Burns Sci Tech
Engineering Summer Camp

SYSTEMS ENGINEERING

AND

ENGINEERING DESIGN PROCESS

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Engineering Design Teams

Areas of Engineering

- **<u>Aeronautical Engineers</u>** would be involved in improving the aerodynamics of the car to reduce drag and maximize gas mileage.

- **<u>Automotive Engineers</u>** are a specialized type of engineers who utilize the skills of many of the other branches of engineering listed here and would be involved in most aspects of the car design.

- **<u>Ceramic Engineers</u>** work with inorganic, non-metal materials, and might develop special ceramic composites (combinations of multiple materials) for use in heat shielding, or bearings. Some high-end cars use specially engineered ceramic brakes.

Areas of Engineering

- **Computer Engineers** would be involved in creating the firmware (software embedded in the car’s microchips) of the car.

- **Acoustical Engineers** might work on minimizing road noise within the car or improve the design of the car’s stereo and speaker system, or even work to improve the sound of the cars engine.

- **Environmental Engineers** would be involved in making sure the car meets all emissions requirements.

Areas of Engineering

- **Heating, Venting, Refrigerating & Air-Conditioning Engineers** might be involved in creating the car's heat and air conditioning systems.

- **Systems Engineers & Industrial Engineers** would be involved in the management and supervision of the car creation process.

- **Control Engineers, Electrical Engineers, and Electronic Engineers** would work on designing & integrating the car's electrical system, software, and sensors

Areas of Engineering

- **Manufacturing Engineers** would determine how to make the individual components of the car.

- **Materials Engineers** would help create new materials for use in the car construction.

- **Mechanical Engineers** would work on the design of the mechanical aspects of the car; anything from the transmission to the engine to the suspension to the design of the snaps that hold the seats onto the frame.

Areas of Engineering

- **Optical Engineers** work on lenses and other optical instruments. They would design the car's mirrors and windows.

Plastics Engineers would create plastic types for use in the car's construction.

- **Process Engineers** would be required to determine the best way to make the car and to ensure it is built correctly.

Areas of Engineering

- **Structural Engineers** might be involved in the creation of the car's chassis and frame.

- **Thermal Engineers** would work on the complex heat transfer systems, such as the engine cooling and exhaust.

WORKING ON AN ENGINEERING DESIGN TEAM

Every student involved in competition robotics will have the opportunity to work on a design team at some point. There are a number of considerations they should keep in mind to achieve success:

- One should always keep an open mind. It is important to allow crazy ideas to develop. The most likely time for a creative solution to be found is early in the design process when wild ideas are expressed.

- No one should become overly attached to any single idea - especially one they created. It is easy to become blinded to other ideas simply because “they aren’t mine.”

- One should not become defensive regarding the opinions of others. Defend one's own opinions and ideas but always focus on the ultimate goal of providing the best solution possible.

- One should always stay positive, even when discussing negatives.

- Engineering is based in logic. One should focus on factual arguments, not those based on opinions. Emotion should not be allowed to interfere with the process.

- It is important not to be offended if disagreements occur, even if things get heated and criticisms are overly harsh. Most engineers get passionate during design discussions and will often be very blunt. It is important not to take this personally.

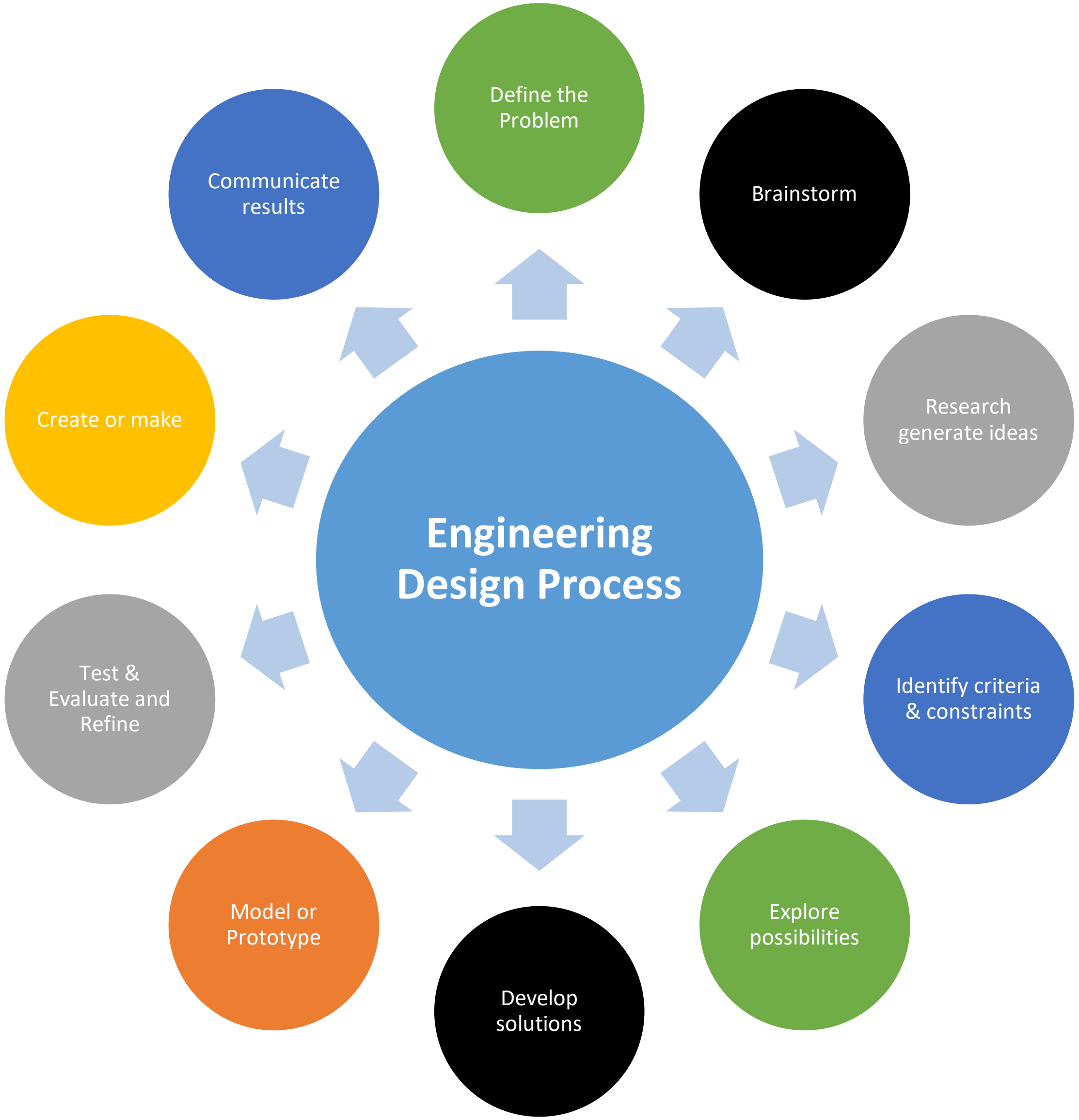
What is the Engineering Design Process?

- **What methodical process do engineers use to solve problems?**

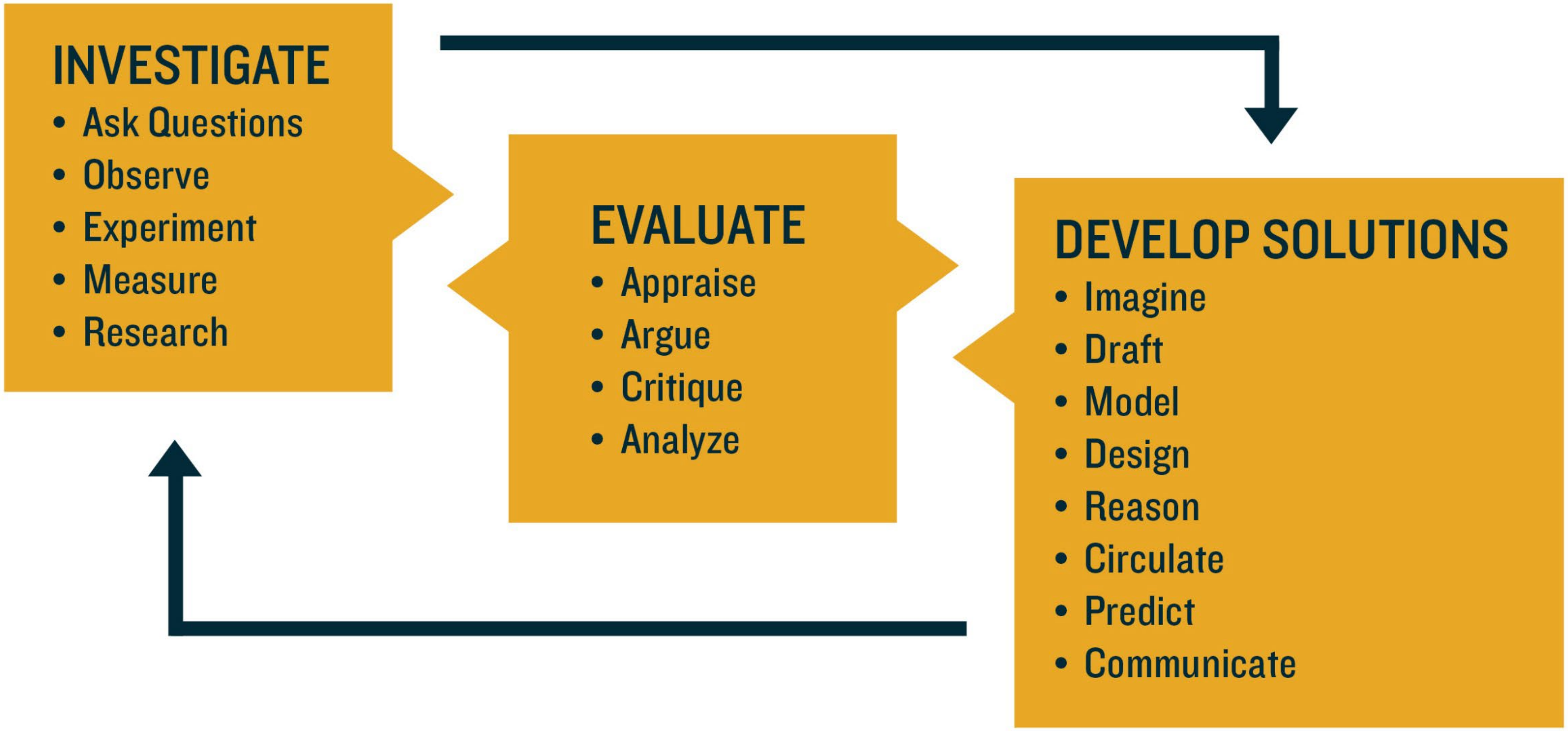
The engineering design process is a series of steps that engineers follow when they are trying to solve a problem and design a solution for something; it is a methodical approach to problem solving.

This is similar to the "Scientific Method" which is taught to young scientists.

Engineering Design Process



THREE SPHERES OF ENGINEERING PRACTICES



In this simple design loop an idea is generated

(1). This idea is implemented

(2). After the idea is implemented, the design group would test the product or evaluate the result of the implementation through testing

(3). Typically, during this testing and evaluation, additional ideas are generated, and the process starts over again.

- Iteration is the act of repeating something over and over again in order to improve the process and eventually achieve a desired goal.

USING THE ENGINEERING DESIGN PROCESS:

- Step 1 – UNDERSTAND – Define the Problem
- Step 2 – EXPLORE – Do Background Research
- Step 3 – DEFINE – Determine Solution Specifications
- Step 4 – IDEATE – Generate Concept Solutions
- Step 5 – PROTOTYPE – Learn How Your Concepts Work
- Step 6 – CHOOSE – Determine a Final Concept
- Step 7 – REFINE – Do Detailed Design
- Step 8 – PRESENT – Get Feedback & Approval
- Step 9 – IMPLEMENT – Implement the Detailed Solution
- Step 10 – TEST – Does the Solution Work?
- Step 11 – ITERATE

STEP 1: UNDERSTAND

- In this step engineers will define the problem they are trying to solve.

- This is the single most important step in the design process. Without fully understanding the problem how can an engineer solve it successfully? This step is often done incorrectly or incompletely and results in a failure of the design. It is important to define the true problem one is solving, not just the symptoms of the problem or the perceived problem.

STEP 2: EXPLORE

- In this step engineers will do background research on the problem their solving. They will investigate the ways others have tackled similar problems.

- Engineers will also gather details on the environment they're dealing with, the situations their solution will be used in, and the ways it will be used.

STEP 3: DEFINE

- In this step engineers will specify WHAT the solution will accomplish, without describing HOW it will do it. They do this through the use of specifications.

- What are specifications?

- A specification is defined as an explicit set of requirements to be satisfied by a material, product, or service. In this case, specifications are requirements for the solution of the problem defined in Step 1 of the design process.

- Specifications typically come from two places:
- 1. Design Constraints
- 2. Functional Requirements

- **What are constraints?**
- A constraint can be defined as a condition that a solution to a problem must satisfy. Constraints, in short, are restrictions.

- **What are functional requirements?**
- Functional requirements describe how well the finished solution must perform.

- Again, specifications outline WHAT the solution will do and how WELL it will do it, not HOW it will do it.

Specifications 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. 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: IDEATE

- Ideate means to formulate, imagine, or conceive of an idea.
- Now that the engineer knows WHAT the solution will do, he or she must determine HOW it will do it.
- Often combining two ideas or compromising between two different suggestions may yield a good concept. Again, improvements and innovations early in the process will yield better results later in the process.

STEP 5: PROTOTYPE

- In this stage of the process engineers takes some of their concepts from the previous step and make mock-up versions of them.

- The goal of this stage is to learn how each concept solution will function in “real life” and how it interacts with the real environment.

- This is also where a designer will start to determine which design concept will work the best.

- These prototypes are designed to be crude, but functional enough to be educational to the designer. The keyword here is “LEARN.”

STEP 6: CHOOSE

- At this point in the process the designer or design group has several different potential solutions for the problem.

- This step is where the designers will use the lessons learned from their prototyping to determine which concept is best and go forward with it.

STEP 7: REFINE

- This is the stage of the design process where engineers take their chosen concept and make it into something more “real.” This stage is all about the details.

- At the end of this stage design teams should have everything necessary so that the full design can be constructed or implemented

- In competitive robotics it is a good idea to make a 3D model of the entire robot in Autodesk Inventor. This can be one of the longest stages in the design process, but the work pays off.

STEP 8: PRESENT

- The detailed design must often go through some sort of design review or approval process before it can be implemented.

- A design review can come in many forms. Some reviews occur as a simple conversation between two of the designers.

Common questions from a Design Review:

- Why was it done this way?
- Did you think of doing it a different way?
- Why did you rule out other alternatives?
- Does it fulfill our requirements and specs?
- How can we make it function better?
- How can we make it weigh less?
- How can we make it faster?
- How can we make it more robust?
- How can we make it smaller?
- How can we make it simpler?
- How can we make it more efficient?
- How can we make this cheaper?
- How can we make this easier to construct?
- What other functionality would be easy to add?

STEP 9: IMPLEMENT

- Once the design has been completed and approved, it needs to be implemented.
- Depending on the nature of the problem being solved, the solutions to the problem could vary wildly. Depending on the type of solution, the implementation could also vary.

- In competition robotics, this is the phase where students "build the thing."

STEP 10: TEST

- In this stage engineers will test their implemented solution to see how well it works.
- The implementation must be reviewed to see what worked, what didn't, and what should be improved.
- The testing procedures and results should be well documented.

- **Once the solution has been implemented, the analysis completed, and the design has been found acceptable, the design process is complete.**

STEP 11: ITERATE

- There were several mentions during the design process of repeating certain steps multiple times until an acceptable result is achieved.
- One important thing designers should note is that iteration does not just take place at the end of the process, it will happen during EVERY stage in the process.

Design Documentation

- Designers must determine what degree of detail and documentation is needed for their specific process.
- Many designers are tempted to do everything in their head, thinking that documentation will only slow them down.
- In truth, a more formalized process will produce a better result. Formalization will promote thoroughness; additional documentation will help prevent mistakes.

Engineering Notebooks

- An Engineering Notebook is a record of the design process; it is basically a “diary” that designers keep as they progress through the process.
- Engineering Notebooks come in many different formats, but they should detail each step of the process.

ENGINEERING TOOLS:

- **Engineers use a variety of tools to help them during the completion of a design process and the solving of a problem.**

- **Autodesk Inventor Professional -** Inventor takes you beyond 3D to Digital Prototyping by enabling a designer to produce an accurate 3D model that can help with the design, visualization, and simulation of the robot before it's built.

- **Force Effect & Force Effect Motion-** ForceEffect enables students to perform static systems analysis using free body diagrams. ForceEffect Motion is ideal for developing mechanical systems with moving parts. Unlike the traditional approach of using paper, pencil, and a calculator to develop equations for design options,

CONCLUSION:

- As seen in this unit, Engineering and the Engineering Design process are both integral to the development of competition robots. Students will gain practical knowledge in topics related to robotics and apply them using the engineering design process to design their competition robot.

LUNAR ROBOT Design Challenge

- Students will be divided up into design teams and use their new knowledge of engineering and the engineering process to complete the following challenge:

- Instruction :

  Rocket Balloon Challenge handout

Instruction :

MISSION
Heavy lift rockets will help the space program progress by lowering the cost of sending cargo and supplies into space.
Working as an engineering team use engineering practices to design and develop heavy lift rockets.

DIRECTIONS
- Use the materials provided to lift as much cargo (weights, paper clips) into space as possible on a given launch.
- You can use any or all of the materials provided to develop your rocket.
- How to launch:
  - Use the fishing line or smooth string that is attached to the ceiling as a guide for the rocket's path.
  - Thread the string/line through the straw(s) so that the straw(s) can slide straight up toward the ceiling as propelled by your rocket.
- The rest of the design is up to your team. Your goal is to get as many paper clips (cargo) as possible to reach the ceiling using your launch system.

MATERIALS (PER TEAM)
- Large binder clip
- Fishing line/smooth string
- 4 long balloons per team - 5" x 24" or 3" x 60"
- Bathroom size (3 o.z.) paper cup
- 2 straight drinking straws
- 50 small paper clips
- Sandwich-size plastic bag
- Masking tape
- Wooden spring-type clothespins (optional)
- Scissor

Not all the steps in the engineering design process are appropriate for this challenge, however each design team should follow the simplified process show here

- Step 1 – UNDERSTAND – Define the Problem
- Step 2 – DEFINE – Determine Solution Specifications
- Step 3 – IDEATE – Generate Concept Solutions
- Step 4 – PROTOTYPE – Learn How Your Concepts Work
- Step 5 – CHOOSE – Determine a Final Concept
- Step 6 – REFINE – Do Detailed Design
- Step 7 – IMPLEMENT – Implement the Detailed Solution
- Step 8 – TEST – Does the Solution Work?
- Step 9 – ITERATE

- All Teams must document the process their group followed in their engineering notebook while including as much detail as possible.

WORK TOGETHER

HAVE FUN