Creative Engineering Design

Module 1: Design, Science, Engineering, Creativity

Centre for Product Design and Manufacturing
Indian Institute of Science, Bangalore, India

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Overall Goal of the course

This course provides a broad overview of the generic concepts of design, design thinking and design research, and within the backdrop of this understanding, focuses specifically on the processes and techniques for carrying out engineering design in a creative manner. The course should be useful for both undergraduate and postgraduate students of engineering and design.

Major References

- Wallace, K.M. IISc Lectures on Engineering Design, 2007
- Pahl, G, and Beitz, W. Engineering Design: A Systematic Approach, 3rd Ed., Springer, 2007
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- Ulrich, K., and Eppinger, S. Product Design and Development, 4th Edition, McGraw-Hill/Irwin, 2007
- Roozenburg, N.F.M., Eekels, J. Product Design, Fundamentals and Methods, Wiley, Chichester, 1995
- Cross, N. Engineering Design Methods: Strategies for Product Design (4th edition), John Wiley and Sons Ltd., Chichester, 2008
- Jones, J.C. Design Methods, 2nd Edition, John Wiley and Sons Ltd., Chichester, 1992
- Chakrabarti, A. (ed.). Engineering Design Synthesis: Understanding, Approaches and Tools, Springer, 2002
- Otto, K., and Wood, K. Product Design, Prentice Hall, 2000
- Terninko , J, Zusman, A, Zlotin, B. Systematic Innovation: An Introduction to TRIZ (Theory of Inventive Problem Solving) , CRC Press, 1998

Outline and Modules

Module	Topic	No of hrs
1	Introduction: design Thinking across domains, major elements of design thinking, definition of system, design, product design, engineering design, creativity, science, design science (research); Importance of design	**6**
2	Product life cycle, Structure of systematic product design process, Structure of systematic product development process, Importance of systematic design, , Case Study	**4**
3	Task Clarification1: overall process and steps, market study, user/habitat analysis using role play, observations and interaction with stakeholders	**4**
4	Task Clarification 2: Problem identification using requirement checklists, study of products and patents using Innovation Situation Questionnaire (ISQ), steps for collating data from multiple sources into a stakeholder requirement list, translating stakeholder requirements into technical requirements, assigning importance to requirements	**4**
5	Task Clarification 3: Problem definition to develop solution neutral problem statements, problem analysis to develop input-output transformation, case study	**4**
6	Introduction to conceptual design: Identification of functions, Ideation, Consolidation into solution proposals (Concepts), and their systematic evaluation for selection of the most promising concept. Details of function structure generation and brainstorming	**4**
7	Conceptual design 2: Details of Synectics method, Trigger Word technique, Checklist method, Examples	**4**
8	Conceptual design 3: Consolidation of ideas into concepts, e.g. with Morphological charts. Use of TRIZ Contradiction or ideality to identify and resolve issues with concepts	**4**
9	Conceptual design 4: Methods for simulation: analytical, virtual and physical simulations, for evaluation or improvement.	**4**
10	Comparative evaluation and selection of concepts: ordinal and cardinal methods	**4**
	TOTAL	**42**

Overview of Module 1

- Why design is important
- Examples from Art, Architecture and Engineering
- Some of the common elements in design and designing
- What design and designing mean
- Science
- Design in the context of Society, Business, Technology
- Innovation, Product Development and Design
- Design creativity and how it can be supported
- What creative engineering design means

Genesis Space Probe

Launched
August 2001

Collect particles
from solar wind

1.6 million km
from Earth

Supposed to launch a
parachute upon re-entry
into Earth's atmosphere

Image Credit: http://www.jpl.nasa.gov/releases/2002/release_2002_119.html

Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008

8 September 2004

Image credit: http://en.wikipedia.org/wiki/File:Genesis_Capsule.JPG

Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008


Oops!
Image Credit: http://www.donnunn.com/spiel/2004/09/genesis_capsule.html
Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008
8

Error

“Back to front switches blamed for space probe crash”

Cost: $250 million

“… the most likely reason for the accident was that engineers assembling the Genesis probe more than four years ago had been misled by faulty designs …”

Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008

Story of the 'Genesis' Probe

"Two years after NASA's Genesis probe failed to deploy her parachute upon re-entry into the Earth's atmosphere, investigators have found the culprit behind the crash: A design flaw resulted in the backwards installation of two critical sensors. Genesis was doomed from the start.

To preserve the delicate samples of solar wind, Genesis would not land on the ground. Instead, a helicopter crew would swoop in and pluck the probe out of the sky by her parachute. But the parachute never deployed, and the Genesis tumbled past the waiting helicopter. The craft slammed into the Great Salt Lake Desert, 85 miles southwest of Salt Lake City, just before 10 a.m. on September 8, 2004."

http://www.popularmechanics.com/science/3045681

Story of the 'Genesis' Probe...

"...the root cause of the crash was an error in the craft's original design. In their design of the probe, subcontractor Lockheed Martin inverted the two accelerometers that were supposed to trigger parachute deployment. "They installed [the sensors] the way the designs said," Genesis project manager Donald Sweetnam says. "But they were backwards." Investigators had suspected that this was the cause since as early as October, 2004.

Because of the error, the sensors never recorded the craft's deceleration, an event that would have signaled that the craft had entered Earth's atmosphere. "The capsule just came in hot and impacted on the ground without anything deploying," says Sweetnam. "It was essentially like a baseball falling from 100 kilometers altitude."

http://www.popularmechanics.com/science/3045681

Story of the ‘Genesis’ Probe...

Design is Important!

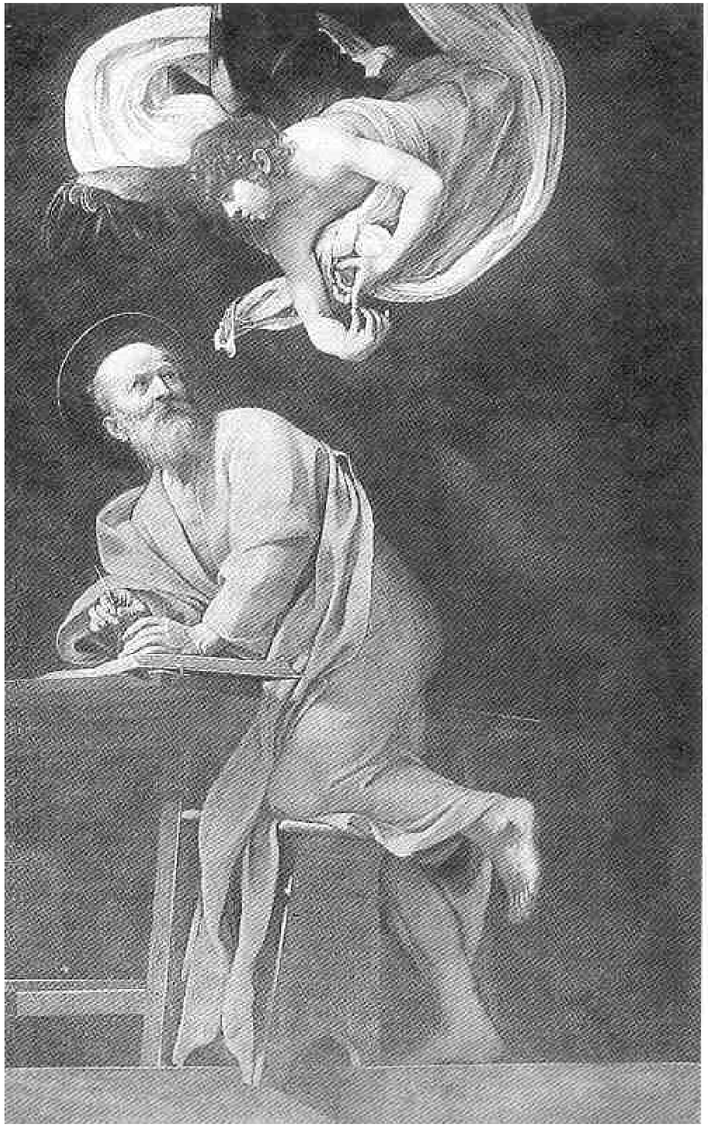
Examples from Art: St. Matthew I

Image Credit: Gombrich, EH: The Story of Art, Phaidon, Oxford, 1989

- Carvaggio, Italian Artist in 15-16 C
- Painting a picture of St Matthew
- For the altar of a church in Rome
- The saint depicted writing the Gospel
- An angel inspiring his writing
- To represent Gospel as the word of God
- Painted St Matthew as bald, bare, dusty
- Awkwardly gripping the huge volume
- Anxiously wrinkling his brow
- Angel holding his hand to help write
- Scandalised Rome, painting rejected!

- Why did he paint this way?

Examples from Art: St. Matthew II



- Painted differently now
- St Matthew as how saints ‘should’ look
- Angel as how angels ‘should’ look
- This time it was accepted

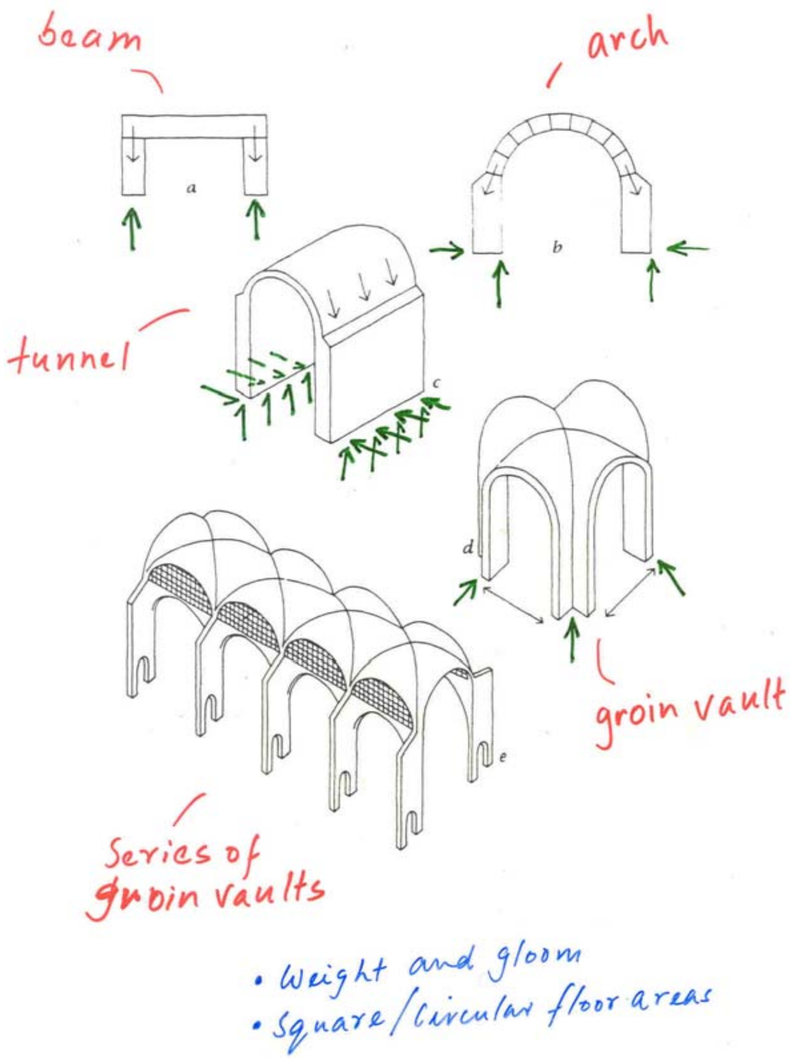
- Notice the goals
- Some more important than others
- Multiple alternatives
- Some are better than others (which one?)

Image Credit: Gombrich, EH: The Story of Art, Phaidon, Oxford, 1989

Examples from Architecture: Greek

The Parthenon, Athens, Acropolis, Designed by Iktinos, about 450 BC (Image Credit: Gombrich, 1989)

Examples from Architecture: Roman



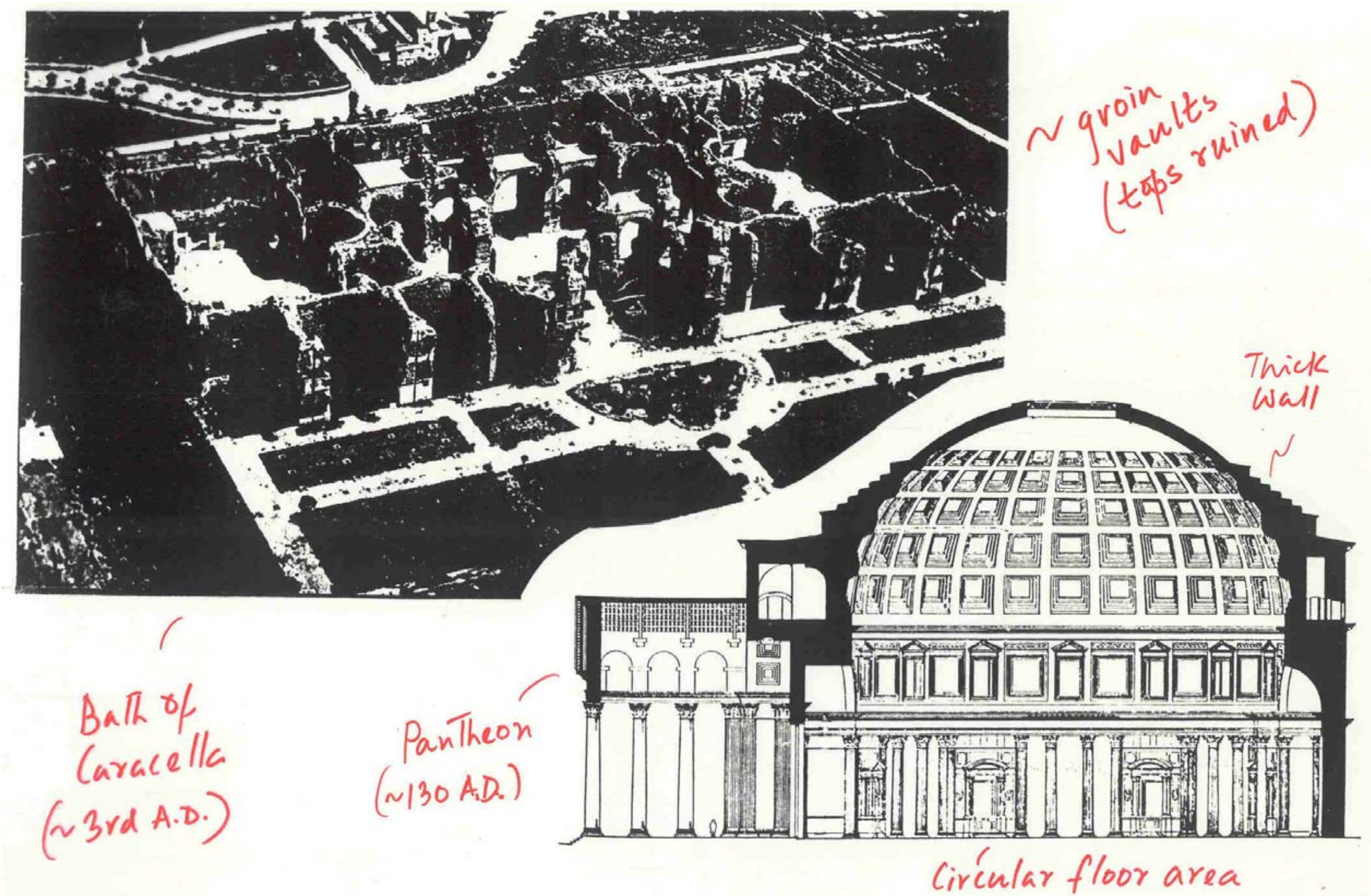
- Need always existed for covering spaces
- With light and air

- One of the first ideas was beams (Greece)
- Stone beams had limited span (and look)
- Romans invented Arches (compression)
- Combined serially into tunnels (pathways)
- Combined radially into halls (theatres)
- Crossed them into vaults (multi-entrance)
- Combined to cover large spaces

- But heavy and gloomy (why both?)
- Only square or circular floor blocks

Examples from Architecture: Roman

(Image Credit: Gombrich, 1989)

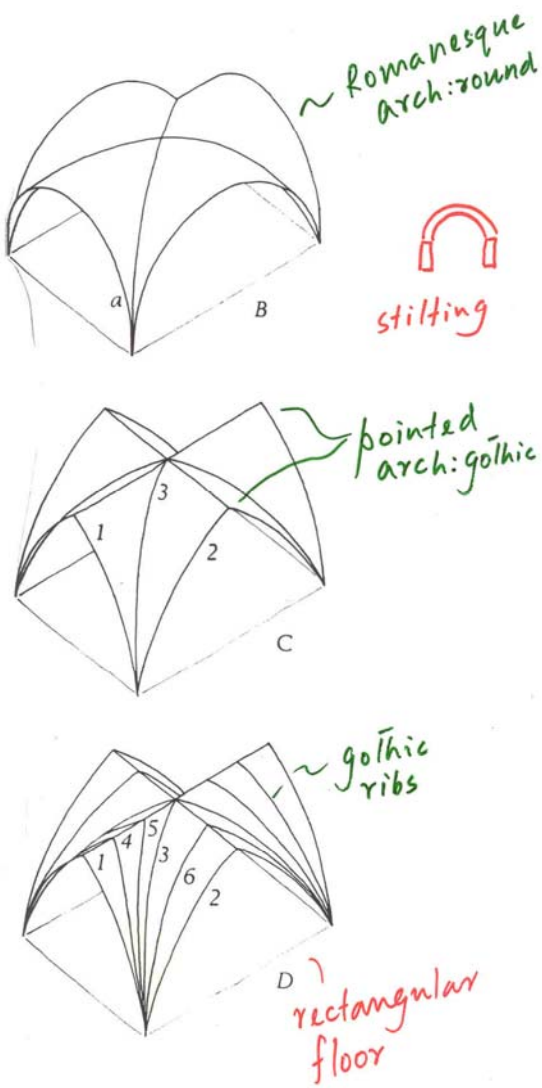


Examples from Architecture

- Interior of Pantheon in Rome
- built around 130 AD
- Painting by eighteenth C painter G.P. Pannini
- Washington National Gallery of Art

Image Credit: Gombrich, 1989

Examples from Architecture: Gothic

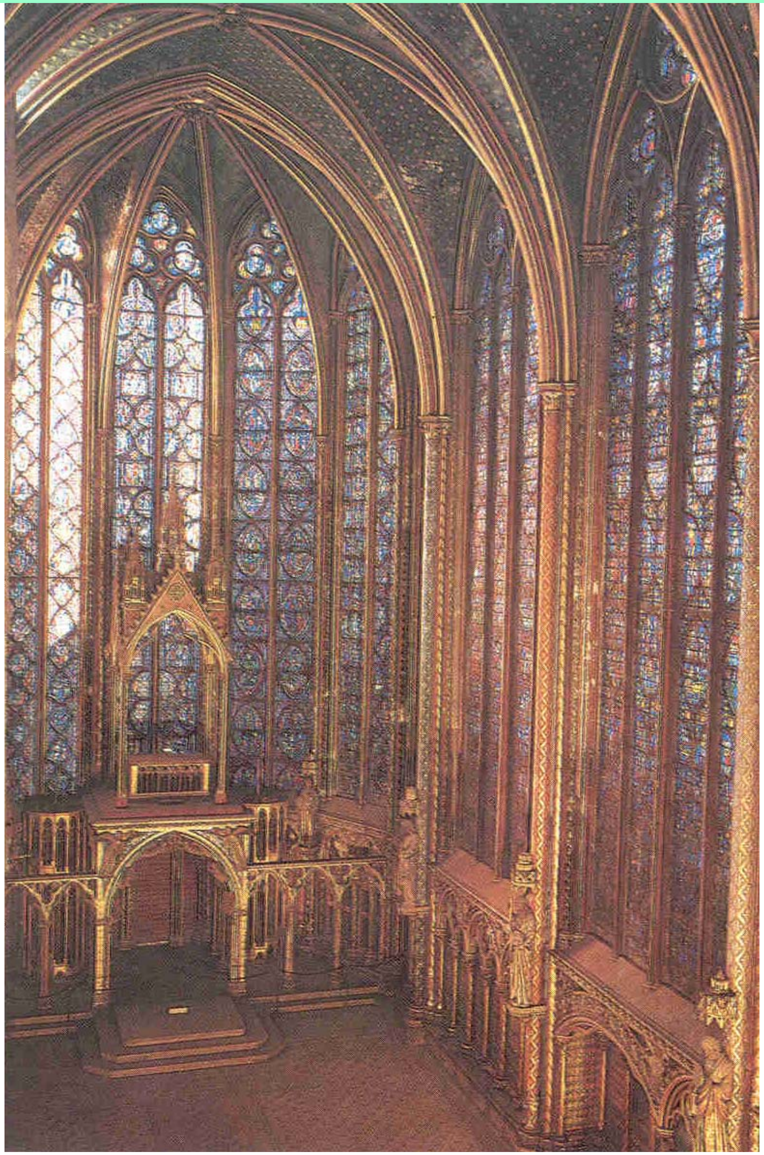


- Romanesque arches heavy to take load
- Very little light due to small windows
- Limited shapes of the doors and ceilings

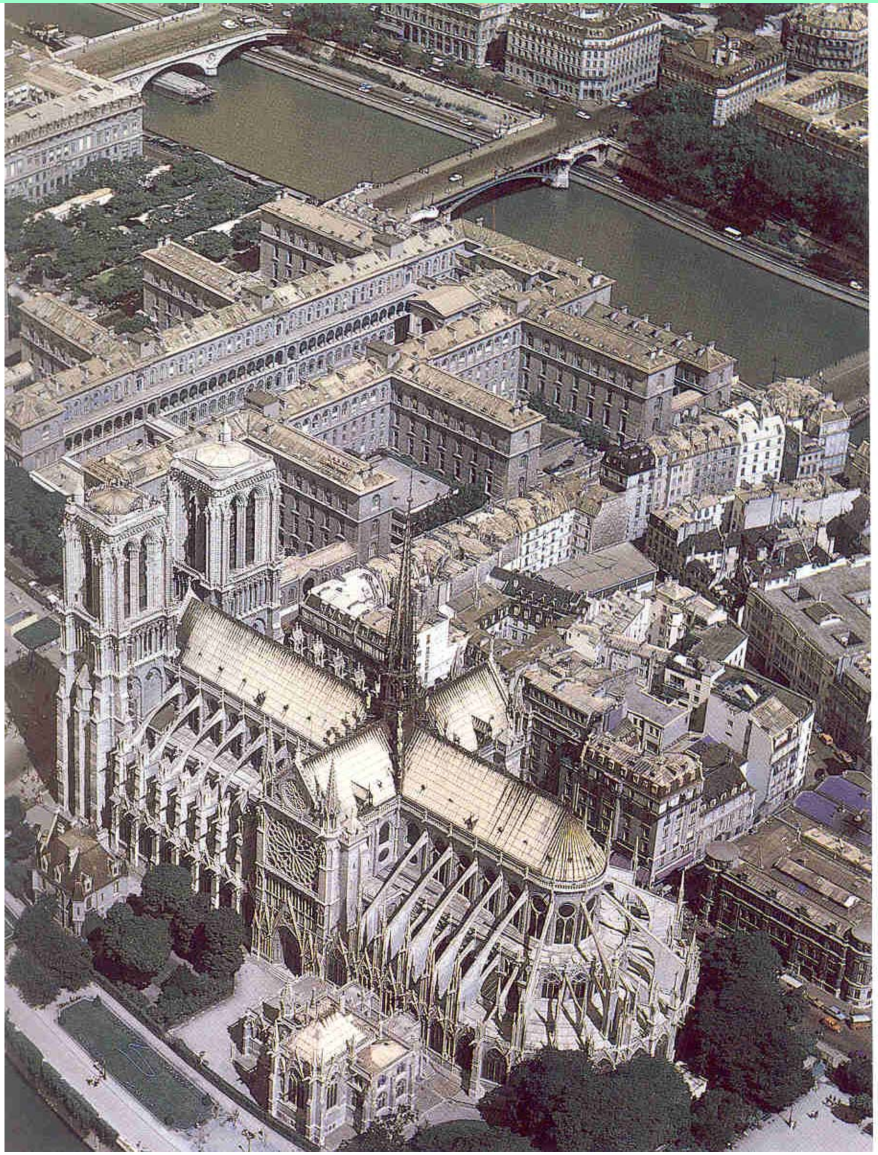
- Localised load bearing pillars (buttresses)
- Walls then did not need the feeling
- Can be filled with glasses (light!)
- Pointed arches (less load sideways!)
- Flying buttresses (support side-load better)

- Notice the goals
- Some more important than others
- Multiple alternatives
- Some are better than others

Examples from Architecture: Gothic

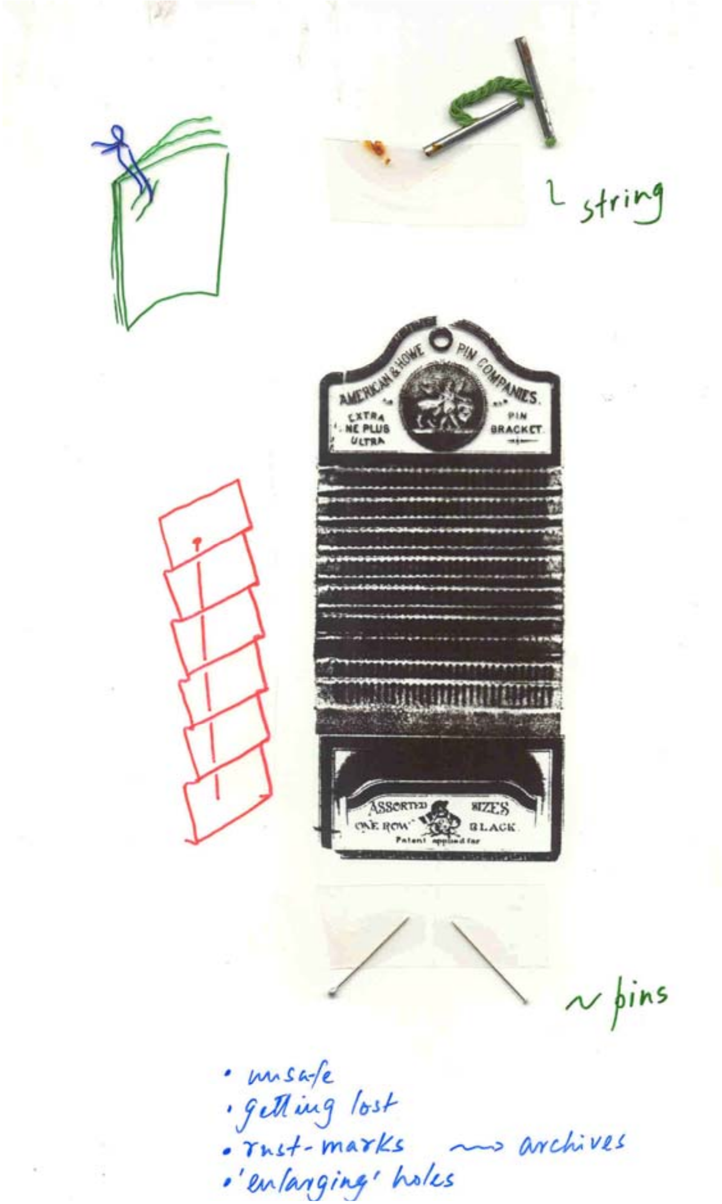


Sainte-Chapelle, Paris (Image Credit: Gombrich, 1989)



Notre-Dame, Paris (Image Credit: Gombrich, 1989)

Examples from Engineering



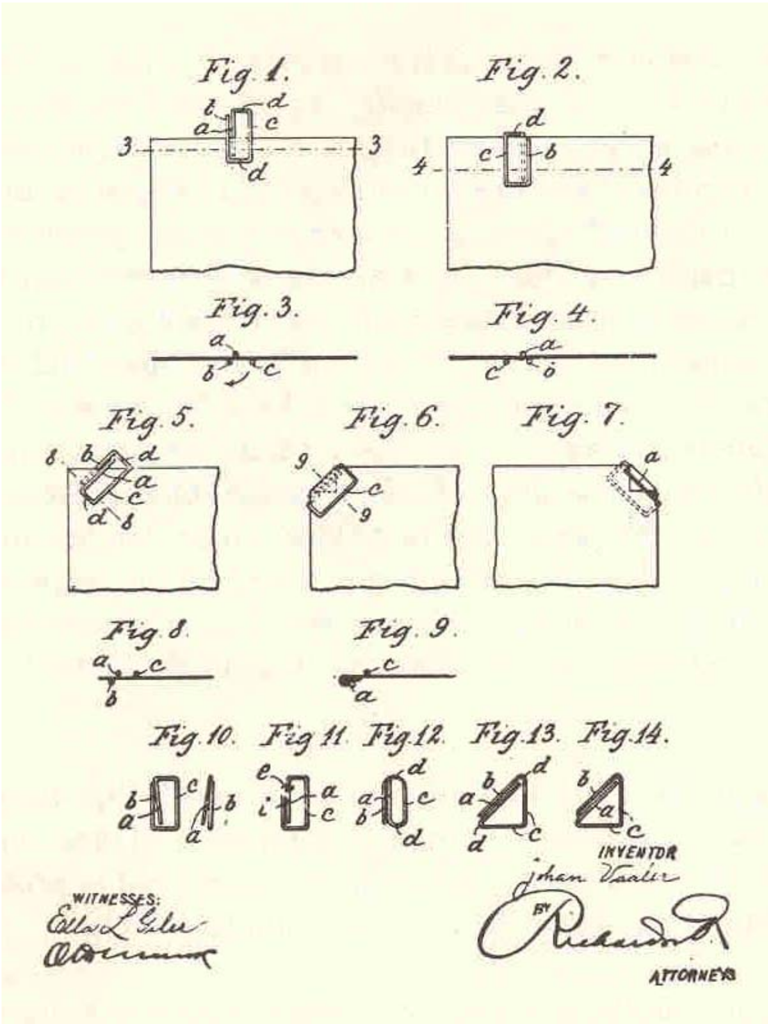
- Holding a bunch of papers together

- Early ones are holes with strings
- Damages the paper
- Difficult to string together

- Pins with pointed end to pierce
- Round head to prevent coming out easily
- But unsafe
- Get lost, rusted, enlarge holes with time

Image Credit: Petroski, H. The Evolution of Useful Things, Vintage, 1994

Examples from Engg: Vaaler's Clip

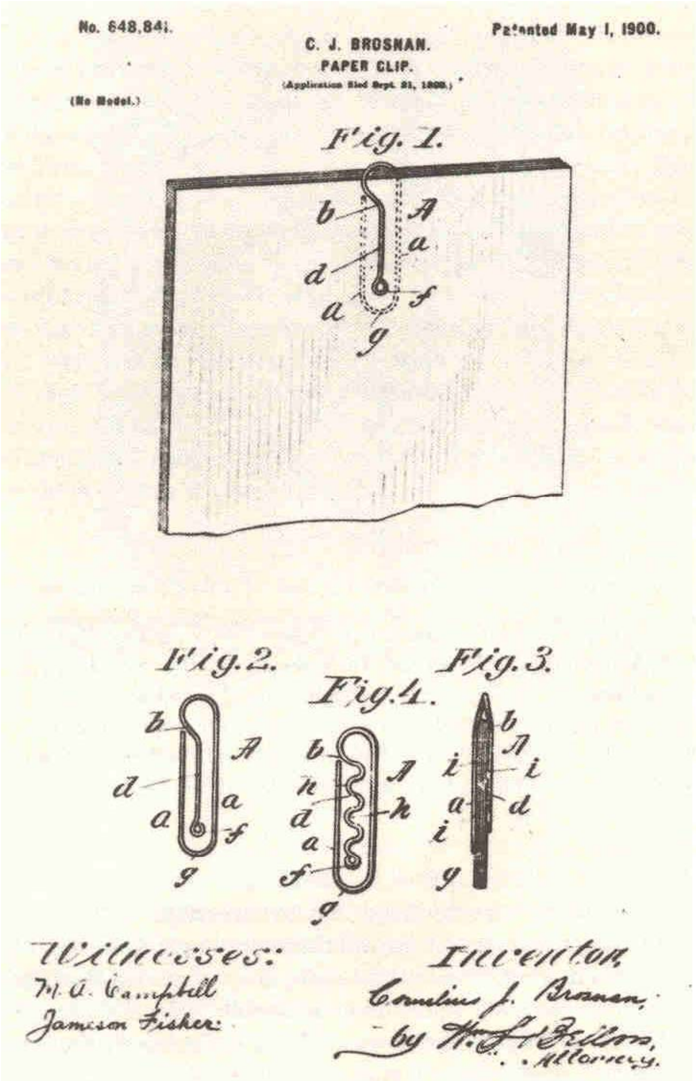


- Norwegian Johan Vaaler's first American patent dated June 4, 1901
- The first patent on paper clip
- The version labelled Figure 12 suggests the beginnings of what will become known as Gem paper clip
- Papers are to be held together by the 'arms' of the clip

- Clips do not 'hang' together
- Lie flat on paper without bending them
- But sharp end scratch or tear papers held

Image Credit: Petroski, 1994

Examples from Engineering: Konaclip



- Cornelius Brosnan's American patent in 1900: 'Konaclip'
- Regarded as the inventor of the first 'successful' bent wire paper clip
- Constructed from a single length of wire
- Bent to form an elongated frame
- With an end portion forming an eye for insertion without scratching the paper

- Papers may not get damaged using this
- Clips do 'hang' together
- Papers do slip out of the clip!

Image Credit: Petroski, 1994

Examples from Engg: Gem Clips

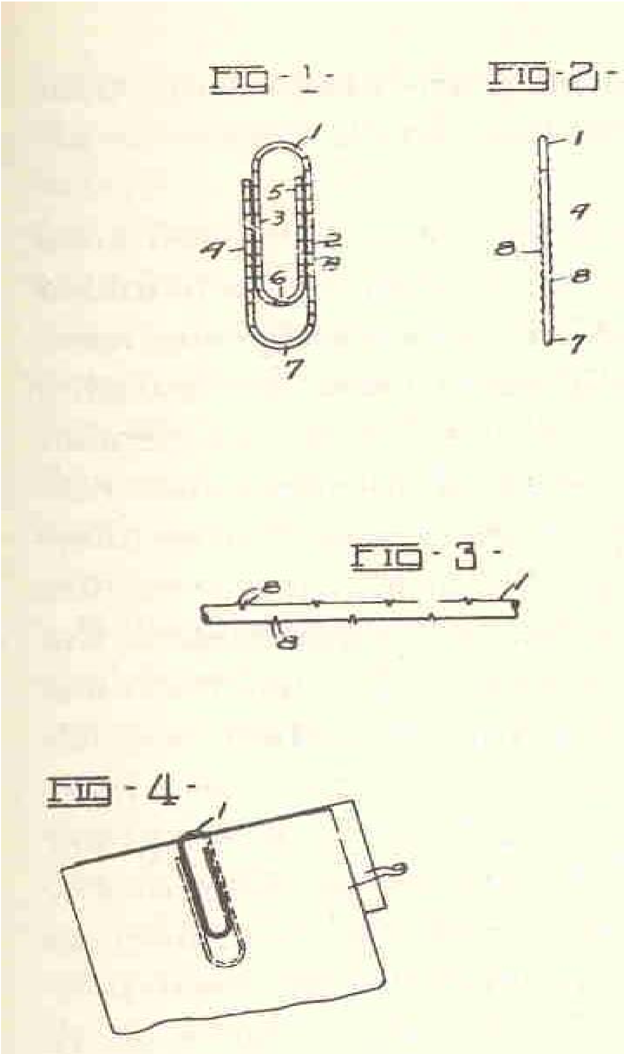


Image Credit: Petroski, 1994

- Initial ‘Gem’ paper clips had the same shape as the one shown here

- Gave non-scratch entry onto the papers
- Papers still slipped out; entry was difficult

- This variant shown is patented by American Clarence Collette in 1921
- With sharply pointed projections
- For keeping papers together

- Papers get damaged using this
- Papers do not slip out, but entry still difficult

Examples from Engg: Gothic clips

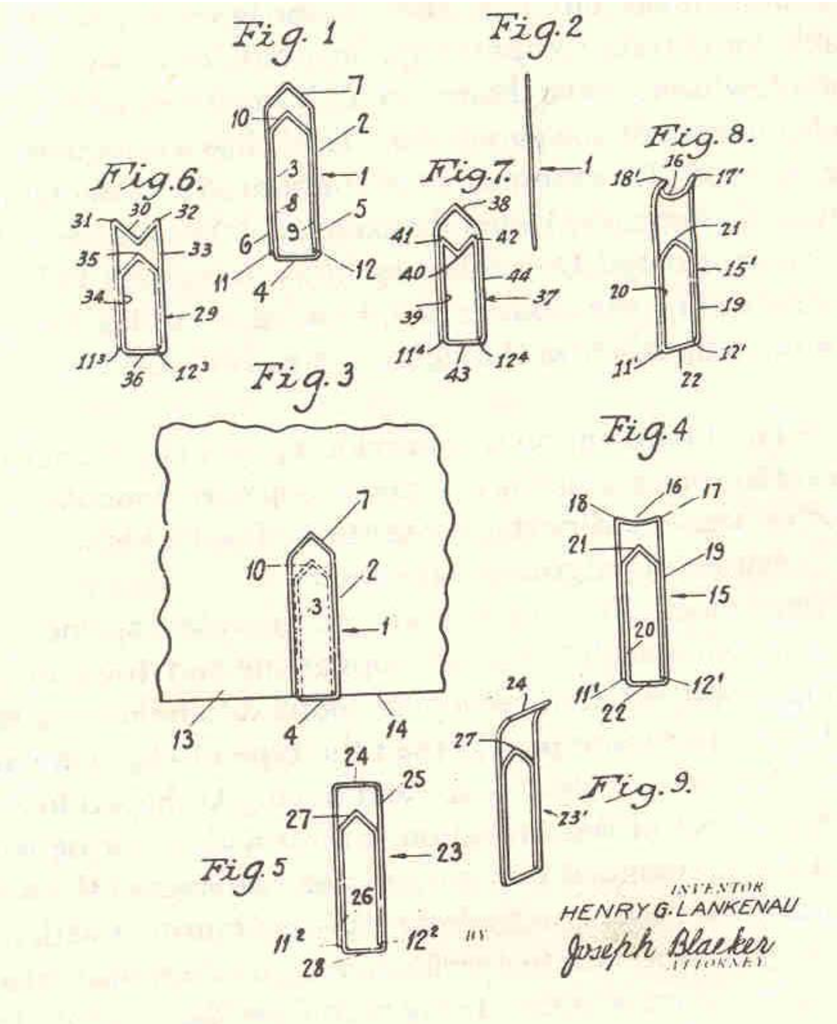


Image Credit: Petroski, 1994

- Henry Lankenau of Verona, New Jersey patented this ‘Gothic clip’ in 1934
- V-shape claimed to provide wedge action
- Slight protrusion at the v-end provides better entry onto the paper pile

- Gave non-scratch entry onto the papers
- Papers still slipped out
- Entry was easy

- Notice the goals
- Some are more important than others
- Multiple alternatives
- Some are better than others (in some respect)

All of these have been designed!

- All designs have multiple goals (they invent **new** reality)
- Usually some are more important than others
- Usually many alternative proposals of how to attain the goals
- Some are usually better than the others (in some aspects)

Design(Noun)

- Blue print of something – a plan for change
- Undesirable situation (current) + Implemented plan→ Desirable situation (future)
- Whether a situation is undesirable and what aspects are desirable: matters of perception
  - Whose perception plays an important role
    - The same car may be stylish to one and boring to another
    - One may find it “cheap”, another may find it “expensive”
  - Where it is perceived plays an important role
    - Ambassador car popular in parts of India (with bad roads) due to stability
    - In other parts, it is considered too heavy, slow, inefficient…
  - When it is perceived plays an important role
    - The same car that was stylish become boring with time for the same person

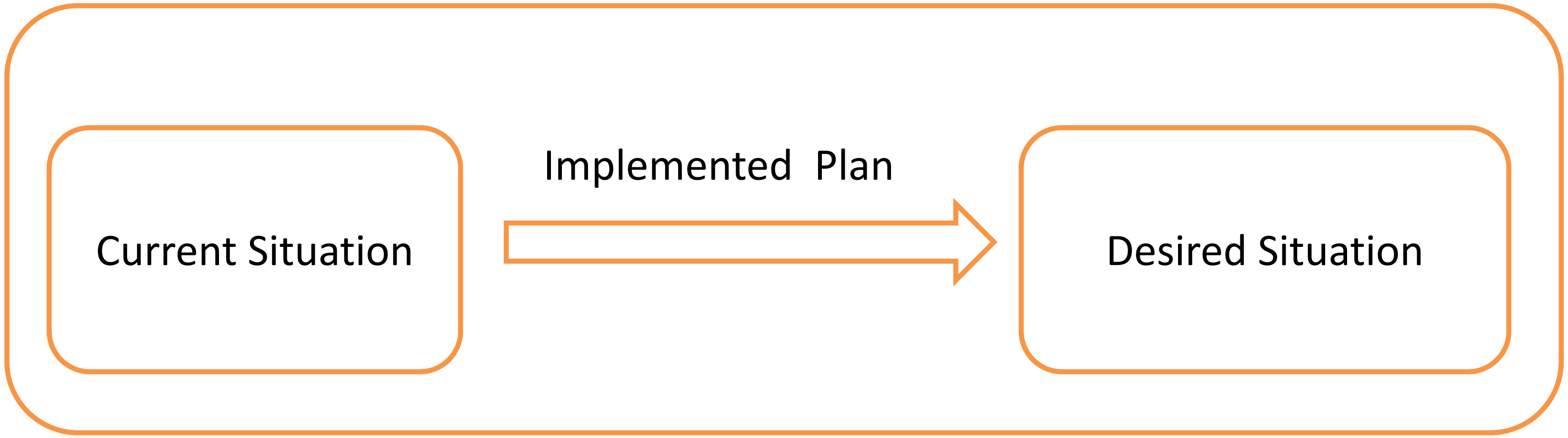
Design(verb)

- Understanding & solving a problem: termed *Designing*
  - Problem understanding: Process or activities for identifying undesirable situations and desirable situations
  - Problem solving: Developing a plan with the intent of changing undesirable situations to desirable situations

Henceforth called Designing

- Involves both problem understanding & problem solving
- Planning is different from designing
- Designing becomes easier when problem is understood

Improving situations with design



EXAMPLE 1: Cooking

Image credit: A Selection of Indian Home-Cooked Foods by Pallavi Damera
(http://www.flickr.com/photos/pallavi_damera/2536005489/)

- undesirable situation –food tasteless
- plan – add adequate salt
- implementation – salt added
- desirable situation – tasty food

EXAMPLE 2: Cycling

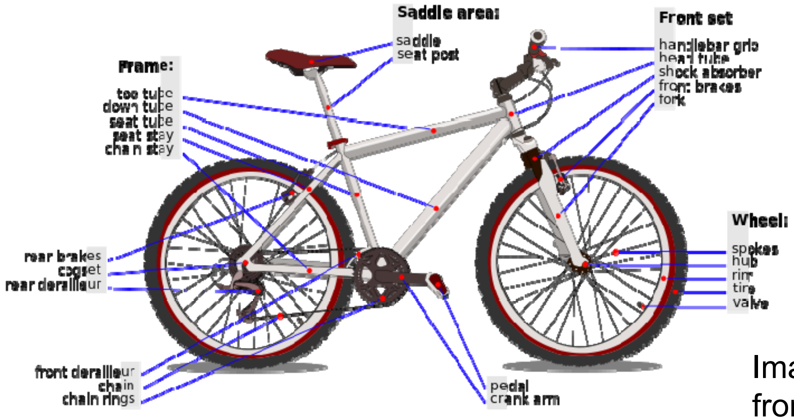


Image credit: Bicycle diagram-en (edit).svg
from wikipedia the free encyclopedia

- undesirable situation – time and effort large in cycling to reach destination
- plan – to check and replenish air in tyres
- implementation – check and replenish air
- desirable situation – reached destination in shorter time with less effort

EXAMPLE 3: Electric Sockets

Image Credit: Electrical socket covers ·
BabyDan Twisting Plug **Socket Cover** safetots.co.uk

- undesirable situation – open sockets accessible to children, unsafe
- plan – to cover sockets
- implementation – make and use socket cover
- desirable situation – socket covered, safe

What is Design?

- Meaning as noun: a design
  - A plan for change from existing to a desired situation
  - An engineering drawing, CAD model, flow chart etc.
  - For Change: includes things, agents, how to install & use
  - Plan for a chair to improve comfort, note taking, ingress…
- Meaning as verb: the act of designing
  - Processes through which designs are developed
  - Constructing the change needed (Problem understanding)
    - Existing and desired situations
    - e.g. current pens do not write smoothly, for long enough
  - Constructing the plan for the change (Problem solving)
    - e.g. not just pen, but how the pen will be made, used, reused etc.
    - Plan for the lifecycle effecting the change

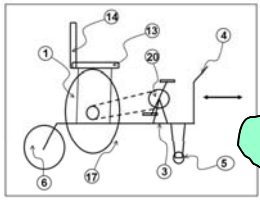
What is design?

Goal

Undesired Situation → Desired Situation

Implemented and utilized as intended

- Village women walk to water source
- Large distance away from home
- Carry clothes which become heavier
- Also carry water back
- For safety go in groups
- Roads to water source bad
- Washing is effort and time consuming



Plan

- Women cycle to water source
- Carry clothes on cycle
- Also washing machine
- Pedal cycle to power washing
- Less effort, faster washing
- Less effort, faster to water source

- Design: **Plan** of a system, its implementation and utilisation for attaining a goal: change undesired to desired
- Designing: **How** a design is developed: **both goal and plan**
- Designs can be for: technical systems (power plant), educational systems (Montessori Method), aesthetic systems (logo designs, advertisements), legal systems, social, religious or cultural systems, theories, Models, etc.

Essential Features of Design

- Design: Intentional constructions; **Plans for achieving goals**
- Designing: goal-oriented process: **how** designs are developed

- Initially: Predominantly only **goals** are known
- Finally: Both goals and **plans** are known and more clearly

- Co-evolution: **both** goals and plans evolve together, one influencing the other

- Multiple goals: some goals are more **important** than others
- Multiple plans: some plans are **better** than others

- But: Designing does **NOT** guarantee that designs will work: some designing may be better than others in achieving goals

How can we develop ‘good’ designs?

- Multiple goals: some goals are more important than others
- Multiple plans: some plans are better than others

- How to identify the goals?
- How to assess how important these goals are?

- How to a generate possible alternative plans?
- How to modify better plans based on this knowledge?

- How to assess which ones are better?

Design Thinking Process

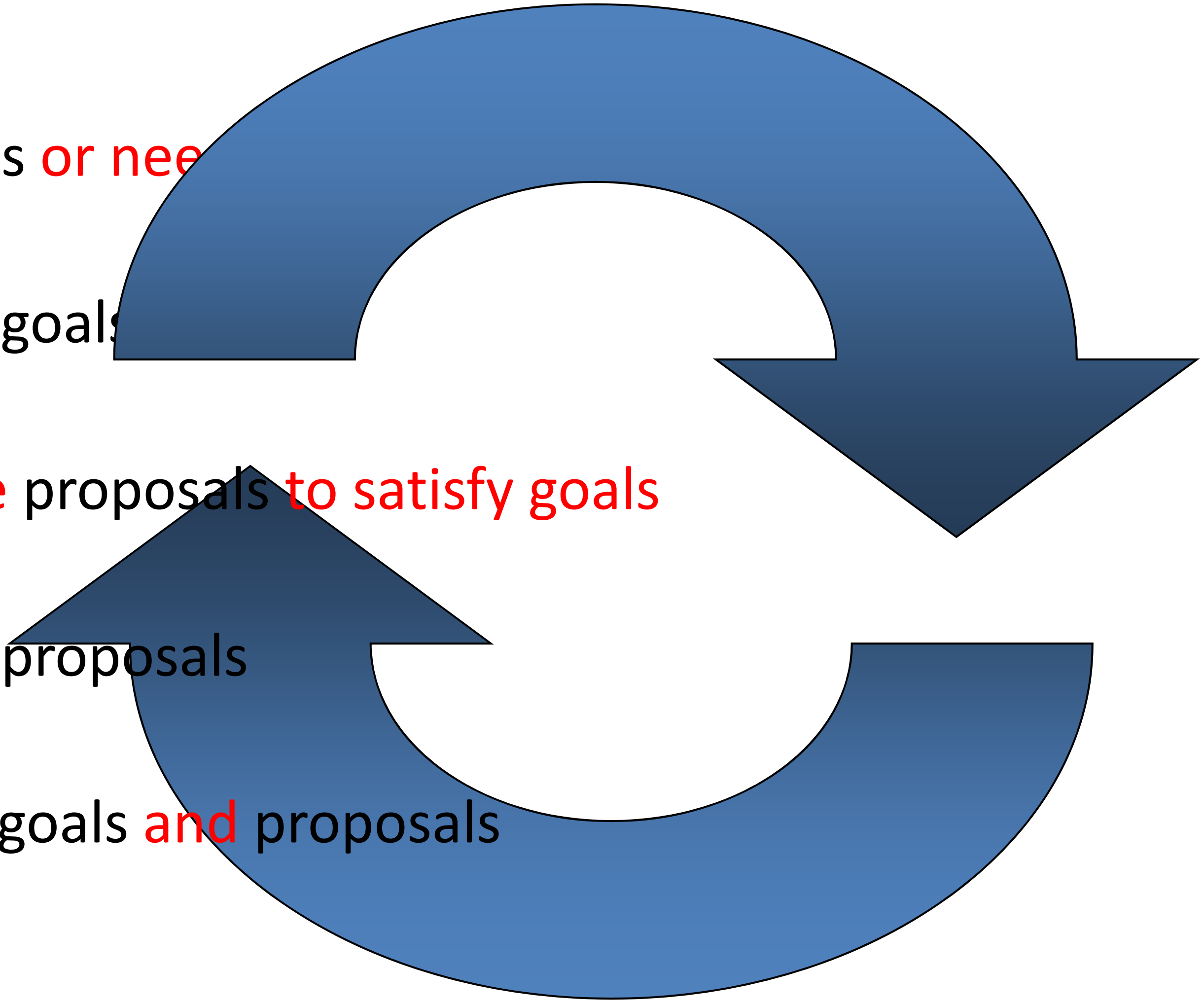
Find goals or nee

Evaluate goal

Generate proposals to satisfy goals

Evaluate proposals

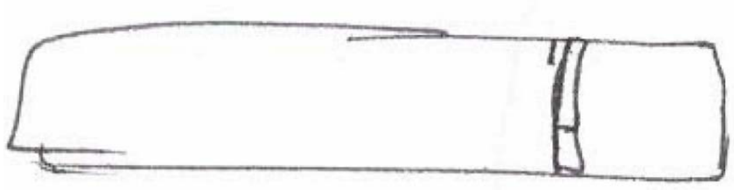
Improve goals and proposals



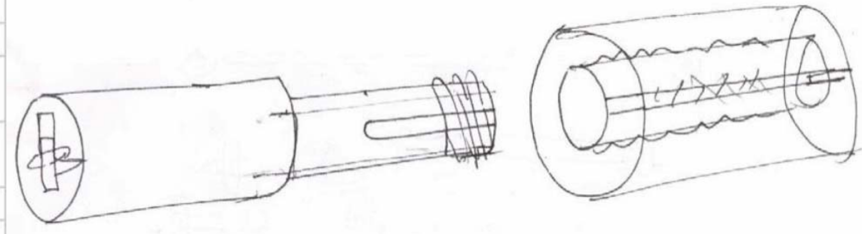
Evolution of Engineering Designs

6.32	S1	First the problem is that executives requires exercises
6.45	S1	and why they require we don't know
6.48	S1	and because they are busy
6.57	S1	and they are reluctant to spend money to buy expensive gym equipment for personal use
7.01	S1	so they are miser
7.04	S1	miser, do not want to spend money for equipment
7.17	S1	which means that the assumption is they know that they have to do some exercise but they are not doing
7.23	S1	and they think that gymnasium equipment is very expensive and I don't need to buy
7.3	S1	because they are quite expensive probably
7.34	S1	well there are some personal use equipment available but they are expensive, ok
7.4	S1	this is a fact
7.44	S1	privacy is not there in gymasium
7.52	S1	privacy is not there means lot of people are feeling, feeling what
8.03	S1	feeling shy of going there, body building exercise probably
8.09	S1	why they don't do exercise wearing the full dress (smile) strange
8.15	S1	current equipment occupies lot of space ok
8.28	S1	and usually are not portable
8.34	S1	these are problems with current equipment
8.39	S1	so the requirements are external requirements, some are constratints
8.46	S1	apart from the solution of the problem, requirements are that
8.52	S1	it should be easily setupable
9.07	S1	it should be setup easily and portable
9.12	S1	and should help in complete workout of the body
9.27	S1	ya
9.29	S1	first of all the thing is that whether we really achieving that

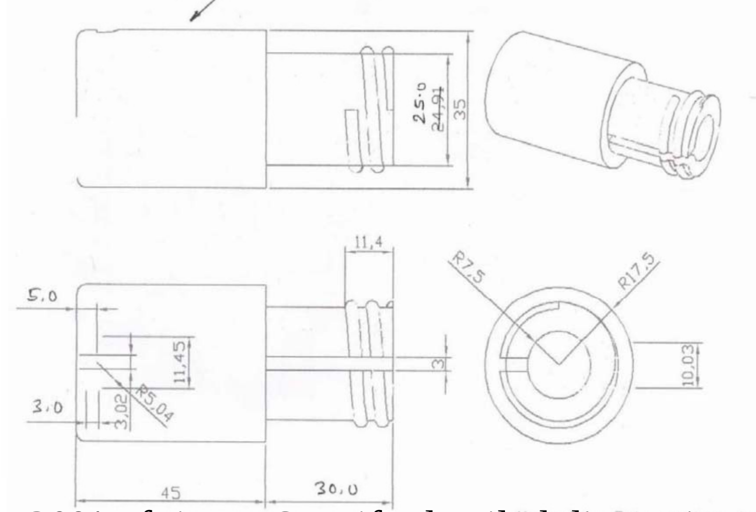
First 20% of time: understand the problem and identify the constraints



Next 30% of time: Specify ideas, spatial layouts and sub-assemblies of the design



Next 20% of time: Specify the interface details in the sub-assemblies



Next 30% of time: Specify detailed dimensions, materials and manufacturing tolerances

What is Science (i.e. Research) ?

- Process of creating new, purposeful, generic and valid knowledge: Systematic study of phenomena of interest
- To develop knowledge: Outcome of research is knowledge
  - Purposeful: improves (understanding of) phenomena
  - New: not before (different from existing knowledge)
  - Generic: applies to multiple things, cases, people…, high reuse value
  - Valid: Has some sense of truth; can be demonstrated to be true/false (observable and falsifiable)

What is Physics?

- Systematic study of physical phenomena
- Develop knowledge
  - Purposeful: Describes/explains/predicts physical system behaviour
    - How objects with mass behave – Newtonian Mechanics
    - How heat flows from one object to another – Thermodynamics
  - New: Not before
    - P=m.f could predict quantitative values of f due to P applied
    - 1st law of thermodynamics: law of conservation of (heat and work) energy
  - Generic: Applies to multiple things, cases, people…
    - Applied to all systems with inertia
    - Applied for all types of heat flow, for all kinds of systems
  - Valid: Has some sense of truth
    - Prediction matched observation (within acceptable limit)

What is Biology?

- Systematic study of biological phenomena
- Develop knowledge
  - Purposeful: Describes/explains/predicts biological system behaviour
    - How living systems evolve – Darwinian Theory of Evolution
    - How e.g. signals flow from one neuron to another – Neuroscience
  - New: Not before
    - Theory of evolution explained qualitatively how species evolved
    - Neuroscience could explain some aspects of the working of the brain
  - Generic: Applies to multiple things, cases, people…
    - Applied to all living species
    - Applied for all human brains or nerves
  - Valid: Has some sense of truth
    - Explanation matched observation (within acceptable limit)

What is Design Research (Science)?

Two different views of Design research –

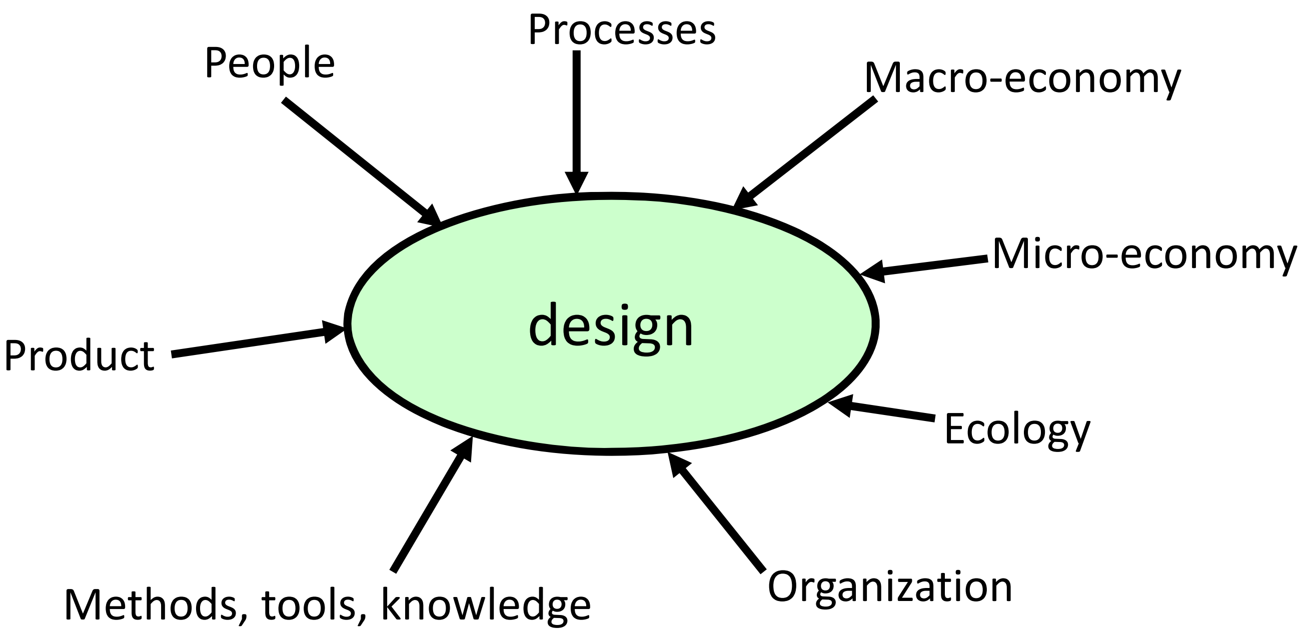
1. User research: NOT focus of Design Science
   – User study during the initial phase in a design project
      - Who is the user?
      - How many users?
      - What does user want?
      - How much can they pay?...

2. Research into design (Science of design): Focus

What is Design Research?

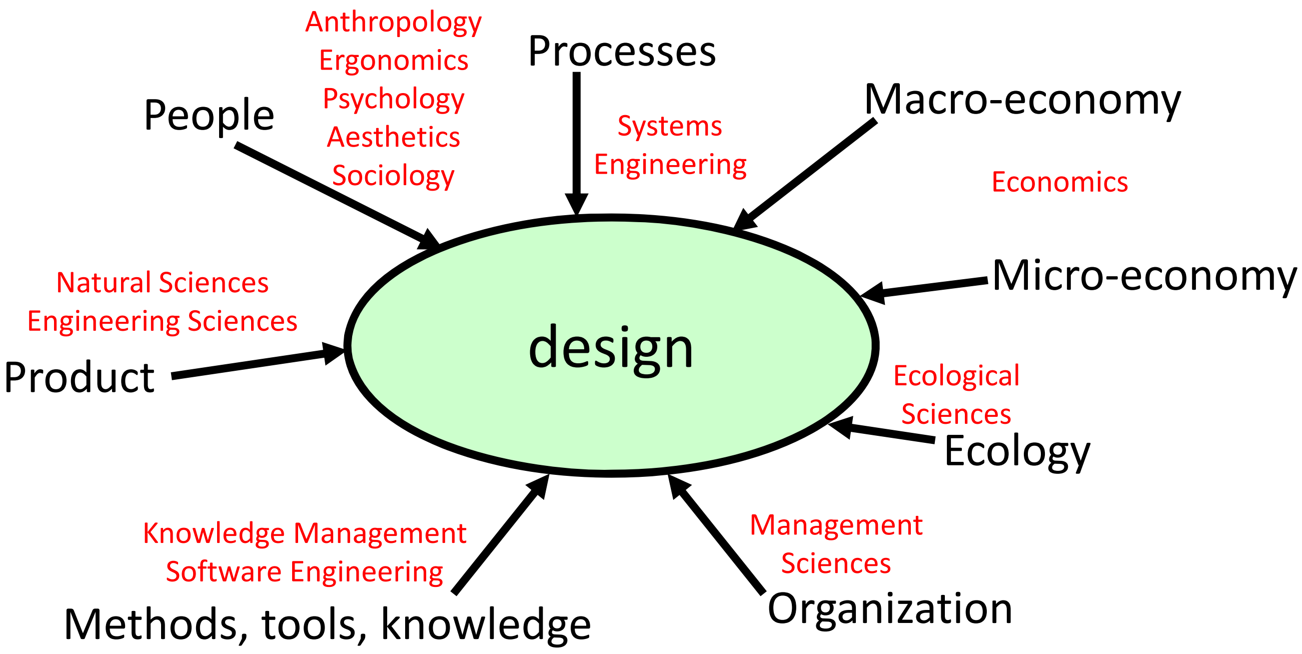
- Systematic study of design phenomena (i.e. phenomena associated with design)
- Develop knowledge
  - Purposeful: Describes/explains/predicts design system behaviour
    - What characterizes technical systems (TS) – e.g. Theory of TS (Hubka, 1984)
    - How design influences novelty of designs – Creativity research (Srinivasan & Chakrabarti, 2010)
  - New: Not before
    - What distinguishes technical systems from non-technical systems
    - E.g. level of abstraction of design outcomes influence design novelty
  - Generic: Applies to multiple things, cases, people…
    - Applies to all technical systems
    - Applied for all technical system designs at early stages of designing
  - Valid: Has some sense of truth
    - description/explanation matched observation (within acceptable limit)

Facets of Design



- Designing is planning for changing existing, undesired situations into preferred ones
- Influenced by people, product, process, tools, organization, economy and ecology
- Multi-disciplinary: uses knowledge from human, natural, engg., ecological, etc. sciences
- Develops necessary knowledge when knowledge is not available for designing

Design Research (DR)



- DR develops knowledge to inform and support practice and education of design
- Knowledge about design phenomena - phenomena associated with design
  - facets of design and their relationships to design
- Multi-disciplinary: research methods used, depending on which facets are explored
  - from human sciences: sociology, psychology, aesthetics, economics, management science
  - from natural, engineering or ecological sciences…
- Typically area of research will be a combination of facets
  - Research methods from the facet areas have to be combined, adapted

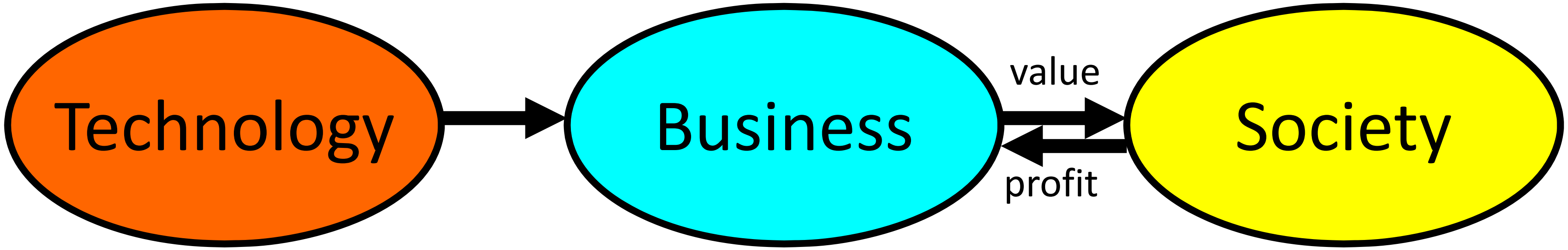
Design Research

- Develops knowledge in the form of
  - **Theories/models:** Theory of Technical Systems, Integrated Model of designing
  - **Guidelines:** Design for Manufacture and Assembly (Boothroyd-Dewhurst)
  - **Methods:** Weighted Objectives method for comparative evaluation
  - **Tools:** Sketchpad – a tool for sketching using GUI (Sutherland, 1963)
  - **Standards:** IDEF0 standards for representing processes
  - **Materials:** Ferromagnetic-composite material for light, conducting aircraft body
  - **Processes:** CNC processes for computer aided machining
  - **Technologies:** Graphical User Interfaces (GUI); micro-pressure-sensors…
- To help develop successful products by making designing
  - **More effective:** better products – novelty, quality, reliability…
  - **More efficient:** less resources – less time to market, iterations, cost…

Design Research

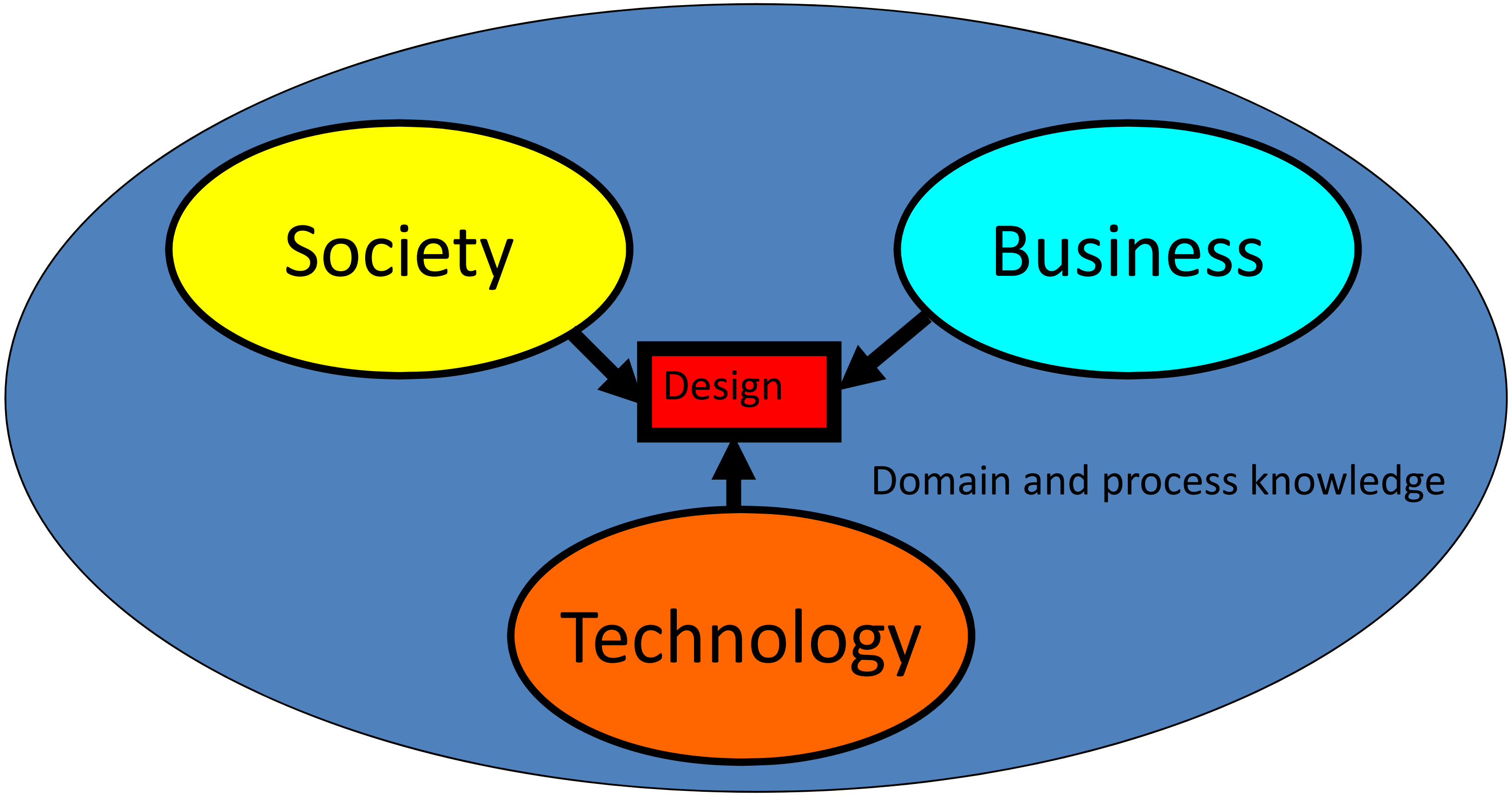
- Two kinds of outcomes
  - Theories providing understanding of the present
  - Support to help make designing better
- Focus different from sciences
  - Sciences: how (well) systems (products, people, organisations) work
  - Design research:
    - Theory: how (well) products are created/developed (taking into account whole lifecycle)
    - Support: how to create/develop better products (taking into account the whole lifecycle)
- "Product" used here to mean
  - Any system designed to change existing situations to preferred ones
  - Hardware, software, service systems, combinations…

Society, Business, Technology



- Value = Performance / Price
- Profit = Price – Cost
- **Profit = (Performance / Value) – Cost**
- Win-win: Both Society and Business win if **both Profit and Value increase**
- For this to happen: Performance must increase and/or Cost must decrease

...And Design



Design draws knowledge from Society, Business and Technology
Develops or integrates technology to provide value to society to fulfil its needs

Society: Value

- Damian Mycroft: Senior Design Manager, Nokia
- When walking through busy streets of India, I saw a boy trying to listen to his music on a mobile amidst loud noise; I asked "Why not make a louder mobile phone?"
  - New slim speakers in Nokia X6
- Must understand the needs of the user; need to **immerse** in the user context
- Need
  - domain knowledge: of user
  - Process knowledge: of how to find their needs
    - Focus groups
    - Innovation situation Questionnaire
    - **Immersion**

Image Credit:
http://archives.thestar.com.my/archives/2010/2/18/lifeliving/f_11damian.jpg

Design Values

Products must perform (function) and be:

Safe

Reliable

Economic

Sustainable

Ergonomic

Aesthetic

Drivers for New Products

MARKET PULL

- Performance → Clearer phones
- Cost → Cheaper motor cars
- Safety → Safer aircraft

TECHNOLOGY PUSH

- Materials → CFRP
- Processes → Micro-electronics
- Inventions → Nexus bicycle Hub

Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008

Derailleur Gears

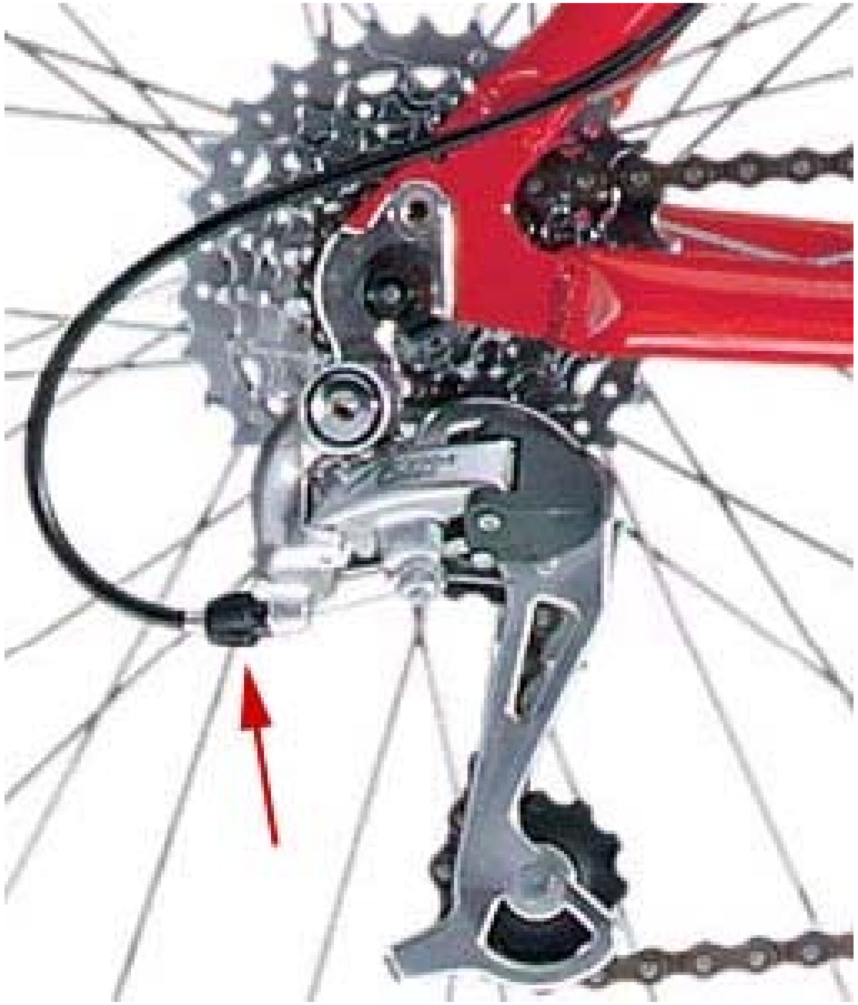


Image Credit: http://bikebarn.com/how-to/how-to-adjust-your-rear-derailleur-pg192.htm

Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008

Nexus Bicycle Hub

Image Credit: http://www.hubstripping.com/shimano-inter8/SG-8C20.jpg

8-Speed + Internal brake + gear shift when stationary

Nexus Bicycle Hub

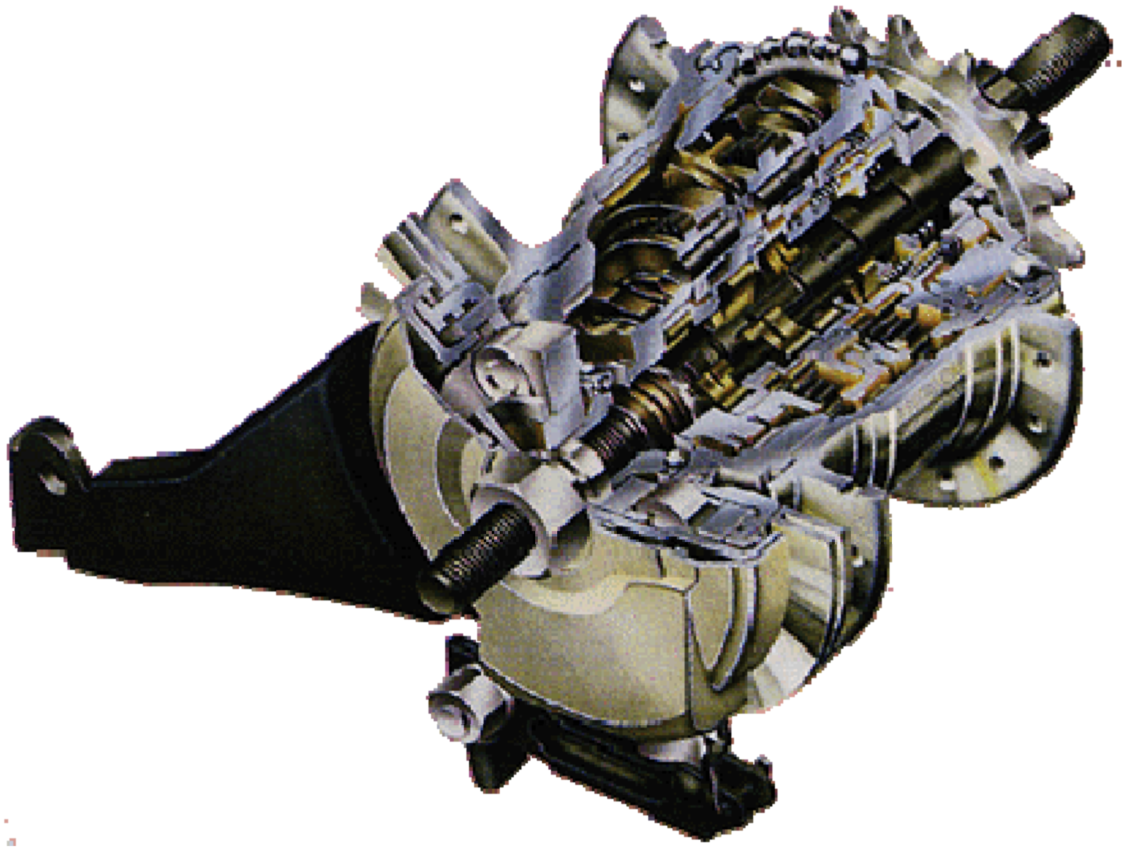


Image credit: https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcTqBdgzUoMN_HBQVgYeTlrbgffLFs-0us4iKEO-nbJymYj7837VAw

Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008

Increasing Concerns

Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008

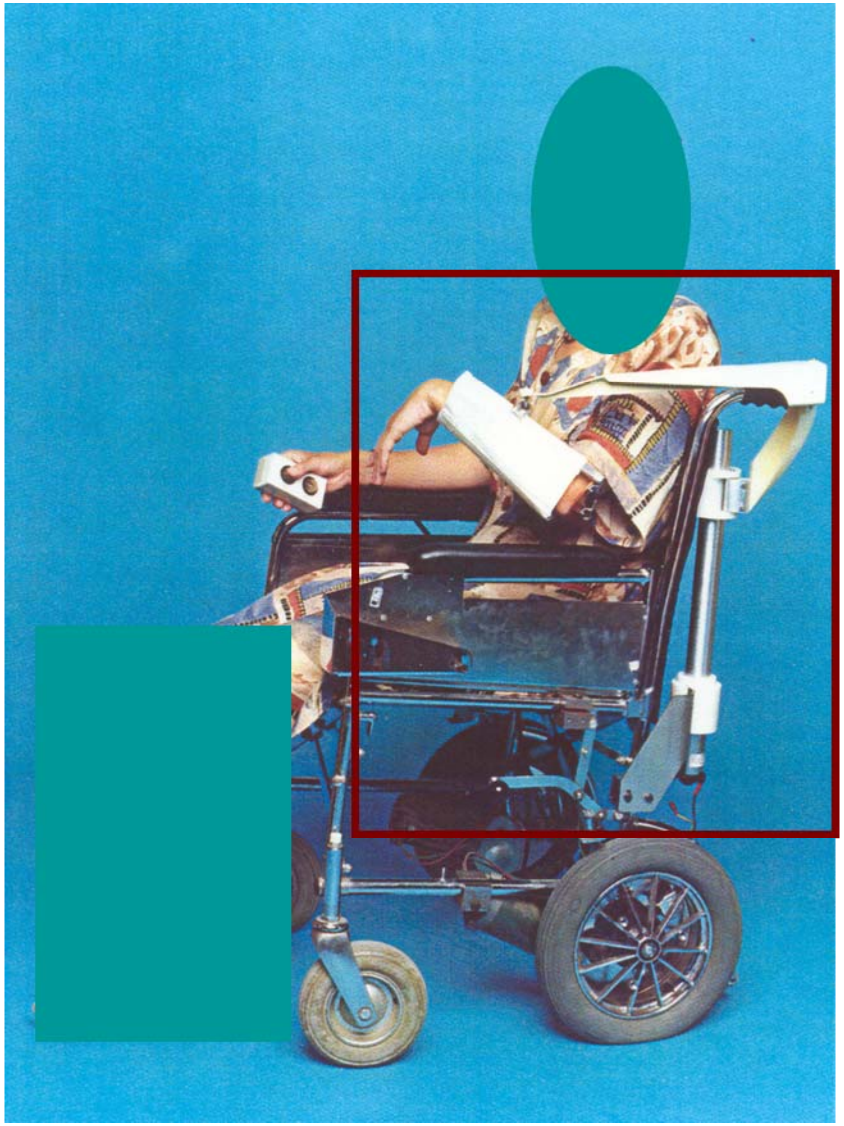
Slide credit: Kenneth M. Wallace, Lectures Series on Engineering Design, Indian Institute of Science, Bangalore, India, 2008

Business: Profit

- Mobile Arm Support
- Developed at CUED for people with Muscular Dystrophy
- Provides greater vertical arm mobility

- Provided performance
  - Users could now move their hand over keyboard in few seconds
  - Previously took five minutes
- But not at an affordable cost or price
  - Could not pay as typically unemployed
  - Finally needed government subsidy

- Need:
  - Domain knowledge of costs of the materials, manufg. And etc
  - Process knowledge of cost modelling
    - Life cycle costing
    - Concept costing
    - Cost to the environment



Technology: Feasibility

- Rolls Royce Trent turbine engine
- Prevent ice formation on turbine cone
- Damages blades

- Heat the cone
  - Expensive (-50 degrees c)
- ‘wiggle’ motor?
  - Low cost
- Cone made of flexible materials
  - Wiggles from engine vibration
  - No energy needed: even lower cost

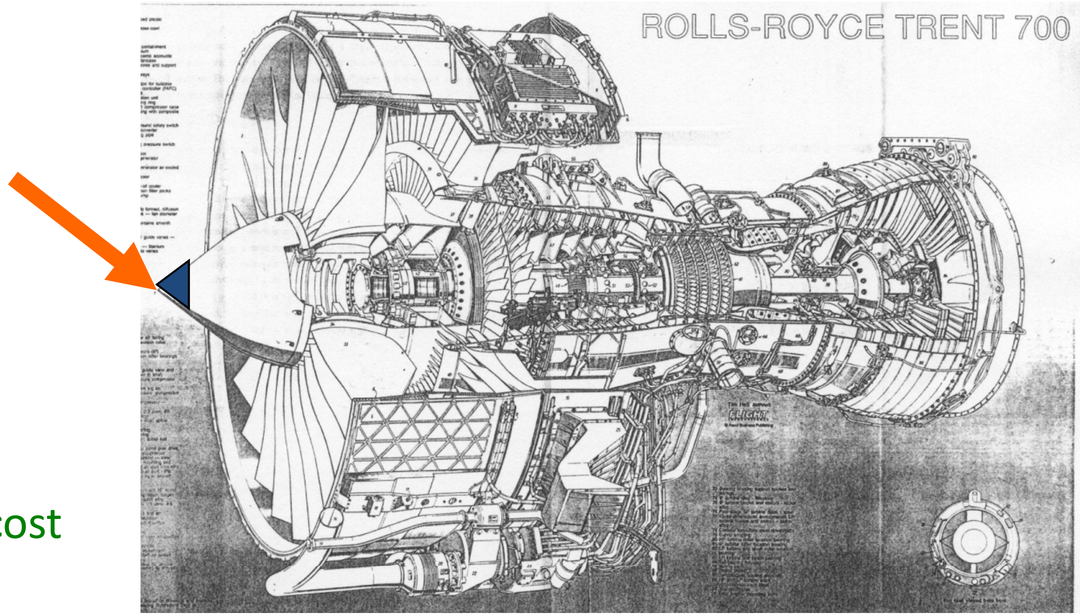


Image credit: Kenneth M. Wallace, University of Cambridge, UK

- Need:
  - Domain knowledge of various technologies, principles from sciences…
  - Process knowledge: how to create ideas
    - Brainstorming
    - TRIZ
    - Stimuli from nature: shrug, tail, sneeze…

Design Creativity

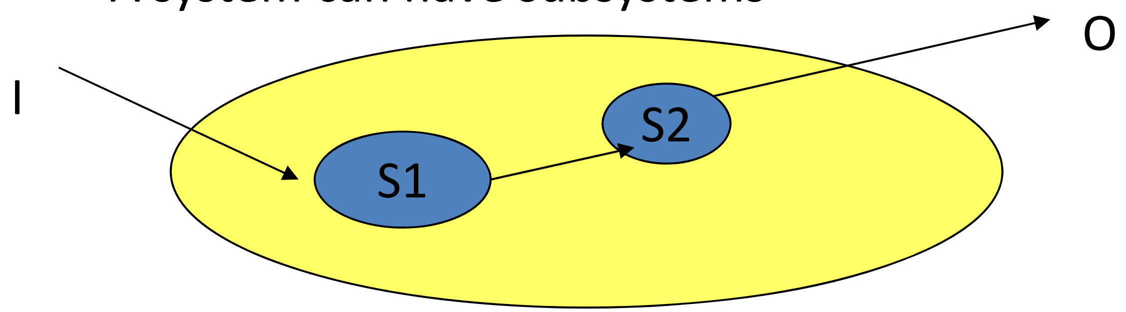
Process or activity of developing

- Ideas, solutions or products that are
- Novel
- Valuable

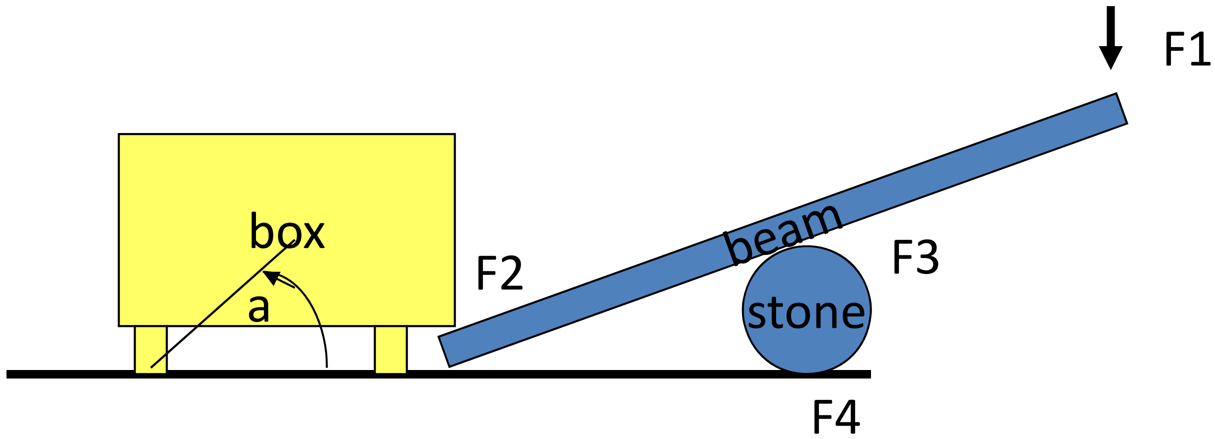
Sarkar, P., and Chakrabarti, A., Assessing Design Creativity, Design Studies, 32(4), 348-383, 2011

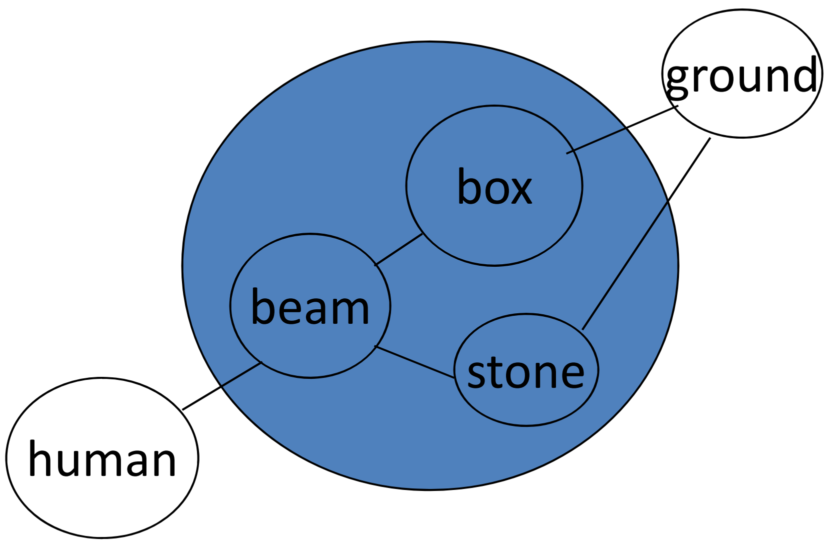
What is a product?

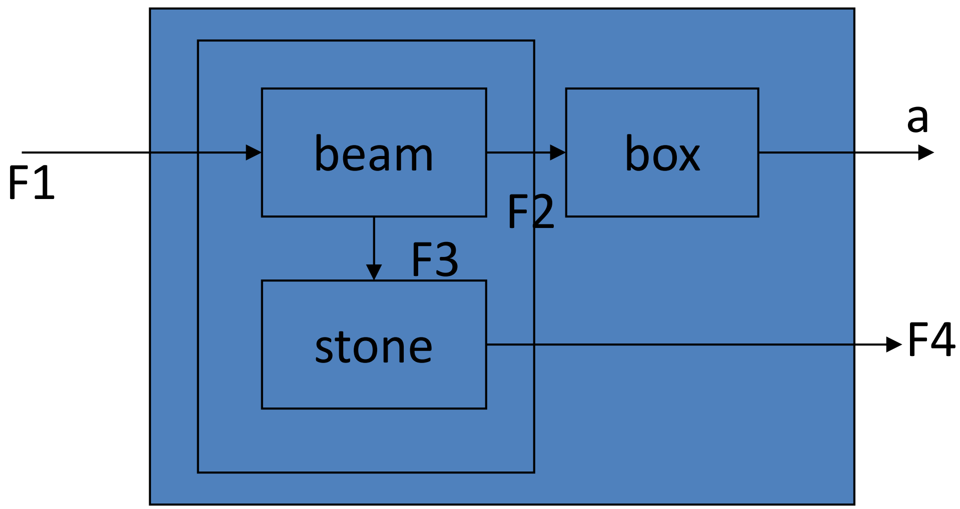
- Products are systems (artefacts or processes) conceived, produced, transacted and used by people because of their properties and functions they may perform (Roozenburg)
- A system is a set of objects with interrelationships between their attributes
  - A system is connected to its environment via system boundary
  - Interaction is through interfaces (inputs and outputs)
  - A system can have subsystems



What is a system?







What is product design?

- A goal-directed problem solving activity (Archer, 1965)

- A creative activity – involves bringing into being something new and useful that has not existed before (Reswick, 1965)

- The imaginative jump from present facts to future possibilities (Page, 1966)

- An iterative, decision-making activity to produce the plans by which resources are converted preferably optimally into systems or devices that meet human needs (Woodson, 1966)

- Initiation of change in man-made things (Jones, 1971)

What is product design?

Process of devising and laying down the plans needed for manufacturing a product

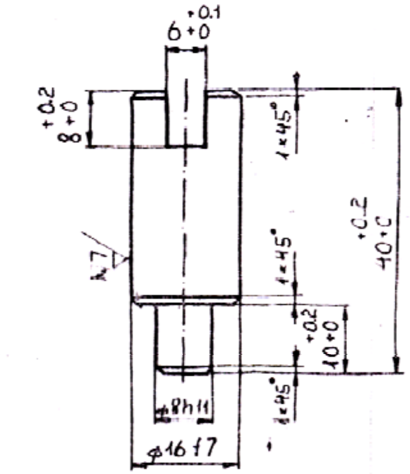


Image Credit: Roozenburg and Eekels, 1996

What is product design?

Need: Ill-defined, ill-structured

- iterative
- goal directed
- decision making

Plan: Well-defined, well-structured
(shapes, materials, processes)

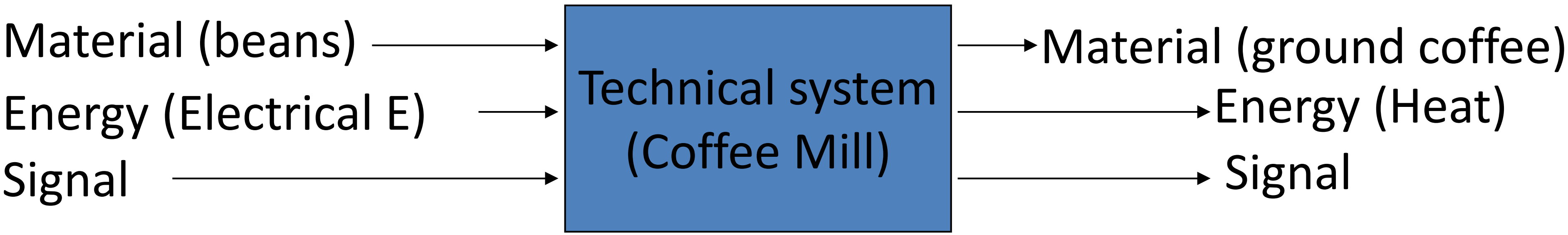
What is Engineering design?

Engineering design is the process of converting an idea or market need into the detailed information from which a **technical system** (product or process) can be produced

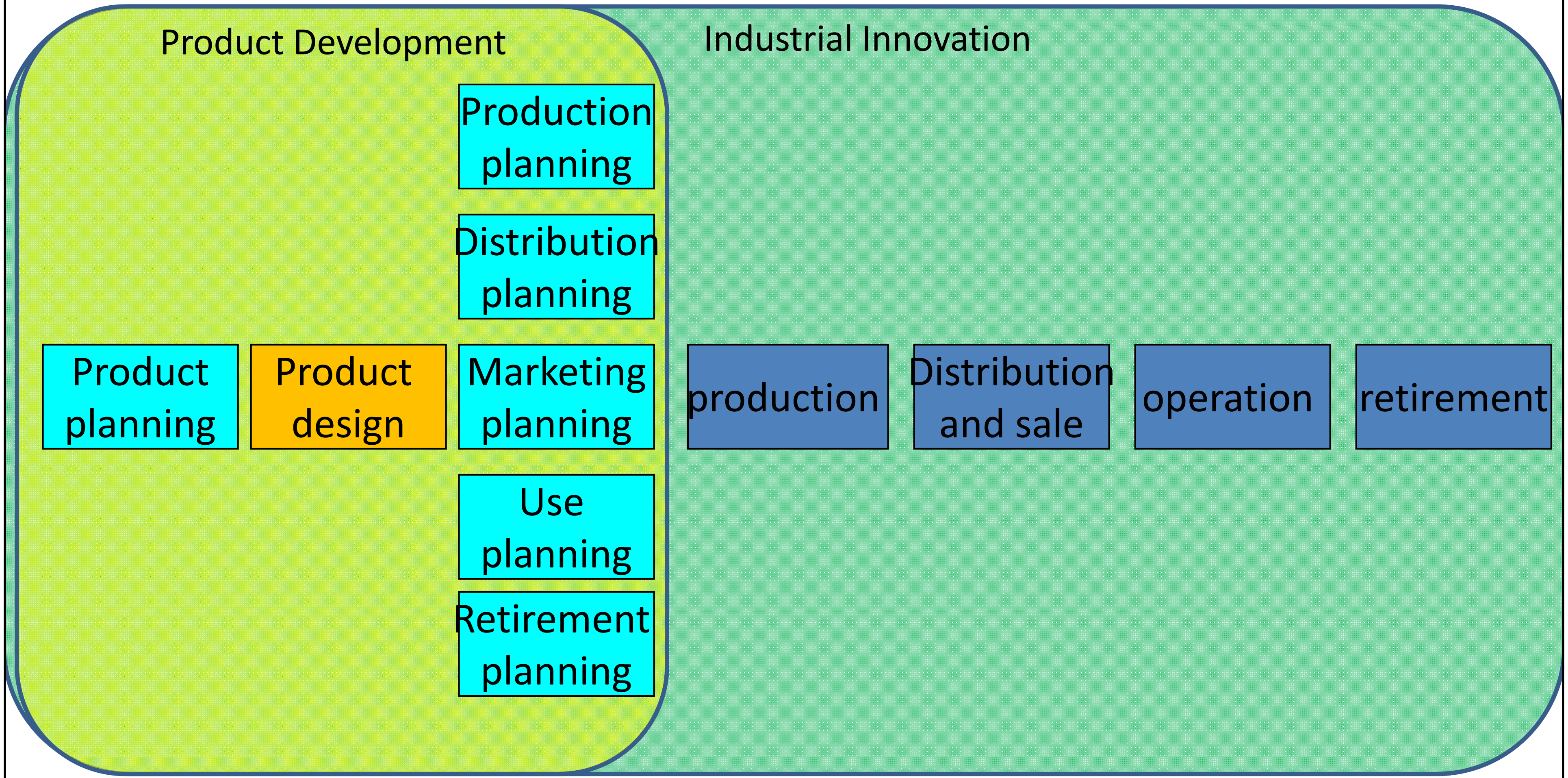
What is Engineering design?

Need: Ill-defined, ill-structured

Plan: Well-defined, well-structured technical system (shapes, materials, processes)



Product design and development



Why is innovation important?

Life cycle of a product

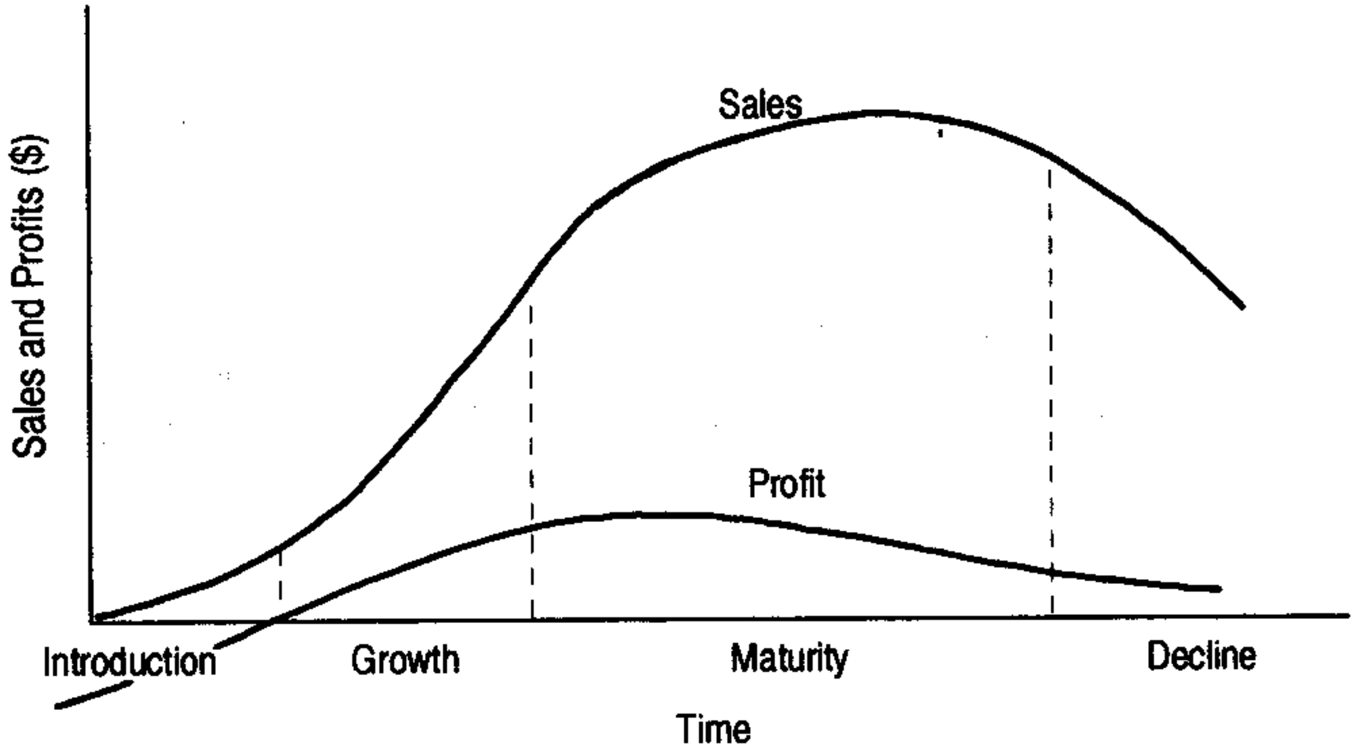


Image Credit: Roozenburg and Eekels, 1996

Why is innovation important?

Company Turnover and products

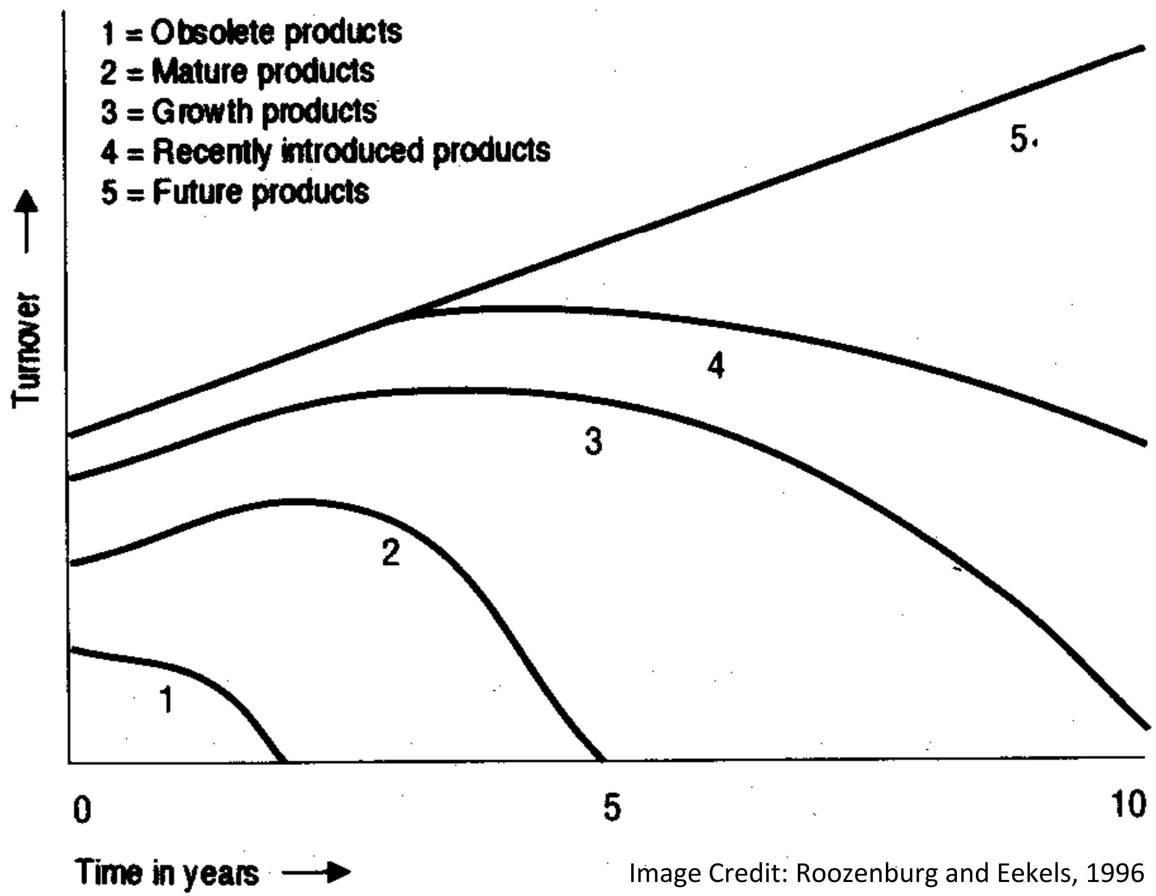
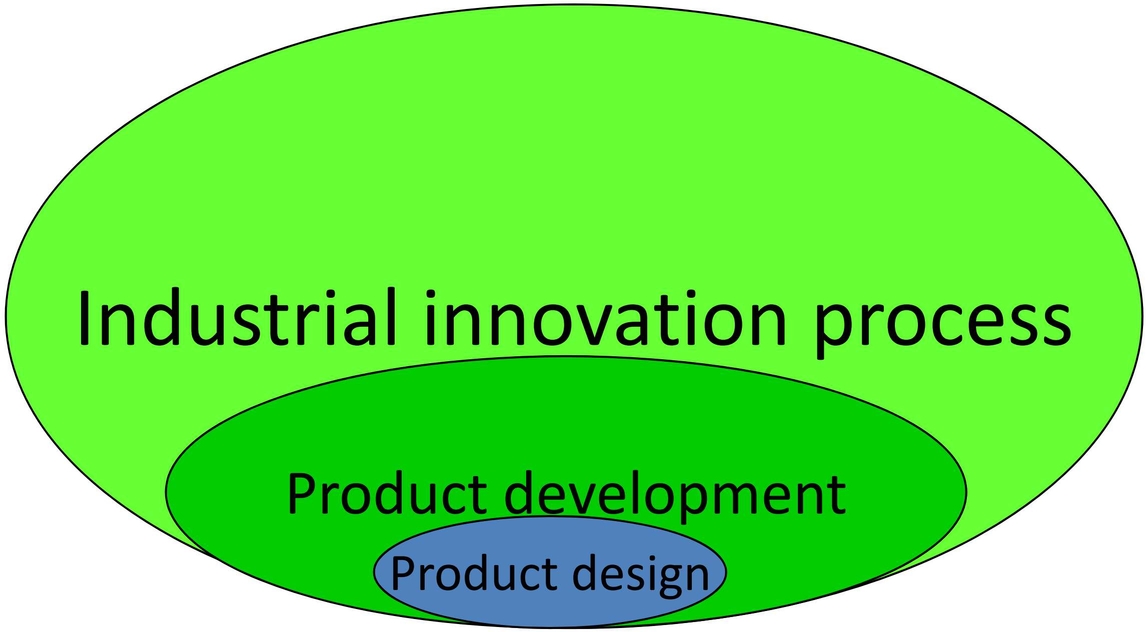


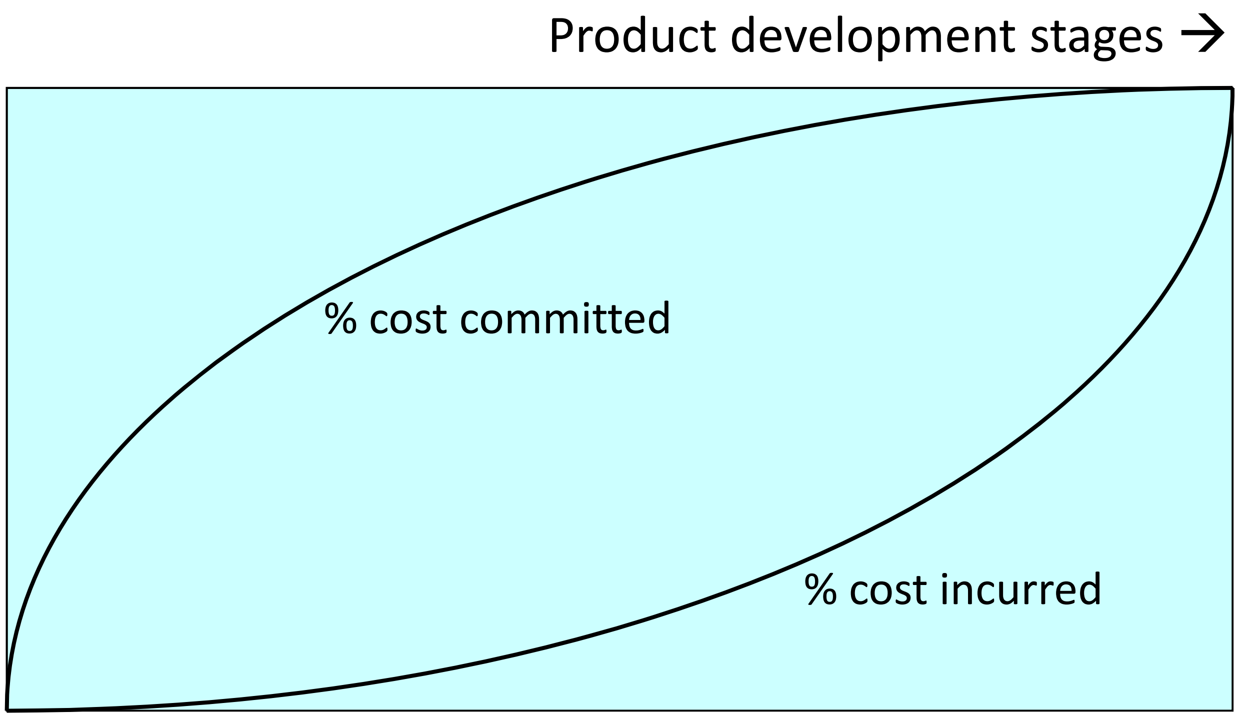
Image Credit: Roozenburg and Eekels, 1996

Why is design important?



- Product design is an essential part of the industrial innovation process which is important for both society and business – hence important

Why is design important?



- Product design is an early stage of product development where It is inexpensive to make changes, but consequences of changes is substantial