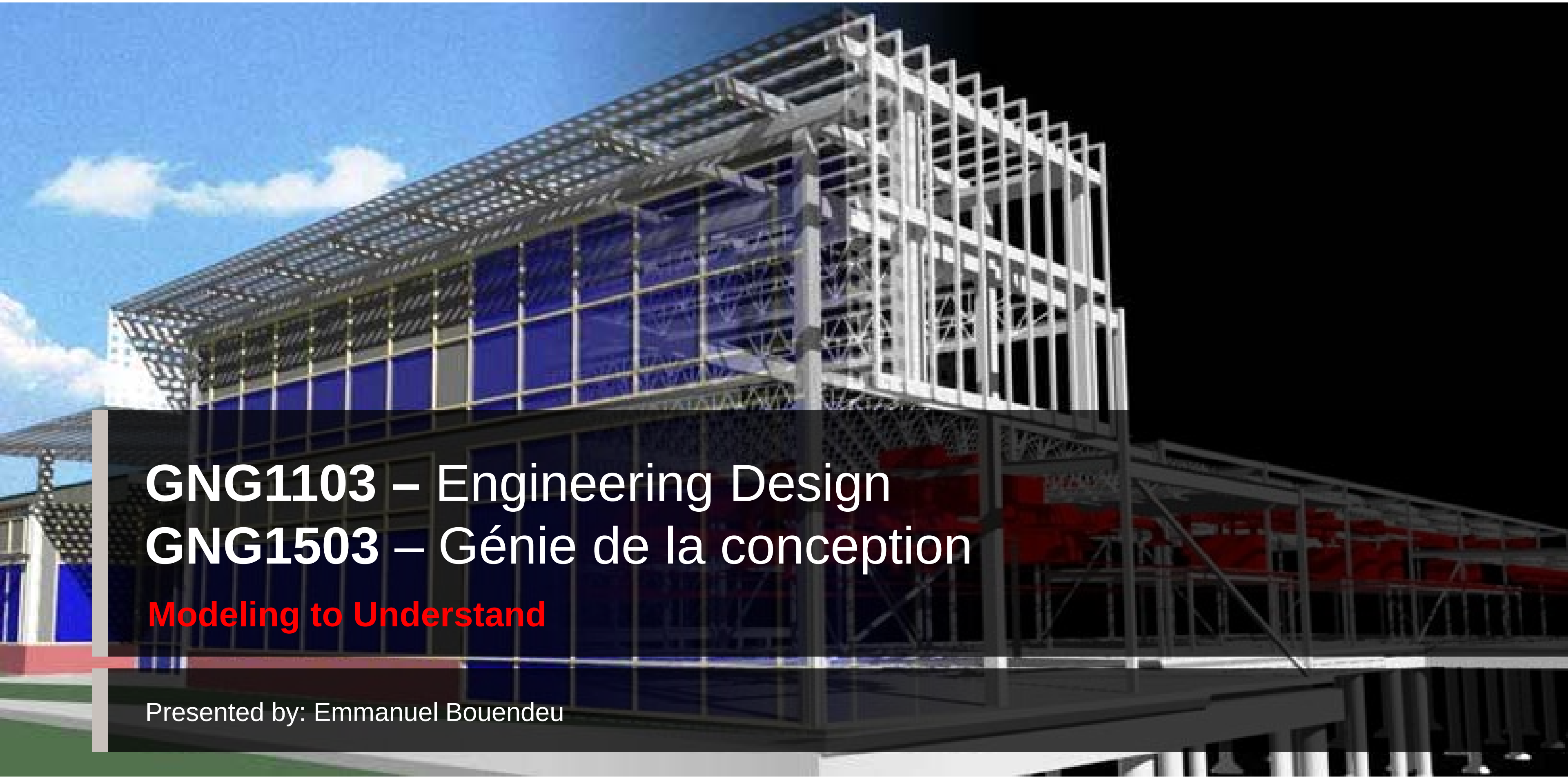


GNG1103 – Engineering Design
GNG1503 – Génie de la conception

Modeling to Understand

Presented by: Emmanuel Bouendeu

http://www.durotechgc.com

Agenda

- Reminders
- **Modeling:** Definition & Importance
- **Modeling Techniques:** Analytical, Numerical, Experimental
- **Modeling Fidelity and Noise**
- **Examples of Modeling**
  - America's Cup Team New Zealand 95
  - Ski-Hill Rescue Device
- **Review Questions**
- Presentation of your Client Meeting 3

Reminders

- **Lab 7**: MatLab (formula search): This week
- **Project Plan** (Week 4,6,8,10): Weekly review & update
- **Deliverable F** (Prototype I & Customer Feedback): March 01
- **Deliverable G** (Prototype 2 & Customer Feedback): March 08
- **Presentation for Client Meet 3** (Submission March 02) : March 04
- What is your summary of **Lecture 12**?
  - User experience design & Importance
  - Persona & Importance in engineering design
  - Usefulness of Jakob Nielson's usability heuristics

Review Questions

1. What is a **model**?
2. List three **modeling techniques** and their advantage.
3. What is the **value of models** in engineering design?
4. In the table below, indicate whether the statements are true or false.

#	**Statement**	**True/False**
1	Understanding assumptions, concepts and constraints is important for modeling.	
2	Modeling is only useful for performance analysis.	
3	Developing a technical model may include building both analytical and physical models.	
4	FEA is used for experimental models.	
5	Numerical models rely on discretization.	
6	Modeling noise makes learning effective.	

So Far...

- We have seen the importance of engineering analysis in order to:
  1. Predict the performance of our design
  2. Prevent possible system failures

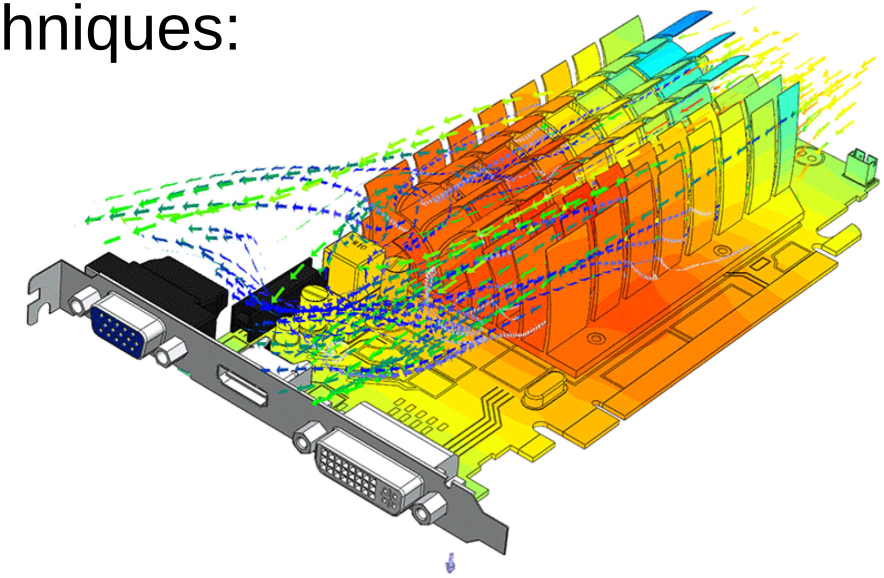
- We have also seen the various types of prototypes which can be useful for:
  1. Learning and understanding
  2. Communication
  3. Reducing risk
  4. Measuring performance

- Finally, we have emphasized the importance of a proper plan for testing your prototypes!

Today...

- We will focus on the benefits of different types of modeling techniques which can be used for analysing critical or risky aspects of your designs in order to gain a better understanding of these aspects

- Types of modeling techniques:
  - Analytical
  - Numerical
  - Experimental



Definition of Modeling

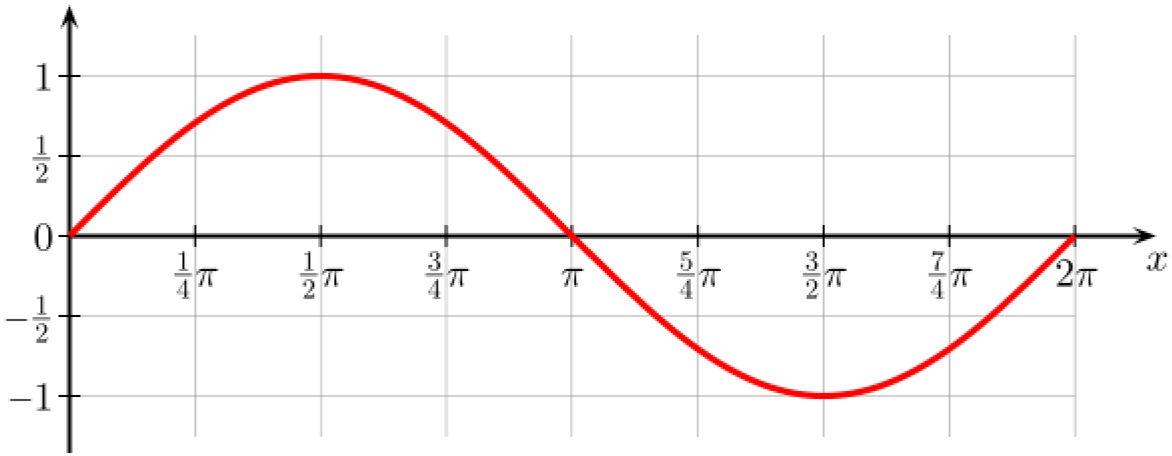
- Modeling refers to using physical or mathematical prototypes to simulate and analyse systems, entities, phenomenon or processes
- Modeling can help:
  - Reduce costs
  - Increase the quality of products and systems
  - Document and archive lessons learned
- When modeling, it is important to understand:
  - Assumptions
  - Conceptualizations
  - Implementation of constraints

Modeling: Estimate & Understand

- Modeling can be used to estimate the ***quantitative* behaviour** of a system
  - ⇨ Analysis of metric performance
- Modeling can be used to understand the ***qualitative* behaviour** of a system
  - ⇨ Customer perceptions, user experience
- Multiple different modeling techniques can be and *should be* used to validate the results and identify modeling strengths and weaknesses
- Each modeling technique has an optimal time and place for its use

Analytical Modeling

- Analytical models are mathematical representations which have closed form solutions (i.e. the solution to the model's equations can be expressed as a symbolic function or can be calculated exactly)



$$y = \sin(x)$$

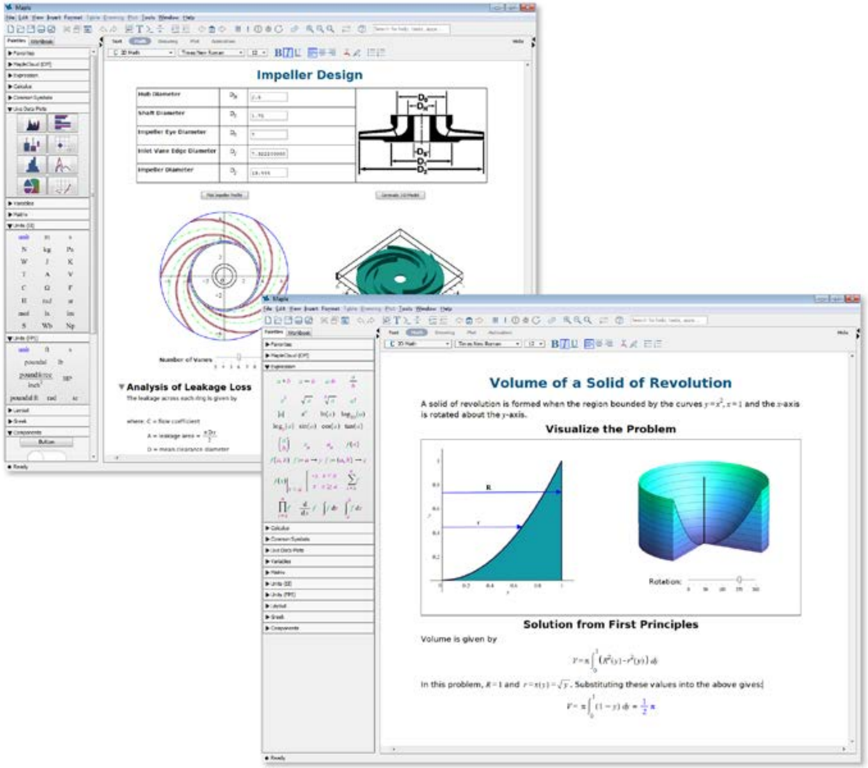
When to Use Analytical Modeling

- Analytical models are best used when a closed form solution exists and the solution procedure is straightforward
- Often quicker to set up for simple calculations
- May be used to extrapolate insight of un-modeled cases due to the nature of the equations involved and their derivation from basic scientific principles

We know the box on the right is harder to push without calculation due to our understanding of the friction force equation

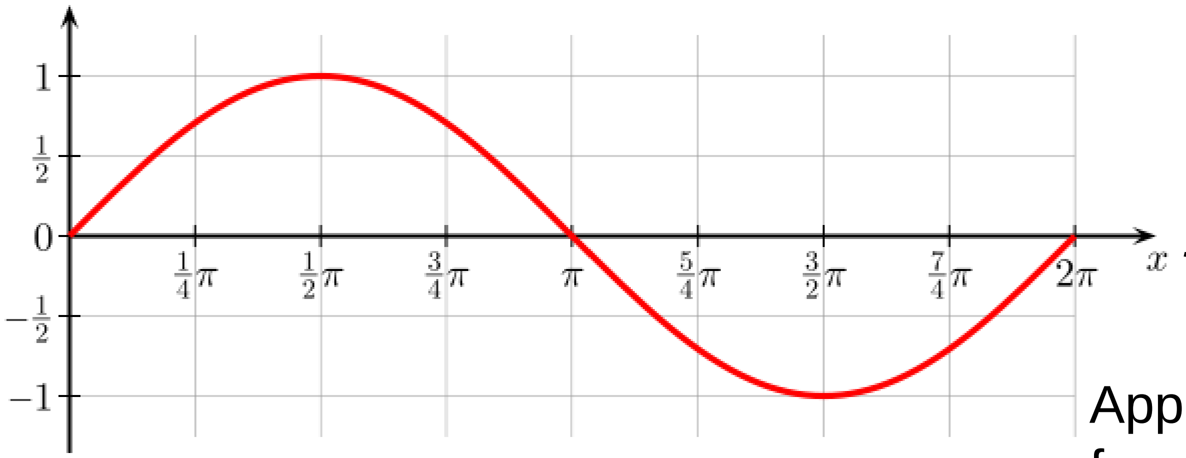
Analytical Tools Available On RemoteApps

- Excel (sort of...)
- **Maple:** A symbolic computing environment
  - ⇨ Lets you solve mathematical problems using symbolic functions rather than numerical approximations!
- Others: Mathematica, MathCAD, MATLAB (with symbolic toolbox)



Numerical Modeling

- Numerical models are mathematical representations that use discretization or time-stepping methods to approximate a solution or describe a behaviour over time (i.e. the solution to the model's equations can be expressed as discrete values in a table or a graph)

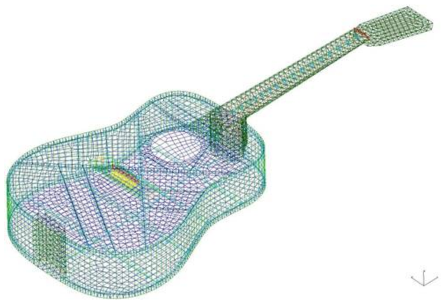


$$y \approx x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \ldots$$

Approximation of the sine function by the Taylor series

When to Use Numerical Modeling

- Numerical models are best used when no closed form solutions exist or the solution procedure is very complicated and computationally demanding
- Often quicker to setup for complex calculations
- May be used to extrapolate a large number of results quickly by varying the parameters and recalculating the results

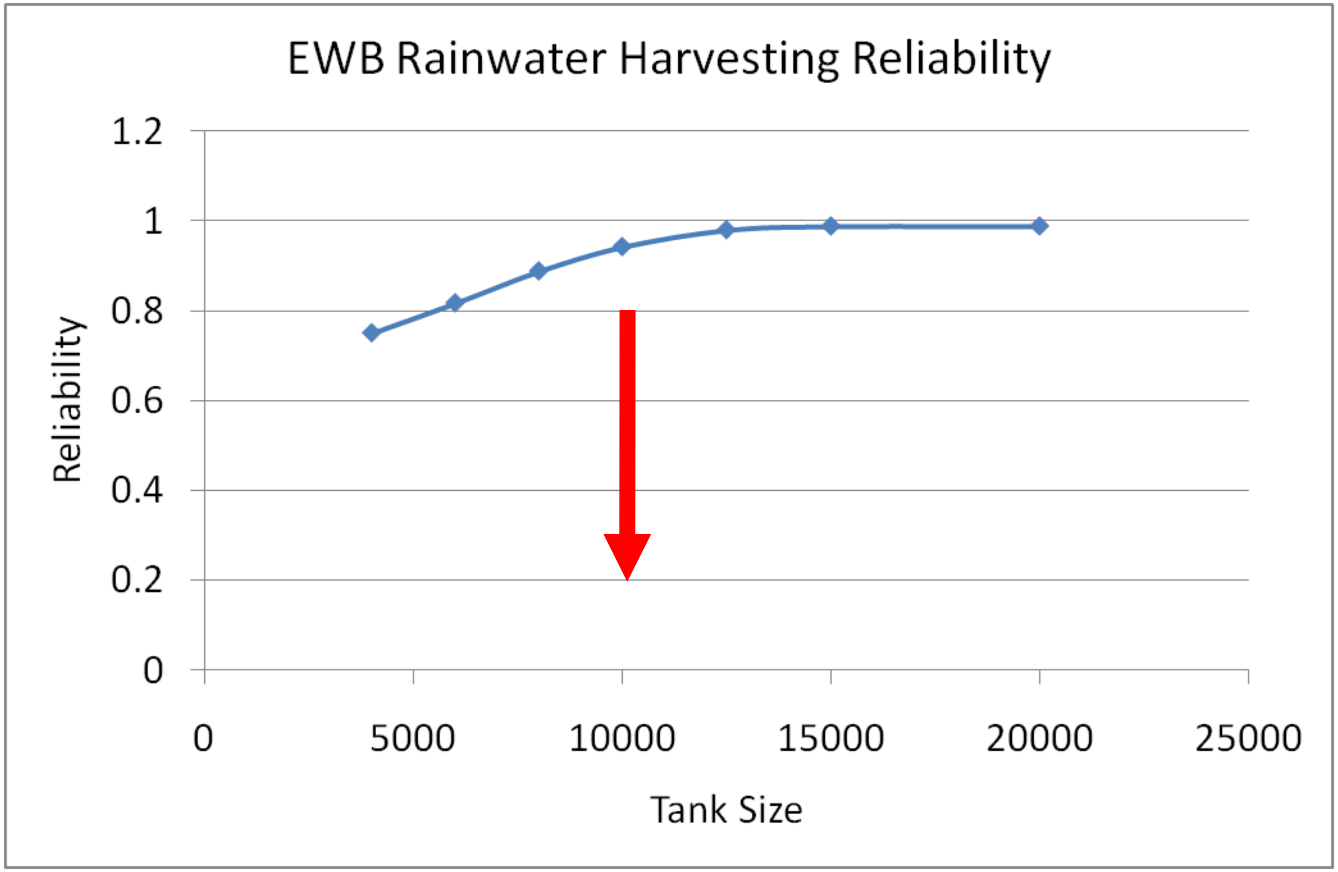


Almost impossible to reproduce analytically, and difficult to measure the effect of parameter changes experimentally

Numerical Tools Available On RemoteApps

- **MATLAB:** A numerical computing environment (also Excel)
- **ANSYS, COMSOL Multiphysics:** Powerful finite element analysis (FEA) software
- **STAR-CCM+:** Computational fluid dynamics (CFD) software
- **S-Frame**, **ETABS**, **SAFE**, **SAP2000** and **CSiBridge:** Structural analysis software (also **GeoStudio:** slopes, **Mike 21:** hydrodynamics)
- **Witness** and **UniSim Design:** Business and process planning/analysis software
- **Alerta Quartus II:** Analysis software for logic circuit designs
- **Advanced Design System (ADS):** RF design software
- **Multisim:** Electronic circuit simulator

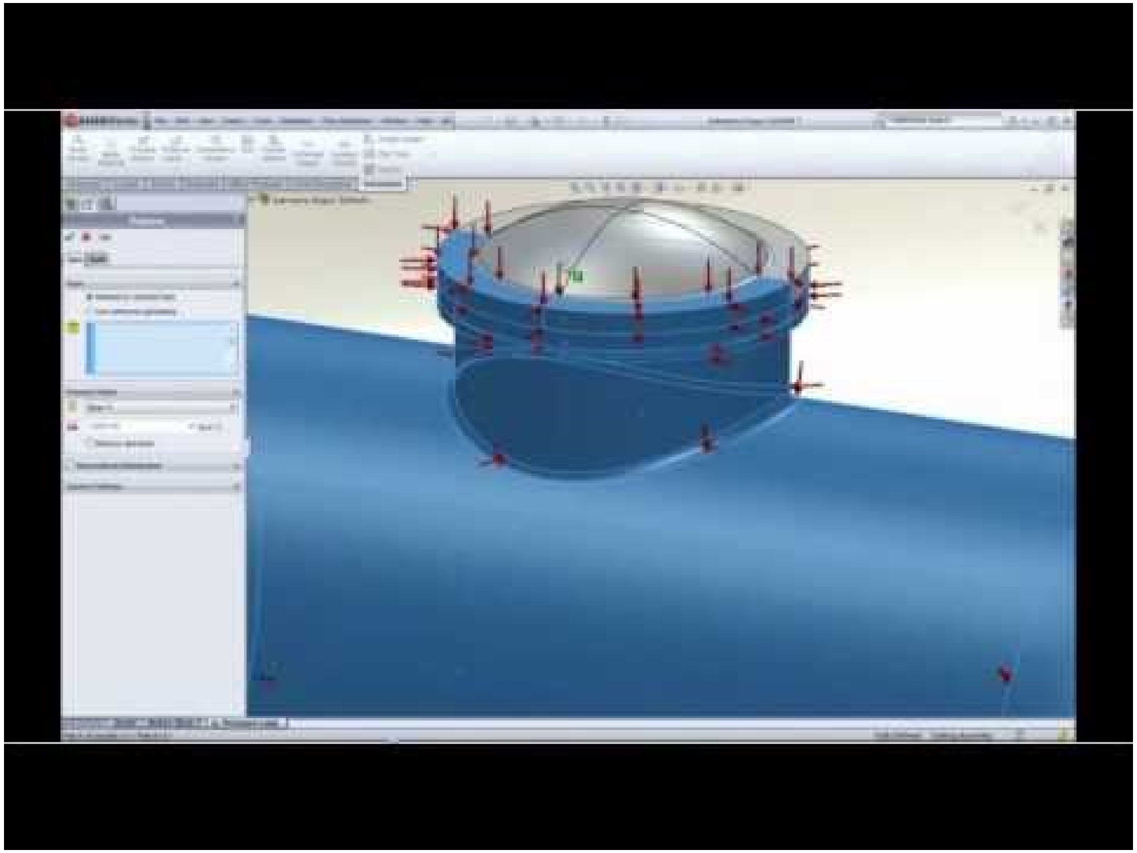
Remember EWB Case Study - Excel



Choose a suitable tank size to maximize reliability while minimizing cost

SOLIDWORKS Simulation

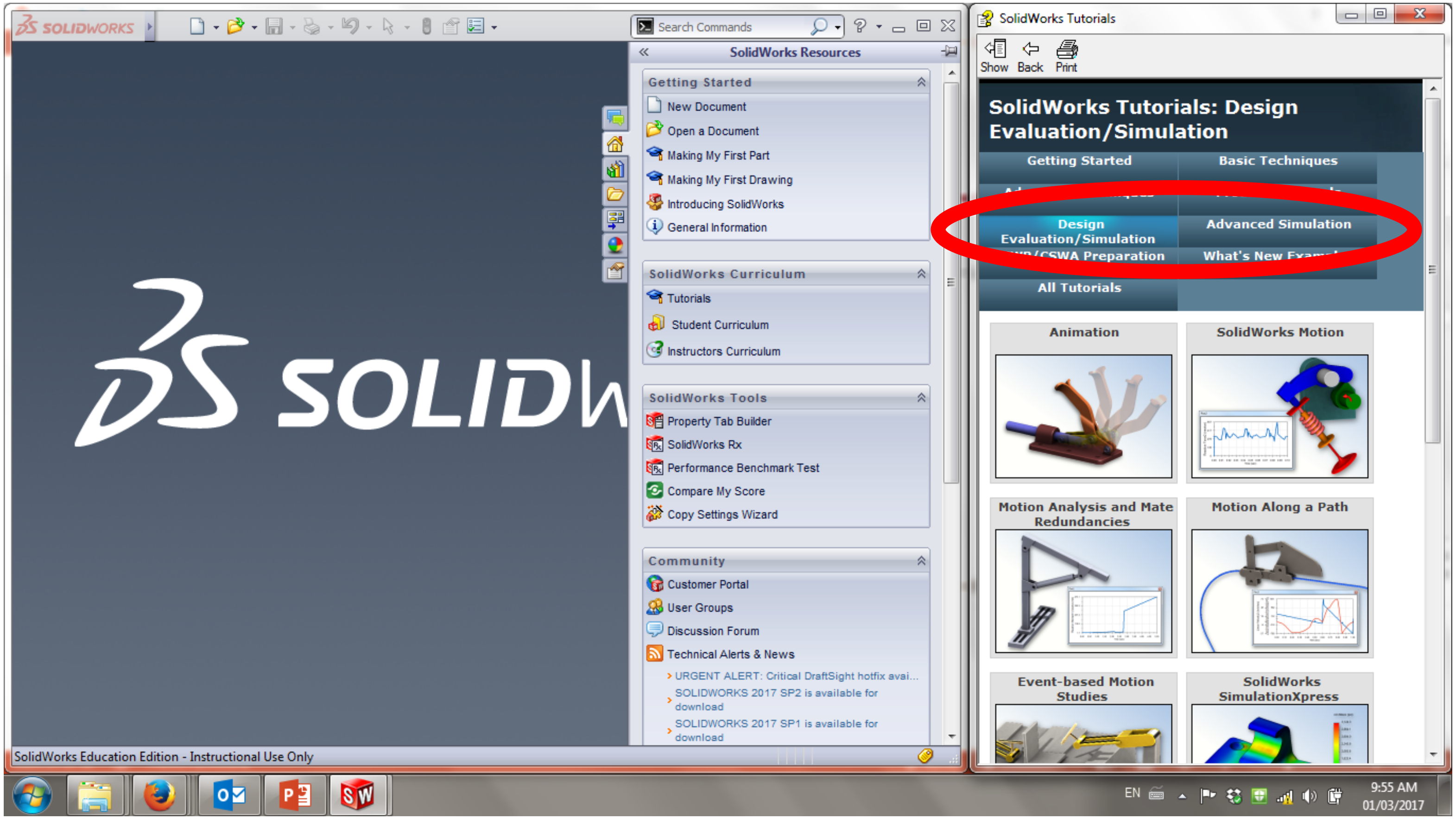
- A very powerful simulation tool for 3D models
  - ⇨ Animation, motion, stresses, pressure, impact, fatigue, etc...



https://youtu.be/y5Fwn-PYg6E

SOLIDWORKS Simulation

- To learn to use SOLIDWORKS Simulation, do some of the tutorials!



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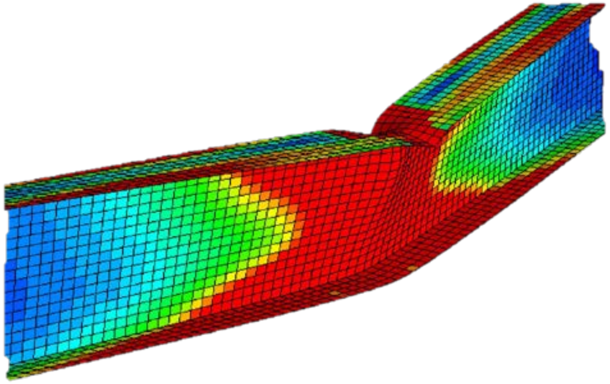
Example: Finite Element Analysis (FEA)

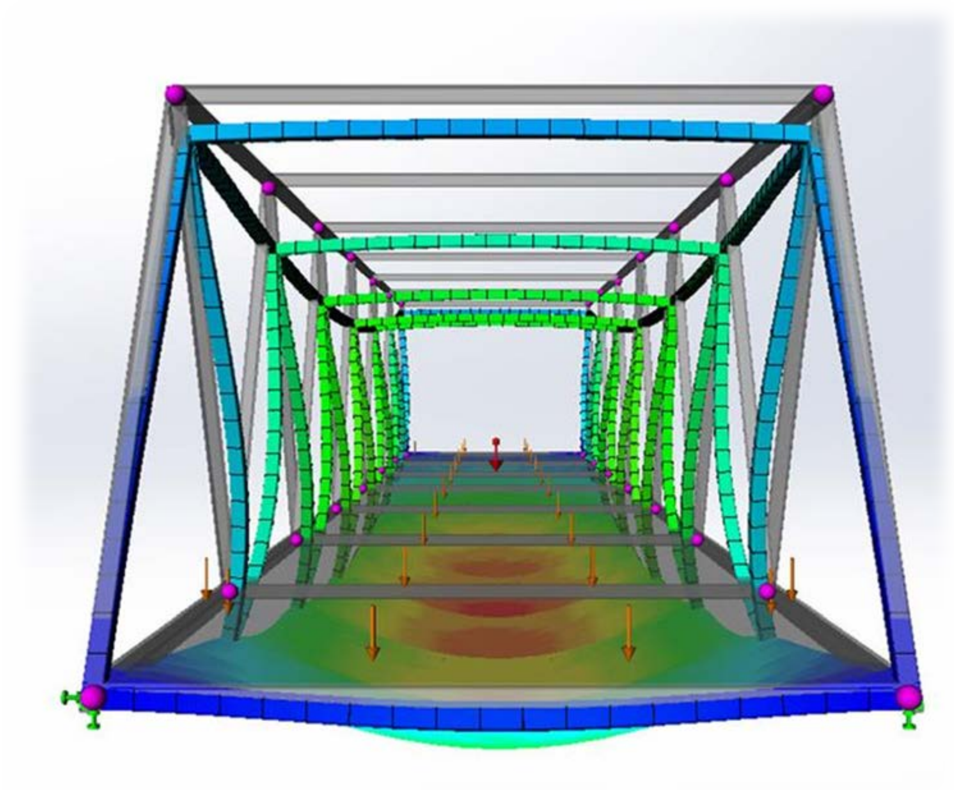
- Uses the concept of superposition on small (finite) easily calculated elements



- Is an **approximation** of complex equations using many simple equations (e.g. approximating a circle with many tiny straight lines)
- Therefore, the types of elements chosen, as well as the boundary conditions between each element is very important

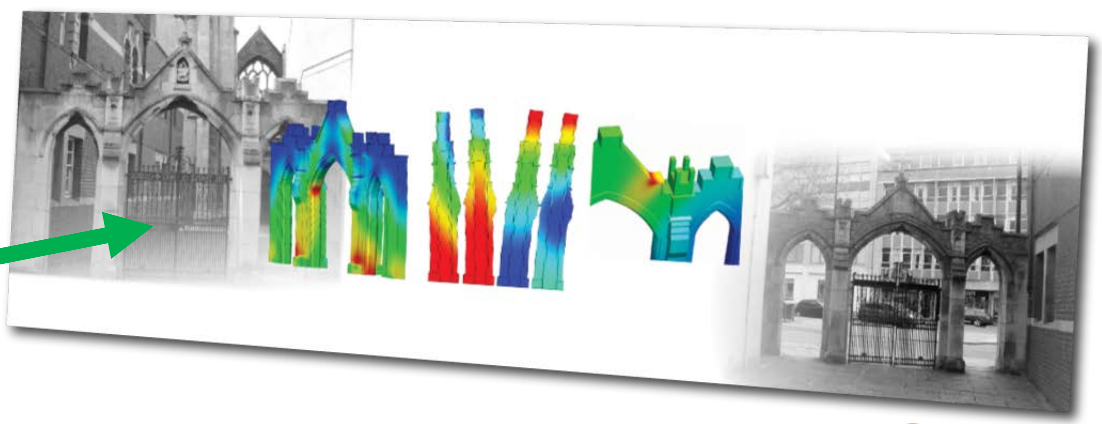
FEA Modules

- Many things can be evaluated under structural analysis:
  - Displacement
  - Stress-strain
  - Thermal
  - Vibration-acoustics



Advantages of Using FEA

- The most prominent advantages of using FEA are:
  - Accurate representation of complex geometries
  - Inclusion of dissimilar material properties
  - Relatively easy representation of the total solution
  - Capture of local effects
- Dynamic solutions are possible with moving boundaries!



Seismic analysis of old structures!

Course Attendance: Registration

- Use your smartphone or laptop to **register/notify** your attendance in this lecture
- Allow **geo location** in the attendance site
- Accept **cookies** from third parties applications
- Log in using only your **Uottawa** account at the link below

  https://attendance.azarm.ca/attendancerecord/gng1103f

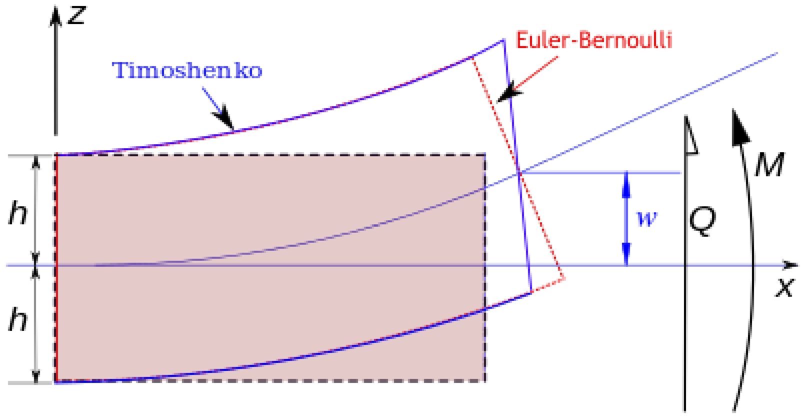
- Your attendance must be registered only **during the lecture** and at the **time specified by the professor**
- You can also use the **QR code** below, to register quickly

Assumptions: Be Careful!

- All numerical tools involve assumptions! We must make sure we know what those assumptions are
- Classical equations usually have clearly defined assumptions
- Numerical tools often provide false confidence:
  - Solutions are provided regardless of faulty inputs
  - Existence of "hidden assumptions" similar to classical equations
  - We often assume that solutions are more exact then they actually are
  - Limitations are not well understood

FEA Element Assumption: Example

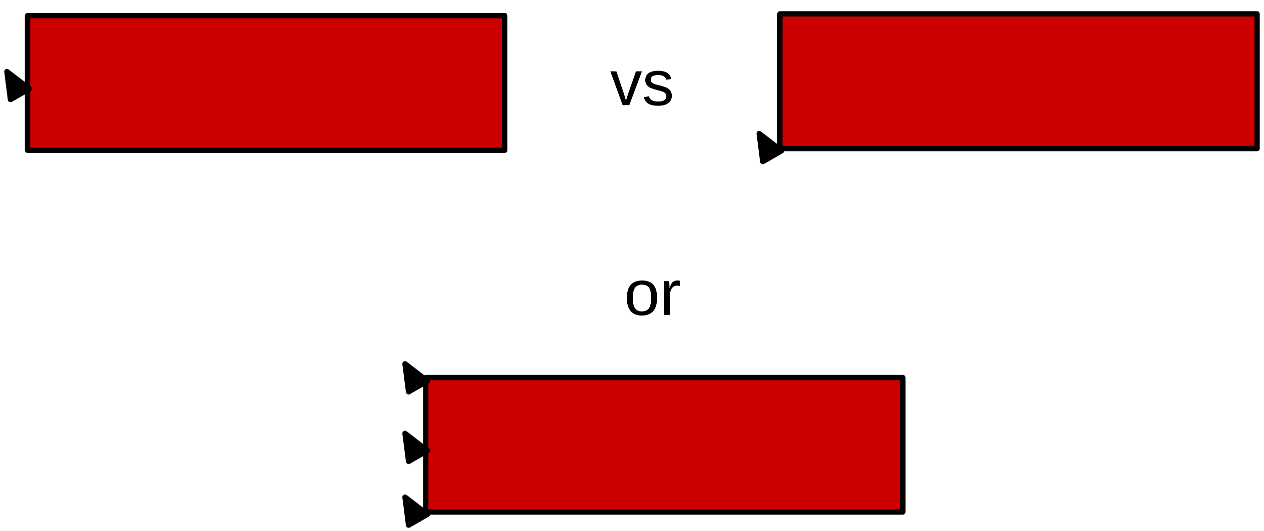
- Euler-Bernoulli versus Timoshenko beam theory:
  (Kirchhoff versus Mindlin plate theory)



- In one case, shear deformation is accounted for and the other it isn't

Boundary Conditions (@ the Nodes)

- When using FEA, boundary conditions are very important!
- Example: simply supported beam/plate:



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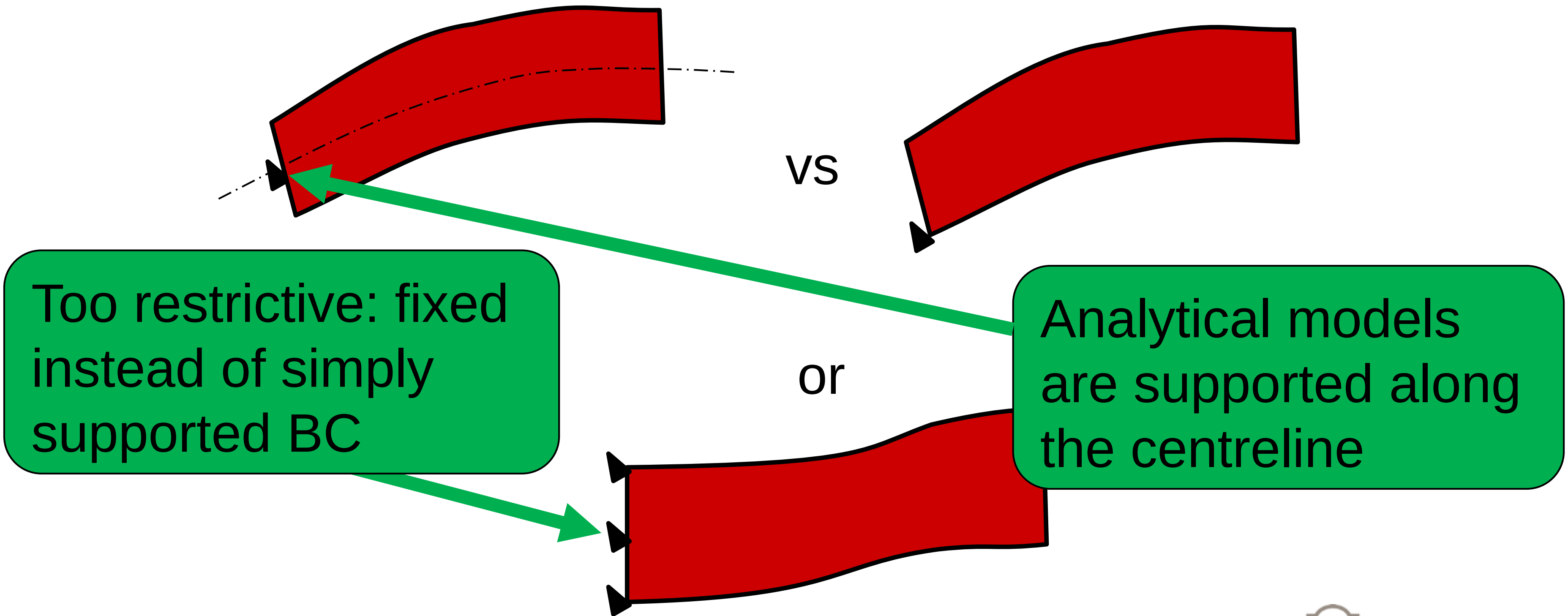


Units

- When using FEA, mass must be written in slugs!
  - In metric system: $1N = 1kg \times 9.81 m/s^2$
  - In imperial system: $1lb_f = 1lb_m$ why??

⇨ Why?? Because $1\ lb_f = \dfrac{1\ lb_m \times 32.2\ ft/s^2}{32.2}$

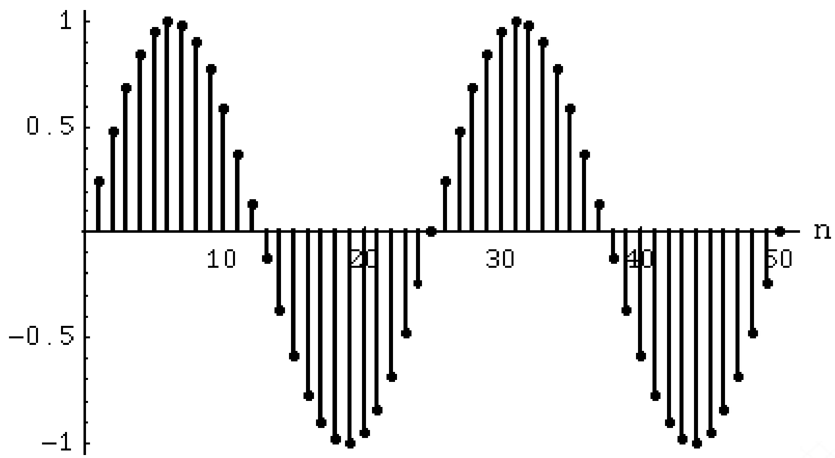
- FEA software (and most scientific calculations) require the use of the slug when specifying mass units:

$$1lb_f = 1slug \times 32.2 ft/s^2$$

$$1slug = 32.2\ lb_m = 14.59\ kg$$

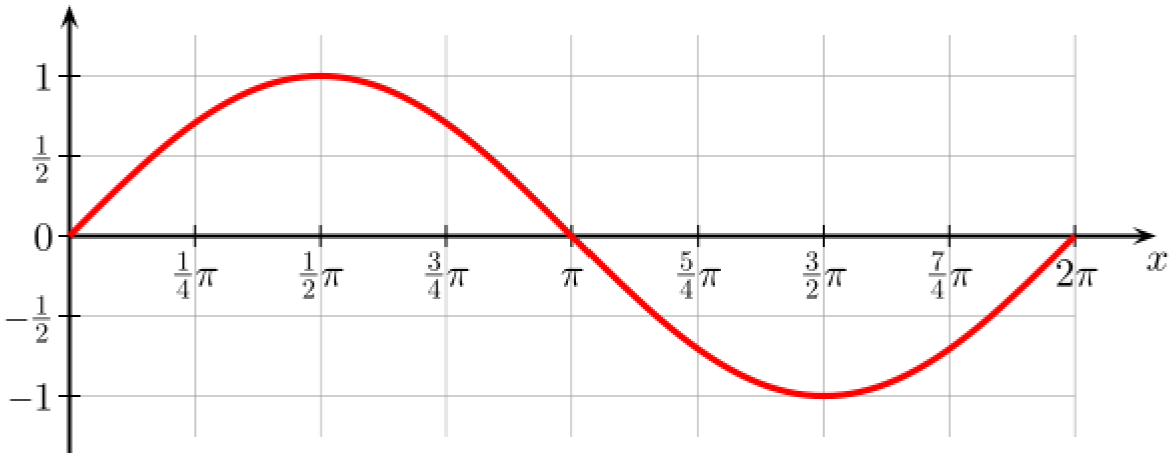
Discrete Time

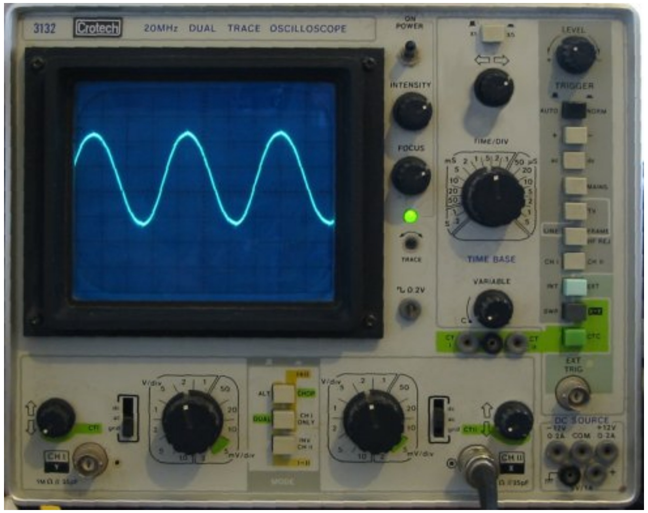
- Numerical simulators all work on discrete time (i.e. the "next event" is activated by the "next event" clock)
- Model variables only get updated at each separate "point in time" (e.g. a digital clock jumps from 10:37 to 10:38 with nothing in between)
- Ensure these time steps are small enough so that you aren't missing out on important results!



Experimental Modeling

- Experimental models are physical representations which can be used to measure outputs or behaviour to given inputs or stimuli (i.e. the output or behaviour of a model can be measured using specialized measurement tools)

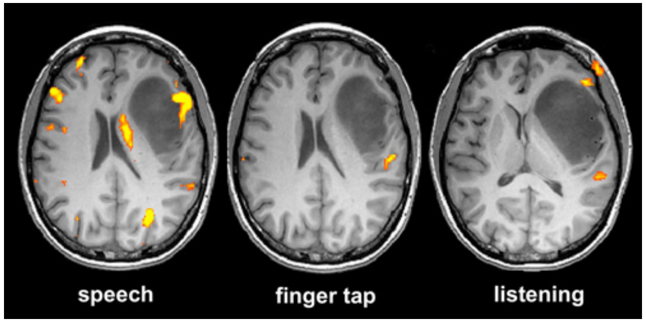




When to Use Experimental Modeling

- Experimental models are best used when no mathematical solutions exist or the solution procedure is extremely complicated and requires too much time to solve computationally

- Often more expensive than analytical or numerical models, but may be the only representation possible

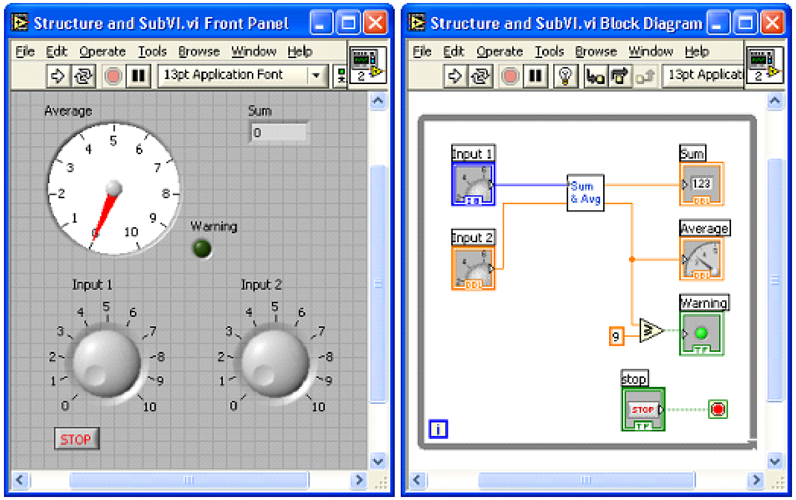


3D models of the human brain are possible, but understanding how it reacts to stimuli is still an experimental endeavour

Experimental Tools Available On RemoteApps

- **LabVIEW:** A visual programming language environment commonly used for data acquisition, instrument control and signal processing

- Great for acquiring experimental test data and testing or running instrument controls



Modeling Fidelity

- Modeling is used on simplified versions of the actual intended design
- The value of the model is to:
  - Reduce financial investments
  - Control out aspects of the real situation to simplify analysis
- Careful:

  "***Garbage in is garbage out!***"
- As a result of an incomplete designs, two types of errors are possible:
  - Designing for failure modes that will not occur (over-design)
  - Failure to detect true problem

Modeling Noise

- Noise occurs when:
  - Certain variables cannot be controlled
  - When too many variables are being manipulated
  - Independent variables have too high a variability
- Noise makes it difficult to discern what is happening during testing
- In any case, noise prevents effective learning from occurring

Example: America's Cup Team New Zealand 95'

- http://www.systeam.co.nz/blog/how-to-develop-new-zealands-most-successful-product-ever

Example: America's Cup Team New Zealand 95'

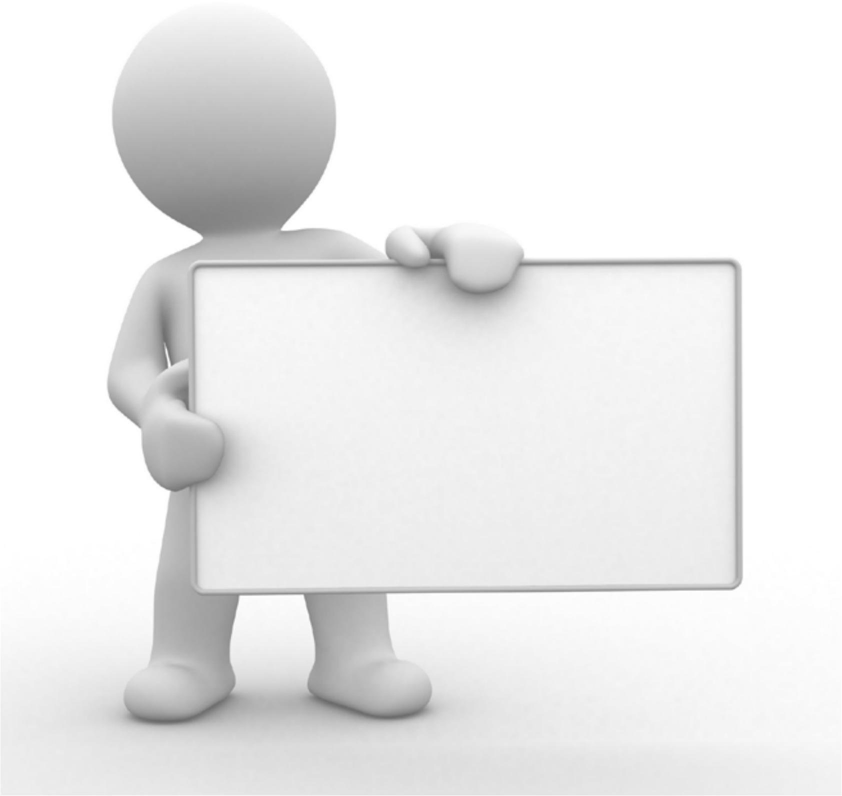
- Team New Zealand won America's Cup by a significant margin, smashing records
- They used a combination of
  - Experimental models by pulling reduced scale prototypes through large swimming pools and wind tunnels
  - Numerical simulations (i.e. FEA, CFD and velocity prediction algorithms)
  - They used two full scale prototypes so they could compare the effect of small changes in design on performance directly, while minimizing noise
- They used short development cycles to maximize the amount they could learn from these models
- They involved the whole team early on because models are only as good as the underlying knowledge and skills of those who use them!

Group Exercise: Creating a Test plan

- Determine a risky or critical aspect of the ***ski-hill rescue device*** that you think you need to model in order to gain a better understanding
- Fill in a test plan as described in "*Lecture 11 – Feedback & Prototyping*"
- In the section "**What** is going on and **how** is it being done?", make sure you describe what kind of model/prototype you should use, how you will use it and why its the best choice!

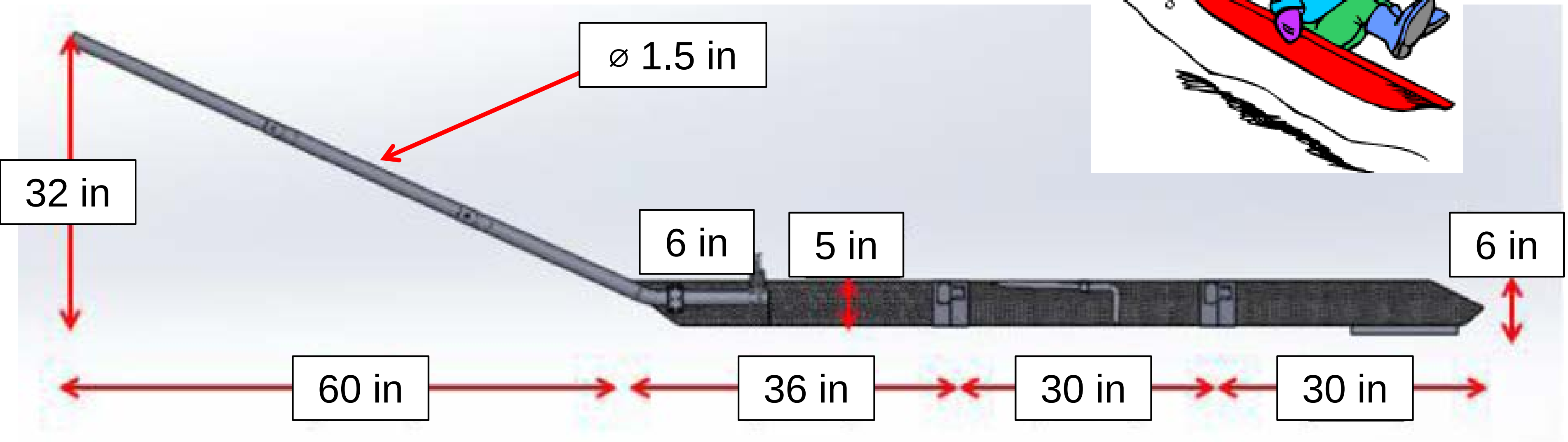
Group Exercise: Creating a Test plan

- What does your test plan look like?



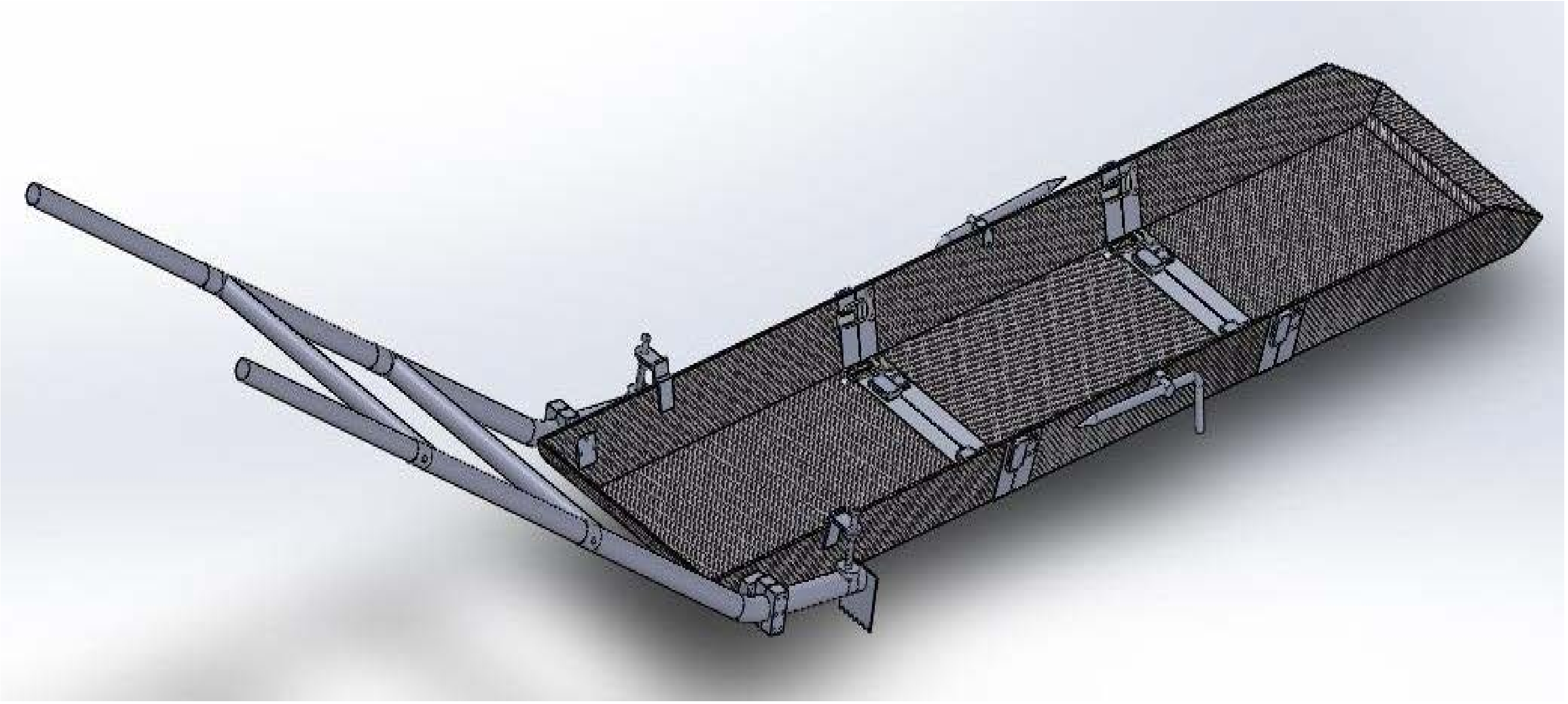
Ski Hill Rescue Device: Analytical Model

- Global dimension, geometry, motion under various snow conditions



Ski Hill Rescue Device: Numerical Model

- Stresses and strains in the handles and in the toboggan structure



Ski Hill Rescue Device: Experimental Model

- Mating performance, storage mechanism, usability, ability to brake

Module 05





Client Meeting 3: Presentation

- Each team will have 7 minutes (5 minutes for presentation + 2 minutes of discussion with the client)
- Prepare a PowerPoint presentation of 5 slides maximum
- Slide content:
  - Your Team (Designation, members)
  - Brief introduction (problem)
  - Your solution and prototype 1 (pictures, graphics, description) & analysis
  - Difficulties, challenges, next steps
- Submit your presentation: Section of lecture 15 in Brightspace: March 02 before midday (Just **ONE** submission per team)
- Prepare your presentation(Content, time, posture, voice) and your questions to the client

Your Pitch Structure

1. Tell who you are.
2. Present the problem as simply and as soon as you can. Keep it simple
3. Present your solution & prototypes 1. Be concise and present your prototype 1 with the appropriate level of detail, them briefly discuss the challenges overcome or to overcome.
4. End your pitch with what to do next (prototype 2 and 3)

Examples of Bad Presentations

- https://youtu.be/ck5vVU8qQWA