ENGG 1100 Introduction to Engineering Design

Lecture 2: Engineering Design & Management + Quiz Information

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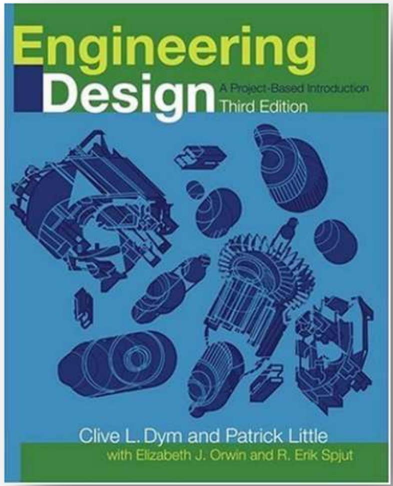
Acknowledgements
Most of the slides were previously developed by Prof. Ken Ma (EE Dept) for the EE design course and by Prof. C.H. Cheng & Prof. K.P. Lam (SEEM Dept) for ENGG 1100 (2013-2014), with inputs from Prof. K.H. Lee (CSE Dept) and Prof. Douglas Yung (EE Dept)

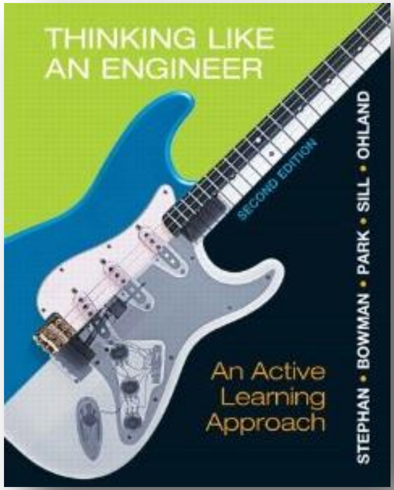
September 16, 2013

Recommended Reading

- Clive L. Dym, Patrick Little, Elizabeth J. Orwin, and R. Erik Spjut, "*Engineering Design: A Project-Based Introduction*", Third Edition, Wiley, 2009.

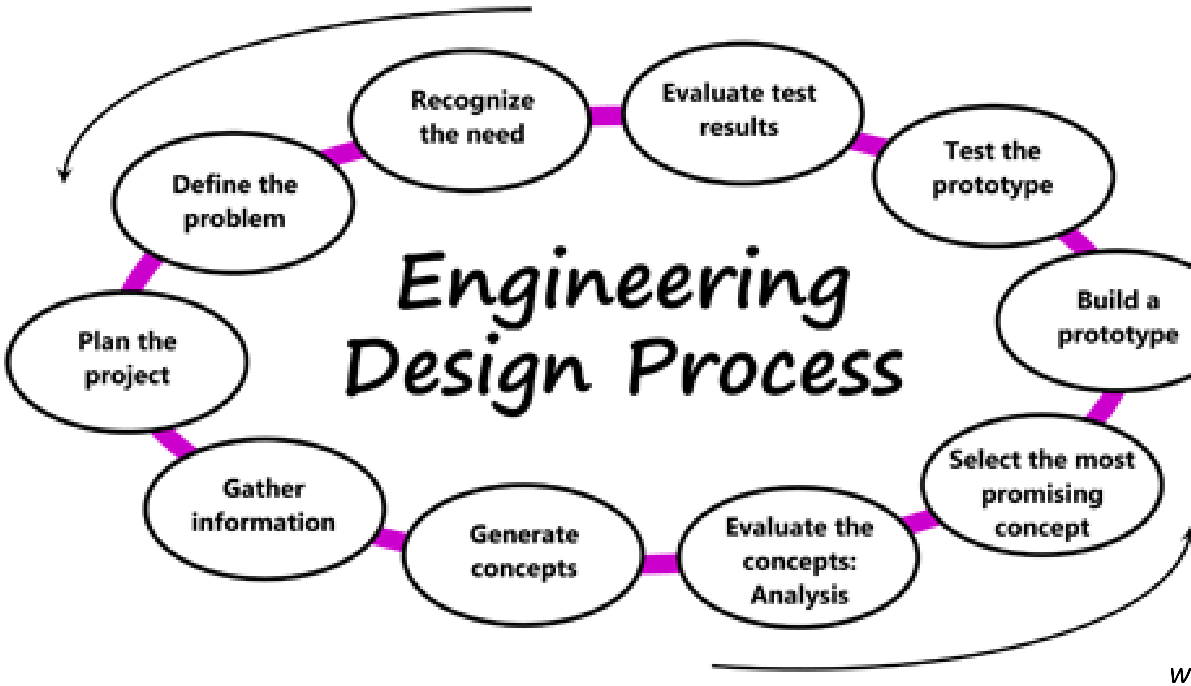


- Elizabeth A. Stephan, David R. Bowman, William J. Park, Benjamin L. Sill, and Matthew W. Ohland, "*Thinking Like an Engineer: An Active Learning Approach",* Pearson, 2012.



What is Engineering Design?

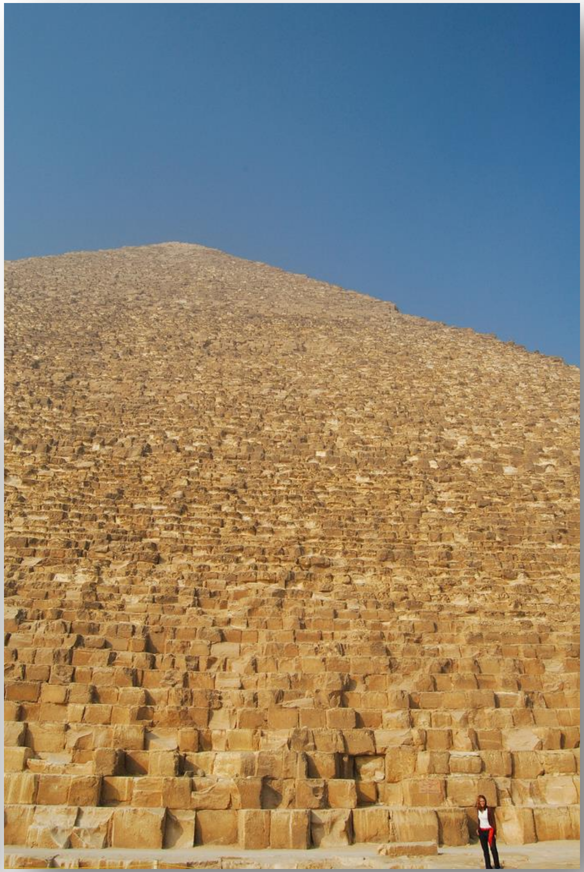
Engineering design **is a systematic, intelligent process in which designers generate, evaluate and specify designs for devices, systems or processes whose form(s) and function(s) achieve client's objectives and users' needs while satisfying a specific set of constraints.**



The steps of the engineering design process. Copyright © Denise W. Carlson, ITL Program, College of Engineering, University of Colorado at Boulder. The source of this material is the *TeachEngineering* digital library collection at *www.TeachEngineering.org*. All rights reserved.

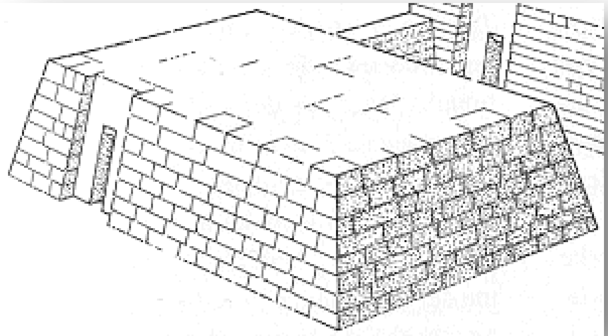
History of Design

- People have been designing things for a long time
- Examples of great designs from the past
  - Great Pyramids in Egypt
  - Mayan Cities and Temples
  - Great Wall of China
- Basic design method in the past > **Trial and Error**



Design Evolution

Mastaba



Step Pyramid

Bent Pyramid

The Design Process

- Scientists see things as they are and ask, **WHY?**
- Engineers see things as they could be and ask, **WHY NOT?**

- Essence of new design
  - **Less expensive**
  - **Faster**
  - **Better**

Mac Computer Evolution

1976: Apple I

1980: Apple III

1989: Mac Portable

1998: iMac

2000: PowerMac G4 Cube

2003: iMac G4

2004: PowerBook G4

2004: iMac G5

Mobile Phone Evolution

1980s

1990s

2000s

2010s

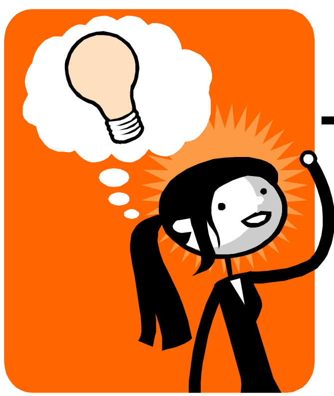
Designs Can Be Different – Variation in Usage

A Variety of Possibilities for Designing a Ladder

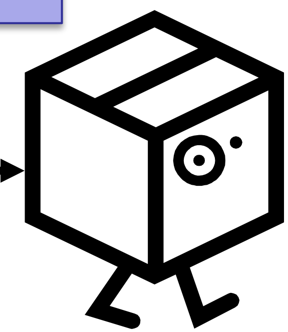
From Design to Manufacture

End Results of the Engineering Design
- Being in the form of Specifications for
  - Manufacturing Products
  - Carrying out Services

Generating Ideas for
- Innovations
- Solving Problems
- Meeting Needs
- Improving Efficiency
- Saving Resources
- …

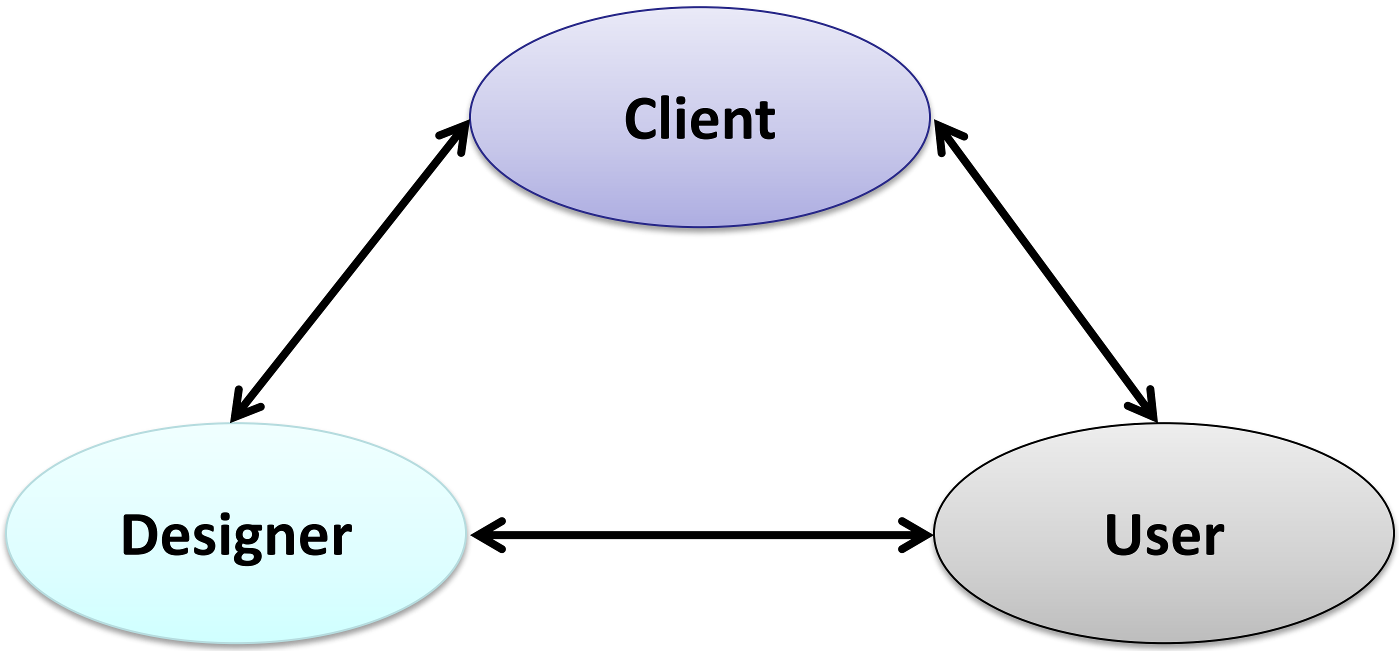


Idea → Design → *Specifications* → Manufacture →



Going through an Engineering Design Process
- Achieving Objectives
- Satisfying Constraints
- Leveraging on Available Knowledge, Skills & Technologies

Designer-Client-User Triangle



- **Client:** person or group or company that wants a design conceived
- **User:** The person who will actually use whatever is being designed
- **Designer:** As its name implies

Engineering Design Addresses Hard Problems

- Design problems are **ill structured** — their solutions cannot normally be found by applying math. formulas, methods, and procedures in a routine way.

- Design problems are **open-ended** — they typically have several acceptable solutions.

Design Process as a Process of Questioning

- Suppose your client wants you to “design a safe ladder”.

- There will be a lot of questions arising:
  - Why do you want another ladder?
  - How will it be used?
  - How much can it cost?
  - What do you mean by “safe”?
  - ….
- Similar sets of questions arise if I simply ask you to “design an automated guided vehicle (AGV)”, without further specifications.

- The designer’s first task is to clarify what the client wants so as to be able translate wishes into meaningful **objectives** and **constraints**.

Example: Design a Safe Ladder

- Questions like
  - Why do you want another ladder?
  - How will it be used?
  - How much can it cost?

  ➔ help **clarify and establish the client's objective.**
- Questions like
  - What does "safe" mean?
  - What's the most you're willing to spend?

  ➔ help **identify the constraints** that govern the design.

Example: Design a Safe Ladder

- Questions like
  - Can the ladder lean against a supporting surface?
  - Must the ladder support someone carrying something?

  ➔ help **establish functions** that the design must perform and suggests **means** by which those functions can be performed.

- Questions like
  - How much weight should a safe ladder support?
  - How high should someone on the ladder be able to reach?

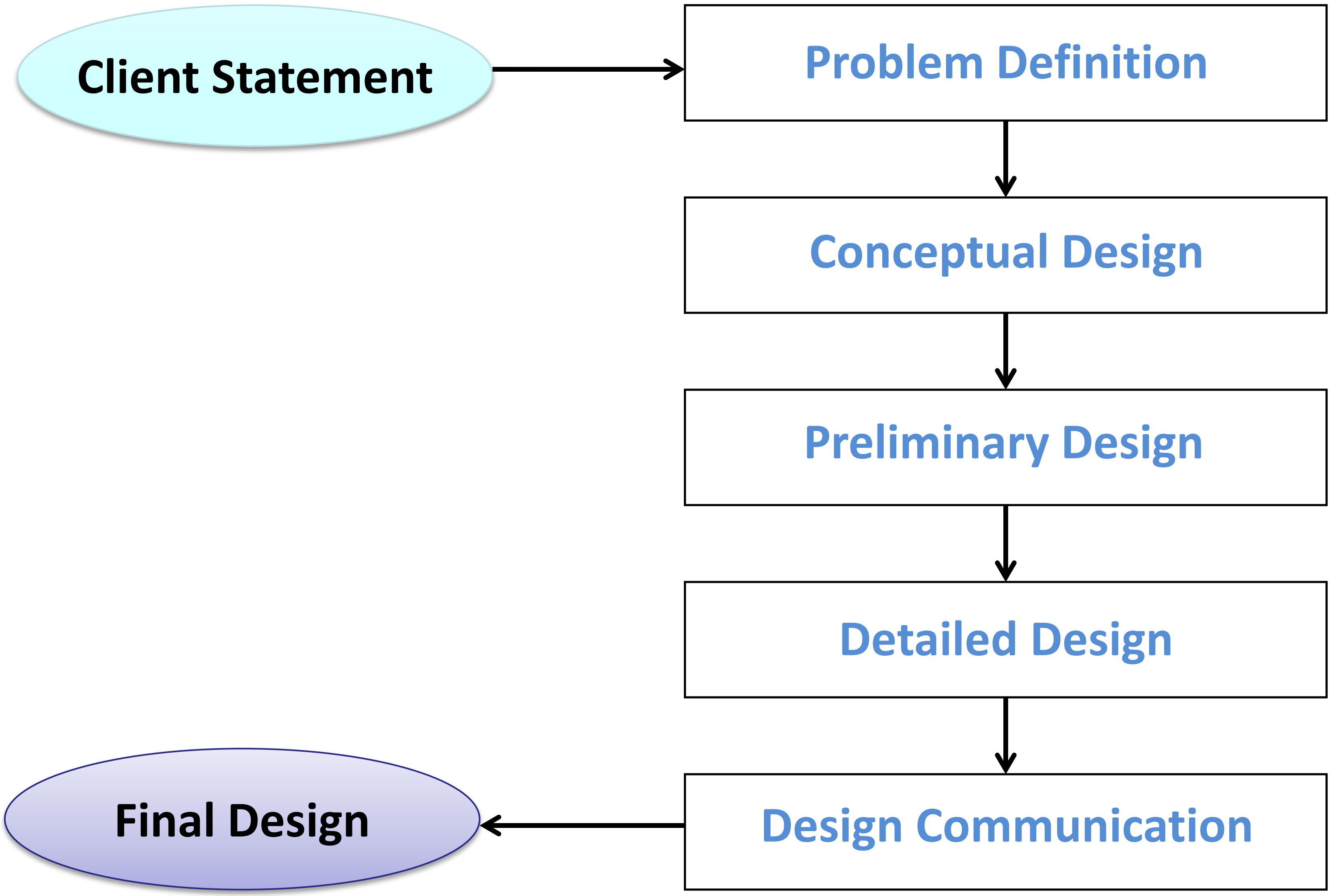
  ➔ help establish **requirements** for the design.

- Can you think about these questions for your design?

Definition of Terms

- **Objective**: something toward which effort is directed
- **Constraint**: strict limits that a design must meet to be acceptable
- **Function**: things the designed device or system is supposed to do
- **Form**: the shape or structure of something
- **Means**: method used to attain an end
- **Metric**: a standard of measurement; e.g., for a car, speed, in km/hr is a metric.

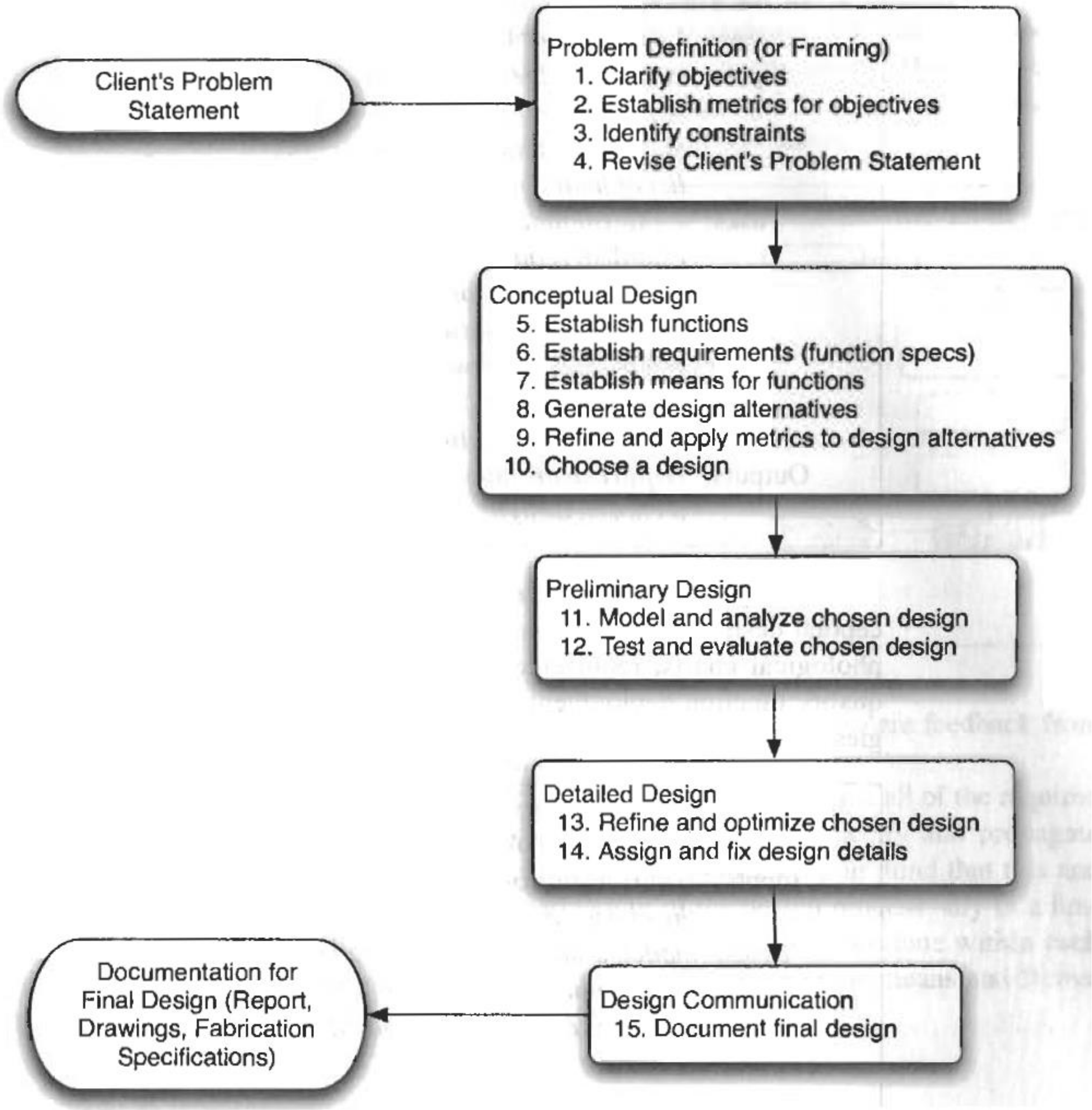
Five-Stage Descriptive Model of the Design Process



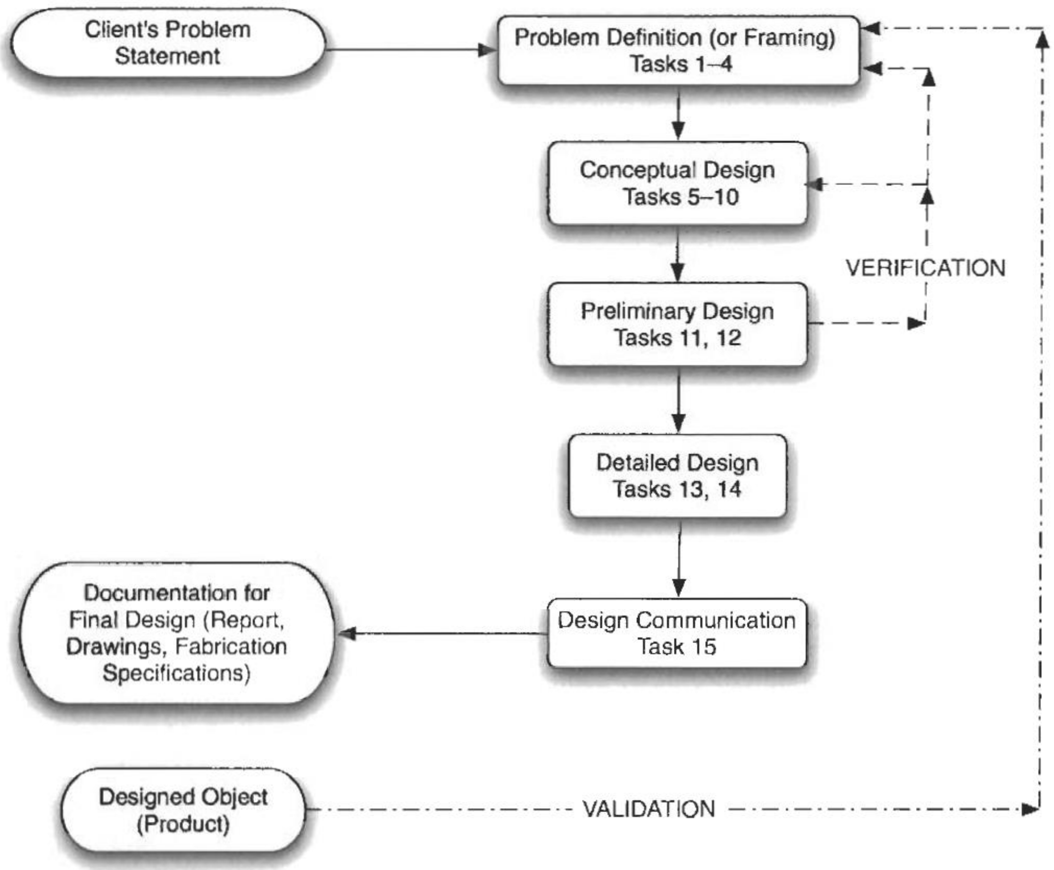
Describing the Design Process

- **Problem definition**: a pre-processing stage that frames the problem by clarifying the client's original problem statement
- **Conceptual design**: different concepts are generated to achieve the client's objective
  - For the ladder project, conceptual designs might be an extension ladder, a stepladder, and a rope.
  - May produce two or more schemes to compete later
- **Preliminary design**: examine preliminary choices of schemes
  - For the ladder project, we may size the side rails and steps, and perhaps decide on how the steps are to be fastened to the side rails.
- **Detailed design**: refine the choices we made in preliminary design
- **Design communication**: a post-processing phase that identifies the work done to collect, organize, present the final design

Specific Tasks of the Design Process



Design Process is Iterative



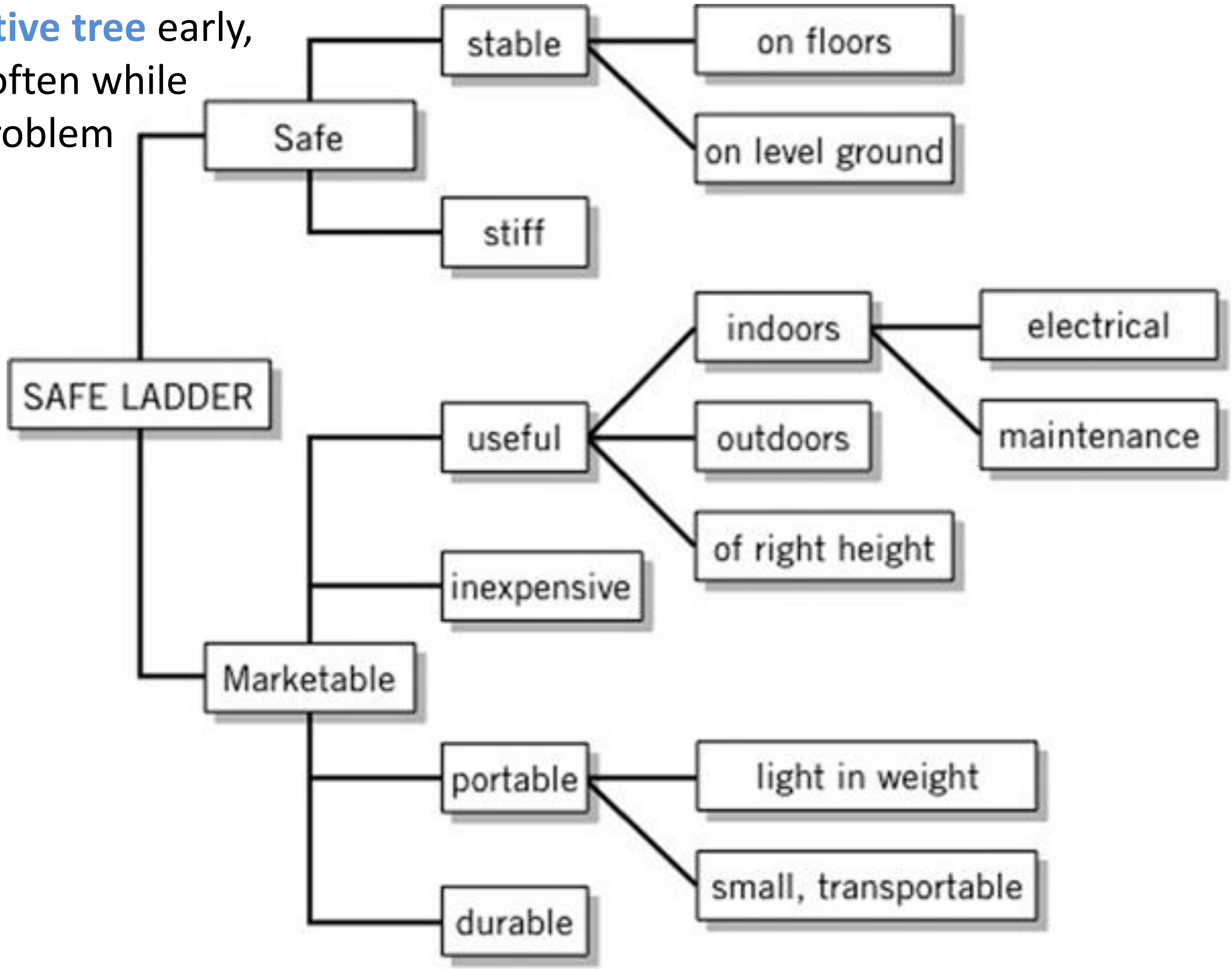
- A design process is not linear or sequential.
- We revise or modify the process from time to time.

Problem Definition – Example: Design a Safe Ladder

• Ladder should be useful	
• Used to maintain and repair outlets in high places	
• Used to replace light bulbs and fixtures	
• Could be a stepladder or short extension ladder	
• Could be made of wood or fiberglass, but not aluminum	**Means**
• Step deflections should be less than 0.5 inch	
• Must support weight of an average worker	**Function**
• Must be safe	
• Must not conduct electricity	**Constraint**
• Should be relatively inexpensive	**Objective**
• Must be portable between job sites	
• Should be light	**Objective**
• Must be durable	**Constraint**
• Need not be attractive or stylish	

Example: Design a Safe Ladder

Build an **objective tree** early, and modify it often while defining the problem

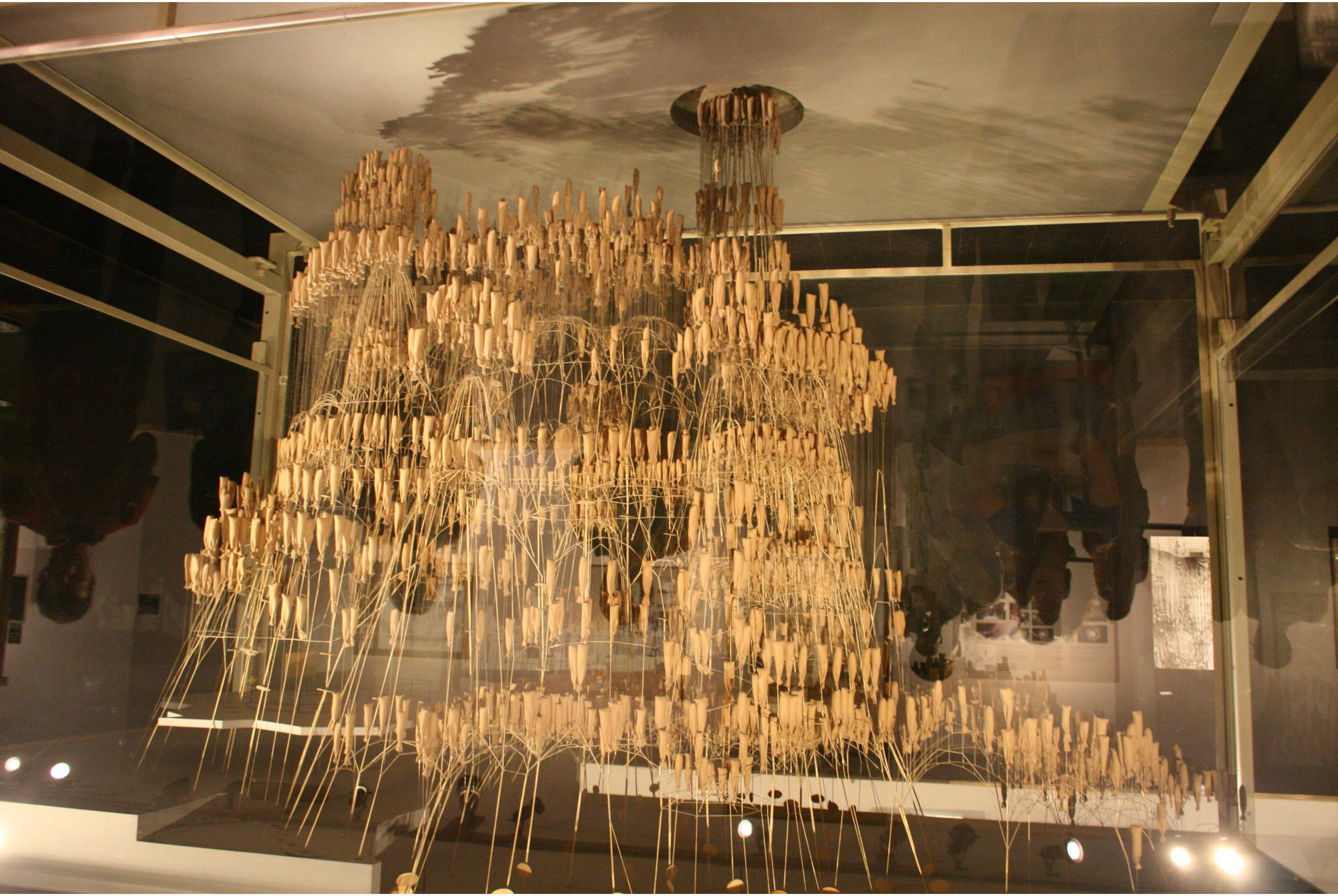


Design a Building: Sagrada Família, Barcelona, Spain

Basilica and Expiatory Church of the Holy Family
Designed by Architect Antoni Gaudí (1852–1926)
http://en.wikipedia.org/wiki/Sagrada_Familia

An On-going Engineering Design Process
Started in 1883, Expected to be done in 2026
Already a UNESCO World Heritage Site

Reverse Model of Strings and Bag, http://www.sagradafamilia.cat/sf-eng/docs_instit/estructura3.php



Means for Designing: 3D Printers

How engineering design can help different clients (art designers, architects, and even movie producers)?

- Digital materials and multi-material 3D printing
- Constraints of the design to be tackled by new material and processing methods, mathematics & software
- What will be the engineering design solutions for a 3D printer to fabricate the design?

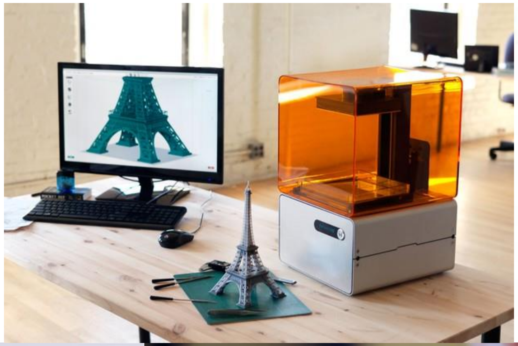
Alternatives in engineering design of 3D printers

- Different users and markets
- The use of different technologies in digital fabrication

3D Printing

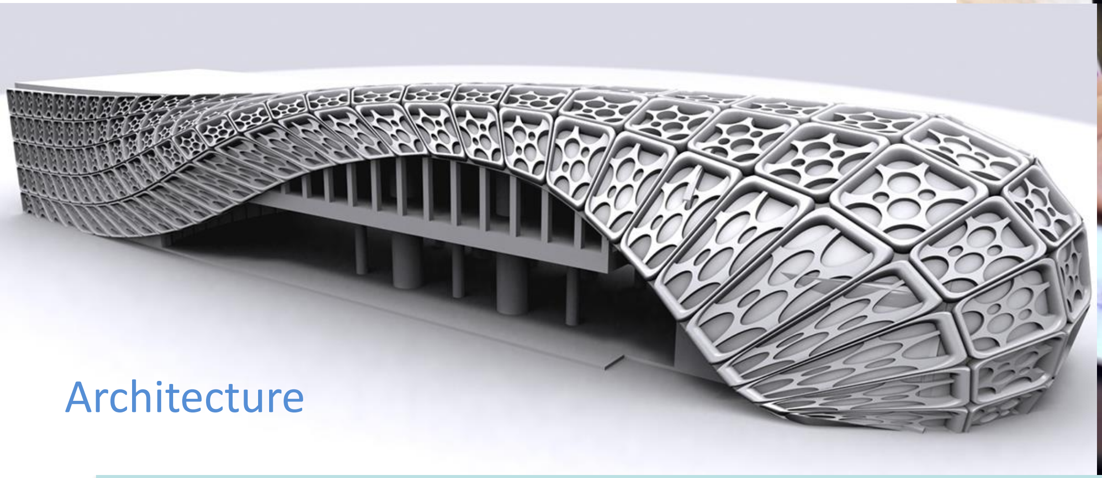
Some selected videos:

- Digital materials and multi-material 3D printing
- Alternatives in engineering design of 3D printers:
  - HP 3D printers
  - Objet
  - uPrint



Clothing

Architecture



Medical Application

Managing the Design Process

- **Project definition**: picking your project, and determining what the "client" wants for the project
- **Project framework**: determining the specific tasks to be done, and organizing a team
- **Project scheduling**: assigning tasks and reaching agreement on when they must be accomplished.
- **Project tracking, evaluation and control**: monitoring the project to insure that deadlines are met, tasks accomplished, and resources used appropriately.

Managing the Design Process – 3S

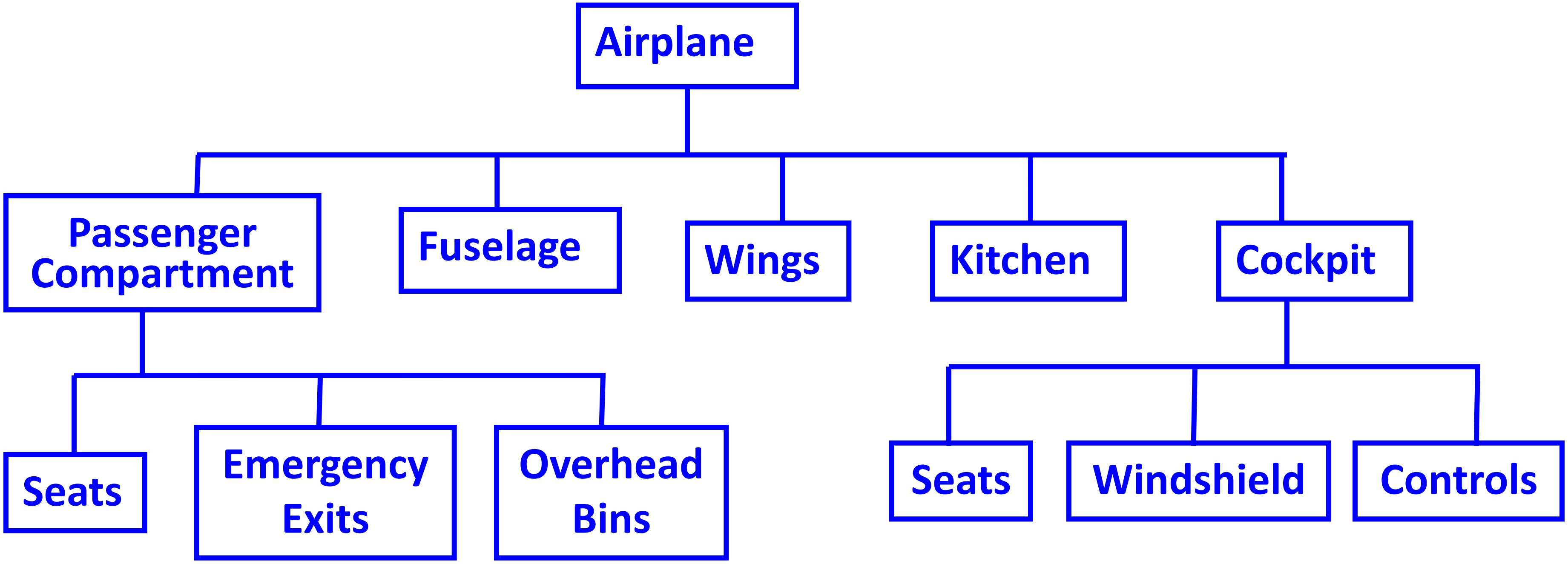
- **Scope**: Clearly understanding what must be done for the project to succeed

- **Schedule**: Determining when each activity must be completed for the entire project to be completed on time

- **Spending**: Managing all the resources that can be spent on a project
  - In commercial settings, this is often translated into dollars.
  - For students, time is the resource to be most closely managed.

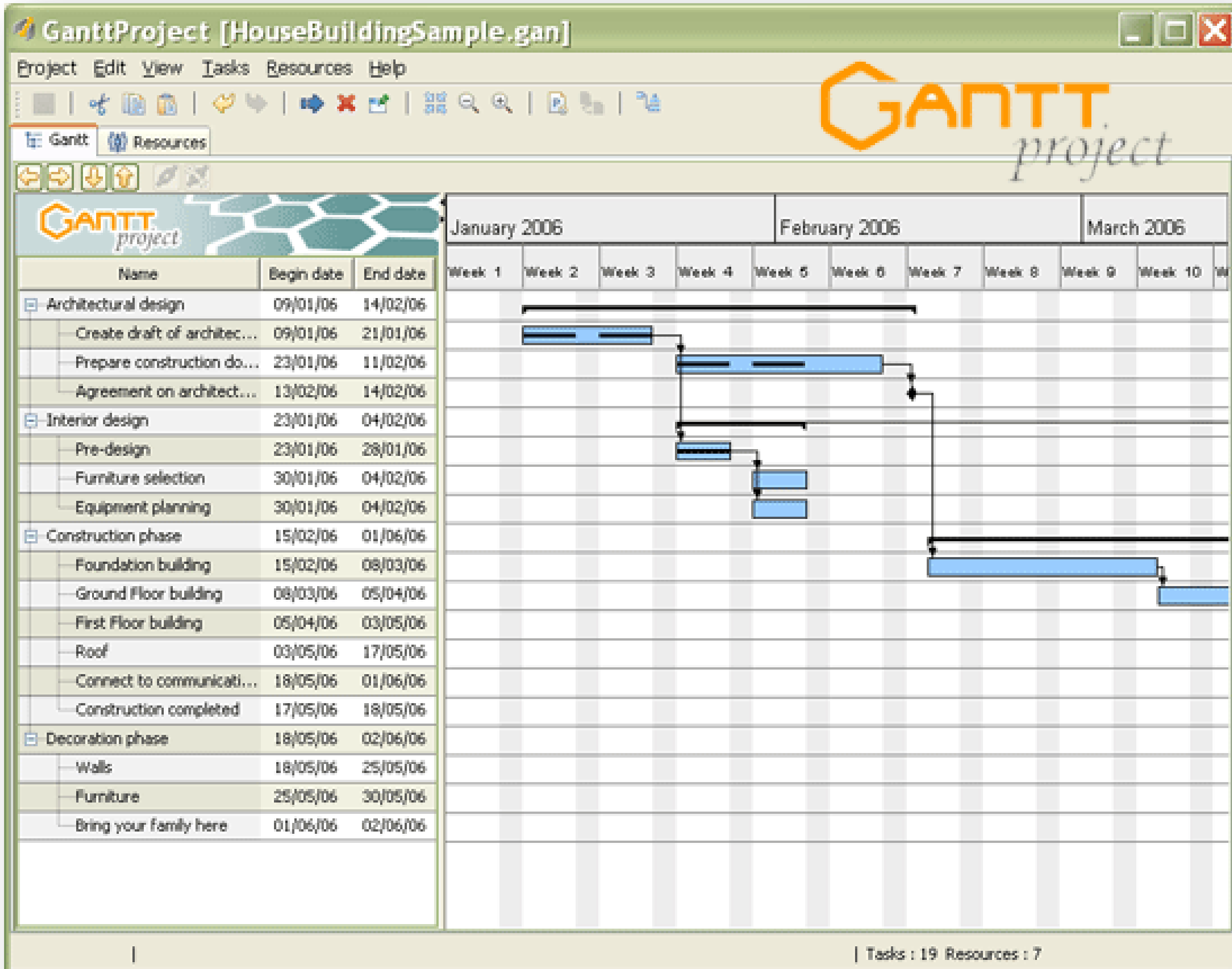
Project Management Tools

- **Scope tools**:
  - Work breakdown structure (WBS): A hierarchical decomposition of all the tasks to be completed for a project to be done.
  - Linear responsibility chart (LRC): show the responsibilities of each team member in terms of the tasks and subtasks to be completed.



Project Management Tools

- **Schedule tools**: team calendar, activity network (logical relationship), or Gantt chart (timeline)
- **Spending tool**: budget



Project scheduling

- **Gantt chart**
  - It enumerates the activities to be performed (on the vertical axis) versus the corresponding duration (on the horizontal time axis)
  - Precedence logic between activities, early or late start schedules
- **Critical path analysis**
  - Critical path methods (CPM) are often used on Gantt chart to depict the critical activities (black bars) with no slacks, and to evaluate the longest and shortest critical paths.
  - Mathematical analysis is often necessary to perform CPM, such as network approach and linear programming approach.
- Reference: A. Shtub, et al., Project Management, Prentice Hall, 1994

Budget and resource planning

- **Time value of money (TVM)**:
  - Capital budgets are essential for supporting project activities over the project duration; but the value of money changes with time (because of interest/discount rates) with the concepts of present value (PV), future value (FV), and discounted cash flow.
  - The starting time and finishing time of a scheduled project activity can have a significant impact on budget planning
- **Net present value (NPV)**
  - NPV (as derived from TVM) becomes an essential financial planning tool in engineering management when dealing with present worth (PW) analysis
  - IRR (Internal Rate Return) is a complementary method of NPV

- Reference: C.S. Park, Contemporary Engineering Economics, Prentice Hall, 2002

When Bad Things Happen to Good Projects

- **Definition of Failure:**
  - Inability of a component, structure, or facility to perform its intended function.
- **Types of Failures:**
  - **Safety Failure**: involves death, injury, or placing people at risk.
  - **Function Failure**: involves compromise of intended usage of structure or facility.
  - **Ancillary Failure**: includes factors that perversely affect schedules, cost, or intended use.

Causes of Failure

• Insufficient of knowledge	36%
• Underestimation of knowledge	16%
• Ignorance, carelessness, negligence	14%
• Forgetfulness, error	13%
• Relying upon others without sufficient control	9%
• Objectively unknown situation	7%
• Imprecise definition of responsibilities	1%
• Choice of bad quality	1%
• Other	3%

Source: Department of Materials Science and Engineering,
State University of New York at Stony Brook,
Engineering Disasters and Learning from Failure

Project Presentation (1)

- Preplanning (5Ws and 1H)

• Who is my audience?	Background, Expectation
• What is my purpose?	Message to Deliver
• Where is all the equipment I need?	Means to Communicate
• When am I on the program agenda?	Context
• Why am I giving this talk?	Importance
• How long should I speak?	Level of Details

- Verbal Elements (4S)
  - Short
  - Simple
  - Strength
  - Sincerity

Project Presentation (2)

- Three Structural Parts
  - Introduction: purpose, what, etc.
  - Body: main content
  - Conclusion
- Visual Aids
- Rehearse your presentation

Communicating Design/End Results to Client

Technical Writing

- We need to write good reports to tell others
  - What you have done
  - Why decisions are taken
  - Lessons learned
  - Future opportunities

- Useful references
  - IET publication: a guide to technical report writing, written by Joan van Emden

Basic Requirements

- No universal rules since not all projects are the same
- Easy to recognise
  - Precise & informative title
  - Well organized layout & formats
- Pleasurable to read
  - Accurate, fluent & concise
  - Appropriate headings
  - Suitable diagrams, charts & graphs

Useful tips

- Keep report as short as possible
- Organise for the convenience of the users
- Write accurately, concisely & unobtrusively
- Use appropriate diagram with right label at the right place
- Provide summaries which will give the whole picture, in miniature
- Include correct references
- Check technical errors, typing errors & inconsistency

Academic Honesty

- Broad definition and expectations on students:
  - Do not **plagiarize** assignments or course works
  - Do not **cheat** in tests and exams
- What is *plagiarism*?
  - Plagiarism is an attempt to pass off the works (in particular the writing of others*) as one's own
- University Policies and Guidelines:
  - http://www.cuhk.edu.hk/policy/academichonesty/

Citing the Source Material in Your Report

- Setting the relevant text apart by **quotation marks**, or in some cases by using a separate indented paragraph

Karl Marx said "Religion is the opiate of the masses." [1]

- A **reference** to the original source
- A **bibliography**, giving the list of references
  - This is usually given at the end of the article/paper, but may sometimes be given at the end of each page.

Example:

http://www.cuhk.edu.hk/policy/academichonesty/p02.htm

Quiz Information

	Quiz 1 – 15 minutes	Quiz 2 – 15 minutes
Date/Time	Oct 7, 2013, 11:30-11:45am	Oct 28, 2013, 11:30-11:45am
Venue	Same arrangement for both quizzes (see below)	
Lecture Coverage	Lectures 1-4: 1. Mechanical Drawing 2. Engineering Design & Management 3. Basic Electronic Circuits and Instrumentation 4. Sensing and actuator	Lectures 5-7: 5. Digital Logic (1) 6. Digital Logic (2) 7. Digital Logic (3)
Format	12 multiple choice (MC) questions	12 MC questions

Venue – Same arrangement for both quizzes:

Class	ENGG1100A	ENGG1100B
Location	3 Labs: • ENGG1100AL-01 – **ERB1103** • ENGG1100AL-02 – **SHB114** • ENGG1100AL-03 – **SHB102**	**Lecture Theatre 5, Lee Shau Kee Building (LSK LT5)** • ENGG1100BL-01 • ENGG1100BL-02