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Systems Engineering

Beach Cities Robotics – Team 294

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June 2009

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Sources of Inspiration

- “Systems Engineering”
  - Rick Roberts – Beach Bot – Team 330
- “How Useful is QFD?”
  - John L Sanford – Thunderhawks – Team 1038

- Special Thanks to
  - Ed Debler – Thunder Chickens – Team 217

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Topics

- Systems Engineering
- BCR Design Process
- Q & A

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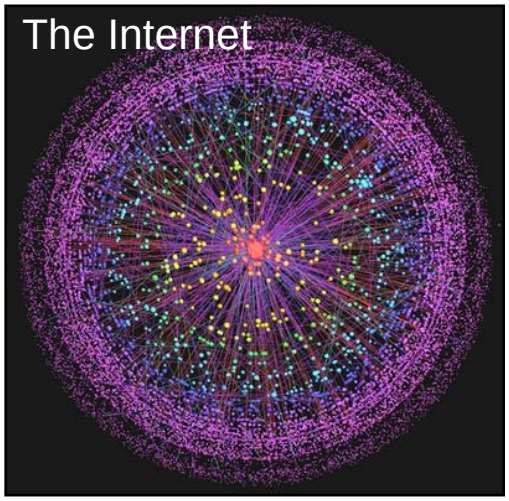
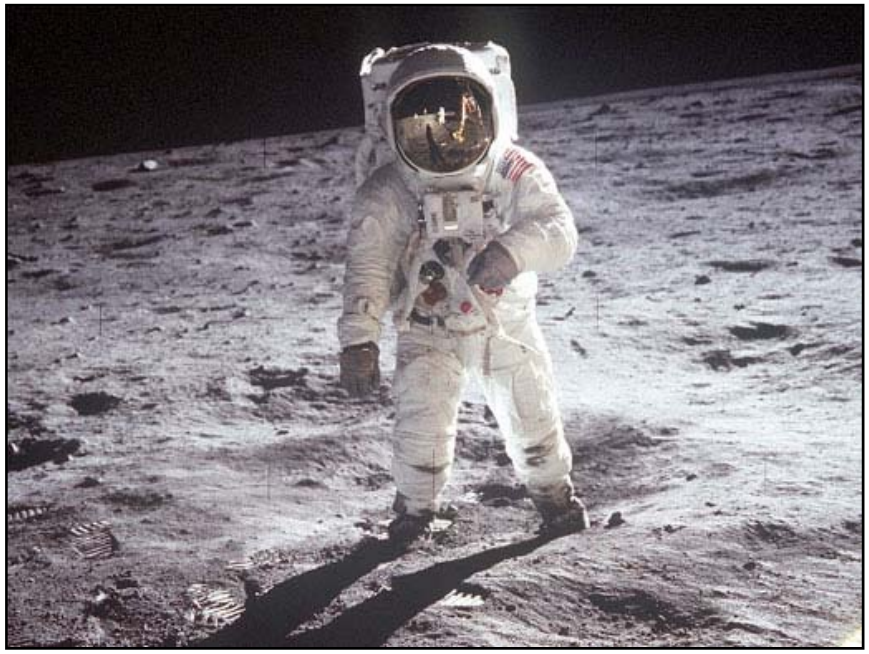
Systems Engineering

- How do you accomplish the following?
- Where do you start?





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Systems Engineering

- How do you accomplish the following?
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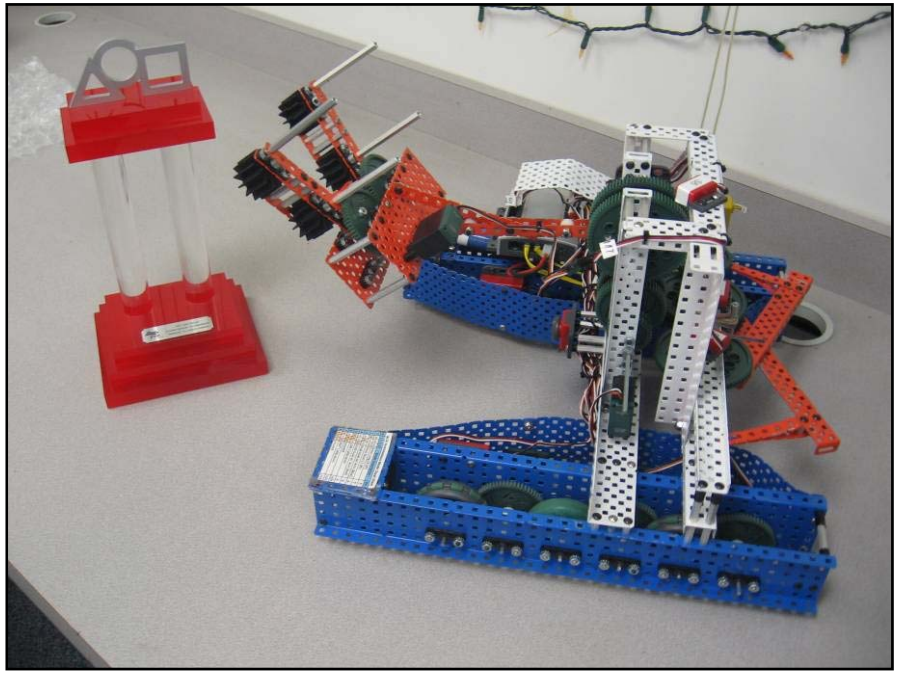

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Systems Engineering

- Systems engineering is the branch of engineering concerned with the development of large and complex systems, where a systems is understood to be an assembly of combination of interrelated elements of parts **working together toward a common objective**.

-University College London

Building a robot is not an objective!

Building a robot to move and pick up 3” cubes from the floor, store 5 internally and discharge them one at a time in goals ranging from 3” to 21” tall is!

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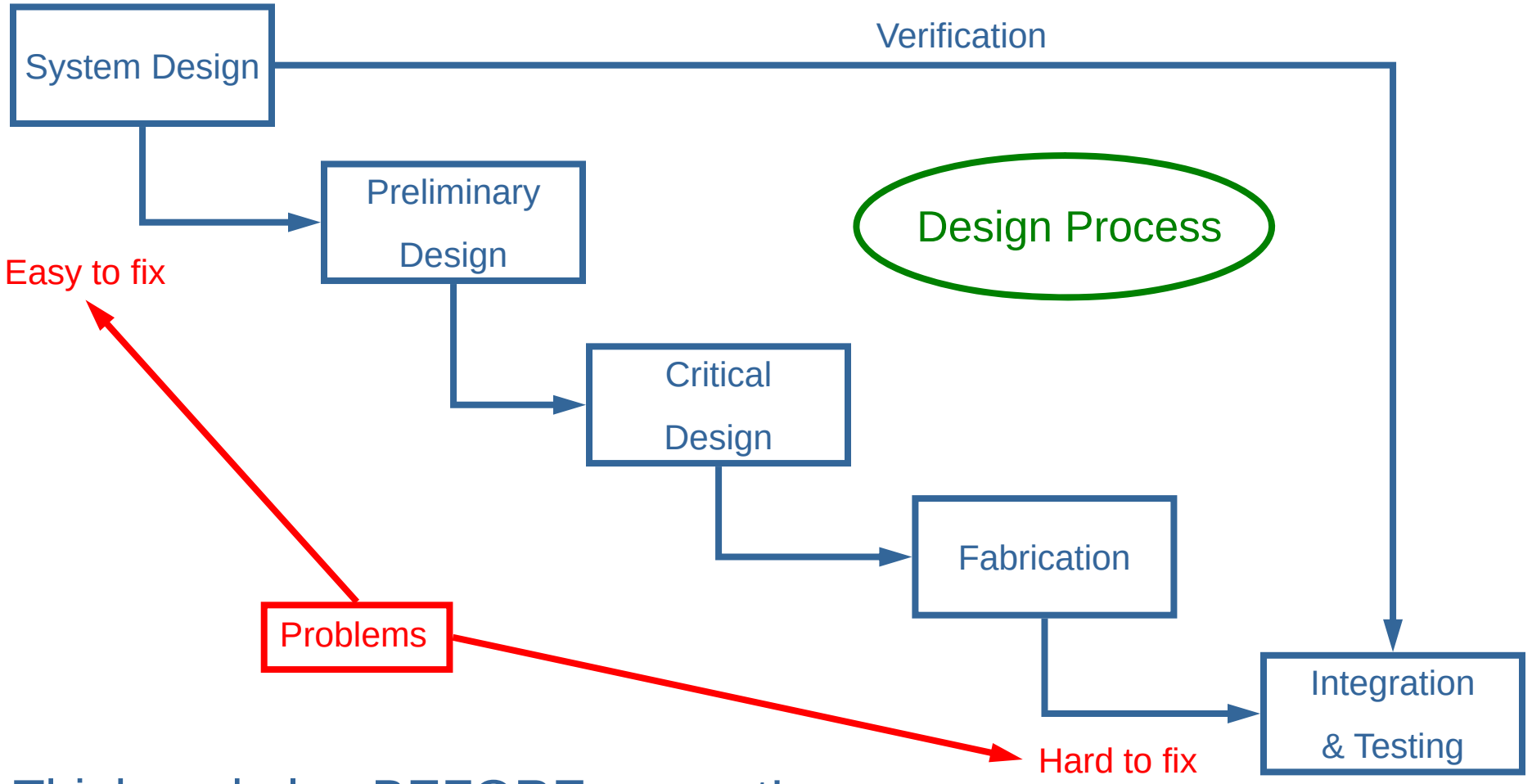
Systems Engineering



Think and plan BEFORE you act!

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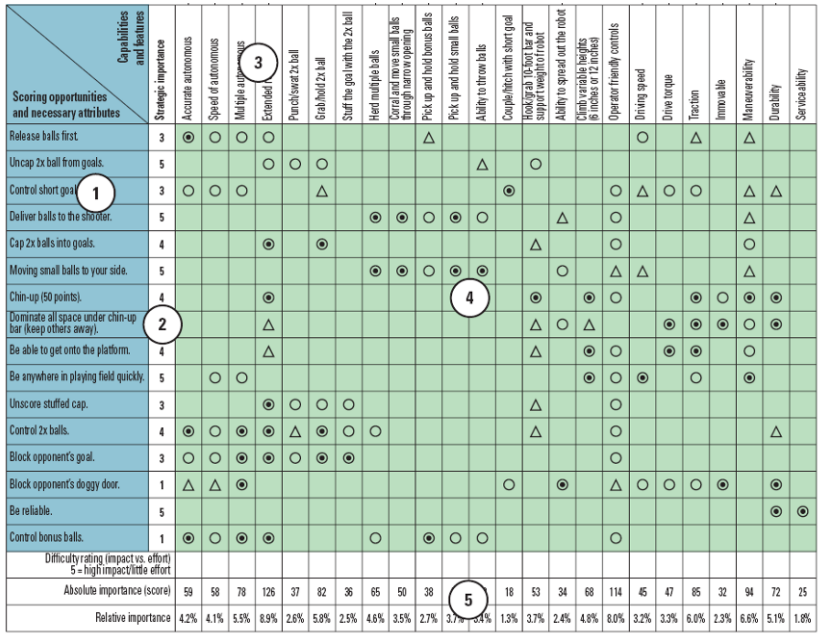
BCR Design Process

Quality Function Deployment

- A scientific method to evaluate design and strategy
  - Pioneered by Yoji Akao at Mitsubishi



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BCR Design Process

1. Watch the Kickoff Video
2. Read and Understand the Rules
3. Analyze the Game
4. Simulate the Game (Chess style)
5. Generate Task List
6. Determine Strategic Importance
7. Research and Discuss Proven Solutions
8. Brainstorm Whole Robot Concepts
9. Determine Concept Effectiveness of Tasks (ie Fill in Matrix)
10. Determine Top Design Concepts
11. Refine Top Design and Re-evaluate

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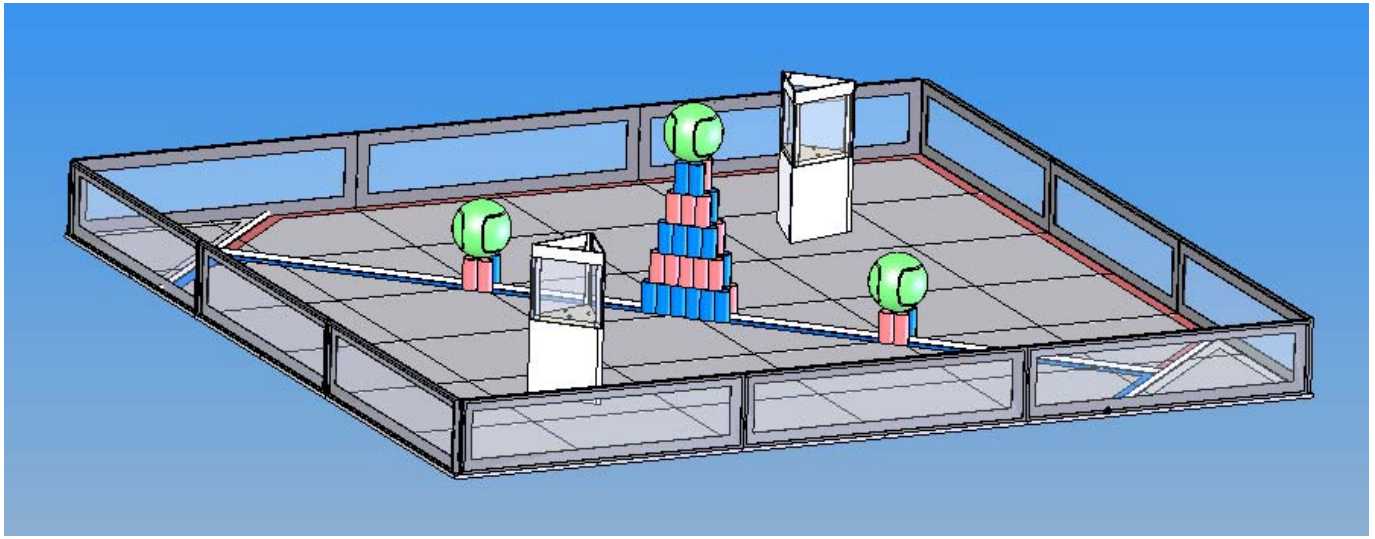
BCR Design Process

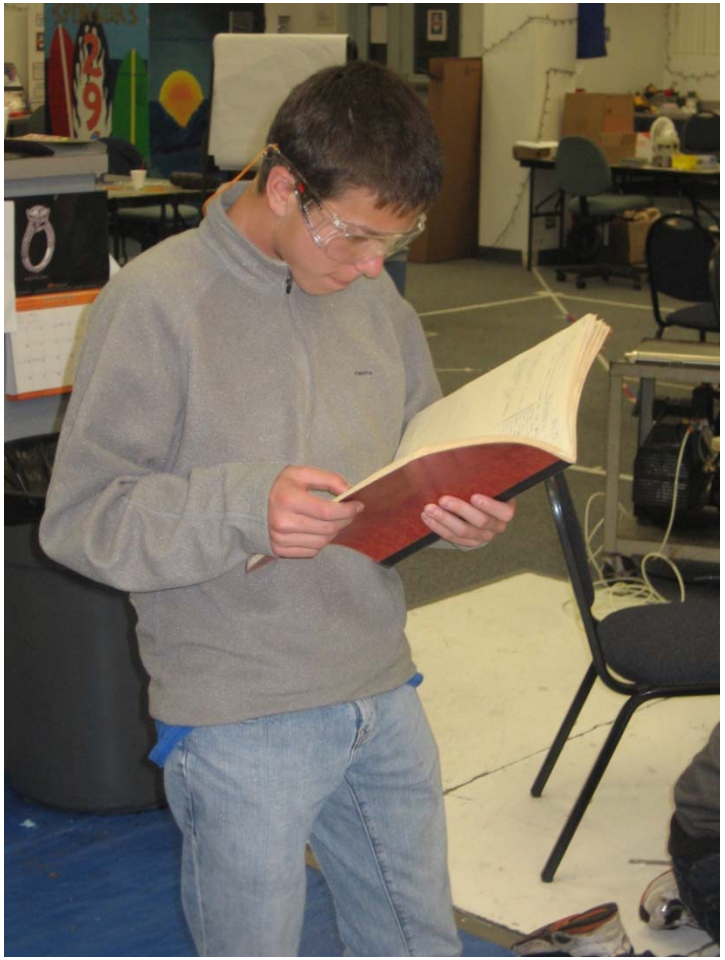
1. Watch the Kickoff Video
    - How big is the field?
    - How many teams are playing?
    - What objects are on the field?
    - Can robots interact with other robots?
    - What general tasks do you need to perform?



Objective: Have a basic understanding of the game

BCR Design Process

2. Read and Understand the Rules
   - In small groups, read the rules aloud
     - “Read” what the rules don’t say
     - If the rules don’t say, it’s legal
   - Discuss the rules
     - What can you do?
     - What can’t you do?
     - What is illegal?
     - Where are the gray areas?
     - What questions need to be elevated to the game designers?



Objective: Understand all nuances of the rules

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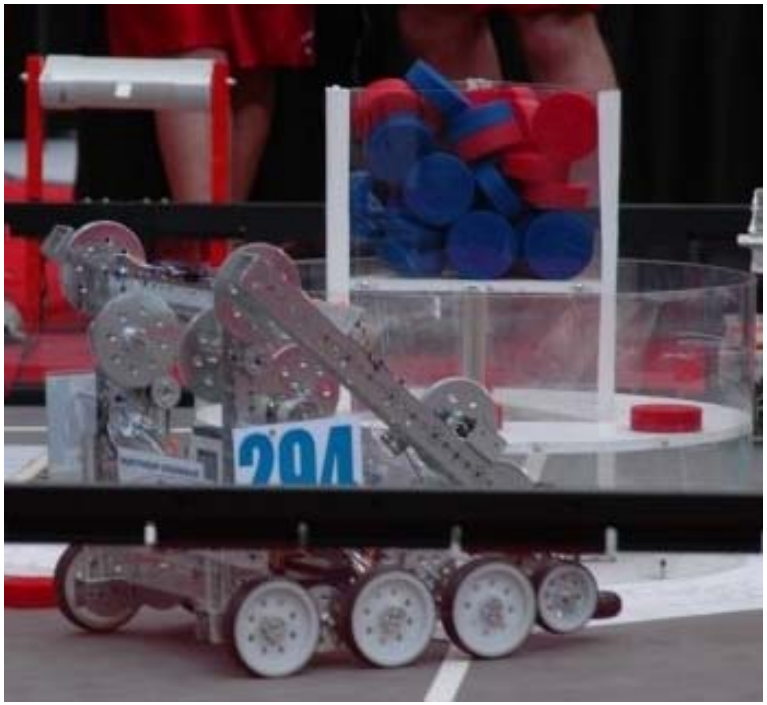
BCR Design Process



3. Analyze the Game
    - Determine the maximum score possible
        - Maximum autonomous score
        - Maximum tele op score
    - Determine importance – or lack thereof – of autonomous
    - Determine maximum capacity of goals or other game objects
    - Rank game piece by strategic importance
    - Brainstorm possible auto/beginning/middle/end game strategies
    - Create a list of scoring differential opportunities
        - Defense is a ‘scoring’ opportunity

Objective: Determine most advantages scoring strategy

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BCR Design Process

4. Simulate the Game (Chess Style)
   - Use robot analogues (you!)
   - Simulate autonomous period and teleop
   - Alternate turns between alliances and ‘robots’
     - Red 1, Blue 1, Red 2, Blue 2, Red 3, Blue 3 and repeat
   - Each ‘turn’ simulates ~10-15 seconds of real time action
     - Picking up game objects counts as a turn
     - Blocking another robot counts as a turn and prevents the blocked robot’s next turn
     - Scoring one or more objects in one goal counts as a turn
   - Set realistic limitations
     - Can only store X game objects
     - Can or cannot descore game objects
   - Be creative and test out different strategies

Objective: Dynamically test game strategies

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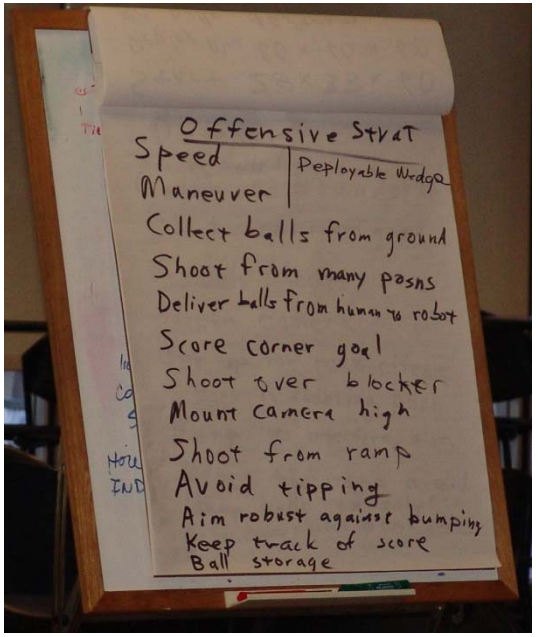
BCR Design Process



5. Generate Task List
   - Generate the list as you simulate the game
   - Whenever someone does something new, write it down
   - Be specific when possible
     - List ‘Score in 21”goal’ instead of ‘Score in goal”
     - List ‘Shoot ball over overpass while in motion’ instead of ‘Toss over overpass’
     - List ‘Drive over ‘rough’ terrain’ instead of ‘Drive across field’
   - Simulating will <u>not</u> produce every task
     - Brainstorm after every simulation other possible tasks
   - List every task that comes to mind
     - Do <u>not</u> disregard an idea because you think it’s trivial

Objective: List all possible tasks within the game

BCR Design Process

6. Determine Strategic Importance
   - Evaluate each task and assign it a weight
     - Scale 1 to 5 (1 = low; 5 = high)
   - Ensure the there is a good distribution of weights
     - 9 5's, 3 4's, 1 3's, 2 2's, and 5 1's is not a good distribution
   - Obtain unanimous support
     - If done correctly, everyone should nod in agreement when completing this sentence…
       - If all we did was [read out the 5's] then we would do well in the competition.

IMPORTANT: Break after completion.

Send everyone home to do the next 2 tasks as homework.

Objective: Assign strategic importance to task list

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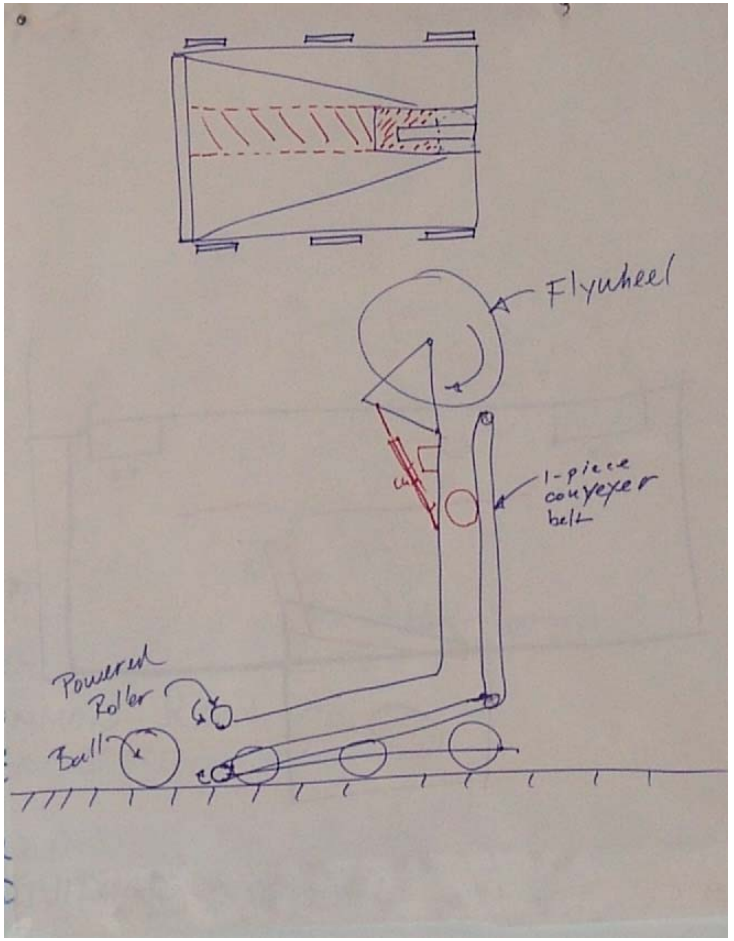
BCR Design Process

7. Research and Discuss Proven Solutions
   - Find designs that manipulate similar objects well
     - Previous FIRST competitions
     - Common industrial application
     - Evaluate why they work well
   - Find designs that manipulated similar objects poorly
     - Previous FIRST competitions
     - Evaluate why they didn't work well
   - Good resources…
     - www.chiefdelphi.com
     - www.vexrobotics.com

Objective: Receive design inspiration and avoid common mistakes

BCR Design Process

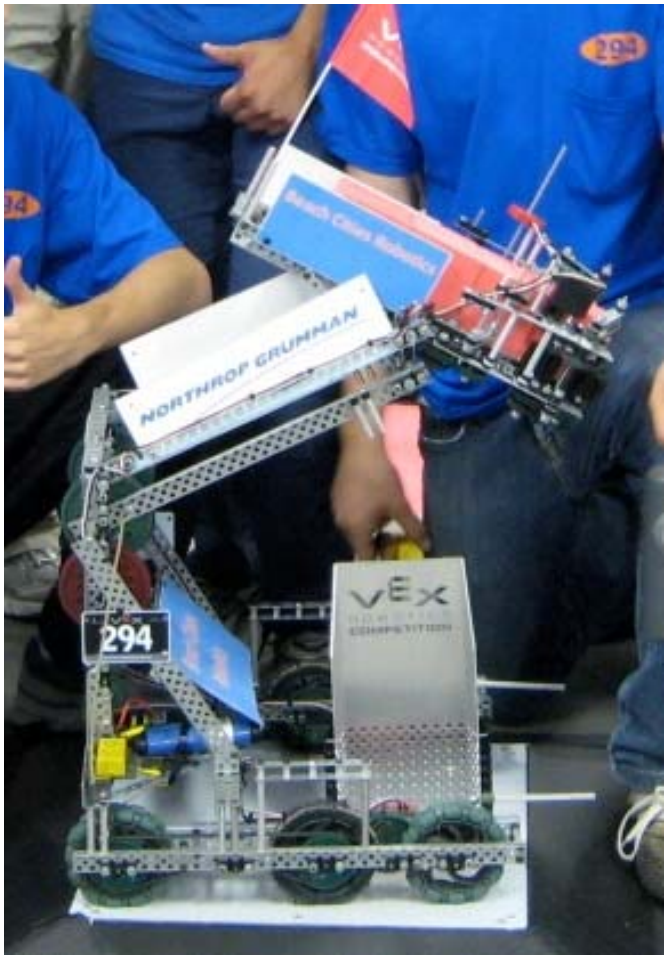
8. Brainstorm Whole Robot Concept
   - Everyone presents
     - All ideas are good ideas!
   - Create cartoon concept drawings
     - No CAD just yet
   - Discuss various mechanisms
   - Allocate motors if possible



Objective: Create a cartoon sketch of what the robot might look like

BCR Design Process

9. Determine Effectiveness of Concepts
   - Evaluate each design for each task
   - Assign a value
     - 0 = cannot perform task
     - 1 = performs the task poorly
     - 3 = performs the task adequately
     - 5 = performs the task exceptionally
   - Values are relative to the design concepts
     - A design may perform something very well, but if there is another concept that performs the task significantly better, then the two concepts should have different values.



Objective: Fill in the QFD matrix

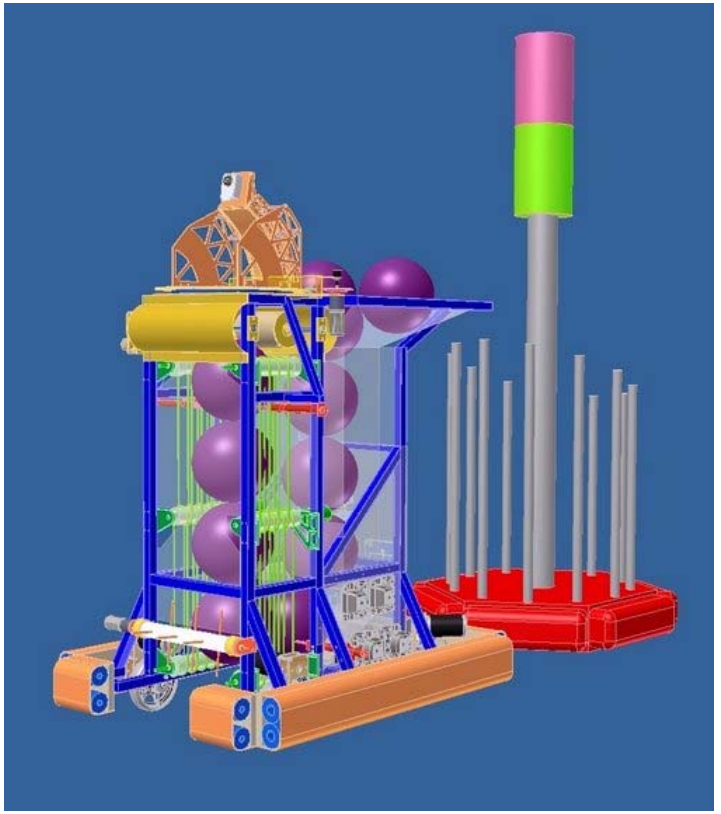
BCR Design Process

10. Determine Top Concepts

- Determine the overall effectiveness of the proposed designs

Relationships	
◉ = Strong	5
○ = Medium	3
△ = Weak	1

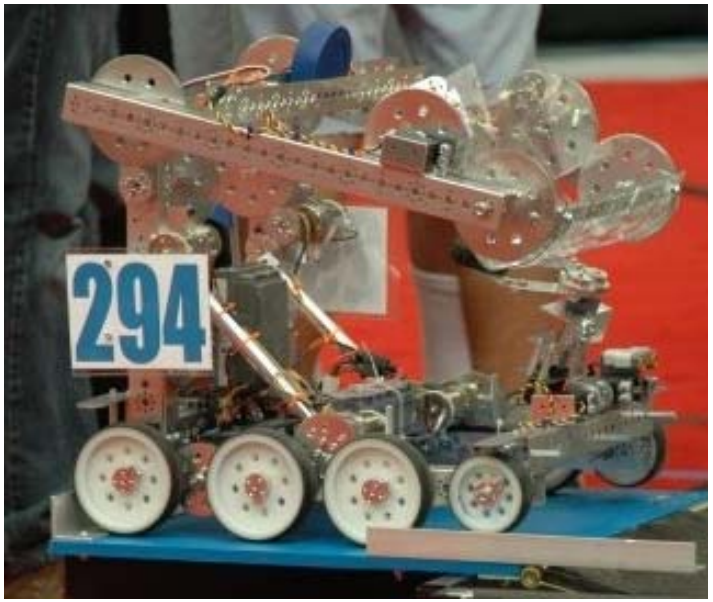
Scoring opportunities and necessary attributes / Capabilities and features	Strategic importance	Accurate autonomous	
Release balls first.	3	◉	3 x 5 = 15
Uncap 2x ball from goals.	5		
Control short goals.	3	○	3 x 3 = 9
Deliver balls to the shooter.	5		
Cap 2x balls into goals.	4		
Moving small balls to your side.	5		
Chin-up (50 points).	4		
Dominate all space under chin-up bar (keep others away).	3		
Be able to get onto the platform.	4		
Be anywhere in playing field quickly.	5		
Unscore stuffed cap.	3		
Control 2x balls.	4	◉	4 x 5 = 20
Block opponent's goal.	3	○	3 x 3 = 9
Block opponent's doggy door.	1	△	1 x 1 = 1
Be reliable.	5		
Control bonus balls.	1	◉	1 x 5 = 5
Difficulty rating (impact vs. effort) 5= high impact/little effort			
15 + 9 + 20 + 9 + 1 + 5 = 59 ce (score)			59
Relative importance			4.2%



Objective: Calculate the importance of the design features and prioritize

BCR Design Process

11. Evaluate Top Designs
    - Place the top concepts on the wall and discuss further possibilities
    - Any new ideas to expand the concept?
    - What strategies would defeat this concept?
    - How might you prevent such strategies from happening?
    - How feasible is the concept?
    - How simple is the concept?



Objective: Find flaws in the design

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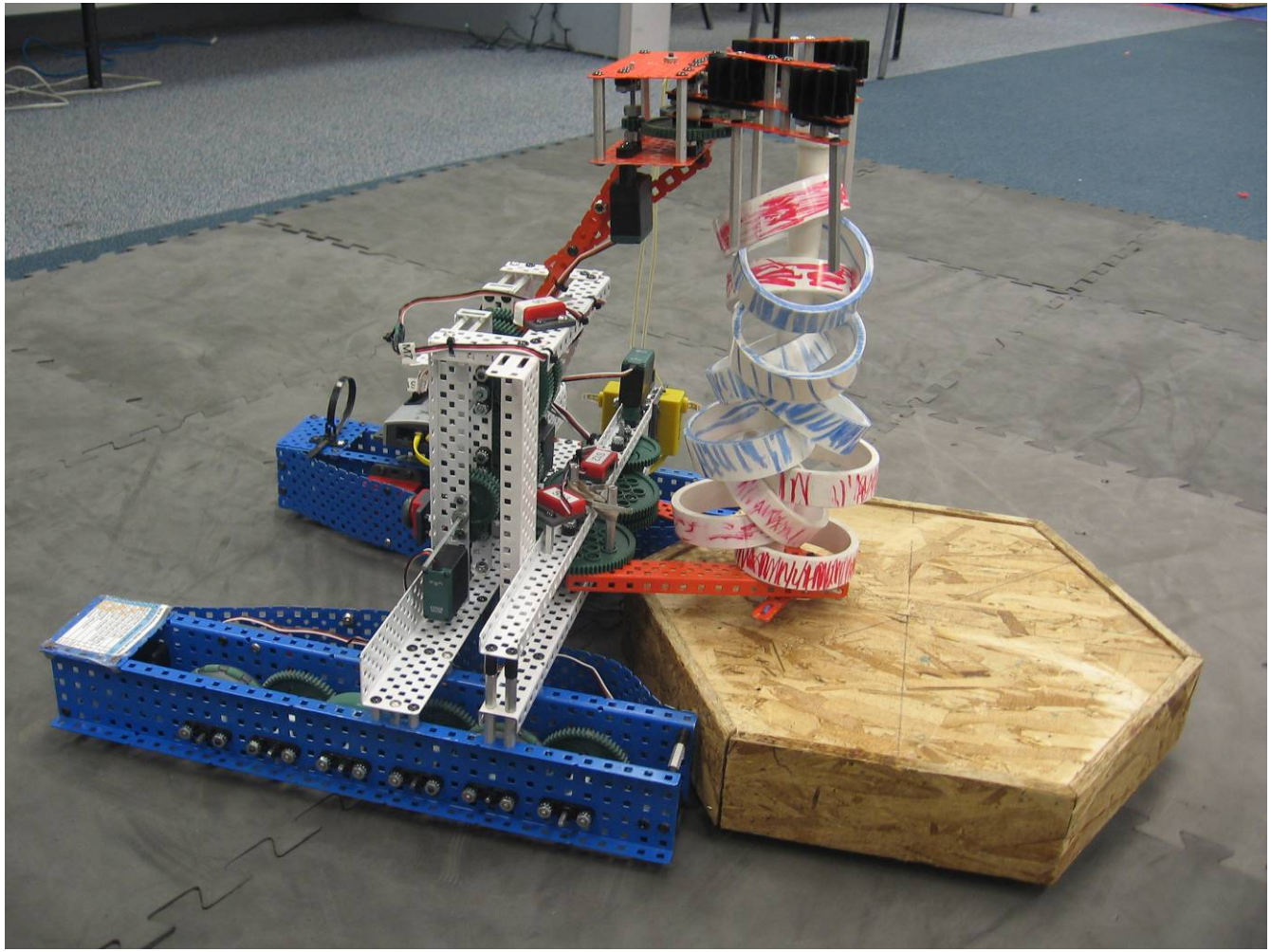
Questions & Answers



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