Assembly Steps	CAPP and CAM are currently being implemented.
Excel	Assembly Files	Quality Control	
Ethernet	Meas. and Toler.		
Intranet	NC Files/Op Sheets		
CRM System	Production Feedback	Reporting	Identify e-files, Write DataFiles, Archive Projects, User Msg.
ERP System	Cost Sheets	Cost Analysis	eFile=vault.GetFileFromPath(filepath)
Cost Analysis	CAD/CAM files	Archiving Installation	Report.WriteLine("Date" & vbTab & "Document" & Vbtab
Excel	Marketing/CRM data	User Interaction	MsgBox("Please enter the following" & "Missing Props")
Publisher	Manuals, Instructions		Dim MyProjects As PDMWProjects = conn.Projects
			MyProjects.Item(ProjectList.SelectedItem)

Specific to design engineers is the Tool Design tab which contains all the CAD interactive functionality. The Tool Design tab is only accessible after selecting a project, allowing the functionality to be customized for a project. Some of the custom functionality includes, starter CAD templates, project allocated part number ranges and predefined working directories. In this portion of AITPLM a designer can do most CAD interactions that are based on creating or opening, modifying, and exporting data.

The key to the Tool Design Tab is the working directory where files can be saved to or opened from by simply filtering for the desired location. AITPLM standardizes the directories for a project by generating them for the user. This allows for quicker searches and easier collaboration for a project.

Most geometry originates from AITPLM's Material Library where a user selects the material cross section of choice and can insert the configurable model into a working design. These parameterized models ensure that the geometry is consistent from designer to designer. As well as guaranteeing a designer can only choose a material cross section that actually exists.

The Tool Design tab has a variety of other functions that include renaming, part numbering, and duplicating for modifying 3D models. Additionally, there are several functions pertaining to 2D drawings. These functions include, drawing title block generation, revision control, and standard view notes. The majority of the 2D functions is what creates the transparency for drawings from designer to designer.

Finally, data can be exported to a number of locations including the release of data to the project bill of materials for manufacturing. The releasing of information if fully automated by extracting the projects top assembly bill of materials and using the model properties to build a custom project bill of materials called the Matrix. The Matrix is sorted by purchased parts, manufactured parts and hardware. It is typically used by project managers, manufacturing, and purchasers to organize, manage and purchase parts for a project.

D. Implementation and Improvement of AITPLM

AITPLM started with the design department because the majority of information is created and distributed from design. It was found that the design group impacts the most departments within AIT mostly due to the concurrent design and manufacturing done for custom engineering. So every department needs as close to real-time feedback as possible to keep up with the continual changes and improvements as a design matures. The impacted departments include: design, purchasing, project management, and manufacturing. Design is included as an effected department because the design can occur in one of four places around the world so it is important that each site is up-to-date. Based on each department and different skill set, information shared between departments need to be filtered for their job role. This filtering is called security trimming where elements and controls of the user interface are visible based on the user privileges. For example, a designer only needs to make sure their design is accurately portrayed on the bill of materials, but not if the parts have been ordered or the cost of purchased parts. Where a purchaser does need to know these details. Security trimming allows for a single user interface to be developed but visual elements, like a column in a grid that shows cost, can be hidden or shown. However, its purpose is not just for hiding elements but also allowing for a cleaner interface that does not inundate the user with too much information.

Initially, the goal was to create an unreplaceable tool that designers could more efficiently get work done with. The work that could be done through automation would alleviate the engineers from tedious tasks and administrative duties. Allowing for more time to be focus on engineering products or more time for more projects. This was accomplished through API's, a custom CAD library and a database that is configurable for each project. In order to gain this type of control over a designers' activities the majority of their day to day CAD functionality had to be actuated through the AITPLM interface. These controls also had to have a better user experience and do more for the user than the controls built into CATIA. For example, a user can open CATIA, search for an existing part for a project and then open it. With AITPLM a user only has to choose the project they are working on, which presents the user with all the existing parts for that project, select a part and click "open". The database will know what project they are working on which contains metadata for the correct version of CATIA for that project. It will automatically launch the correct version of CATIA, on the user's computer, followed by a couple additional checks in the event that CATIA was already open, and eventually open the part. Keep in mind this is all done behind the scene and takes place just as fast as the using the existing CATIA controls but with more functionality.

Numerous types of CAD functionality, like the examples given in this paper, are used throughout the design portion of AITPLM for creating, modifying and exporting. This amount of control has proven to speed up design as well as allow for a more collaborative environment. Now as part numbers are set aside for projects they can be allocated to new models during the design because all saving activates are done through AITPLM. So as one engineer uses a part number, no other engineer can use it because it has been allocated. Thus preventing confusion in the manufacturing downstream.

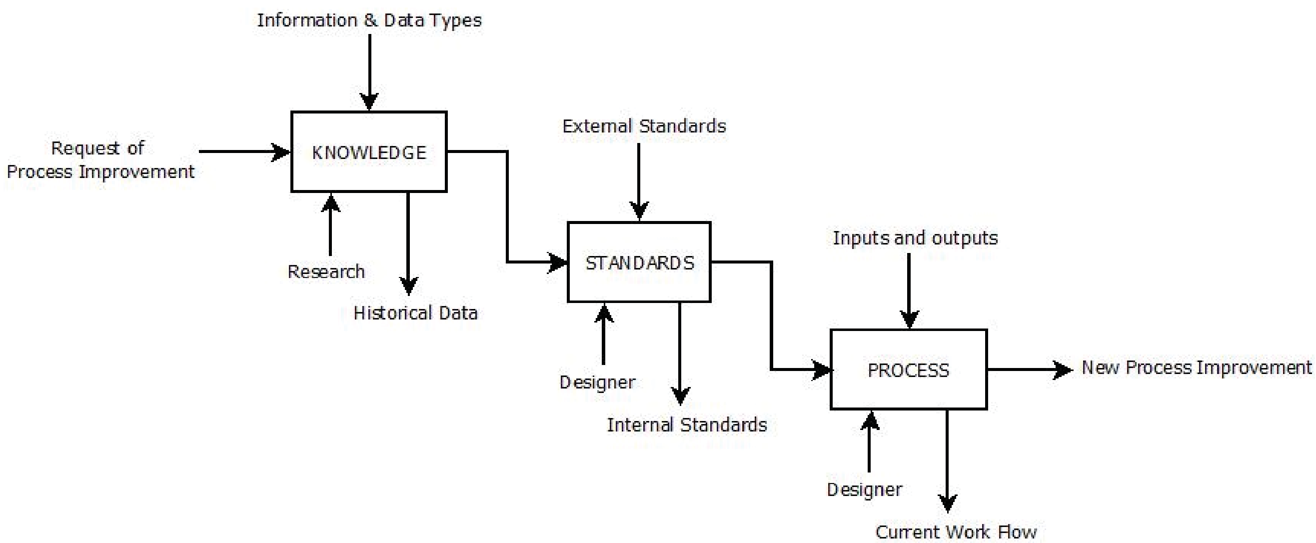

Fig. 6 IDEF Diagram for Continuous System Improvements

IV. Discussion and Future Plans

The level of integration that has been successfully achieved using the AITPLM system in design is now sought after from other departments that want the same level of integration and automation. This can more easily be implemented now that the information that stems from design is more uniform and standardized. There are both short term and long term improvements and expansions planned for the AITPLM system. Work is currently underway to provide access to more of the system in remote offices such as Spain and Sweden. This requires a more robust web interface and security in the delivery of information. Manufacturing planning and CAM is also an area where many opportunities have been identified to streamline the transition from CAD to CAM, including the use of Product Manufacturing Information (PMI) to enrich the database and documentation used between engineers and production personnel. In the near future, developers and managers will take a closer look at how to incorporate more "filters" so that employees using the system only receive and work with information that is absolutely necessary for them to complete their jobs. In the long term, a more robust knowledge base and expanding the utilization of company and industry standards and best practices so that engineers are given instant feedback on the decisions that are being made and possibly give recommendations or alternative plans. The continuous improvement of the system motivated management and developers to implement guidelines and a diagram to represent this process and follow a standard procedure for this process (See Fig. 6).

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