The Design Process

- “Creating something out of nothing.”
- The design process is the very BEST part of a technology career – exciting, satisfying, and fulfilling.
- Being involved in design work – part design, process design, system design, test design – makes the schooling, early experience and mistakes made along the way worthwhile.
- The design process can be rigorous and exhausting, involving one approach after another, testing alternatives to find the best one (the highest performance, the lowest cost, the “best value”).

We Are All Designers

- **We all design things:**
  - **Cooks design great dishes.**
  - **Hobbyists design modifications to their model airplane kit.**
  - **Men and women design "high fashion" clothes.**
  - **Writers "design" plot for books, movies, and plays.**
  - **Many homeowners "design" beautiful yards and landscapes.**
- **In fact, the design process is <u>all around us</u>, and many of us act as "designers" in many of the day-to-day activities in which we are involved.**

Designers (2)

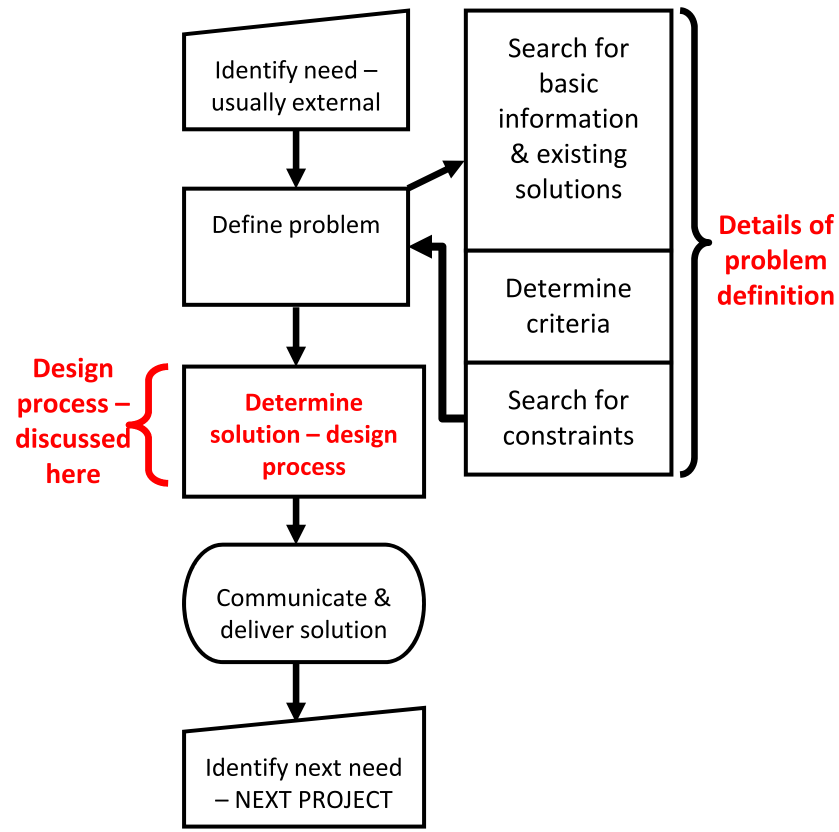
- **The technical professions have designers whose work provides many of the wonders of our modern world:**
  - **Architects design innovative homes and buildings.**
  - **Electrical engineers design tiny chips with up to billions of transistors that provide us with television, computer, display, communication, and entertainment magic.**
  - **Mechanical engineers design new aircraft and robotic marvels.**
  - **Petroleum engineers design new and innovative ways to scavenge oil and gas from previously-inaccessible sources.**
  - **Computer scientists design innovative programs that make computers, notepads, MP3 players, and smart phones useful.**

Design Expertise: Born or Learned?

- **Consider Steve Jobs, founder of Apple.**
- **You might think that Steve Jobs was a brilliant designer, when you consider the iPod, iPhone, and iPad.**
- **But – some of Jobs first designs were terrible!**
  - **Example: The Apple Lisa. The Lisa was an interesting, overpriced first-generation Macintosh computer.**
  - **Lisa was massively overpriced ($9,995), and not very useful.**
  - **To be fair, Jobs did not have complete control over Lisa – nor was he with the project at the end.**
- **This tells us that Jobs was not born a great designer – rather, he learned his craft.**

Design as a Process

- We know from Lecture 8 that projects have a structure. This suggests that there is a structured approach to design, as the act of design can be considered a project.
- This suggest that every design exercise will have a project structure associated with it, with a similar process flow.

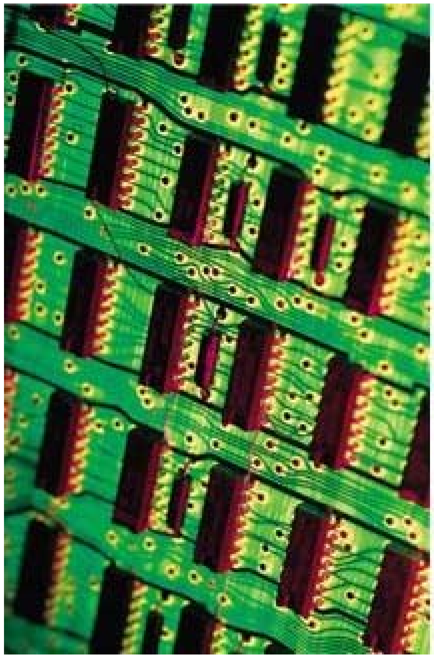


A Suggested Design Method

- Identify a need; define the problem. (May include preliminary work estimate, funding required, manpower, project timeline.)
- Assemble the design team.
- Identify constraints and criteria for success (last is very important).
- Search for solutions (never start from scratch if you can help it).
- Choose an approach and do (one or more) preliminary design(s).
- Choose best prel. design and start final design.
- Test and validate solution with success criteria.
- Release to production (may be initial beta).

Iterative

Ongoing communication with management



Identify Need and Define Problem

- **May be a general customer description that the engineer must make into a detailed need statement.**
- **For defense contractors, this might be a VERY detailed (thus the cost of military hardware!).**
- **Sometimes this may be a marketing group perception of a company (or individual) need that even customers have not perceived (e.g., the iPhone or iPad).**
- **Once a need is clearly understood, a project is defined that solves the need. This may include a preliminary timeline, manpower needs, and a rudimentary budget.**

Examples: Need for Design Innovation by Mobile Phone Producers

- Nokia has a current need for innovative mobile telephones and/or "smart phones."
  - IPhone has eaten into Nokia market.
  - Choices: Cheaper phones? More features? Lighter/smaller?
  - Clearly, some design innovation is needed!
- Research in Motion (Blackberry) is facing stiff competition in the smart phone market.
  - IPhone is snagging some business users.
  - Android phones (Motorola, Samsung, etc.) are big competition.
  - Stick to business roots? Attack Apple?
- Palm is having severe marketing issues.
  - IPhone, Android phone heavy impact
  - Operating system a mess; just signed with Microsoft to use Windows Mobile.
  - Needs a big winner.

Assembling a Design Team

- **All technology projects are accomplished by teams.**
  - **Includes experts and specialists needed to solve the design problem that will provide the solution to the need.**
  - **A popular team approach is concurrent engineering. The entire project is addressed from the start with required skills:**
    - **Stylists (to make the product or solution appealing).**
    - **Electrical, mechanical, etc. engineers to design the solution.**
    - **Software engineers or scientists to produce the code (everything has software in it now!).**
    - **Production engineers to design production flow and equipment.**
    - **Marketing to design a sales campaign (if needed).**
    - **Many parts are built by subcontractors (i.e., seats, steering wheels in cars), so the team may have subcontractor specialists as well.**

Identify Constraints and Criteria for Success

- Constraints may include:
  - Budget
  - Project timeline (a product late to market is worthless)
  - Available off-the-shelf components
  - Material requirements
  - Legal considerations
  - Competitive products
  - Manufacturability
- The criteria for success may include:
  - Appearance
  - Performance
  - Environmental impact
  - R&M (reliability, maintainability) (if it's broken a lot, it's not very useful)
  - Safety
  - Primary use
  - Cost
  - Comfort
  - Quality

Search for Solutions

- Search current knowledge base for answers.
- Review previous similar projects, products, and processes. Previous work may be applicable. Any technology that is available saves time in the development process!
- New viewpoints or approaches ("out of the box") may be tried.
- Combining or separating functions may create a new paradigm.
- (Always go back to basic principles if the solution is not apparent.)
- "Brainstorming" or similar techniques may be used to come up with new ideas (previous example of babysitting 40 pre-teens).

Preliminary Design

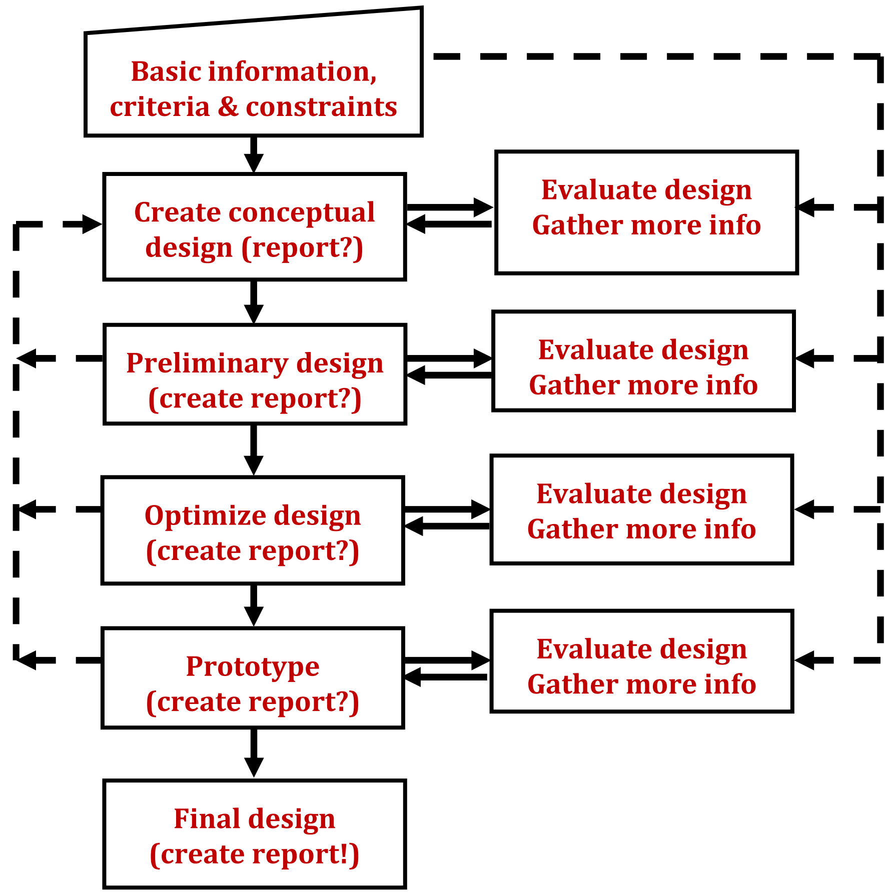
- **Preliminary design begins when approach is chosen.**
- **In high-risk or high pay-off projects, multiple preliminary designs may be started, particularly if two or three approaches look good.**
- **Potential profit or payoff may justify the LARGE expense of several parallel preliminary projects.**
- **Critical hurdles (more difficult problems) of the project should be addressed FIRST! Critical problems should be at the top of your list (ref. computer company project).**

Detailed (Final) Design

- When the final project design is settled, the product or process development goes forward.
- As we learned when studying project management, there is usually a "critical design review," at which management reviews the process carefully, including overall project cost, time-line, and the expected product or process profit and/or benefit to the company.
- Assuming the critical review does not discover any serious project "show-stoppers," or deficiencies in the expected product performance, go-ahead is given to go to completion.

Core Design Process

- The core design process (from preliminary design to design completion) may look like this:



End of the Project

- **Project completion – The project is now executed to its end. This often involves not only product design, but manufacturing design, maintenance procedure development, vendor and subcontractor liaison for materials and parts, and interface with product sales.**
- **Evaluate and verify – The project is not completed until the assembly or process line is flowing and there are no major product recalls! In some organizations, the project manager documents the project and compiles a "lessons learned" report and suggestions for future projects.**

Project Problem

What follows is a design project example to show the process in a multi-discipline project involving chemical, mechanical, electrical, and computer engineering, as well as software conceptualization, design, and development. Hopefully, it will give you a flavor of the real industrial design process.

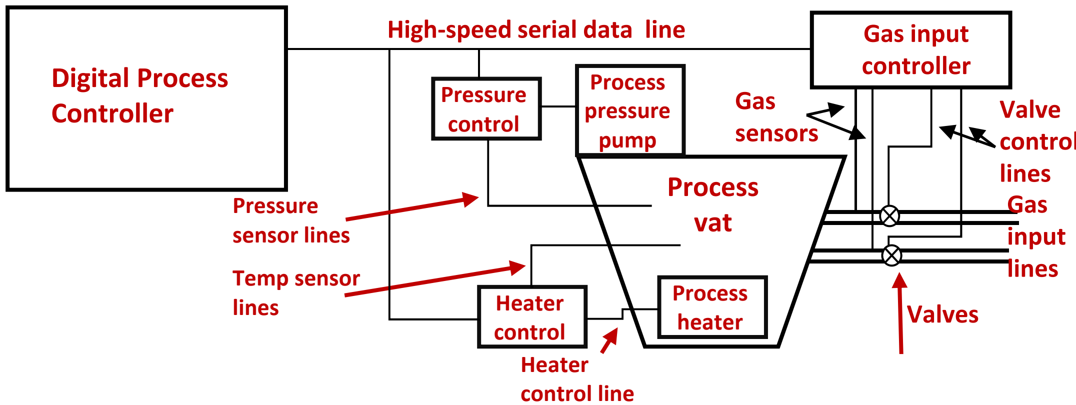
Chemical Process Design Control

- You are a senior electrical engineer for a large chemical company.
- A new product requires a new processing line.
- The project chief is (naturally) a chemical engineer/ project manager.
- You are chief of the digital controls project, which will make the control equipment that automatically keeps the process running properly.
- The process team has prepared a specification for control. If you “meet spec,” the project manager is happy.

The "Spec"

- Process maintained at specific temp. and pressure.
- Once started, process must complete.
- Process must be carefully timed.
- Temperature and pressure limits are critical.
- Two ingredients must be introduced at precise times.
- Process is very precise in terms of time, pressure, and temperature constraints.
- Critical parameter sampling/control is at 1000 Hz.
- Computer control system monitors process, controls heating elements, pressure system, gas valves, and gas pressure.
- Computer system controls process start-to-finish.
- Product cannot be made in a continuous process, but must be made batch-by-batch.

Chemical Process System



Block Diagram, Process Control System

- You considered and studied the spec (step 1 – note that in this case, the chemical project team has clearly defined the problem!).
- You assembled a team of control and computer engineers (step 2) and laid out a block diagram of the process, as shown above:

Constraints

- **Step 3 is to consider constraints and define criteria for success.**
- **The criteria are simple – that the process is successful!**
- **What about constraints? There are a bunch!**
  - **Precise temperature and pressure limits for the process.**
  - **Mix timing for the ingredients to be added.**
  - **The requirement for 1000 full monitoring/control cycles per second.**
  - **Clearly, as the diagram shows, you need auxiliary pressure and heat controls, as well as a gas controller.**
  - **The central processing element must monitor all parameters (via the high-speed serial data lines – these exist and are supposedly part of the plant local area network [LAN]).**

Search for Solutions

- An upscale dual PC is chosen as the central controller.
- It will have to be "process hardened" for plant conditions.
- What about monitors/controllers for temperature, pressure, and ingredient mix? Do they have to be separate?
- Final decision: Due to the high sampling speed and process accuracy, the controllers should be separate.
- Several team members feel that the controllers should be microprocessor-based.
- One older hand, a long-time process control engineer, argues that the microprocessor approach is too slow, that local processors should be unique FPGA (field-programmable gate array) designs to increase speed.

Preliminary Design

- You decide that the design choice is too close to call.
- Since building double hardware is extravagant, your simulation experts are tasked to "build" both sets of processors in software and run process trials.
- Other team members begin to investigate required sensors.
- After a few tense weeks, the simulation team reports that although process temperature changes are gradual, pressure changes and the mix controls are sensitive and need rapid response.
- Your review the data and agree that an FPGA-based controller is required; the project manager okays it.

Preliminary Design (2)

- You complete the system design, with sensor engineers, controller engineers, system engineers, and data communication engineers all working together.
- You finish your preliminary design, check all the estimated process control cycle times, spec the central control computer, and begin to send out purchase orders.
- A final review with management (the "critical design review") confirms your approach, which project management approves.

Detailed System Design

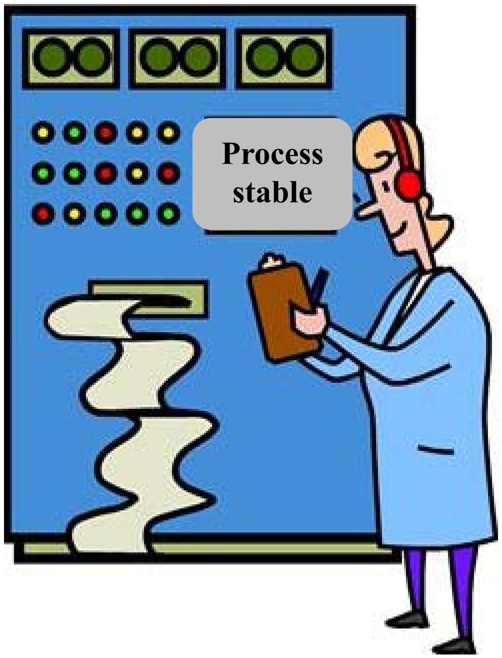
- You begin the final design, initiate parts orders, and order a new simulation of the entire proposed system.
- Vendor problems are encountered (the desired FPGA's are in short supply), but are solved (expedite fees solve many problems!).
- Parts and components begin to arrive.
- The control computer is procured and your software experts begin to produce the system control software.
- Simulation reveals no unanticipated problems, and the project management gives approval to the final design and gives permission to complete the system.

Building the System

- Parts and subsystems (such as pressure and temperature sensors) arrive.
- The FPGA pressure controller and gas controller subsystems are designed, and programming of the FPGA's starts.
- The microprocessor temperature controller subsystem is also under way.
- Controllers are finished and system integration starts.
- Installation begins on the process vat itself.
- Communication lines are tested.
- The computer and control console arrive, and final integration starts.
- Finally, the system is complete!

Design Verification and Documentation

- The first process batches are a disaster (as usual).
- System "glitches" are worked out, and within a reasonable time, the system is operating.
- The very tough parameter and sampling constraints are met, and the manufacturing system is declared fully operational.
- You complete project documentation, including operation and maintenance manuals, project history, lessons learned, and suggestions for the next process controller that must be built.
- Then you then accept your boss's plaudits, accept your raise and promotion, and proceed with your career!

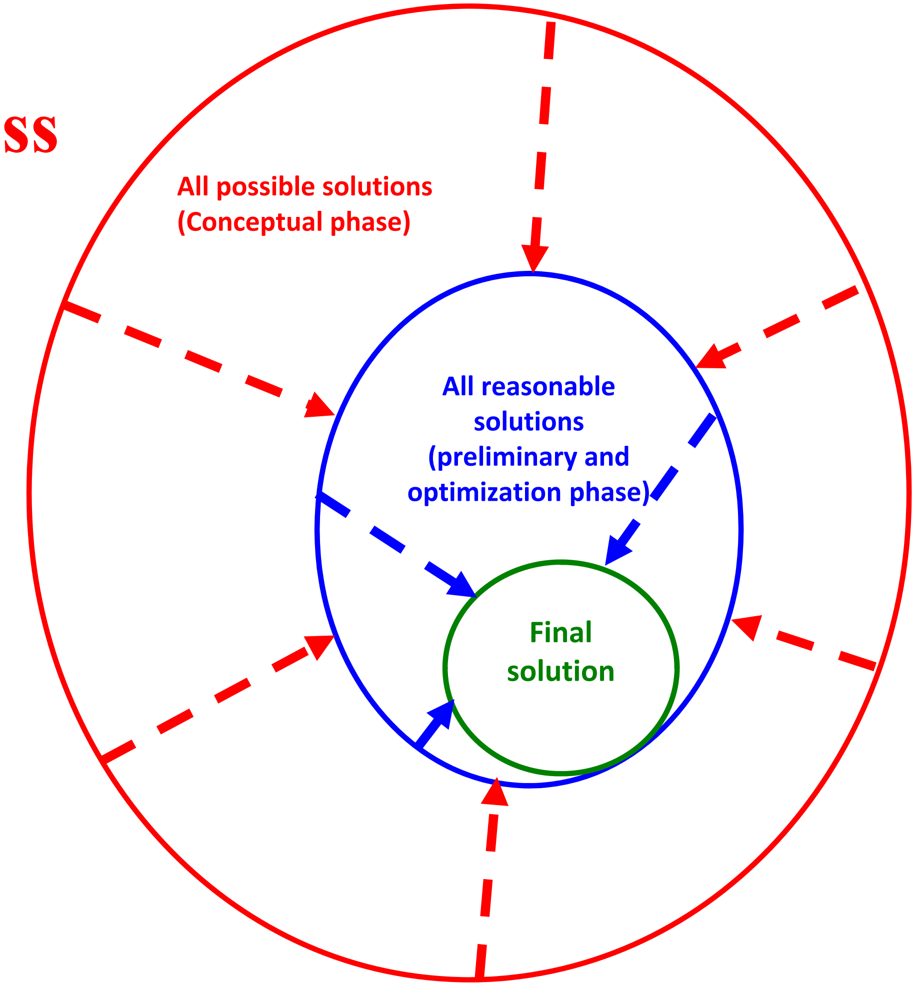


Overview of Design Process

- One can think of the design process as a series of steps aimed at finding the best solution to a given problem.
- With each step, you close in on the best solution for the problem that you are trying to solve.
- If you cannot find a useful solution, you need to expand the regime in which you might expect to find the solution (i.e., try "thinking outside the box").
- The process may look like the "zeroing in" diagram shown on the following page.

The Design Process

The process "necks down" the design approach universe to (1) a few "reasonable" solutions (cost-effective, achievable) and then (2) chooses the best of those alternatives.



Exercise: Designing a New Chair

- You are a one of several project teams tasked to design a new chair for a furniture company.
- There is only enough funding to develop one model.
- However, the company needs a new "home run" model, so that management is entertaining particularly innovative inputs.
- Your chair can be a deluxe living room chair that would fit in an upscale home.
- It could be a fancy controllable reclining chair with space for video games and a TV remote.

Things to Consider

Rank	Design	Strengths	Weakness	Unknowns	"Wow" Factor
1	Design 5	Upscale	Material looks (and is) expensive	Wearability unknown	High.
2	Design 2	Very stable	Possible environmental issue	Environmental issues with material choice?	"Modern" appeal.
3	Design 3	Very strong	Expensive materials	What is the cost of welding?	Looks cheaper
4	Design 4	Possibly cheap to make	Looks cheap	How much is a molding tool?	None
5	Design 1	Simple	Can fall over	How much weight can the material hold?	None

- You may have ideas for several designs.
- In the preliminary design phase, you might consider +/–'s for each approach.

Alternatives

- **Your chart can be long – several pages (in a real design exercise, you might have to break the design into parts).**
- **Choose the best result.**
  - **Notice the ranking – you need to decide which design = best results (market share, profit, etc.).**
  - **This should be a team decision, as close to unanimous as possible.**
- **Document and communicate results.**
  - **At this point you may need to document the results of your conceptual design and communicate that choice – with the reason for that choice – back to your project sponsor.**
  - **If so, all members of the design team take part in writing up the report – and each should sign off on its completeness.**

Continuing the Process

- **During the preliminary design phase, you will begin to make detailed calculations of your potential solution(s).**
  - **Occasionally you will work on two or three possible solutions as once, particularly if all have big weaknesses or unknowns.**
  - **You will also need to eliminate as many unknowns from your conceptual design as possible.**
- **Analysis of possible solutions:**
  - **Again you will make use of the table above, limiting it to the designs that you are directly working on.**
  - **You will also need to begin to create detailed designs. Often, you will also have several versions of your design… making your table (next page):**

Process…

Rank	Design	Strengths	Weakness	Unknowns	"Wow" Factor
1	Design 5	Upscale	Material looks (and is) expensive	Wearability unknown	High.
2	Design 2	Very stable	Possible environmental issue	Environmental issues with material choice?	"Modern" appeal.
3	Design 3	Very strong	Expensive materials	What is the cost of welding?	Looks cheaper!

- Notice that you are now getting more detailed in your design.
- Choosing the best result after further consideration:
  - Using the chart and other design information that you have accumulated, make a best estimate on which design will give you the best results.
  - If none of the results are good enough, you may need to go back one step.

Prototyping

- **At this point, you are ready to build a functional model of your design, perhaps as a simulation in software.**
  - **You can model the design, looking for strengths, weaknesses and unknowns.**
  - **Again, choose best result.**
  - **There will be a new rank, based on the modeling. If the results are poor, you may need to go back one a step.**
- **Document and communicate results of your conceptual design.**
  - **Communicate the choice and supporting data back to the project sponsor.**
  - **Again, all members of the team take part in writing the up the report and sign off on it.**

Final Design Choice

- Now, you are ready to build a system that might be put into operation (i.e., the "production prototype").
- You might actually make several prototypes of the system (or chair), to be sent to possible customers.
- Your customers will provide feedback, which can be put into the final chair design. You are making use of their input in this step as a final optimization step.
- Here may have several adjustments or modifications suggested. For example, (table on next page):

Final Design Decision

Rank	Design	Desirable Qualities	Critical Issues	Suggested Corrections	Overall Assessment
1	Design 5	•Upscale look, feel •Leather wears well •Customer very enthusiastic	•Price high •Value questions	•Find alt. vendor •Rework frame to reduce cost	Best profit, most positive customer comments.
2	Design 2	•Favorite design •Fabric got good comments •Easiest to move	•Fragile (two models broke) •Fabric tore •Tipping problem	•Go to all aluminum frame •Use alt fabric •No current solution	Stability issue a killer.
3	Design 3	•Only fabric got favorable comment	•"Looks cheesy" •Value questions	•Use alt. fabric •Add TV remote slot	Excellent profit. Appearance issue serious.

- **This table leads to the final (in this case obvious) choice.**
- **Again, document the final design choice, complete the report, and have all members sign off on design.**

Chair Design Assignment

- **Each team is assigned the task of developing an innovative chair design (design only, no prototype).**
- **The design is due next class period.**
- **You can consider a number of designs and price points.**
- **Be prepared to give a two-minutes "elevator speech" and turn in a report. The report should include:**
  - **Your target customer.**
  - **The cost, and the expected price and profit.**
  - **An illustration of the final, viable design.**
  - **A complete parts and materials list.**
  - **An expected first year sales total, revenue and total items sold.**
  - **In this case, you only go through the documentation phase once.**