

FUNdaMENTALS of Design

Topic 1

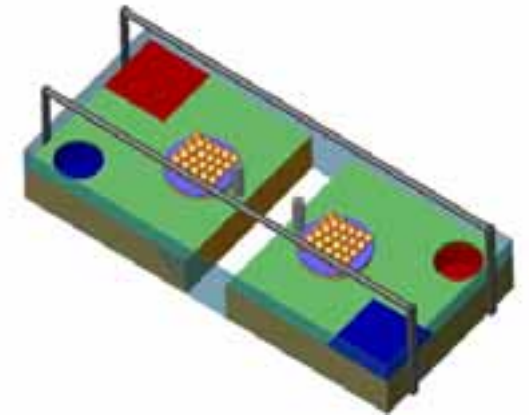
Design is a *Passionate* Process

♥Passion♥ LOVE to Create

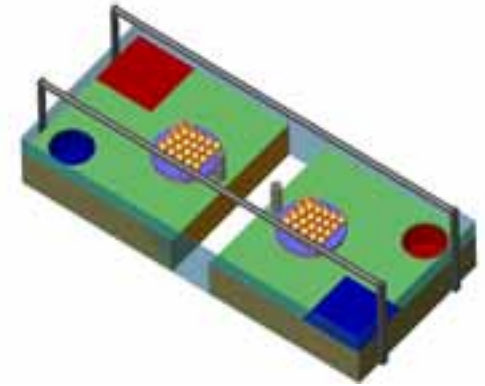
"Enthusiasm is one of the most powerful engines of success. When you do a thing, do it with all your might. Put your whole soul into it. Stamp it with your own personality. Be active, be energetic, be enthusiastic and faithful and you will accomplish your object. Nothing great was ever achieved without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

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?’*

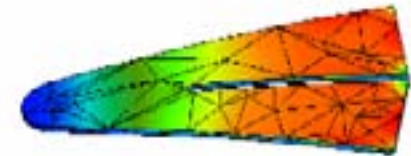
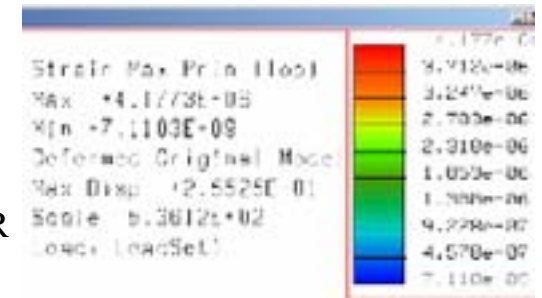
Avoid complexities and make everything as simple as possible

Remember the get-ability of parts

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

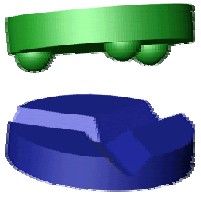
♥Passion♥ Best Engineering Practice

- 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, for example:
 - 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* illuminated thoughts!



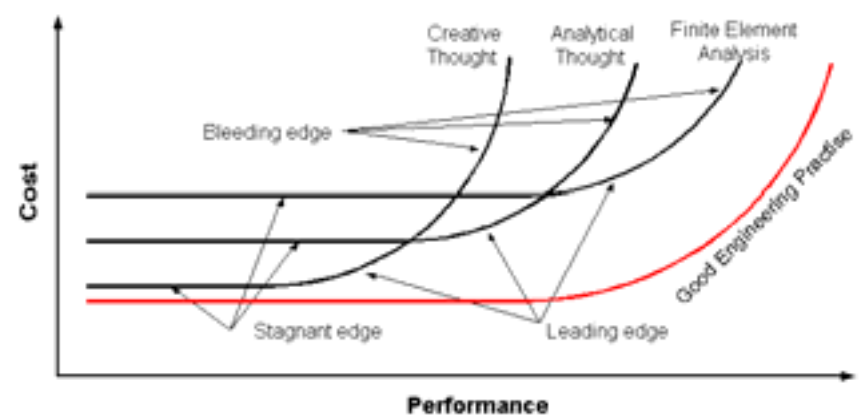
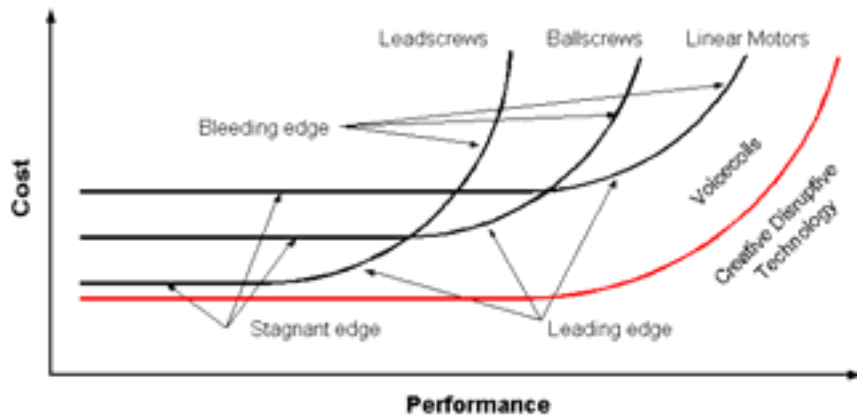
♥Passion♥ (*Play, Sketch, Model, Detail, Build & Test*)^N

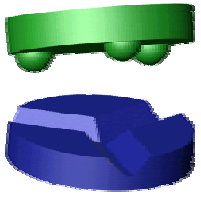
- Engineering is often a tactile, visual, verbal, cerebral, and physical activity:
 - Play with the table and the kit parts
 - Sketch ideas
 - Create physical and analytical models to identify opportunities and test possible strategies
 - Detail the machine using all the engineering skills and tools at your disposal
 - Build & test your machine!
 - *“Personal self-satisfaction is the death of the scientist. Collective self-satisfaction is the death of the research. It is restlessness, anxiety, dissatisfaction, agony of the mind that nourish science”* Jacques-Lucien Monod
- Students who follow *best engineering practice* create very impressive machines with just the correct amount of effort (and have time for a life!)



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!
 - *“If you board the wrong train, there’s no use running along the corridor in the opposite direction”* Dietrich Bonhoeffer

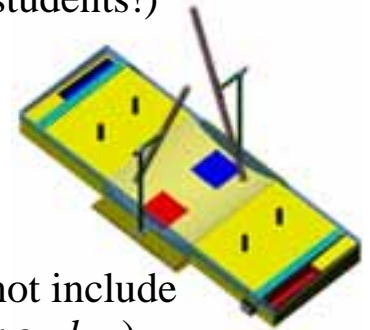
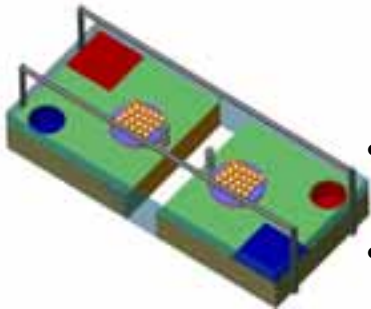


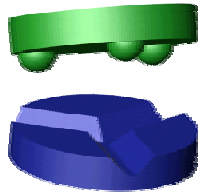


Deterministic Design: *Reverse Engineering*

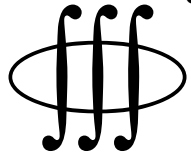


- How would you create a contest where the overall goals are:
 - The inertia of the machines is on the order of the inertia of the system
 - The system is SIMPLE to build and solid model (for the staff and the students!)
 - The contest can have MANY different possible winning strategies
 - Engineering 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 (a *strategy* can be thought of as a *tactic* or a *plan*)
 - 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



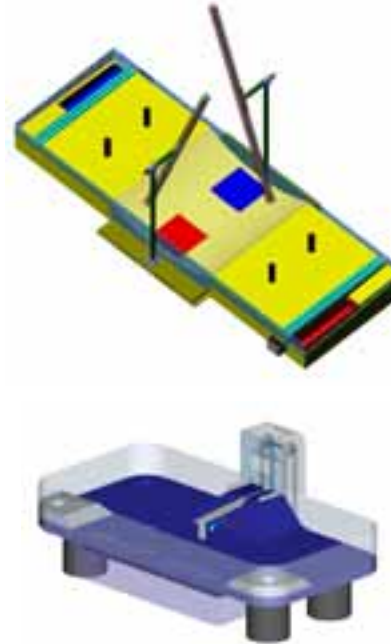


Deterministic Design: *Disruptive Technologies*



- Analysis is the lens which brings a problem into focus and lets you clearly see the best return on your investment

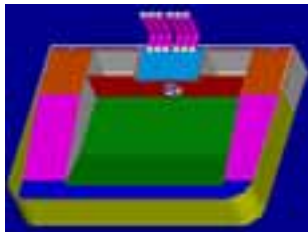
- Value analysis of scoring methods
- Physics of scoring methods
- Risk analysis
- Schedule analysis



2001's *Tiltulator!*



2000's *Sojourner This!*



1995's *Pebble Beach!*



1997's *Pass The Puck!*



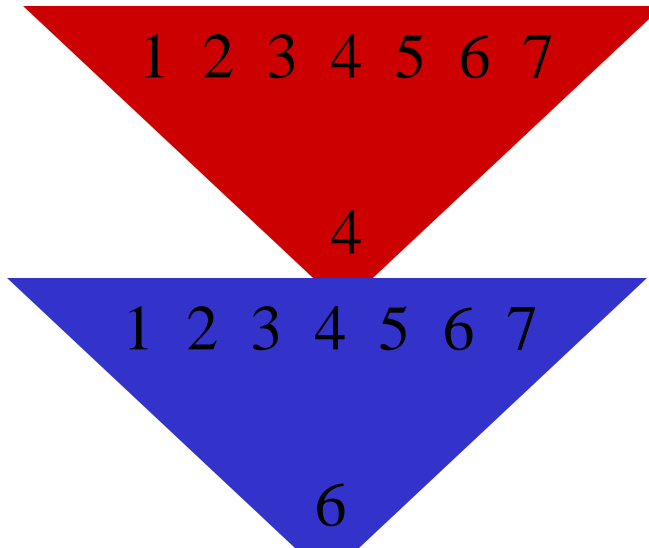
1998's *Ballcano!*



1999's *MechEverest!*

Deterministic Design: *Funnels: Strategies* *Concepts* *Modules* *Components*

- Deterministic Design leaves LOTS of room for the wild free creative spirit, and LOTS of room for experimentation and play
- Deterministic Design is a catalyst to funnel creativity into a *successful* design

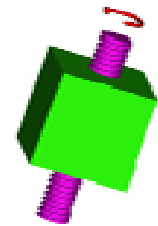
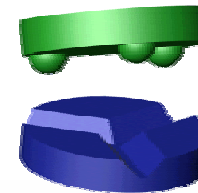
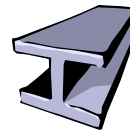
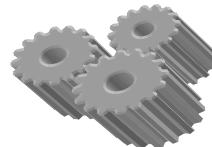
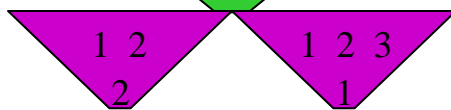
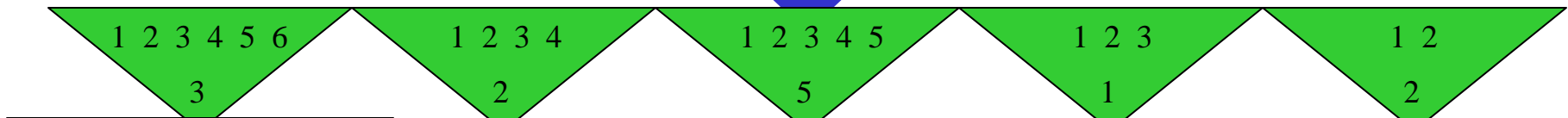


Strategy: Plan or tactics to score but there may be many different types of machines that could be used

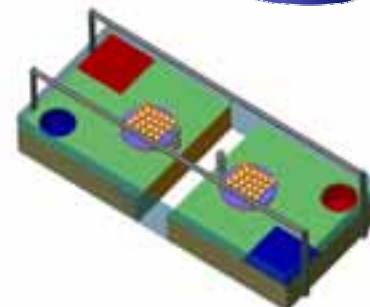
Concept: An idea for a specific machine that can execute a strategy

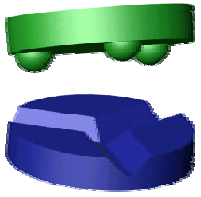
Module: A sub assembly of a machine that by itself executes a certain function

Component: An individual part



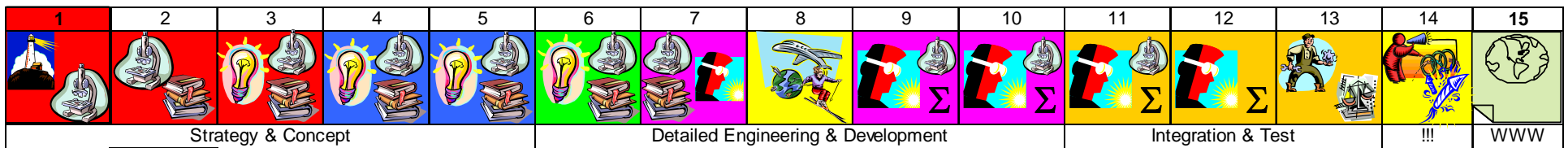
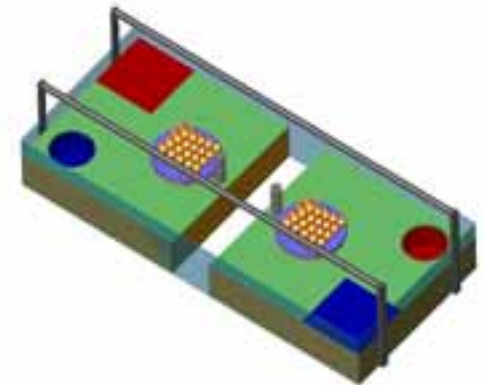
- It is OK to iterate...
 - A goal is to never have to backtrack
 - A good engineer, however, knows when its time to let go...

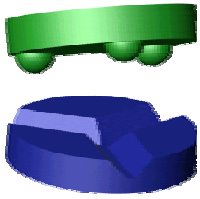




Deterministic Design: *Schedules*

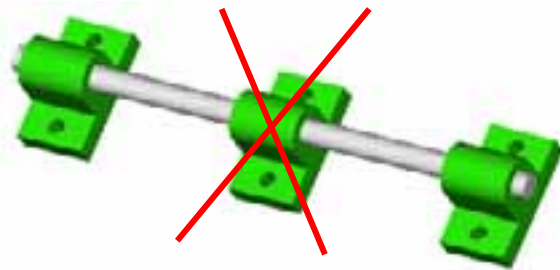
- Time is relative, but you will soon run out of it if you keep missing deadlines!
 - No matter how good your ideas are, their value decays exponentially with every day they are late
 - Once a customer starts buying a product, if the manufacturer maintains diligence, you will find it extremely difficult 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
 - Assemble, integrate, test, and modify as needed
 - Document and ship
- You must create a schedule and stick to it!
 - This is true in ALL pursuits
 - Yes, sometimes the schedule will slip...this is why you have countermeasures for risky items that fail, and you build in capacitances (float time) to allow for troubles...



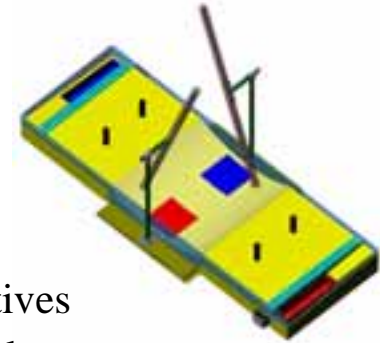


Deterministic Design: *Risk Management*

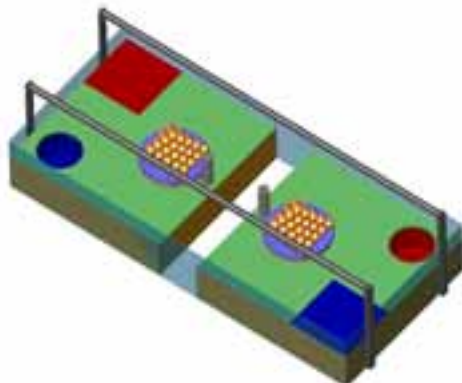
- The key to deterministic design is risk management
- For every idea, risk must be assessed
 - Ask yourself which ideas and analysis (physics) are you most unsure of?
 - Which element, if defined or designed wrong, will neutralize the machine?
 - For every risk identified
 - Estimate the probability 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



experience how much of each to use!

ie's tracked vehicle won, because he used sandpaper to increase the
on his starting platform!



Systematic Organization of Ideas: *FRDPARRC*

<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

The FRDPARRC table is an exceptional catalyst to help you identify opportunities for applying reciprocity to uncover new ideas and solve problems.

