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Team Project

Information Systems Challenges and Solutions in Product Engineering Organizations of Automotive and Aerospace Industries in the U.S.

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II. EXECUTIVE SUMMARY

After a decade of cultural change that took product engineering groups from drafting boards, through two dimensional CAD systems, and into the world of three-dimensional design, we see that any doubts regarding acceptance of digital design technology have evaporated. These doubts are replaced with a savvy user community that does not accept, as they did a few years ago, whatever the latest SW/HW revision was and purchase based upon the providers' recommendations. Instead, providers are responding to increasingly precise requirements as defined by the users. Beyond SW development, we see integration of applications onto common platforms, such that once autonomous groups within organizations are dynamically linked through various distributive technologies. Beyond integrated systems, the trend is for seamless integration which makes systems architecture completely invisible to users.

III. INTRODUCTION

Over the last decade the speed at which information moved, and the density of it, continued to explode at a pace unprecedented and unperfected by those who now use it as a basis for everyday business survival. Hardware and software development companies, initially the catalysts that spurred the masses into seeing the advantages of digital information exchange, now are being pushed by customers to develop the next generation of communication technology in ever decreasing time cycles. It includes Internet, electronic mail, corporate communication systems, and sophisticated engineering design and analysis applications tailored for specific industries.

This paper focuses on aerospace and automotive product engineering groups, and explores such areas as the continuing need for change, efforts required to keep pace with changing technology, challenges, solutions and trends. In addition to acquiring information from publications, our research includes data from questionnaires that were completed by working professionals.

We formulated the hypotheses given in the body of the paper to use as a guideline in our literature search. We did not expect to cover the whole scope by testing these hypotheses and to get meaningful results in the given time. Nevertheless, based on the limited literature search and the short survey we made, we could get some useful results for the future studies. Some points addressed in the hypotheses were so critical, and crucial for the industry, that it might be worth some time to make in-depth research in those areas. These will be addressed in the conclusions.

A. Overview of Automotive and Aerospace Industries in the U.S.

Both automobile and aerospace industries were started with profound inventions in 19th century, and reached their technological and industrial maturity in 20th century. From the first prototypes made in inventors' garages, to the production of world giants such as Boeing and General Motors, the product evolution moved in two main axes[1]:

1-Internal structure of the product has become more complex. Not only the technological sophistication of each individual component, but also the interdependencies and the internal coordination of the products.

2- Customer- product interfaces have become very complex in terms of the relation between the product features and customer needs. In today's world, both products mean more to the customers than meeting their basic transportation needs. Most of the time end users (drivers, passengers) are not able to tell what they really want and their current expectations may not reflect their future behavior as a customer.

Clark and Fujimoto [1] put the automobile into the complex products group (see. Fig I-a) in both axes. Using the above criteria and similarities between two products, airplanes can also be included to the same product group:

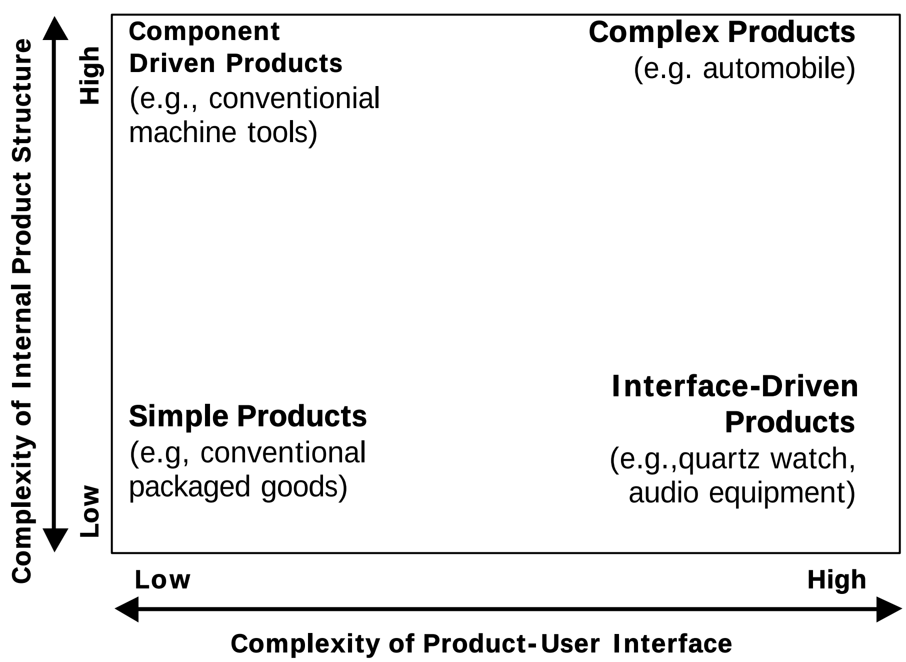

Figure I-a Type of Product Complexity. Adapted from Clark and Fujimoto [1]

In these industries, product integrity, rather than the superior performance or functionality has become the focus in the competition. Product integrity is determined by two main factors: 1) The coherence which is a measure of consistency between its components and the concept and 2) Technical functionality of the product and the degree of product's fit with customer objectives and expectations [3].

As in many other industries, organizational structures in auto and aerospace have changed from the simple functional structures to more complex matrix-type structures which can react faster to the changing environment [13]. Focus on the competition's product intensified as all companies reached a certain level of maturity in manufacturing and quality practices. As a result, the role of product engineering in the overall performance has become more important. To increase the performance and effectiveness, global re-organization of product engineering along with the implementation of new information technologies have gained acceleration in recent years. Almost all big automobile and aerospace companies have started long-term programs for these types of changes. Ford has launched Ford-2000 program in January 1995 to merge all global design activities into three vehicle centers to design world-cars. This operation changes the locations of nearly 25,000 employees. [10] [11]. Other companies are also going through changes, maybe at a smaller scale, but still with big impacts on their product engineering processes.

B. The Need For Information and Information Flow

As the trend of globalization of businesses continues and the technologies get more sophisticated and complex, the demand for systems to store and exchange increasing amounts of data grows. At the same time, new organization philosophies require more interaction and communication between the departments. Engineering groups are no longer the somewhat autonomous organizations of yesterday. They have become intricately linked and must communicate not only with other corporate disciplines within their immediate location, but with associated groups at other facilities and in other geographic regions [3]. Communication does not take place primarily through managers, but at the functional level by all individuals assigned to a project, be they engineers, or technical and administrative support personnel. Information storage and communication channels, for all types of data, must be instantly available to all team members, otherwise they will be unable to respond to the speed of today's business, which demands greater precision and decreasing cycle times for product development and production.

Hypothesis 1: In product engineering (PE) departments/ organizations the need for information exchange has grown due to a combination of the following factors:

1.a- Organization philosophies have changed, product development process requires more interaction with other departments and between companies (OEM/ supplier, supplier/ sub-supplier etc.)

1.b- Quantity and complexity of the knowledge created in engineering has increased to meet the reduced development time and expanded product requirements (more complex products, more options)

1.c- Manufacturing sites, supplier base and markets are being more global. But the product development activities are centralized. So, the product engineering organizations should have more links to more diverse environments.

1. Product Documentation System (PDS)

PDS (also referred to as PDM - Product Data Management) provide status such as revision level data for engineering releases, Bills Of Material (BOM) for associated engineering releases, and BOM revision status. In early engineering times, the BOM was part of the engineering drawing. As CAD became prevalent, the BOM was stored within the computer, but manually input to a separate application, which could not verify a 100% match between the BOM and drawing [5]. Today, PDM software alleviates that problem by reading part data directly from the engineering design system, and formatting it into a parts list that can be hard copied to generate orders from suppliers, or digitally linked to suppliers who will automatically ship parts. The data is simultaneously linked to the cost control department.

PDM also tracks engineering model revision status and through dynamic pointers, revises the BOM as models change, and can notify linked suppliers and engineering associates of such changes, thus reducing coordination time for the engineer.

2. Engineering Design Information

The primary media for engineering design information, since the earliest days of engineering, had been the “blueprint”, or engineering drawing. Other types of engineering information, such as material and test specifications, standards etc. were either somewhat linked to or used in engineering drawings. In the late 1980s and early 1990s the blueprint became virtually unheard of, as Computer Aided Design (CAD) systems became prevalent as a means for creating and printing engineering drawings. The next generation moved to Three-Dimensional (3D) computer systems that produced digital models with solid texture, and capabilities to analyze part-to-part and system-to-system clearance/ interference characteristics.

Today, design is generated and shared via integrated computer networks developed specifically for large product development environments [22]. As the hardware and software matured, its usage grew from that of experimental status, to the catalyst for a huge cultural change and the core way of doing business.

CATIA (Computer Aided Three Dimensional Interactive Applications), as the most popular CAD software in auto and aerospace, constitutes a very good example for the evolution of CAD software: CATIA was the tool selected by the Boeing Company in 1986 for evaluation of its potential capabilities in commercial aircraft design. The software, developed by Dassault

Systems of France, was loaded onto IBM mainframes and prototyped by limited areas of 767 engineering groups. CATIA allows engineering to develop in a 3D digital environment whereby parts, assemblies, and entire products are viewed in Solid rendering, both during early stages of product development, and at final stages. Analytical functions are incorporated such as mass properties analysis, kinematics, clearance/interference with other product systems, and stress analysis [22].. Although early versions ran on mainframes, most functions are now downloaded through distributed networks, and it is through these that engineers share their designs amongst other group members, and with other engineering teams [19]. Continuous design sharing allows for engineers to view other designs as they develop, instantaneously, and without the need to spend time finding other engineers from other teams to exchange paperwork.

CATIA is used extensively throughout aerospace and automotive industries, both in the United States and overseas. The list includes: Beech Aircraft; Bell Helicopter; Boeing Commercial; Boeing Helicopter; BMW; British Aerospace; Canadair; Chrysler; Daimler-Benz; DeHavilland; Freightliner; General Dynamics; General Motors; Goodyear; Grumman; Gulfstream; Honda; IPTN (Indonesia aircraft); Isuzu; Kawasaki; Kenworth; Korean Air; Lear Jet; Lockheed-Martin; Mitsubishi; Nissan; Porche; Rohr Industries; Peugeot; Rover; Saab; Saturn Corp.; Subaru; Suzuki; Snecma (aircraft engines); Textron; Volkswagen; and Volvo.

3. Information Exchange Between OEM And Its Suppliers

Just as information must be readily shared within the OEM (Original Equipment (or product) Manufacturer), so must it be distributed to suppliers. Suppliers may be involved for design, production, or both, and are becoming linked to OEM's core computer networks to facilitate efficient exchange of design and production data [6]. By using a CAD system, a supplier can see a design as it unfolds, make suggestions at an early stage to facilitate improved manufactureability, prepare tooling facilities ahead of time and thus optimize cycle time. Although face-to-face meetings are still beneficial, the number of business trips and coordination sessions are greatly reduced since engineers from the OEM and supplier have constant access to each others' work.

4. Information Exchange Between The Different Locations in the Organization

Technology is under development for Total Integration. As technology for engineering to production linkages matures, industry seeks more advancement in terms of Total Integration (TI). TI will link all company interests onto a common platform, to include areas such as, engineering, production, marketing, sales, procurement, administration, finance. and the legal department, such that activities in one area are visible to other areas, who can then make appropriate responses, when necessary [3]. It is becoming standard to use digital linkages between engineering and production organizations. More recently, technology yielded planning/statusing systems that read data from digital design modules and automatically reports design progress on a part-by-part, system-by-system, and product-by-product basis. Information is fed into a progress tracking module that is combined with budget data from the cost control department, and a progress report is automatically generated that management can read via desk top computers. Such automation relieves line management from creating manual reports, that at many times are "smoke screens" to appease upper management. Tracking technology is also being generated to read NC data as parts are produced, so real-time production progress and budget visibility is provided 11].

The same technology is used by multi-national corporations whereby engineering activities, in various parts of the globe, are linked and complex designs are completed by engineers who may never meet face-to-face or speak a common language. Again, coordination time and expense is reduced, cycle time is reduced, and precision is increased.

These product engineering systems are being linked directly to production Numerical Control (NC) equipment whereby the need for hard-copy drawings no longer exists. At time of production, finalized design data is downloaded to manufacturing, and it is input to Numerical

Control (NC) equipment [20]. The machine operator is responsible for loading the appropriate material into the machine, pushing the start button, and watching as the milling machine, for example, cuts the block of mild steel into a recognizable part.

The same digital data is used for Quality Control. Three-Axial Coordinate machines measure the machined part for compliance to engineering data.

5. New Product Development

Gone are the days of layouts and physical mockups. New products are generated via Digital Mockup (DMU) hardware and software that interfaces with systems such as CATIA.

DMU has many applications [8]. First, it is used by a prototyping group to render solid models of a potential product, such that marketing can acquire initial consumer feedback. Secondly, design engineering groups submit developing designs into a DMU module, and view it on a large screen at status meetings. Here, they have excellent visibility of systems as the product takes shape, and problems such as part interferences are detected at early stages. Third, a customer can view the product as it develops, and request changes before it becomes impractical to incorporate new ideas. An example of this was the development of Boeing's 777 commercial aircraft. Airline representatives viewed the interiors of the planes on screens that rendered full-size models of cabins, by using DMU software called *flythru*. The result was a virtual walk through the aircraft, at which time recommendations were made in areas such as stowage bin height, galley layout, seating design and cockpit layout. As a result, Boeing designed the 777 knowing the customer had pre-approved the product, long before delivery date arrived.

IV. THE NEED FOR CHANGE: NEW RULES OF COMPETITION & CHALLENGES.

In the last 30 years, the competition in major industries, like automotive and aerospace, added many new world-scale players to the few giant companies of 1970's. At the same time, customers have become more sophisticated and demanding. Technology has become more complex and more diverse. In such an environment, product development[1] has inevitably become the focal point of competition and managerial action [1]. Between the years 1970 and 1990, companies like Honda increased their production as much as 475% as a result of successful product strategies [16].

Hypothesis 2 : The rate of penetration of the information technologies to the engineering organizations is not homogeneous throughout the industry. Use of different generations of hardware and software, lack of standardization in the software and system incompatibility often create problems. In the larger organizations, switching to the next technology is always a difficult decision because of the investment made for adapting the existing system and training requirements.

A. Reduced Lead Time. Higher Productivity. Better Quality.

The contribution of product development performance on overall competitiveness of the company has been found very important by many researchers [1] [2] [5] [16]. There are many factors affecting product development performance from complexity of the product to the organizational structure and level of supplier integration [1] [16] [21]. Three main parameters of performance are taken as development lead time, quality and productivity, as suggested by Clark and Fujimoto [1].

The use of information technologies not only affects all performance parameters, but also contributes to changes in the organizational structure, product diversification and supplier integration. In the 1980's, computers were mainly used in the development process to speed up the drafting and engineering analysis. They merely replaced some manual operations like drafting and engineering calculations without changing the whole process. But, in the 1990's

[1] In this paper, the term "product development" is used in its broader meaning. It is not limited to new product development, but covers all design and development activities during the life cycle of a product.

information systems used in engineering became critical for competitive power which led to the re-engineering of all product related activities in many companies [1] [3]. With their new integrated engineering information system, C3P, Ford expects to improve engineering productivity up to 35-40% percent while reducing the prototype costs by the same percentage [14]. However, the transition has also caused lots of disappointments, wrong investment decisions and chaotic processes in many companies [19]. Even bigger companies have made lots of mistakes during the transition. Fred Craig, director of desktop computing at General Motors, makes the following statement:

> *"We probably had one of every system that had ever been made. And our PC's were attached to servers, LAN's mainframes, and everything in between.[4]"*

Problems and disappointments are not over yet. Making the right information systems investment is still one of the biggest challenges for many companies. The penetration of the new information technologies in automotive and aerospace industries, has now reached such a level that no one can afford to stay behind it. Emphasis is being placed on procurement processes with well defined user requirements, rather than continuing to invest based upon the latest and greatest as recommended by hardware and software suppliers. Because, having the newest technology does not necessarily create better communication, or increased productivity [4] [5] [19].

B. Information Technologies (IT) in Engineering Departments

Information has always been essential in product engineering departments where most data is not only created but also processed and transmitted to the other departments. Figure II-a shows the information processing model of product development as discussed by Clark and Fujimoto (1991) [1]. Since the engineers *simulate* the production by prototyping and *simulate* the customer experience by testing, product development can be seen as the *rehearsal* of the production and consumption of the product [3]. At the same time, the requirements for reduced development time, better productivity, increased complexity and sophisticated customer demands are drivers for the better utilization of information [1] [13].

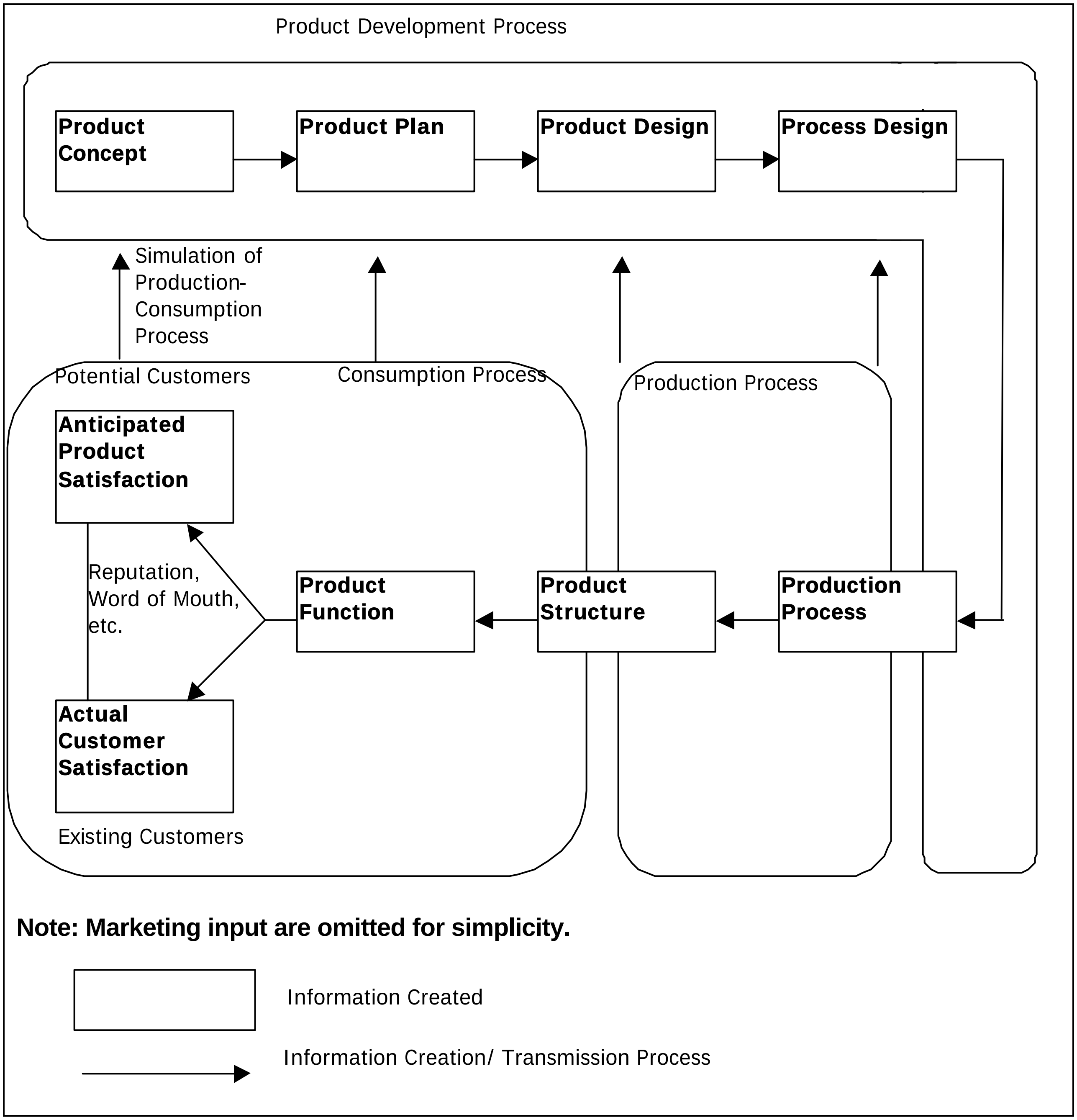

Fig. II-a. The information-processing model of product development. Adapted from Clark and Fujimoto[1].

Use of information technologies in product engineering started as early as the 1960's with the mini and mainframe computer systems capable of processing and storing product databases or engineering bills of material much faster than with card indexes. In the seventies and early eighties, corporate mainframes and mini systems used in engineering labs and small companies processed huge amounts of data and crunched numbers to help systems work with increased product lines and more complex products. Office automation with word processors, fax machines and electronic mail helped faster communication. Only super-computers used in R&D labs and universities were able to tackle the hardest science and engineering problems using graphical simulation programs. By using mainframes, sophisticated engineering problems could be solved via numerical methods to create more optimized designs with lower failure rates and lower cost. All five sophistication levels of MIS capability were technologically possible, but could not be widely used yet[13].

With developments in graphical systems and networking in the late 1980s, workstations and client-server systems started to be used in engineering environments. In addition to CAD/ CAM and FEA software, spreadsheets, statistics and project planning programs, other engineering calculation and graphics programs brought more flexibility to the design and development processes and increased engineering power. Different concepts and design alternatives could be tried and design alterations were more efficient.

In 1987, almost half of the manufacturing establishments with 250 or more employees were using CAD. But, not every company could utilize the full promised benefits and turn their investment of those expensive systems into profit [9]. Many problems, like inefficient 3D modeling ability and inadequate assembly analysis capability have since been resolved with the advancements in CAD software. However, in addition to organizational issues, there are still technical problems to be resolved in CAD technology that until fixed, will limit utilization for automation of design tasks. Some of them are as follows [9]:

- Design transfer between different CAD systems is highly problematic even with newest transfer protocols.
- Seamless transfer of data between CAD systems and engineering analysis software is limited..
- CAD systems have limited integration with the product documentation systems, and weak or no interfaces with the engineering bills of material system.

Smaller companies and suppliers to the big Original Equipment Manufacturers (OEM) suffer from design transfer issues [19]. Because, big OEMs made their system selections based on their own priorities, like integration of their internal systems, long term reliability and consistency [8] [15]. Recently, GM, Ford and Chrysler, independent from each other, made decisions for three different CAD systems. In Aerospace, the situation is similar; McDonnell Douglas, Lockheed Martin and Boeing are using different CAD software [8]. Suppliers are asked to provide data to OEM's CAD systems, which presents difficulties since suppliers may contract with more than one EOM while having budget for one system only [15].

C. Need To Handle Complexity

In 1920, Ford offered only one product line with little variety. Chrysler entered into the U.S. auto market using the marketing theme of greater variety and innovation [1]. Since then, product variety has been a significant factor for a company's competitive position in automotive industry. With differentiation of market segments and increased variety of tastes and preferences, more and more complexity has been added to products. Since variety comes at a price - primarily in terms of additional engineering hours, and increased design and production complexity - added value must be measured against technical capabilities and budget constraints.

Information systems help to increase the product variety in many ways such as; less engineering hours required for creating, prototyping and testing a new design; ability to optimize part flow by utilizing common parts among different product lines, and increasing variety with minimum effort. [2] [3].

1. Advanced Technologies

New component technologies attract customers and contribute to increased product sales in the short term, and when used strategically they increase customer satisfaction and yield a sustainable competitive advantage in the long term [1]. New, advanced technologies, usually require sophisticated engineering knowledge and more development time, while product life cycles are getting shorter. As a result, in the last 20 years, OEMs have moved away from vertical integration leaving much technology development of components and sub-assemblies to suppliers, because, their engineering did not wish to commit extensive time to up-to-date engineering knowledge in all areas. The second effect of the technology advancement has been the development of tools to help shorten the most time consuming iterations of a new technology development: concept generation, concept model, concept testing, design, prototype and prototype testing.

This changed the focus of CAD systems, from 2D drawings or routine design work to new areas such as concept generation and analysis, assembly analysis and interference checking, rapid prototyping, stress analysis, dynamic simulation, vibration and flow analyses etc. This target to develop a final production prototype stage by simulation [9], has generally been met [7] [8].

2. More Models, Derivatives and Options

Increasing demand for product variety forced companies to develop different strategies to meet this demand. Some companies increased fundamental product varieties while trying to limit the number of optional configurations, by packaging combinations of options [1]. Other companies reduced engineering time by overlapping the development and sharing critical components among multiple product lines. In spite of increased risk, multiple project strategies which allow companies to transfer technologies and designs during development of multiple models, are efficient in terms of lead time and engineering hours[2]. Honda tries to keep product cycle times as short as four years by carrying over most mechanical systems from previous levels and changing visible components. They share components among different product lines, and have a few fundamental varieties but many options for accessories.

During the times when information technologies were not yet developed, both engineering time and production costs increased dramatically when developing new options. However, increasing product complexity beyond the capabilities of manual systems could cause production systems to collapse. The level of information technologies today makes it possible to have many different configurations and many options without a major increase in engineering hours. Production systems are sophisticated enough to assemble completely different vehicles one after the other on the same assembly line without causing any major confusion. Yet increased models or options can still increase the cost more than the customer will pay because of lower production volumes of each component. We must not forget that other additional costs coming with product differentiation, although minimized with IT technologies, are not zero.

D. Compatibility Challenges. Why Don't the Computers Understand Each Other?

In 1992, Liker, Fleisher and Arnsdorf drew attention to the difficulty of transferring data between CAD systems [9]. Even though many attempts have been made in the past 6 years, to develop new transfer protocols and standardized formats, a few achievements were made. A survey made in 1994, showed that suppliers need different media to communicate with each auto maker, because auto makers invested heavily in their own systems instead of standard systems [19].

The Big three auto makers have been investing to integrate their design, engineering, manufacturing and product management systems [8] [14] [15]. The productivity losses due to the communication problems between systems equate to a 40% increase in productivity of engineering with the new organization and new information technologies in place [7] [14].

Benjamin in 1980, predicted that integration of applications across functions would be completed by 1990 to a great extent. In 1992, he accepted that this was not achieved and made cautious predictions about standardization for 10 years from then on [6]. Looking at the current situation, we might find his cautiousness appropriate.

V. OVERVIEW OF THE CURRENT STATUS: CONTINUOUS EFFORT TO KEEP PACE WITH THE CHANGING TECHNOLOGY AND CHANGING NEEDS.

While the engineering world becomes ever more reliant on digital information exchange and analytical SW, computing development companies rush to provide the latest and greatest solutions. The result is an enormous amount of choices from a growing market of providers, and many deployed systems built from a kluge of HW and SW, that are at times integrated such that performance is not optimized.. Companies at times feel swamped with the choices available, but know HW and SW must be procured in order to remain competitive. As a result, processes for SW/HW evaluation and procurement, with a clearer understanding of user requirements, are being developed.

Hypothesis 3 : There are many efforts towards integrated solutions from customized integrated solution packages (hardware + software) to custom developed solutions with different combinations of the integrated functions and different levels of integration. There are also standardization efforts and interface/ conversion types of solutions to create a common base for different systems to be used side by side. And there are some new technologies like Internet/ intranet which might bring completely new possibilities in future but implementation tools have not been developed in this specific area yet. Type of solution chosen by the organization would mostly depend on the weights of need factors in hypothesis one and cultural issues.

A. Integrated Solutions by Hardware/ Software Providers

Providers are available to generate and integrate custom SW depending upon a specific company's needs. This is generally done when a customer has purchased and installed SW and/or HW and found it to be close to performance expectations, but not meeting all requirements. A provider may at that time, develop and integrate a tailored solution to deploy only at that customer's site as a no-cost Beta project. This allows for the customer to potentially gain specific performance, while the provider tests a new product in the field, that can later be sold to other consumers. An example of this was at Boeing in 1994 when a high-end Engineering Management application was needed. Current SW did not meet requirements so a company from San Diego, already developing SW close to requirements, provided and integrated their product on a Beta agreement. As things turned out, even the changes made to the Beta product did not meet requirements, but the company in San Diego gained knowledge while Boeing did not loose money on an unusable product.

B. Attempts To Develop A "Custom" Solution

While providers continue efforts to upgrade existing products and push technology further, customers become increasingly savvy in terms of generating in-house custom solutions to augment purchased HW and SW. Aerospace and automotive companies typically generate Graphic User Interfaces (GUI) that are loaded onto the front end [9]. GUIs are developed by an in-house computing organization, at times where the cost of contracting a custom solution to the external developer would be unjustifiable, when time constraints do not allow for external solutions, or when the GUI is so company specific that an external provider will not become involved even at a Beta level because there will be no other market for the resulting SW. A large company may typically load a few hundred onto the system, that become part of the primary menu, whereby the user is unaware if the function selected is part of the "core code" or an add-on GUI. There must be a strong business relationship between the SW provider and the customer for such customization, because to develop GUI applications, the in-house developer must interface with the provider's core code, an area that is proprietary, so specific licensing contracts must be acquired.

C. Standards and Rules

As systems such as CATIA become predominant, the ways in which the system is used become standardized. Initially, end-users engaged whatever techniques they wished, to provide a model and drawing, which created endless inconsistency. It became increasingly time intensive for recipients of engineering datasets to sift through and determine the location of various types of data. Industry standards are now being documented that delineate the format of a dataset in areas such as specific layers for certain types of data, methodology for creating solid geometry, rules for identifying elements, plotting formats, and formats for packaging and transferring electronic data. Such standardization is not only critical for the sharing of data within companies, but for efficient downloading/ uploading to and from suppliers. Also, the movement of Human Resources is inefficient when transferring personnel between groups or organizations if an extensive learning curve must encountered. Process standardization alleviates such down time.

D. New Technologies. Internet/ Intranet.

The Internet offers potential for rapid development of mechanical products to meet global competition. In the past several years, a variety of geometric algorithms have been developed to evaluate CAD models with respect to manufacturing properties such as feedability, fixturability, and assembleability. To date, most of these algorithms are tailored to a particular CAD system and format and so have not been widely tested by industry. The World Wide Web (WWW) may offer a solution: its simple interface language provides a de facto standard for the exchange of geometric data with industry and research groups. The University of California at

Berkeley is conducting a feasibility study for such an interactive system, which explores Internet's advantages in terms of speed, efficiency, and automation regarding design and manufacturing analysis. They deployed a module called FixtureNet which can be directly tested at http://teamster.usc.edu/fixture/. Although it is not ready for practical use by industrial designers, it shows that geometric part descriptions can be sent over the Internet and how the WWW can provide remote execution of geometric algorithms and graphical display of results. A practical application for this kind of data exchange is that industrial companies, rather than owning a user license and copy of software, can send data and receive results, with payment based upon usage. This would alleviate a company from constantly working with software providers and maintaining latest revisions on their own computer networks [24].

VI. CONCLUSIONS. TRENDS.

A. Survey

1. Methodology

Survey questionnaire given in Appendix B was used to get opinions of professionals in Auto and Aerospace industries. The questionnaire was designed to be filled in about 15 minutes and had a mix of multiple choice and open-ended questions. The questionnaires were sent to 12 professionals who mostly are the managers of product engineering groups. 6 responses have been received by the time the evaluations were made.

Since the sample size was very small and the questions were not designed to be used for any specific statistical analysis method, no statistical analysis has been made. Instead, responses are evaluated individually to see the similarities and differences with the others.

2. Results

Out of the 6 responses we got, 4 organizations have had a major change in the organizational structure in the last 5 years. The current changes having the most significant impact on the organization show variation, but reduced product cycle times(4/6), increasing need for knowledgeable personnel (3/6) and international links (3/6) seem to be the most common ones. More interaction with suppliers (2/6) and with customers(2/6) are other changes affecting the organizations.

Three organizations have a product information system older than 5 years, which does not satisfy their needs. One organization has a mixed system, developed in different times and they are not satisfied with the system performance either. Organizations having a recently developed, customized systems think that the product information system satisfy their needs. This correlation can be a good point to be tested in future research, to find out which type of needs can not be satisfied by older systems. Product information systems are run in almost any platform and mostly (4/6) more than one platform.

The use of CAD features show tendency to the increased use of advanced features like 3D solid modeling, CAE, and assembly analysis when compared to the results of other surveys made a couple of years ago. The averages percentages of usages of different features are as shown below:

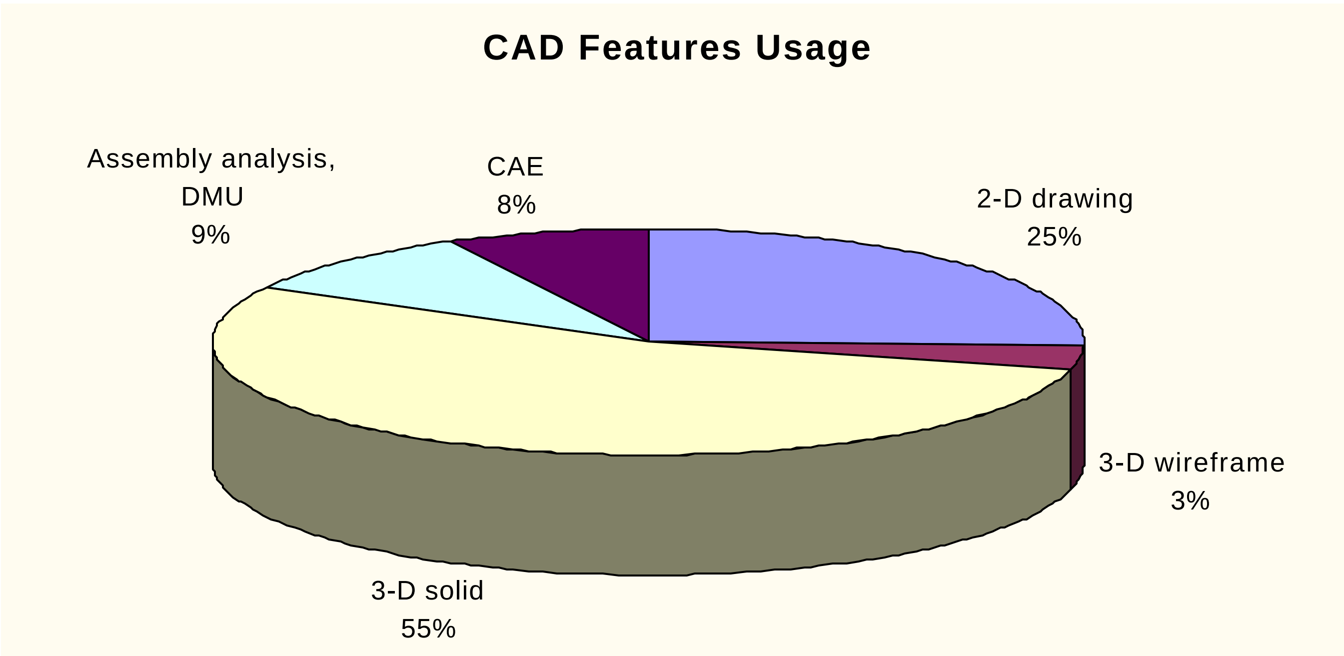

Fig. VI-a. Survey Results. Usage of CAD Features.

CAD systems are run on workstation networks (6/6). Only one company runs its CAD systems on mainframe, too. CAD training is either given by an outside company (5/6) on need basis or with a contract or in-house(2/6).

In most companies, current CAD system was selected since it was standard in the parent company (5/6), so the engineering organization itself was not the decision authority. One supplier selected the CAD system its major customer was using. Now if they were to decide on a new system, the selection criteria would be; being a standard software in the industry (3/6), companies design needs(3/6), compatibility with major customers' CAD system(3/6- all of them are suppliers), being a standard in the parent company (2/6) and finally compatibility with major suppliers' system (1/6- auto OEM). This shows that engineering managers have completely different perspectives for what is important in selecting the CAD system, than the decision makers. This is another topic that can be worth to deepen the research as selecting the right CAD system is one of the major challenges in the industry.

3. Limitations and Evaluation of the Survey

The survey results are not to be generalized without other supporting information as the sample size is too small. Respondents were selected among the individuals we had personal contacts. Since they do not include representatives of different OEM and supplier groups in the industries, results might not give the whole picture. Most of the suppliers are chassis system suppliers to commercial vehicle manufacturers and their needs and problems can be substantially different from that of body component or plastic parts manufacturers.

All survey results should be taken cautiously. Nevertheless, two main findings of the survey can be tested by follow-up research:

- Older product information systems do not meet companies needs. Newer systems currently seem to meet the needs, but they might not in a couple of years. What needs to be done to prevent the product information systems to be obsolete since changing these are very costly and very hard to implement?

- The criteria used in the selection of current CAD system, seem to be different than what the engineering managers consider to be desirable. Is there a relation between the CAD system selection process and the satisfaction or engineering performance with that system?

B. Summary and Conclusions

Recent research results and our survey both indicate supporting evidence for Hypothesis 1. A survey conducted by Deloitte and Touche Group in 1994 has shown that the current information systems either do not satisfy the auto suppliers' needs or requires greater resources than desired [19]. Another study by Dimancescu and Kemp in 1996 shows that poor communication is one of the main reasons for the failures in product development [5]. Chrysler, made its major move in 1990's by changing the organizational structure and supplier management styles. They mainly used the suppliers' development power in the new products [21].

Increased complexity of the product with more models and options have been observed by many automotive industry specialists in recent years. A compilation of the research findings can be found in Cusumano and Nobeoka [16], Same study shows that Japanese companies have approximately the same product complexity but more projects and higher replacement rate than their U.S. and European competitors.

Globalization and merging products and organizations into single global units, again, another trend which have been observed for a long time by industry experts. One big attempt is the Ford-2000 program launched in 1995, which would merge all Ford design engineering organizations worldwide into three major product line design centers [11] [12]. GM also tries to develop strategies that would reduce the duplication of capacities [15]. Honda aims to design its world cars only in one development center, U.S. or Japan depending on the model. Our survey also showed that growing supplier and international relations has a significant impact on the engineering organizations.

Our findings in regards to Hypothesis 2 show that the research findings and the current industry practice together indicates a major compatibility problem a characteristic of the transition stage we are in. Liker, Fleischer and Arnsdorf, in their survey published in 1992 [9], found that market penetration of CAD software was very high for such a new technology. Almost 50% of all midwestern manufacturers having more than 250 employees had CAD systems in 1987. After the more flexible and cheaper systems had become available, this penetration has continued with an increased rate. Today, it is very difficult to think of any engineering design activity that does not use some sort of CAD system. The same research shows that in 1992, CAD was underutilized by many companies for various reasons. At that date, usage percentage of 2-D drafting was about 62% while 3-D solid modeling was used in less than 1% of all projects. When we compare this with the results of our survey, we can see the fast penetration of advanced CAD technologies into the industry in the last 5 years. However, advanced features require knowledgeable engineers to utilize them. As indicated by our survey and by many other sources including [6], [8] [9] and [20], the need for specialized computer skills are growing in the industry. One respondent to our survey wrote the following:

Major challenge- In order to fully utilize the benefits of CAD (FE analysis, simulation) there is need to have the machines run by the degreed engineers. Historically, these machines have been run by non-degreed designers. This presents a two-fold problem in both training of engineers and obsolescence of designers.

The penetration of information technologies was not a controlled penetration, and did not satisfy many of the users of these systems. They soon came to recognize the bottlenecks and the efficiency issues. The big companies did not want to carry a messy mix of all systems ever been built and started to replace them with new integrated systems to increase the efficiency of the engineering organizations [4]. But this is now creating a new disappointment for the suppliers who try to catch up big companies' technologies [19]. Four of our survey respondents indicate the use of different systems as a major challenge. One of them wrote:

Ford, Chrysler and GM use all different CAD software. However, they force their suppliers to deliver native CAD data (native to their respective systems)!

Another respondent (from OEM) wrote:

..Most of the suppliers are caught in a squeeze because Chrysler, Ford and GM use different CAD systems and suppliers deal with all three. The company that develops a truly universal translator will be able to name their price.

It seems that it will take a while before this can be accomplished all across the industry.

In regards to Hypothesis 3, the industry practice show a couple of different attempts towards the same goal. Big three automotive companies came to recognize the relation between overall success of the company and how well their computer based design, engineering and manufacturing disciplines are linked [8]. Ford plans to deploy C3P (the new integrated system) by 1999 [8] and expects 35-40% increase in engineering performance when it fully deployed [7] [8] [14]. Chrysler has already benefited from its CAD system choice with its increased sales in the last 5 years, They plan to expand 3-D CAD usage, but has no plans for further integration [8]. GM recently got rid off all different systems they used to have and went to unification and standardization in both PC networks and CAD systems [4] [8] [15]. They decided on EDS-Unigraphics as their core system.

In the aerospace industry, the big three aerospace companies are also going different ways. They selected three different CAD systems, which coincidentally, are the same systems as selected by automotive's big three.

Smaller companies and suppliers are trying to go to more flexible and standardized systems. But, more flexible systems that run on client server networks are not compatible with OEMs systems and the translation software are not good enough yet. One of our survey respondents blame big companies as follows:

There is no near future agreement of major automakers on one common CAD system (and IGES is not a good enough solution). In fact, they are allying with CAD providers to maintain uniqueness, not commonality. For suppliers who supply many carmakers (not just the "big three"), it is becoming difficult and expensive to have CAD expertise in their chosen software.

This may be the most important outcome of our study: The information technology solutions big companies are implementing to increase their performance are currently creating problems for their suppliers and seem to affect suppliers' performance in a negative manner. Sophisticated translation software or other ways that would allow easier information exchange have not been developed yet. Undoubtedly, the information needed to make more refined predictions for the future or to make propositions towards the solution of the problem is much more than we have and this is beyond our scope. We believe that further research and on-site observations and detailed interviews would provide very useful results in that area.

C. Future Trends

1. Trends In Automotive/ Aerospace Technology

The term “integrated” is much used when looking at design technology within Automotive and Aerospace companies, and may be misunderstood as the trend of today. Integration is part of the overall picture. It links many different systems such that accessibility of various applications is provided to different organizations by screen picks, and sometimes direct input of code for session changes. Integration allows a user the move between systems, but to do so the user must be aware of which systems to move into, and how to get there. The term that best describes today’s trend is “seamless”. Seamless technology puts various systems and applications onto one common platform. This lets the user to pick any application from window icons of a common screen, without the need to know which sub-system the actual application is housed on. Such technology makes system architecture invisible to the user, and in doing so gives back time for an engineer to work on the primary job at hand. This seamless technology does not only apply to engineering design and analysis systems and BOMs, but to informational and all other systems the product engineering staff use.

2. Predictions of the Next Five Years

We predict that over the next five years, and beyond, integration of systems will continue to the point of becoming “seamless”. Users will not need to know where there application is housed, or need to use techniques such as screen jumps to access engineering data, or any other data. A homogenous window will be in place from which any application and informational data can be selected form a window icon. The engineering organization will continue to realize they are less autonomous than traditionally thought, as seamless technology directly and visibly links them into all other aspects of the corporation.

SW and HW providers will place greater emphasis on providing exactly what the user wants, as opposed to selling what the provider thinks the user should have. This will be in response to an increasingly savvy customer who will develop processes to gain precise understanding of user needs. Additionally, product companies will try to decrease their hours spent in SW and HW maintenance, wherever possible, by looking for technologies that may be provided via the Internet, similar to FixtureNet that is now at an exploratory stage. Standards will also become increasingly dominant as companies look for decreasingly long learning curves for users, that have for the past ten years been side-tracked from their primary job as digital technology took hold. Standards will primarily come not from formal groups assigned to generate them, but from *de facto* techniques that informally become predominant.

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VIII. APPENDICES

A. Summary of Survey Results

B. Survey Questionnaires