Understanding the Robot Design and Construction Process

Paul Lutes, North Houston BEST
Michael Carroll, War Eagle BEST

Technical Session for BEST National Conference 2011, Auburn University, Alabama

Understanding the Robot Design and Construction Process (BEST Specific)

Presentation Material is released under the Creative Commons Attribution-NonCommercial-ShareAlike v3.0 License. Please attribute presentation to http://mjcarroll.net or e-mail me at carroll.michael+best@gmail.com If you find this presentation helpful, or you use portions of it, please leave a comment on my post at: http://mjcarroll.net/?p=299

Purpose

- Introduce helpful engineering concepts
- Increase odds of having a successful team
- Provide a season walkthrough
- Conclude with Q&A and discussion

The purpose of this presentation is to (in order of importance):

Introduce engineering design principles in the context of the BEST competition
Increase the odds of having a successful team (especially first-year teams)
Provide a season walkthrough (2003 - Transfusion Confusion)
Conclude with discussion from both new teams and veteran teams

Engineering Design Process

An <u>iterative</u> decision making process to convert resources optimally to meet a stated objective.

We are engineering engineering!

First of all, what is it? Here’s a textbook (or wikipedia, just as good) definition.

These large engineering projects require time effort and money commitments from large groups of people. We are just trying to maximize efficiency, we are engineering engineering.

If it doesn't work the first time, get feedback as to why it doesn't work, and improve the process. As time goes on, you approach an ideal process.

+ BEST

Teachers
Students
Mentors
Returnables
Consumables
Game Rules
TIME!

Successful Robot
Successful Team

Enlightened and
Excited Students

Let’s look at our inputs and outputs for a BEST team.

2-3 mentors, 10-50 students, 1150 consumables parts, 125 returnables parts, 1000 hours (42*24)
Most teams want the first two points on the right, but the bottom one is often overlooked.

6 weeks programming or in the shop may increase those skills (but marginally), but 6 weeks of following the design process can be unlike what students have ever had before. It’s creative, and open-ended, and the students get to see direct feedback on their knowledge. It’s what got me excited about being an engineer as a high school student, and hopefully other people will as well. That’s what we’re trying to do, right?

Prerequisites

- Gather your team!
  - Review the engineering process
  - “Film Study”
  - Shop Safety
- Establish good communication
- Set up a preliminary schedule
- Find a venue
- Engineering Notebooks

Before we get into the actual design process in the season, let’s talk about a few BEST-specific prereqs.

These should be handled BEFORE kickoff day.

Review the engineering process with your team! A good way to do this is through team-building activities (egg drop is a good example), or by doing what I call "Film Study". Give you team a copy of old rules (Available via BRI, I believe), and have them come up with designs on paper. Compare these designs to game-winning designs to see what works. Also, review shop safety.

A major point of successful teams is to establish an official communication medium for the team and mentors. This can be a phone tree, or more likely e-mail. For high-school students these days, Facebook (for discussion) and Twitter (for broadcast) are good ways to communicate (a perfect example of this done right is @darcrobotics on Twitter)

Set up a preliminary design schedule for the 6 weeks of the season.

Find a stable venue. Building the robot is much easier if you can spread out and leave your stuff there. If you have to devote time to packing and unpacking at each meeting, that's time you are taking from the design process.

Every step of this process should be kept track of in engineering notebooks! Every student should have one! Valuable for tracking the process and other reasons (in appendix)

Preliminary Schedule?

	Milestone	Schedule
Pre-Season	TB, Assessment	MW 3-4
Week 1	Kick-off	MWF 3-5
Week 2	Prototyping	MWF 3-6
Week 3	Start Build	MWFS 4-7
Week 4	Build	MWFS 4-7
Week 5	Mall Day	MWFS 4-7
Week 6	Refinement	MTWRF 5-7

The goal with the preliminary schedule is to set broad milestones and establish times that teams can meet.

Don't worry if it's not 100% accurate, older engineers still don't "get it right" all the time.

This follows the schedule from the BRI website.

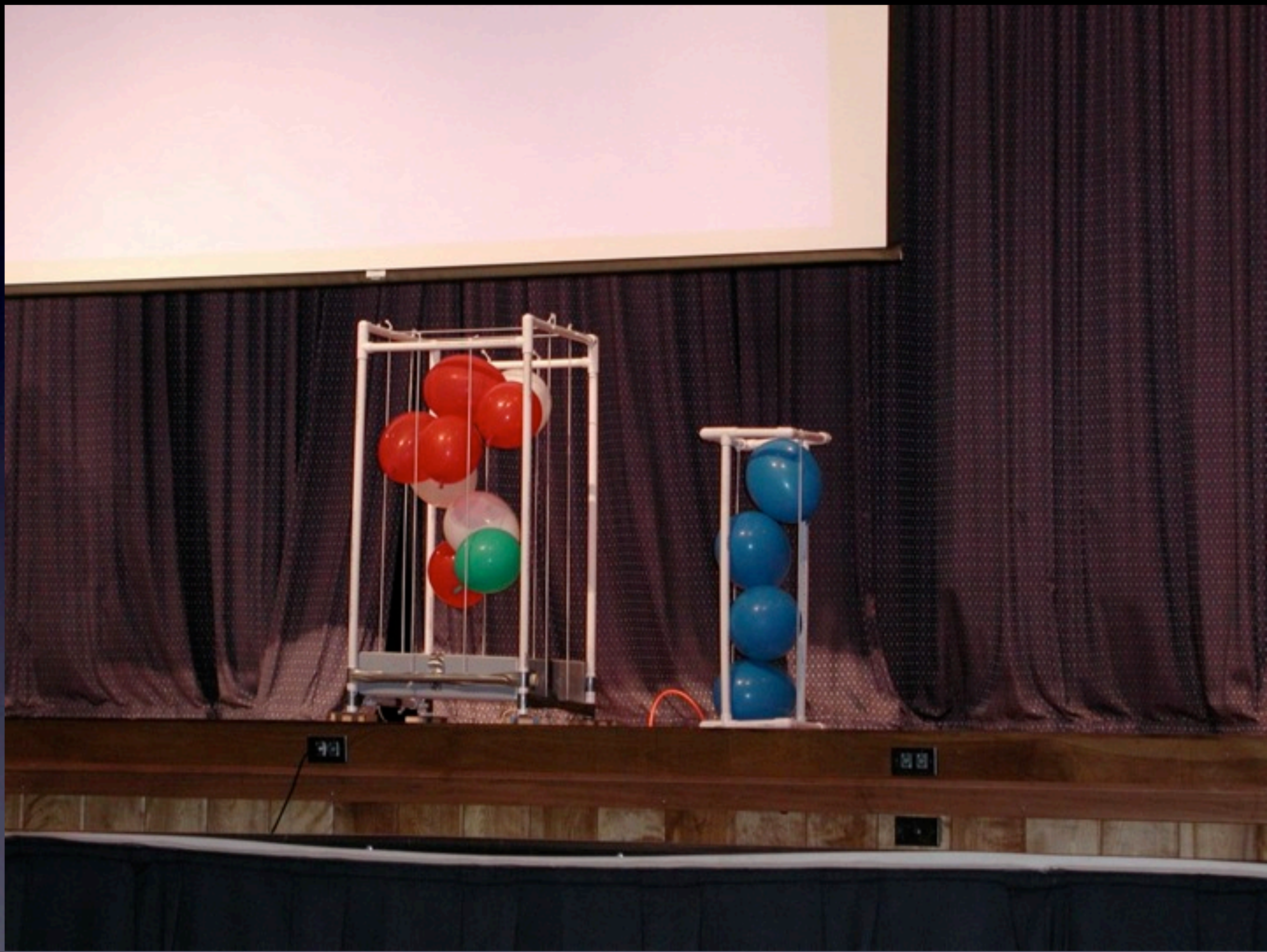
Notice that only TWO WEEKS are devoted to building (thx Larry), the rest are devoted to the process and refining the design. Last minute changes almost always turn out poorly.

Let’s Get Started!

- Take as many students/mentors to kickoff as money will allow
- Have a design meeting RIGHT AFTER

Let's get started on the BEST season with Kickoff day

It's best to take as many students as possible, and have a design meeting THAT AFTERNOON to start the process. It's best to have that information fresh.



Kickoff!

Here we are at Kickoff. The point of 2003 was to retrieve balloons from one portion of the playing field and move them to another container. The red, white, and green balloons were of higher value, but were moved around by a box fan in the bottom of the container. Blue balloons were static, and worth less.

The balloons then had to be deposited in a lower or upper hopper (upper worth more).

Kickoff!

After finding out about the game, collect your kits (returnables and consumables).

Kickoff!

A good exercise is to inventory the kits AS A TEAM in your afternoon design meeting. This both lets you know that you got everything you were supposed to, and it lets the team get familiar with the materials and resources available in the kit.

READ THE RULES

Clarify Design Objectives
Establish Functions
Establish Requirements

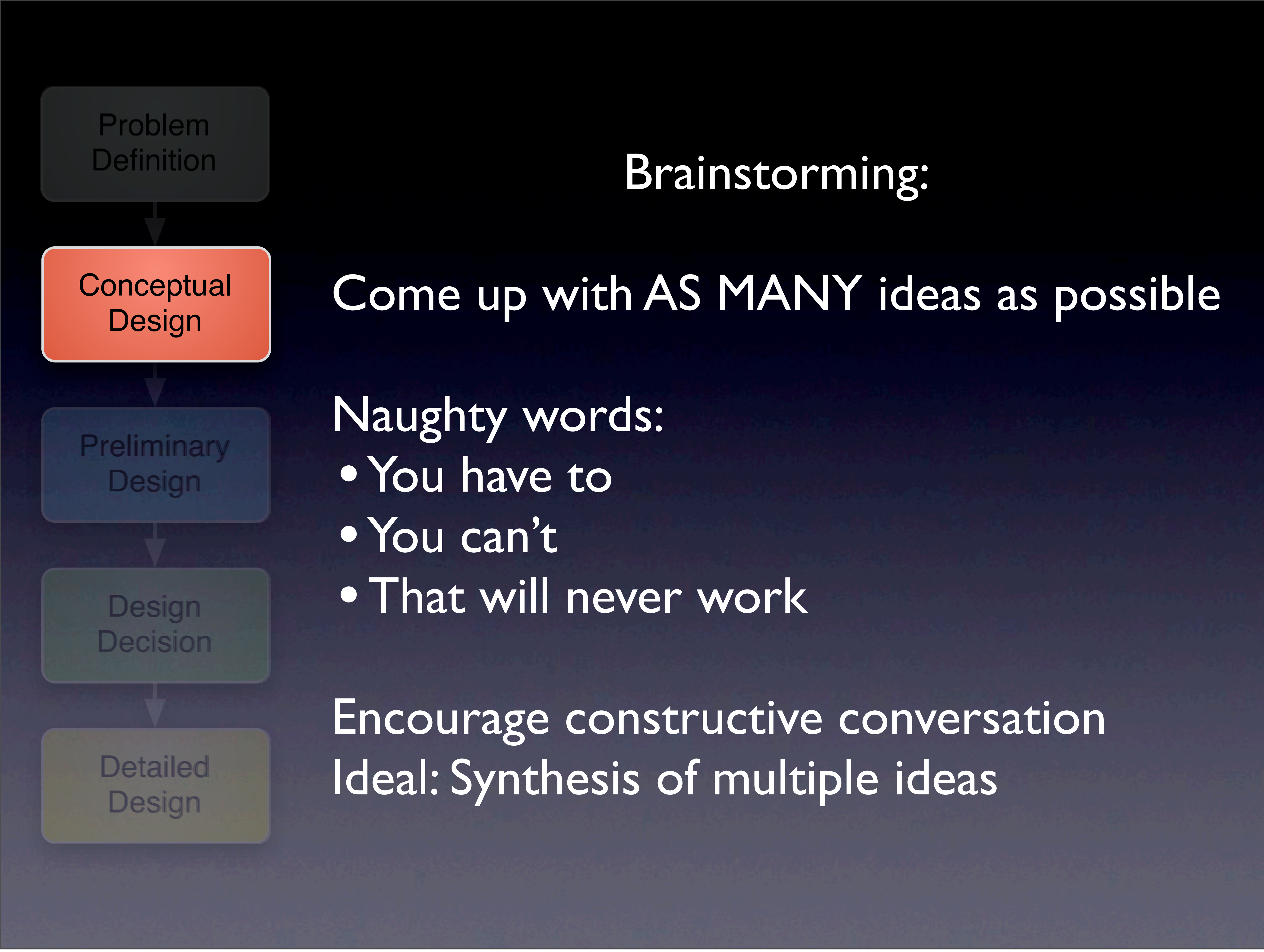
NOT Solution Specific

Discussed as a team
Agreed to as a team

Problem Definition gives a “framework” for brainstorming

You want to establish the functions and requirements of the robot. This can be hard items (weight and size limit), and soft items (easy to control, robust, reliable).

We are trying to avoid specific solutions here. For this competition, you could say that collecting the moving balloons is an important goal (because of their high value), and collecting static balloons is less important. Another step of this is to have a robot capable of depositing the balloons in a 40" tall hopper (2x the points of the low hopper).



Brainstorming is an opportunity to come up with as many diverse ideas as possible. From Wiki: Focus on Quantity, Withold criticism, welcome unusual ideas, combine and improve ideas.

It's best to have as many "lateral" solutions to the problem as you can. Try not to let one person dominate the conversation and make all of the decisions. Everybody should have equal chance to contribute.

If the conversation gets unproductive, try some of the following techniques:

Nominal group technique - everybody drafts up ideas on paper anonymously. The ideas are then collected by a moderator and the group selects several ideas to keep discussing. This is good for "loud" students.
Mapping - try and place all of the ideas in a graph or map to associate ideas. This is good for idea synthesis (combining ideas in new ways).

Problem Definition

Conceptual Design

Preliminary Design

Design Decision

Detailed Design

Preliminary Design is all about prototyping the ideas that come out of brainstorming.

Having field components early is a huge plus. Get mentors to do this and quickly. Physically playing with field components can improve the quality of discussion

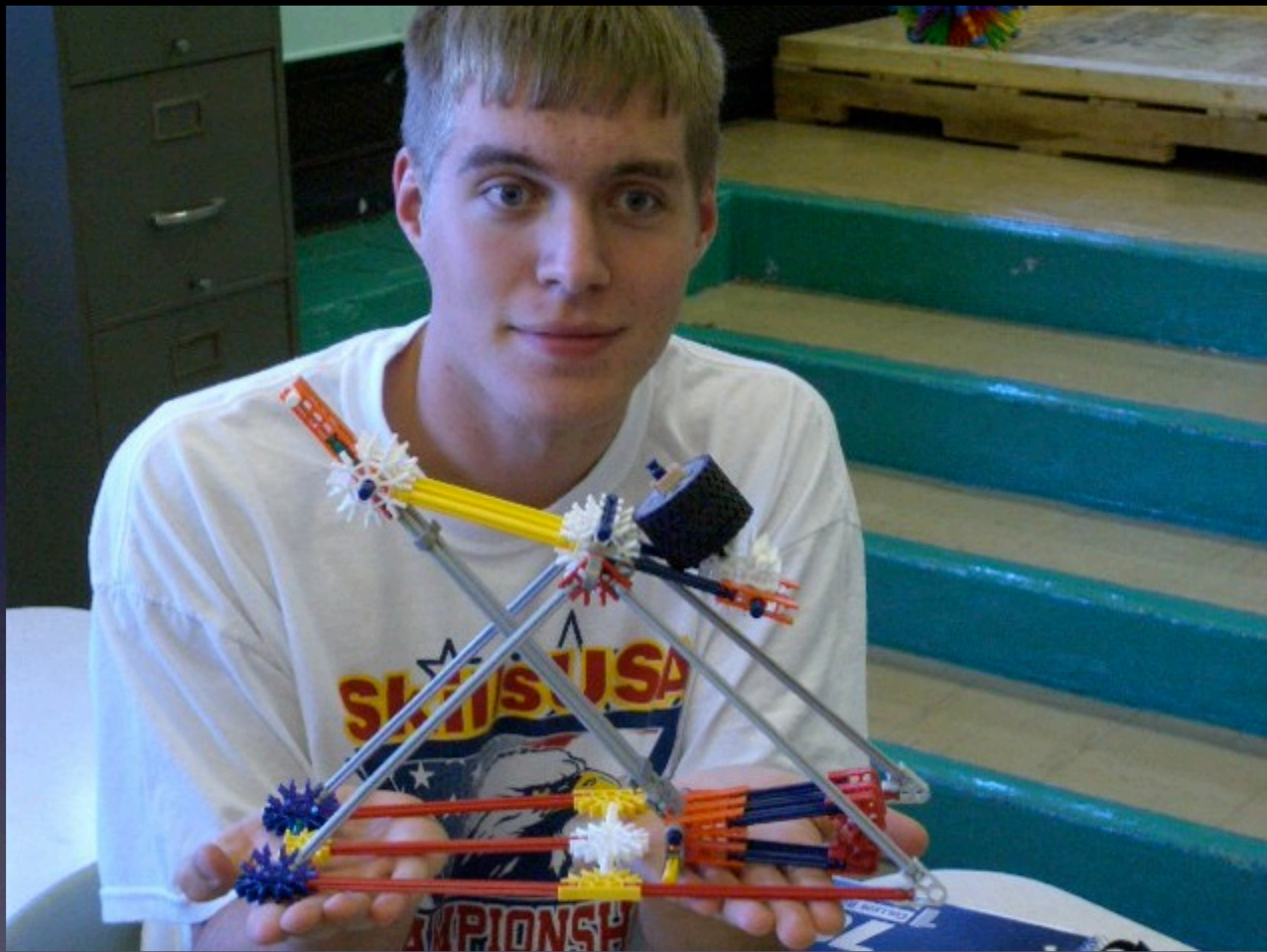
Problem Definition

Conceptual Design

Preliminary Design

Design Decision

Detailed Design



Build prototypes of your ideas. Here is K'nex. Also good, Lego and Erector.

(This is a terrible picture of me. I was such a nerd)

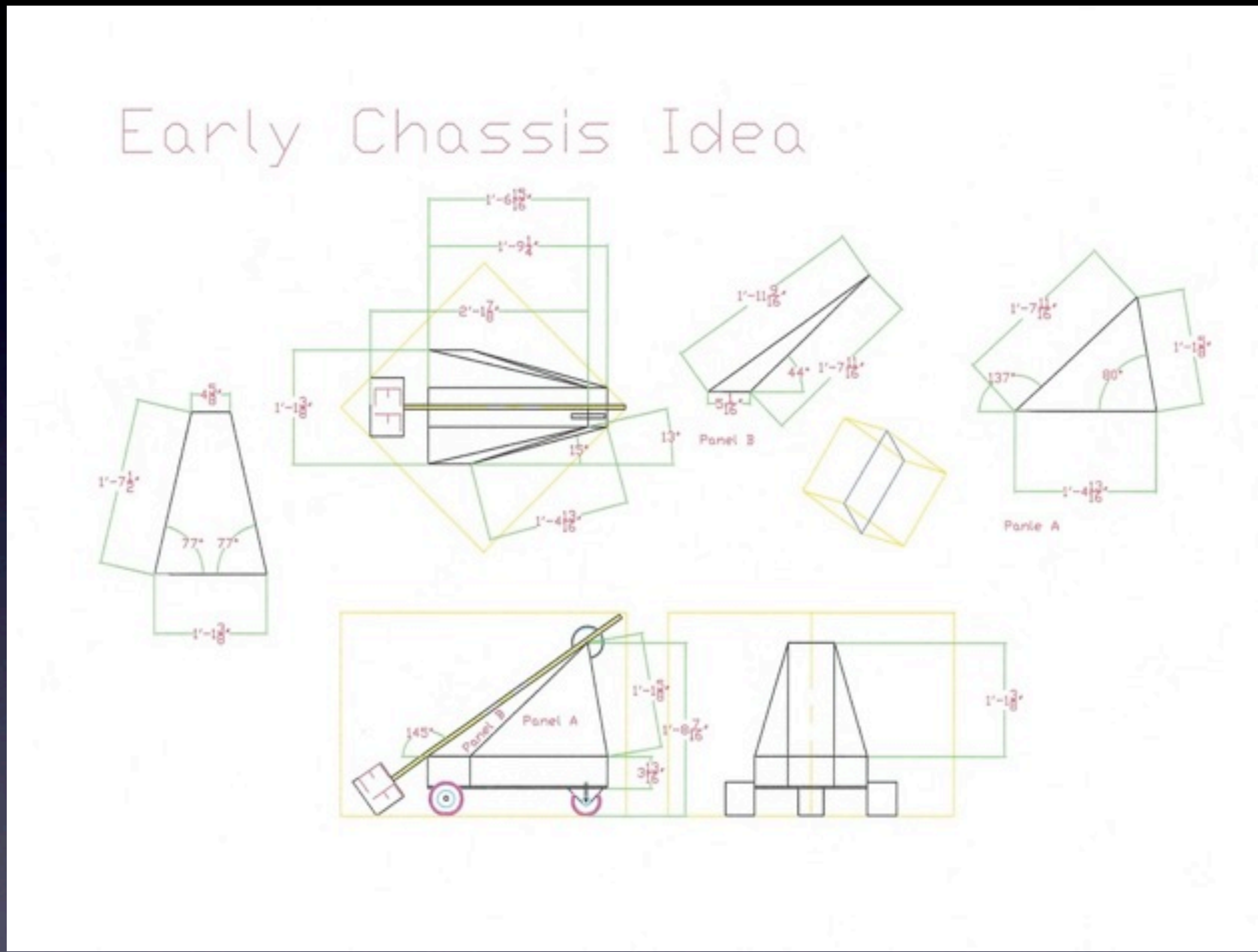
Problem Definition

Conceptual Design

Preliminary Design

Design Decision

Detailed Design



CAD works well too. This is for a different competition, but shows a good technique. Here, a “diagonal” chassis was considered to get more reach.

With Solidworks, this becomes even easier to do ANIMATIONS of concepts before actually building.

Problem Definition

Conceptual Design

Preliminary Design

Design Decision

Detailed Design

Here is an idea being tested with non-kit components. Prototyping just has to show that an idea can work. Implementation can be handled in the Detailed Design phase.

Problem Definition

Conceptual Design

Preliminary Design

Design Decision

Detailed Design

Outside of the design technique proper, but more BEST-specific.

It can be a HUGE morale boost to get a rolling chassis early. This lets you know that your returnables kit materials work, and it gets the team excited about working.

It often goes “That’s AWESOME, let’s get back to work!”

Problem Definition

Conceptual Design

Preliminary Design

Design Decision

Detailed Design

Here is a prototype of what we ultimately went with.

The balloons were actually rotating in the cage, and sticking a “fin” in would channel the airflow (and balloons) into a box to catch the balloons.

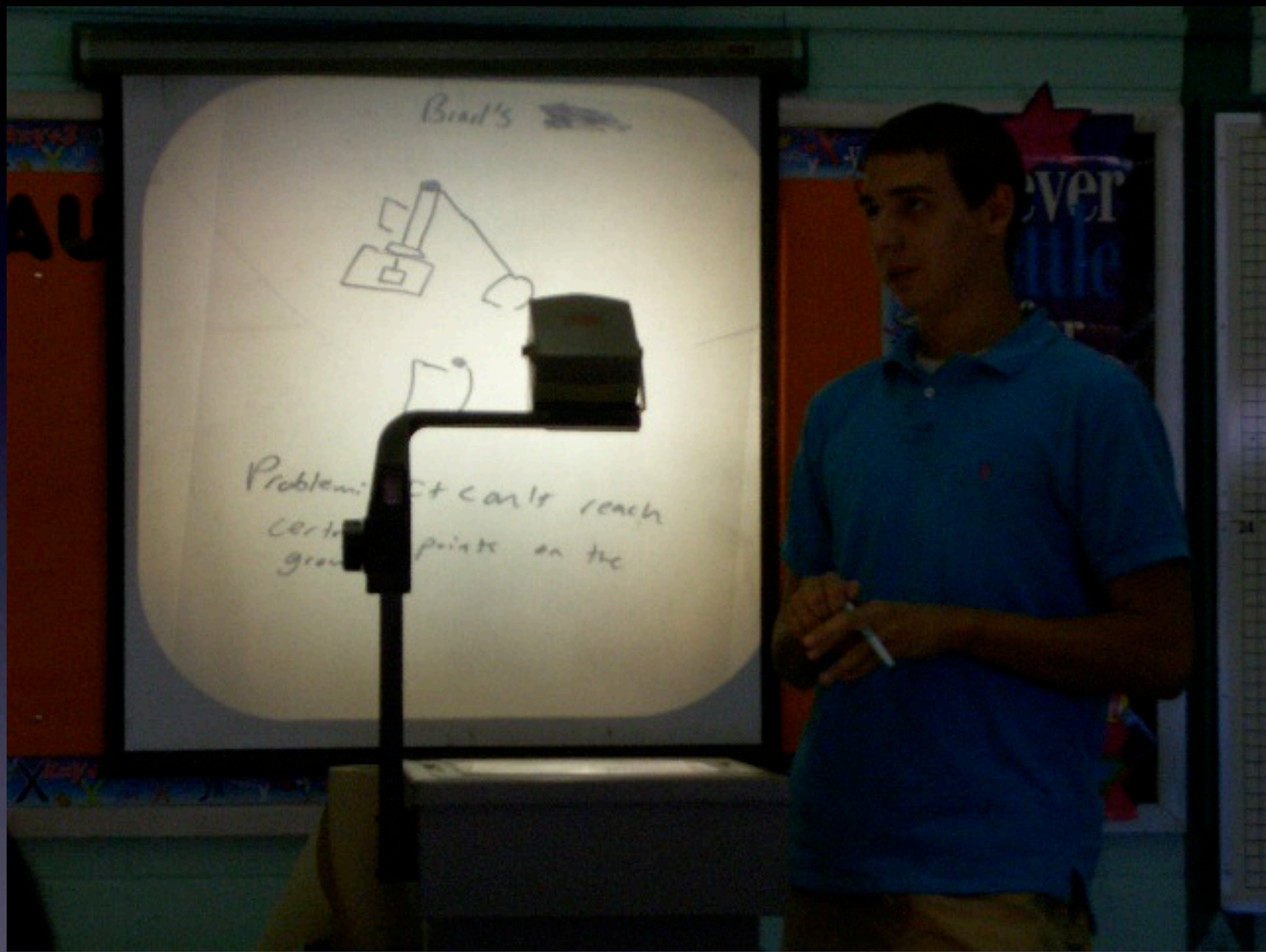
Problem Definition

Conceptual Design

Preliminary Design

Design Decision

Detailed Design



Now that we have agreed to a list of requirements as a team, come up with concepts, and proved that some of these concepts work, it's time to choose one.

You may find that “factions” develop in your team. Some competition is actually beneficial, as each group has to defend their idea, and this can ultimately lead to a better design. It’s best not to let the competition get to the point that someone is cut out of the process. Give each idea a fair shake.

In the past, we have done presentations of each design.

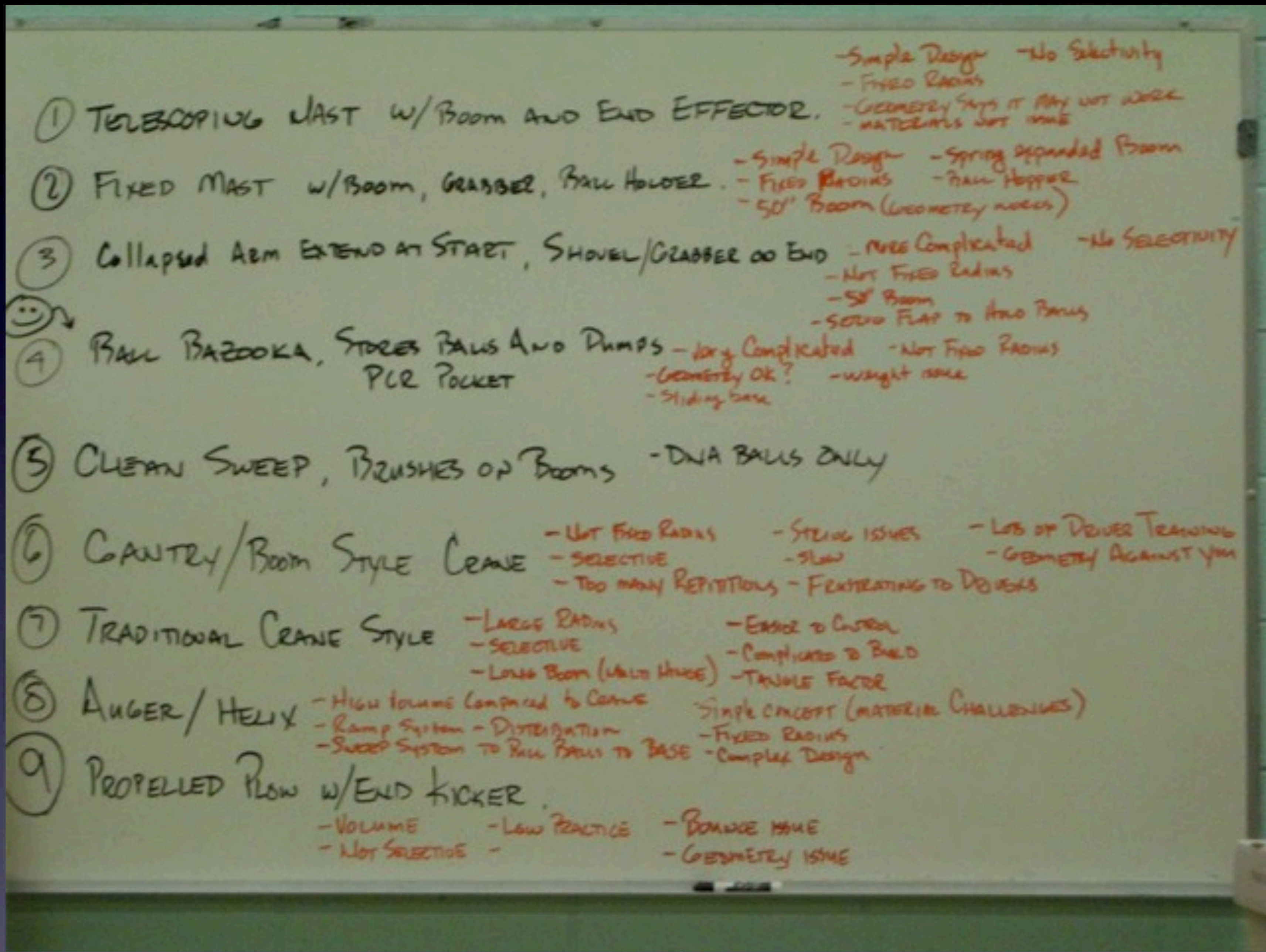
Problem Definition

Conceptual Design

Preliminary Design

Design Decision

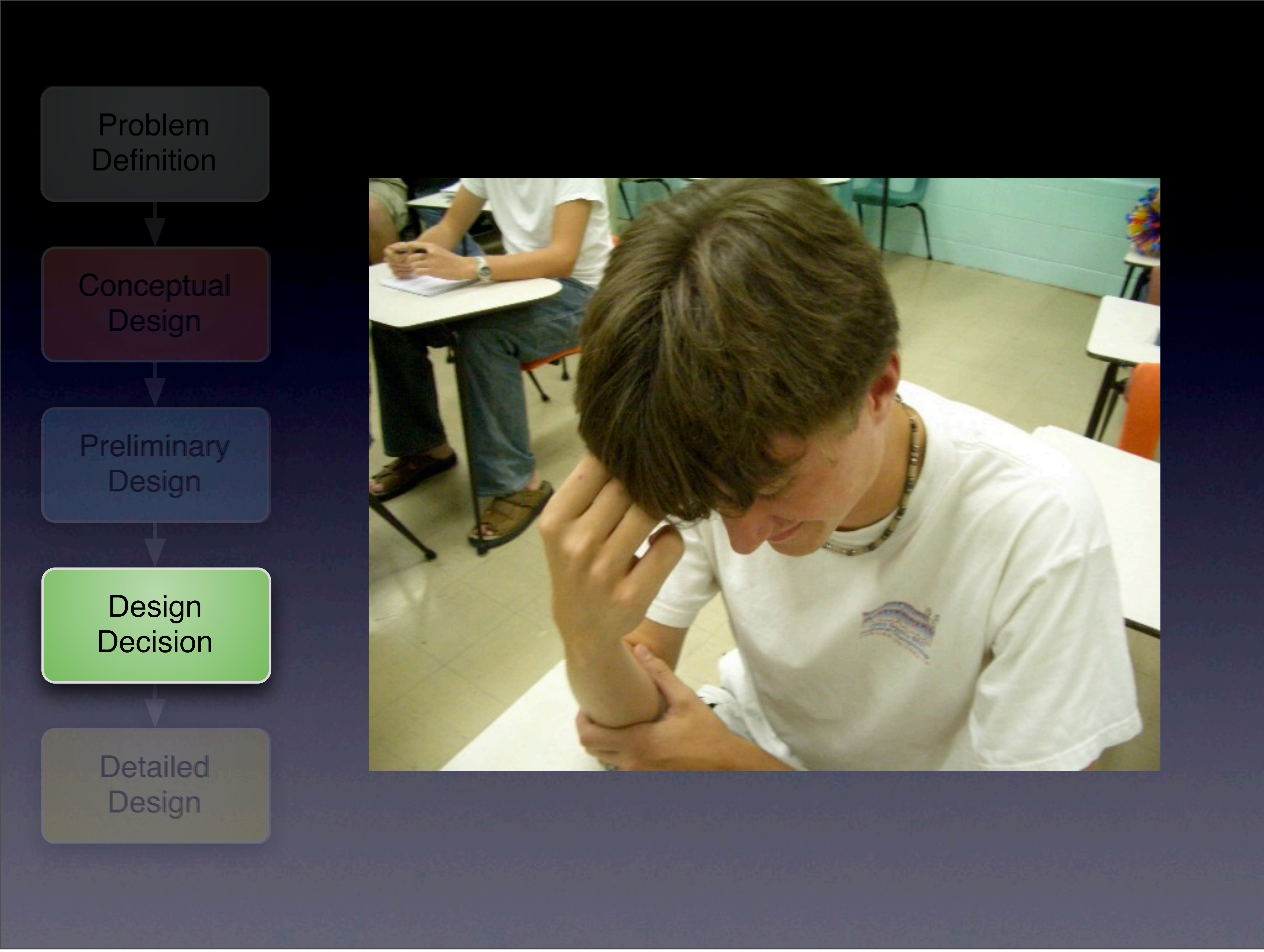
Detailed Design



After presentations, we make a list of all ideas (9 in all, here). This was also for the 2004 competition (BEST Fever). It's sometimes cool to see other teams implement alternatives to your main idea, so you can see how each idea "works out" at the competition.

Next to each idea are the pros and cons. This is an informal way of doing this, but there are more options.

A good idea would be a "trade study", where all of the design ideas are listed on the left, and requirements on the top. Each idea gets a score for each requirement generated in the problem definition stage, and then a sum is generated. This provides a good baseline for the decision making process.



Ultimately, someone may get their feelings hurt, it happens. (This slide is just a joke, rest assured).

Following the process tends to take some of the human emotions out of the process (GAH, now we're robots). But in all seriousness, if you use a technique such as the trade study in the previous slide, you can see which idea successfully completes the most of the design requirements outlined in the problem definition. If you do each step as a team, then students can understand why one idea is QUANTITATIVELY better than another.

Two Caveats:
Your requirements generated in the first step may be wrong. When you come up against the design decision, you may want to step back and re-evaluate your problem requirements before scoring the ideas.
Sometimes, a design that doesn't seem the best can be VERY successful. For instance, the box met few of our initial requirements, but was a 1st place design at the local level hub (and 5th at South's). Understand that you can "throw out the process" sometimes, if you have to. Don't be afraid to.

An okay idea done well is much better than a great idea done poorly.

Sometimes, a highly complicated design comes out of the process. Keep in mind KISS (Keep it Simple, Stupid!). A simple design can be easier to design and implement.

Just because it isn't the most complex design doesn't mean that it won't win.

Problem Definition

Conceptual Design

Preliminary Design

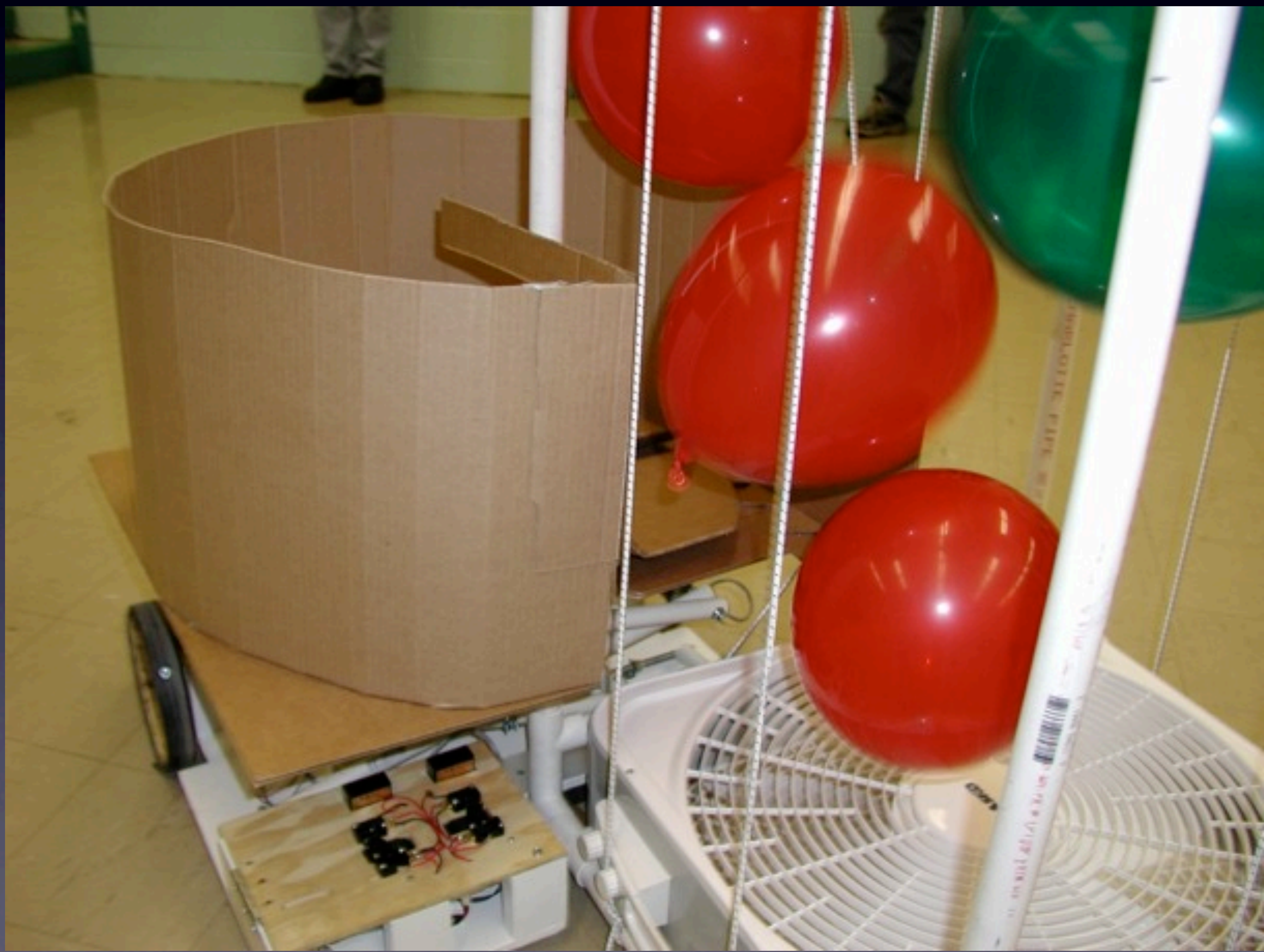
Design Decision

Detailed Design

There is a video in this slide (sorry for those following along at home). It shows the robot emptying an "artery" in just a few seconds, this was at week 4.

In the detailed design, you work out the details of the design that you have choosen. Often, this means iteration! Here are 8 iterations on our box, as small details made a huge difference in the performance.

What happens now?



Driver's Practice

What happens now?

Have the engineers watch driver's practice.

Find the things that are wrong with the design and fix them.

What happens now?

More practice!

What happens now?

More evaluation and iteration!

I think that we built about 8-10 boxes in all.

“Maintenance” Phase

- “Run the bugs out”
  - Prioritize your fixes
- Failure Analysis
- Build replacement parts

Once you have a working robot, you enter the "maintenance" phase.

Like I already said, you want to iterate all of the bugs out of your design. At the same time, make sure that you prioritize your fixes. If you have a week to competition, and a fix for a small problem requires a major redesign, then maybe that isn't a fix worth pursuing.

To find more fixes, as a team do a Failure Analysis after mall day. Make a list of all of the things that you think that can go wrong, and come up with mitigation techniques. Part of this is making additional copies of "high value" or delicate components. In our case, we produced a second copy of the box, because if it was broken, we knew that we could not compete (VERY high value!)

Other Build Thoughts

- Get the actual game pieces
- Build a portion of the game field
- Have a robot by mall day
- Don't let students get "hung"
- Check for sane designs
- Use standard parts

Companies and sponsors like to buy/build game pieces and the field.

If possible, team up with other local teams to practice. If games include robot interaction, a school with more resources may want to practice with a school with less resources just for testing the interaction portions of the competition. Also, established teams are often interested in getting BEST points.

A huge indicator of success for me is seeing teams at mall day. You get to practice on the ACTUAL playing field. If your practice field was built incorrectly, missing this opportunity can often mean a non-scoring robot! We give you this opportunity as a hub, so take it!

Don't let students get "hung" on a complicated part. Ask questions, ask about similar designs in "real life" (simple machines are everywhere!)

Make sure the students use "sane" designs. Teach about torque and force. Make sure that returnables components won't be damaged, and designs are robust against mechanical failures. For this, use standard parts as much as possible (general kit notes), and use parts the way that they were intended (for the most part).

Competition Words of "Wisdom"

- If it can go wrong, it will in competition
- Performance varies "under the lights"
- Have a competition checklist
- Assign a "battery minder"
- Talk to other teams

Murphy always takes over. Student stress takes over as well!

To mitigate these things, create a competition checklist. Someone should check any maintenance issues encountered in the driver practice and failure analysis. Every point on this list should be checked off (by a student!) before the robot goes to staging.
Example: we found that the floors can get dirty over the course of the day, so traction would get lost. We made sure that the wheels were always clean before a round.

In addition to the competition checklist, have one responsible student montior the charge on all the batteries! Don't go out there without a battery!

Very important - talk to other teams! Find out what they had to overcome in their designs, and build up a "library" of solutions to common design problems. Write them in your notebooks!

Post-season

After the season is over, take a break!

Tension can run high over the course of the season, and you want everyone to come back. The way that we did this was through a "gag-trophy" compeition. As you can see here, our creative director was getting the "headache" award (bottle of asprin on a plaque)

It's good fun, and can diffuse any tension from the season.

Post-season

- Lessons learned - SWOT

	Internal	External
Positive	Strengths	Opportunities
Negative	Weaknesses	Threats

Also, do a lessons learned!

As a team, sit down and evaluate your performance over the season. Make a list of things that can be done better. Get feedback!

A good method is SWOT (more on wikipedia), but you basically brainstorm on postive/negative internal/external factors. This brainstormed list gets fed back into the process, so it can be better next year (see what I mean about engineering engineering?)

Most Importantly

None of this is set in stone. You do what works.

Adapt to the skills of your mentors, teachers, and students.

Remember that you can learn just as much from a design that doesn't win as one that does.

Discussion/Questions?

Michael Carroll
http://mjcarroll.net

@carromj

carroll.michael+best@gmail.com

BY NC SA

Appendix (Bonus!)

- First year teams often attempt to do everything for scoring on the field instead of doing one thing well. Keep it SIMPLE!
- Rank goals from highest to lowest to demonstrate what to focus on first to last. This produces a robust scoring machine!
  - If the lowest priority goal isn't reached, you will still have a functioning machine, and diversifies risk. Some design features can be the "icing"
- Remember to go for BEST award to increase standing with lower performing robot to keep students encouraged in the entire process.
- Remember, you only have two weeks to build a robot by Mall/Demo day.
- In industry, notebooks are used to capture all that an engineer does. This serves several purposes: Makes the engineer easier to replace in case of emergency, used as a defense for patentable idea, makes decisions easier to remember (coming back after months or years can be hard!)
  - For BEST, date all the pages, and record everything, you can use this as part of the engineering notebook, and reference past designs later.

Not intended for actual presentation use. These are points that came up during our discussion.

Appendix (Bonus!)

- Kickoff Day hints
    - Line up students by the field and have them sketch field parts and ideas in the notebook. Often the process of writing and drawing can cause inspiration for ideas that can be used in brainstorming.
    - Ask hubs to provide game pieces (if possible)
- Assign a rules and compliance minder for the design process. You don't want to get kicked out on a technicality. On game day, this person can keep up with driver/spotter order, and pit safety (SAFETY GLASSES!)
- Be sure to provide feedback to hub personnel (maybe not when they are super-busy, and ESPECIALLY NOT with yelling, please).
- There is more opportunity to learn from failure than from success! There is learning even without winning!

Not intended for actual presentation use. These are points that came up during our discussion.