ECE398psc – Innovation and Engineering Design

https://courses.engr.illinois.edu/ece398psc/

Welcome

- Jamie Norton
- Course staff
- Structure
- Schedule
- Policies

Introduction to Engineering Design

- Jamie Norton
- What is engineering?
- Problems
- Engineering design

Painstorming

- Brian Lilly

Course Staff

- Instructors
  - Brian Lilly
  - Scott Carney
- Head TA
  - Jamie Norton
- Project TAs
  - John Capozzo
  - Daniel Gardner
  - Vignesh Sridhar
  - Jackson Lenz
  - Other members of the ECE445 TA corps

Jamie Office Hour
Friday from 10-11AM in 2072 ECEB

Structure of the course

- Class once a week
  - First hour will generally be lecture.
  - Second hour will be:
    - Guest lecture
    - Group activity
    - Case study
- Presentations/Design Reviews
  - There are two scheduled presentations and one mock presentation workshop.
    - These will take place outside of class.
  - Generally half an hour each.
- NO exams!
- In place of a final, may have individual 2-page funding proposal.

Projects

- Will be taken on in groups of 2-3 students.
- Discourage individual projects.
- Must be two DIFFERENT projects.
- Must be two DIFFERENT teams.

- Project #1
  - First nine weeks (including today)
  - RFA due during week 4
  - Documentation will be due in individual components
  - Final deliverable is an oral presentation of the project.
    - This may be a straight presentation, may be a design review, TBD

- Project #2
  - Five weeks from start to finish
  - Documentation will be in the form of a proposal, design review document, and formal design review.

TAs and TA Meetings

- Best part of the course!!!
- TAs will be assigned based on your project.
- You can also visit 445 office hours for questions about specific (project related) problems.

- Your TA is your guide and advocate.
- Meeting will take place weekly at a time and place defined by the team and the TA. Prefer if meetings held in 2072 ECEB.
- Majority of your assignments will be submitted to and graded by your TA.
- TAs will be reassigned for your second project.

Policies

- Will post any changes to website and send email.
- Grades will be posted on Compass.
- Late work will be penalized 25% per day late.
- If you have any problems meeting deadlines or with conflicts, please send your TA an email and cc Jamie.
- We want you to be successful and have fun!!!

Part II

- What is engineering?
- Engineering vs. Science
- What is a problem?
- Engineering Design

The beginning: Why become an engineer?

- I was good at math and physics.
  - Go study math and physics
- I want a job when I graduate.
  - Get a vocational degree
- My parents said to.
  - Yeah. That's nice
- I like tinkering.
  - Cool. Open a repair shop.
- I want to solve big problems. (and get paid to do so)
  - Yes, you should study engineering

Bit of history

- Been around a long, long time.
  - Imhotep, first (?) named engineer. https://en.wikipedia.org/wiki/Imhotep
  - 2650-2600BC
  - Created incredibly famous engineering artifact, first Egyptian stepped pyramids.
- Electrical Engineering
  - Study of electricity can be (debatably) can be traced back to ancient Greece.
  - Thales of Miletus
  - 624-546BC.
  - Described static electricity. https://en.wikipedia.org/wiki/Thales_of_Miletus
  - Engineering though, Baghdad battery dates from 250BC. https://en.wikipedia.org/wiki/Baghdad_Battery

Artifact of engineering.

According to the Accreditation Board for Engineering and Technology (ABET) Definition

"Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind."

Note: UIUC is accredited by ABET.

http://cecs.wright.edu/~dkender/egr190/IntroEng(Notes).pdf

Breaking this down….

- profession
- knowledge of the mathematical and natural sciences gained by study, experience, and practice
- applied with judgment
- develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind

Profession

- Group of people defined by:
  - Their ethical standards.
  - Knowledge and training.
  - Pay for work in area of knowledge and training…
  - Australian Professional Standards Councils
    http://www.psc.gov.au/what-is-a-profession

- Engineering as a profession.
  - Ethical standards defined by professional organizations.
    - What are they?
    - IEEE
      http://www.ieee.org/about/corporate/governance/p7-8.html
    - ASME
      https://community.asme.org/colorado_section/w/wiki/8080.code-of-ethics.aspx
    - AIAA
      https://www.aiaa.org/CodeOfEthics/
  - Knowledge and training
    - ABET

Knowledge and training - Let's talk about ABET…

Accreditation every six years…

GENERAL CRITERIA FOR BACCALAUREATE LEVEL PROGRAMS

1. Students
   "Student performance must be evaluated. Student progress must be monitored to foster success in attaining student outcomes, thereby enabling graduates to attain program educational objectives. Students must be advised regarding curriculum and career matters…"

2. Program Educational Objectives
   "The program must have published program educational objectives that are consistent with the mission of the institution, the needs of the program's various constituencies, and these criteria…"

Knowledge and training - Let's talk about ABET…

3. Student Outcomes

(a) through (k) plus any additional outcomes that may be articulated by the program.

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) an ability to function on multidisciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

There are 5 more criteria…

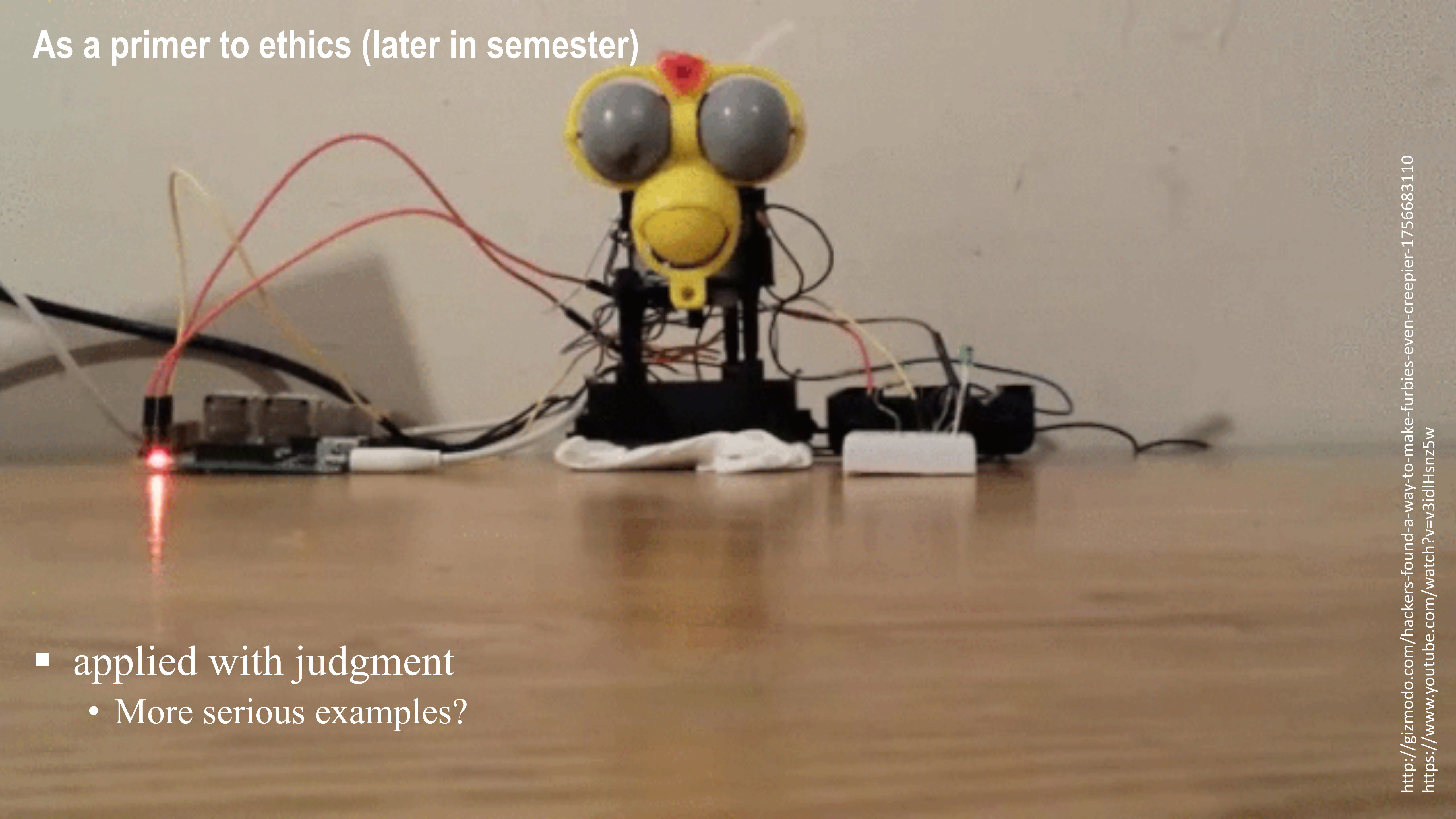
http://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf

As a primer to ethics (later in semester)

- applied with judgment

https://i.kinja-img.com/gawker-media/image/upload/s---PHrgsJ1--/c_scale,fl_progressive,q_80,w_800/uyei6imj0aovvnjdkd7b.gif

As a primer to ethics (later in semester)



- applied with judgment
  - More serious examples?

http://gizmodo.com/hackers-found-a-way-to-make-furbies-even-creepier-1756683110
https://www.youtube.com/watch?v=v3idlHsnz5w

https://www.amazon.com/Edison-Electric-Chair-Story-Light/dp/0802777104

Image from: http://stuffnobodycaresabout.com/wp-content/uploads/2015/08/first-electric-chair-Auburn-NY-photo-International-News-900x686.jpg

Develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind

- Engineers ask “what can I make with it?”
  http://cecs.wright.edu/~dkender/egr190/IntroEng(Notes).pdf
- Note, “utilize”, aided by science…but not science.
- Knowledge used in engineering is developed by scientists.
- Divergent- engineering leads to more engineering, invention to invention.

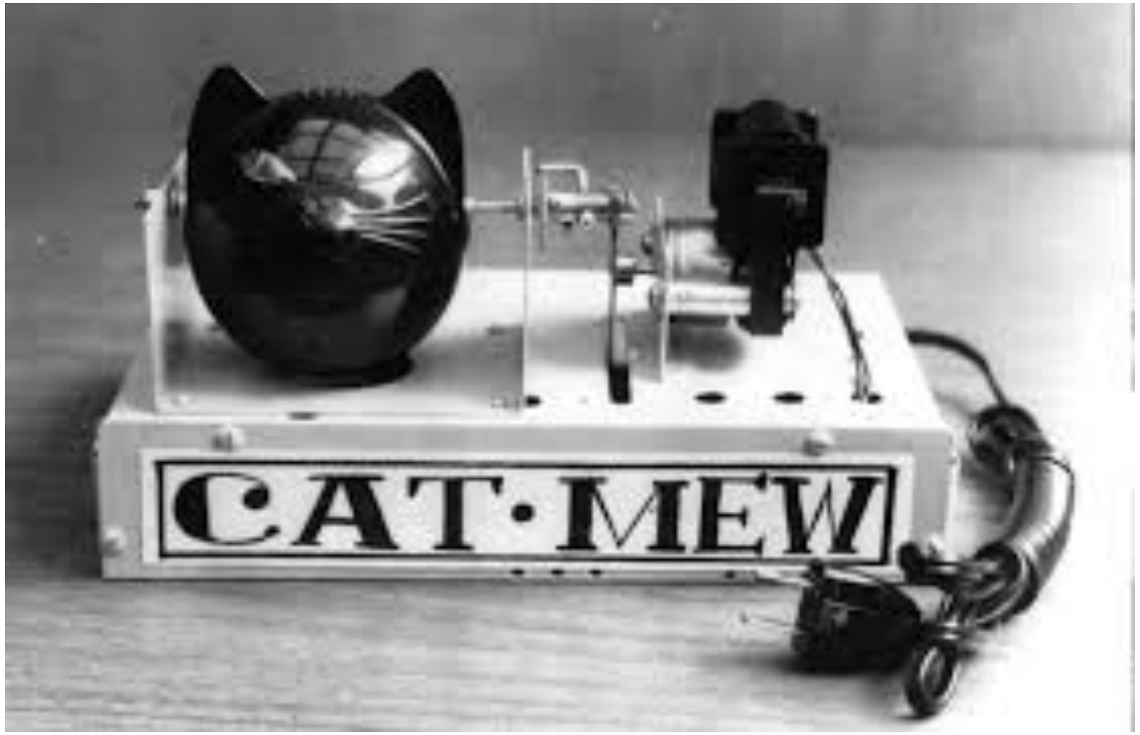


Image taken from (01/16/2017): http://assets3.bigthink.com/system/tinymce_assets/3942/original/GettyImages-3270480.jpg?1479660200

Not to be confused with science...

- Scientists ask, “why?”
  http://cecs.wright.edu/~dkender/egr190/IntroEng(Notes).pdf
- Scientists want to understand why our world behaves the way it does.
  http://cecs.wright.edu/~dkender/egr190/IntroEng(Notes).pdf
- Hypothesis ➔ prediction ➔ experiment ➔ theory
- Aesthetics promote simpler theories or theories that explain more phenomena from fewer conjectures
- In principle, the more science is done, the less there is to do (not true in practice)

Marie Curie, awesome scientist.
Image from (01/16/2017) : https://upload.wikimedia.org/wikipedia/commons/thumb/7/7e/Marie_Curie_c1920.jpg/220px-Marie_Curie_c1920.jpg

GPS: engineering vs. science

Time dilation in gravity wells….

$$v_s = 3.9km/s \rightarrow -7.3\mu s/day$$

$$r_e = 6375km, \qquad \frac{2GM}{r_e c^2} = \frac{r_s}{r_e} = \frac{8.9mm}{6375km} = 1.4\times 10^{-9}$$

$$\rightarrow -60.5\mu s/day$$

$$r_{sat} = 4r_e \rightarrow -15\mu s/day$$

$$net = 38.2\mu s/day$$

Adjusting time…

Develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind

- Notice it doesn’t say that engineers do this in a set way….it leaves that part up to the individual.

- Another definition

  “the expression or application of human creative skill and imagination”

  Webster’s dictionary

Design

- Engineers aren’t artists.
  - Engineers always have process.
  - The goal of engineering is not to provoke thought.
  - Produce things whose purpose are immediately apparent.

- Rather, engineers have more in common with designers.

Design
“Design establishes and defines solutions to and pertinent structures for problems not solved before, or new solutions to problems which have previously been solved in a different way.” - Dieter 2013

- Admittedly, I find it difficult to create a precise delineation between art and design…we should ask each of the two artists who will be guest lecturers later in the semester.

Let’s summarize

“Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.”

Person paid to use science to design solutions to problems (when ethical).

ECE398psc – Innovation and Engineering Design

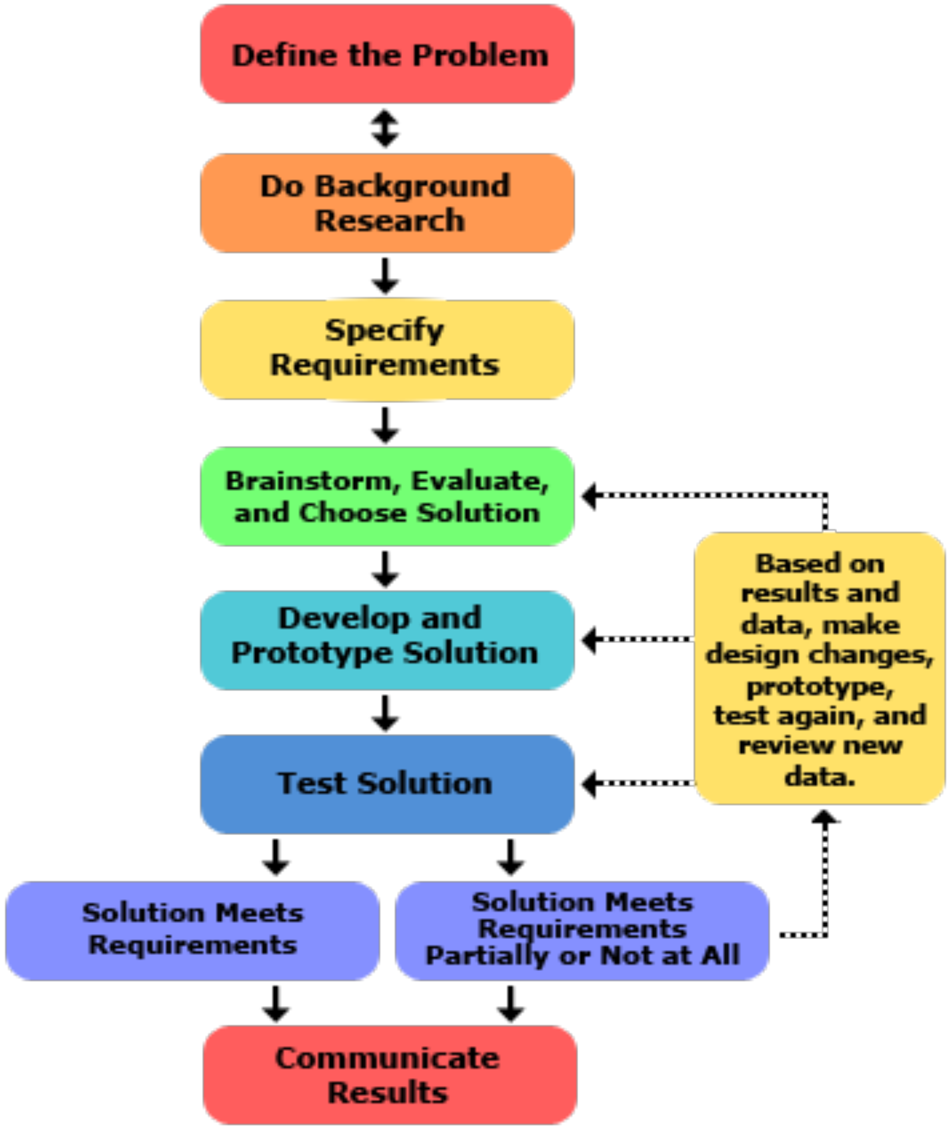
- Most (?) of your other courses have concentrated on teaching you the science of being an engineer.
- In this course and in ECE445, we concentrate on the design aspect of being an engineer.
- As we mentioned, while art has no rules, design does.

- **Engineering Design**
  "Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs."

Engineering Design

- Process
- Iterative
- Depends on the application of knowledge
- Optimal
  - In what sense?

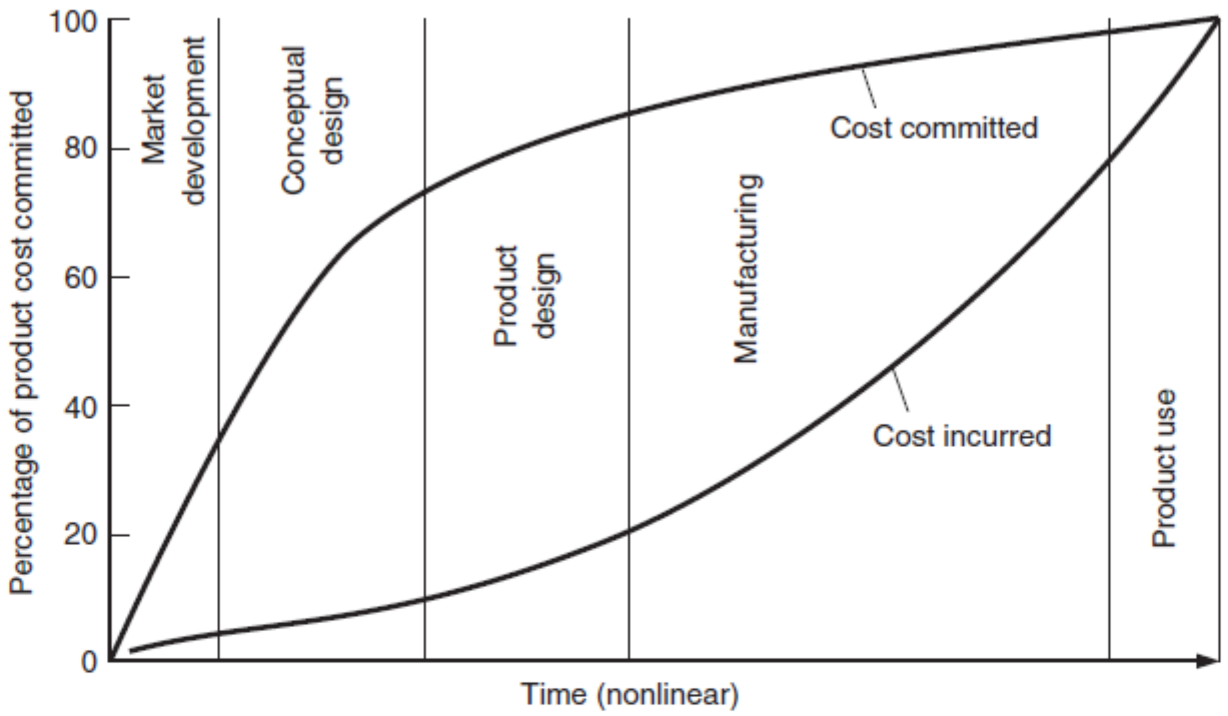
- Recall in our definition of design:
  "problems not solved before, or new solutions to problems which have previously been solved in a different way" – Dieter 2013
- Already agree it is not science.
- Does it require invention?
  - Sometimes, but not always



http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess

Why is design important?

- Design choices effect every step of development.
  "Decisions made in the design process cost very little in terms of the overall product cost but have a major effect on the cost of the product ."
- Quality is designed into the product.
  "You cannot compensate in manufacturing for defects introduced in the design phase ."
- Design can save time and money.
  "The design process should be conducted so as to develop quality, cost-competitive products in the shortest time possible ."



All text and figure from Dieter 2013

Types of Design

- Original design
  Designing from scratch to meet a need.

- Adaptive design
  Taking a solution from one application and using it to solve a problem in another.

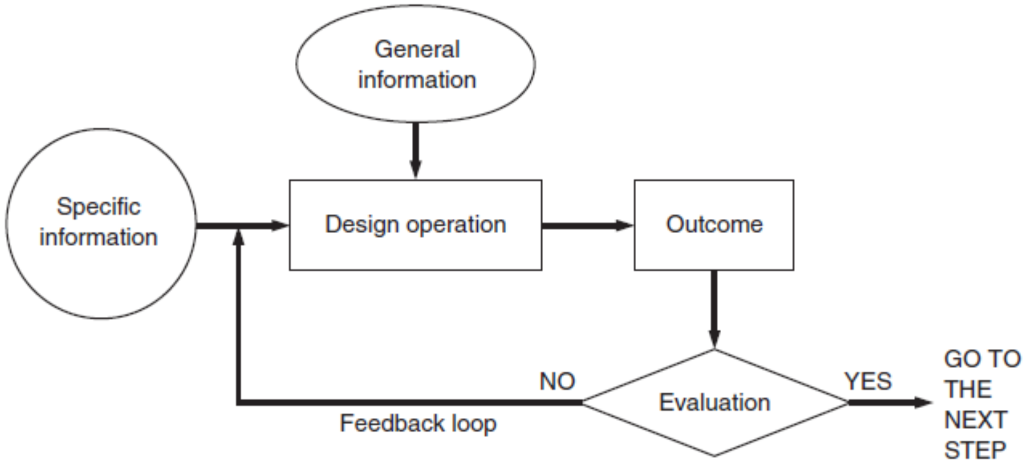
- Redesign
  Making things better.

- Selection Design
  Using known and available (standard) components to achieve a design.

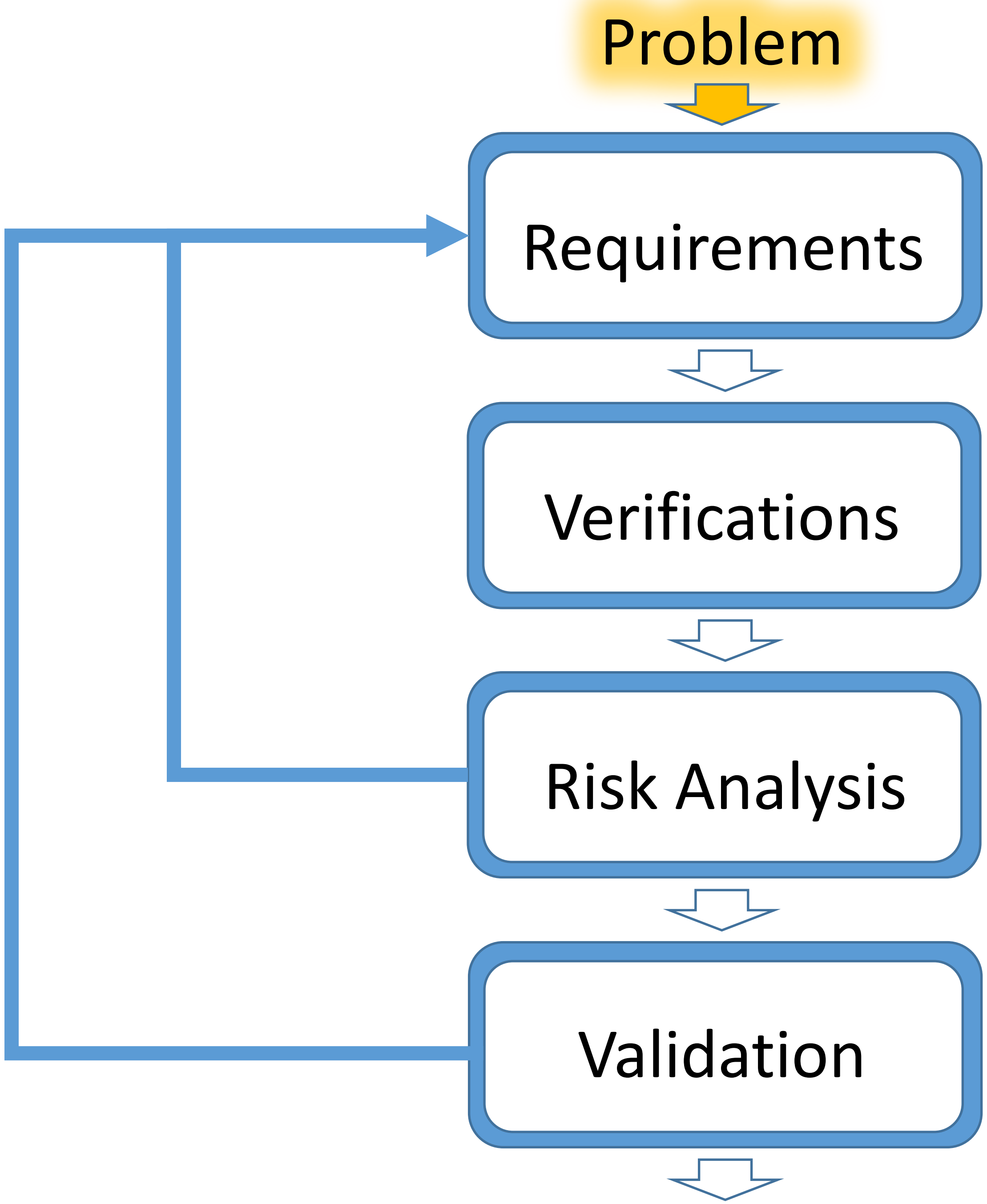
All text and figure from Dieter 2013

The Process!

- There are multiple ways to think about the engineering design process.
  - All involve the acquisition of information.
  - All involve iteration (as mentioned before).
  - The number of iterations and time spent will depend on the project goals.
- Feedback control
- Problem solving methodology



One way to think about the engineering design process (Asimow from Dieter 2013).

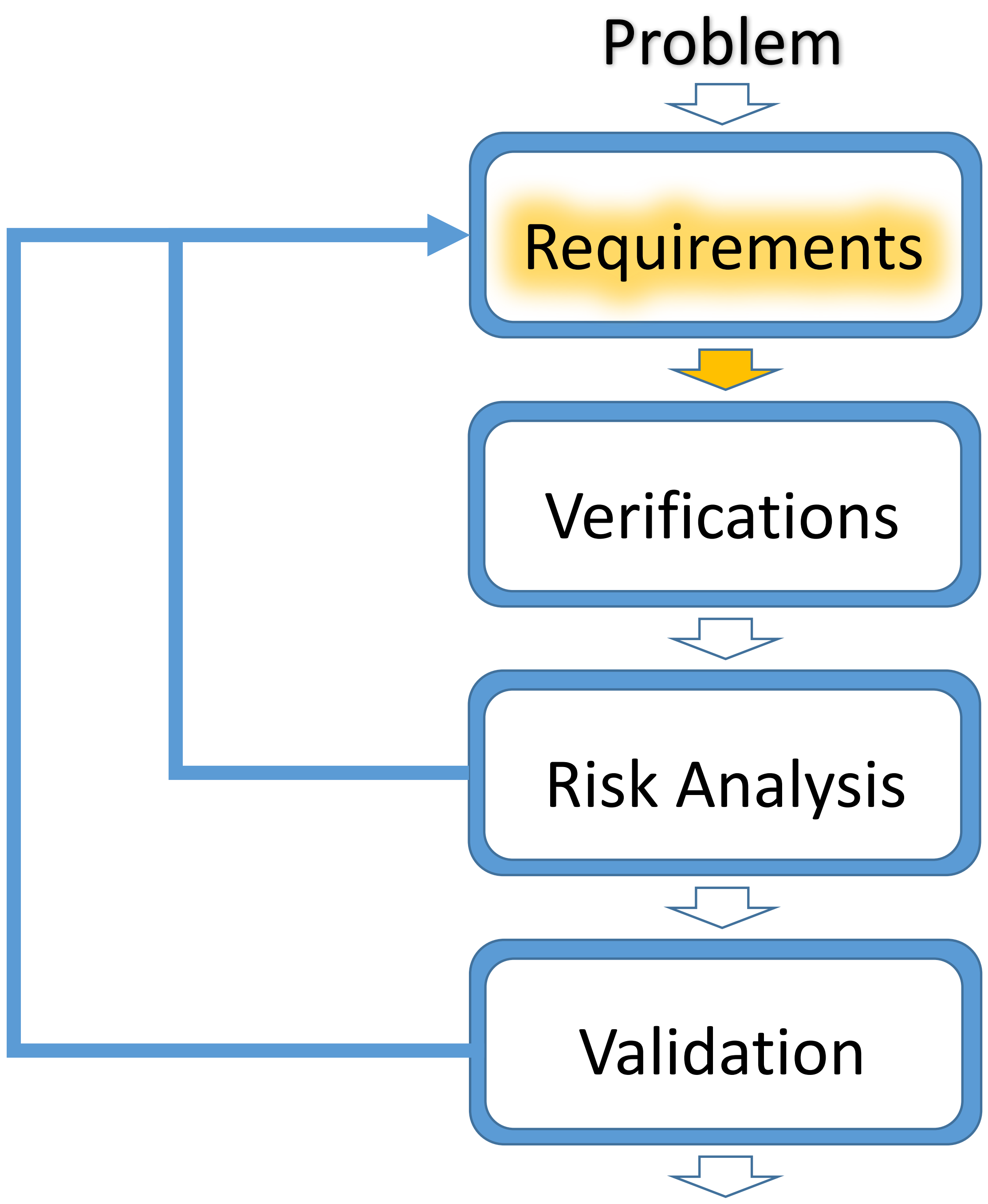


Problem Statement:

A description of what you are trying to solve and why.

A problem statement should be:

- Brief
- Clear
- Unambiguous



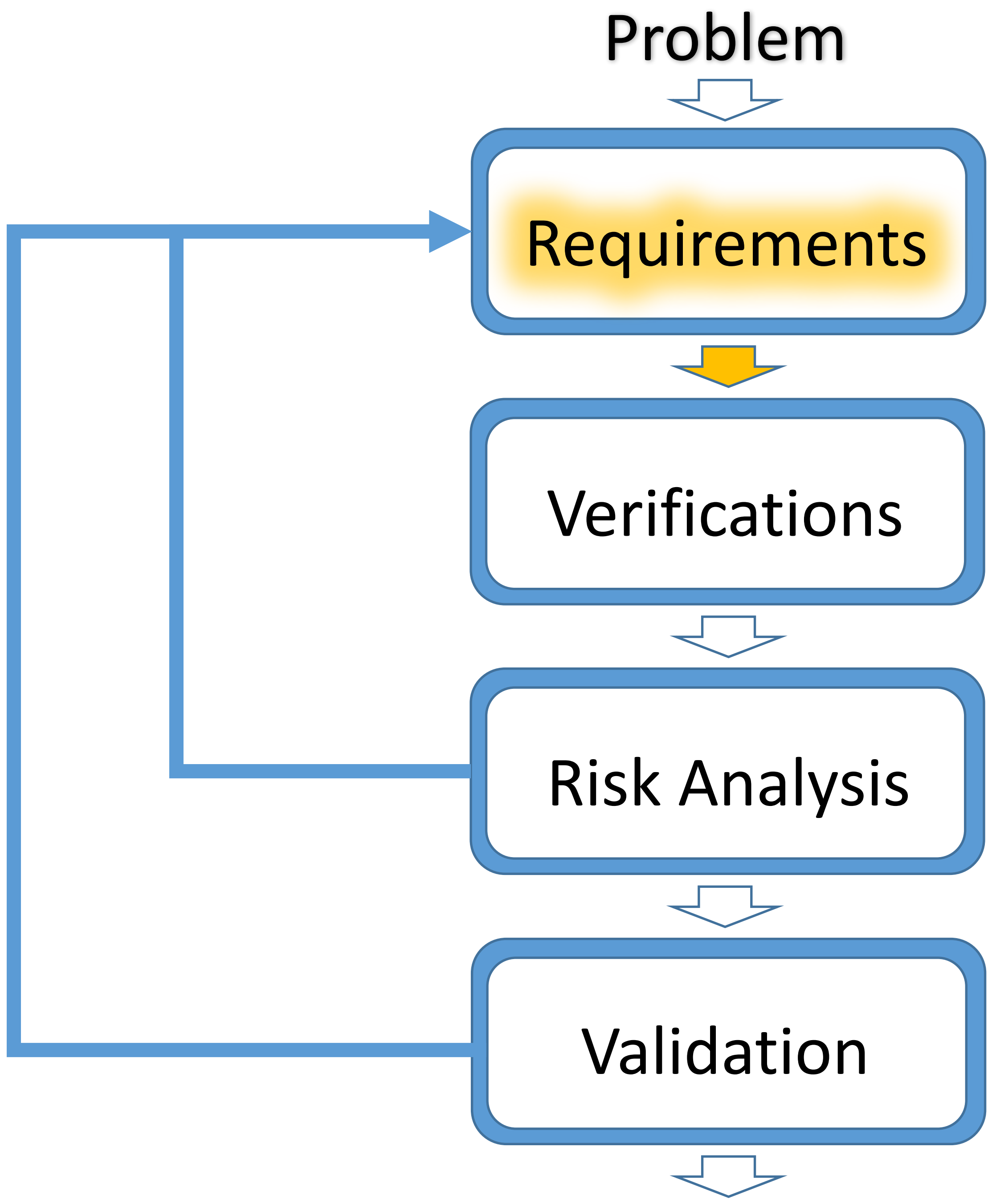
Requirements:

Problems are often complex.

Design requires that after you have a problem, you **decompose** it into a set of manageable parts.

Each of these parts should be **analyzed** to predict their behavior and then any solution should involve a **synthesis** of all working parts into a complete design.

Terms from Dieter 2013.



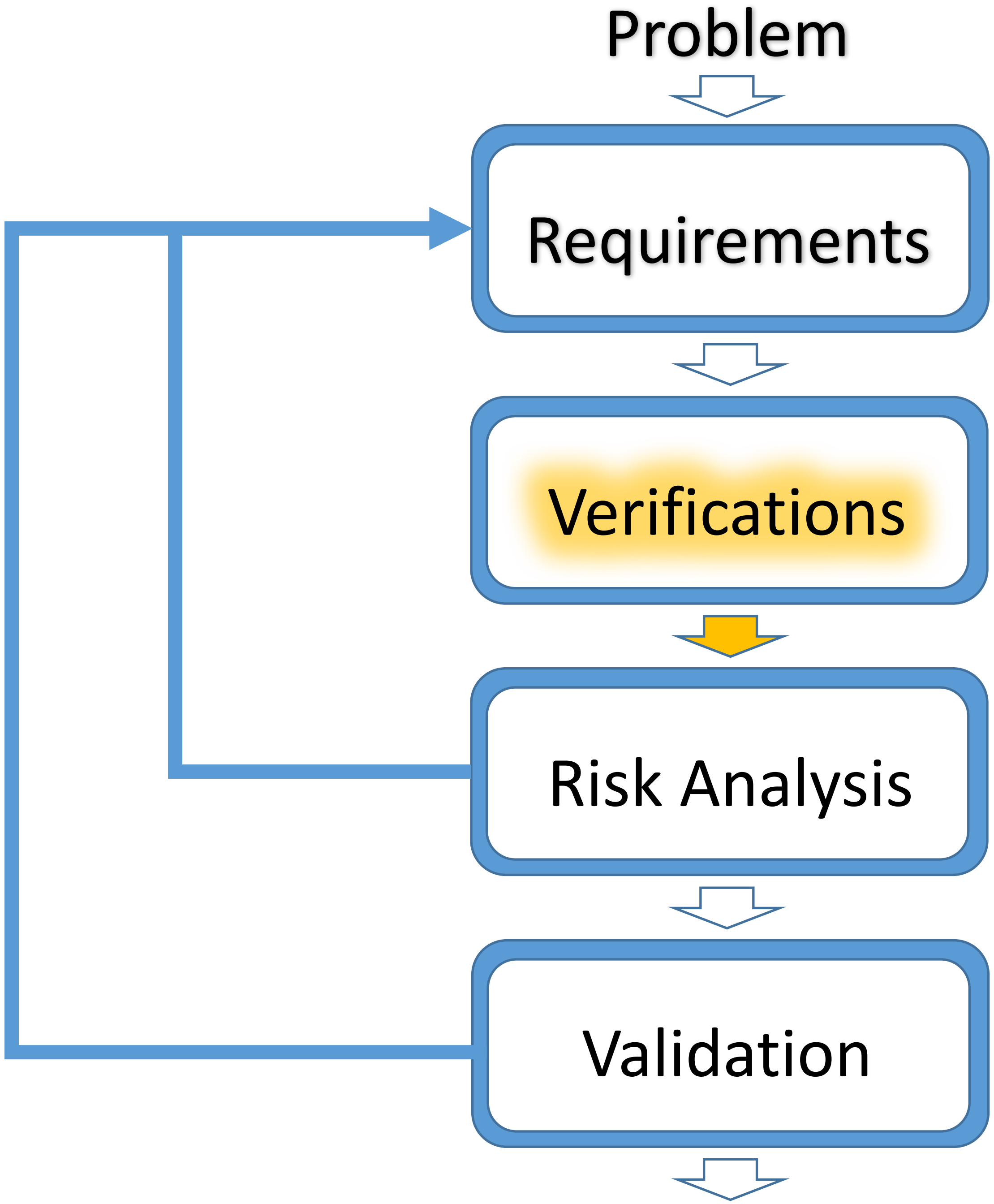
Requirements:

Requirements come from this analysis and synthesis.

They are set of statements that describe the attributes your system must have to solve your problem.

They should be:

- Quantifiable
- Relevant
- Detailed

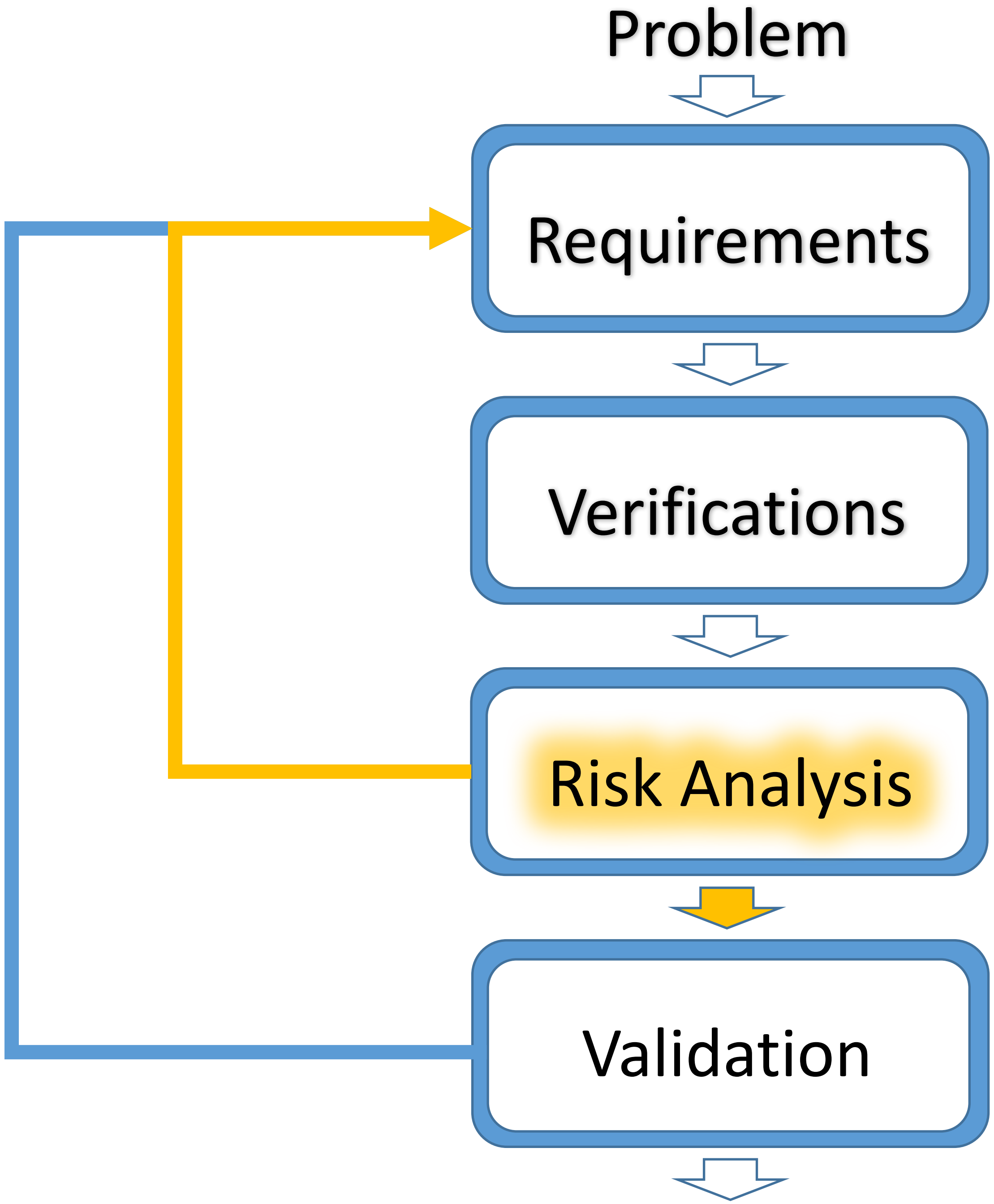


Verifications:

A set of statements that describe tests you will perform to make sure that your system meets the requirements.

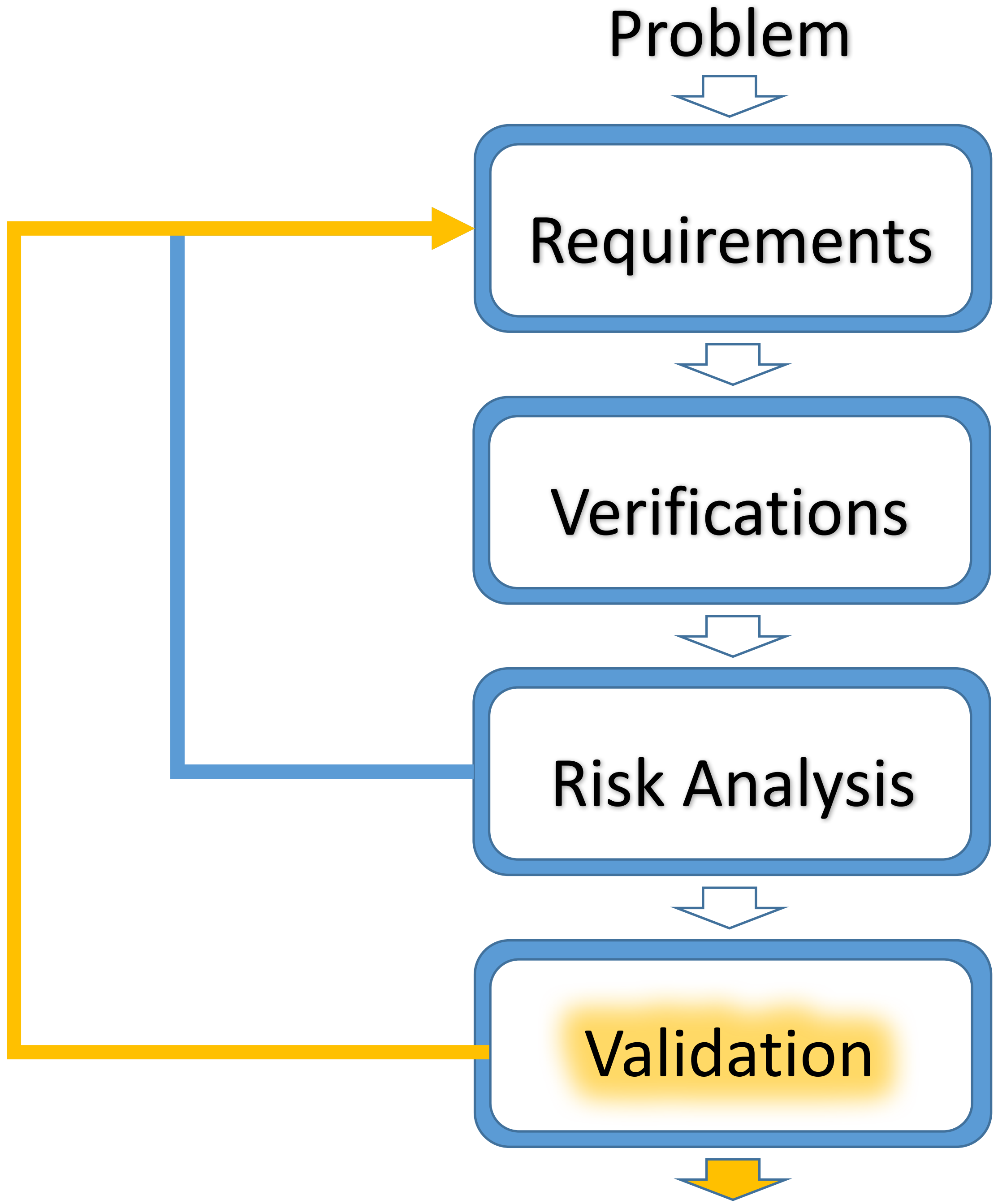
They should:

- Include measurement.
- Procedure for conducting measurement.
- Evidence that will be provided in report that requirement has been met.



Risk and Tolerance Analyses:

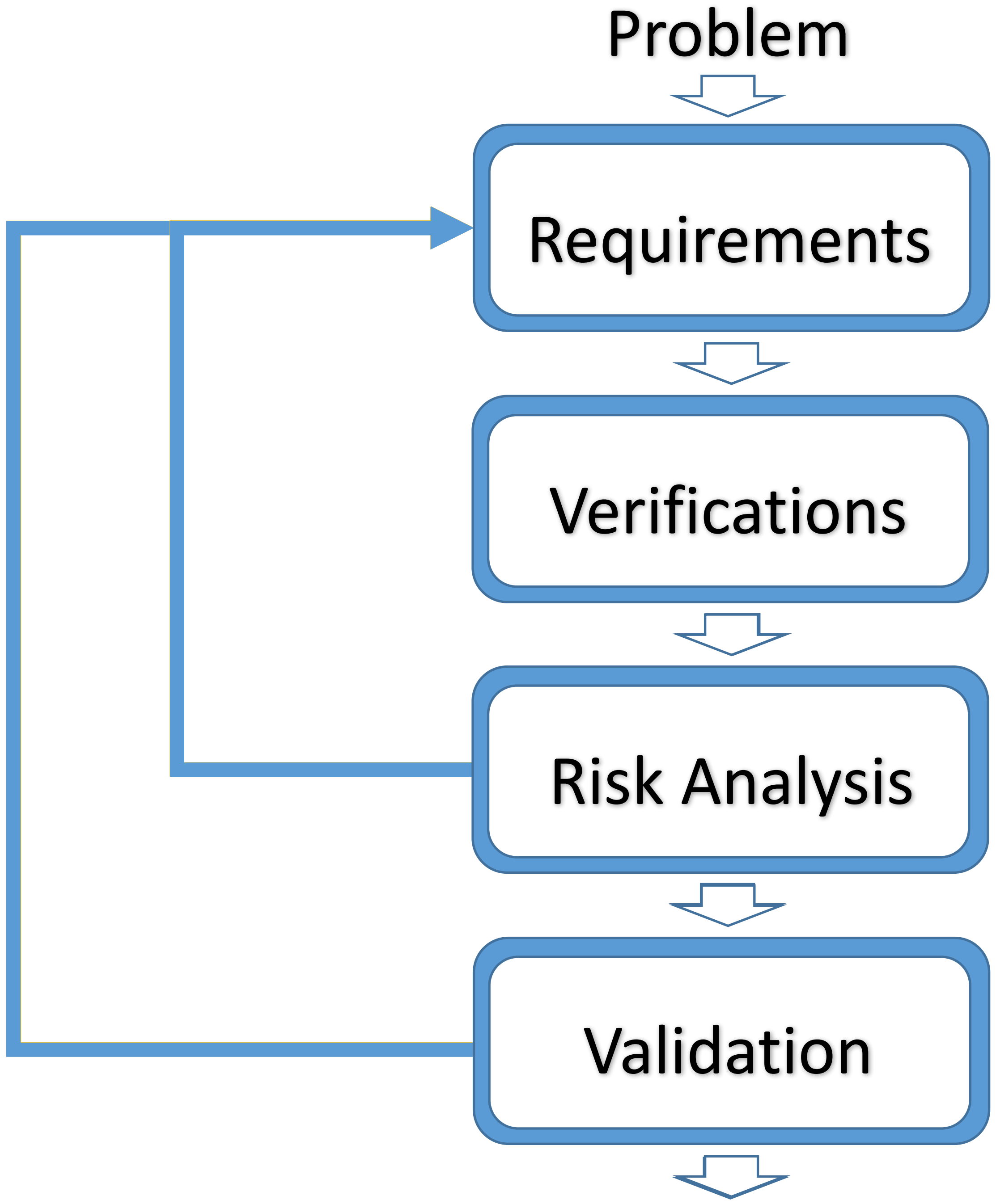
The risk of the failure of specific system component is dependent on two variables, the **consequence** of the loss and the **probability** that the loss will occur.



Validation:

Tests performed on prototype product to determine if they solve the problem of the user.

Often performed by an independent agency.



This process is iterative!!

Do not confuse your first set of requirements with your final set of requirements.

Engineering Design Process - Iterative

Image taken from: https://static1.squarespace.com/static/559fddc2e4b096931b40cd6a/t/56088aeee4b02ca27d368014/1443400432813/
1/16/2017

The four C’s of design

- **Creativity**
  Requires creation of something that has not existed before or has not existed in the designer’s mind before

- **Complexity**
  Requires decisions on many variables and parameters

- **Choice**
  Requires making choices between many possible solutions at all levels, from basic concepts to the smallest detail of shape

- **Compromise**
  Requires balancing multiple and sometimes conflicting requirements

Problems vs. Projects

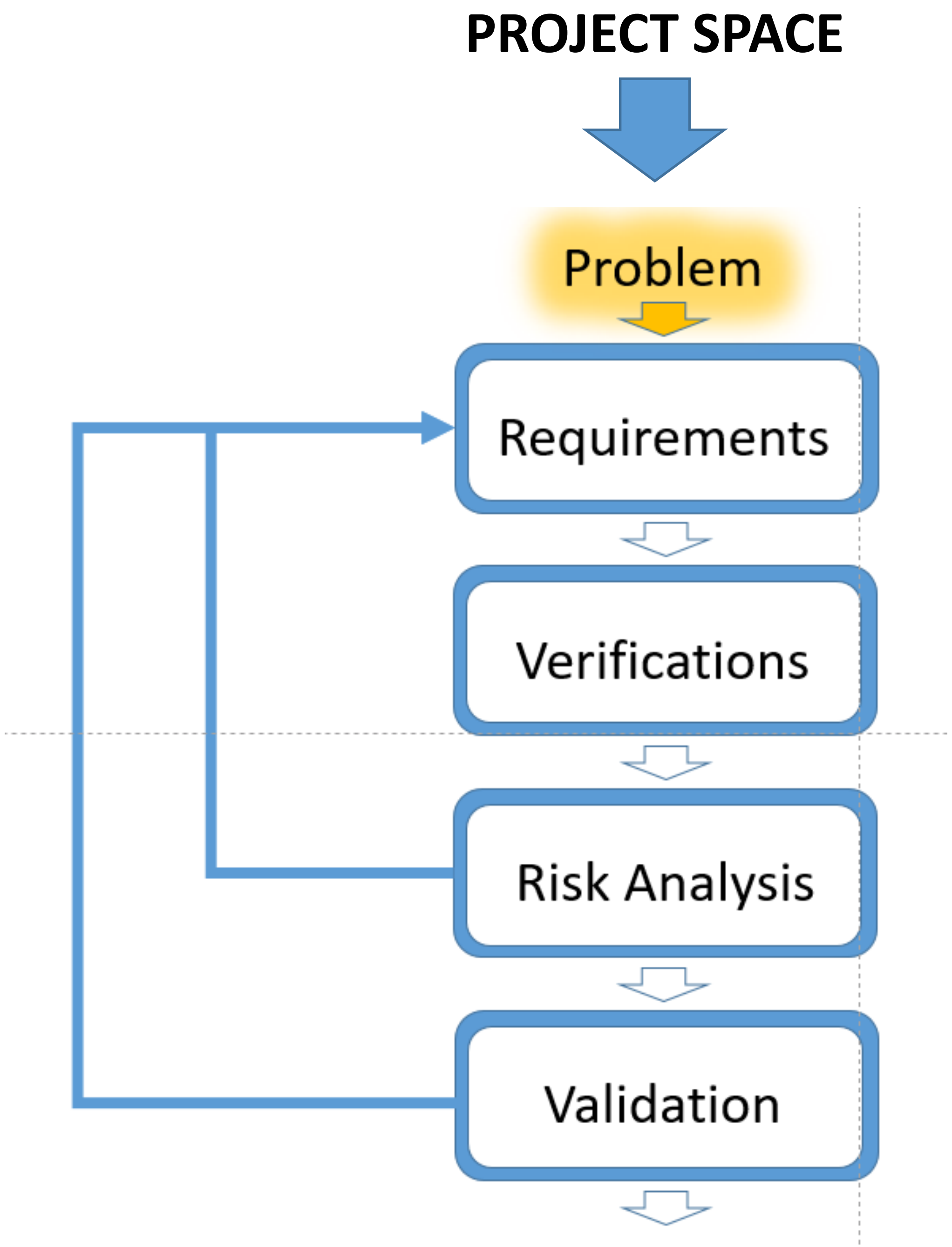
- Engineering Design - Dieter and Schmidt 2013 (page 10)

  “The most critical step in the solution of a problem is the problem definition or formulation. The true problem is not always what it seems at first glance. Because this step seemingly requires such a small part of the total time to reach a solution, its importance is often overlooked.”

Problems vs. Projects

- Before we can think about design, need to define a problem…
- Problem statements can be deceptive.

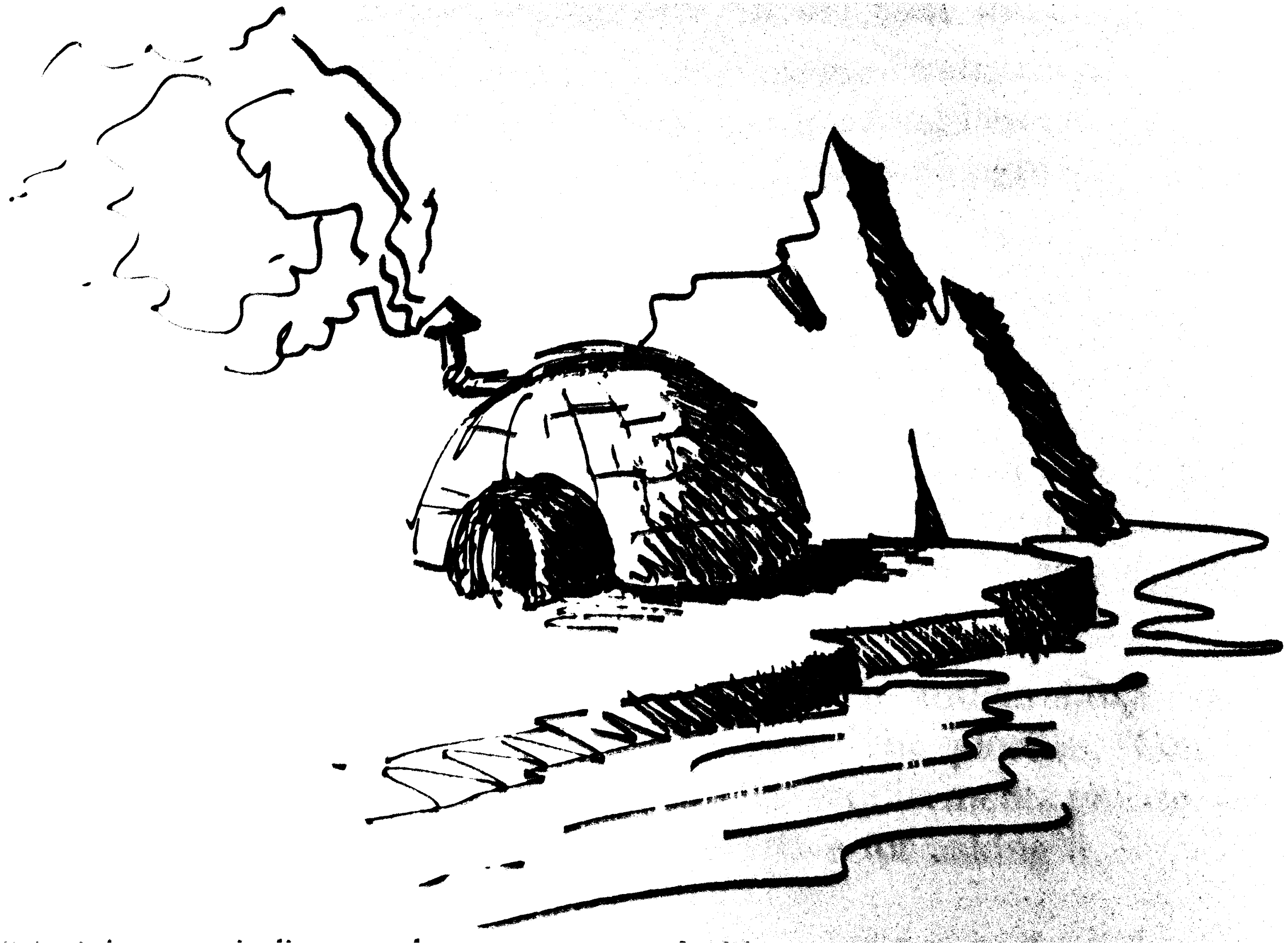
- In my opinion, one of the main reason that senior design projects fall short.
- Instead of jumping into problem statements....we will first define a project space and then we then refine that into a problem statement.



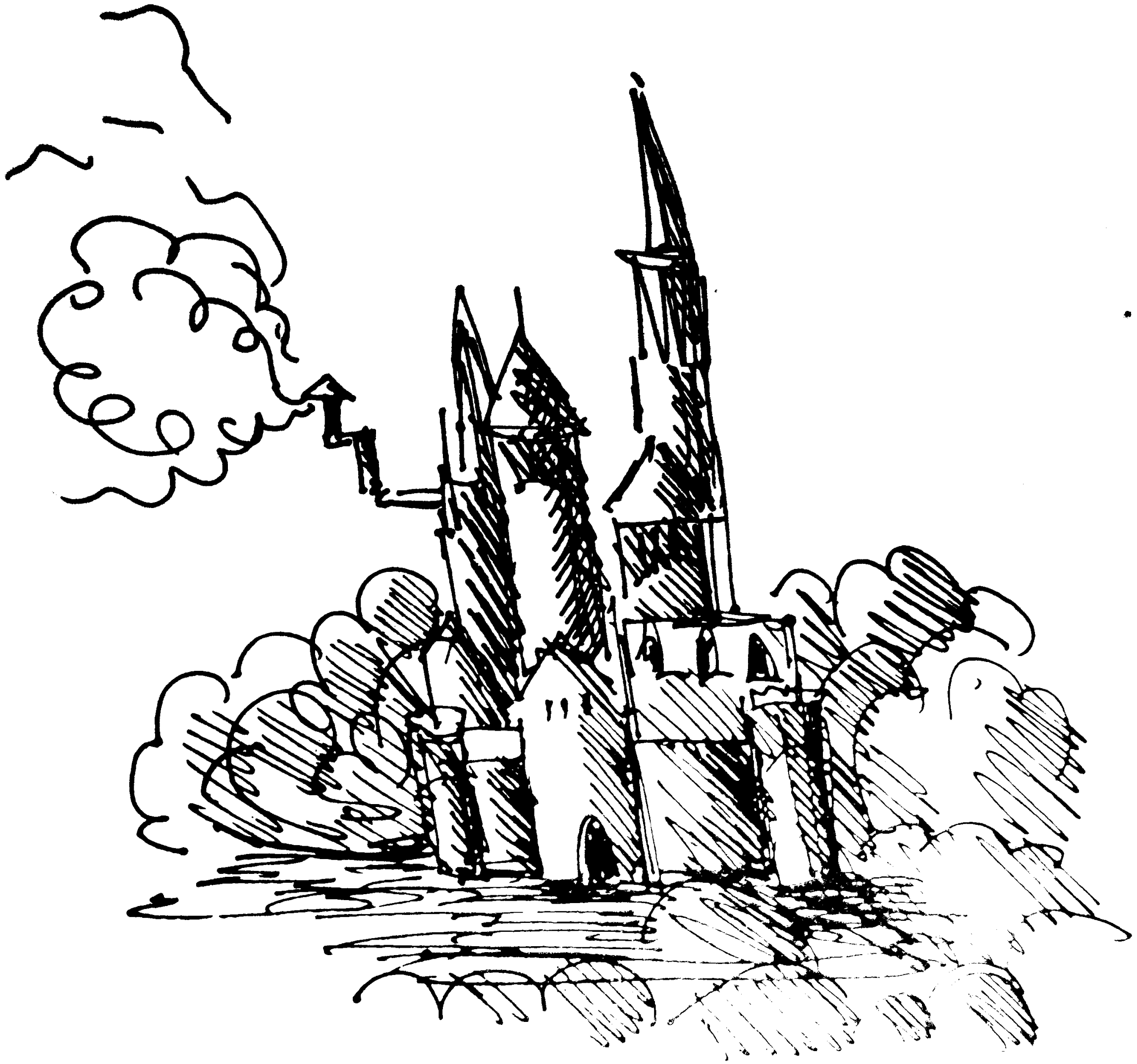
Why are we starting like this?

Create a means to protect a small group of humans from the hostile environment.

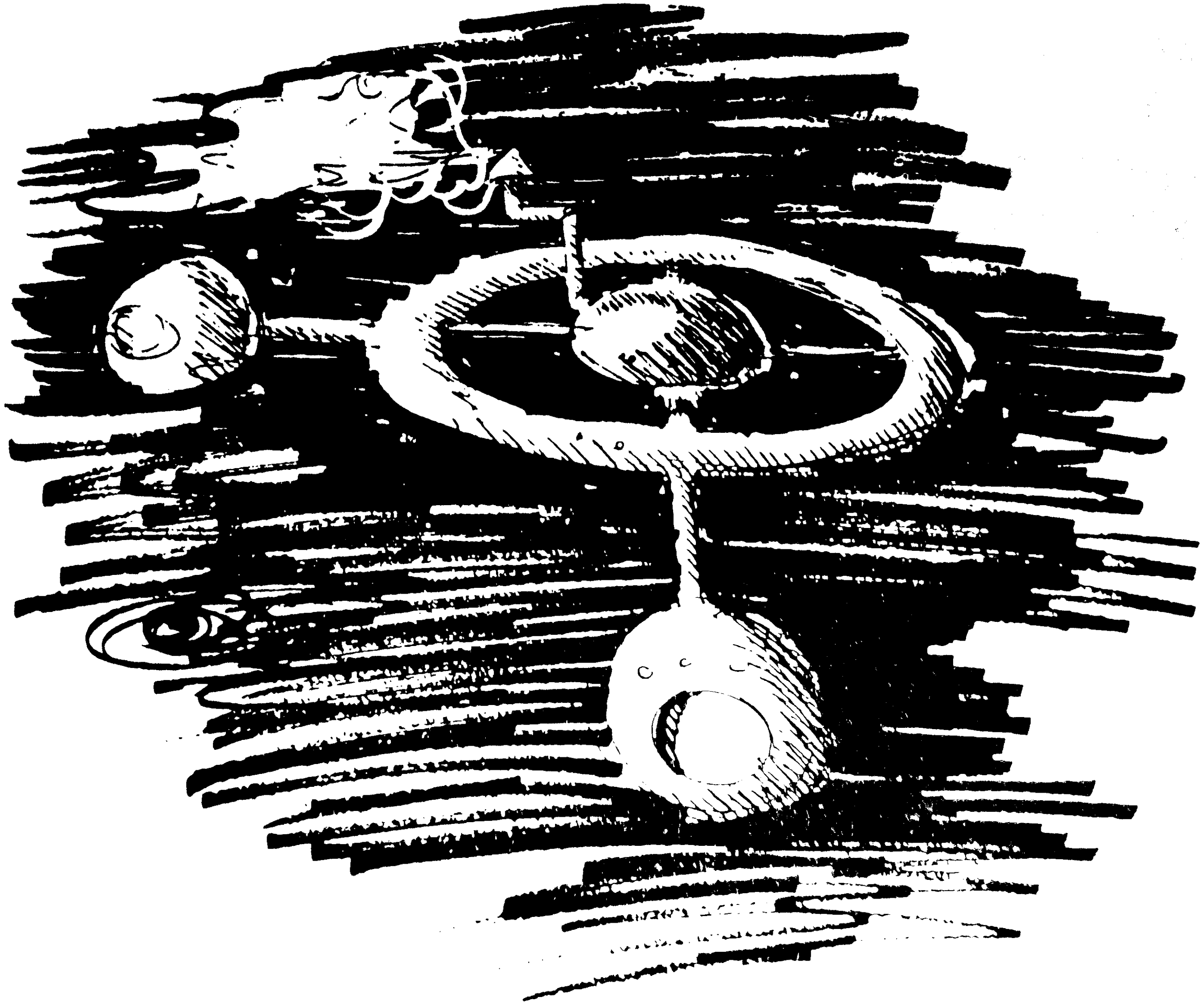
Example from: “Exploring requirements – quality before design” – Weinberg and Gause



Example from: “Exploring requirements – quality before design”



Example from: “Exploring requirements – quality before design”

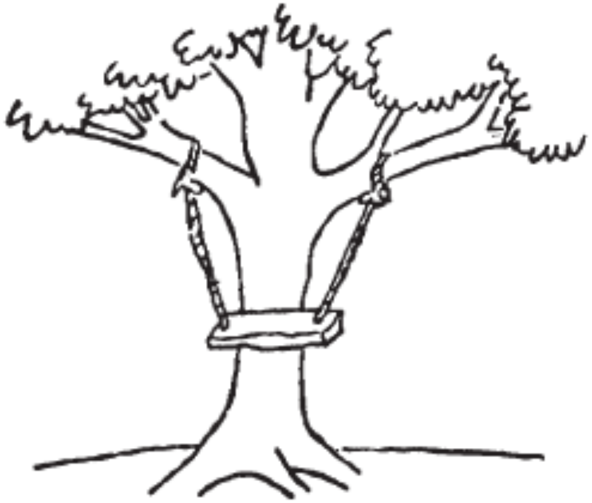


Example from: “Exploring requirements – quality before design”

As proposed by the project sponsor

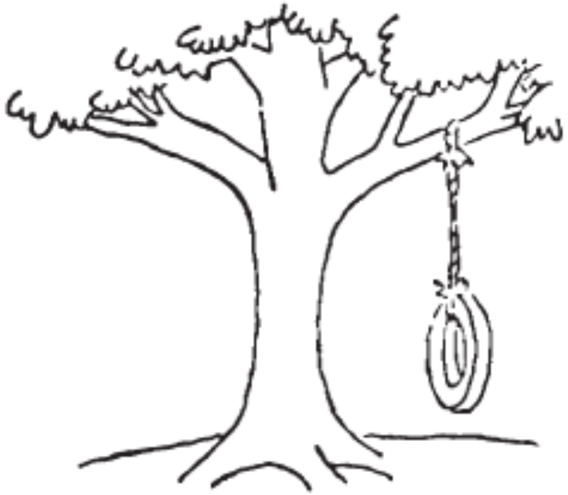
As specified in the project request

As designed by the senior designer



As produced by manufacturing

As installed at the user's site



What the user wanted

From Dieter 2013

Review of Problem Statements

- Brief
- Clear
- Unambiguous

- We are just not there yet.

Sources of project spaces.

- Your own observations

- Other people
  - Customers
  - Friends
  - Family
  - Hobbies

- Basically everywhere

- Assignment on Painstorming

Schedule

- Problems
  - First four classes
  - Order of the lecture content for these four classes is somewhat in flux…
- Planning and documenting a solution
  - Next eight-ish classes
- Miscellaneous topics
  - Last few lectures

Moving towards a problem definition

- Next time….brainstorming….moving from a project to a problem.

Painstorming (Brian Lily)

- Assignment
  - Problems are everywhere!
  - We tend to think about problems that we have direct experience with.
  - As such, others tend to think about problems they have experience with.
  - Get out, into the community, your job, your family, and find out what people have problems with!
  - You may talk to your fellow students, but (1) we prefer you didn’t and (2) only about their work or hobbies.

- To turn in, post on the Web board.
  - Everyone must post, this is an individual assignment.
  - Your post must include: your name, who you talked to, what you talked about, and the problem that they identified for you.
  - This problem can be vague, we will work on refining problem statements next week.

References

- http://cecs.wright.edu/~dkender/egr190/IntroEng(Notes).pdf