**Engineering Design Process \***

**What is *Engineering*? Engineering IS problem solving**.

“Engineering” is following a methodical process using available resources and experience to solve complex problems.

**What is *Design*? Design is creating something to solve a problem**

“Design” is thinking of and creating something new, or adapting something old to solve a problem and/or satisfy a need.

**What is the *Process*? Idea – Implementation - Testing**

The “Process” is a simple loop where an idea is generated, this idea is implemented, the resulting product is tested or evaluated. Typically, during this testing and evaluation, additional ideas are generated, and the process starts over again.

**The Engineering Design Process – Example Approach:**

**Step 1 – Define the Problem**

Define the *true problem,* not just the *symptoms* of the problem or the *perceived problem*.

* What is the most effective strategy for playing the game? How do we win matches?
* How can the robot score the most points during the match? How do we score more than our opponents?
* How fast does the robot need to move?
* How can the robot pick up the game object?
* How can the robot pick it up quickly?
* How many game objects does the robot need to hold?

**Step 2 – Generate Specifications**

Specifications are requirements for the solution of the problem defined in Step 1 above, and typically come from two places**:** *Design Constraints* and *Functional Requirements*.

**Design Constraints**:

A constraint can be defined as a condition that a solution to a problem *must* satisfy. Constraints, in short, are restrictions. Some restrictions are imposed by the game rules, and some may be “self-imposed”; such as:

* Must be manufactured without “complex machinery”
* Must fall within designer’s budget
* Must utilize parts the designer already has

**Functional requirements:**

Functional requirements describe how well the finished solution must perform. They outline WHAT the robot does, not HOW it does it; such as:

* Robot can run for 2 minutes continuously without draining its power supply
* Can hold 10 game objects
* Can be controlled by a student driver from 40 feet away who is looking through blurry glass
* Can push with 150 lbs of linear force
* Can accelerate to top speed in less than 1 second
* Can drive at a top speed of 10 ft/sec

**Subsystems Integration:**

During the design process think about the ways each subsystem will affect and interface with each of the others.

**Example Subsystems of a Competition Robot:**

* Power
* Control
* Sensors
* Pneumatics
* Drivetrain
* Robot Arm
* Shoulder Joint
* Wrist Joint
* Manipulator

In order to design any one of these systems, one must have knowledge of the others.

Each of these subsystems will have its own individual design process as part of

the overall design process.

**Step 3 – Specification Ranking**

All specs are not created equal, some are more important to the design than others.

Designers need to think about what is most important, and why. Ranking the specifications will make it clearer what to focus on. Specifications are often ranked

in some way to denote their importance. One such scale is:

* **W = Wish** (not that important, but it would be nice if it is possible)
* **P = Preferred** (important, but the project won’t fail without it)
* **D = Demand** (critical to the project, MUST be included)

**Step 4 – Generate Concepts & Alternatives**

Figuring out “HOW” to accomplish the “WHAT” from the specifications. Brainstorm multiple ways to fulfill the specifications.

 **“*Steal from the best, then invent the rest.*”**

Generate concept strategies, concepts for the overall system, and concepts for

individual subsystems and mechanisms. Concepts are recorded as diagrams, sketches, and descriptions.

**Brainstorming –**Focus on *quantity* of ideas generated instead of *quality* of ideas. Generate m*any* ideas in the hope that a *few* good ideas will develop. Do NOT make any judgment on the ideas proposed. Record EVERYTHING.

**Step 5 – Prototyping**

Chooses several of the concept solutions and prototype them. The goal is to LEARN how the solution will function in “real life” and how it interacts with a real environment. Try to see how each concept fulfills the specifications generated in Step 2. Not all prototyping needs to involve building; it is also important to do some basic

testing (i.e. learn how a ball bounces, or how much force it takes to slide a goal).

Prototype *Strategy* to understand how matches will play out and to figure out how long it takes to accomplish specific tasks. Run time trials with old robots. Act out matches

with students pretending to be robots.

**Step 6 – Choose a Concept**

Use the lessons learned from prototyping and determine which concept is “best” and go forward with it. Compare how each concept fulfills the specifications and see if

one is significantly better than the others. Look for the simple and elegant solution.

**Weighted Objectives Tables**

One tool used to help during the concept selection stage of the design process is the

weighted objectives table (WOT). The weighted objectives table can be used to help designers choose between several options based on several criteria. The WOT is an especially effective tool because of how it helps a designer compare alternatives based on what is “most important” to the designer.

**Step 7 – Detailed Design**

CAD Models, Assembly Drawings, Manufacturing Plans, Bill of Materials, Maintenance Guides, User Manuals, Design Presentations, Proposals and more.

**Step 8 – Design Presentation, Review, and Approval** The goal of a design review is to find any problems with the design or potential places where the design can be improved. During the design process, several alternative concepts were generated and one was chosen. There are many such choices made during the design process. Justifying these choices is one of the key parts of the design presentation.

**Cost-Benefit Analysis** isan analysis of what it costs, and how much benefit it provides. A feature’s cost refers to the resources that must be diverted to it; these could be time, personnel, money, space on the robot, weight, and more.

**Step 9 – Manufacturing & Implementation**

**Step 10 – Testing & Analysis** The implementation must be reviewed to see what worked, what didn’t, and what should be improved.

**Design Groups**

* Keep an open mind. It is important to allow crazy ideas to develop. The best time for innovation to occur is early in the design process.
* Don’t become overly attached to any single idea - especially one of your own.
* Do not become defensive; do not blind yourself to logic and the arguments of others.
* Defend your opinions and your ideas but always focus on the ultimate goal of providing the best solution possible.
* Try to stay positive, even when pointing out negatives.
* Engineering is based in logic. Do not allow emotion to interfere with the process.
* Don’t let feelings be hurt if someone disagrees with you, even if they give into emotion and are (overly) harsh.
* An unjustified opinion is a worthless one. Describe WHY you like or dislike something.
* Provide quantitative proof (a proof that can be measured) that will win an argument and prove which idea is better.

**Design Documentation**

Keep documentation of the design. The notes can also be useful when explaining

the design to competition judges and for future team members who want to understand the process used.

**Example Design Schedule –** 6-week process**:**

**Day 1** – Read & Learn the Game Rules, Play with Game Objects, and Analyze Scoring

**Week 1 –** Choose Match Strategy, Generate Concepts and Build Prototypes

**Week 2 –** Choose Robot Concept and Begin Detailed Design

**Week 3 –** Finish Detailed Design and Begin Manufacturing

**Week 4 –** Finish Manufacturing and Begin Testing

**Week 5 & 6 –** Test, Tweak, Improve, & Practice

**Example Design Process**

**Kickoff Process (1 day):**

* Outline the plan to the team in advance.
* Watch Game Animation
* Read Game Manual as a team, and paraphrase rules so everyone understands them.
* List any questions on game rules that the team feels are unclear.
* Explain “What is Brainstorming” to the team.
* Begin Game Analysis:

List all the ways a robot may score in the game.

List all the ways a robot may de-score in the game.

List all the possible defensive moves.

List any offensive or defensive “power moves” in this game.

* Do Rough Scoring Analysis:

o Does the difficulty of tasks match the reward? Cost-Benefit Analysis.

o Determine if there are any “scoring lock” wins

* Brainstorm Match Strategy Options

o Determine “WHAT” the robot will do, not “HOW” it will do it.

o List any questions the team has about playing the game

**Prototyping & Initial Design (1st week):**

* Built Prototypes and perform tests to answer the questions developed during

brainstorming.

* Start determining what robot strategy is best for winning matches.
* Start determining what system design best fulfills the strategy.
* Do research and find existing ideas that will work as part of the overall design.
* Test individual subsystem concepts (i.e. drivetrain, arm, claw, etc.)

**Choose Robot Strategy & Robot System Design (2nd week):**

* Based on the lessons learned during prototyping, choose the best strategy.
* Based on the lessons learned during prototyping, choose the best overall system plan.

**Detailed Design, Additional Prototyping**

**Manufacturing & Assembly (3rd & 4th weeks)**

**Testing & Design Iteration – “Keep improving until you can’t.” (5th & 6th weeks)**

\*This paper is a summary of an article by **John Vielkind-Neun**, a mechanical engineer and mentor of Team 148. To read the complete articles, go to

[**http://www.robowranglers148.com/uploads/1/0/5/4/10542658/engineering\_design\_process\_in\_competition\_robotics.pdf**](http://www.robowranglers148.com/uploads/1/0/5/4/10542658/engineering_design_process_in_competition_robotics.pdf)

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