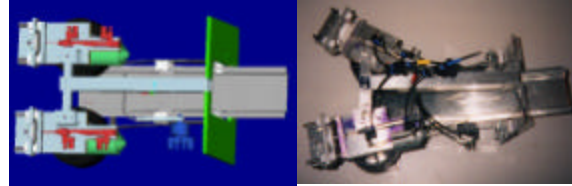




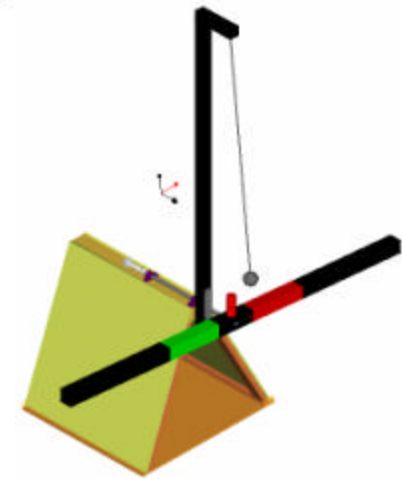
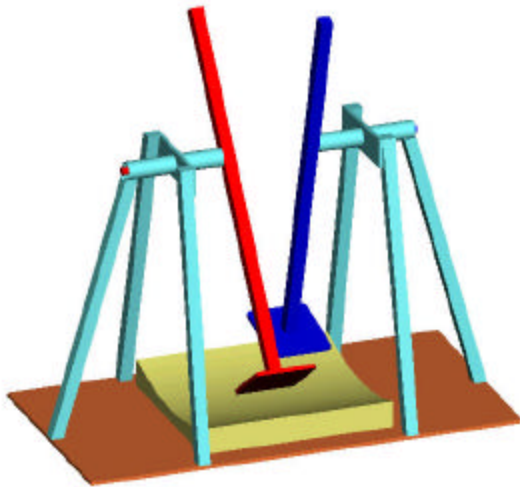
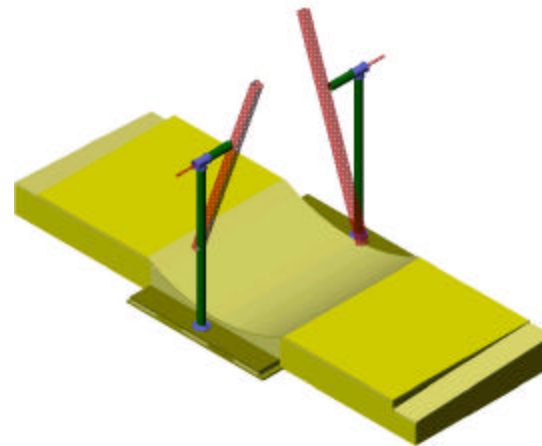
Topic 1

Design is a *? Passionate ?* Process



Topics:

- *Passion*
- Deterministic design
- Systematic Organization of Ideas
- Design Process
- Milestones

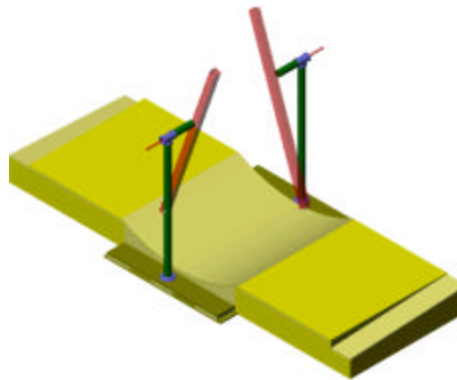


Design Contest: *The MIT and the Pendulum!*

- “Rules”:
 - Only use materials in the kit and plus fasteners and adhesives
 - Machine must fit into starting zone (0.5 m cube) at the base of each pendulum
 - You can start with your machine engaged (wheels preloaded) to a pendulum
 - “Score” is evaluated at the end of 45 second contest:

$$Score = \left(q_{Total_pendulum_angular_distance_traveled_in_radians} + 1 \right) \left(m_{total_mass_in_grams_of_street_hockey_balls_and_pucks} + 100 \right)$$

- You may not damage the table or willfully damage your opponent
 - No nets or entanglement devices
- What would *you* do?
 - How would you go about designing and building a machine to participate?
 - How would you balance your effort with all the other obligations you have?



1-2

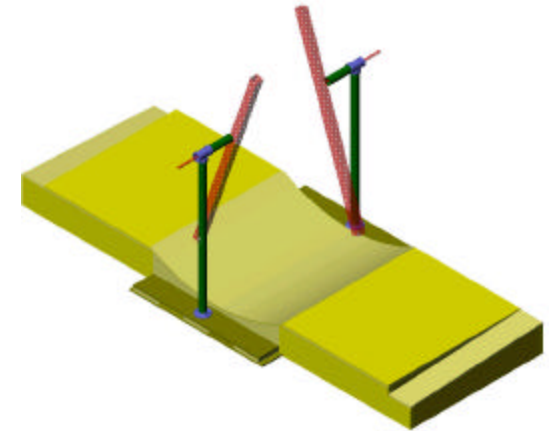


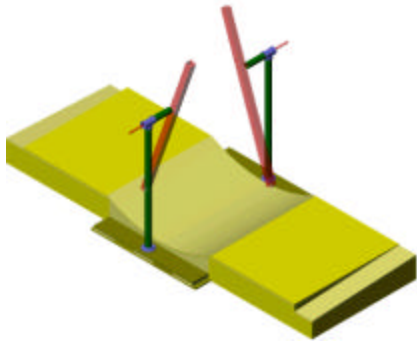
? Passion? LOVE to Create

"Enthusiasm is one of the most powerful engines of success. When you do a thing, do it with all your might. Put your whole soul into it. Stamp it with your own personality. Be active, be energetic, be enthusiastic and faithful and you will accomplish your object. Nothing great was ever achieved without enthusiasm"

Ralph Waldo Emerson

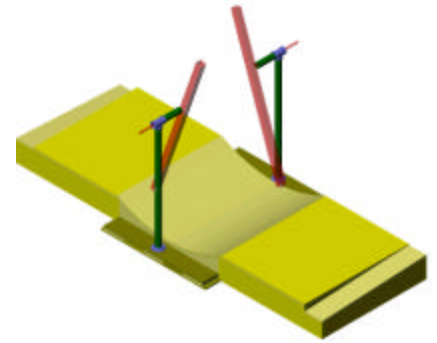
- Use ? Passion? as a catalyst to make ideas become reality:
 - Never stop asking:
 - “Is this really the best I can do”
 - “Can the design be made simpler”
 - Create, never stagnate
 - Do you see machines in ink blots?





? Passion? FOCUS!

Keep Your Eye on the Prize



***“You can’t always get what you want
But if you try sometimes well you might find
You get what you need”***

Mick Jagger & Keith Richards 1969

<http://lyrics.all-lyrics.net/r/rollingstones/letitbleed.txt>

Get a clear notion of what you desire to accomplish, then you will probably get it

Keep a sharp look-out upon your materials: get rid of every pound of material you can do without. Put yourself to the question, ‘What business has it there?’

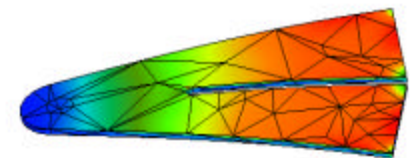
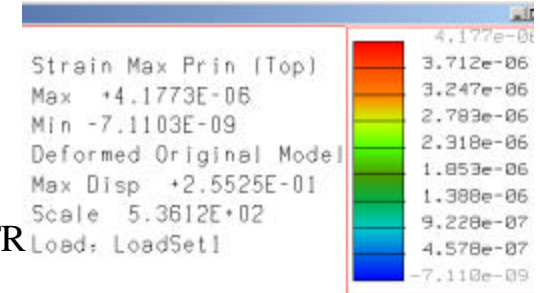
Avoid complexities and make everything as simple as possible

Remember the get-ability of parts

Henry Maudslay (1700’s, the father of modern machine tools)

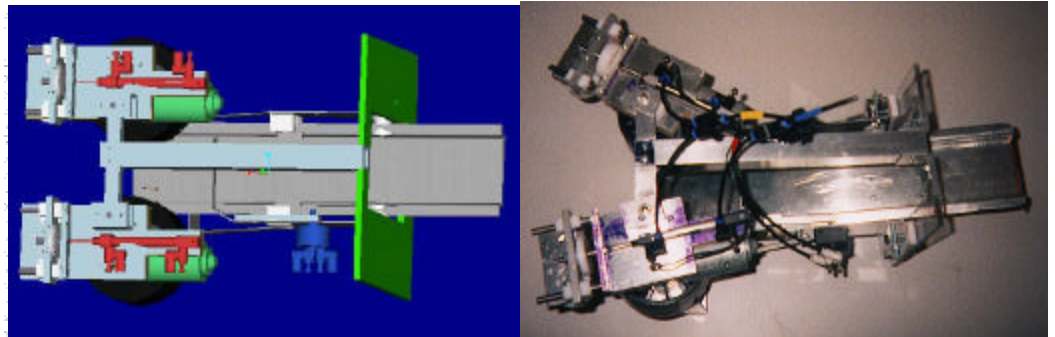
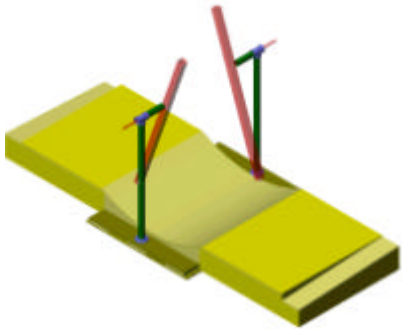
?Passion? Best Engineering Practice

- Before we can talk about a process for design, we must consider the things the best designers do as they solve problems
 - *Best Engineering Practice* entails careful forethought and following standards
 - **62.5 grams of prevention is worth a kilogram of cure!**
 - **“Random Results are the Result of Random Procedures”** *Geoffe Portes*
 - Prevent problems before they occur:
 - Does not meet customer needs
 - Prevention:
 - » Identify the *Functional Requirements* (FR)
 - » Develop a *Design Parameter* that accomplishes each FR
 - Failure
 - Prevention: Design to withstand external and internal loads
 - Poor performance
 - Prevention: Design to be robust to tolerances and errors
 - Cost too much
 - Prevention: Create clever, frugal, manufacturable designs
- *Deterministic Design* is a key element of *Best Engineering Practice*
 - It is a means to systematically solve even the most complex problems in a rational, logical manner, while still allowing you to have wild crazy creative zoombah illiminational thoughts!

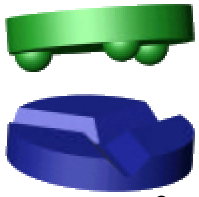


?Passion? *Play, Sketch, Model, Detail, Build & Test*

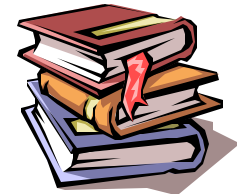
- Engineering is often a tactile, visual, verbal, cerebral, and physical activity:
 - Play with the table and the kit parts
 - Sketch ideas
 - Create physical and analytical models to identify opportunities and test possible strategies
 - Detail the machine using all the engineering skills and tools at your disposal
 - Build & test your machine!
- Students who follow *best engineering practice* create very impressive machines with just the correct amount of effort (and have time for a life!)



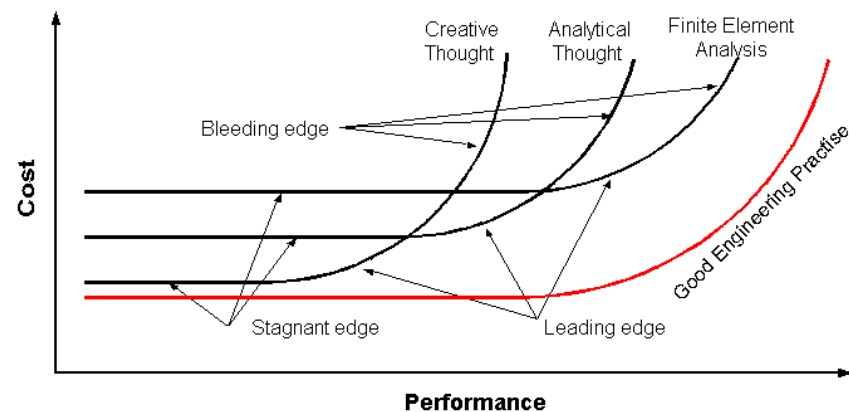
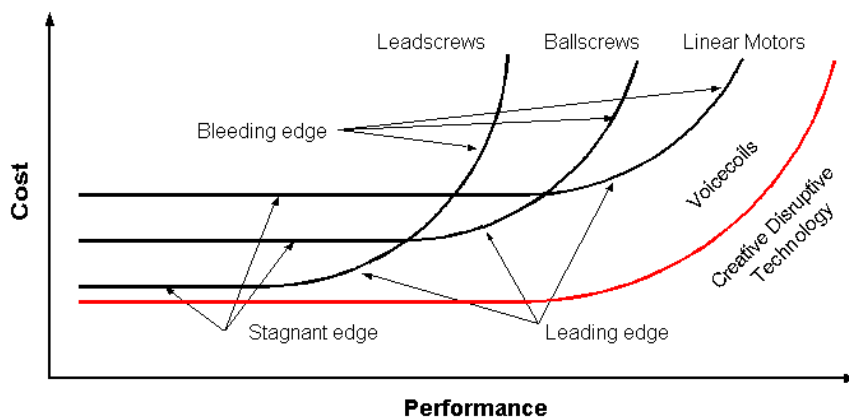
Alex Sprunt's machine was almost exactly like the solid model, and it worked "out of the box"!

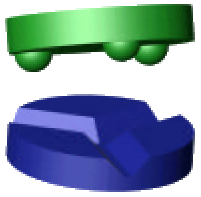


Deterministic Design



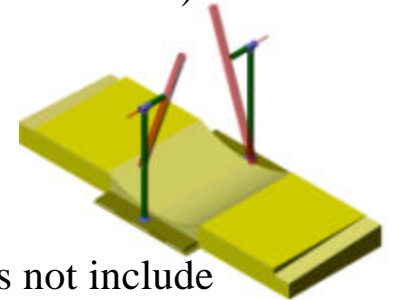
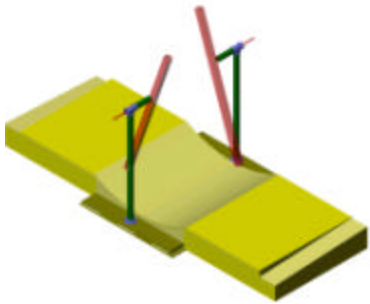
- Everything has a cost, and everything performs (to at least some degree)
 - If you spend all your time on a single tree, you will have no time for the forest
 - If you do not pay attention to the trees, soon you will have no forest!
 - You have to pay attention to the overall system and to the details
- Successful projects keep a close watch on budgets (time, money, performance)
 - Do not spend a lot of effort (money) to get a small increase in performance
 - “Bleeding edge” designs can drain you!
 - Do not be shy about taking all the performance you can get for the same cost!
- Stay nimble (modular!) and be ready to switch technology streams
 - It is at the intersection of the streams that things often get exciting!

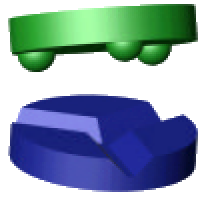




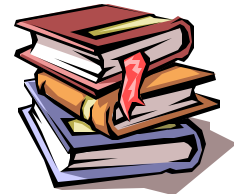
Deterministic Design: *Reverse Engineering*

- How would you create a contest where the overall goals are:
 - The inertia of the machines is on the order of the inertia of the system
 - The system is SIMPLE to build and solid model (for the staff and the students!)
 - The contest can have MANY different possible winning strategies
 - Engineering analysis can tip the scales in a student's favor!
- The answer is to:
 - Envision potential *strategies*
 - A *strategy* is an approach to solving a problem, but it does not include mechanism detail
 - Consider the feasibility of *strategies* in terms of physics, resources required, and resources available (available materials, equipment, time...)
 - Select one or two *strategies* for further development which define the detailed mechanism....
 - *Concepts, Modules, Components*
 - Follow a process whose pattern of development repeats at each level of detail
- What better way to design a robot for a contest than to understand and use the process used to design the contest?!
 - Try to *reverse engineer* the contest, including building and taking apart a model (CAD solid model or a physical model) of the table and recreating the analysis that likely went into its design

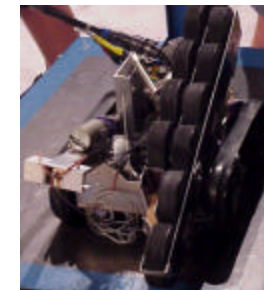
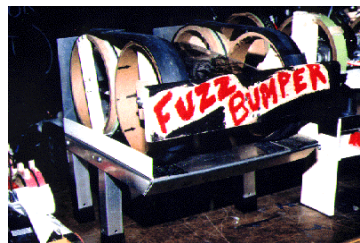
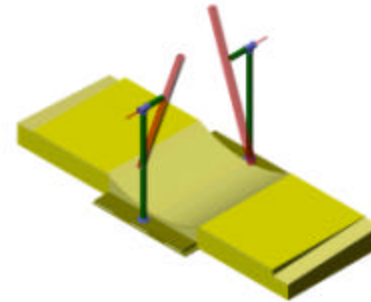


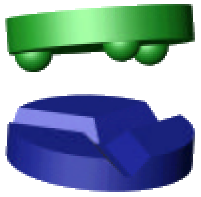


Deterministic Design: *Disruptive Technologies*



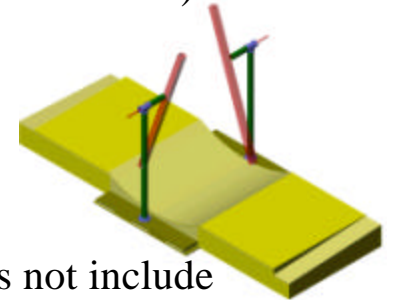
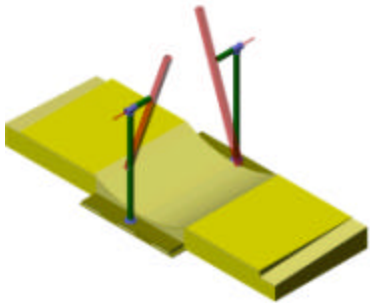
- Analysis is the lens which brings a problem into focus and lets you clearly see the best return on your investment
 - Value analysis of scoring methods
 - Physics of scoring methods
 - Risk analysis
 - Schedule analysis

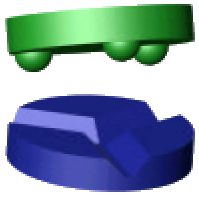




Deterministic Design: *Reverse Engineering*

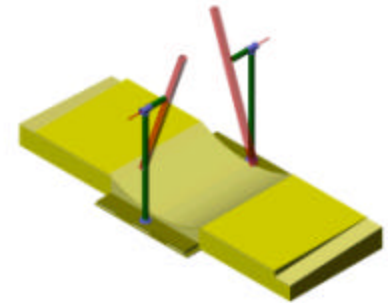
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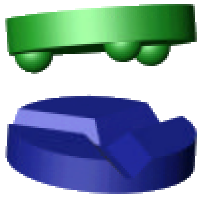


Deterministic Design: *Schedules*

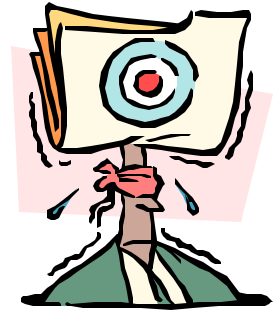
- Time is relative, but you will soon run out of it if you keep missing deadlines!
 - No matter how good your ideas are, their value decays exponentially with every day they are late
 - Once a customer starts buying a product, if the manufacturer maintains diligence, you will find it extremely difficult to regain market share
- The process of getting a product to market involves phases
 - Identify & study problem, develop solution strategies and evolve “best one”
 - Create concepts and evolve “best one”
 - Create modules
 - Detail design, build, & test the modules starting with the most risky
 - Assembly integration, test, and modify as needed
 - Document and ship



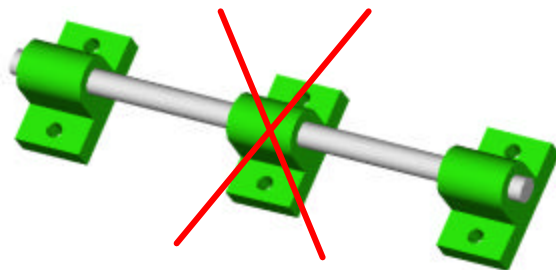
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development				Integration & Test				!!!	WWW	



Deterministic Design: *Risk Management*

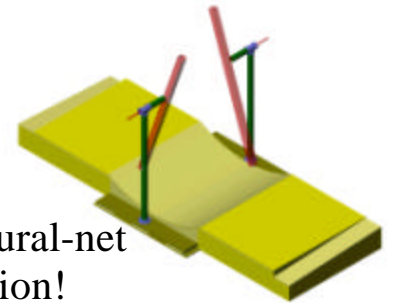


- The key to deterministic design is risk management
- For every idea, risk must be assessed
 - Ask yourself which ideas and analysis (physics) are you most unsure of?
 - Which element, if defined or designed wrong, will neutralize the machine?
 - For every risk identified
 - Estimate the probability of occurrence (High, Medium, Low)
 - Identify a possible countermeasure
 - Prioritize your risk and continue to do analytical, computational, or physical *Bench Level Experiments* (BLEs) to test ideas before you move forward!
 - *Good Engineering Practice* continually applies!
 - Prayer is for your personal life!
 - Determinism is for design!

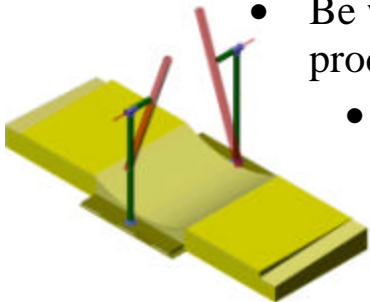


Deterministic Design: *Analytical Instinct*

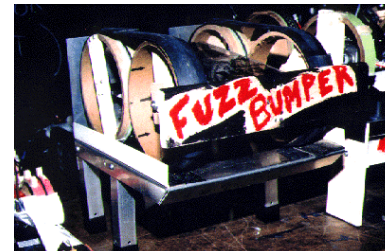
- **TRUST** your analytical & deterministic training
 - Seek to create and then defeat ideas by exploring ALL possible alternatives
 - In a Mr. Spock™ - Commander Data™-like manner, logically seek to establish the need, understand the problem, create many concepts, subjectively evaluate ideas, analyze the bajeebees out of the idea.
 - This is the careful execution of the *Design Process*
 - This is what the best designers do to turn dreams into realities



- **& LISTEN** to your instincts
 - Be wild, random, and impulsive, and take great ideas that your bio-neural-net produces and keep evolving and hammering it until it yields an invention!
 - Sketch the first thoughts that come to mind when you encounter a problem!
 - This is the Captain Kirk™, shoot from the hip, John Wayne approach.
 - This is the element of passion that is the essence of great design!
 - This is what drove Mozart, Edison, Einstein, Elvis...the great creators!



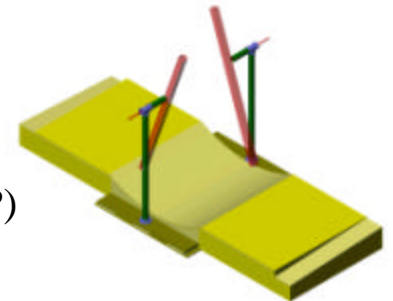
- Combine *analysis & instinct* to become a successful *passionate* design engineer!
 - Learn from experience how much of each to use!
 - Tim Zue's tracked vehicle won, because he used sandpaper to increase the friction on his starting platform!



Systematic Organization of Ideas

<i>Functional Requirements (Events)</i> <i>Words</i>	<i>Design Parameters (Idea)</i> <i>Words & Drawings</i>	<i>Analysis</i> <i>Experiments, Words, FEA, Equations, Spreadsheets...</i>	<i>References</i> <i>Historical documents, www...</i>	<i>Risk</i> <i>Words, Drawings, Analysis...</i>	<i>Counter-measures</i> <i>Words, Drawings, Analysis...</i>
A list of independent functions that the design is to accomplish. Series (1,2,3...) and Parallel (4a, 4b..) FRs (Events) can be listed to create the <i>Function Structure</i>	Ideally independent means to accomplish each FR. AN FR CAN HAVE SEVERAL POTENTIAL DPs. The “best one” ultimately must be selected	Economic (financial or maximizing score etc), time & motion, power, stress... EACH DP’s FEASIBILITY MUST BE PROVEN. Analysis can be used to create DPs!	Anything that can help develop the idea including personal contacts, articles, patents, web sites....	High, Medium, Low (explain why) risk of development assessment for each DP	Ideas or plan to mitigate each risk, including use of off-the-shelf known solutions

- To actually use the FRDPARRC Table:
 - Create one actual table that becomes your development roadmap
 - Dedicate one sheet to each FR/DP pair
 - This can become your Milestone Report (“Press Release”) for an idea (DP)



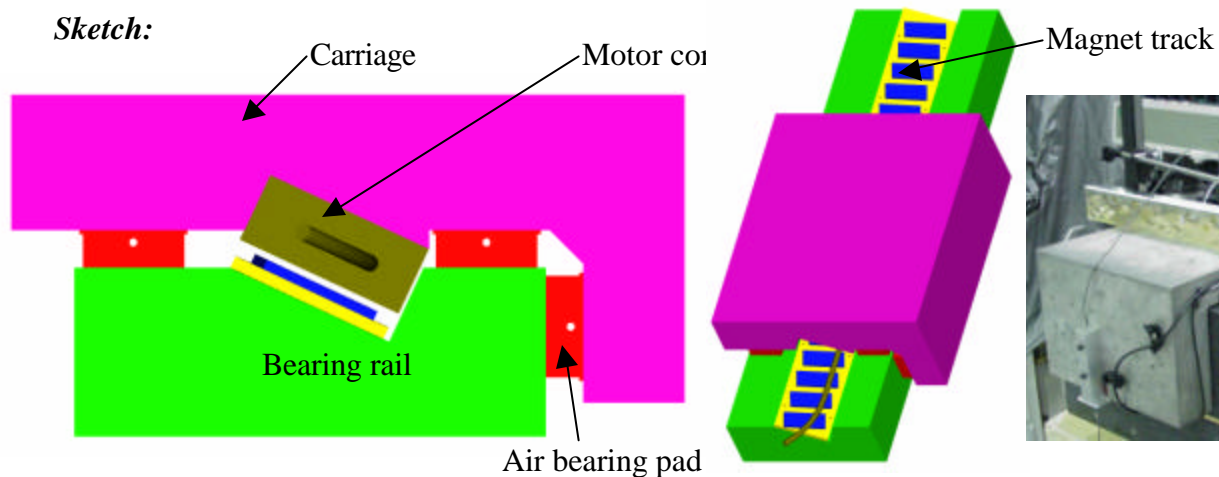
FRDPARRC Example: A Precision Linear Motion System

FRDPARRC Sheet Topic: Precision Low Cost Linear Motion Stage

Functional Requirement (Event) Preload air bearings

Design Parameter (description of idea) Preload air bearings using magnetic attractive force of motor, so air bearings need only ride on two surfaces instead of having to wrap around a beam; thus many precision tolerances to establish bearing gap can be eliminated

Sketch:



Assume we want even preload pressure per pad	
Motor preload angle	26.57
Motor attraction force, Fm	4000
Motor width (mm), L	130
Motor thickness	47
Space for motor thickness	65
Supply pressure, Ps (Pa, atm)	600000
bearing efficiency, m	0.35
preload proportion of total load capacity, f	0.5
vertical/horizontal load capacity, vh	2
X direction pads' total area (mm^2), Ax	21994
Y direction pads total area, (mm^2) Av	43989

Analysis (physics in words) The magnet attraction force is 5x greater than the motor force, so it can be positioned at an angle such that even preload is applied to all the bearings. As long as the magnet attraction net vertical and horizontal force are proportional to the bearing areas and is applied through the effective centers of the bearings, they will be evenly loaded without any applied moments.

Analysis

$$F_v = F_{magnets} \sin q \quad \frac{F_v}{F_H} = \frac{A_v}{A_H} = \tan q$$

$$F_H = F_{magnets} \cos q \quad q = \arctan\left(\frac{A_v}{A_H}\right)$$

References: Vee & Flat bearings used on many common machine tools where gravity provides preload. NEAT uses two magnet tracks, one horizontal and one vertical, to provide horizontal and vertical preload force. Patent search revealed no other relevant art.

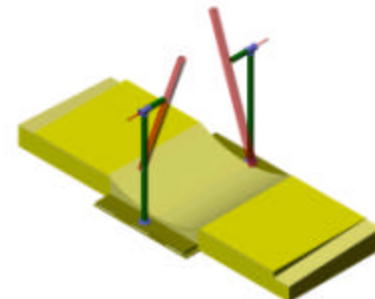
Risks: The magnet pitch may cause the carriage to pitch as the motor's iron core windings pass over the magnets

Countermeasures: Add steel out of phase with motor core position, or if the error is repeatable, map it and compensate for it in other axes

Design Process



- Follow a design process to develop an idea in steps from **COARSE** to **fine**:
 - **First Step:** Evaluate the resources that are available
 - **Second Step:** Carefully study the problem and make sure you have a clear understanding of what needs to be done and what are the constraints (rules, limits)
 - Steps 1 & 2 are often interchangeable
 - **Third Step:** Start by creating possible **strategies** using words, analysis, and simple diagrams
 - Imagine possible motions, data flows, and energy flows from start to finish or from finish back to start!
 - Continually ask “Who?”, “What?”, “Why?”, “Where”, “How?”
 - Simple exploratory analysis and experiments can be most enlightening!
 - Whatever you think of, others will too, so think about how to defeat that about which you think!
 - **Fourth Step:** Create **concepts** to implement the best **strategies**, using words, analysis, and sketches
 - Use same methods as for **strategies**, but now start to sketch ideas
 - Often simple experiments or analysis are done to investigate effectiveness or feasibility
 - Select and detail the best **concept**...
 - **Fifth Step:** Develop **modules**, using words, analysis, sketches, and solid models
 - **Sixth step:** Develop **components**, using words, detailed analysis, sketches, and solid models
 - **Seventh Step:** Detailed engineering & manufacturing review
 - **Eighth Step:** Detailed drawings
 - **Ninth Step:** Build, test, modify...
 - **Tenth Step:** Fully document process and create service manuals...





First Step: *Resource Assessment*

- Before even thinking about potential solutions to a problem, one has to first take stock of the available resources:

- What time is available?

- When is the project due?
- How many person-hours a week can be spent on the project?
- What are the hours of operation for support facilities (library, shop, computers...)
- Designer engineers are often *way too* ambitious!

- What materials and components are available?

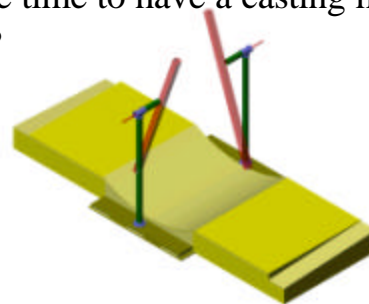
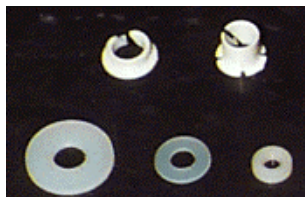
- Lay out all the materials you have (physically or catalogs) in front of you and play with them, let them talk to you, what are their limits, how have others used them...
- Look through hardware magazines
- Check the Web: <http://pergatory.mit.edu/2.007> , <http://www.efunda.com/home.cfm>
- Look at other machines
- Knowing your hardware is a **POWERFUL** design catalyst

- What manufacturing processes are available?

- You may not have access to a wire EDM, nor the time to send out the parts!
- You may not have the time to have a casting made!

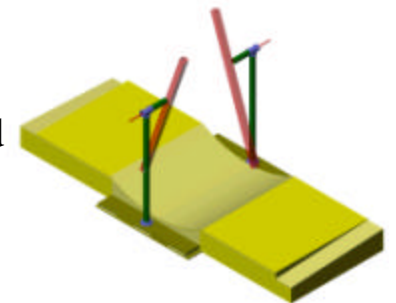
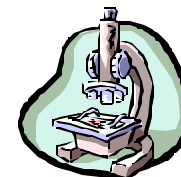
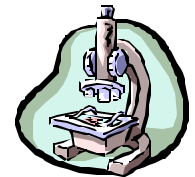
- What people are available?

- Engineering?
- Manufacturing?
- Management?
- Marketing....?



Second Step: Understanding the *Problem (Opportunity!)*

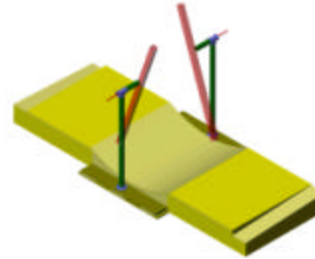
- Any problem can be dissected and understood by establishing a starting point, and then analyzing the system and its elements
 - It is like creating a design in reverse
- Study a problem and then define it in terms of its energy storage and dissipative elements, and its geometry and materials:
 - **Simple physical models**
 - Physically play with the kit and contest table: Let the hardware talk to you....
 - A *sketch model* made from simple materials enables you to play with the problem
 - **Simple drawings**
 - A simple hand-drawn isometric figure helps you to pattern the problem into your bio neural net
 - A simple solid model can also be very useful, particularly when later seeking to test your solid model solution on the problem
 - **Physics: First-Order-Analysis**
 - Words to describe the physics
 - Simple analysis with guestimates of realistic numbers (spreadsheets)
 - **Words** (in a table or bulleted list) to describe what problem must be solved
 - What must be accomplished? (e.g., tip a balance...*functions, events*)
 - What are the constraints? (e.g., rules, cost, size, time)





Third Step: *Developing Strategies* Concepts Modules Components

- Playing
 - Play with the contest table and the kit parts
 - Create simple experiments
- Drawing
 - Sketch all the motions that might occur (use arrows to indicate motions)
 - ROUGH Sketch potential concepts (just stick figures)
 - Overlay sketches and search for patterns and AHAs!
- Reading
 - Study past 2.007 contests
 - Study construction equipment, websites of mechanisms and other robot contests....
- Writing
 - Write a story about how the contest was won.....imagine the future!
 - The FRDPARRC Table is a fantastic catalyst
- Arithmetic (analysis)
 - Analyze the effectiveness of different scoring methods with a sensitivity study
 - Create time/motion studies of the table
 - Investigate geometric packaging options
 - Sketch free-body-diagrams to understand how the forces flow within the system
- Load your mind with information
 - let your bio-neural-net start creating broad overall pictures of what gets the most done with the least effort

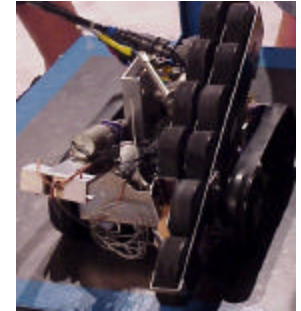


Third Step Example:

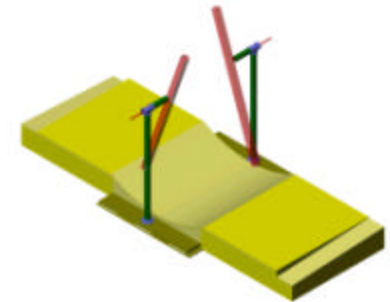
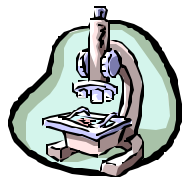
Strategies for The MIT and the Pendulum!

Functional Requirements	Possible Design Parameters (Concept's FRs)	Analysis	References	Risk	Counter-measures
Score with balls	1) Acquire balls and move them into the goal 2) Collect balls and pucks and deposit in goal 3) Bat them into the goal	1) Linear motion 2) Linear motion, Power to raise the balls to the goal 3) Trajectories, Conservation of momentum	1) 8.01 text 2) Past 2.007 contests 3) Ball shooters from past contests	1) Opponent scatters balls and pucks 2) Machine becomes too big, opponent blocks 3) Balls are too large and heavy	1) Acquisition device must also be able to pick up from the ground 2) Gather a few, Set up blocking gate 3) Ball on ramp, pinball shooter
Score with pendulum	1) Actuate from ground 2) Actuate from pendulum	?	?	?	?
Block opponent from scoring	1) Scatter pucks and balls 2) Anchor the pendulum	?	?	?	?

Fourth Step: *Developing Concepts*



- A **concept** is a vision of how one could actually accomplish the **Strategy**:
 - Words to describe what the concept must do, and how it will work
 - Ideally in simple tabular form, like a FRDPARRC Table
 - Simple sketch
 - A simple hand-drawn isometric figure often suffices
 - A simple solid model can also be very useful
 - A sketch model made from simple materials can also be very useful
 - First-Order-Analysis
 - Spreadsheet-based time and motion study
 - More detail based on better estimates of machine size...
 - Preliminary power, accuracy, or stress calculations
 - More detail based on better estimates of machine weight...
 - The design engineer needs to take care to propose a concept in just enough detail to be assured that it could indeed be implemented
- Example: **Concepts** for **Gather pucks and balls and deposit in goal Strategy**
 - **Concept A** for **Strategy 1**: Drive around picking up pucks and balls and deposit them into the goal one-by-one, so as to avoid complexity or jamming
 - After scoring with objects, the vehicle could go and actuate the pendulum
 - **Concept B** for **Strategy 1**: Gather pucks and balls using a combine-like harvester that collects them and dumps them into a bin, and then drives over and raises the bin and dumps it into the scoring goal
 - After scoring with objects, the vehicle could go and actuate the pendulum



Fourth Step Example:

Concepts for the Knock Down Balls Strategy

Functional Requirements (Distilled from Strategy's DPs)	Possible Design Parameters (Modules FR's)	Analysis	References	Risk	Counter-measures
Gather pucks and balls and deposit in goal	1) Pick up and score one at a time 2) Harvest lots and dump loads	1) Time/Motion study, Friction/slip, Linkage design 2) Friction, slip, linkage design	8.01 text and Past 2.007 contests. Farm equipment websites	1) Not enough time to make multiple trips 2) Gather bin is too large	1) Gather 2 or 3 objects 2) Gather 2 or 3 objects
Actuate pendulum from ground	1) Vehicle knocks pendulum as it drives by 2) Fixed-to-ground spinning actuator	?	?	?	?
Block opponent	1) Molestabot 2) Pendulum clamp	?	?	?	?

Fifth Step: *Developing Modules*

- A **module** is a subassembly that has a defined envelope and specific inputs and outputs that can be engineered, built, and tested and then assembled with other **modules** to implement the **concept**



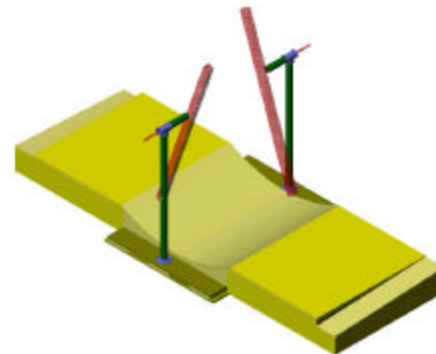
- Pick any **module**, and you will also get sub- **modules**
 - Example: Powertrain: Transmission, Motors, Crawler tracks
 - Hence the term “**module**” implies a *granularity* of detail



Words to describe what the **module** must do, and how it will work (FRDPAARC)

- Drawings
 - Initially a simple hand-drawn isometric will suffice
 - There may be many different ways of designing the **module**
 - » The process of **strategy, concept, module, components** can be applied again!
 - A solid model (layout drawings) will eventually need to be created
- First-Order- and Detailed-Analysis
 - Motion, power, accuracy, stress...
 - Greater detail as the module detail increases
- Developing **modules** is the first part of what some called the “**embodiment**” phase of design

- Example: **Modules** for the **Harvester Concept**
 - **Module 1** for **Concept B**: Gatherer
 - **Module 2** for **Concept B**: Bin
 - **Module 3** for **Concept B**: Deposit mechanism
 - **Module 4** for **Concept B**: Vehicle



Fifth Step Example: *Modules for the Harvester Concept*

Functional Requirements (Distilled from Concept's DPs)	Possible design Parameters (Components' FRs)	Analysis	References	Risk	Counter-measures
Harvest objects	1) Rotary paddles or brush 2) Reciprocating paddle 3) Crab-claws	1) Angular acceleration 2) Linkages 3) Triggers	1) Street sweepers, Combine Harvesters 2) Hungry Hippos game 3) Crabs	1) Objects jam 2) Complexity 3) Complexity	2) Reversible, or raise and lower 2) Single central arm to make T 3) Rotary system
Bin	1) Passive half-cylinder hands 2) Actuated fingers	?	?	?	?
Deposit mechanism	1) Conveyor 2) Raise & dump	?	?	?	?
Vehicle	1) Crawler treads 2) 4WD	?	?	?	?

Sixth Step: Developing *Components*

- *Modules* are made from *components*, *sub-assemblies* or *machine elements*:



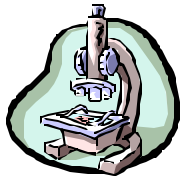
- Words to describe what the *component* must do, and how it will work

- Ideally in simple tabular form, like a FRDPARRC Table



- Drawings

- Initially a simple hand-drawn isometric will suffice



- There may be many different ways of designing the *component*

- » The process of *strategy*, *concept*, *modules*, *components* can be applied again!

- A solid model (part drawing) will eventually need to be created

- Detailed engineering analysis

- Motion, power, accuracy, stress, corrosion...

- This is the super detailed phase of design

Sixth Step Example:

Components for the Reciprocating Paddle Module

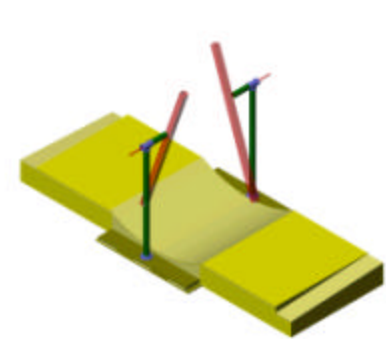
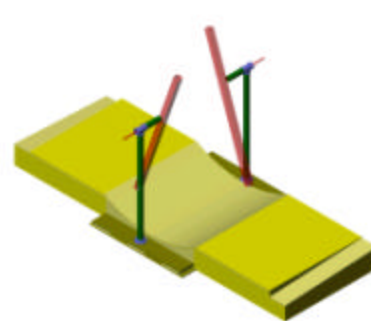
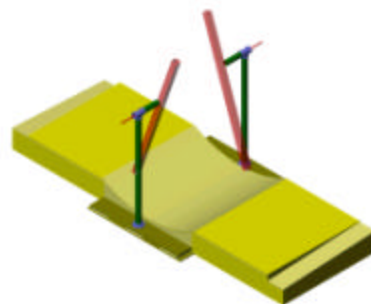
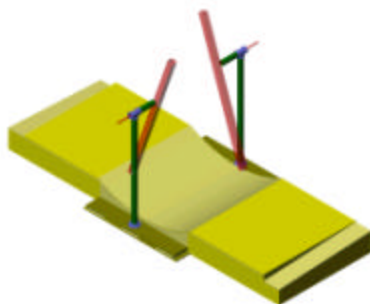
Functional Requirement's (Distilled from Module's DPs)	Possible design Parameters	Analysis	References	Risk	Counter-measures
Linkage	1) Revolute joint linkage 2) Revolute & prismatic linkage	1) 4-bar synthesis & force analysis 2) Trigonometry & force analysis	Freshman physics, Chapter 4 of this book	1) Too simple motion 2) Complexity	1) Use option 2, or a paddle 2) Make one single center linkage
Paddle	1) Bent sheet metal 2) Welded truss	?	?	?	?
Bearings	1) Nylon 2) Metal pins	?	?	?	?
Actuator	1) Screwdriver motor 2) Piston	?	?	?	?

What else?...

Patterns from the Process: *Repeats* Repeats Repeats Repeats



- Notice how each *Strategy's* Functional Requirements will each generate one or more *Design Parameters (Concepts)*...
 - Notice how each *Concept's Functional Requirements* will each generate one or more *Design Parameters (Modules)*...
 - Notice how each *Module's Functional Requirements* will each generate one or more *Design Parameters (Components)*...
- Executing a systematic design process can help you develop a *rapid design reflex*:
 - Rapidly and effectively solve design problems with a minimum of floundering!
- *As you take more and more trips around the sun, the design process and a rapid design reflex becomes hard-wired into your bio-neural-net!*



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Strategy & Concept				Detailed Engineering & Development						Integration & Test				!!!	WWW



Week 1: Milestone **ONE** (10 pts)

Resource Assessment

Deliverables:

NOTE these deliverables can be completed even though you have yet to meet in your lab sections

- Obtain locker and kit and check kit for completeness
 - PUT YOUR NAME ON YOUR TOOLS AND Critical KIT PARTS (motors!)
 - There are no free lost motor replacements for lost: you can buy your own replacements at Home Depot or from Amazon!
- Sign up for your lab section's email list (see syllabus for details)
- Review sample *Milestone Reports* on the web, so you know what to do in the future (not too much, not too little)
- **CAREFULLY READ AND ASSIMILATE TOPICS 1,2, AND 3!**
- Create a personal website for 2.007 where you can post your milestone summaries
 - If you build a good website as you go, you can get 20 extra bonus points added to your grade!
 - A great website that illustrates how you design is an invaluable interviewing tool
- Create a solid model of the table, post it on your website, and also turn in a hardcopy
- Play with the table and kit parts, and observe and discuss scoring physics (**Strategies**)
- Create a spreadsheet or Matlab script that models the physics and scoring potential at at least one **strategy** (e.g., a basic time & motion study using freshman physics knowledge)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development						Integration & Test			!!!	WWW



Week 2: Milestone **TWO** (10 pts)

Understanding the Contest & Creating **Strategies**

Deliverables:

- Play with the table and kit parts to investigate different scoring ideas (**Strategies**)
 - This includes making simple sketch models and Bench Level Experiments (BLEs)
 - Record observations, including sketches, pictures of sketch models, and analysis
- Describe the physics of the contest, including the dominant variables and means by which you can influence them (1 or 2 pages, be brief)
- Describe various scoring methods and their physics, including the dominant variables and means by which you can influence them (1 or 2 pages, be brief)
- Sketch lines of motion (actions) or simple stick figures for different **Strategies** that come to mind on printouts of your solid model of the contest table.
 - DO NOT SKETCH detailed MACHINE CONCEPTS!
- With your evaluation team, complete a Rohrbach evaluation of each other's **Strategies**
- Complete “Modular Right Angle Gearbox” design and manufacturing exercise, and demonstrate a working right angle gearbox
 - Two such gearboxes allow you to easily create a vehicle
 - If you think a vehicle may be a useful module, go ahead and assemble one and test it as a Bench level Experiment!

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept			Detailed Engineering & Development						Integration & Test			!!!	WWW	



Week 3: Milestone **THREE** (20 pts)

Developing **Strategies** & Creating **Concepts**

Deliverables:

- Evolve and refine your **Strategies** with sketches, pictures of sketch models, and analysis, include:
 - Lines of motion (actions) or simple stick figures for different strategies on a printout of your solid model of the contest table. **DO NOT SKETCH detailed MACHINE CONCEPTS!**
 - FRDPARRC Sheet for **Strategies** to *exploit* the physics of the scoring methods
 - FRDPARRC Sheet for **Strategies** to defend
 - FRDPARRC Sheet for **Strategies** to attack
 - Analysis to predict your score (time budget, physics, etc)
 - Bench Level Experiments (make simple machines from kit parts and play with them!)
- Create a weighted **Strategy** selection chart to evaluate your ideas
 - Show how you combine elements of different **Strategies** to create “best overall evolved **Strategies**”
 - Be VERY CAREFUL to analyze risks and countermeasures of each **strategy!**
- With your evaluation team, complete a Rohrbach evaluation of each other’s **Strategies**
- Play with your kit elements and sketch several **Concepts** that could implement your “best” **Strategy**
 - The reality of what you can actually build may be cause for **strategy** modification!

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development						Integration & Test			!!!	WWW



Week 4: Milestone **FOUR** (10 pts)

Developing **Concepts** & Most Critical **Module**

Deliverables:

- Based on contemplating **Concepts**, FINALIZE & LOCK-IN your **Strategy** from Milestone **Three**:
 - Present the final description of the **Strategy** in a FRDPARRC Sheet
- Evolve and refine **Concepts** for your final **Strategy**, and for the top three **Concepts** include:
 - FRDPARRC Sheet
 - Be VERY CAREFUL to analyze risks and countermeasures of each **Concept**
 - Appropriate sketches
 - Bench Level Experimentation and/or sketch models
 - Create a weighted **Concept** selection chart to evaluate your ideas
 - Show how you combine elements of different **Concepts** to create a “best overall evolved **Concept**”
- Rohrbach evaluation of each other’s **Concepts**
- Play with your kit elements and identify the most critical **Module** in your **Concept**, and sketch ideas for implementing it using the elements in your kit
 - The reality of what you can actually build may be cause for **concept** modification!

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development				Integration & Test				!!!	WWW	



Week 5: Milestone **Five** (10 pts) Developing **Modules**

Deliverables:

- Based on contemplating **Modules**, FINALIZE & LOCK-IN **Concept** using the weighted selection chart from Milestone **Four**:
 - Present the final description of the **Concept** in a FRDPARRC Sheet
- Separate your **Concept** into **Modules**:
 - Create a sketch showing how the **Modules** fit together
 - For each **Module**, create:
 - FRDPARRC Sheet
 - Be VERY CAREFUL to analyze risks and countermeasures of each **Modules**
 - Appropriate Sketches
 - Select the best version of each **Module** using a weighted selection chart
 - Show how you combine elements of different **Modules** to create “best overall **Modules**”
- Start development of the Most Critical (risky) **Module**
 - Perform Bench Level Experiments to help start developing the Most Critical **Module**
- Rohrbach evaluation of each other’s **Concepts** and Most Critical (risky) **Module**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept					Detailed Engineering & Development					Integration & Test			!!!	WWW



Week 6: Milestone **Six** (10 pts)

Developing the Most Critical **Module** (MCM)

Deliverables:

- FINALIZE & LOCK IN Most Critical **Module** from Milestone **Five**:
 - Present the final description of the most critical **Module** in a FRDPARRC Sheet
 - Be VERY CAREFUL to analyze risks and countermeasures
- Proceed with detailed engineering of **Components** for the Most Critical **Module**
 - FRDPARRC Sheets
 - Appropriate analysis (silicon is cheaper than metal!)
 - Bench Level Experimentation (if analysis too tough for you or teacher, run an experiment!)
 - REMEMBER, part of development is creating BLEs (get in the lab and build and experiment and try stuff!)
 - Sketch the idea and identify sensitive design parameters (e.g., dimensions)
 - Solid Modeling of **Components** for the Most Critical **Module** so you can make its parts
 - Manufacturing drawings and process plans (know what you need to do before you step up to the machine!)
 - Solid Modeling of **Components**
- Rohrbach evaluation of each other's **Modules**

Your intention should be to build & test the Most Critical **Module** first, so you have a good idea of will your concept work well before spring break

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development				Integration & Test				!!!	WWW	



Week 7: Milestone **Seven** (15 pts)

Test & Evolve Most Critical **Module** (MCM)

Deliverables:

- Finish building and testing your most critical **Module**
- Determine what works and what doesn't, and evolve your **MCM** accordingly
 - If the MCM is a total unsalvageable failure, this will not affect your grade, IF you can show how you plan to fall back to a less risky **concept** (or **strategy**)
 - Now is the time to change, or forever hold your peace
 - You only have SIX weeks left, and soon it will be warm and sunny outside!
- FINALIZE & LOCK-IN the remaining **Modules**:
 - Present the final description of these **Modules** in FRDPARRC Sheets
- Rohrbach evaluations of each other's most critical **Modules**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development				Integration & Test				!!!	WWW	



Week 8: Milestone **EIGHT**

Spring Break: Relax!

Deliverable:

- Come back Relaxed!

**NOTE: Colin
was a 2.007
winner!**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Strategy & Concept				Detailed Engineering & Development						Integration & Test				!!!	WWW



Week 9: Milestone **NINE** (15 pts) Most Critical **Module** Complete

Deliverables:

- Finish building and testing most critical **Module**
 - It should now be a working module, ready to integrate into the rest of your machine!
- Complete manufacturing drawings and process plans for what you will build next week
- Develop a manufacturing, assembly, and test schedule for rest of the course
- Proceed with detailed engineering of **Components** for the remaining **Modules**:
 - FRDPARRC Sheets
 - Use what you learned in building the MCM to carefully do the risk and countermeasures analysis!
 - Appropriate analysis (silicon is cheaper than metal!)
 - Bench Level Experimentation (if analysis too tough for you or teacher, run an experiment!)
 - Sketch the idea and identify sensitive design parameters (e.g., dimensions)
 - Solid Modeling of **Components** (you need drawings to machine parts!)
 - Manufacturing drawings and process plans (know what you need to do before you step up to the machine!)
- Rohrbach evaluation of each other's drawings and process plans
- Revise schedule for next week

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development						Integration & Test			!!!	WWW



Week 10: Milestone **TEN** (10 pts) Design, Build, Test

Deliverables:

- Manufacture **Components** from drawings made last week
- Test **Modules** from **Components** made
- Evaluate what did and did not work, and take appropriate action (fix it!)
- Proceed with detailed engineering of **Components** for the remaining **Modules**:
 - FRDPARRC Sheets
 - Use what you learned in building the MCM to carefully do the risk and countermeasures analysis!
 - Appropriate analysis (silicon is cheaper than metal!)
 - Bench Level Experimentation (if analysis too tough for you or teacher, run an experiment!)
 - Sketch the idea and identify sensitive design parameters (e.g., dimensions)
 - Solid Modeling of **Components** (you need drawings to machine parts!)
 - Manufacturing drawings and process plans (know what you need to do before you step up to the machine!)
- Rohrbach evaluation of each other's drawings and process plans

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept					Detailed Engineering & Development					Integration & Test			!!!	WWW



Week 11: Milestone **ELEVEN** (10 pts)

Design, Build, Test, & Begin Integration

Deliverables:

- Manufacture **Components** from drawings made last week
- Test **Modules** from **Components** made
- Begin Integration of **Modules**
- Evaluate what did and did not work, and take appropriate action (fix it!)
- Proceed with detailed engineering of **Components** for the remaining **Modules**:
 - FRDPARRC Sheets
 - Use what you learned in building the MCM to carefully do the risk and countermeasures analysis!
 - Appropriate analysis (silicon is cheaper than metal!)
 - Bench Level Experimentation (if analysis too tough for you or teacher, run an experiment!)
 - Sketch the idea and identify sensitive design parameters (e.g., dimensions)
 - Solid Modeling of **Components** (you need drawings to machine parts!)
 - Manufacturing drawings and process plans (know what you need to do before you step up to the machine!)
- Rohrbach evaluation of each other's drawings and process plans
- Revise schedule for next week

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development						Integration & Test			!!!	WWW



Week 12: Milestone **TWELVE** (20 pts) Demonstrate Working Machine

Deliverables:

- Manufacture **Components** from drawings made last week
- Test **Modules** from **Components** made
- Evaluate what did and did not work, and take appropriate action (fix it!)
- Assemble and demonstrate working machine (at least to some degree)
- Evaluate what did and did not work
- Complete manufacturing drawings and process plans for all **Components** that need to be **finished!**
- Revise schedule for next week

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development						Integration & Test			!!!	WWW



Week 13: Milestone **THIRTEEN** (10 pts) In-Class Contest & “Ship” Machine

Deliverables:

- Clean up your machine and test, test, test!
- Have a working machine ready to compete in the in-class contest
 - Your score will determine your seeding in the final contest
 - High score machines will be matched against low score machines
- Evaluate what did and did not work
- “Ship” your machine:
 - Machine is judged for size and weight:
 - **Green dot means you can compete and win**
 - **Red dot means you can compete in first round, but cannot win**
 - Machine is boxed in FREM container and put into locked locker
- Recycle unused materials and components
- Clean up your 2.007 web site (if you have one!)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development						Integration & Test			!!!	WWW



Week 14: Milestone **FOURTEEN** (80 pts) Final Contest (Celebration!)

Deliverables:

- Check the website for details
- Pick up your machine (and FREM box) from the Lab before 5 PM on the first contest day and take it to the Contest Arena
 - Place your machine in your designated section area
 - Make sure your batteries are charged and you bring your charger
- You **MUST** (please) wear your 2.007 T-Shirt and **safety glasses** to the contest
- Have FUN!

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strategy & Concept				Detailed Engineering & Development					Integration & Test			!!!	WWW	



Week 15: Milestone **FIFTEEN** (20 pts)

Document the Design

Deliverables:

- Website (if you chose to do one) containing at least:
 - What you did for each milestone:
 - Either this is already done (you did it each week), OR:
 - A clear description of how you evolved your machine
 - FRDPARRC Sheets for final **Strategy, Concept, Modules**
 - One page summary from each earlier milestone
 - Post-contest analysis:
 - What worked and what didn't?
 - What would you have changed if you could do it all over again?
 - How well did you follow the schedule
 - What do you think your grade should be, based on the fact that your grade is based 100% on how well you met weekly milestones?