GNG1103 – Engineering Design
GNG1503 – Génie de la conception

Engineering Design Analysis

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Image from: http://cdn.quotesgram.com

Agenda

- Reminders
- **Review Questions**
- **Introduction du Engineering Design Analysis**
  - Definition & General Principle
  - Importance
  - Analysis Process & Tools
- **Engineering Design Analysis: Ski-Hill Rescue Devices**
  - Preliminary Concept Selected
  - Material Choice & Activity
  - Calculation of the Values of Specifications & Activities (25 minutes)
    - Device Weight
    - Braking Force
  - Comparison of the calculated Values to the Specified Values

Reminders

- **Lab 5** (Project specific Lab: Unity): This week
- **Project Plan** (Week 4,6,8,10): Weekly review & update
- **Project Deliverable D** (Conceptual Design): Feb. 9
- **Client Meet 2** (Sketches & Questions): Feb. 11, 12 & 14
- **Mid-term Exam** 75 minutes (Lecture 1 to 11): **Feb. 12**
- **Project Deliverable E** (Project schedule & Cost): Feb. 16
- **Peer Feedback & Team Dynamics 1**: Feb. 16
- What is your summary of **Lecture 9**?
  - What is project management?
  - Types of tasks & task duration estimation
  - Project plan & tracking & risk mitigation plan
  - Project cost

Review Questions

1. Define **engineering analysis** and describe its **general principle** and **usefulness**.
2. Describe the **four steps of the engineering design analysis** used for the ski hill rescue device case study.
3. In the table below, indicate whether the statement is true or false.

#	Statement	True/False
1	Engineering design analysis is useful only during the conceptualization phase of design thinking.	
2	The analysis is helpful for predicting results and preventing failures in engineering design.	
3	Experimental prototyping cannot be used for engineering design analysis.	
4	Seeking the simplest solution and required information is important in engineering design analysis.	
5	A good engineering designer shall always be able to justify the components and materials selected for his/her design.	

Engineering Design Analysis

Engineering analysis involves the application of principles and scientific analytical processes to study the properties and state of a system, apparatus or mechanism.

Engineering analysis is done in stages (analysis principle):

1. Separate the system being analyzed into the constituent modules or operational subcomponents
2. Analyze or examine each operational subcomponent
3. Recombine these analyzed subcomponents using basic principles of physics and the laws of nature

- Wikipedia

Engineering Design Analysis

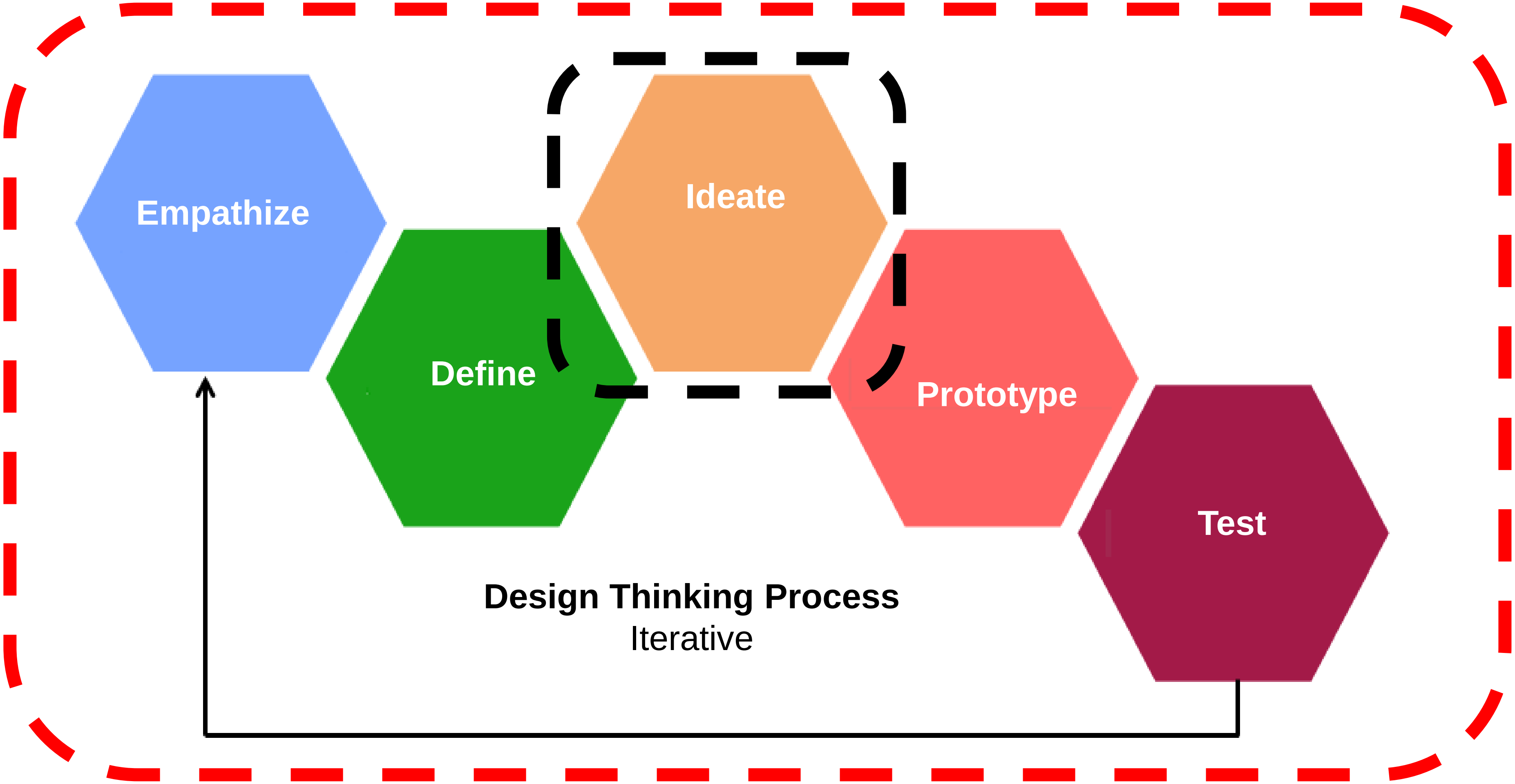


Image from: http://dschool.stanford.edu

Importance of Engineering Analysis

- Engineering analysis is one of the fundamental pillars of our profession
- This analysis is what allows us to guarantee our work
- A good analysis allows us to predict the results of our design and prevent possible system failures

Image: http://preib2-mrso.wikispaces.com/file/view/Atlas.jpg/246221437/Atlas.jpg

Engineering Failure Cases

The Engineering Design Analysis Process

1. Based on the preliminary concepts selected, determine a list of initial components and materials that best meet the target specifications

2. Use the values of the properties of these components and materials to calculate as accurately as possible the specific values of the design based on defined metrics

3. Compare to the target specifications and change your choice of components and materials as necessary

4. Repeat steps 2 and 3 until you are satisfied

Tools Used for Engineering Analysis

- Engineering Analysis uses mathematical calculations, models, simulations and experimental prototyping to ensure that each subsystem meets design specifications
- Don't forget to use the knowledge that you ***already*** have!
- In engineering, always try to use the simplest method first to arrive at a satisfactory result
- If you are missing tools or information, realize this fact (not always easy) and then go and find what you need!
- Don't be shy about checking or verifying your work with others... Nobody is perfect!

WARNING!

- Do **not** make *random* choices for components & materials!

Advice:

- – Check compatibility between selected components and materials
- – Check availability of selected components and materials
- – Check if the components and materials you choose are commonly used (otherwise they may be expensive)

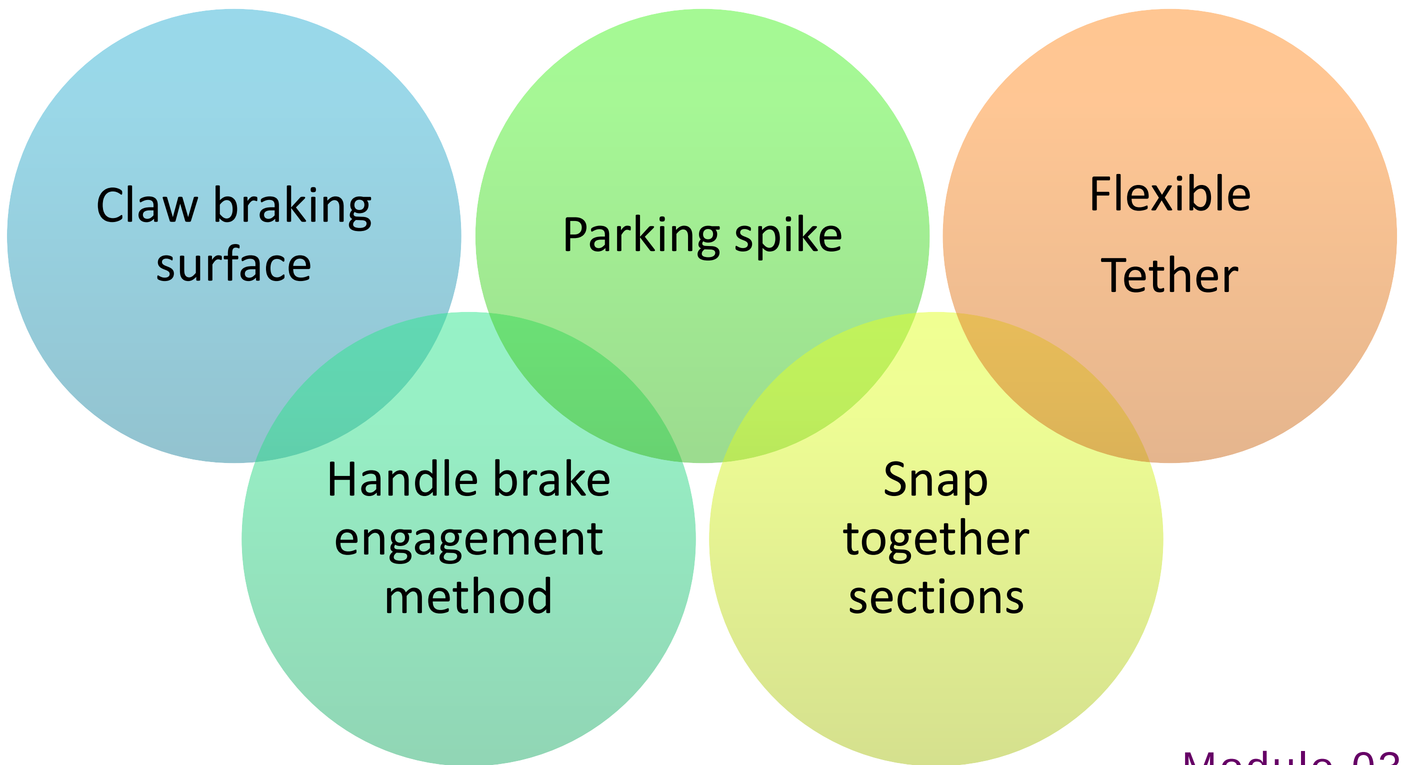
- That said, do not be afraid to use new materials and new components if these can be justified (for innovation?) or are necessary to get the job done!

DESIGN ANALYSIS

Ski-Hill rescue device

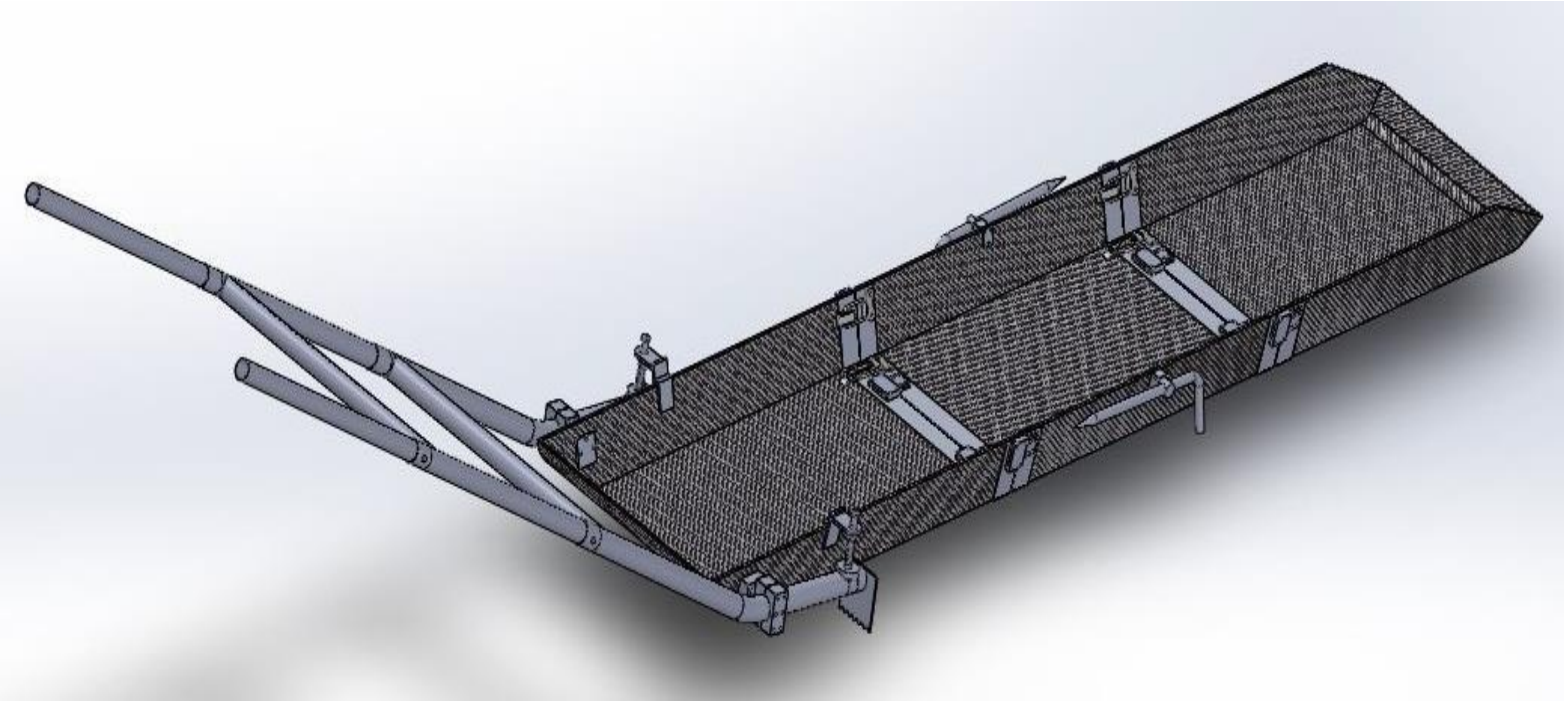
WCDE 00395-03

Selected Preliminary Concept for the Ski Hill Rescue Device



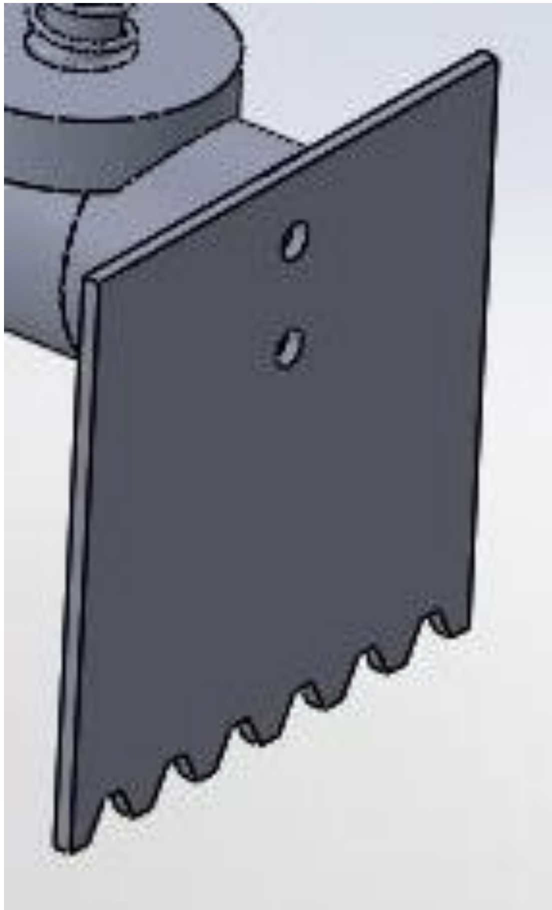
Module 03, Figure 12

Complete Concept

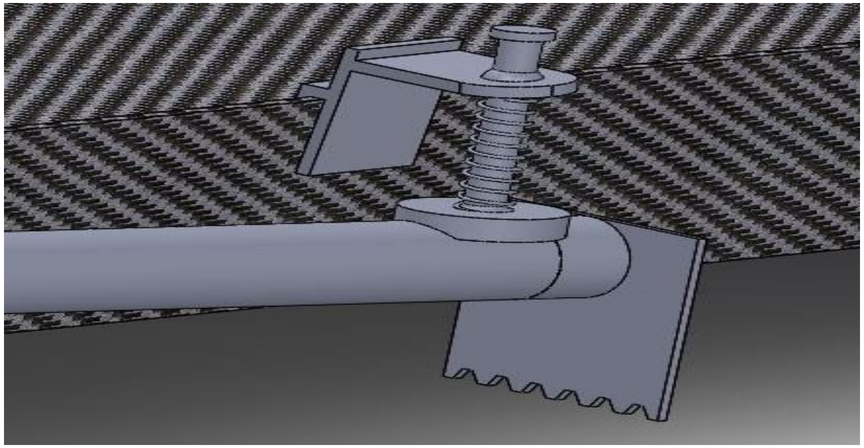


CAD model of device in deployed state, full assembly

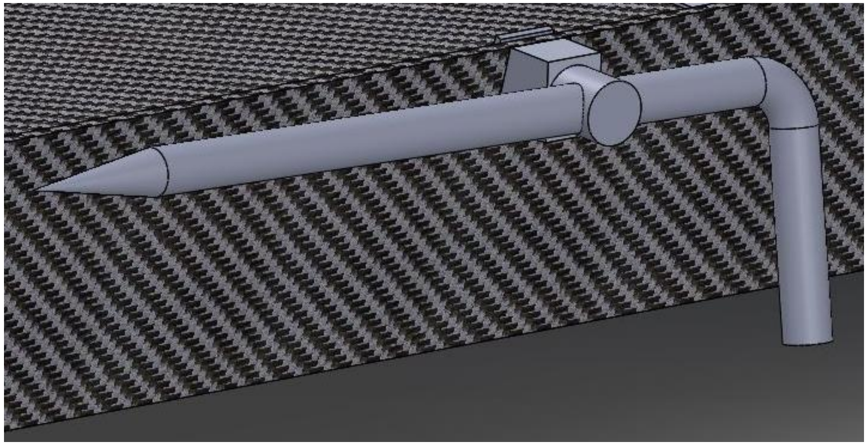
Braking System



(a) Closer view of brake

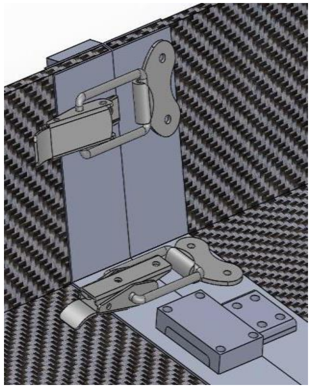


(b) Spring system

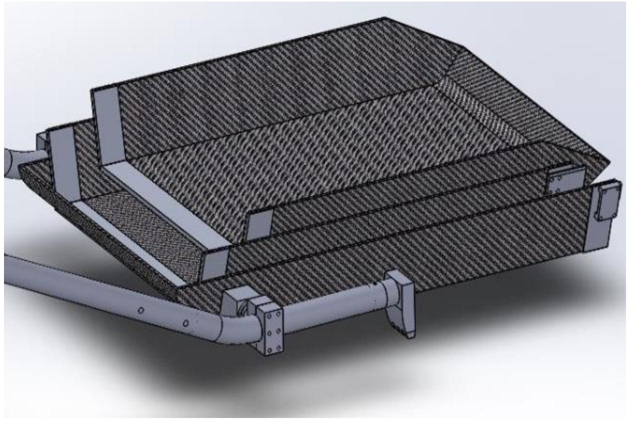


(c) Parking brake

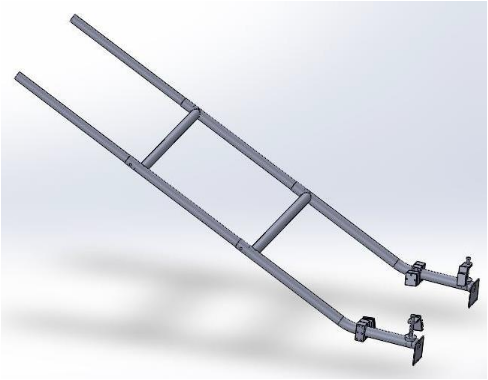
Portability



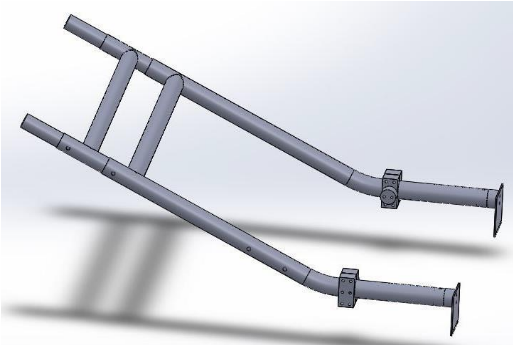
(a) Close up of buckles and section guides on tub



(b) Tub sections stacked (un-deployed state)



(a) Overall view of handlebar-brake system



(b) Handlebar collapsed into un-deployed state

Engineering Design Analysis Process

1. List of initial **components and materials** best to satisfy target specifications
2. Calculation of **values of specifications** based on material properties
3. Comparison of the calculated values with the values of the **target specification**
4. Repetition of steps **1 to 3 until satisfaction**

1. List of Components and Materials

- Start with the preliminary concepts chosen and the target specifications:
  - Create a list of components and materials needed for the design concepts
  - Make sure that the components and materials can meet the list of metric and non-metric specifications (based on your knowledge and experience)
  - If choices conflict with each other, a compromise is required
- In case of compromise, use the design criteria priorities to help choose the most important specifications

EDS: Functional Requirements

	Design Criteria	Relation (=, < or >)	Value	Units	Verification Method
	Functional Requirements				
1	Transporting a person on snowy terrain	=	yes	N/A.	test
2	Supported weight of person	>	250	lb	Analysis, final verification
3	Failsafe method to stop device motion	=	yes	N/A	test
4	Gradient Braking	=	yes	N/A	test
5	Set-up time	<	5	min	test
6	Stability (stretcher shape)	=	yes	N/A.	test

EDS: Engineering Design Specification

EDS: Constraints

1.Material
2.Calculation
3.Comparison
4.Iteration

	Design criteria	Relation (=, < or >)	Value	Units	Method of verification
	Constraints				
1	Weight	<	60	lb	Analysis
2	Cost	<	1,500	$	Estimation, final verification
3	Deployed Dimensions	=	8x2x1.5	ft	Analysis
4	Size/ Volume of device (not deployed for operation)	<	24	ft^3	Analysis
5	Conditions of operation: temperature	=	-40 to 25	°C	test
6	Conditions of operation: snow, ice and slush	=	yes	N/A	test

EDS: Non-Functional Requirements

	Design Criteria	Relation (=, < or >)	Value	Units	Verification Method
	Non-Functional Requirements				
1	Aesthetics	=	yes	N/A.	observation
2	Product Lifetime	>	7	years	Analysis
3	Corrosion and UV resistance	=	Yes	N/A.	similarity
4	Safety: minimum pinch points	=	Yes	N/A	Test
5	Safety: Use of gloves possible	=	Yes	N/A	Test
6	Reliability	=	yes	N/A.	Test

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

Group Activity 1 (2min) : Material Selection

- Based on the highlighted specifications, make a choice of materials for handles, braking mechanisms and for the toboggan

Material Selection

- Selected: Aluminum 6061
  - Relatively cheap
  - Does not rust
  - Fairly light
  - Tough enough
  - Wide temperature range

- Not selected:
  - Steel (rust, heavy)
  - Plastic (less resistant, brittle when cold)
  - Composite (expensive: both the material and manufacturing)
- Other considerations?

2. Calculation based on properties

- Research to find the properties of the components and materials:
  - Create a table of properties that will be useful
  - Refer to the sources for these properties (in case you need more information)
- Calculate the specification values for your design concepts to allow comparison with the target specifications
  - Assume reasonable values if the concept is still not sufficiently well-developed
  - Overestimate assumed values, when possible, to provide for a margin of error

Group Activity 2 (2min) : Aluminum Properties

- What are the physical and mechanical properties of aluminum?

What *are* the Properties of Aluminum?

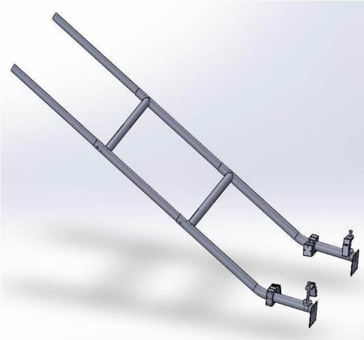
- From www.matweb.com:
  - (aluminum 6061-T6 is the most common type of Al)

Properties	Values
Density	0.0975 lb/in^3
Modulus of Elasticity	10,000,000 lb/in^2
Shear modulus	3,770,000 lb/in^2
Poisson's coefficient	0.33

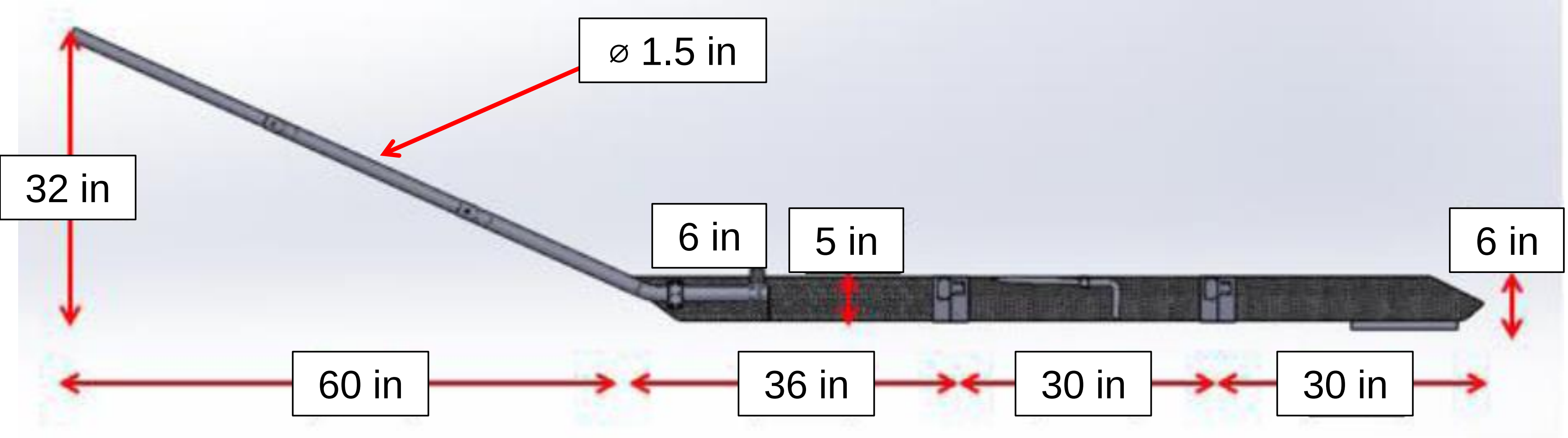
Group Activity 3 (8min) : Weight Calculation

- Calculate the total weight of the rescue device

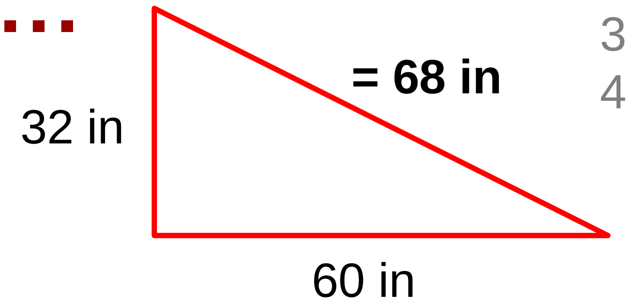
First Determine Rescue Device *Size*!



- Width = 24 "
- Thickness of aluminum sheets and hollow tubes: 1/8 "



Calculate the Volumes…



- Handle Tubes:

$$L = 2 \times 68'' + 2 \times 24'' + 2 \times 6'' = 196''$$

$$V = (\pi r^2 \times L)_{ext.\,dia.} - (\pi r^2 \times L)_{int.\,dia.}$$

$$V = \pi(1.5''/2)^2 \times 196'' - \pi(1.25''/2)^2 \times 196''$$

$$V = 105.8\ in^3$$

- Base of the toboggan (assume a box shape):

$$L = 36'' + 30'' + 30'' = 96''$$

$$V = V_{ext.} - V_{int.} = (96'' \times 24'' \times 5'') - (95.75'' \times 23.75'' \times 4.875'')$$

$$V = 433.9\ in^3$$

Calculate the Weights...

- Density of aluminum 6061: $\rho = 0.0975\ lb/in^3$
- Handle Tubes:

  $$Weight = V \times \rho = 105.8\ in^3 \times 0.0975\ lb/in^3 = 10.3lb$$

- Base of the toboggan (assume a box shape):

  $$Weight = V \times \rho = 433.9\ in^3 \times 0.0975\ lb/in^3 = 42.3lb$$

- Other mechanisms and components (brake, parking brake, fastener, etc.):

  $$Weight \approx 10lb\ ?$$

- $Total\ weight = 10.3lb + 42.3lb + 10lb = 62.6\ lb$

3. Compare with Target Specifications

- Compare the values that you have calculated with the target specifications
- If the calculated values are not within the target specifications, modify your choice of components and materials

4. Repeat steps 2 and 3 as required

Warning!

- According to specifications, we want a total weight that is < 60 lbs!
- The calculated value is 62.3 lb, so we might have to change material for the handles or for the base of the toboggan
- It is possible that we have overestimated the volumes by overly simplifying or by using weak assumptions about toboggan shape (e.g. box)
- A more precise analysis is sometimes necessary when the values are close (computer-aided numerical methods can be useful)

Group Activity 4 (5 min): Required Information

- An important need is the ability to stop the toboggan
- How much **force** is required to stop a toboggan in motion on a ski slope?
- As a group, identify the required information to calculate this force

What Information is Required, exactly?

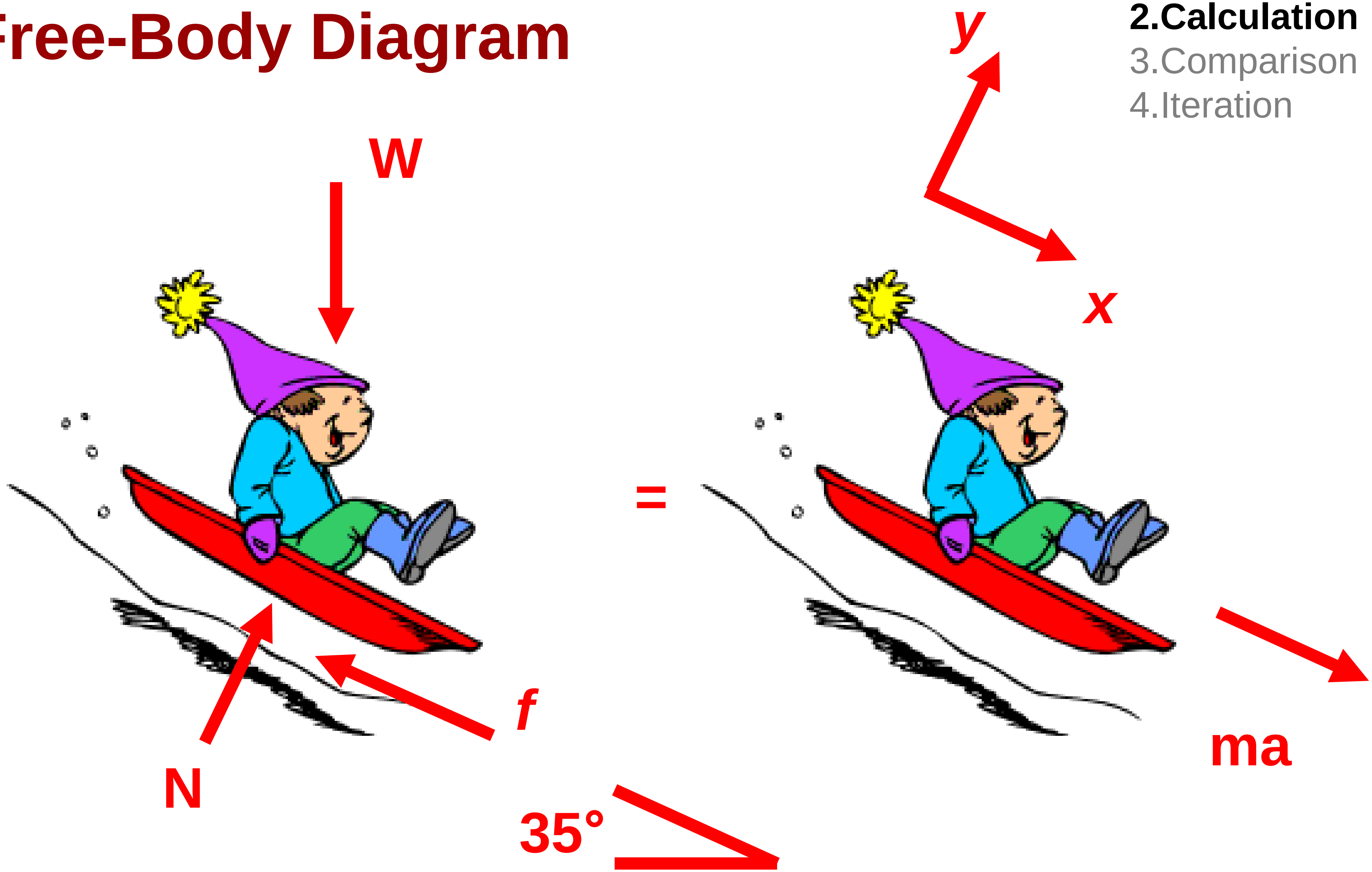
Worst-Case Assumption:

- Patient and Toboggan weight:
  (Based on target specifications)
  - $W_{patient} = 250$ lb
  - $W_{toboggan} = 60$ lb
- Friction Coefficient:
  (http://hypertextbook.com/facts/2007/TabraizRasul.shtml)
  - $\mu_k = 0.03$
- Steep ski slope angle:
  (http://www.skibum.net/do-it-up/comparing-steepness-of-ski-trails/)
  - Slope = 35°

Group Activity 5(8min): Braking Force

- Calculate the braking force required to stop the rescue device
- ***Use*** your knowledge of mechanics!

Free-Body Diagram



Calculation of Forces

- Sum of forces in the x direction (down the slope) and y direction (perpendicular to the slope):
- $\sum F_y = 0 = N - W\cos 35°$

  $\rightarrow N = (250lb + 60lb)\cos 35° = 253.9lb$

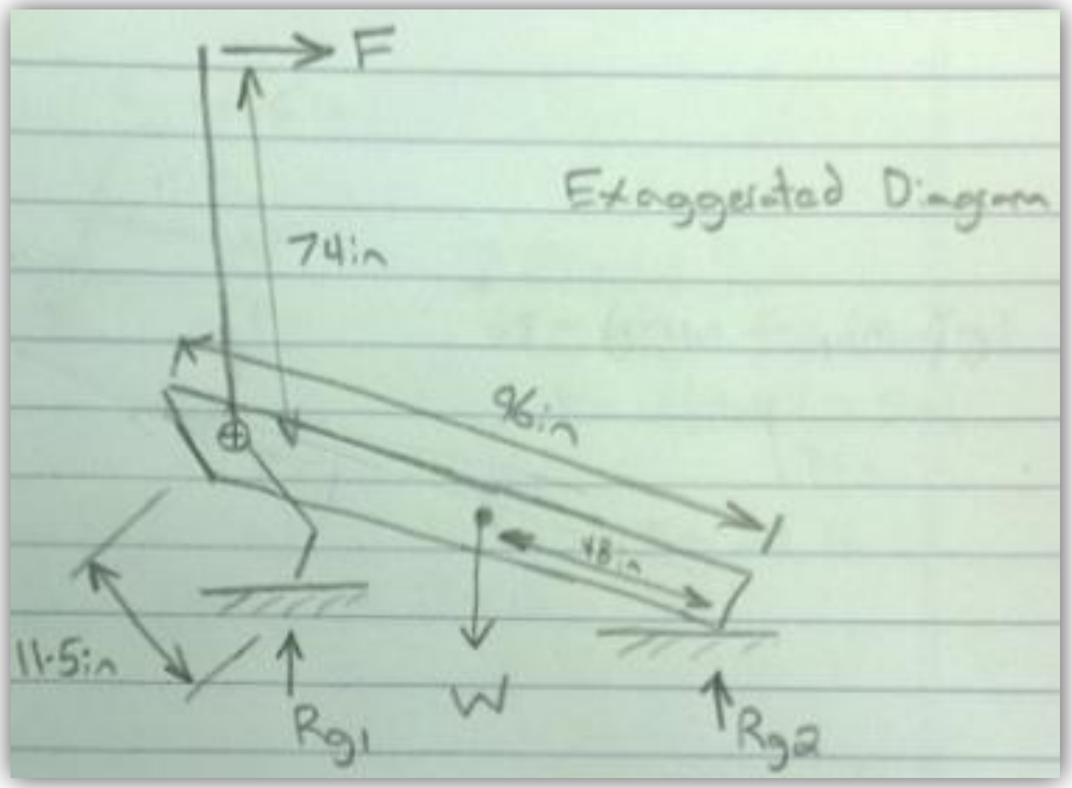
  $\rightarrow f = \mu_k N = 0.03 \times 253.9lb = 7.6lb$
- $\sum F_x = ma = W\sin 35° - f = F$

  $\rightarrow F = (250lb + 60lb)\sin 35° - 7.6lb = 170.2lb$

Braking force (to stop) = 170.2 lb

What other Things Should we Calculate?

- Weight supported
- Bending force
- Spring Force
- Stopping distance
- Stresses
- Cost
- etc ...



Warning!

- We do **not** know *yet* if the claw brakes can exert the required 170.2 lbs of force to stop the slide!
- This is *difficult* to calculate ... We'll have to do some prototyping!
- … In the next class!

Limitations of Analysis

- While you might be able to calculate it, this does **not** mean it will work ... ***Hyatt Kansas City***

Nicely Calculated, … but Impossible to Build

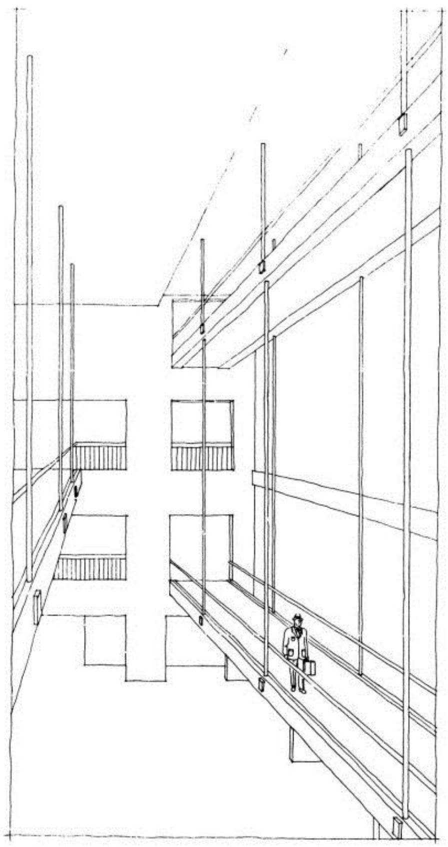


Figure 3.4 Schematic of walkways as viewed from north wall of atrium.

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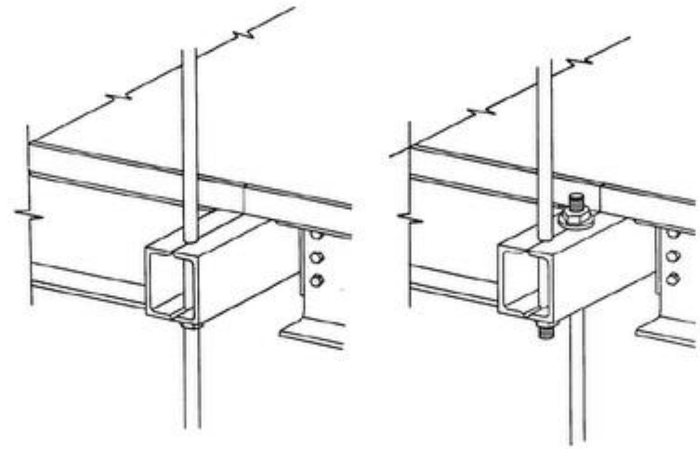

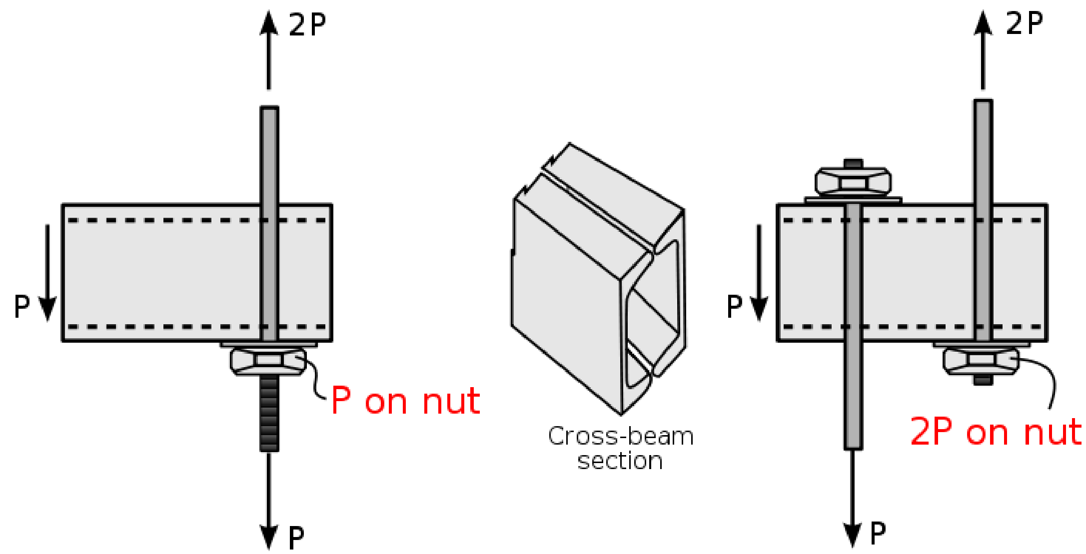

(a) Original design

(b) Actual construction

https://en.wikipedia.org/wiki/Hyatt_Regency_walkway_collapse