ECOR 1010
Lecture 8

Introduction to Design

"Scientists investigate that which already is; engineers create that which has never been"

Albert Einstein

What is Design?

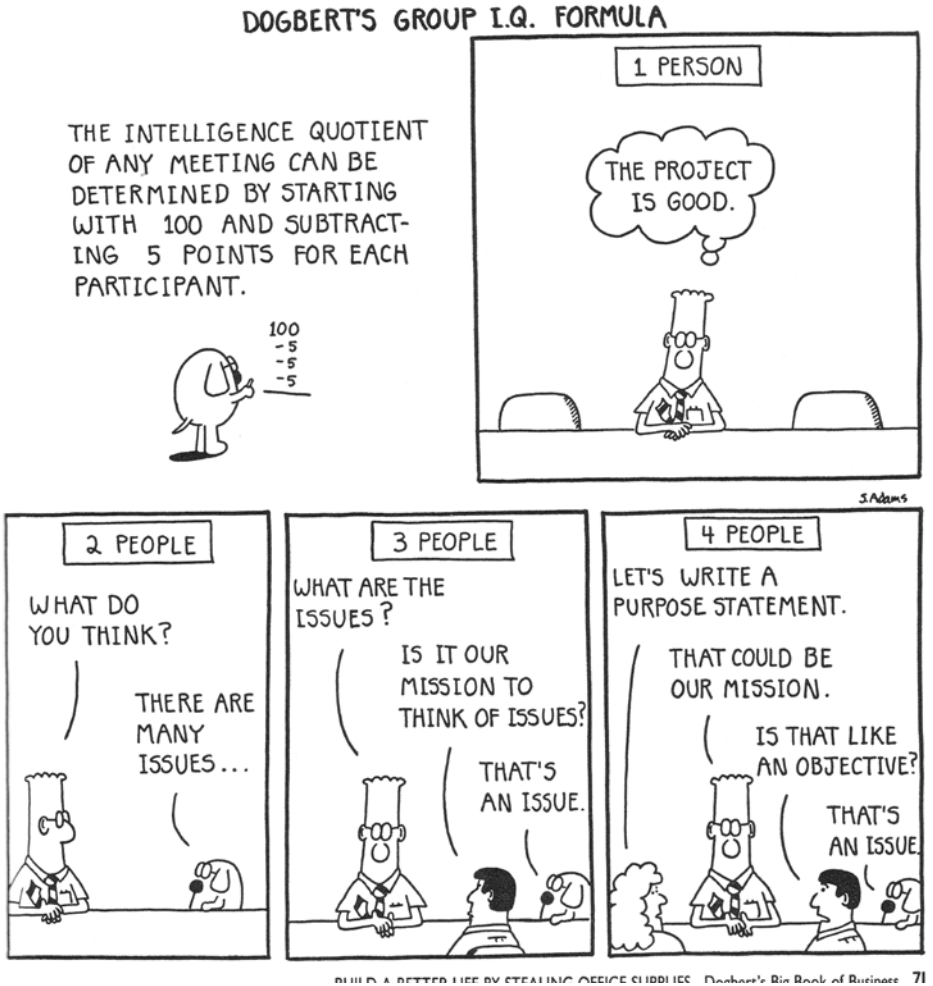
- Design is a creative process
- Incorporates all areas of an engineering education
- Design is basically what engineers do
- Almost always involves a team effort
- An iterative process
- Open-ended problems, often with many possible solutions
- Usually only a handful of good solutions

Engineering Design

- Engineering design
  - Identifying problems, solving them, and implementing the solutions
- The textbook gives the following definition of design:
  - "Process of developing workable plans for the construction or manufacture of devices, equipment, machinery or structure, to satisfy some observed need"
- Canadian Engineering Accreditation Board (CEAB) definition:
  - "Engineering design integrates mathematics, basic sciences, engineering sciences and complementary studies in developing elements, systems and processes to meet specific needs. It is a creative, iterative, and often open-ended process subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may relate to economic, health, safety, environmental, social, or other pertinent factors."

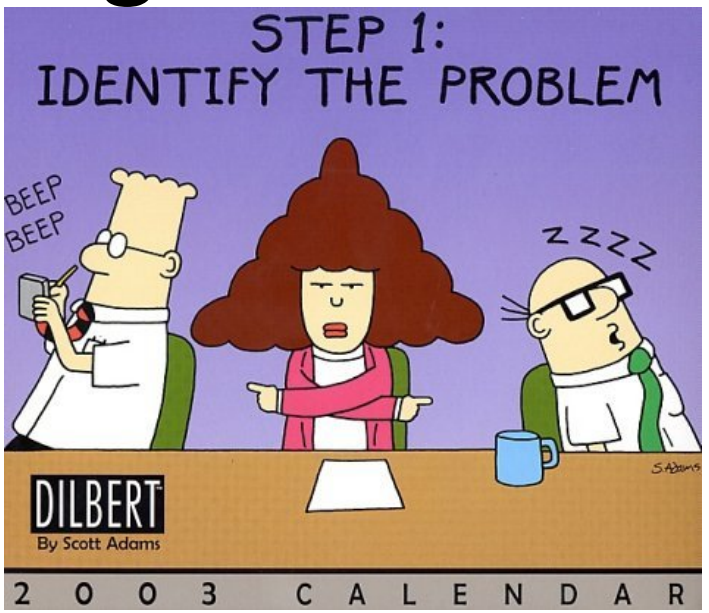
Design Ingredients

- Good design requires
  - Organization
  - Teamwork
  - Communication
- In addition, creativity and criticism are essential
- The key is knowing when to be creative and when to criticize



Engineering Design

- Before a problem can be solved, it must first be identified!
  - Evaluate the present state and determining how it differs from the goal state.

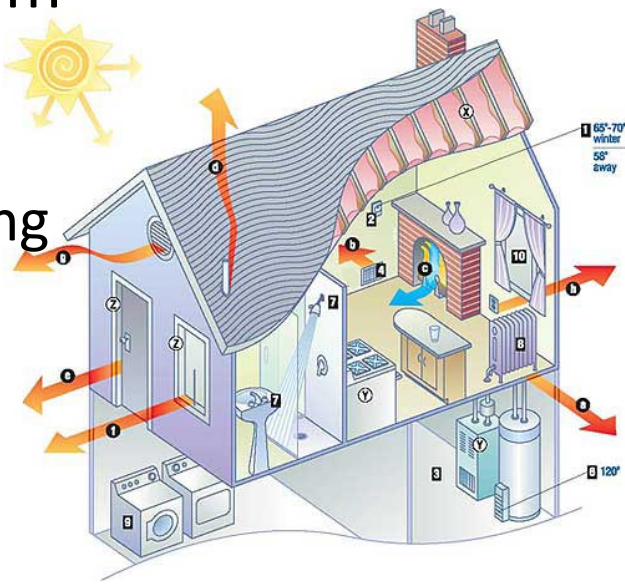


- Needs should be categorized and defined in a Statement of Requirements (SoR)
- Most design problems can be categorized as:
  - **Systems design**
  - **Product design**

Systems Design

Systems design deals with the arrangement of available products into a unique combination that yields the desired result

- A residential building is a complex system consisting of many components and products
  - Heating-ventilation and/or air conditioning systems (HVAC)
  - Plumbing systems (water and/or natural gas)
  - Electrical systems
  - Window, door, floor systems, etc.



- A commercial tool shed is not a complex system, but it still has to be designed; it is a product

Systems Design

- Systems design requires additional professionals
- Consider designing a highway
  - Lawyers: traffic laws; zoning ordinances; right-of-way; liability, …
  - Historians: past trends and historical data must be reviewed, …
  - Social Scientists: highways bring commercial development, shopping centres, gas stations, …
  - Psychologists: driver characteristics and tendencies, other human factors affecting safety and function, …
  - Scientific principles developed through research can be applied to building more durable driving surfaces, bridges, underpasses and overpasses, improving the system in general

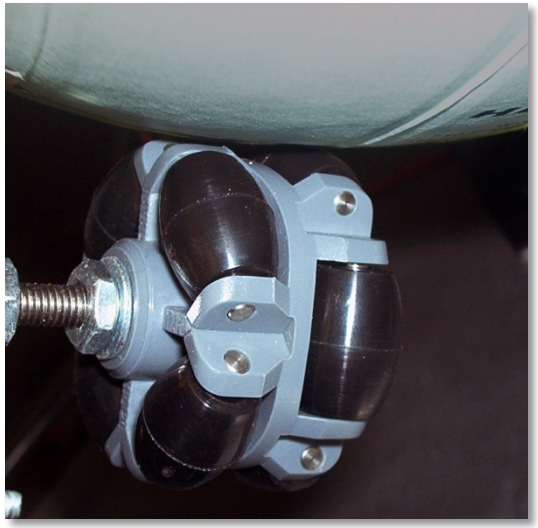
Systems Design Example #1:

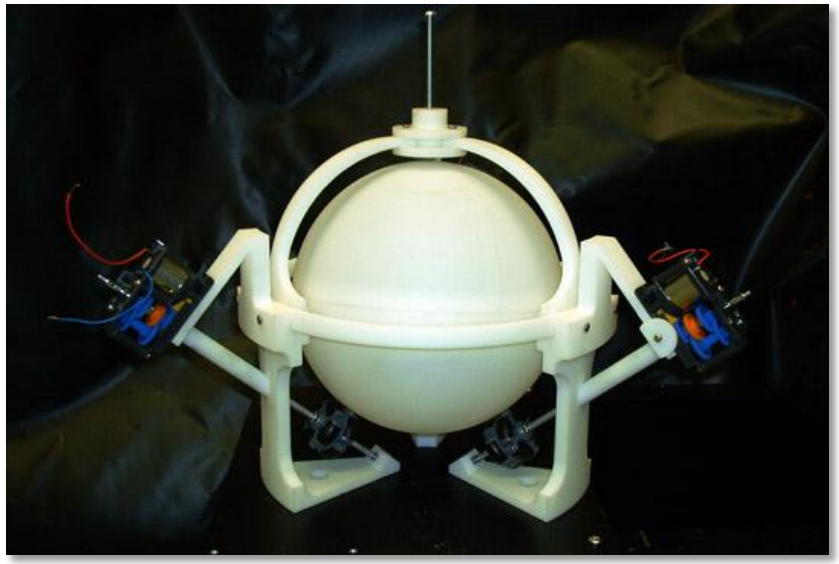
CU Simulator Project (CUSP)

- Multi-year project (4th-year)
- The intention is to design and build a full-scale reconfigurable simulator facility
- The full-scale simulator is scheduled to be completed at the end of the fifth year
- By nature the project is multidisciplinary
  - Mechanical, Aerospace and Computer Systems Engineering
  - Department of Psychology

ATLAS Platform

- The 6 DOF platform is novel architecture
- 3 AC synchronous motors; 3 dual-action electromagnetic rams
- Projection, control, and simulation systems are interoperable RTI's (Run-Time Infrastructure) that are IEEE (Institute of Electrical and Electronics Engineers) HLA (High-Level Architecture) compliant





Systems Design Example #2:

Formula FSAE

- Open Wheel Race Car
  - Dynamics
  - Structure
  - Propulsion
  - Electrical
  - Brakes
  - Safety

Systems Design Example #3:

UAV – Unmanned Aerial Vehicle

- Designed for Geophysical Survey
  - Structures
  - Aerodynamics
  - Control
  - Payload
  - Safety & Airworthiness

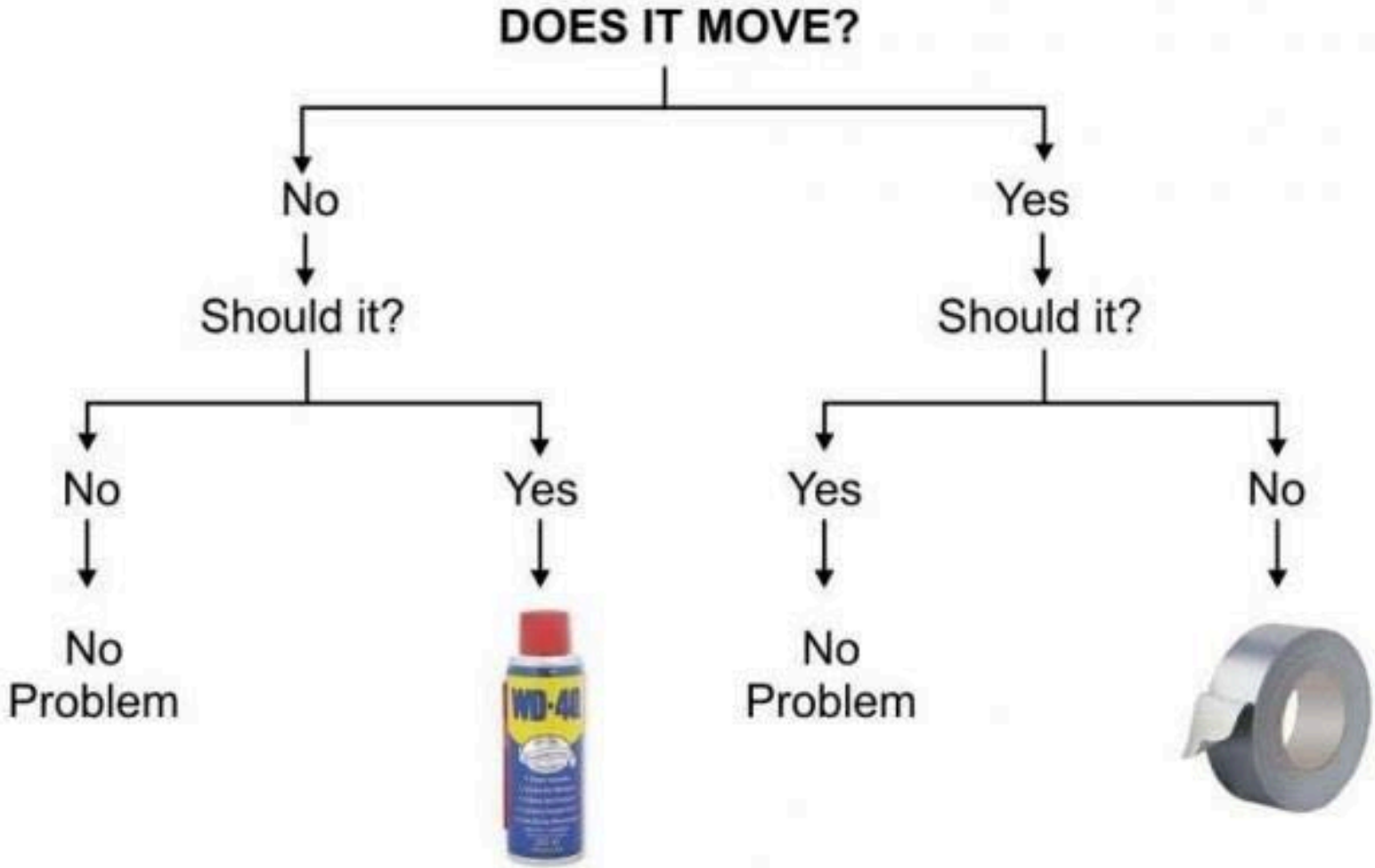
Product Design

- Product design deals with design, testing, manufacture and sale of (generally) mass-produced goods
  - Appliances, tools, televisions, toys, cars …
- Product designers must deal with
  - Current market needs, production costs, function, sales, distribution, profit expectations …
- Some products are complex systems
  - High-rise office building, container ship, car, space shuttle, robotic devices …
- Others are not
  - can opener, nail clipper…

The Design Process

- Design involves as much art as science
- The process from idea to finished product involves a series of sequential steps …

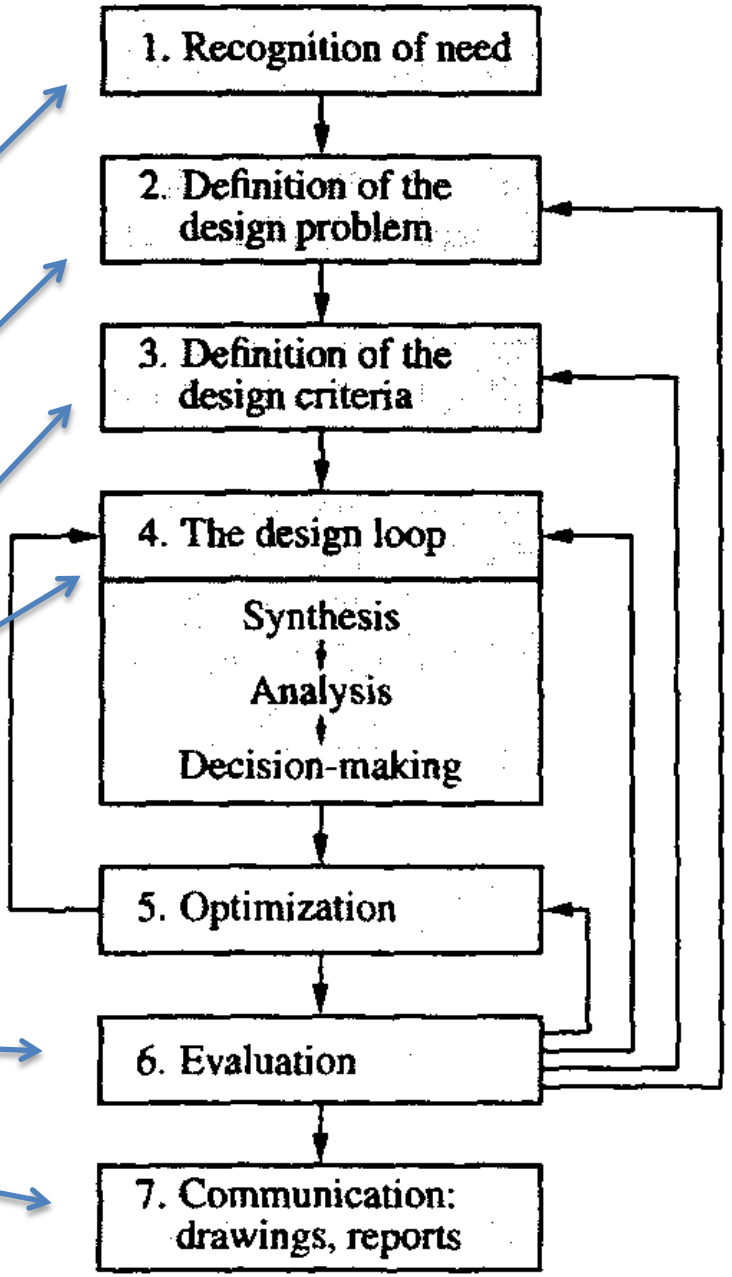
Engineering Flowchart

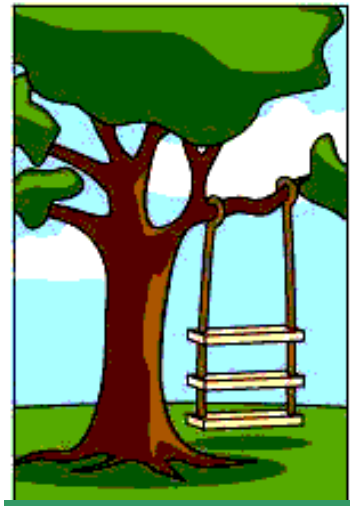


Method Of Design

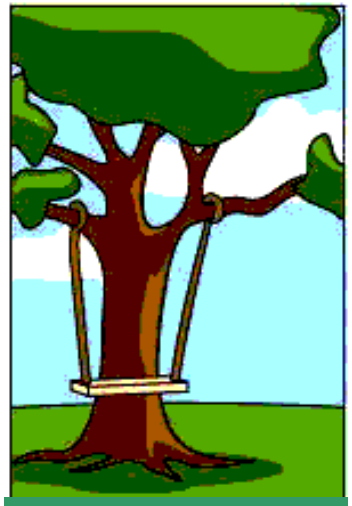
Seven steps:

1. Recognition of need
2. Definition of the design problem
3. Definition of the design criteria
4. The design loop
5. Optimization
6. Evaluation
7. Communication



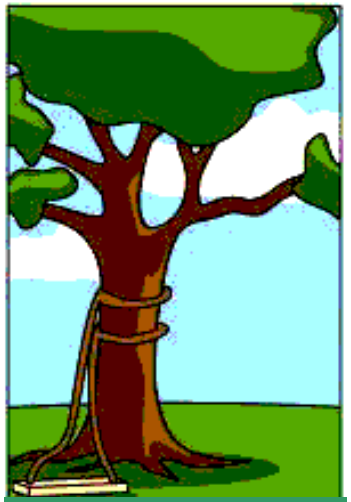


How the customer explained it

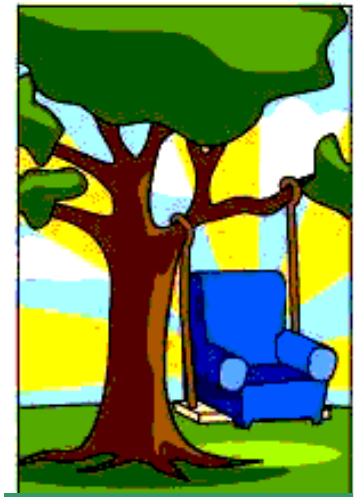


How the project manager understood it

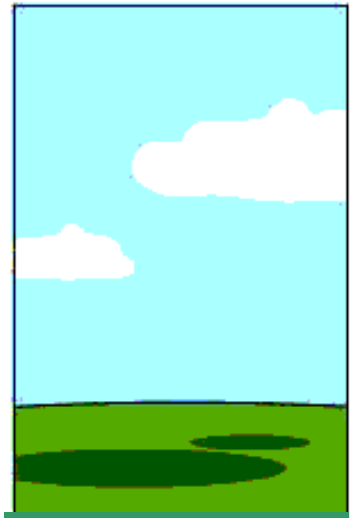
How the engineer designed it



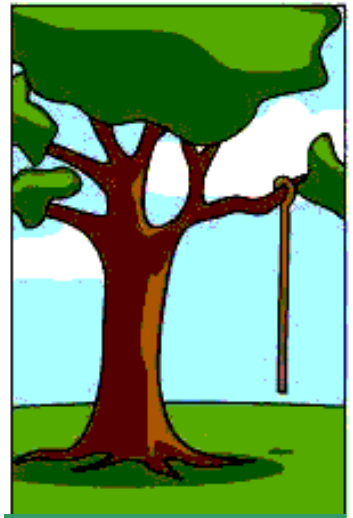
How the programmer wrote it



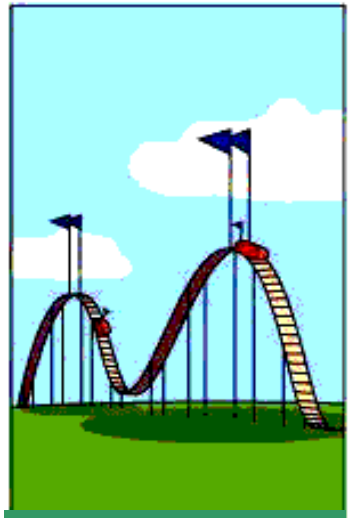
How sales & marketing sold it



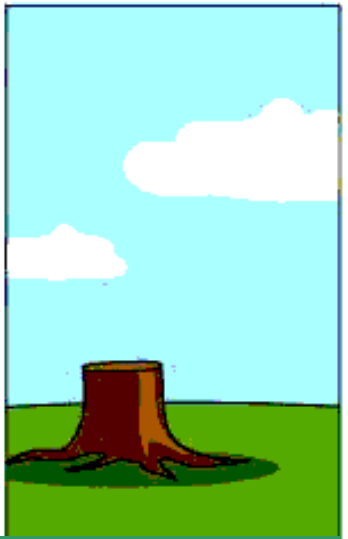
How the project was documented



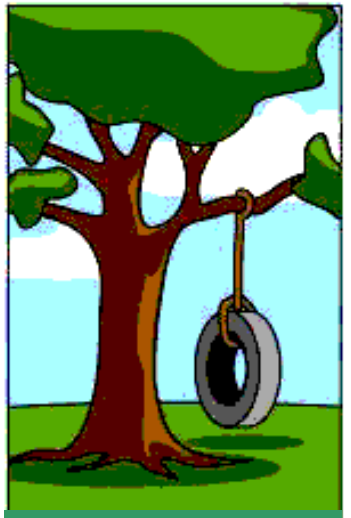
What operations installed



How the customer was billed



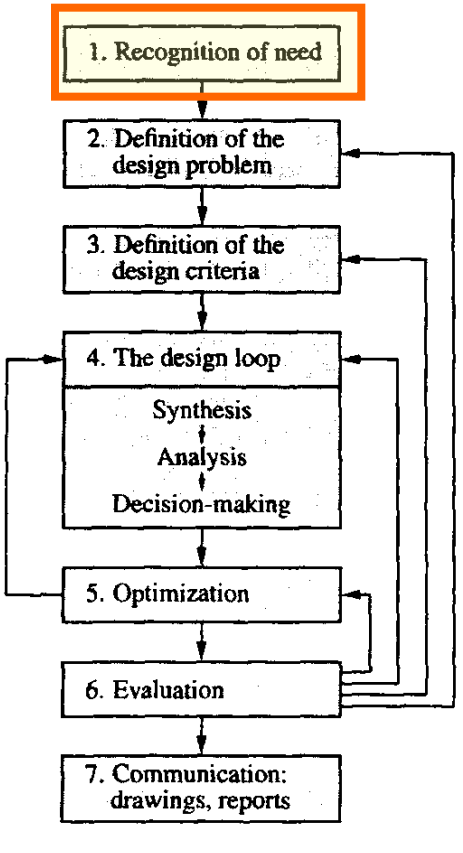
How it was supported



What the customer really wanted

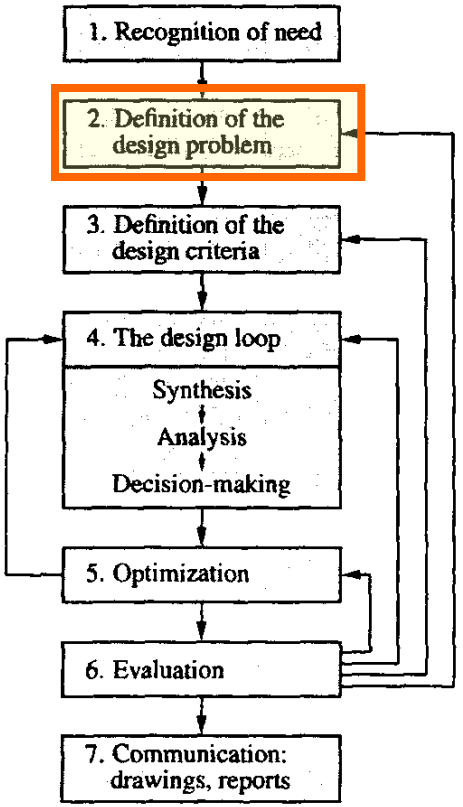
Method Of Design

- Recognition of need
  - A need can be either very obvious or hidden
  - Usually very vague
  - The vagueness of the need can cause the design process to become open-ended
  - Often the need is written in a Statement of Requirements (SoR)



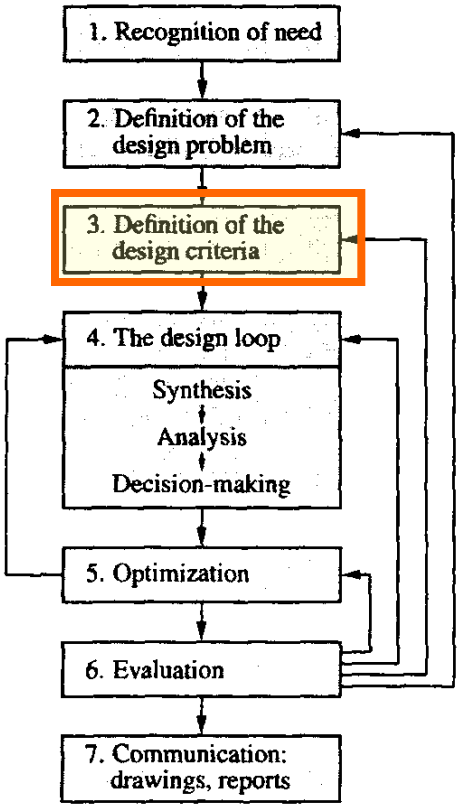
Method Of Design

- Definition of the design problem
  - Critical for a good design
  - May require the gathering of information on the topic (*i.e.,* Research)
  - Must define the problem correctly in order to provide a solution



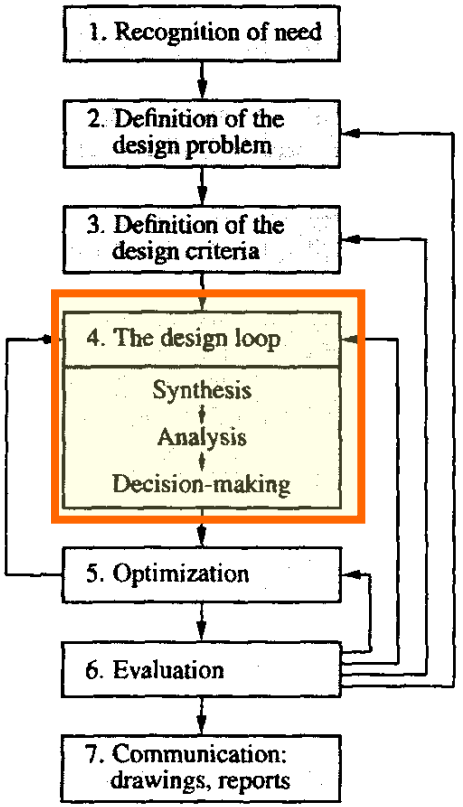
Method Of Design

- Definition of the design criteria
  - Design criteria are performance standards to be met by the design
  - Design constraints are limitations placed on the designer
  - The design criteria and constraints must be quantitative values, otherwise it may be impossible to agree on whether the final design is acceptable



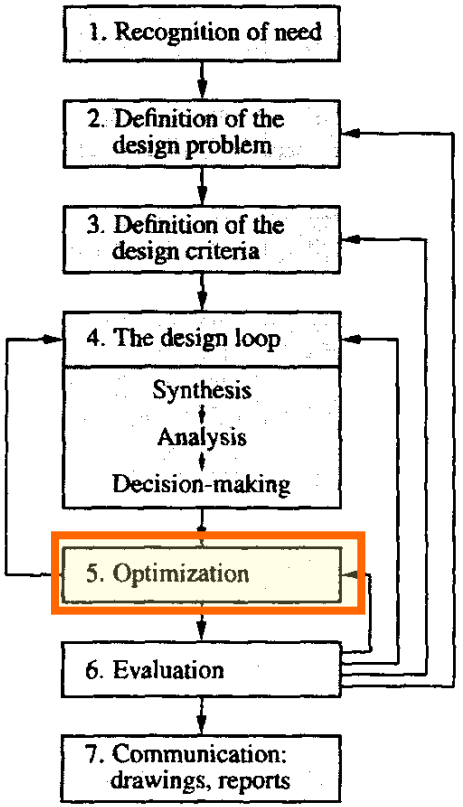
Method Of Design

- The design loop
  - Synthesis
    - Suggesting ideas or methods to solve the problem
  - Analysis
    - Calculating the expected result of each idea or method
  - Decision-making
    - Deciding which alternative is best



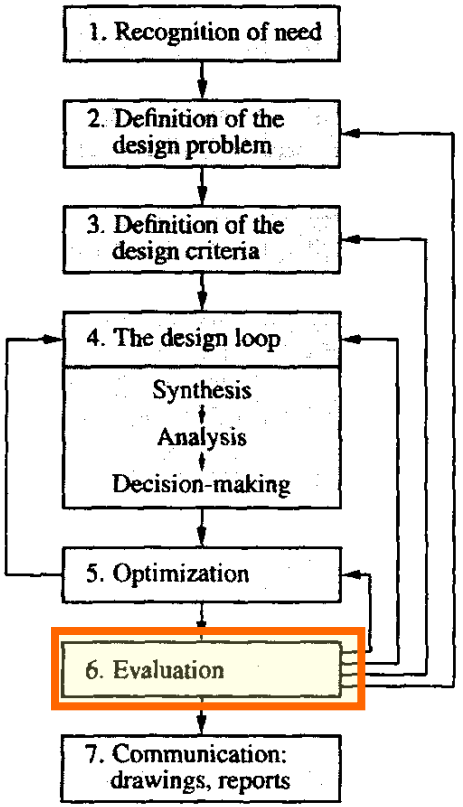
Method Of Design

- Optimization
  - Optimum implies a compromise between costs and benefits – the best design at a reasonable cost
  - In order to judge whether the design is optimum, the design criteria in step 3 are used
  - If the design is not optimum, the design loop may need to be reiterated



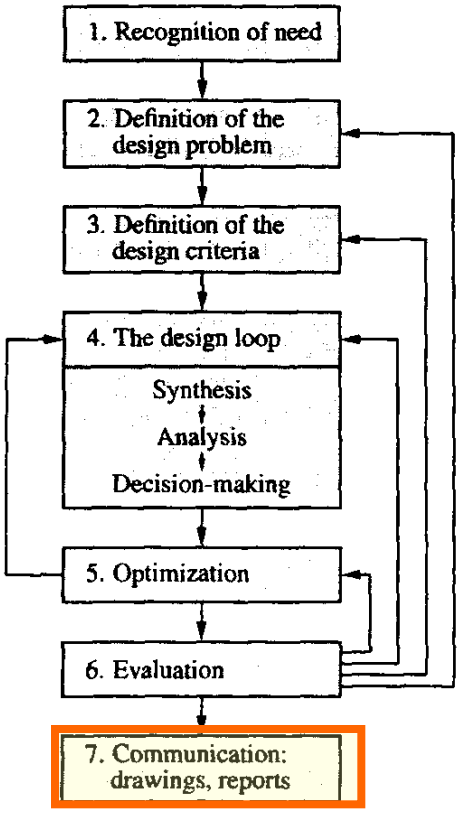
Method Of Design

- Evaluation
  - Once the design is completed, it is reviewed
  - The senior engineer, and ‘others’, must approve the design before it is finalized
  - If flaws are detected, the design must be iterated, beginning at step 2 if necessary



Method Of Design

- Communication
  - Once the design is approved, it can be built or manufactured
  - The final design must be communicated effectively
    - Reports
    - Technical drawings



Codes and Standards

- Code
  - A code is a set of specifications for the analysis, design, manufacture, and construction of things
  - The purpose is to achieve a specified degree of safety, efficiency, performance, or quality
- Standard
  - A standard is a set of specifications for parts, materials, or processes intended to achieve uniformity
  - Places limits so as to provide reasonable inventory of tooling, sizes, shapes, varieties, etc.

Codes and Standards

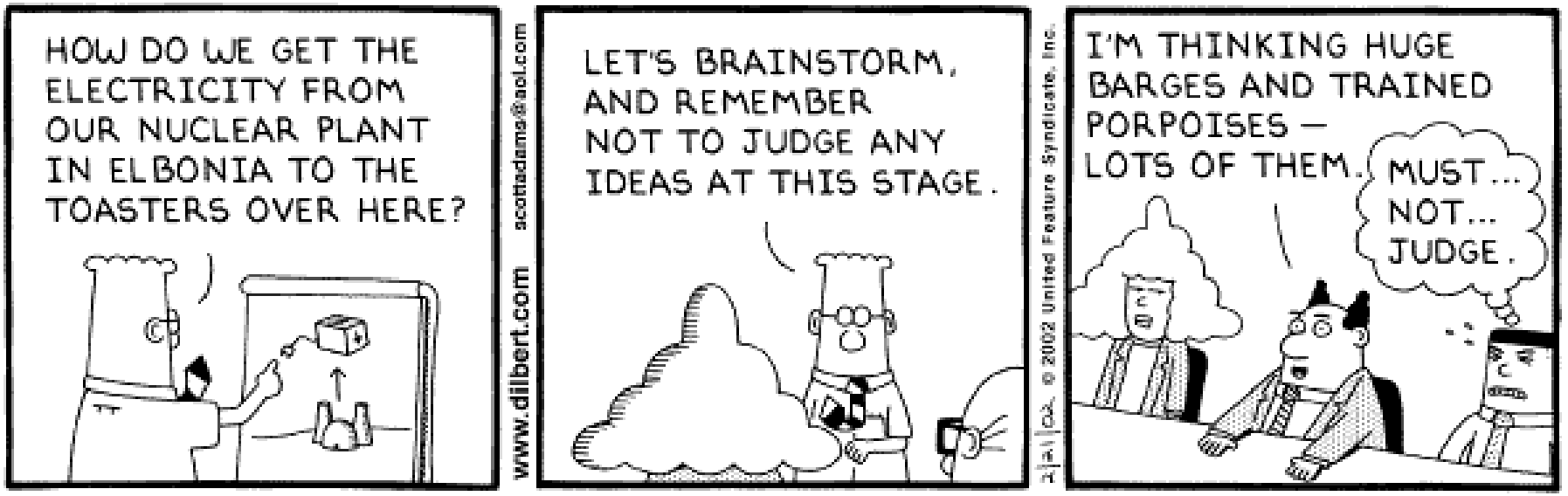
- Standards Organizations
  - International Standards Organization (ISO)
  - American National Standards Institute (ANSI)
  - Canadian Standards Association (CSA)
  - Canadian Society for Mechanical Engineering (CSME)
  - American Society of Mechanical Engineers (ASME)
  - Institution of Mechanical Engineers (I. Mech. E.)
  - Institute of Electrical and Electronics Engineers (IEEE)
  - Society of Automotive Engineers (SAE)
  - Society of Manufacturing Engineers (SME)

Creativity and Innovation

- Creativity and innovation are very important in the design process as a whole
- They are especially important during the design loop stage of synthesis
- Is it something that can be taught?
  - There are ways to stimulate creativity and innovation …

Stimulating Creativity and Innovation

- Brainstorming
  - A group of people generate a number of solutions to a problem
  - Judgment of ideas is prohibited at this point



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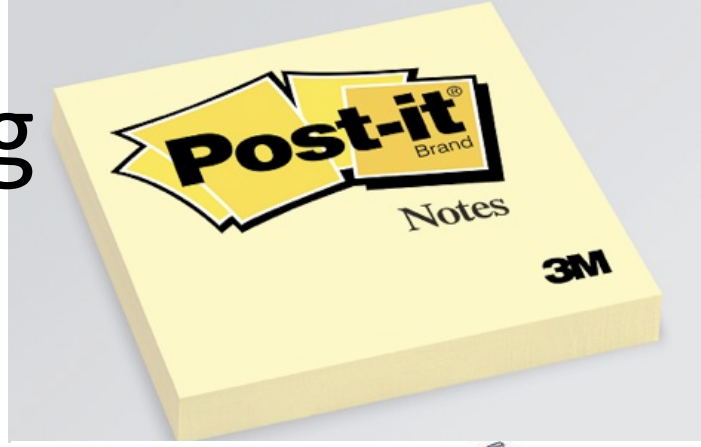
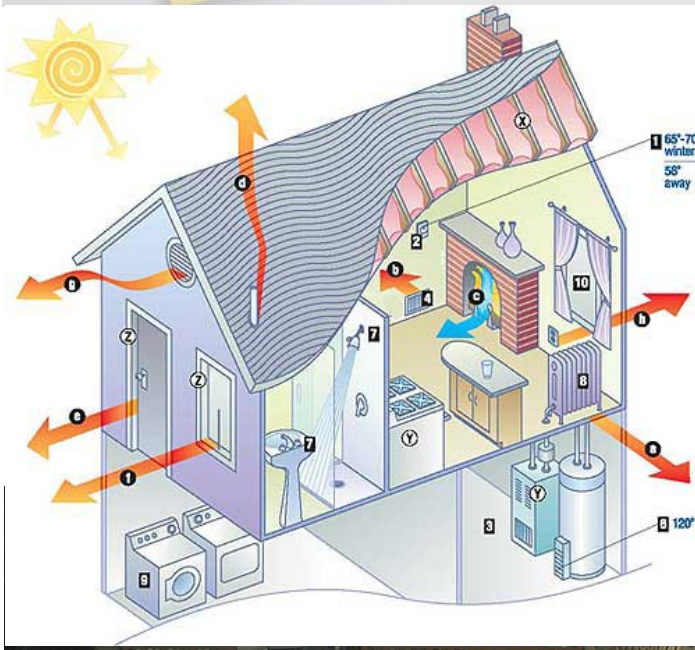
Stimulating Creativity and Innovation

- Brainstorming
  - A group of people generate a number of solutions to a problem
  - Judgment of ideas is prohibited at this point
  - All ideas are considered equal until evaluation
  - After a set period of time, all ideas are discussed, evaluated, and perhaps ranked
  - The best ideas are examined further

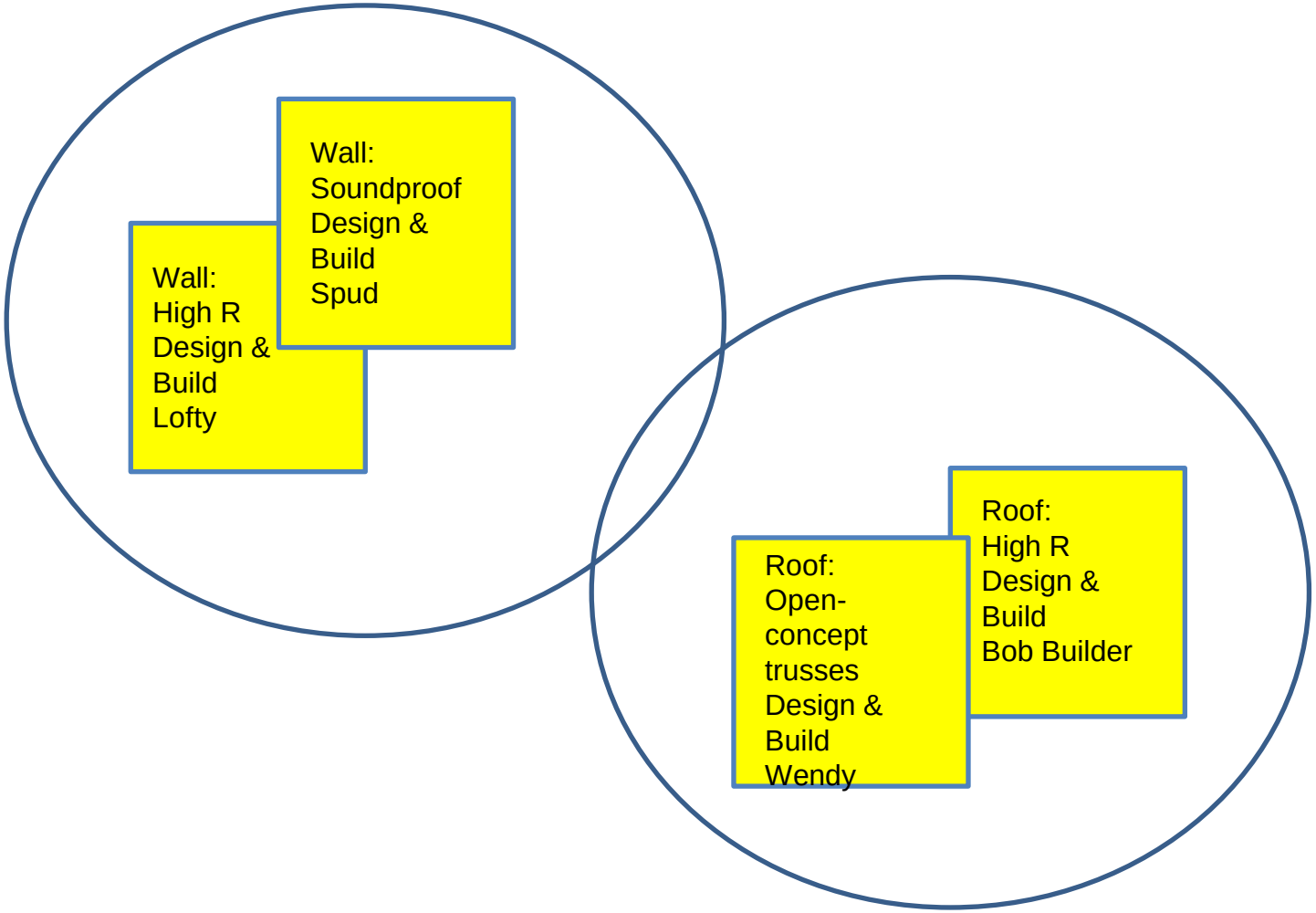
Sticky-note Brainstorming



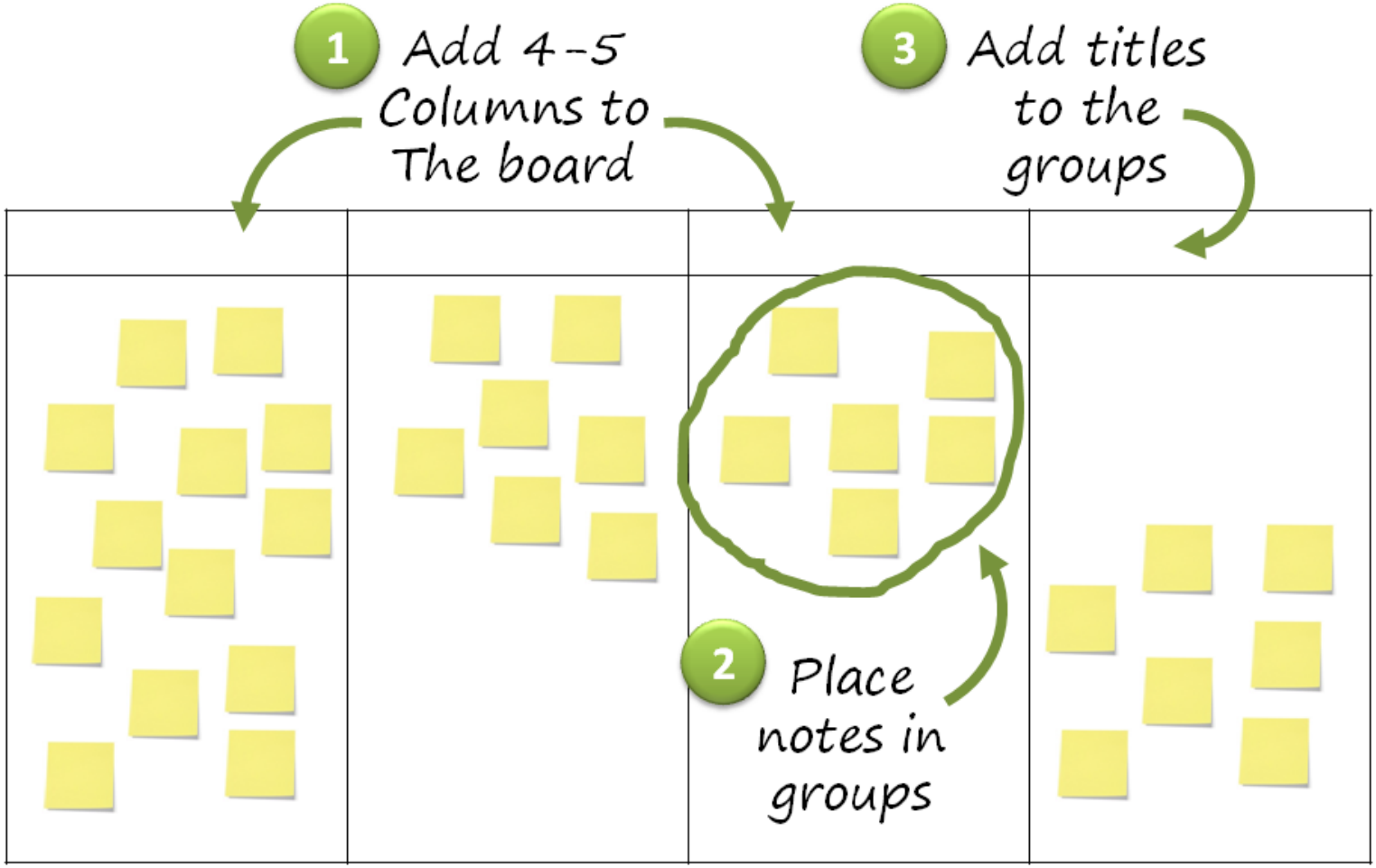
- Come up with at least one idea for a project to design a more energy-efficient house
- Describe it generally in one or two words: door, window, roof, etc.
- Describe what we might do: design and build a **green** roof with a high thermal resistance.



Sticky-note Brainstorming

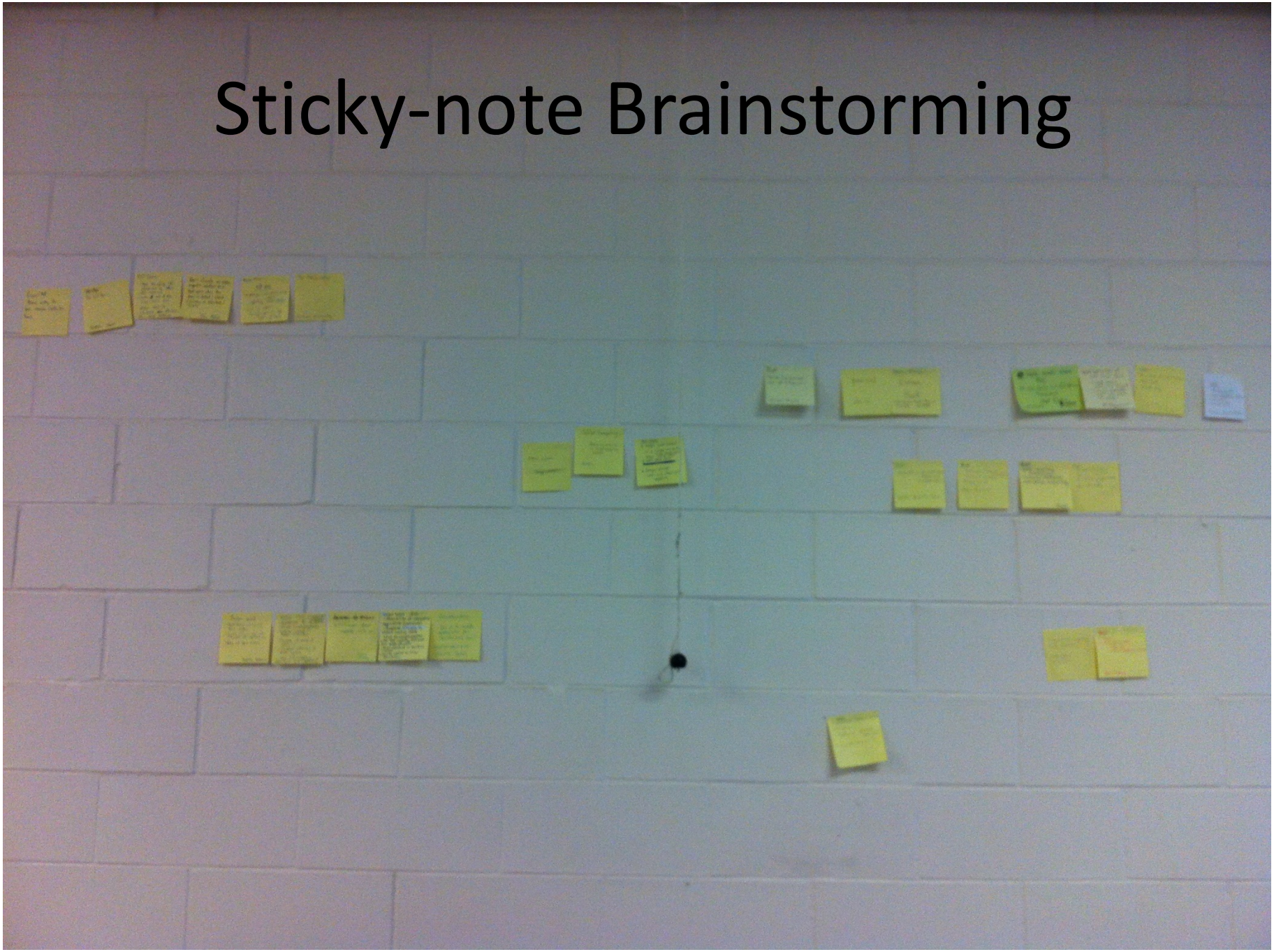


Sticky Notes: Bottom Up Grouping



Use: Organizing items into a whole

Sticky-note Brainstorming



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Team Ontario 2013

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- international competition held every two years
- 20 university teams design, build and operate solar-powered houses that are cost-effective, and energy-efficient
- winning team of the competition is the team that best blends affordability, consumer appeal, and design excellence with optimal energy production and maximum efficiency

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Stimulating Creativity and Innovation

- Brainwriting
  - Similar to brainstorming – instead of sticky notes, ideas are written out in more detail
  - After some time, the sheets with the written ideas are swapped
  - You then try to expand on the ideas listed on the new sheet of paper
  - Forces constructive ideas without negative feedback
  - Evaluation of the ideas takes place later

Stimulating Creativity and Innovation

- Tips for overcoming creative blocks
  - Don’t assume there is only one answer
  - Don’t avoid new ideas for fear of making mistakes
  - New ideas don’t have to be hard work – simplicity is a good thing
  - Don’t worry about unworkable ideas – having no ideas is much worse
  - Say or write anything because your ideas may stimulate other people

Design Reports

- There are three primary means of communication
  - written
  - oral
  - graphical
- To be successful as an engineer you must be not only technically competent, but versatile with all three forms of communication!
- All three forms of communication are of critical importance in each design step
- The design process is documented in the design report

Written Reports

- The keys to writing great reports:
  - Organize logically
  - Pay attention to detail
    - Never any spelling errors
    - Never any grammatical errors
  - Proof Read, Proof Read, Proof Read
  - **If you don't know how to write well, get help!**
  - **Have someone review your report before you submit it!**

Written Reports

- There are generally three types of written report:
  - Proposal
  - Progress Report
  - Final Report

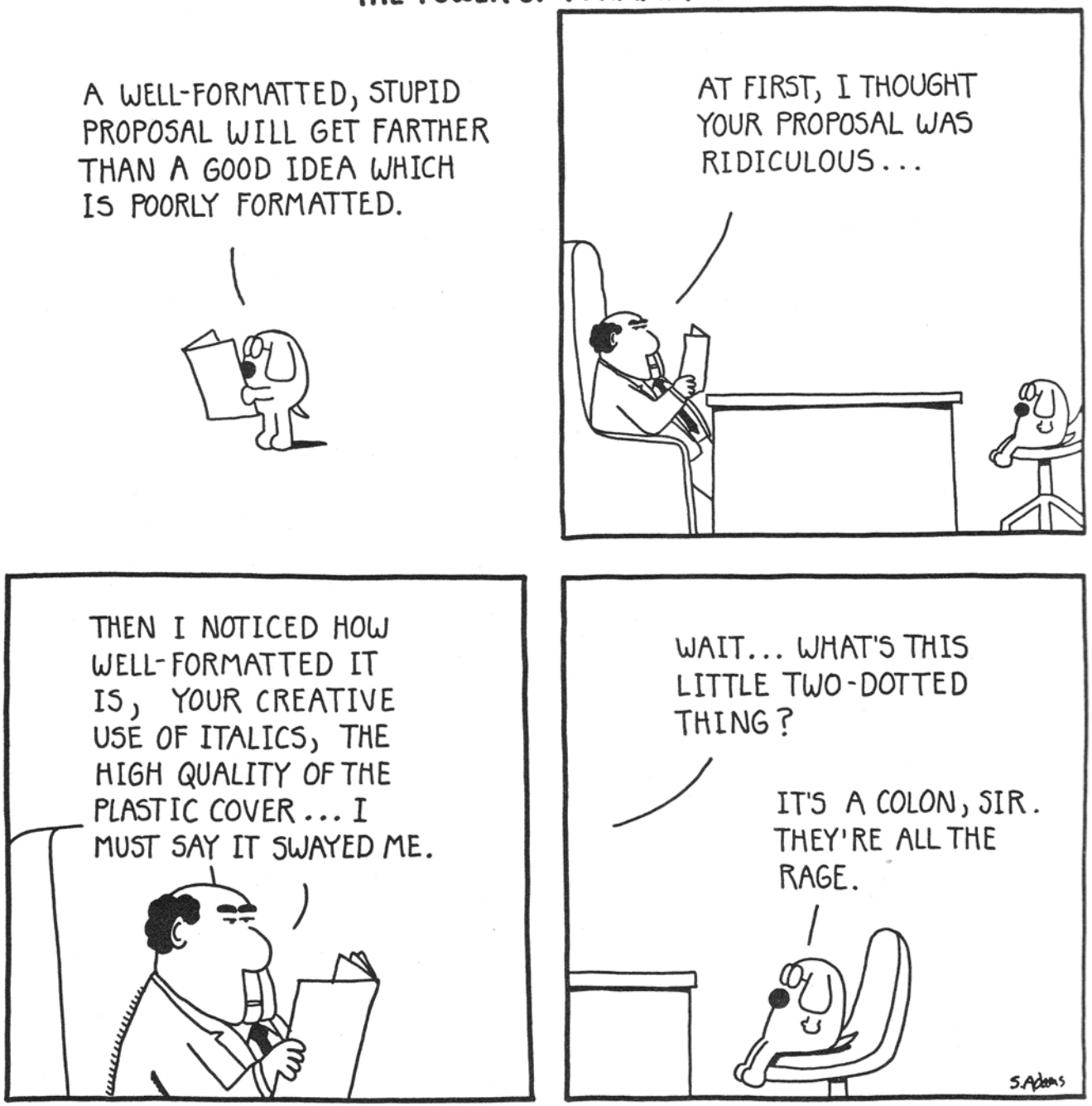
Proposals

- Proposals are written to convince people with money that they should pay for the project
- Proposals should reflect the interests and language of the reader (*i.e.*, know your audience)
  - Investors are interested in profits and returns
  - Managers are interested in benefits and costs to the company
  - Engineers are more concerned with function and feasibility

Proposals

- A typical proposal may contain the following fundamental elements
  - Problem statement; benefits of the work
  - Proposed work plan; how are you going to do it
  - Personnel and facilities needed
  - Schedules for milestones and deliverables
  - Budget
  - Summary

THE POWER OF FORMATTING



Progress Reports

- Periodic reports (i.e., quarterly reports) on the status of the project
- Usually brief letters or memos
- Tells your customer how things are going:
  - Have you discovered something?
  - What problems are you having?
  - Are you on time?
  - Are you on budget?
  - What are you doing to correct any problems?

Progress reports are usually easier to write if you have done some work! Even if you made no progress.

Final Report

- The final report is the final step in the project
- It generally contains:
  - Abstract (Executive Summary, Implications, etc.)
  - Introduction (Problem Statement)
  - Methods Used
  - Body (Results, Findings)
  - Discussion
  - Conclusions

Final Report Format

- A final report typically contains the following elements, or variations on them, depending on the nature of the particular project and on the requirements of the customer
  1. Cover
     - The report should be bound with the title, authors and their affiliations on the cover
  2. Letter of Transmittal (optional)
     - Letters of transmittal are simply cover letters sent with documents to intended readers summarizing the contents

Final Report Format

3. Title Page
   - Contains the title of the report, the authors names and affiliations, and the date (usually the same as the cover)
4. Abstract and/or the Executive Summary
   - The ‘take-home’ message, and the value and implications of the work → what you want the big boss to know
5. Table of Contents
   - The major sections, sub-sections, and their page numbers are listed
6. List of Figures, List of Tables (optional)
   - Usually required for long formal reports
7. Acknowledgements
   - Here any help, financial or technical, in completing the project is recognized

Final Report Format

7. Introduction
   - The problem statement is discussed
   - Explains importance of and need for a solution
   - Background information is outlined
8. Method (actual section title may vary)
   - Covers the general methods and approach used to solve the problem
   - Experimental methods and apparatus are described
9. Body (actual section title may vary)
   - This is the main section
   - It describes collected data, analysis, and steps taken to solve the problem
   - This section usually contains sub-sections that describe distinct components of the solution

Final Report Format

10. Discussion (may be included in the Body)
    - Project findings should relate clearly to the data and analysis presented in the Body
11. Conclusions
    - The findings are summarised and major results listed
12. Recommendations (Suggestions for Further Work)
    - These may also be presented in a sub-section of the Conclusions
13. Appendix
    - Drawings, sketches, raw data, letters, and any supplemental, but extraneous, information related to the project but does not need to be in the main body

Final Report Format

14. References (Bibliography)
    - All reference material not developed by the authors must be listed according to an accepted bibliography style (examples of which you can find in the Library)
        - Reference books
        - Scientific Journal Articles
        - Codes and Standards
        - Magazine Articles
        - Private Communications
        - Theses
    - Always cite your sources, no matter how trivial

Reading Assignment

- For next lecture read Chapters 16 & 17.