"Producing" the Design:
Designing Electronic Products in the Year 2000 and Beyond

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ABSTRACT

This paper documents a long-term study conducted to establish the critical success factors involved in successfully launching a new electronic product from concept.

Traditional development models are contrasted with a new generalized model and a suggested product development template is offered.

The study makes the case that in order to minimize the product development cycle time and reduce recurring product cost, a strategy is needed that goes well beyond the now widely accepted DFMA (Design for Manufacturing and Assembly) mind-set. In addition to manufacture and assembly, the strategy must include the concurrent treatment of the design's ability to be cost optimized for:

1. production test,
2. environment performance,
3. product reliability,
4. in-process rework, and
5. post-ship product serviceability.

It addition, a prediction is made that suggests a migration in the make-up of electronic product development and manufacturing personnel from the traditional "one-function based" background, to the multi-disciplined "super-engineer" – an individual who, while having an area of specialization, is well-versed in all the technical and administrative disciplines that have an effect on the success of a new product.

The case is made that this "skill-morphing" is being driven by the need for new product development speed and by the complexity that now exists in each individual technical discipline. It is enabled by an unprecedented level of current and near future desk-top data processing power and software tools that was not even imaginable only a few years ago. Most importantly, the super-engineer is skilled in the judgement ability needed to trade-off the often conflicting individual discipline interest, and in the areas needed to work successfully in a team environment.

Finally, a need is identified to develop an expert system tool that will, in a quantitative, as well as qualitative fashion, lead a product development team to a design that will encompass the attributes needed to meet the "non-product performance" design goals. These goals are minimizing the product's total true cost and time-to-market.

INTRODUCTION

The year 2000 finds those of us in the electronic product development and production business confronted with several daunting challenges. Never before has advanced electronic product innovation and introduction been primarily driven by the "D," and not the "R," in "R & D." Research continues to be sure, but currently the science and technology already exists for many of our industry's new product "dreams."

Our existing science reservoir is brimming with new product potential. If the science is there to make these products possible, what has jumped on the critical path to a new product's development, and hence, its introduction? - Three primary factors contribute to the time it takes to bring a new product to market:

1. paying back the development costs of existing products currently on the market, (in general, the new product will make existing obsolete)
2. the length of the product development cycle and,
3. product price points, or the product pricing that creates enough market demand to justify production volumes (ways must be found to design and produce a product at a cost that will create market demand).

PRODUCT DEVELOPMENT

Product Development Goals

The general product development goal has not changed much over time: design a product that you can sell lots of at a good margin. Another way to say this is: Design the right product the first time, while designing the product right the first time.

This subtle play on words captures, albeit in perhaps an oversimplified way, the desired strategic objective of a product development programs. The first phrase, "Design the <u>right product</u> the first time," refers to developing an initial product specification that includes the functionality the customer will consider of value. The second phrase "Design the <u>product right</u> the first time," refers primarily to the product's time-to-market and product's recurring cost.

The change in the best way to meet this strategic objective emerges when we consider what the best tactical plan is in today's development environment.

Critical Success Factor Determination

Experience with a number of real-world product design environments permit the observed common policies and practices to be organized into two basic product development approaches. For the purposes of this paper these approaches will be personified as two companies that design and produce similar products.

The design, by the two companies, of new electronic devices that monitors the growth of a person's toenails will be used as an example of the two product development approaches.

Company A

Company A, Clips Ahoy!, is a company that has been in the toenail trimming business for 50 years and has garnered an 80% market share in providing the public with the workhorse of the toenail trimming business – "The Yankee Clipper." In addition to sales success, the unique "Clipper" technology has enabled the company to realize hefty profits.

Clips Ahoy! is a traditionally managed OEM company with a traditional management hierarchy for an organizational structure. It has a marketing department that has been put under pressure to introduce a new product because upper management has noticed a slow, but steady erosion in sales. It seems newer, "lean & mean" companies have begun to introduce a flurry of products that perform as good or better as "The Yankee Clipper," but at only 20–30 % of the price.

One day Joe Cuticle, the marketing director, is having dinner with a long time distributor. The distributor passes along a story she heard third hand from their largest retail outlet "Nail World." It seems that customers have been complaining that they are so busy, that they frequently lose track of their toenails' length - occasionally resulting in an in-grown condition. Joe pounces on this opportunity and quickly prepares a draft product specification and product development plans, which include a product introduction time-line consistent with the president's demand to have a new product on the market in nine months. In addition, a product price point is established and a return-on-investment (ROI) analysis is conducted to support a claim of the incredible profit-generating potential of what he calls the "Electro-guard 2000." Of course, the price point and ROI have now locked-in the product's maximum cost.

Point 1 – *Each functional group in the organization has its own self-interest, which is defined by how they are measured by management. In this case, the marketing department's performance is measured by product introduction, market share, and net profit. They will worry about market share and net profit later. Right now, they need to get a new product launched to satisfy the President's immediate demand.*

Joe schedules a meeting with the President and invites the design engineering manager. He presents them with a plan the is attractive to the President, but leaves the Design Engineering manager, who is seeing it for the first time, scratching her head. The President asks her whether her group is up to this challenge. Not wanting to seem "negative," she bows to the pressure and commits to the project with the caveat that she is permitted to hire additional resources. (60% of her staff is dedicated to "fighting fires" and crisis managing the"Clipper" product which has never been able to be built in manufacturing reliably – however, with 80% market share and fat margins these additional costs have never posed an serious issue).

Point 2 – *Technical advances have continuously shortened products' useful lifetimes. A company must be able to quickly replace technologically obsolete products with ones if they hope to maintain or increase market share.*

Point 3 – *If management refuses to accept bad news, they will never hear bad news – until it's too late.*

Upper management selects the new Electro-guard 2000 product development manager from the Design Engineering group because this is where the majority of the action will be for the first 6 months of this projected 9-month development program. Manufacturing can't afford to be represented on the team since they are measured on the actual product cost of the "clipper" product which is on the manufacturing floor and having team representation would adversely affect the short term performance of their cost center.

The Design Engineering manager and manufacturing manager hate one another - upper management often plays them off against each other by placing blame on one at the other's expense. The decisions these functional group managers make are often made to make the other manager look bad without regard to what would be best for the product – let's face it, they have their own self-interests to protect.

The design begins in electrical engineering where schematics are prepared. A breadboard model is assembled with components that are only available from one source and have very tight tolerances – if ten percent parts may work, certainly one percent will work. There is no time to do an electrical statistical tolerance analysis.

Point 4 – *The rule of thumb is: 80% of a product's cost is locked in after only 20%of the product design is done.*

The design engineering manager gets a few new hire requisitions approved, but has no time to go through the resume search and interview process. The schedule she signed up for has caused her to have to do some of the engineering work. She also has four members of her group that haven't had performance reviews in over 18 months. Moral is low since no one really believes it is possible to launch the product in accordance with the published schedule – however, no one wants to openly question the schedule and be "negative" by saying, in effect, "the emperor has no clothes." And besides, upper management has the reputation of "killing the messenger."

Mechanical engineering begins work about 6 weeks into the project. They are given some concept sketches and a product specification that is mostly "T.B.D.'s"

Project review meetings are held weekly, but these are used primarily by the program manager (who is falling behind in the design tasks he is responsible for) to try and place blame as milestone after milestone slips.

Point 5 – *Having a program manager that has a sizable technical responsibility for the project as well, sets up an immediate conflict of interest causing a team imbalance - decisions always seem to be made that are biased toward the program manager's area of expertise.*

The mechanical design group makes up some physical models, primarily to give upper management the feeling that the design is making progress. Upper management likes one in particular. This design immediately becomes final design even through no one is sure the electronics will fit. Manufacturing has not been very involved. They attend a few review meetings, but when they question the design approach they are perceived as slowing the project down - they stop attending.

Point 6 - *We often don't have enough time to do a job right, but we always seem to find the time to do it over.*

The design is in its sixth month when marketing announces that the Electro-2000's battery life has to double from the originally specified twelve hours to twenty-four hours. This is based on the marketing manager talking to hospital worker who says he has seen a few cases where people working more than 12-hours a day have had occasional toe-nail damage because of their inability to identify a problem brewing until it was to late. The conditional even has a name: ANGS – or Accelerated Nail Growth Syndrome. It effects 100 people in a million!

Point 7 – *Use "cost/benefit" and "risk/reward" analyses to help make decisions that are statistically sound.*

Design engineering goes ballistic, but quietly realizes that they now have an excuse why the design will not be on time. Marketing insists that without the change they can not guarantee that they will meet the first year's sales forecast. The product launch date is slipped four months!

Two months later marketing announces that there is considerable interest for the new product in the European Community and that this market is now projected to account for about 50% of product sales. Someone in the quality assurance group seems to recall reading about new EC legislation that subjects the manufacturer to a required product "take-back" at the end of the product's useful lifetime – based on the materials currently designed into the product, this will increase total produce cost by about 15%. Upper management cannot tolerate another slip. The project continues. It is "completed" 6 months late with a product cost 50% above the initial projected cost point.

The product won't sell at a price point 50% higher than the initial price point. Upper management decides to cut margins and lay-off 15% of the work force to reduce overhead enough to allow the price to be only 20% above the initial plan. However, the product is launched with a number of bugs in the software (There was not time to proper validation). Costs mount as two product recalls are required. The company is now losing money on each unit that is shipped. The more units that are shipped, the more money the company loses! More layoffs are made to try and "stop the bleeding." Finally, the FDA gets involved in investigating the recalls and finds a number of Electro-2000 product development irregularities (one example is a software validation procedure that is dated after the date the validation testing actually occurred. The FDA shuts down Clips Ahoy! The Board of Directors decides to sell the company. They are bought primarily for their assets since there is very little value left in the business.

Company B

Company B, "Trim and Fit," is a company that has been in business for two years. Before the doors opened, the owners put a business plan together that raised the necessary capital by selling a unique package to the investment community.

The package stressed company growth through rapid, frequent, low cost product development that was centered around product development teams, not functional departments. This eliminated much of the traditional overhead by only incurring costs that added to the products' value – after all, they reasoned, we sell toenail-related products to our customers, not electrical or manufacturing engineering departments.

They reasoned further, if the products we develop are successful, the entire company will benefit. How successful could an individual department be if the product they help development is a flop – even if a particular department could demonstrate that they couldn't be held directly responsible for the failure?

This approach separated them from competition like Clips Ahoy! – at least in theory. After a few minor successes, they were ready for more a more ambitious product development challenge.

The leadership group, comprised of the company owners and other senior staff, formed a multi-disciplined exploratory team to conduct focus groups with and potential users of their products. They selected a person with a solid marketing background and some toenail-related technical skills. Those required skills she did not possess, such as

FDA regulatory knowledge, were secured by adding members to the team who had these needed skill sets.

The team got together and brain-stormed some strategic goals with clear, specific objectives and then complemented the strategic goals with a tactical plan that everyone agreed had a good chance of success. Part of the tactical plan was to use a Quality Functional Deployment framework to identify true customer given product features. They also developed a budget and work-schedule which the leadership group quickly approved.

The team completed its work and captured what it learned in a product specification. The leadership group was excited by what the read: a new product that combined toenail length monitoring with automatic trimming and clipping disposal. This product had the potential to take the market by storm – the team felt confident in this prediction because it was their customers that told them so.

Many technical obstacles would have to be overcome however to bring this product to market. The leadership group authorized the funding of a feasibility analysis. The skill-sets needed for this analysis were identified by a combination of the leadership group and some personnel working on other projects. All functional disciplines were represented on the feasibility team including manufacturing. The analysis was encouraging. In addition to the analysis the team generated a product design specification. This was a true team effort consisting of contributions from each functional team member. Target markets such as Japan caused the spec. to include a requirement for MITI approval. End of product life "take-back" requirements by countries in the EC and Japan caused the team to require no-lead solder in the product's assembly. The project began to development momentum as the team felt all bases were covered in the design spec.

The leadership group assigned a product development manager. Although the manager had some good technical experience, on this team he would have no technical design responsibility. With the leadership group's help, he assembled a development team with skill-sets that were consistent with the needs of the product and design specifications

The first meeting was used to establish how the team would manage itself. They decided on team meeting frequency and what to do if a member knew they would be absent from a meeting. They wrote down and agreed on their individual roles and responsibilities as team members. Finally, without having experienced a conflict of opinion, they agreed to use consensus decision making when team members disagreed (i.e., the team would not force a decision if any member "could not live with it."). A team dynamics trainer was brought in to facilitate an 8-hour team building session. This was combined with a team picnic.

With input from each team member, budgets and schedules were generated by the product development manager. The person with marketing responsibility established product price points. This was fairly straightforward since much of the needed data were established during the exploratory study. A cost tracking spreadsheet was developed as a team tool to keep tabs on the recurring product cost as the design evolved.

The following written plans were generated by the team members how had the direct responsibility for each specific plan:

1. design verification, including accelerated life testing to predict product reliability (a minimum mean-time-between failure was specified in the design spec.)
2. design validation, electrical performance /
3. software validation
4. production quality assurance
5. production test
6. end-of-life requirements
7. product introduction
8. regulatory

All team members reviewed the plans for general comments and potential conflicts. The team members knew these plans would be adjusted slightly as the product design developed, but felt good about having made a first cut this early in the program.

As the electrical team developed the schematics, five solids models were being developed on the computer by the industrial design expert that reflected five potential product "look" options. These options also defined the preferred user interfacing that was gleaned by the QFD study. Concurrently, the mechanical team member was looking at materials that were consistent with the end-of-life plan requirements.

The team selected the three best product "looks" and had appearance models fabricated. The leadership group was asked to select the appearance model they preferred. The mechanical design engineer had a strong opinion that the model chosen would make the display, keypad, circuit board interconnections very difficult and expensive - both for material (rigid flex) and assembly (significant hand soldering). The team respected this position and selected the look that was considered second best.

Many changes were made early in the design, driven by trade-off discussions around conflicting interests. A brassboard model of the electronics demonstrated the electrical performance and verified the schematics. The software specification that was a requirement of the software plan was used to begin writing code. Manufacturing worked closely to help optimize the design for manufacturing (part fabrication, - e.g., the injection molded plastic housing, etc.) and assembly (Through this process the team functioned well. Small team member irritations were aired at the team meetings and quickly resolved.

The product was launched on time and the cost came in 6% below target. As the sales campaign accelerated, production demand exceeded forecast by 15%. This dropped the cost even more since the material could be purchased for less.

The development team celebrated the launch, as well as the product's first year anniversary - by this time, most of the Clips Ahoy! workforce had found other jobs.

The accounts of the two companies are obviously fictional. However, all practices ascribed to the companies were real-world observations made at a number of companies over a number of years. These experiences are captured below in terms of product development critical success factors.

The 12 Product Development Critical Success Factors

1. No one person, group or discipline dominates the development process to the exclusion of others whom will be affected by the design.
2. The product that is designed is what the customer actually attaches value to, not what marketing and engineering think is a good idea.
3. The design team is self-contained and given both the responsibility and the decision-making authority to manage the project to the goals for which they have signed-up.
4. Upper "Management's" role should be primarily one of an enabler, ensuring the development team has the skill-sets, tools and resources necessary for success. They also serve as a check and balance on the team's progress and performance to budget and schedule. In addition, they ensure team goals stay aligned with company goals, as well as, providing corporate leadership and encouragement. Finally, they resolve team conflict only when they are petitioned by the team to do so.
5. The product launch date is task-driven, not schedule-driven. "Bottoms-up" task definition and resource allocation leads to a potential launch date. If not aggressive enough, then, staffing, out-sourcing decisions are made to shorten development cycle.
6. The schedule allows time to address and resolve issues that will arise as the development process proceeds, even though these issues can't be specified at the time the schedule is generated. (Three schedules "best," worst," and "most-likely" cases are developed, maintained and communicated)
7. The product's projected recurring cost (including amortized non-recurring costs) in monitored by using a cost monitoring spreadsheet from the beginning of product development through product launch.
8. The development effort is truly team-based. Team members must have team dynamics training. The team members themselves will establish the team environment they will work under (e.g., communication methods, meeting protocols, specific team roles and responsibilities, the method they will use to resolve conflict, etc).
9. Throughout the development process, time is taken by the team to celebrate their successes and learn from their disappointments.
10. Individual recognition is given to team members.
11. All decisions made by the product development team should be made in the best interest of the product, not a team member's (or department's) self-interest.
12. Team members should be encouraged by the team to question and challenge and provide input and alternatives, but once a decision is made every member of the team should be able to support it.

PRODUCT DEVELOPMENT MODELS

Traditional models

1. The Serial Product Development Approach

The serial product development approach is characterized by activity that is sequential in nature. It is founded on the traditional company model that accumulates and manages personnel of like disciplines in functional groups (e.g., electrical design department, mechanical design department, manufacturing engineering department, etc).

The design is passed from one functional group to the next as a baton is passed from one runner to the next during a relay race. Thus, the design evolves as it travels from the marketing department to the electrical engineering department and on down the line to manufacturing. Figure 1 is a schematic representation of this approach.

There are seldom conflicts between departments since groups inherit other groups' work, which they are never asked to comment on while the work is being done. When a group does challenge the work of an upstream group, they are tagged as "non-team players" because they are perceived as trying the slow the development effort down. They crumble under the pressure, and simply add their layer of self-interest on top of the prior groups.

2. The DFMA Model

Now consider a variation of the serial model. The DFMA approach considers the produceability of the design as the functional performance of the product is developed. It is categorized as "weakly concurrent" since, although it considers the simultaneous consideration of manufacturing (part fabrication) and assembly (putting components together), it does not seriously treat factors such as testability, reliability, serviceability, etc.

New Model

3. The New Total Concurrency Model

This product development model requires input from each functional discipline starting at the outset of the design process and continuing until the design is launched and is being produced with capable and controlled production processes. The best vehicle for actualizing this model is a true product development team, not a group of individuals from different departments who are thrown together and called a "team." The best corporate structure for actualizing a true product development team is a company without the traditional organization structure (departments), but with only two principal groups: a leadership group and a group of product development teams.

THE NEW PRODUCT DEVELOPMENT COMPANY

Functional departments like electrical engineering, mechanical engineering and process engineering are excess baggage to the new product development effort. They introduce immediate conflicts of interest between the individual department goals and the product team goals. This adds no value to the product development process.

Conflict is important to the process to be sure - however, it should be the right kind of conflict, e.g., efficient layout of a circuit board for manufacturing vs. electrical performance issues that this layout will create. This type of conflict is very different from the conflict that arises from the self-interests of the product development team and the functional managers (e.g., how will I look to my functional manager – you know, the one that is supposed to evaluate my performance?)

The team should consist of a group of "super engineers" that are selected by the leadership group and, by working together, provide the team with all the skill sets necessary to successfully develop the product. But, in addition to being an expert in their selected field, they should have a good working knowledge and understanding of all the other disciplines that will be used to develop the product. This is crucial since team members cannot successfully critique the work of other team members without having this expanded knowledge base. It is this questioning, challenging and judging that forges a solid team development platform by surfacing and addressing issues early. It also assists in stimulating vigorous change early (see figure 2).

Another crucial ability the team must have is being able to make good decisions. This skill is predicated on a team's ability to exercise good judgment. The team's collective experience base is the primary tool that is employed for this purpose. But even with a deep experience base, it difficult to know with certainty that when a particular decision is made it is the best one. This is because of the number of variables at work, the variables interaction with one another and their statistical nature.

This dilemma and the team's ability to trade-off often conflicting rule-based sets of design guidelines such as electrical performance, testability and assembly would be a good subjects to address with an expert system software program. In addition, with the right software, product form (design) could emerge from the computer with a description of product function (e.g., the fact a product must be portable says something about its weight and housing). Imagine an expert system that suggests design options based on simply inputting product function requirements.

Traditionally, we take our best shot at a design based on understanding the product requirements and exercising judgment. We look at the result, modify the design and look again. We repeat the process until we feel another spin will not add any value to the design and then go ahead and launch the product.

There will come a day when a knowledge-based expert system will change the iterative design process we currently employ to an almost instantly designed product with all considerations like cost, performance, form and reliability optimized - until that day comes, companies like Clips Ahoy! will continue to go out of business.

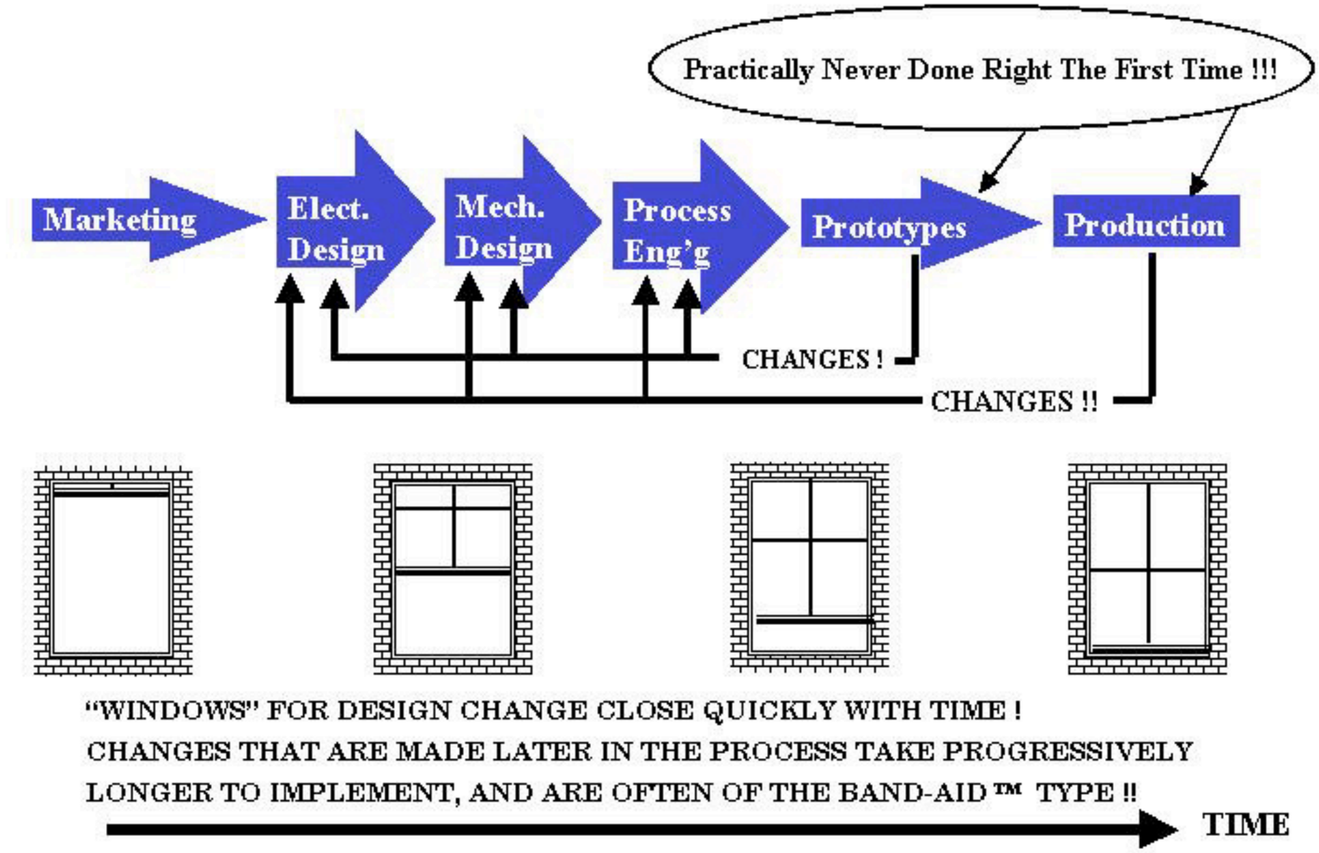

Figure 1. Serial Product Development

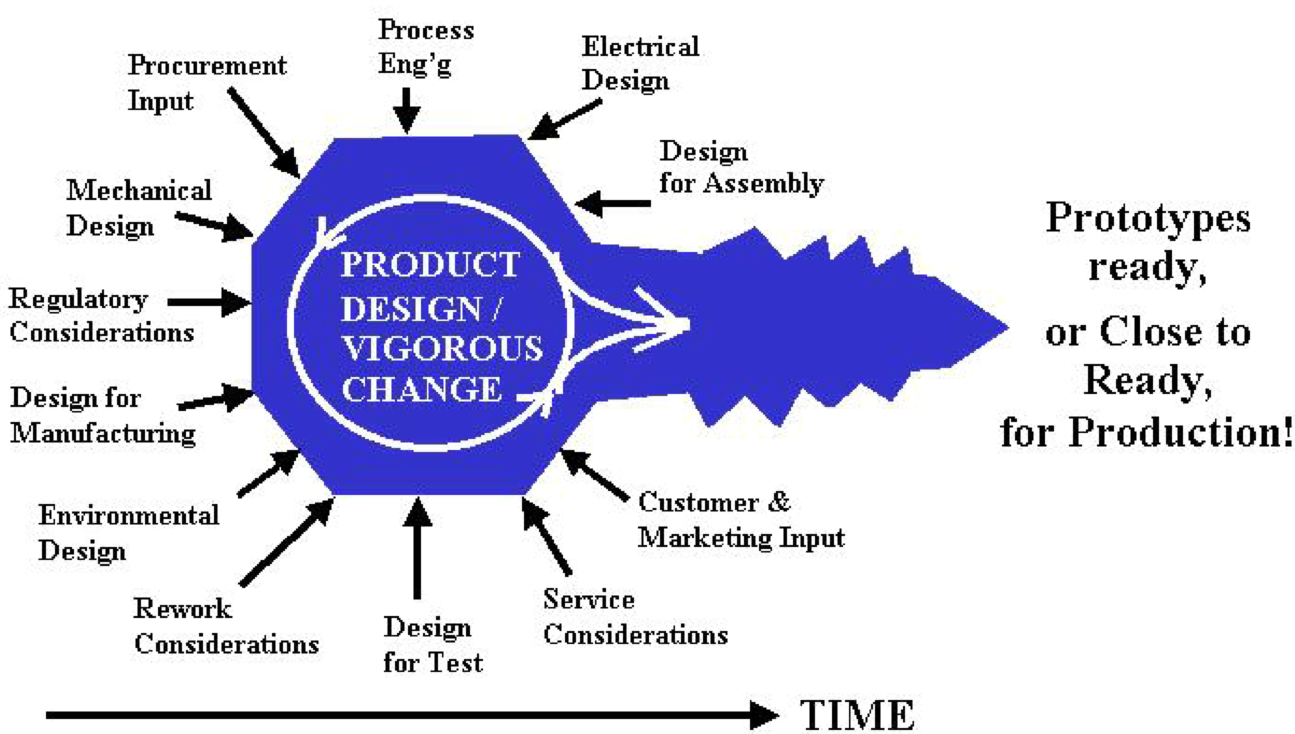

Figure 2. Total Concurrency Product Development