ENGR 13x2
Engineering Design with CAD

ENGINEERING DESIGN & THE DESIGN CYCLE

Agenda

- Engineering as a set of skills
- Design vs Analysis vs Replication
- The Design Cycle

The engineer:
Central to project management

- Common aspect of the engineering profession
- Engineers seldom sit alone in a cubicle or lab all day solving problems and designing machines
  - Problems are complex and multidisciplinary
  - Require expertise from many areas
- An example . . .

New federal law requires reduce NOx emissions by 20%

- Develop a new catalyst to enhance the conversion of NO and NO_2, to N_2, H_20 and CO_2 (chemist)
- Ramp up catalyst production (chemical engineer)
- Design a new catalytic convertor (mechanical engineer)
- Modify engine control systems (electrical engineer and software engineer)
- Modify manufacturing techniques (industrial engineer)
- Evaluate cost of meeting new regulation (accountant)
- Decide how to price / market the modified vehicle (CEO, marketing)

Engineering as a set of skills

- Theoretical and practical knowledge / skills
  - Calculus, Physics, Statics, Thermo . . .
  - Heat exchanger design, manufacturing tolerances for microchip fabrication . . .
  - Regulations, corporate design standards . . .
- Broad knowledge in “non-major” areas
  - Economics, related engineering disciplines . . .
- Organization, communication, documentation
  - English, Speech, Sociology, Philosophy . . .
- Knowledge, experience, intuition

Knowledge

- The body of facts used to form strategies, analyze systems, and predict results
  - Formal education
  - On-the-job training
  - Life-long learning

Experience

- The body of methods, procedures, techniques, and rules of thumb used to solve problems
  - Mentoring (passing on the “secrets” and tricks of the trade)
  - Completion of successful projects
  - Failure
- Sometimes the best design isn’t the “right” one
  - Engineers work within a system of constraints that include cost, manufacturability, maintenance, marketing, etc.

Intuition

- A basic instinct about what will or will *not* work as a problem solution
  - “Good engineering judgment”
  - Can help to narrow down the design process when too many potential solutions exist
  - Grounded in experience and knowledge
    - Practice, practice, practice

CHAPTER 2 - HORENSTEIN

What is Design?

- Any activity whose objective is to meet a need
- Merriam-Webster: to create, fashion, execute, or construct according to a plan

Design / Analysis / Replication

- **Design** is an <u>open-ended</u> process in which more than one feasible solution can exist.
- **Analysis** is the use of math to predict or confirm an outcome.
- **Replication** is the process of re-creating something that has already been designed.

What is this???

- Find the fastest land travel route between two cities.
  - Analysis *(answer is probably related to minimizing distance and/or traffic)*

- Find a way to mount a cell phone on a bicycle to permit safe hands-free operation.
  - Design *(many ways to accomplish, use creativity and choice to arrive at the best solution)*

- Find a way to produce individualized bar-coded badges for attendees of a conference.
  - Replication *(bar coding is well understood, just a matter of applying it to this situation)*

Good Design vs. Bad Design

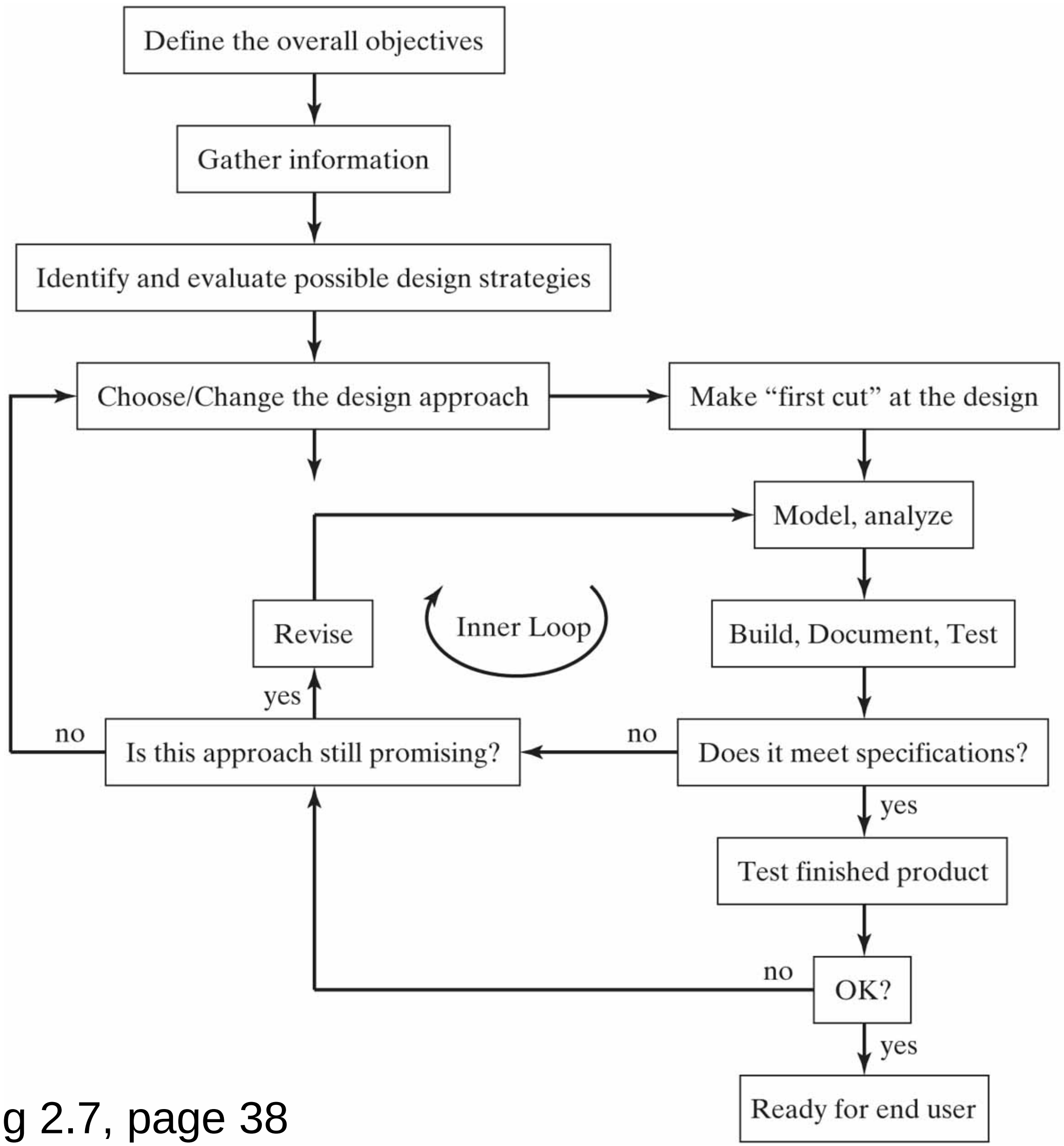
- Good Design ☺
  - Meets all technical requirements
  - Works all the time
  - Meets cost requirements
  - Requires little or no maintenance
  - Is safe
  - Creates no ethical dilemma
- Bad Design ☹
  - Meets only some technical requirements
  - Works initially, but stops working after a short time
  - Costs more than it should
  - Requires frequent maintenance
  - Poses a hazard to users
  - Raises ethical questions

Table 2.2 Horenstein

The Design Cycle

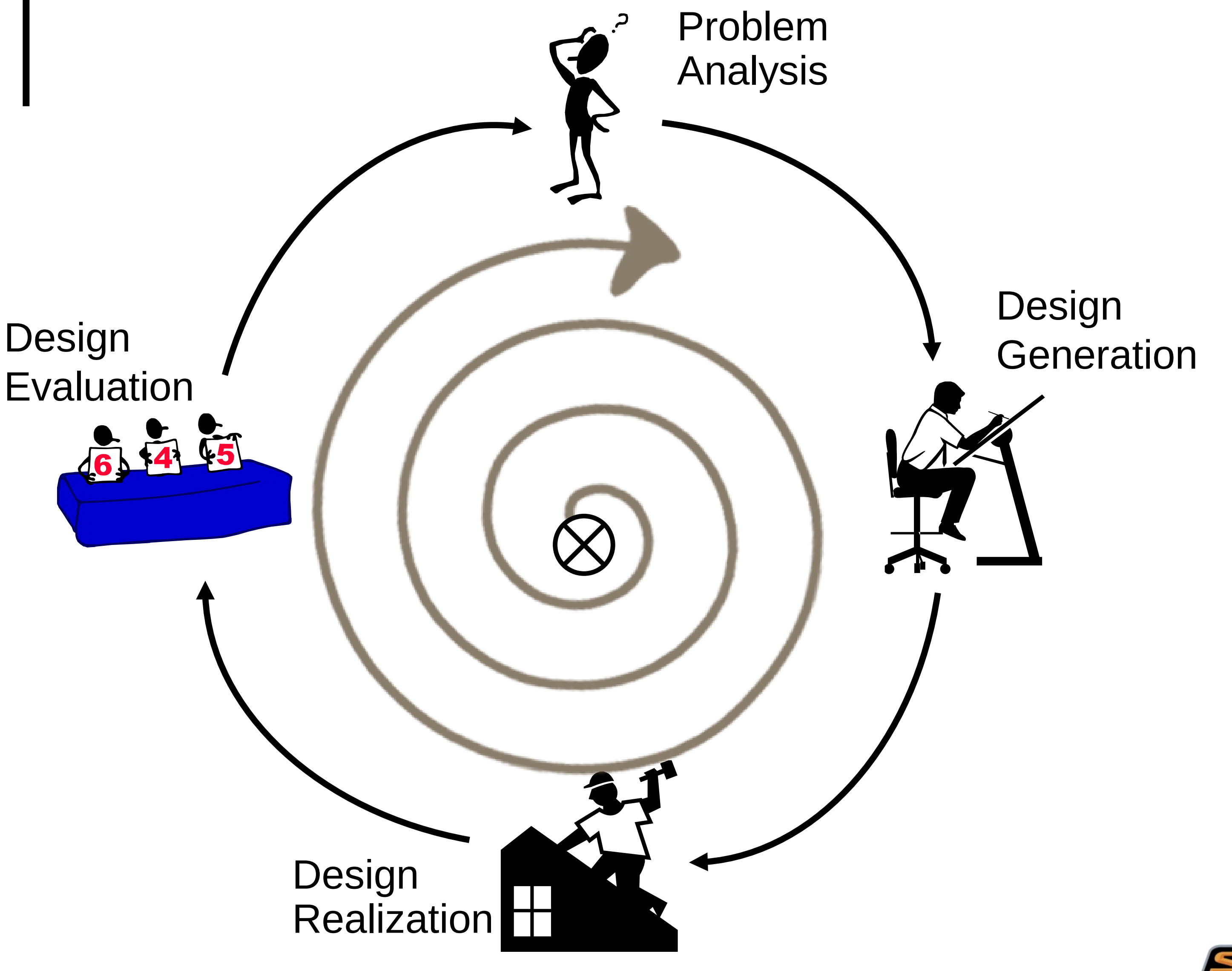
- Sequence of events from idea generation to finished product

- Steps may vary depending on the product or field of engineering, but this is pretty representative . . .



Horenstein, Fig 2.7, page 38

A simpler representation



Problem Analysis

- ***Goal:*** Clear and complete statement of problem to be solved.
  - Critical first step
  - What problem are we trying to solve?
  - What are the constraints?
  - Who is the customer / end-user? What are their needs?
  - Have to have vs. nice to have
  - Do research -- Has problem already been solved?
  - Can off-the-shelf components be utilized?

Note: Invest the time here!!
Don’t solve the “wrong” problem!!

Problem Analysis, cont.

- ***Process***:
  - Clearly state the problem as given by the customer.
  - Analyze to determine if this is the “real” problem or a “symptom”
  - Identify all **given requirements** (from customer)
  - Investigate additional requirements that logically emerge from initial rqmts. (**“Derived” rqmts.**)
    - Example: Customer wants “all weather” operation. What does “all weather” really include?
  - Identify all **externally imposed requirements**

    - Legal, regulatory, environmental, ethical
    - Example: EPA, OSHA, DOT…
  - Prioritize from most to least important
  - Translate to Technical Requirements

Design Generation

- ***Goal:*** Come up with multiple candidate solutions for the problem and select "best" to carry forward.

- Techniques include:
  - Brainstorming (individual & group)
    - Formal & informal process for generating ideas
  - Benchmarking
    - How have other people solved the problem? (Don't reinvent the wheel!)
  - Back of Envelope analysis
    - Quick check using very simplified model to estimate performance
  - Tradeoff Analysis
    - Which idea will work "best"?

Design Realization

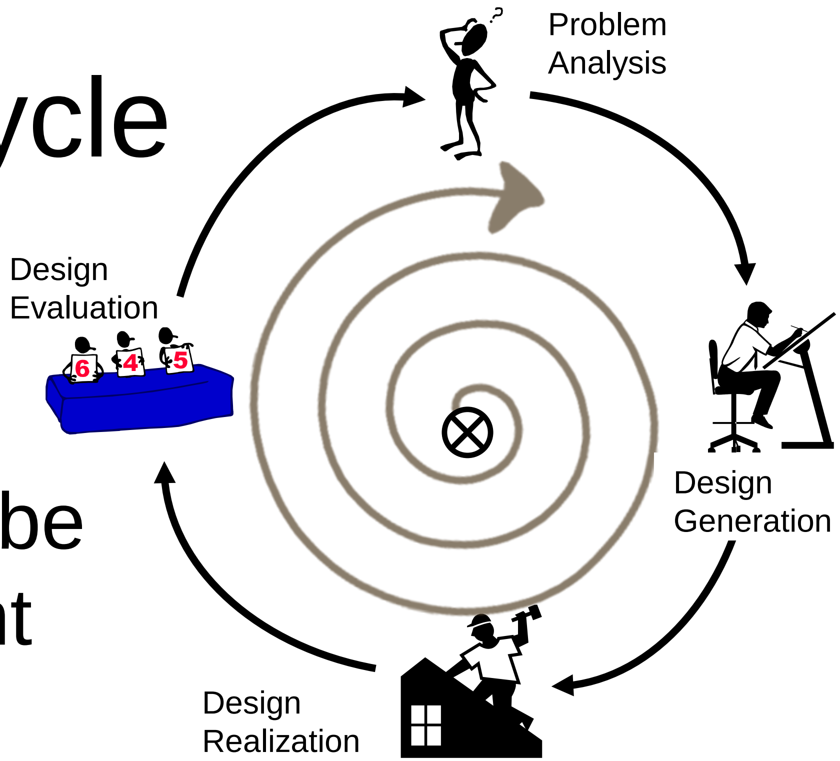
- Modeling / analysis / simulation
- Create a working prototype (if practical)
  - Needs to function, doesn't have to be pretty.
  - Use materials that are easy to work with.
  - Later prototypes may come very close to final production.
- Document throughout the process
  - What worked, what didn't work, design modifications, etc.
  - Necessary for patents, redesign efforts, manuals, etc.

Design Evaluation

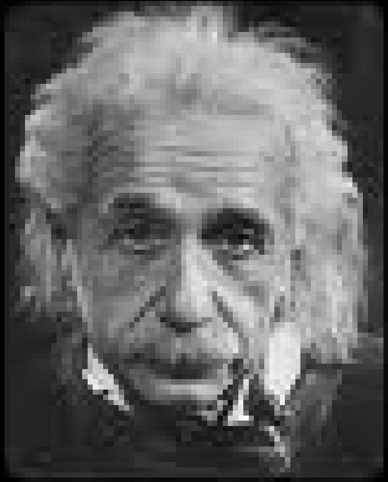
- Test thoroughly!
- Does it work?
- Meets all technical specifications?
- Assess performance in many different conditions and scenarios.
  - Beta testing?
- Repeat the design cycle if problems are discovered.

The Design Cycle

- Design is an iterative process!
- Final product may be completely different than what was initially envisioned.
  - This distinguishes design from replication.
  - Prepare for failure (and learn from it).



"No problem can be solved from the same level of consciousness that created it."



- Albert Einstein