ENGINEERING DESIGN PROCESS

FRC Team 1640 Sab-BOT-age
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  - Mentor – Team 1640 (2012-present)
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  - Student – Team 1640 (2010-2012, Co-captain & Driver 2012)
  - Mentor – Team 1640 (2012-present)
- Mechanical Engineering Student – Delaware County Community College
Engineering Design Process

- **What is it?**
  - Design new products
  - Iterate existing products
    - Make them better
  - Design systems
    - Large scale – manufacturing systems
    - Small scale – product subsystem
How does this apply to FIRST?

- IT’S WHAT WE DO!
- We use this process to design our robots and all of its’ subsystems
- Also award entries, business strategies, training, etc.

Circular, non-linear process

- Return to any point during the process

So, what exactly is it?

- Varies industry-to-industry, but the fundamentals are the same
Implementation and Iteration

Strategic Design

- Define the Problem
- Research
- Define Specs
- Brainstorm
- Prototype
- Choose
- Refine
- Design Review
- Implement
- Test
- Iterate

Engineering Design Process

Note: this separation is for this presentation series.
Define the Problem

- Beginning of Strategic Design
  - Define what you need to accomplish
  - What are this year’s objectives? Rules? Penalties?

- The objective is to UNDERSTAND the game inside and out and to determine possible game strategies

- For a more in-depth description of Strategic Design, please watch:
  - [https://www.youtube.com/watch?v=4ysSvxR-tAs](https://www.youtube.com/watch?v=4ysSvxR-tAs)
  - [https://www.youtube.com/watch?v=smWy7FQ8jLE](https://www.youtube.com/watch?v=smWy7FQ8jLE)

Define the Problem

- Create a Scoring Model
  - Define ALL tasks/actions
  - Define value for accomplishing tasks/actions
    - Some tasks/actions might not have a point value, but do have a time value
  - Define probability of completion for each task/action

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Seconds to Completion</th>
<th>Probability of Completion</th>
<th>Point Value</th>
<th>Cumulative Probability</th>
<th>Expected Value</th>
<th>Tele-Op Time (Sec)</th>
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</thead>
<tbody>
<tr>
<td>Time to Score High</td>
<td>10</td>
<td>75%</td>
<td>10</td>
<td>75%</td>
<td>7.5</td>
<td>140</td>
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<tr>
<td>Time to Hurdle</td>
<td>8</td>
<td>100%</td>
<td>10</td>
<td>100%</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>First Assist</td>
<td>10</td>
<td>80%</td>
<td>10</td>
<td>60%</td>
<td>6</td>
<td></td>
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<tr>
<td>Second Assist</td>
<td>10</td>
<td>75%</td>
<td>20</td>
<td>45%</td>
<td>9</td>
<td></td>
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<tr>
<td>Ball Return Time</td>
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<td>100%</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td></td>
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<tr>
<td>Catch</td>
<td>15</td>
<td>10%</td>
<td>10</td>
<td>10%</td>
<td>1</td>
<td></td>
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<table>
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<tr>
<th>Resulting Teleop Scores</th>
<th>Best Case Score</th>
<th>P(Best Case)</th>
<th>Expected Value</th>
<th>Grade</th>
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<tr>
<td>One Robot Scoring</td>
<td>70.00</td>
<td>75%</td>
<td>52.50</td>
<td>Bad</td>
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<tr>
<td>One Robot Hurdle &amp; Score</td>
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<td>75%</td>
<td>87.50</td>
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<td>One Assist, Score</td>
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<td>60%</td>
<td>63.00</td>
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<td>One Assist, Hurdle &amp; Score</td>
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<td>60%</td>
<td>86.58</td>
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<td>6%</td>
<td>64.72</td>
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<tr>
<td>Two Assist, Score</td>
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<td>5%</td>
<td>74.44</td>
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Define the Problem

- Develop game strategies
  - Decide on a game strategy utilizing your scoring models and determine all possible game strategies
  - LET THIS STRATEGY GUIDE YOUR DESIGN!!!
    - Don’t let your design dictate your strategy!
  - What happens when your strategy has to play with other strategies? With the same strategy? Against your strategy? Against other strategies?
Research

- See what has been done in the past to accomplish this task
- FIRST games may share similarities with previous games
Research

- Look in industry to find inspiration
- Look on the web
  - Chief Delphi
  - FRC Designs
  - The Blue Alliance
  - VEX/FTC
  - Google
Define Specifications

- This is where we start to define WHAT we want to do

- Two types of specifications:
  - **Design Constraints**
    - Specifications that the robot MUST follow
      - Max height; Max weight; # of motors; follow all rules; must be manufacturable; Can’t reach # outside from robot; Is within budget; etc.
  - **Functional Requirements**
    - What the team believes the robot should be able to do
      - Hold # of game pieces; Mechanism can lift # tall; Mechanism is # fast; etc.
    - Expand these requirements with what you Wish, Prefer, and Demand the robot be able to do
Brainstorm

- Moving into Mechanism Design (separate PowerPoint will elaborate on these parts of the process)
- Begin to determine HOW to accomplish specs and perform strategy
- Napkin Sketches
- Utilize your research
Prototype

- Create some of the concepts from brainstorm
- Collect data from the prototypes **under real-world conditions**
  - Doesn’t matter if it can hold 1000 of a game piece if it can’t score them in the allotted game period
- Begin to utilize CAD if necessary
  - Makes choosing/designing the final product easier in the long run
- Try to see if your specs will work or need tweaking
- Try to find any critical components to the design
- DON’T MAKE THE PROTOTYPES “Yours”; they’re the team’s prototypes
- Record all successes and failures and iterate the prototypes
Choose

- Can’t prototype forever
- Need to pick a direction
- How?
  - Put prototypes against each other using QUANTITATIVE data
  - Do they meet the specifications? How well do they meet them? Can they meet them better?
  - Weighted-Objectives Table
- DON’T PERSONALIZE the designs!
Weighted-Objectives Table

- Use specifications
  - Add weight to specs based on importance to strategy/team
- Give the prototypes a value for each specification
  - Based on the quantitative data
- Multiply these values by the weight and sum the resulting values
Refine

- Begin to design the final product
  - Utilize CAD!
  - Math and Physics!
  - Make sure you can make it!

- Determine design calculations
  - Someone might have done it before – see what you can find
  - Excel is your friend!
When designing the final product, keep in mind:

- **Modular design**
  - Quickly and easily replaceable parts
- **Interchangeable replaceable parts**
  - No “left side” or “right side” parts
- **Robustness**
  - FIRST is a contact sport
- **Serviceability**
  - If parts need to be repaired on-robot, make sure hands and tools can get where they need to be
- **Don’t go overboard with different sizes and types of hardware**
  - Using only a few sizes and types of nuts, bolts, washers, etc. reduces the number of tools and spare hardware needed at competition
Design Review

- Review your design
  - Minimum: with student leads and mentor leads
  - Maximum: with entire team (can be too much)
  - Go over why design decisions were made
  - Address any potential design issues
  - Address potential critical design points
  - Does it meet the specs?
Implement

- Time to put everything together
- Systems integration
  - Put your robot together
  - See if any designs interfere with each other
    - Should have been done in CAD before, but might have missed it
Test

- MAKE SURE EVERYTHING WORKS
- If not, what can be done to make it work?
  - Does it really need to be completely redesigned?
  - Are you sure?
- Let it run under it’s own power and it’s own code (if ready)
- See if it meets the specifications and see if it can complete the strategy
Iterate

- Can it work better? More efficiently? Faster?
- Can it be lighter?
  - Is it possible to make it lighter?
- Does it meet all the specifications?
  - What can we do to make it meet the specs?
- Restart the process when/where necessary
Some Notes

- Don’t make designs/prototypes personal
  - That makes choosing personal

- Use quantitative data when choosing
  - Don’t pick a design because you “feel it’ll work” or because you “want this design”
  - This and/or the first point will degrade the choosing process until it becomes a screaming match, which is NOT how a design is chosen

- Remember: GP applies all the time!
Some Notes

- Don’t design something that you can’t make
- Only given 6 weeks and 3 days!
- Make sure you can assemble the systems and put them on the robot
  - If parts need to be welded to the chassis, then that needs to be determined and conveyed ASAP
- Make sure parts can be repaired
  - Things break
  - Murphy’s Law (Stuff happens at the worst possible moment)
- Try not to start brainstorming immediately after kickoff
  - Understand the game and define your strategy first
Questions?
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