Faculty of Engineering

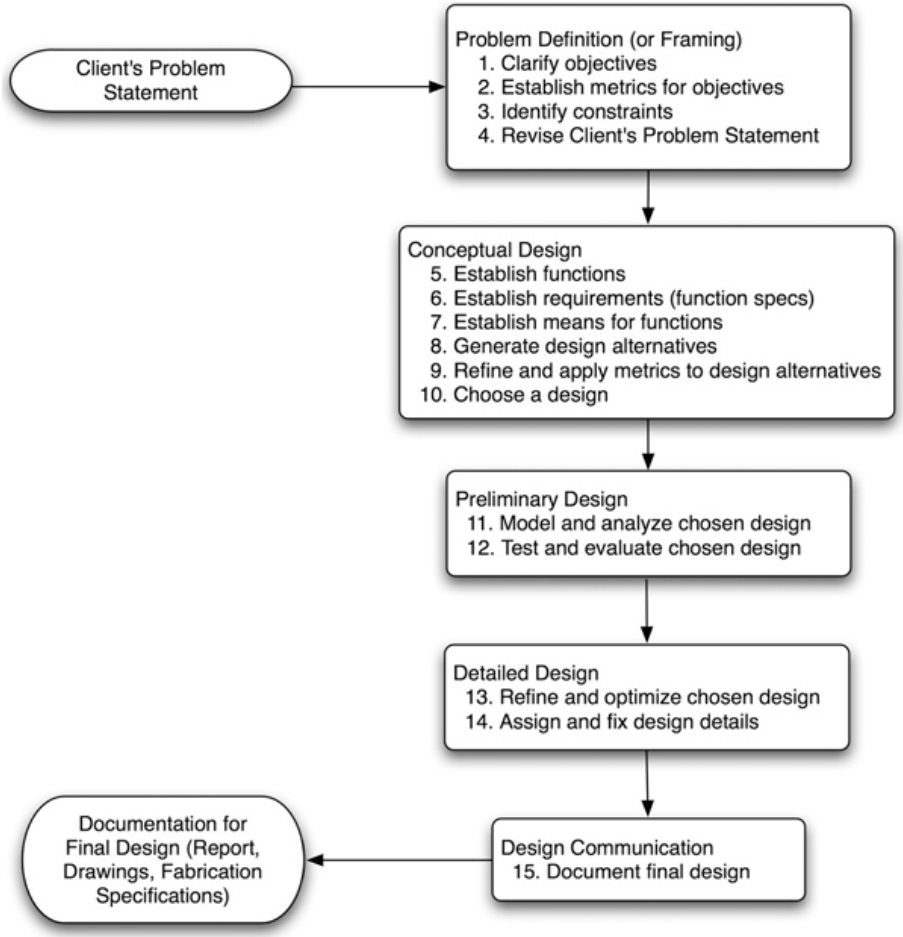
ENGG1000 Engineering Design and Innovation

Semester 1 2018

Lecture 4 – Conceptual Design Phase (Common Design Stream)

Design Process

The structured process through which Engineers solve engineering problems:

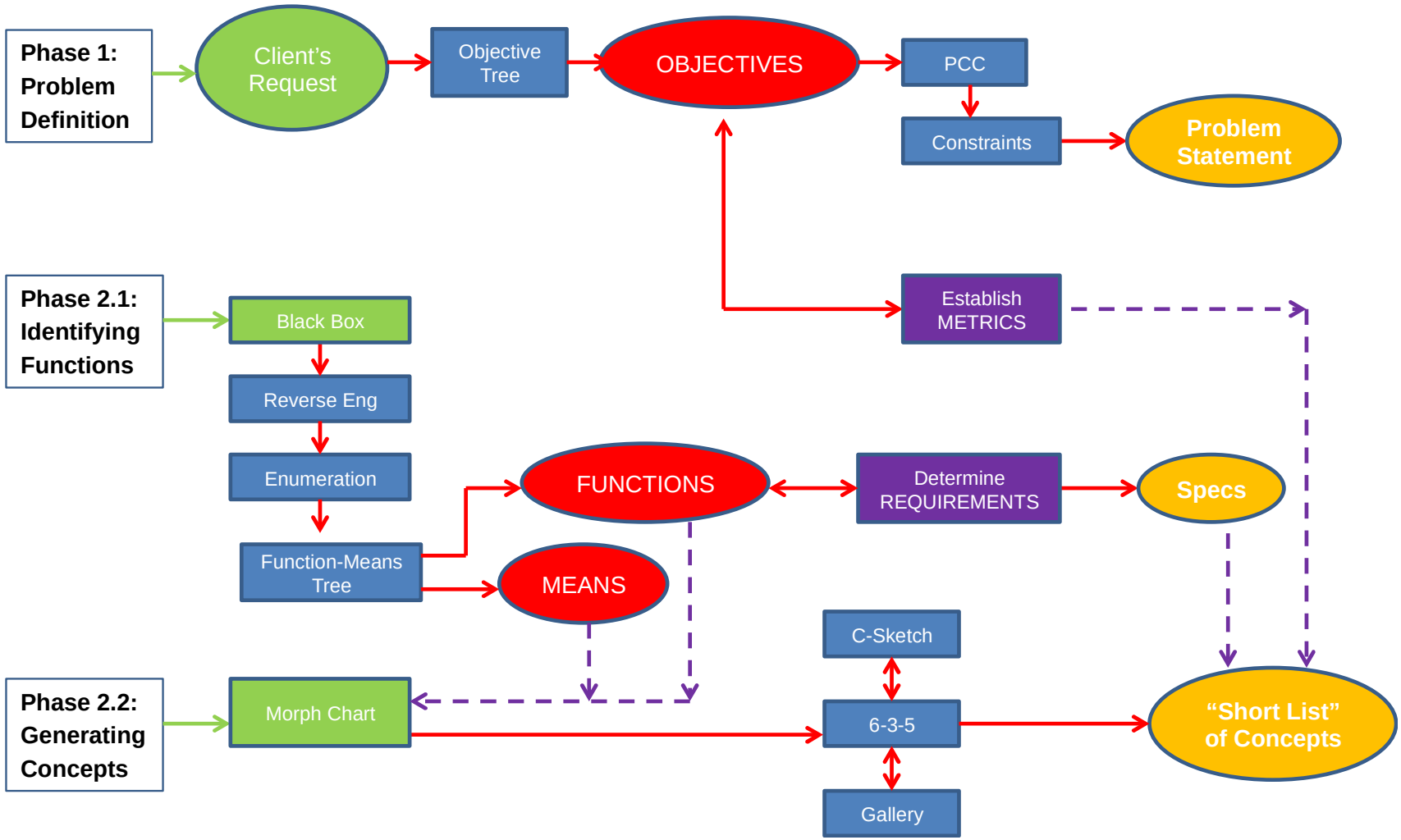


We are now moving into here

Problem Formation/Framing

- Client's Problem Statement
- Understand the Design Objectives
  - Engage the Client
  - Objective Trees
- Establish Metrics
  - Pairwise Comparison Chart
- Identify the Constraints
  - Hard and soft
- Revise the Problem Statement
  - Solution Independence

(Dym) Problem Definition leading to Concept Generation



Functional Analysis

- Determine what functions, independent of implementation, the system must perform to achieve goals/objectives
- What system needs to do without defining how to do it
  - Detect Aircraft (not have a radar system)
  - Gauge Temperature (not have a thermistor)
- Remember to be Solution independent
- Natural process complimenting Requirements Generation and System Architectural Design

Functions

- Functions – Actions the system/device must perform to achieve desired outcome
- Use ‘verbs-object pairs’
  - ‘Cool’ air; ‘Compress’ data; ‘Display’ instructions; Carry load; negotiate obstacles
- **WHAT** the system must do, not HOW
- Typically focussed on input/output relationships
- Example – Vending Machine

Example – Vending Machine

Are the following good functional descriptions, free of design elements? What, not how?

- Display the current temperature
- The current temperature is displayed to within a tenth of a degree, in Centigrade
- Accepts Australian Dollars
- Scan currency and determine the denomination

Example – Vending Machine

- Display the current temperature 
- ~~The current temperature is displayed to within a tenth of a degree, in Centigrade~~
  - Implementation specific
- Accepts Australian Dollars 
- ~~Scan currency and determine the denomination~~
  - Why scan? It could use weight instead? Starting to move into ‘how’ space here

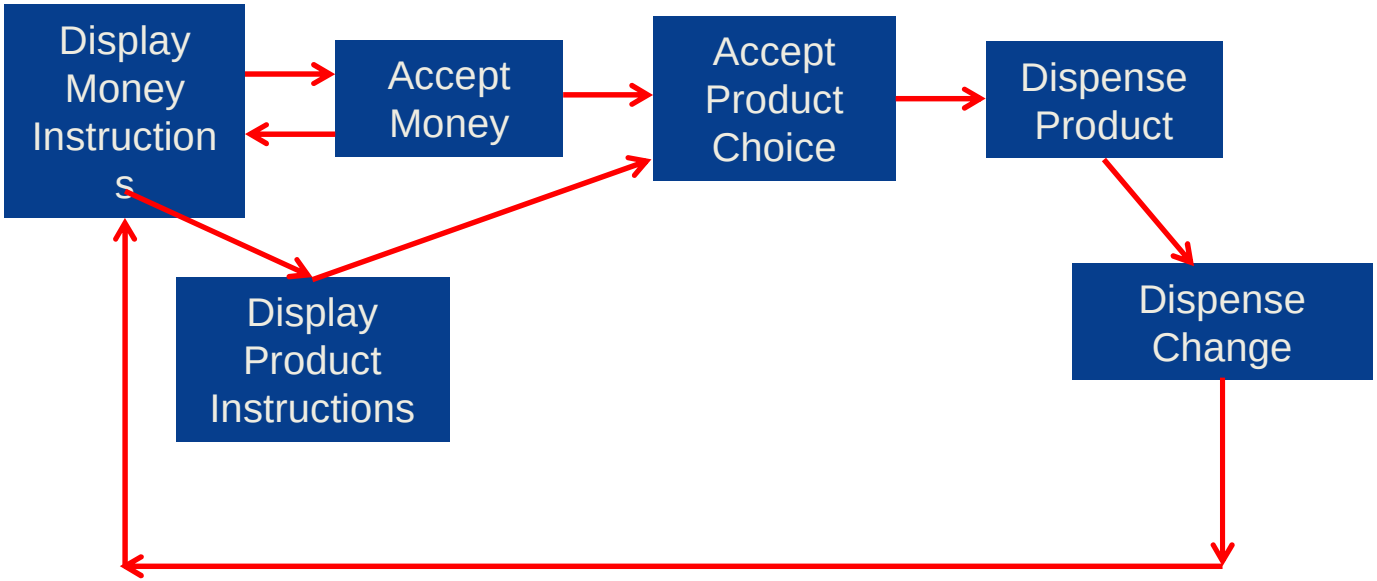
Example – Vending Machine

Possible Function List

- Display Money Instructions
- Accept Money
- Display Product Instructions
- Accept Product Choice
- Dispense Product
- Dispense Change

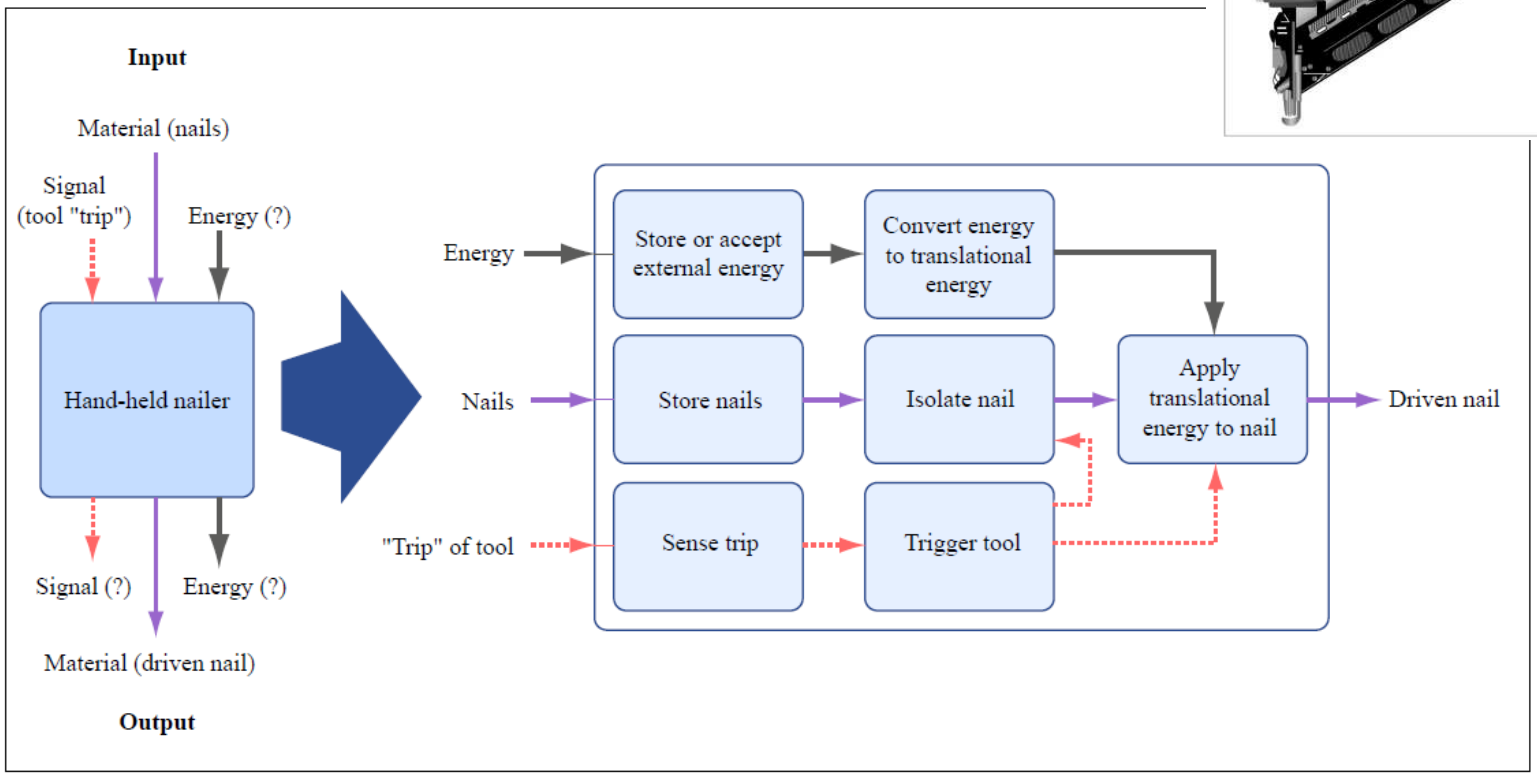
Functional Analysis

- ‘Determine inputs, outputs, constraints for each
- Functional Flow Diagram
  - Link functions together via IOC



Source: Raytheon, Principles of Systems Engineering

Example – Electric Nail Gun



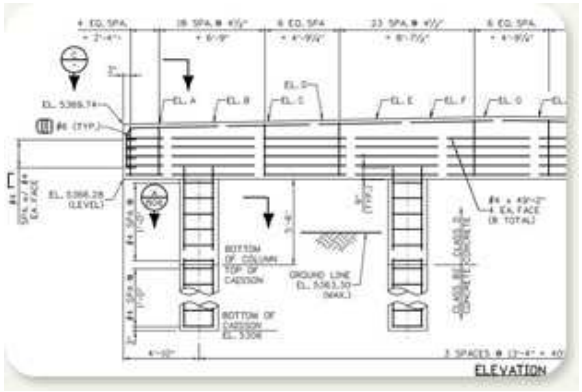
- Create a list of functions that the solution must perform
- Consider how these functions relate to each other

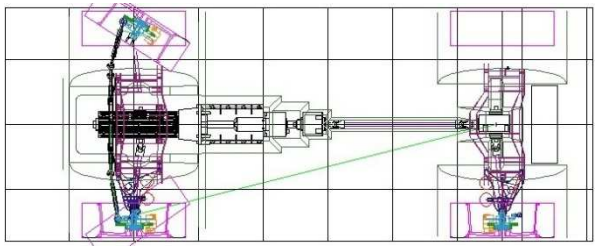
Source: Qi Van Eikema Hommes, Systems Engineering, MIT 2010

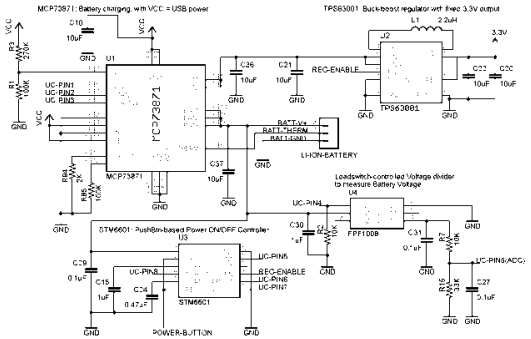
How do Engineers define Engineering Solutions?

Specifications

- An Engineering Design usually ends in a set of specifications
- Drawings, Bill of Materials, Part List, Bill of Materials, Complied Software, etc…







How do Engineers define Engineering Problems?

Requirements

- Definition: A condition, attribute, or capability needed by the system to solve a problem or achieve an objective
  - What, how, and under what conditions
- How Engineers ‘frame’ problems
  - Often the contract between client
  - Always independent of specific implementation, design, or construction (unless specifically required by the client)
- Compliment the Problem Statement
  - Important for Design Evaluation, Detailed Design Phases, and Integration/Verification phases

Requirements

To frame the Engineering problem, requirements should be:

- Necessary
- Implementation-free
- Concise and unambiguous
- Verifiable
- Traceable
- Complete and Consistent
- Feasible
- Non-redundant
- Quantifiable (where possible)

Requirements

Typical types of requirements:

- Functional
  - The system shall display instructions in English
- Performance
  - The system shall deliver change within three seconds of product choice
- Interface
  - The system shall accept Australian Currency
- Characteristics
  - The system shall have a capacity of at least 50 containers of 12 different products
- Constraints
  - The system shall cost no more than $75 000

Morphological Chart

- Bound the design space and list means for solutions
- An efficient way of structuring this systems analysis during the conceptual design phase
- List as a vertical column all the functions and attributes required by the solution
- Next to each function/attribute list all possible different means of implementing that function/attribute that you can think of
- Each possible combination of means represents a possible design choice → this is the **design space**

Example – Morph Charts

- Example from the textbook (Dym – Chapter 5)
- Design Problem – design a beverage container to promote sales
- Functions and Attributes of the solution:
  - Contain Beverage
  - Material of Beverage Container
  - Provide access to juice
  - Display Product Information
  - Sequence of Manufacture of Juice and Container

Example – Morph Chart

MEANS FEATURE/ FUNCTION	1	2	3	4	5	6
Contain Beverage	Can	Bottle	Bag	Box	••••	••••
Material for Drink Container	Aluminum	Plastic	Glass	Waxed Cardboard	Lined Cardboard	Mylar Films
Mechanism to Provide Access to Juice	Pull Tab	Inserted Straw	Twist Top	Tear Corner	Unfold Container	Zipper
Display of Product Information	Shape of Container	Labels	Color of Material	••••	••••	••••
Sequence Manufacture of Juice, Container	Concurrent	Serial	••••	••••	••••	••••

Source: Dym and Little, "Engineering Design", 3rd Edition, 2009, pp104

Possible Solutions

MEANS FEATURE/ FUNCTION	1	2	3	4	5	6
Contain Beverage	Can	Bottle	Bag		Box	••••
Material for Drink Container	Aluminum	Plastic	Glass	Waxed Cardboard	Lined Cardboard	Mylar Films
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Display of Product Information	Shape of Container	Labels	Color of Material	••••	••••	••••
Sequence Manufacture of Juice, Container	Concurrent	Serial	••••	••••	••••	••••

(a)

MEANS FEATURE/ FUNCTION	1	2	3	4	5	6
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Sequence Manufacture of Juice, Container	Concurrent	Serial	••••	••••	••••	••••

(b)

Source: Dym and Little, “Engineering Design”, 3rd Edition, 2009, pp105

The Next Phase

- Research/Trade Studies
  - Research on possible design solutions, methodologies
  - Improve background knowledge in relevant topics
  - Help you make informed design alternatives
  - All Engineers do this – no matter how experienced
- Brainstorming
  - Generate possible design solutions
  - Initially in a functional, conceptual way
  - The more ideas/possible approaches → the better!

Research

- On-going through the entire design cycle
- There's no need to 'Reinvent the wheel' on every project:
  - Find out what's there?
  - Learn as much as you can about relevant technologies
  - Do similar solutions already exist?
  - What can be learned from them?
  - DOCUMENT YOUR RESEARCH AND FINDINGS!

Sources

PEER-REVIEWED:

- Books
- Patents
- Research Papers
- Articles
- Are there any off-the-shelf products that can be incorporated in your design?

Sources

- The Internet!
- An amazing source of information, but beware!

  → NOT PEER-REVIEWED.

- There’s no guarantee that all the information is correct.

Research Themes

- BENCHMARKING
  - how well do they perform their relative functions?
  - how do they guide your approach?

- REVERSE ENGINEERING
  - how do they work/perform their function?
  - Are their better ways?

Generating Design Concepts

- A Problem:

- How to clear the frost off???

A Silly Idea?

A Solution!

- A cost-effective, efficient solution:

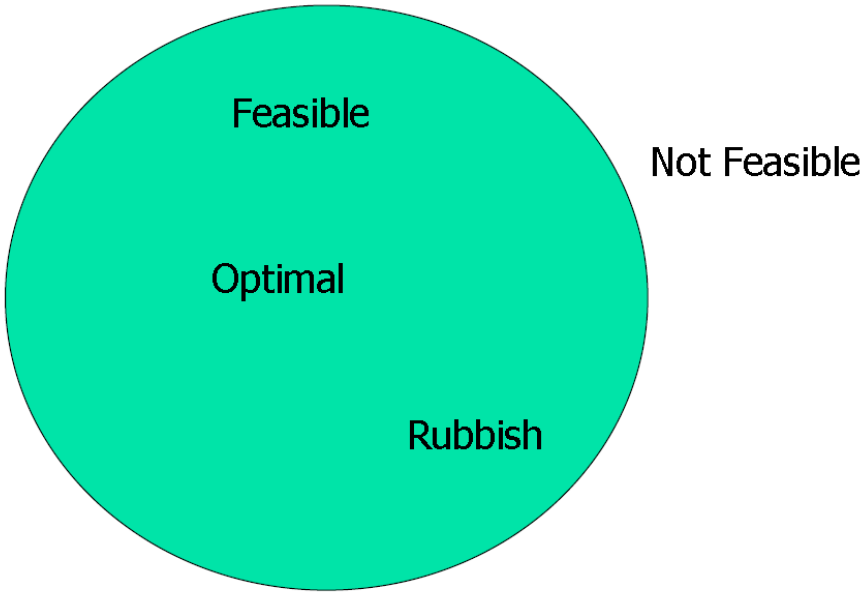
- Never would
  have been conceived if not for the ‘silly idea’.

Conceptual Design

- Generate as many ideas for solving the design problem as possible
- The more the better!
- Quantity is quality here.
- The first, most obvious solution is seldom the best (most innovative, simplest, etc.)
- Focus on abstract general concepts through which the problem could be solved → the details come later...

Conceptual Design

- The most innovative, original part of the design process
- Widen the design space: An established solution will limit your thinking too much.



Techniques

There are numerous techniques for inventive, lateral thinking:

- Brain-storming
- Brain-writing
- TRIZ (theory of inventive problem solving)
- Check-listing
- Synthetics

→ we'll focus on Brain-storming mainly

Brain-Storming

- Requires lateral thinking
- **Divergent Thinking** versus Convergent Thinking
- Generate as many different ideas and solutions as possible → don't judge yet
- To increase the pool of ideas:
  - More people
  - More research
- For most teams, a formal structure for a brain-storming session is beneficial
  - To prevent the 'louder' people from dominating
  - Not just a chaos of ideas

Brain-Storming

- The key is to establish a friendly, non-judgemental environment → for the uninhibited free flow of ideas.
- The Ground rules (establish beforehand):
  - No holding back (any idea, any time)
  - No boundaries (nothing is too outrageous)
  - No criticising (not until evaluation phase)
  - No dismissing (not until evaluation)
  - No limit (never too many ideas)
  - No restrictions (any area of expertise)
  - No shame (no one should ever feel embarrassed)

Brain-Storming

Structure:

- One Facilitator
- One Minute-taker

A Method – The ‘Idea-Trigger Method’ (Horenstein)

Three Phases:

- Phase 1 – Idea Generation
- Phase 2 – Idea Trigger Phase
- Phase 3 – Compilation Phase

Brain-storming

- Phase 1 - Idea Generation Phase
  - Problem has been established (Problem Statement)
  - Objectives, Functions, Constraints established
  - No talking – everyone write down as many ideas as possible
  - Make it the first Column on the page
  - No matter how crazy/wild the idea may be
  - Try the 2 minutes on, 1 minute off, 1 minute on.
- Phase 2 - Idea Trigger Phase
  - Take turns to read out your ideas from Column 1
  - Cross off any in common
  - Jot down any new ideas in Column 2 → the triggers from the first round of ideas
  - Continue until all Column 1 ideas have been exhausted
  - Then work through Column 2 to form new ideas in Column 3, etc...
- Phase 3 – Compilation Phase
  - Facilitator complies all the ideas
  - The group is ready for the next phase – Concept Evaluation

Mentor Session – Week 6

- This is focus of EDP Peer Assessment – Concept Generation
- As a group, conduct a formal brain-storming session on the Design Project
- Present it as a team to your mentor + peers
- Begin with a Morph Chart
- Facilitation Guide will be available on Moodle soon
  - Use either Brain-storming, Brain-writing, or C-sketch method to generate ideas

Brain-Writing

- Called the ‘6-3-5’ method in the textbook
- Every group member writes three ideas on a piece of paper
- Then pass the ideas around the group, where every person adds one more idea to each list
- Then compile all the lists at end
- Described in the Group Facilitation Guide

C-Sketch Method

- Also described in the textbook and the Group Facilitation Guide
- Similar to Brain-writing, except instead of writing design ideas each group member sketches possible design solutions
  - Each successive member adds to or comments on the sketch
- Might sketch block diagrams/functional analysis
- Gallery Method – display sketches of design ideas

Conceptual Design Phase

Think of many possible solutions to the problem...

because the first (most obvious) solution is seldom the best

Brain-Storming

- Engage in Brain-storming and system abstraction with your group...

Generating Ideas

- Divergent thinking is ideal
- Don’t hold back
  - Speak first, think later
  - Everyone is qualified to contribute
- Do not analyze or criticize
  - Wait until idea generation is complete
- Trigger new ideas from others
- Crazy ideas are OK
- Record everything

No Regrets

- There will be a time during final testing, when your group will look at each other and say:
- “Why didn’t we think of that???”
- The answer: because your brain-storming wasn’t effective enough!
- Don’t let this be you...

Coming Up

- Thursday – Technical Streams 2-4pm
- Next Monday – Concept Evaluation
  Lecture – here, CLB7
- Mentor Meeting this week
  - EDP Problem Statement Peer Assessment

EDP Peer Assessment 1

- Mentor Session – Week 4
  - Based on the Problem Statement lecture from last Monday
- Preparation:
  - Read the Guide for the Generation of the Problem Statement on the Engineering Design Process tab on Moodle
  - Bring an Electronic device to Week 4 mentor session, that allows you to access Moodle
  - Bring a printed copy of your individual problem statement. You'll hand this to your mentor

EDP Peer Assessment 1

- During the session:
- Hand your individual Problem Statement to your mentor
- Take note of the runsheet – when you are presenting and who you are marking
- Log in to Moodle and open EDP – Problem Statement Assessment task
- If you are the first team, line at ready to present in order

EDP Peer Assessment 1

- During the Presentations

- You have 2 minutes to present. Mentor will keep time
- Remain at the front with your team until the whole team has presented
- You will then mark all students in the class that are not in your team
- The assessment sheets will appear in Moodle for you
- Fill in the marking criteria as they present
- Mark fairly and consistently. They will be reviewed and potentially moderated afterwards
- Marks may be reduced if you are late or fail to assess your assigned students