ECSE-211
Design Principles and Methods

Lecture 1D: Introduction to Engineering Design

Date: 4 January 2023

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Introduction to Engineering Design

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Objectives of the Lecture

- What is Engineering Design and why is it needed?
- Engineering Design in the 21st Century
- What is a Specification?
- A basic Process – an overview of the V-Cycle

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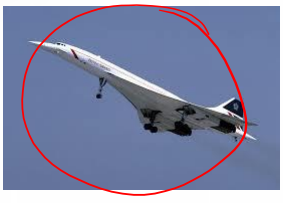
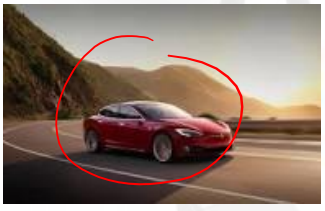
Society and Artifacts

- People
  - live in built structures
  - Use manufactured tools
  - Travel on mobile platforms
  - Communicate over vast distances
  - …





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Society and Artifacts

- What do all these have in common?
  - They do not occur naturally
  - They have all been constructed to fulfil a need
  - They are all “structures” or “systems”
  - The structures have been based on
    - What people need
    - What the existing state of knowledge makes possible
    - What the existing technologies provide

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The Evolution of a Device/System

- End User Needs drive the Engineering Design Process
- The Solution is time and technology dependent
- As knowledge increases and manufacturing capabilities change, solutions change…

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The Evolution of a Device/System

Transportation device – traditional – missing a drive system

Possible power unit (but not the only option)

Nineteenth century electric vehicle – basically cart + electric motor

Evolved 21st century vehicle – also specialized – not great for passengers!

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The Evolution of a Device/System

So – what happened?

+

Constraints Change

Increasing Knowledge
New Materials
Advances in Technology
Changes in Manufacturing

Addition to the user needs/requirements

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When did Engineering start?

- When people began creating structures
  - Before beginning to build, there has always been a "conceptual" phase…
  - Either the "designer" had
    - prior experience – i.e. knew what worked last time (a rule-based system)
  - Or
    - Mathematical models were constructed to enable design performance to be predicted
    - E.g.
      - Pythagoras (mathematician) – how to compute geometry – needed to construct buildings
      - Archimedes (engineer and mathematician) – theory of levers, buoyancy, geometry,…
  - Models and processes are fundamental to all engineering
- The goal of this course is to examine how engineers achieve solutions to problems

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What is Engineering Design?

- Design has two meanings:
  - The Process of Moving from a Need or Requirement to a Solution which addresses the Need or Requirement
  - The Completed Structure or System and its Associated Description
- *The end of the process is the description of the structure and the "physical" implementation of the structure*

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What is Engineering Design?

- Engineering Design is a particular form of the design process

The Engineering Design Process (EDP)

- The process is intended to start from a set of specifications for an artifact and finish with the working structure
- It involves the "art of the possible" subjected to hard constraints – e.g. time, money, state of technology, etc.
- It is a "controlled" process

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Engineering Design in the 21st Century

- *The Engineering Design Process evolves with technological capability*
- Engineers use models to verify the performance of a structure –
  - *as much as possible before committing to a physical implementation*
- Models are based on the current state of knowledge – usually the physical universe
- Up to the 17th century, the models were simplistic
  - Calculations performed by hand or an abacus (developed in 2700 BC)

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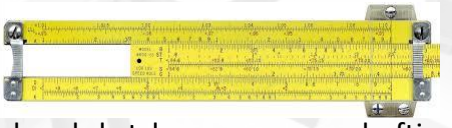
Engineering Design in the 21st Century

- The development of physics, mathematics and the slide rule enabled more complex models
  - Performance was estimated using these tools



  - "Visualization" was performed through hand sketches on paper – drafting was a key skill of the design engineer (*and still is for expressing ideas*)
  - Through most of the 20th century, performance was verified though physical testing

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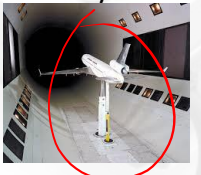
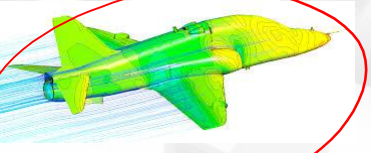
Engineering Design in the 21st Century

- The emergence of digital computers in the 1960's/70's allowed the construction of more complex physical models
  - Computational fluid dynamics analyses to replace wind tunnels – reducing the design time by months





  - Structural analysis determines the performance under loads

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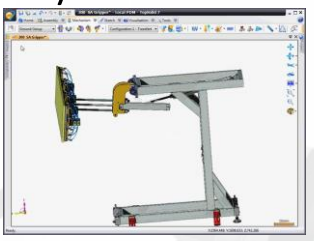
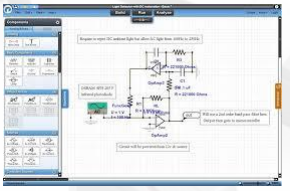
Engineering Design in the 21st Century

- Mechanical simulation can handle dynamics



- Electrical simulation can predict the performance of electrical circuits



- The development of Computer Aided Drafting tools facilitated the construction of drawings and their easy modification

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Engineering Design in the 21st Century

- The development of computer based simulation tools has allowed engineers to explore design solutions to a set of requirements
- *Simulations are not the same as the physical systems* – they include approximations
- However, more and more complex simulations minimize the number of physical prototypes needed
- The result is often referred to as a

Digital Twin

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Requirements and Specifications

- The starting point of the Engineering Design Process has always been the same
- A set of requirements are identified
  - This could be for an entire system

  - Or for a component

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Requirements and Specifications

- A requirement is something a system or component must do or a capability it must have
  - E.g. an automobile must be able to transport people…
- But an automobile is a *system*
  - A system is constructed from components
  - As a system design is refined requirements for each component are defined
  - E.g. an electric vehicle needs an electric motor
    - The motor has to fit in a specific space
    - The motor needs a particular torque-speed characteristic
    - The motor has to use a particular voltage…

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Requirements and Specifications

- A specification is essentially a more detailed, or implied, requirement
- It may put values on some requirements
  - E.g. the requirement says “motor must fit in the space provided in the chassis” – the specification says max motor dimensions are 0.3m x 0.3m x 0.5m
  - The requirement says that the maximum torque must accelerate the vehicle to 100 kph in 5 seconds – the specification says that this needs to be 70Nm
- In a sense, requirements and specifications are the same
  - The requirements are what the customer (either end user or systems engineer) needs.
  - The specifications describe the performance of the system – and a production device must meet them to be acceptable
- A specification could come from an international standard related to a device designed for a particular need

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