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Abstract: This paper introduces many of the different rapid prototyping technologies and discusses the benefits and disadvantages of each process. Solid modeling software is also detailed: what is available to the foundry industry and the benefits of using this software prior to creating tooling. The future of rapid prototyping and it's importance to the pursuit of concurrent engineering strategy are also discussed.

Rapid Prototyping & Concurrent Engineering, Current Issues in Manufacturing Management

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RAPID PROTOTYPING & CONCURRENT ENGINEERING

CURRENT ISSUES IN MANUFACTURING MANAGEMENT

ENGINEERING MANAGEMENT 510

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Concurrent engineering has gained rapid popularity among industries today. Some industries that have utilized Concurrent engineering (CE) now view it as a new approach to project management. In the past, traditional engineering has relied on a few talented engineers that had the primary responsibility for all parts of the product design phase. The complexity of today's products now demand that a focused team effort be exerted to produce higher quality parts in less time. This focused team approach is the key to the success of Concurrent engineering. CE has been described as "a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support." Concurrent engineering does this by combining the experience and knowledge from many disciplines early in the product development process. This early focused effort involving all of the necessary individuals on the product development team can offer a substantial savings when one considers that although very small sums of money are spent during the early stages of product development, the design decisions made during this period commit the vast majority of the project's life-cycle funding. [1]

Concurrent engineering is structured around multifunctional teams that bring specialized knowledge bases together. These knowledge bases are called product development teams (PDTs). These groups are empowered to develop and integrate all of the products that a new program requires. The responsibilities of the PDT extend completely through the product's life cycle and often include requirements, design, manufacture, operations and disposal. CE also benefits from supplier and subcontractor input during the design phase. [2]

Many experts believe that the first step in product and process design is focusing on quality at the earliest stages. Integrating product and process design through use of the PDT is challenging because these two groups are often in conflict with each other.

The subjects of controversies between design and manufacturing groups is the form and function issues versus manufacturability issues, including such technical details as material specifications; design tolerances vs. machine capabilities; operator/machine cost vs. target cost; tooling specifications; and alternate operations and associated costs. [2]

The success of a particular product or service design is not dependent on material selection issues or manufacturability studies. Rather, success largely resides in the management of the total design process, starting from idea generation to full-scale production. [3]

The US Department of Defense (DOD) has been an early proponent of the use of concurrent engineering and has developed 11 features that are present in a CE environment. The DOD calls these 11 features the "10 + 1 Commandments of CE." [1] They are as follows:

- Create multifunction teams.
- Improve communications with the customer and the user.
- Design manufacturing and support processes concurrently.
- Involve subcontractors and suppliers early.
- Incorporate lessons learned.
- Create a digital product model.
- Integrate CAE tools with digital product model.
- Simulate product performance.
- Simulate manufacturing processes.
- Improve process continuously.
- Integrate technical reviews.

During the design phase, customer involvement is used to design a part that meets their needs. Due to the high level of technical expertise that customers have today, this step is often relatively easy. But some customers still have difficulty understanding a 3-D solid CAD model even after participating in the design of their product. A cultural or educational bias may exist that prevents some customers from fully understanding and benefiting from the CE experience. The same may also be said of many of the members on the PDT. With the high level of sophistication and computing power available from many CAD systems, it is increasing difficult to stay knowledgeable about all of the computer software modules needed to design and develop a new product even if the person using it has an engineering background.

Often, the members of a PDT are situated near other team members to further eliminate communication problems. However, this is often difficult since some of the most productive CE teams have members from many different departments, including purchasing, marketing, sales, research and development, design, production planning and manufacturing.

I am employed as a manufacturing engineer at the Esco Corporation, a steel foundry located in Portland, Oregon. I think Esco has an organizational structure very common to industries in the US today. At Esco, the purchasing department is located in one building, the design engineers in another building, the marketing group is on another floor of that same building, the manufacturing engineers occupy another structure nearby, and finally the manufacturing personnel occupy various plants of which three are located in Portland and many other manufacturing facilities are located across North America. Many licensees are also producing Esco products in many foreign countries. Esco deals with the communication issue with a networked Unigraphics CAD system supported by the EDS Corporation.

In other instances where the satellite foundries lack the corporate CAD system, the foundry tooling is built at pattern shops located in Portland where the design and construction of the tooling is monitored by design engineers and tooling technicians that specialized in that specific plants molding processes. It is often difficult to design tooling for other foundries because Esco uses many different types of processes to manufacture steel castings such as green sand, no-bake, vacuum molding, and shell processes. Each different type of production process requires its own dedicated foundry tooling specifically designed for that plant. Occasionally, tooling may be designed that does not produce high quality castings and the tooling may require extensive falsification or even require that the tooling be remanufactured. All of these steps take time to perform which may delay getting a new product to market. This is especially troublesome for Esco where products are usually made to order for an specific customer who may suffer costly down-time while their equipment sits idle, waiting for replacement parts. Even stock replacement parts are vulnerable to tooling delays because Esco recently implemented a program that commits to ship a casting within three weeks from receiving an order from the customer. Inventory levels are reduced to minimum levels to save costs which also adds pressure to the product development team.

Many of the problems plaguing corporations today could be reduced by shortening the time required to design, develop, and manufacture tooling that produces parts that meet or exceed the customer's expectations. This goal fits well with the focus of concurrent engineering. In 1986, a revolutionary process was patented that offers the potential to reduce mistakes and communication errors in the product development phase. This new process is called Stereolithography. Stereolithography is the first of many different types of processes that fall under the broad category of Rapid Prototyping and Manufacturing.

New developments in rapid prototyping technology were among the featured subjects at the Autofact '91 Exposition and Conference held in November in Chicago by the Society of Manufacturing Engineers. Rapid Prototyping is a growing technology by which an engineer's CAD files can be quickly converted into physical three-dimensional models by means of various photochemical, sintering, deposition, layering, or sculpting techniques. Industry experts say that these systems can cut prototyping times for many products by a factor of 10 and development costs by a factor of 5, thus speeding the process of introducing a new product to market. [12]

In this paper I will introduce many of the different types of rapid prototyping technologies and discuss the benefits and disadvantages of each process. Solid modeling software will also be covered: what is available to the foundry industry and the benefits of using this software prior to creating tooling. I will conclude the paper with a discussion of the future of rapid prototyping and why it is important to pursue a concurrent engineering strategy.

On Wednesday, April 21, 1993 I attended a rapid prototyping (RP) seminar in Bellvue, Washington sponsored by the EDS / Unigraphics Corporation. This seminar was presented by John Miller, an EDS employee. I believe that General Motors owns the EDS corporation which gave John experience operating several of the different types of RP machines at GM's technology center in Michigan. [3]

John showed how the rapid prototyping industry has grown over the years. In 1988, there was only one vendor of RP machines in existence offering only one type of machine which used one specific type of molding material. There were six machines in operation worldwide with no US service bureaus. A service bureau is an agency which subcontracts RP projects from other companies. [3]

Today, there are 12 RP vendors in existence offering 16 different types of machines. These machines have over 50 molding materials which are certified for use. The reason molding materials are mentioned is that these materials have different properties which are needed for different applications from investment casting wax to hard epoxy to paper. Worldwide there are over 475 machines in operation today. There are 48 service bureaus in the US. [3]

The current RP machine vendors are:

- 3D Systems, Inc.
- Cubital Ltd.
- Stratasys, Inc.
- Helysis, Inc.
- DTM Corp.
- Soligen
- DMEC (JSR / Sony), CMET (Mitsubishi), Sparx AB, Electro Optical Systems, Teijin Seiki Co.

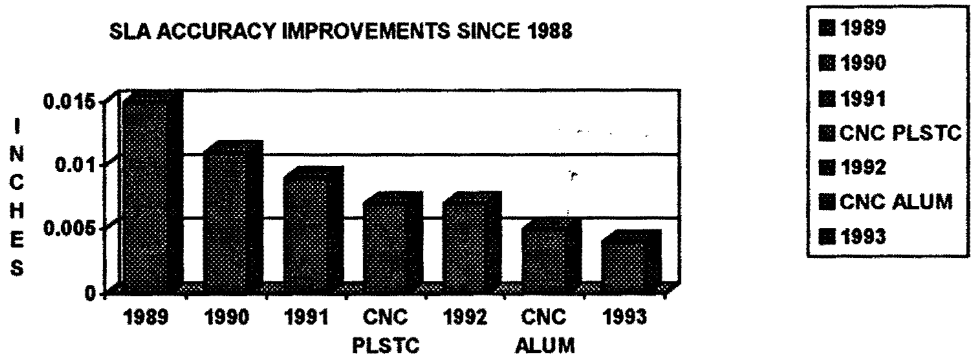
The first three vendors listed above are the largest and the oldest companies. 3D Systems, Inc. of Valencia, California is the pioneer in RP machines. Their process is called stereo lithography apparatus (SLA) which uses a laser to activate the catalyst in the liquid photo polymer. They offer two different machines, the SLA-250 and the SLA-500. The machines sell for $210,000 and $420,000 respectively. The build size is 10x10x10" for the SLA-250 and 20x20x24" for the SLA-500. The energy sources are HeCd or ArIII lasers. [3]

The latest projects a 3D Systems include the following:

- New QuickCast method to increase build speed
- New epoxy-based resins
- Improved model accuracy
- Thinner fabrication layers (0.0025") improves accuracy and surface finish.

SLA Advantages:

- Oldest RP company, in existence since 1988
- Best accuracy in the industry with the capability of achieving high detail and good surface finish.



SLA Disadvantages: [3]

- After the models are laser scanned, the resin in the interior of the model isn't fully cured and post-curing in a ultraviolet-type "microwave" oven is necessary. This increases the possibility that the model will be deformed. As a result, a comprehensive support structure is needed. This support structure can be difficult and costly to remove.
- There is a limited supply of photo polymers on the market today.

A recent announcement was made that showed how the SLA process was more valuable than for merely creating prototypes. An article showed how E-Systems in Greenville, Texas used the SLA process to produce flexible, reinforced rubber parts for the advanced electronics industry. The photo polymer model was used directly to create tooling. E-Systems claims that the main advantage of this process was a reduction in tooling requirements. This reduction in tooling requirements saves process time and labor costs. Cycle time for creating this part was reduced from 19.1 to 5 days. Labor also decreased from 54.1 to 10.1 hours for the first part. Successive part construction was reduced to one-third of previous amounts. [8]

Another advantage of the SLA process over the existing process is that design changes are easier to incorporate. Changes made to the CAD model are easily placed into production with minimal interruption to the production schedule. [8]

The next type of RP machine John discussed used the solid ground curing (SGC) process developed by Cubital Ltd. of Reran, Israel. This process utilizes non-laser UV lamps which activate a liquid photo polymer. As each 0.005" layer of resin is applied to the model, the remaining space in the building area is filled with wax. The UV lamp then cures the resin. After the curing stage, a milling machine removes 0.0025" of resin and wax. It takes approximately 90 hours to build the entire 20 x 14 x 20" build area. However, many different parts can be stacked and nested inside the build area and the entire 20" build height doesn't have to be built each time, i.e. a 10" high model would only take 45 hours to construct. [3]

Cubital Ltd. offers only one type of machine called the Solider 5600 which has been in production since November, 1990. So far, only 15 units have been sold at a price of $550,000. [3]

The polymer that the Solider 5600 uses is called the Solimer F-5621 photo polymer, developed by the Coates Brothers in the United Kingdom. This photo polymer is revolutionary because it can be drilled and machined when cured. The polymer is also water-resistant, non toxic, and does not require solvents. 3M Company, Compaq Computer Corp., and Whirlpool Corp. are currently using the Solider 5600 for rapid prototyping. Some of the parts have been used to produce limited-run castings for field evaluation. Cleaned and painted, other models are often used as marketing samples. [11]

The advantages of the SGC process are: [3]

- Limited warpage occurs because the entire layer of resin is cured.
- Throughput is high because small parts can be nested inside larger ones.
- Because wax is poured around each separate layer, moveable assemblies of parts can be made.
- This process is very economical for small parts.
- No support structures are needed due to the fully cured resin and the wax around the parts acts as a support.
- Photo polymers are fully machineable, nontoxic, and do not require solvents.

The disadvantages of the SGC process are: [4]

- The Solider 5600 is the most expensive machine to acquire.
- The machine is large in size and is very heavy.
- The machine has high maintenance costs due to the high number of moving parts.
- OSHA mandates that an operator be present during the entire build cycle.
- The number of modeling materials is limited.
- This process is very wasteful, the wax can only be used twice before it must be

discarded. Because half of every layer of wax and resin is milled away, the material usage for the model is double the volume.

John Miller introduced another type of RP process that is called Fused Deposition Modeling (FDM). This process was invented by Stratysis, Inc. of Minneapolis, Minnesota. Their machine is called the 3D Modeler of which they have sold 13 units. These machines use a heated extrusion head that applies spools of material to the model. The machine costs $186,500 and the build size is 12x12x12". [3]

A second model was recently introduced that boasts a machine weight of only 250 pounds and a build size of 30 x 30 x 68". This machine is much faster than its predecessor with an extrusion head speed of 15 inches per second. [7]

The advantages of the FDM process are listed below: [4]

- No post curing is required.
- A variety of materials is available and the material can be easily and rapidly changed by swapping spools of materials. Therefore, a model can be made with two different types of plastic or wax for different applications. This should be a popular feature for investment casters who sometimes require wax patterns with different solubility, i.e. some wax is water soluble some is soften by heat.
- Recently, Stratysis and 3M signed an agreement that 3M would research and supply new materials for this process.
- The small size of this machine can allow it to fit into offices. There are no fumes

  generated by it, so a special HVAC system isn't needed.

- This process is fast on small hollow parts because the extrusion head applies only a small narrow bead to the model, the less material the model contains on that specific layer, the faster it completes that layer and advances to the next layer.

An orthopedic company in Warsaw, Indiana called Biomet produces custom investment castings for hip, knee, shoulder, and other bone joint replacement surgeries. Biomet stated that it used to take their pattern makers up to 40 hours to create hip joint pattern of investment casting. Today, with the use of FDM, wax patterns are created in less than one hour. In the first six months after installation, Biomet created over 300 prototypes resulting in enough savings that the machine paid for itself.

John Amber, Biomet manufacturing service manager stated, "The FDM technology helped cut the lead time in half for moving new products to the market place." [7]

The disadvantages of the FDM process are: [2]

- This process is not desirable for small features and details due to the large filament size of the material spools.
- Surface finish is poor due to the large filament size.
- Structural supports are required on some materials.
- Models may often lack structural integrity in the Z axis due to the layered model.

  Often large models are even weaker because it takes longer for the extrusion head to travel clear around the layer allowing the previously deposited material to cool down which results in a poor bond between layers.
- The build time is slow on large heavy-walled models.

A letter was recently received by an engineer at the Esco Corporation that claimed that Stratasys now is offering a model called the FDM 1000. This model costs much less than the earlier model at $50,000 and benefits from its smaller size. The letter claims that the resolution and accuracy is good, but the build size was not mentioned. [9]

The next process covered during the seminar was Laminated Object Manufacturing (LOM) developed by Helysis, Inc. of Torrence, California. Helysis now has two units on the market, the LOM-1015 and the LOM-2030. They have sold 10 units with prices of $95,000 to $180,000 respectively. The two machines have build sizes of 10x15x14" and 32x22x20" respectively. The LOM process uses a CO2 laser which fuses layers of bleached kraft paper (similar to butcher's paper). This explains the large build size, it simply builds a model as large as the paper size. John joked that this process would be appreciated in the environmentally conscious Northwest US because we finally have a machine that turns paper back into wood. That is exactly what the models looks like...plywood.[2]

The advantages of the LOM process are: [3]

- No post curing is required.
- Support structures aren't needed.
- No shrinkage or warpage occurs.
- No internal stresses are built into the model.
- Big, wood-like models are possible. Patterns could be directly made for a green sand or soft (Alpha-set) nobake sand foundries.

The disadvantages of the LOM process are: [3]

- Poor surface finish
- Scrap removal can be difficult because the scrap must be chipped out of the interior of the model by hand with a chisel.
- Models have plywood properties, i.e. a weak Z axis.

- Models deteriorate in wet or humid environments. A sealant must be sprayed on the models.
- The models don't machine accurately.

The next process discussed was Selective Laser Sintering (SLS). This process was developed by the DTM Corporation located in Austin, Texas. DTM (Desk Top Manufacturing) Corporation features two models called the Sinterstation 2000 and the SLS-125. Both units use a CO2 laser which adheres finely grained powders together. The main difference between the two models is the size of the laser. Only six Sinterstation 2000 and five SLS-125 models have been sold at a cost of $397,000 to $427,000. Both units are capable of building a 12" diameter by 15" high cylindrical object in their work area. [2]

New developments in SLS include the availability of nylon as a material. DTM has three new US service bureaus and one in Germany. They shipped six new production machines, of which one was sent to Germany. [2]

The advantages of the SLS process are: [3]

- Wide variety of materials that require no post curing.
- Build times can be very fast.
- Because the model is imbedded in a cylinder of powdered material, support structures aren't needed as often.
- A tremendous advantage for the future is that ceramics and metals can be directly sintered. Sintering is a process that is uses extreme pressure and heat to bond dissimilar powdered materials together. This process is being used to produce many of the advanced composites that are found today. Some of these sintered superalloys can withstand pressure up to 300,000 psi. Therefore,

instead of building a tool to manufacture an object, a metallic or ceramic part could be directly produced by Selective Laser Sintering. [10]

The Soligen, Inc. system was briefly covered by John Miller. He said that Soligen, Inc. is guilty of selling "vaporware". Vaporware is a term used to describe when marketers start selling a process, concept or idea that isn't actually ready for production. Sometimes marketers do this to beat the competition to the marketplace. I researched Soligen's process on my own and found an interesting article in the March 1993 issue of Foundry Management and Technology which contradicts John Miller's vaporware claim. This article states that Sandia National Laboratories in Albuquerque, New Mexico, recently installed the first of three alpha units. Soligen announced that the company poured aluminum into the first ceramic mold generated by the Direct Shell Production Casting (DSPC) system, producing a metal casting. [4]

The other two alpha units were sent to United Technologies' Pratt & Whitney Group, and Johnson & Johnson Orthopedics division. [5]

This process is called Direct Shell Production Casting (DSPC) and is designed specifically for the metal casting industry.

Yehoram Uziel, former vice president of engineering for 3D Systems Inc. and current president and CEO for Soligen, Inc., stated that, "rapid prototyping, as a concept, is great. It's certainly true that engineers need a quick and easy way to verify CAD designs and fix any problems before they proceed with tooling and production. But as we all know, most rapid prototyping systems really aren't very rapid and they don't produce real prototypes. At best, current machines make plastic models. Engineers want something that can make real parts right now." [5]

Mr. Uziel's viewpoint is understandable and valid. The new technology of DSPC was developed by the Massachusetts Institute of Technology. Last year, Soligen obtained the license to develop the MIT process for production of ceramic molds for investment casting of metal parts. This process consists of producing ceramic shell molds, complete with integral cores, directly from the tooling designer's CAD file, without using any type of pattern or tooling. [4]

The DSPC machine consists of two pieces of equipment: a shell design unit (SDU) and a shell production unit (SPU). The SDU is a graphics workstation running specialized software that allows the geometry of a casting shell (mold and cores) to be generated from a CAD file. The desired shrinkage factor for the desired alloy is inputted and the number of parts per mold is specified. Also, the mold thickness is specified at this time. After the SDU designs the mold, the program runs a simulation of the casting process for design verification. The article doesn't specify what part of the casting process will be simulated. I hope the program will be capable of analyzing fill rate to detect cold lap and avoid oxide inclusions related to turbulent flow, solidity to detect shrinkage and carbon segregation, internal stresses to detect hot tears, etc. [4]

The shell production unit (SPU) then automatically fabricates the shell from raw materials by rolling thin layers of alumina ceramic powder which is distributed from an overhead bin. Above the roller is an ink-jet printhead that is supplied with liquid binder (colloidal silica). The printhead rapidly travels over the layer of ceramic powder hardening the powder into a hard ceramic shell. [4]

Each beta unit is expected to sell for $250,000. and be available for purchase in 1993. The build size is 20 x 20 x 20" and the machine builds in layers of 0.002" and 0.002" resolution. Therefore, critical fit surfaces required by Esco are possible only by washing a coating over this surface. The engineers at Soligen are working on the surface finish problem. The build rate is 350 cubic inches of mold sand per hour, resulting in a build time of 9 to 20 hours depending on the mold geometry. Obviously, this process would not be practical for production runs, but trial, custom orthopedics castings, and R&D castings could benefit from this process. [4]

The advantages of DSPC are: [4]

- Direct printing of a CAD file to mold without any misinterpretation.
- Reduces the time to make tooling for trial castings.
- Intricate internal cavities and areas of back draft can be produced without cores because there is no pattern to extract from the mold.
- First system designed specifically for the metal casting industry to make molds instead of patterns.
- Beta units will have a larger build size of 20 x 20 x 20."

Mr. Uziel added, "Because it requires no tooling or patterns, DSPC is a totally flexible and highly automated manufacturing process for metal parts. Thus, the process can dramatically reduce time to market for new products while lowering development and manufacturing costs." [5]

The disadvantages of DSPC are:

- The process is very new and unproven.
- Soligen was founded very recently in 1991.
- The process produces poor surface finishes.
- The elimination of tooling will only be realized when the process achieves a build speed equaling conventional molding methods on mass-produced castings.
- The alpha unit's 8 x12 x 8" build size is inadequate for many large castings.

Originally, a consortium was founded by MIT to develop and fund the research of DSPC technology. Additional consortium members include General Motors Corp., AMP Inc., 3M, proctor & Gamble Co., and the National Center for Manufacturing Sciences in Ann Arbor, Michigan.

The DMEC, CMET, Sparx AB, Electro Optical Systems and Teijin Seiki Co. systems were not discussed by John Miller. I'm not sure if these five companies actually have systems in use yet, but with support from Sony and Mitsubishi, I doubt it will take long to develop a working system that will be useful to manufacturing. [3]

General Trends and Concerns in the Rapid Prototyping Industry:

- Industry realization of the importance and benefits of rapid prototyping.
- Improved model accuracy and better surface finishes.
- RP machine costs are steadily rising.
- Wider material selection with improved properties are available.
- Customers are demanding smaller, less expensive units.
- Waste generation, disposal, and gas fumes reduction are environmental concerns that are highly important to RP users.
- Many of the RP machines generate fumes or need to work at a stable temperature, therefore costly HVAC systems are required by some systems.
- Depending on the machine, startup costs may be 1.5 to 2.5 times the machine cost due to HVAC, CAD and uninterrupted power requirements.
- Photo polymer resin costs are too expensive today from $400 to $1200 per gallon.

The Future of Rapid Prototyping:

Many universities and corporations are working on rapid prototyping. The organizations and their RP development interests / technology are listed below: [4]

- MIT, Light Sculpting
- BPM Technology, Laser 3D
- Texas Instruments, Laser 3D
- Babcox & Wilcox, Electroset Synergistic Technology (EST)
- Univ. of Nottingham, EST
- Carnegie Mellon Univ., Incre
- Visual Impact Corp., Formigraphic Engine
- Battelle, Osaka Perfecture
- Univ. of Texas at Austin, Chem-Form
- Bowling Green St. Univ., Laser Fare
- Cybervid, Landfoam Topographics

The future of rapid prototyping is exciting with the benefits of improved visualization of 3D models, design optimization, design for manufacturability, design for assembly, machineability testing, functional testing, (like flow testing of engine exhaust manifolds), checking for interference of moving assemblies, rapid investment casting capabilities, rapid design changes and increased communication effectiveness for the product development team. All of the above are essential components which are necessary to implement a concurrent engineering strategy.

Some opponents of rapid prototyping doubt that the current capability and accuracy of these machines is adequate to serve the needs of industry. These opponents ask the question why not just CNC machine a prototype out of a metal block in the time it takes to build it using rapid prototyping technology? The service bureaus say that there is no contest, that rapid prototyping is much faster when compared to CNC machining.

The service bureaus justify this claim (they also do prototype machining) by pointing out the fact that to successfully machine a complex 3D shape, many extra setups are required. They also mention that the programming six-sided parts (3D parts) is very time consuming when compared to rapid prototyping with its single setup and relatively minor programming operation. [13]

However, John Miller, EDS's rapid prototyping expert, mentioned that early rapid prototyping models were of pistons for internal combustion engines. John mentioned that this was an example of a part that should never have been created in Stereolithography. He noted the symmetry of the part and the ease of setup would make a this an ideal part to CNC machine. John advised the audience to use rapid prototyping primarily only on complex shapes, i.e. parts with internal cavities and complex surfaces that would be difficult to machine. By focusing the efforts on complex parts, the highest time savings and labor savings would result.

Don't let this paper with all of its boasting of rapid prototyping fool you into believing that creating 3D prototype models is easy. Many organizations that bought rapid prototyping machines struggle with them to get their desired model. Machines must be fine-tuned to produce the desired results. There are many critical factors that must be addressed before obtaining accurate models, i.e. adding supports, interpreting material chemistry problems, and setting the laser's speed. Chuck Hall, the president of 3D Systems, claims that Stereolithography produces the desired results only about 80% of the time. Many users give up entirely and rely on service bureaus to produce their parts because they had difficulty controlling this new process.

Other problems with many RP technologies is that part strength is often weak. Another concern is that of disposing of the waste products. Once the available technology solves the resolution, accuracy, waste disposal, polymer strength problems, rapid prototyping should be an option available to many manufacturing organizations. John advised the audience that prior to buying an expensive RP machine, one should first contract a service bureau to make parts for them. This requires no large amounts of capital. This trial would enable the interested party to see if RP models actually accomplish the productivity gains that they hoped. After learning more about the process through contracting their models with service bureaus, many corporations find that their existing infrastructure is inadequate to support RP technology. It takes a high-performance CAD program and hardware to rapidly model objects in the 3D Stereolithography Apparatus (SLA) file format. At Esco, we create must of our complex 3D CAD models in surfaced models which don't readily convert into SLA output. As a result, we had to contract 3D Systems to convert our Unigraphics surfaced model to SLA output using a feature-based, parametric CAD program called Pro-Engineer. This operation added another $1200 to the $8000 costs for creating the model.

The people at EDS / Unigraphics are excited about the idea of a 3D printer. They estimate the cost to be below $20,000 with accuracy of plus or minus 0.0025". The machine will be small enough to fit on a desktop (30x30x24") and be able to produce parts as large as 6x6x6". The machine will only weigh 40 lbs. which will benefit the field engineer who frequently travels.

With transportable rapid prototyping machines, the field engineer could interface with his/her computer network to the other members in his/her product development team through use of a modem to design models on the customer's site. This could eliminate any communication problems that might occur between customer, design engineer, and the PDT members. Also, many of the modeling materials are fully machineable which allows us to machine the model as if it were a casting. This model may then be used to look for interference with assemblies and to better achieve design for manufacturability. All of these items mentioned above are beneficial to achieve a concurrent engineering strategy.