

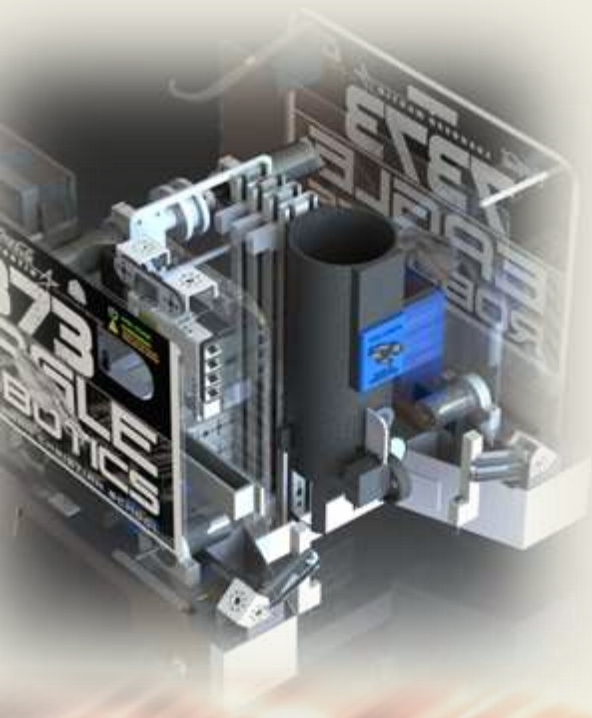


The Engineering Design Cycle

Training, August 31, 2017

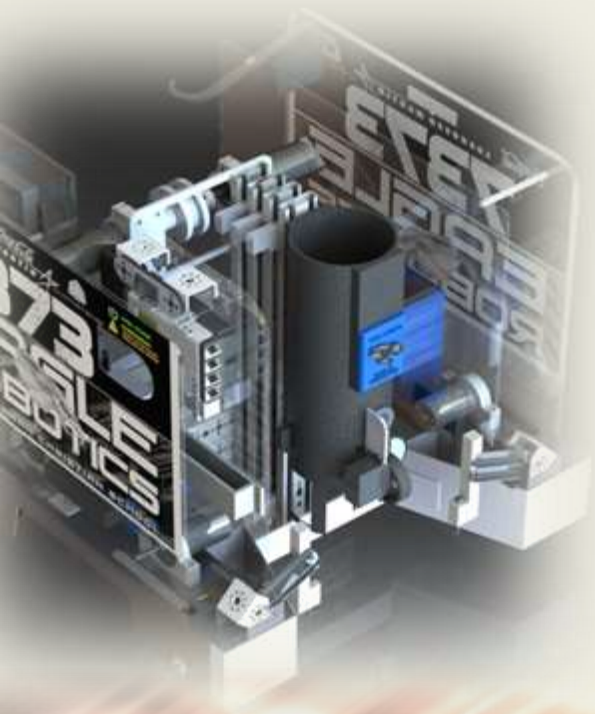
Head Coach, Brad Smith

Overview of Session



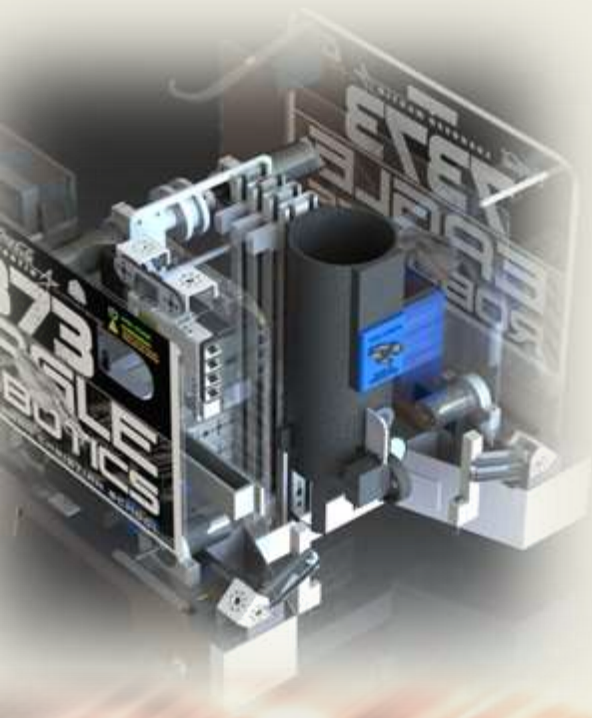
- Definition of Engineering
- Overarching Issues
- 10 steps to help organize the process
- Direct application to FTC

Definitions – The Engineering Design Cycle



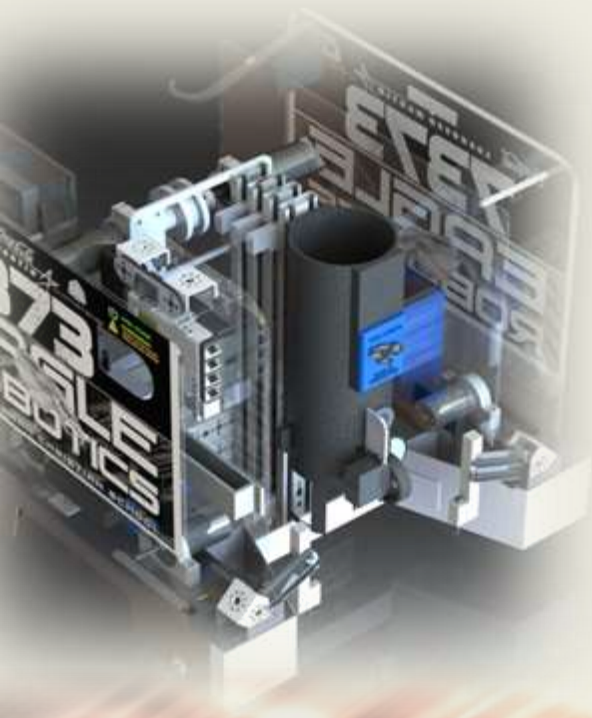
- A systematic process by which solutions to the needs of humankind are obtained.
- A process of devising a system, component, or process to meet desired needs (ABET).
- Fundamental elements
 - Establish objectives and criteria
 - Synthesis and Analysis
 - Construction, testing, and evaluation

Overarching Issues



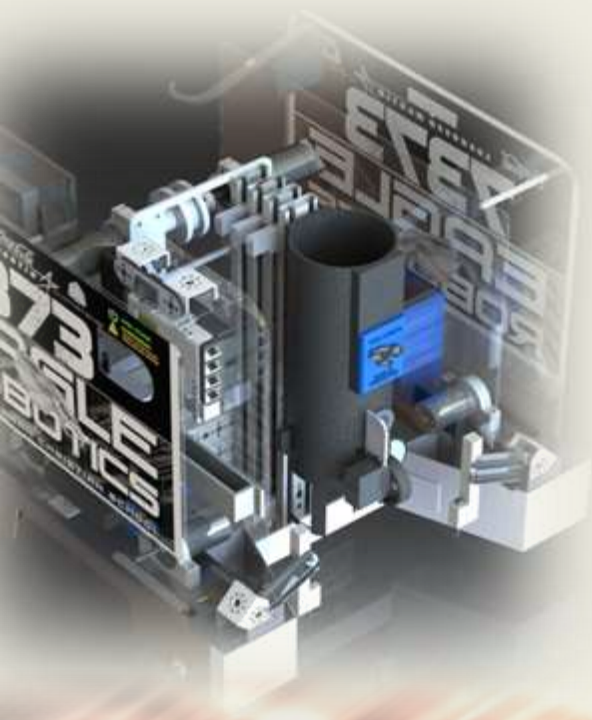
- A step-by-step process, but not usually linear
- All steps need to be included
- Customer or end-user satisfaction
 - Assumes basic requirements will be met
 - Performance requirements client specifies
 - Enhanced (exciting) requirements outside client range of knowledge or vision
- Divergent thinking involving synthesis and evaluation needed (Bloom's taxonomy)

10-Step Process



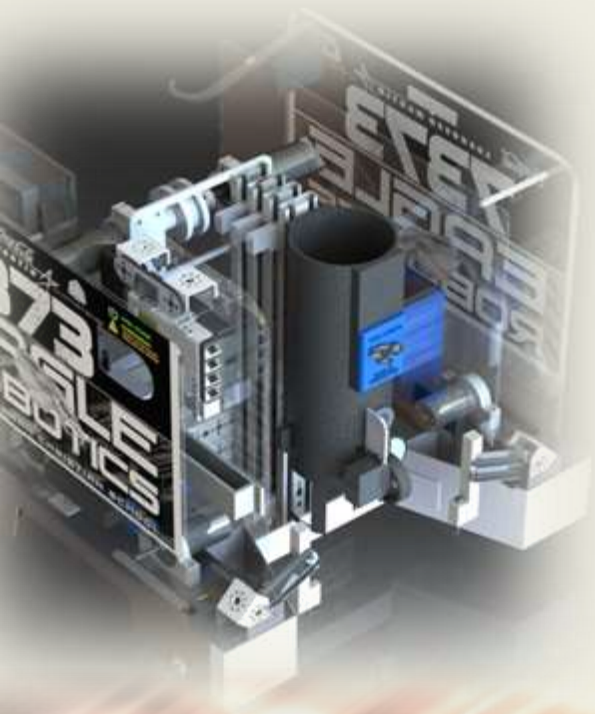
1. Identify the need
2. Define the problem
3. Search
4. Constraints
5. Criteria
6. Alternative Solutions
7. Analysis
8. Decision
9. Specification
10. Communication

1. Identify the Need



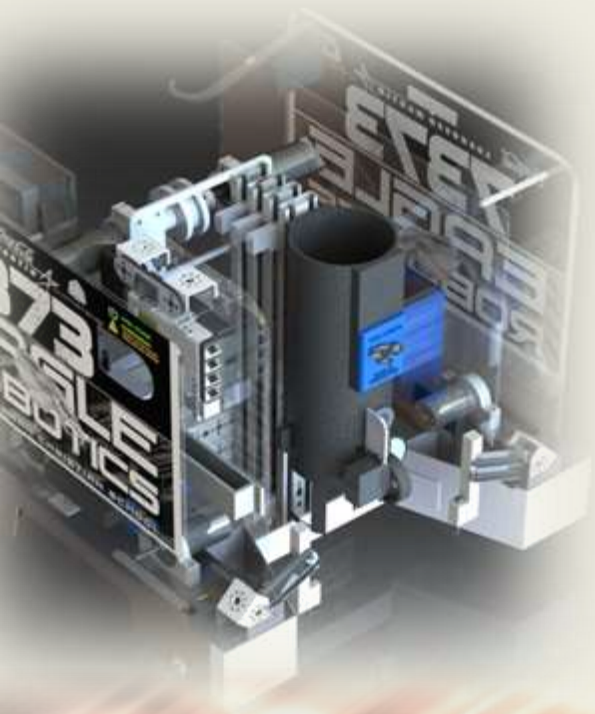
- Usually identified by someone other than the engineer.
- Customers are ultimately the judges
- Consider the product life cycle
 - Development: costs high and sales low
 - Peak demand: high profits
 - Obsolescence: declining sales and increasing costs

2. Define the Problem



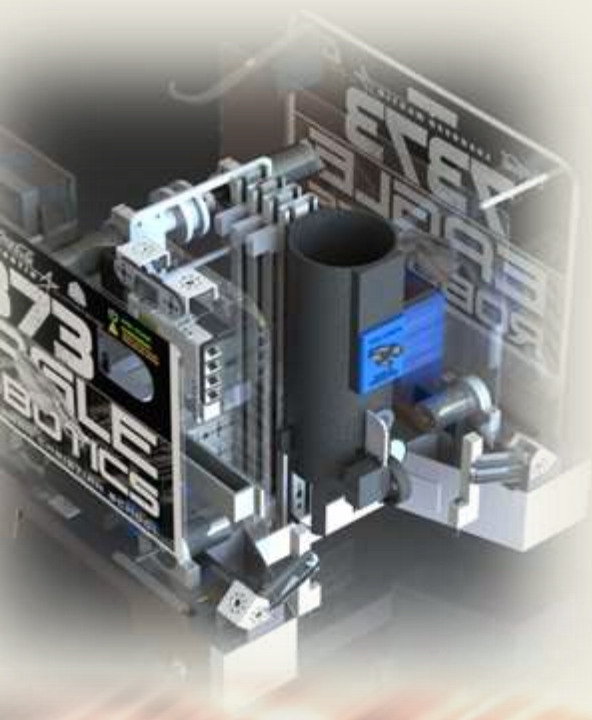
- **Clear statements of exactly what the problem is are essential to solving it.**
- If you can't express clearly what you're trying to solve, then you really can't have a clear picture about how to solve it.

3. Search



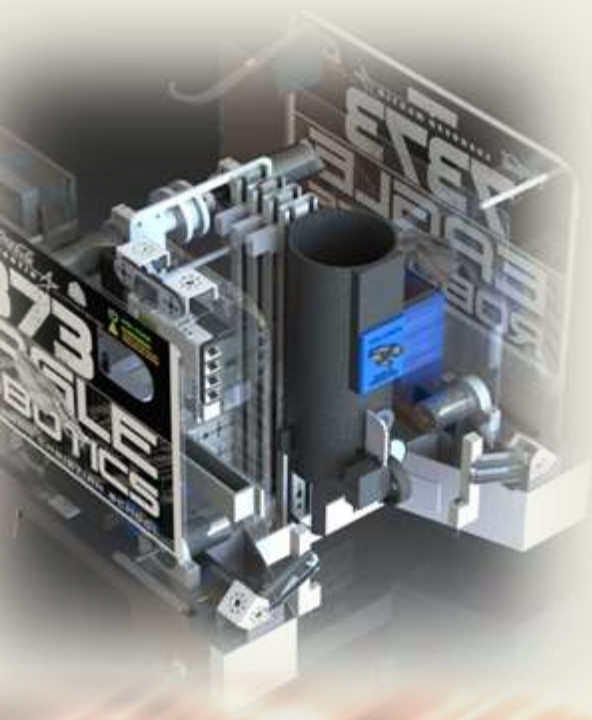
- All solutions begin with a fact-finding expedition
 - Has this problem been solved by someone else?
 - What solutions have been proposed or utilized previously?
 - What solutions are currently being implemented?

4. Constraints



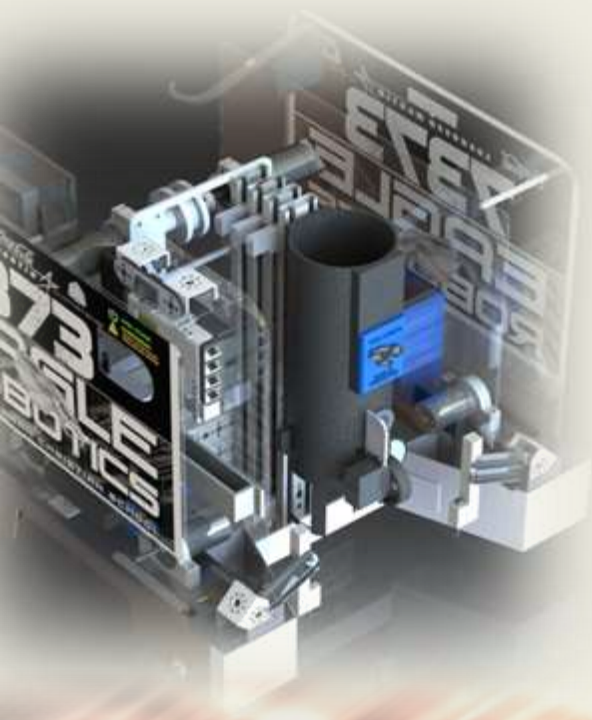
- *Constraints* are physical or practical limitations
- Examples
 - Maximum price to remain competitive
 - Standard household voltage
 - Size and weight for particular applications (laptop computer)
- *Boundary conditions* are limits or constraints imposed by engineering formulas (models) within a field of engineering.

5. Criteria



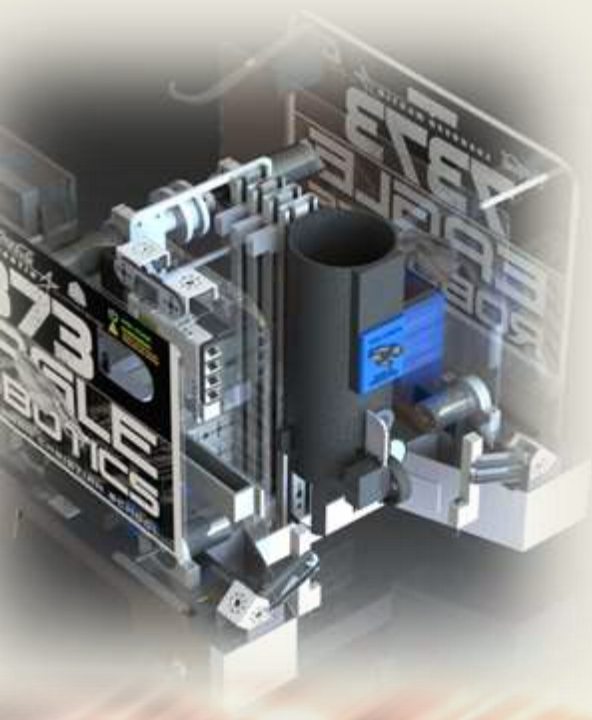
- *Desirable characteristics based on experience, research, market studies, and customer preferences*
- Might include cost, reliability, weight, ease of operation and maintenance, appearance, compatibility, safety features, noise level, effectiveness, durability, feasibility, and acceptance
- *Cost can be both a constraint and a criterion*

6. Alternative Solutions



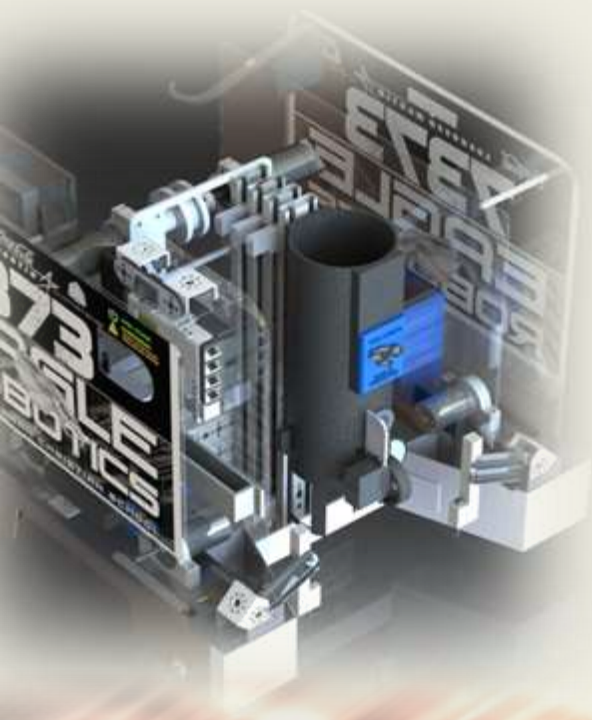
- *Must move past inhibitions and “conformity training”*
- *“If everybody is thinking alike, then somebody isn’t thinking” – General George Patton*
- Checkoff lists: different color, different shape, stronger or weaker, larger or smaller, longer or shorter, different material, modify, rearrange
- *Brainstorming*
 - *Optimal group size: 4-8 persons (NOT 24!)*
 - *Emphasis on freedom to express ideas*
 - *Everything recorded – evaluation comes later*

7. Analysis



- ***Use of mathematical, scientific and engineering principles to determine performance of possible solutions***
- Time, costs, and expertise are limiting factors in choosing methods for analysis
- Analysis might involve mathematical models, prototypes, or pilot plants along with statistics

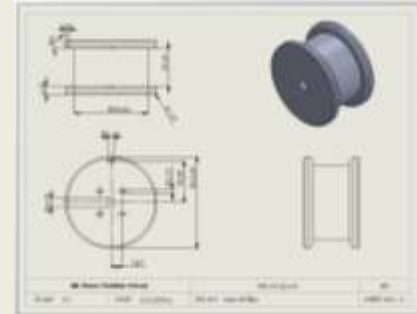
8. Decision



- Based on **optimization** – finding **the best solution** based on a short list of possible solutions
- Consider costs, materials, performance, manufacturability, and feasibility
- The criterion for the best solution is sometimes called the **payoff function**
- **Computation and testing often guides the best decision.**

9. Specification

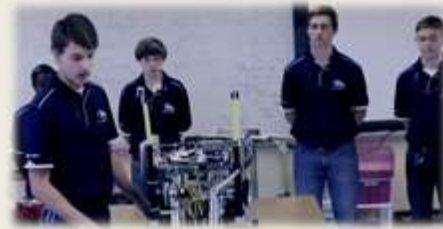
- *Involves clearly describing the solution for those who will fabricate and assemble the components.*
- Involves written, spoken, and graphical languages
 - Size and shape of each part
 - Subassembly and assembly drawings
 - Notes tolerances, specifications
 - Bill of Materials



ITEM ID	Part Description	QTY	Cost	Subtotal	MRP	Gene Rule / Parent Reference
1	Robot Frame	1	100.00	100.00	100.00	
2	Motor	2	50.00	100.00	100.00	
3	Gear	4	12.50	50.00	100.00	
4	Bracket	1	10.00	10.00	10.00	
5	Washer	2	5.00	10.00	10.00	
6	Washer	2	5.00	10.00	10.00	
7	Washer	2	5.00	10.00	10.00	
8	Washer	2	5.00	10.00	10.00	
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50	Washer	2	5.00	10.00	10.00	

10. Communication

- *Goal is to inform others of findings and developments*
 - *Convince decision-makers that the idea is worth development*
 - *Persuade management to go into production*
- Written reports – internal and external
- Oral presentations – high quality in speech and visuals





Design Process Example

1. Identify problems and opportunities
2. Frame a design brief
3. Investigate and research
4. Generate alternative solutions
5. Choose a solution
6. Developmental work
7. Model and prototype
8. Test and evaluate
9. Redesign and improve



Design and Problem Solving in Technology

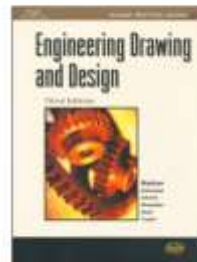
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Design Process Example

1. Identify the need
2. Define the criteria
3. Explore/research/investigate
4. Generate alternate solutions
5. Choose a solution
6. Develop the solution
7. Model/prototype
8. Test and evaluate
9. Redesign and improve



Engineering Drawing and Design (3rd edition)

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Design Process Example

1. Define the problem
2. Brainstorm
3. Research and generate ideas
4. Identify criteria and specify constraints
5. Explore possibilities
6. Select an approach
7. Develop a design proposal and model or prototype
8. Make a model or prototype
9. Test and evaluate the design using specifications
10. Refine the design
11. Create or make solution
12. Communicate processes and results



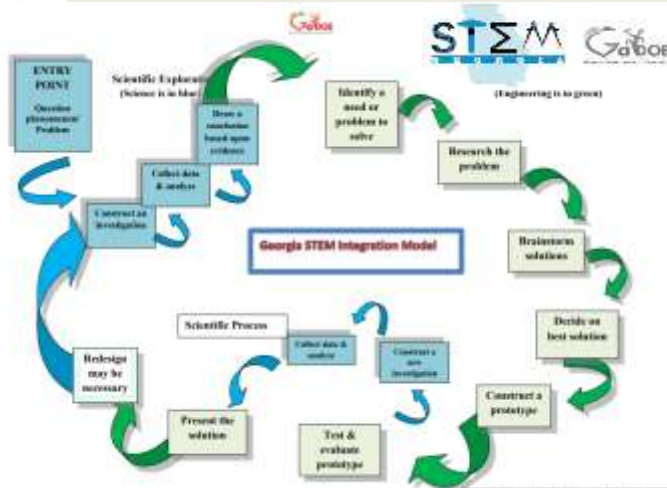
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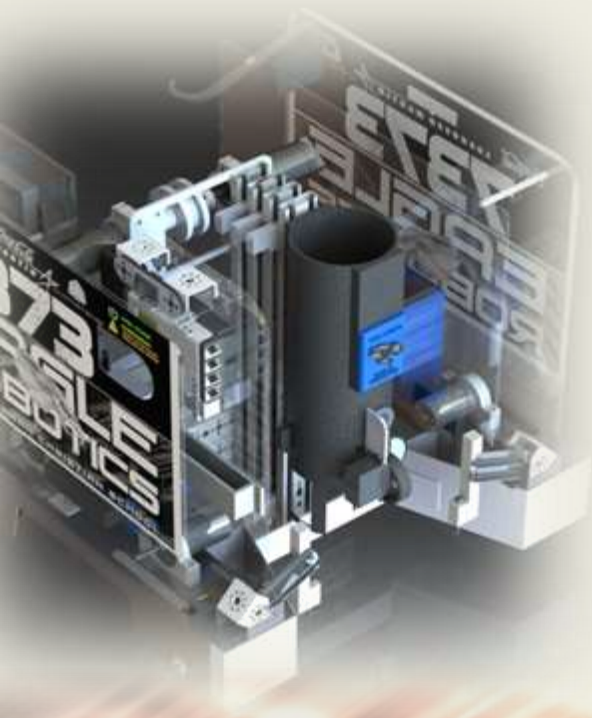


Developed by Dr. Juan Carlos Aguilar & Dr. Gailyn Lynn

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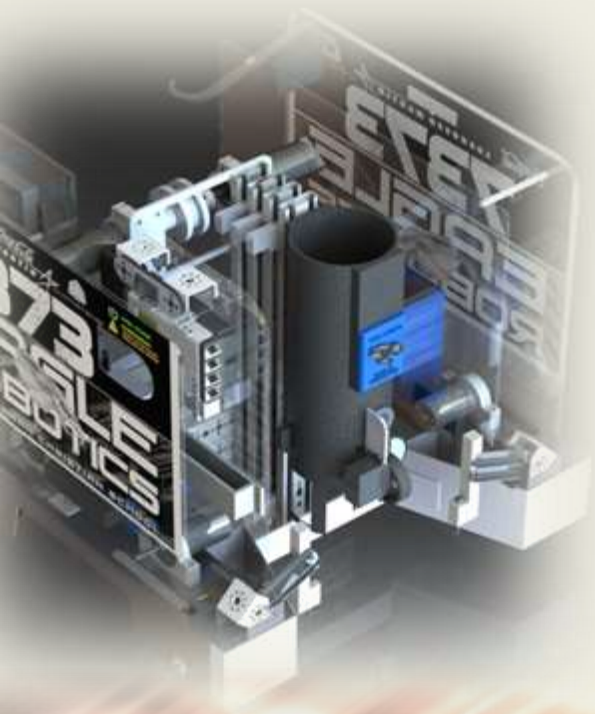
How do we utilize this cycle for FTC?

- Some elements are decided for you
 - For example, the “need” is defined by the game itself.



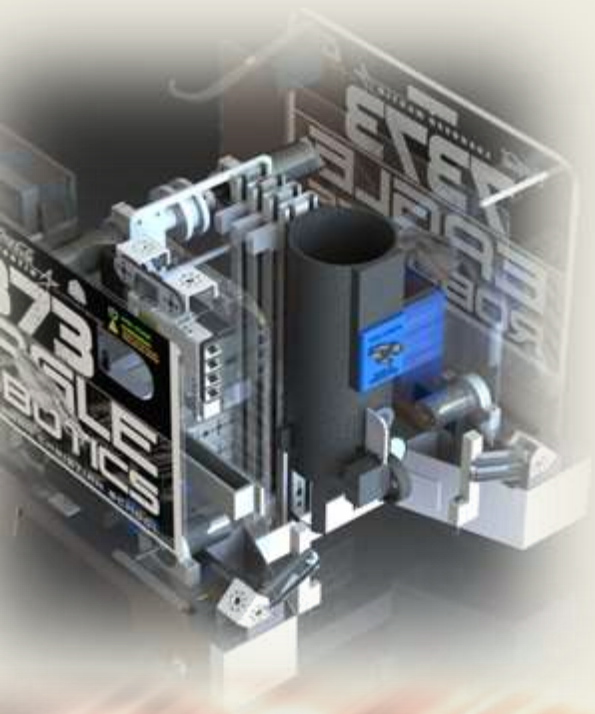
How do we utilize this cycle for FTC?

- Some elements exist, but need to be further refined
 - The problem(s) need(s) to be clearly stated



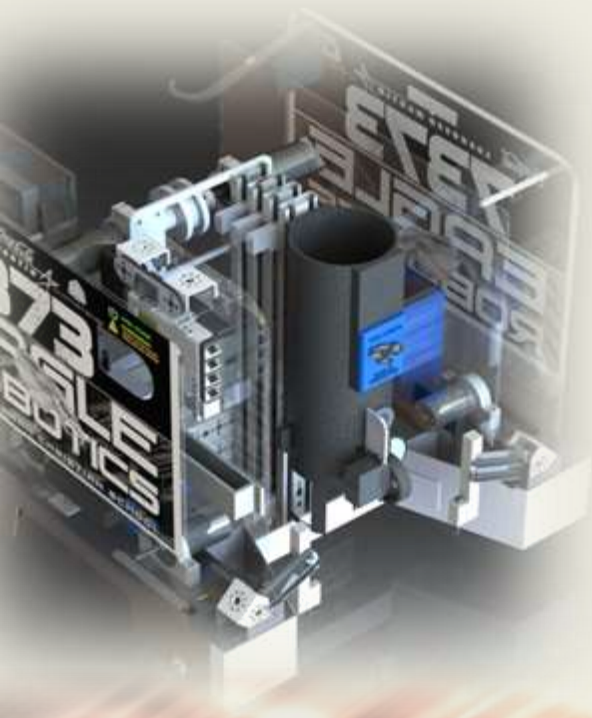
How do we utilize this cycle for FTC?

- Searching is encouraged, but severely limited by time, and search expertise of team members

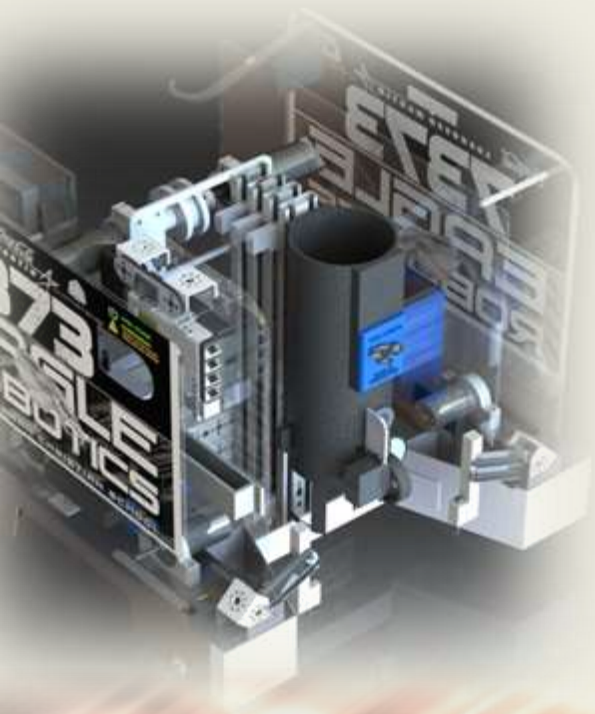


How do we utilize this cycle for FTC?

- ALL team members need to recognize the constraints in step 5
 - Time
 - Rules
 - Resources
 - Tools
 - Expertise



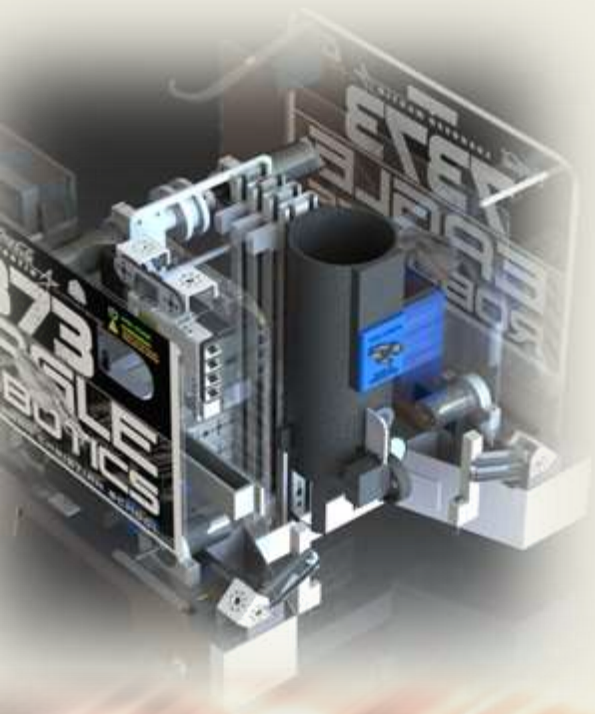
How do we utilize this cycle for FTC?



- ALL team members need to understand the brainstorming process for step 6.
 - Divergent thinking is encouraged
 - Ideas are not shot down at this stage
 - Clarity is essential

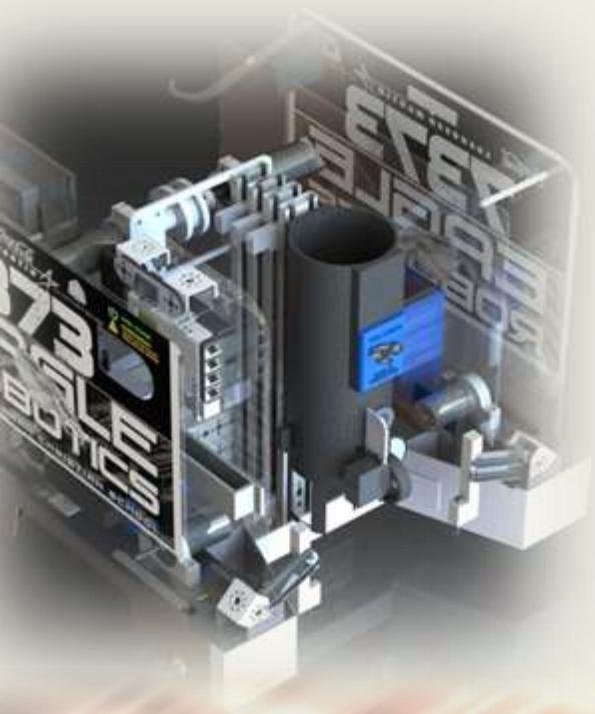
How do we utilize this cycle for FTC?

- **Results of proof-of-concept testing, prototyping, scale modeling, mathematical modeling, time and costs** must drive decisions that indicate performance of the best solutions.



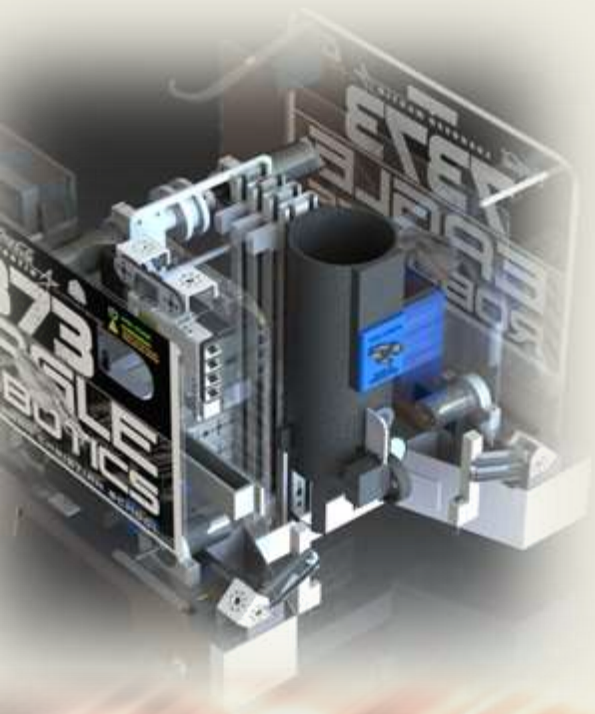
How do we utilize this cycle for FTC?

- ***Optimization*** is a decision of the team leadership. It is a difficult and weighty decision that affects the entire team. All factors bearing on the decision need to have been brought to the team's attention by this time.



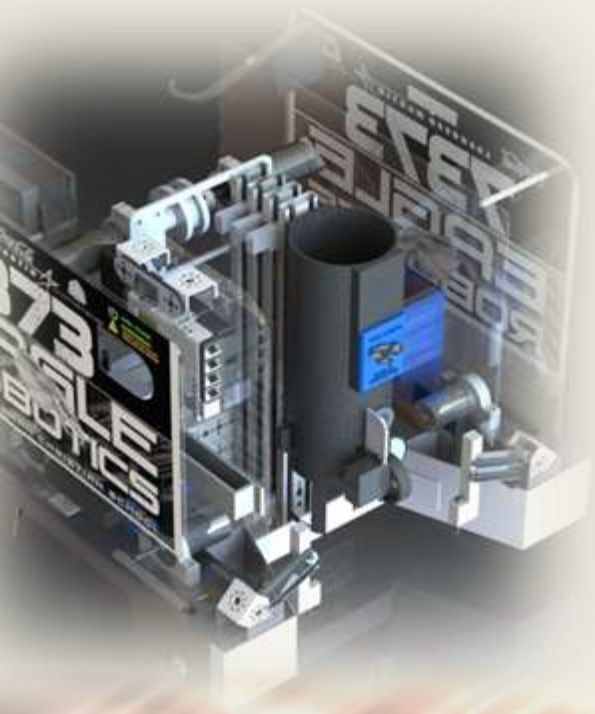
How do we utilize this cycle for FTC?

- ***Specification** is the responsibility of each contributing team member and division. Clarity and completeness of drawings and specifications are what is required to produce the optimized part or system in SolidWorks*



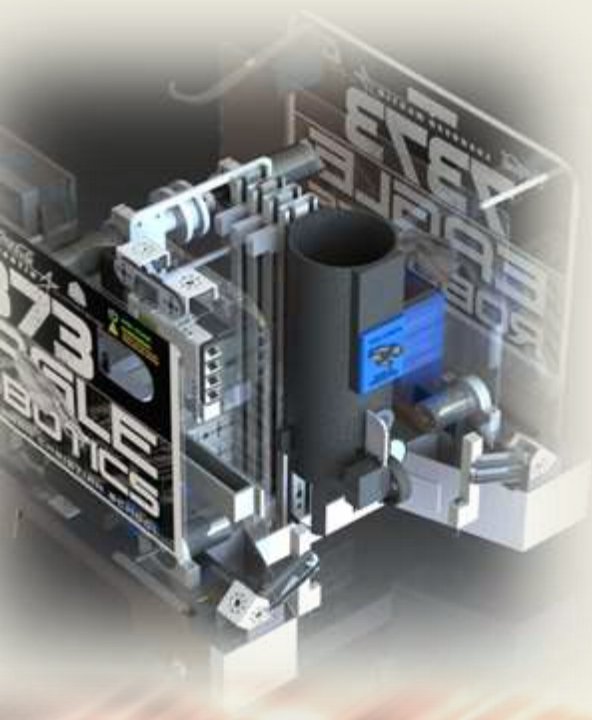
How do we utilize this cycle for FTC?

- **Communication** is the goal of each team member. Expressing an idea, or the superiority or inferiority of one idea vs. another is paramount. Written entries in the engineering notebook and high quality oral presentations for judging make or break us at competition.



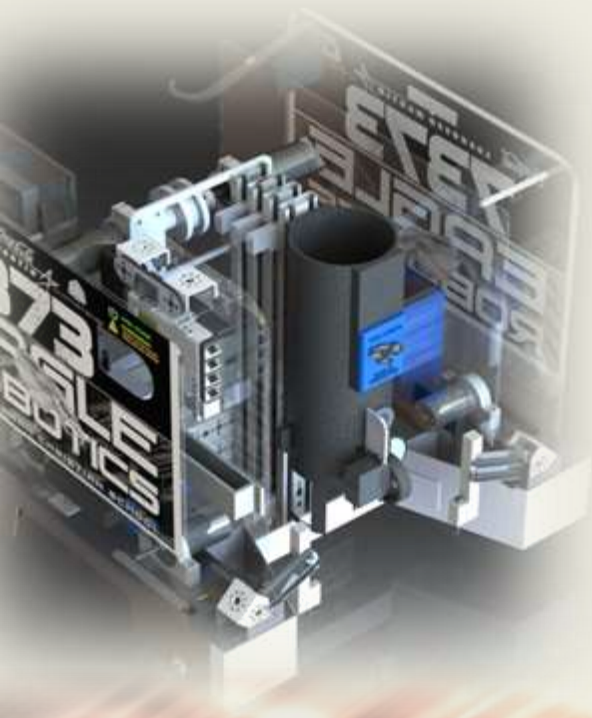
Do we have to do all this for FTC?

- ***Only if you want to win***
 - *One of the goals of FIRST and FTC is to recognize the engineering design process and “the journey” that a Team makes during the phases of the problem definition, concept design, system-level design, detailed design, test and verification, and production.*



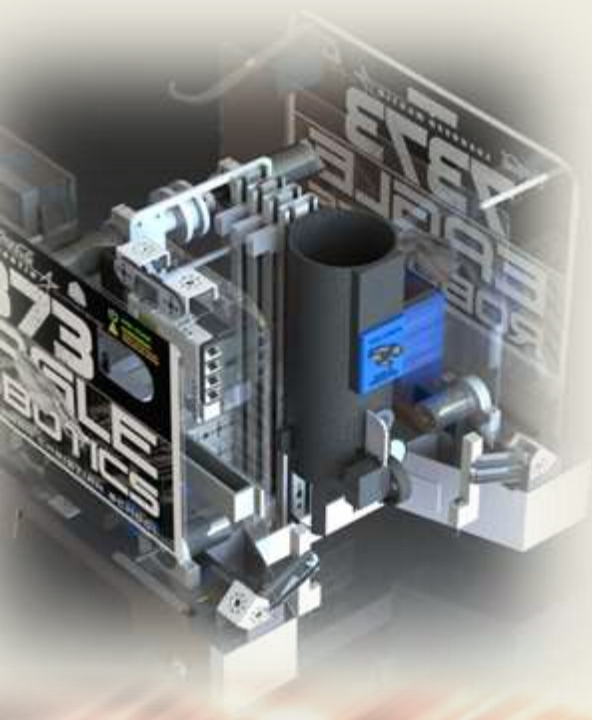
Do we have to do all this for FTC?

- ***Only if you want to win***
 - *Throughout the process of building and designing a Robot, Teams will come across obstacles, lessons learned, and the need to draw things out on paper. This is where Teams will use an Engineering Notebook. These notebooks follow the Team from kickoff throughout the Competitions. Judges review a Team's Engineering Notebook to better understand the journey, design, and Team as a whole.*



Do we have to do all this for FTC?

- ***Only if you want to win***
 - *The FTC Engineering Notebook is a complete documentation of the Team's Robot design. This documentation should include sketches, discussions and Team meetings, design evolution, processes, obstacles, and each Team member's thoughts throughout the journey for the entire season. A new notebook should be created for each new season.*



Do we have to do all this for FTC?

Engineering Notebook Requirements by Award

Inspire Award

Engineering Notebook must be submitted, and must include an Engineering Section, a Team Section and a Business or Strategic Plan. The entire Engineering Notebook must be high quality, thoughtful, thorough, detailed and well organized.

Think Award

Engineering Notebook must have an Engineering Section that includes entries describing underlying science, mathematics, and game strategies.

Engineering Notebook must demonstrate that the Team has a clear understanding of the engineering design process, with pictures or drawings and details documenting all stages of Robot design.

Notebook must recount the Team's journey, experience and lessons learned throughout the season.

Connect Award

An Engineering Notebook must be submitted and must include a Business or Strategic plan that identifies their future goals and the steps they will take to reach those goals. The plan could include fundraising goals, sustainability goals, timelines, outreach, and community service goals.

Do we have to do all this for FTC?

- ***Only if you want to advance***
 - **2. Inspire Award Winner**
 - 3. Winning Alliance Captain
 - **4. Inspire Award 2nd place**
 - 5. Winning Alliance, 1st Team selected
 - **6. Inspire Award 3rd place**
 - 7. Winning Alliance, 2nd Team selected
 - **8. Think Award Winner**
 - 9. Finalist Alliance Captain
 - **10. Connect Award Winner**

