ENGINEERING DESIGN PROCESS

FRC Team 1640 Sab-BOT-age

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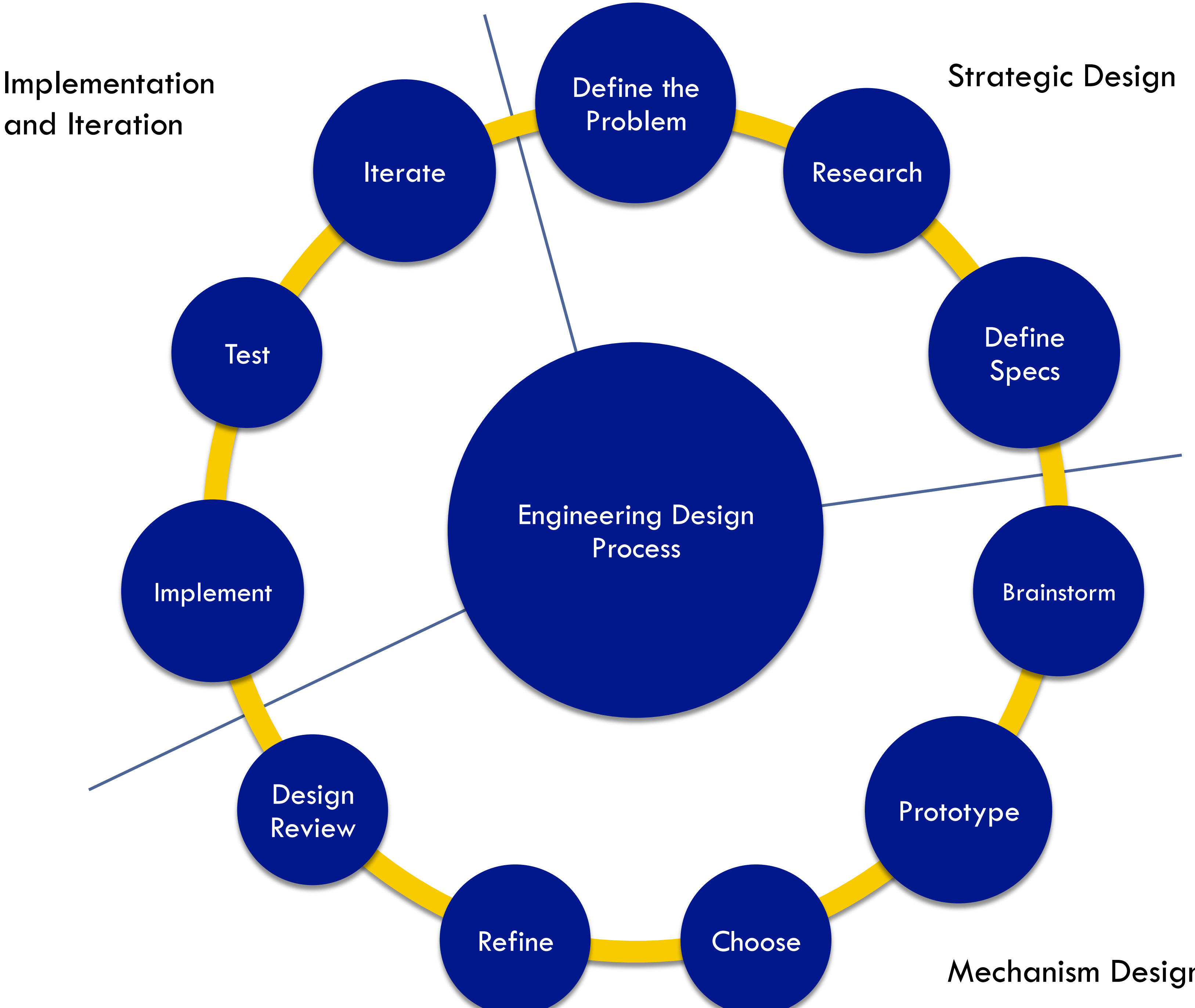
Engineering Design Process

- 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, 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.

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 [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 Probablility	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
  - 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)

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 <u>under real-world conditions</u>
  - 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 prototpes
- 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

		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!

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?

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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