ENGINEERING DESIGN PROCESS

FRC Team 1640 Sab-BOT-age

Rev. 2

Andrew Weissman

- 7 years in FRC (10 years in FIRST)
  - Student – Team 1640 (2010-2012, Co-captain & Driver 2012)
  - Mentor – Team 1640 (2012-present)
  - Lead CAD Mentor – Team 1640 (2015-present)
- Associate of Science in Engineering – Delaware County Community College
- Mechanical Engineering Student – Pennsylvania State University – Brandywine Campus

Quotes

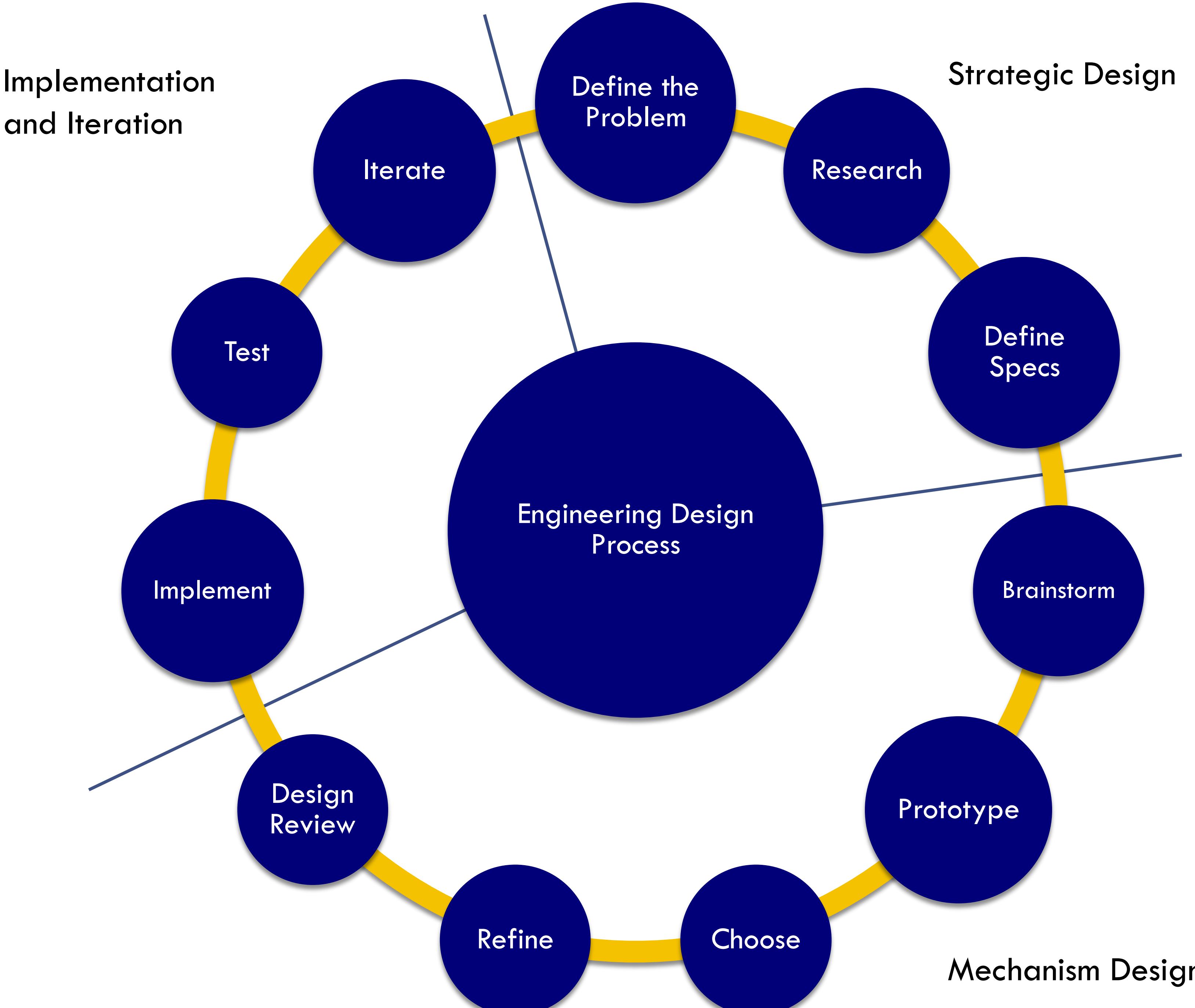
- *"Gentlemen, we are going to relentlessly chase perfection, knowing full well we will not catch it, because nothing is perfect. But we are going to relentlessly chase it, because in the process we will catch excellence. I am not remotely interested in just being good."* – Vince Lombardi
- *"If you want creative workers, give them enough time to play."* – John Cleese
- *"Any sufficiently advanced technology is indistinguishable from magic."* – Arthur C. Clarke's Third Law
- *"Every revolutionary idea — in science, politics, art, or whatever — seems to evoke three stages of reaction. They may be summed up by the phrases:(1) "It's completely impossible — don't waste my time"; (2) "It's possible, but it's not worth doing"; (3) "I said it was a good idea all along." "* – Arthur C. Clarke's Law of Revolutionary Ideas

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

Engineering Design Process

- 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, grant-writing, demo preparation, 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



Note: this separation is for this presentation series.

Strategic Design

- Define the Problem
- Research
- Define Specifications

Define the Problem

- ***READ THE RULES!!!!!***
- 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 [1]
  - https://www.youtube.com/watch?v=smWy7FQ8jLE [2]

1: Kanagasabapathy, K. (Director). (2014, October 8). *Simbot Seminar Series - Strategic Design* [Video]. Youtube.
2: FIRST. (Producer), & Kanagasabapathy, K. (Director). (2013, November 6). *FRC Ask an Expert: Effective FIRST Strategies with Karthik* [Video]. Youtube.

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

Inputs	Seconds to Completion	Probability of Completion	Point Value	Cumulative Probability	Expected Value		Tele-Op Time (Sec)
Time to Score High	10	75%	10	75%	7.5		140
Time to Hurdle	8	100%	10	100%	10		
First Assist	10	80%	10	60%	6		
Second Assist	10	75%	20	45%	9		
Ball Return Time	10	100%	0	100%	0		
Catch	15	10%	10	10%	1		
Resulting Teleop Scores	Best Case Score	P(Best Case)	Expected Value				
One Robot Scoring	70.00	75%	52.50	Bad			
One Robot Hurdle & Score	100.00	75%	87.50	Great			
One Assist, Score	93.33	60%	63.00	Bad			
One Assist, Hurdle & Score	110.53	60%	86.58	Great			
One Assist, Hurdle, Catch & Score	105.66	6%	64.72	Bad			
Two Assist, Score	140.00	45%	78.75	Okay			
Two Assist, Hurdle & Score	145.83	45%	94.79	Great			
Two Assist, Hurdle, Catch & Score	133.33	5%	74.44	Okay			

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
  - Stronghold (2016), Aerial Assist (2014), Breakaway (2010) & Overdrive (2008)
  - Ultimate Ascent (2013), Rebound Rumble (2012), Aim High (2006) & FIRST Frenzy (2004)
  - Logomotion (2011), Rack 'N' Roll (2007) & Triple Play (2005)
  - Recycle Rush (2015) & Stack Attack (2003)

Research

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

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

Mechanism Design

- Brainstorm
- Prototype
- Choose
- Refine
- Design Review

Brainstorm

- Begin to determine HOW to accomplish specs and perform strategy
- Napkin Sketches/Crayola CAD
- Utilize your research
- Keep in mind:
  - Rules
  - Reality
  - Physics
  - Strategy
  - Requirements

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 teams' 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

Weighted-Objectives Table Ex.

2014 Game Weighted-Objectives Table

		Slingshot		Catapult (Elastic) (Low)		Catapunt (Elastic) (High)		Catapult (Motor)		Linear Launcher / Roller Claw	
	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Complexity (Higher is less complex)	5	8	40	7	35	8	40	8	40	4	20
Range (Allowing Driver Error)	5	4	20	6	30	10	50	7	35	10	50
Safety	15	9	135	4	60	4	60	8	120	6	90
Autonomous	10	3	30	8	80	9	90	5	50	8	80
Space	2	4	8	4	8	3	6	3	6	1	2
Ball Containment	10	9	90	5	50	7	70	6	60	10	100
Weight	3	8	24	8	24	6	18	5	15	2	6
Height	10	9	90	4	40	9	90	4	40	2	20
Total	60	54	437	46	327	56	424	46	366	43	368

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!
- KISS!
  - *"Keep It Simple, Stupid"* – Kelly Johnson
  - Simple parts/assemblies are easier to make/control/repair/upgrade than complex parts/assemblies

Refine

- 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?
  - Can it be made with tools available?
  - Is there an easier/simpler way?
  - Will it fit with everything else (CAD)?

Implementation and Iteration

- Implement
- Test
- Iterate

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

Final Thoughts

- 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!

Final Thoughts

- Don't design something that you can't make
  - Likewise, don't make something that you can't test off-robot
    - Off-robot testing allows programmers to refine code without taking the full robot
    - Ultimately helps your team have everything ready for the first competition
- 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?

Contact

- Andrew Weissman
  - drewittheroboteer@gmail.com
- Team 1640
  - Facebook
    - Sab-BOT-age: FIRST Robotics Team 1640 (Sabotage)
  - Twitter - @FRC1640
  - Instagram - @frc1640
  - FRC1640@gmail.com
  - Team Website

Thank you!

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Revision 1 Slide Changelog

Mike Geldart

- 6 Years involved in FRC
  - Student – Team 1902, 2614
  - Mentor – Team 1640 (2012-2015)
- Former Engineering Student – Delaware County Community College
- Aerospace Engineering Student – Embry Riddle Aeronautical University – Daytona Beach, Florida