An Overview of the Engineering Process

Preface to “The Game”

Think of the BEST committee as the customer and your team as an engineering firm. The customer provides the product definition and constraints to several engineering firms at “kickoff.” Each firm develops a product to satisfy customer expectations and returns to the customer six weeks later to present a working product to compete, or bid, for the contract. In this competition, the award(s) represent the contract that will provide revenue for the firm.

The rule booklet defines the product, the task it is to accomplish, and its physical constraints. Each team is bound to using only kit parts to produce their machine. No additional parts are permitted except to replace original parts. Replacements must be identical and the total of a machine’s constituent parts must not exceed the initial issue. These part limitations simulate budget and preferred supplier constraints.

The rule booklet and kit of parts issued to each team at kickoff comprise the customer’s original product definition and physical and budgetary constraints. Product development normally involves specification, clarification, and changes by the customer. Also, each firm may initially believe that they understand the product and its constraints. However, upon closer inspection of the documentation, firms may determine that they are uncertain about the requirements and question the customer. During the six weeks of the competition, the customer provides all questions asked, answers to those questions, clarifications, and changes to each firm via periodic bulletins or messages.

BEST Objective

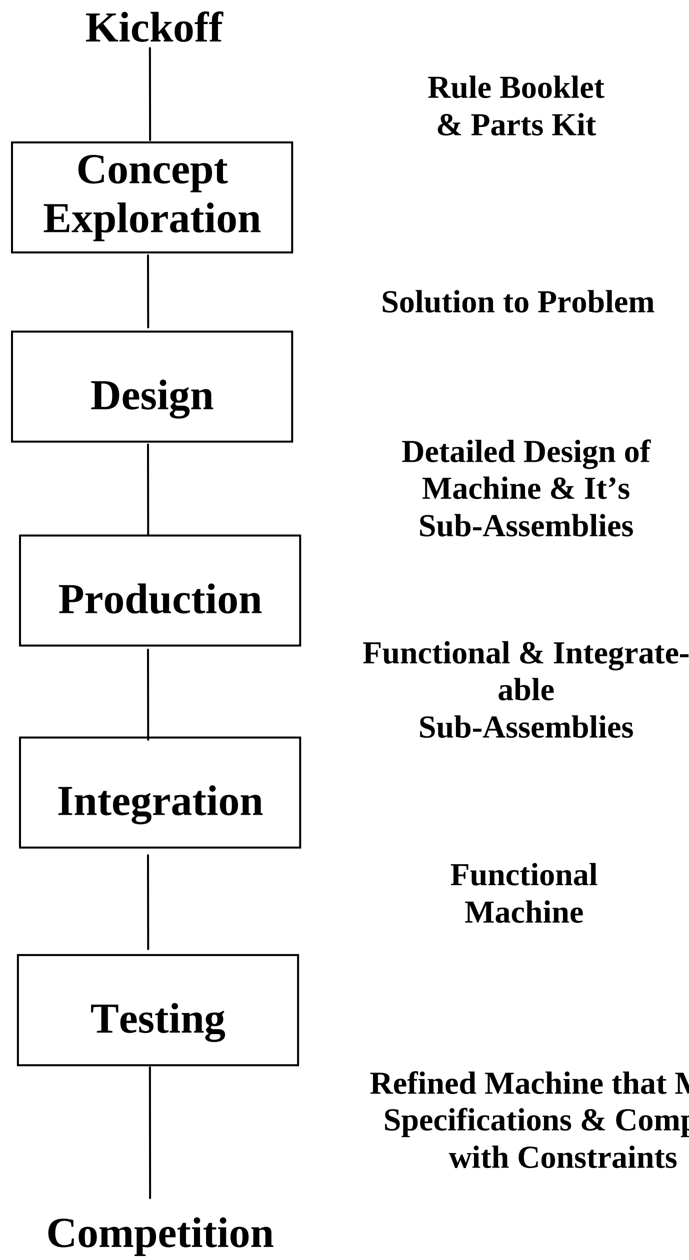
To **B**oost interest in **E**ngineering, **S**cience, and **T**echnology using a sports-like technology contest.

Method

Produce a machine within a short period of time that, when strategically operated, will perform a given task. Each performance of the task is rewarded with points. Therefore, both offensive and defensive strategies are employed to earn or to deny the opponent(s) points.

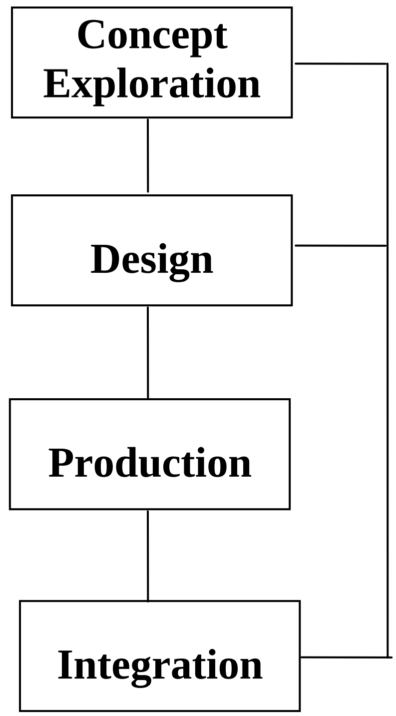
Product Development

The purpose of this text is to provide an introductory overview of product development for the BEST competition. It is one, but by no means the only approach to solving a group design problem in a short period. The following diagram illustrates a typical product development flow:

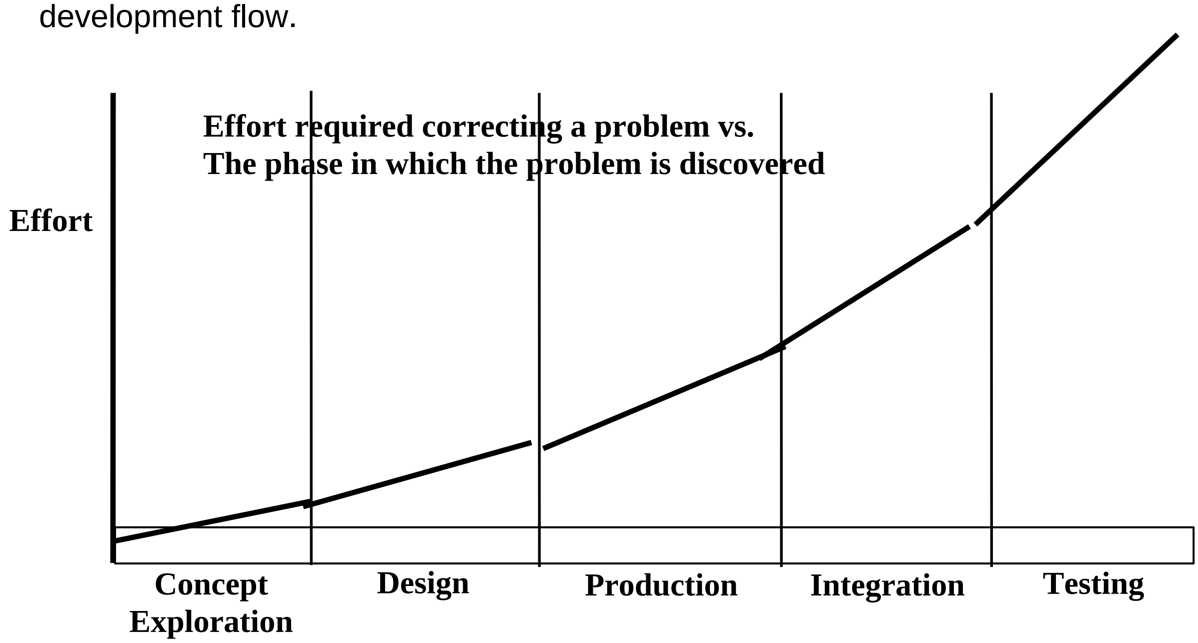


The flow begins at the kickoff and ends at the competition. The diagram depicts a top-down flow.

It should be noted that the flow is normally cyclical amongst phases. For example, a team might leave the production phase then realize during integration that a sub-assembly will not function as desired. The team might re-enter the design phase or concept exploration phase depending upon the extent of the problem.



The following graph illustrates the need for development of a robust design early in the development flow.



It should be obvious that time and effort spent in the beginning of the flow will save time and effort over the course of the development process.

Concept Exploration

This phase begins with thorough research of the customers' specifications and constraints. Each team member should understand the contents of the rule booklet. Once the specifications and constraints are understood, break the team into small groups. Each group should have a coach that will guide them through a brainstorming session. The output of each group's brainstorming session should be a list of possible solutions to the problem. For example, the customer specifies a vehicle that will carry passengers over land. The only constraints for this simple example are that the vehicle must carry two occupants and do so safely.

Normally a person would think of an automobile as fitting the criteria outlined above. But given the specifications and constraints several solutions are possible. The point of breaking the team into several groups is to draw on the innovative synergy of each group. Furthermore, a leader will emerge in each group. That leader may or may not dominate the discussions. In either case, having several leaders and groups leads to several ideas rather than one idea dominated by the most vocal (not necessarily the most reasonable) person of the overall group.

Each group should break the overall function of the machine into smaller sub-functions. This is known as "functional decomposition." When decomposing the problem, resist the temptation to make sketches. Instead, give detailed descriptions of each idea. This should prevent "etching" of any one potential solution into the team's collective "mental drawing board." At this point in the competition, it is important to keep the team's focus on the direction to the finish line and not the actual route.

Once a group begins thinking outside of the norm or "out of the box," solutions that involve vehicles with other than four wheels, seats, and an engine evolve. Each group should decide upon a general solution to the problem. In the case of the vehicle example, the sub-functions might include a method of propulsion, type of mobility, a means to protect the vehicles occupants from the elements and so on.

Suppose that three small groups developed the following ideas:

	Propulsion	***Mobility***	***Passenger Housing***
Group 1	Sail	Runners	Carriage
Group 2	Motor	Tank Tracks	Seats with overhead cover
Group 3	Fans	Bed of Compressed Air	Cabin

Group 1's solution is limited to operating in a windy, slick-surfaced (e.g. icy) environment. Group 2's solution could operate wherever group 1's would and in sand, mud, on concrete and so on. Both are limited to moving in contact with the ground. Group 3's solution potentially satisfies the customer's requirement to carry passengers over land from one point to another, yet it is capable of doing so over generally level terrain and even water. There are significant trade-offs associated with the use of each solution. For example, each solution lists a means of propulsion that requires wind, battery power, or fuel. Which of these resources is readily available to the customer for powering the vehicle?

Once each group has settled on their general solution and their decomposition, they should collectively decide on the solution to use. It might turn out that one group's idea for a sub-function works well with sub-functions from another group or something else altogether. Maybe removable wheels on the sled would meet the requirements and still beat the hover-craft type solution in the area of constraint compliance: namely budget and materials available. The decision on the team's solution is the output of the concept exploration phase.

Design

This phase begins with a clear understanding of the team's approach to solving the problem. Each sub-function is transformed into a detailed design for the machine and its sub-assemblies. This is the time for creation of detailed sketches. Using the combined runners with wheels solution, the team must design the wheels, runners, carriage and so on. Each sub-assembly must be designed within the constraints and such that each will function and fit together to form the machine.

The output of this phase should be a detailed design of the machine and its sub-assemblies. This phase requires the most thought and, if done without haste and oversight, provides the most benefits. The preceding graph indicates that the concept exploration phase provides the most savings of effort. However, the competition's rule booklet details and limits the conceivable solutions. It is the design phase, in this competition, that is more open to interpretation.

A robust design is one that at least has the following characteristics:

- **Production Understandable** - Can and do team members understand and communicate the design? Can the machine be operated without an extensive training period?

- **Simple** - Is the design simple in its production and operation? Does the production require special tools or processes that are unavailable to the team during the actual competition?

- **Reliable** - Does the machine's design make it prone to breakage or functioning only in the best of conditions?

- **Changeable** - Can any sub-function be redesigned without changing the overall design of the machine?

- **Producible** - With the tool and facility resources the team has, can they produce the sub-assemblies? Do the sub-assemblies easily interface with one another?

- **Maintainable** - Can a part or sub-assembly on the machine is replaced quickly and easily with limited tools in the heat of competition? Can parts be accessed without dismantling the machine?

- **Strategic** - Does the machine's shape and function allow it to be used offensively and defensively?
- **Foolproof** - Is the machine inherently tolerant of operator mistakes? For example, does it automatically align itself with the goal?

This phase begins with a robust design. Machine sub-assemblies are produced according to the detailed design. During production, attention must be given to consumption of kit materials. The team makes the wheels, runners, axles, and so forth, yet has enough materials left to make the carriage. This is particularly true if prototypes are developed. Prototype parts should be reusable in the final machine.
Avoid becoming fixated on aesthetics of the machine at this point. Do not discount appearance altogether, but remember that it is below functionality on the list of priorities. The output of this phase should be several sub-assemblies, each performing some sub-function(s) of the machine, that function and fit together per the design.

Integration

This phase begins with all the completed sub-assemblies. The sub-assemblies are put together and made to function as one machine. Attach the axle with its wheels and the runners to the carriage. Connect the drive train between the engine and the axle. The team may find that the wheels don't stay attached to the axle or that the drive train doesn't provide enough torque to turn the wheels.

This is where the criticality of the design phase comes into play. If it is realized during integration, which is usually late in the development timeline, those subassemblies do not function or fit together, some quick yet well-thought-out plan must be developed. Develop a plan that permits a quick recovery from the problem with as little rework of completed and functional subassemblies as possible. Remember, the team's time and materials are becoming more limited as time progresses. The output of this phase should be a working machine that is ready for testing.

Testing

This phase begins with the working machine. Even though the machine is working, it may not be working as well or in the manner that the team would like. At this point, it is wise to have a small portion of the playing field constructed and ready for use in testing of the machine. Several of the team members should practice with the machine and begin developing strategy for use in the competition. Practice, practice, practice! During a Game Day match is not the time to learn about controlling the machine or its special quirks!

It is advisable to take the team and its machine to Mall Day for final testing. This event provides opportunities to see other machines and develop strategy against them while practicing on an actual playing field. The team should leave the pre-competition event totally satisfied that their machine is ready to win. More likely, though, the team will leave with ideas for refinements to make on the machine in the following week that will make it ready to win.

Conclusion

The preceding document describes “The Game,” the BEST objective, and the method for achieving that objective. It also took you through the product development process, which consists of the following: concept exploration, design, production, integration, and testing. Hopefully, this information will be helpful as you strive to compete in the present BEST contest. Happy engineering and good luck!