Engineering 180
Systems Engineering

Systems Engineering Overview

Professor Kenneth Kung

kennethkung@ucla.edu

(Cell) 562-387-3493

Credits

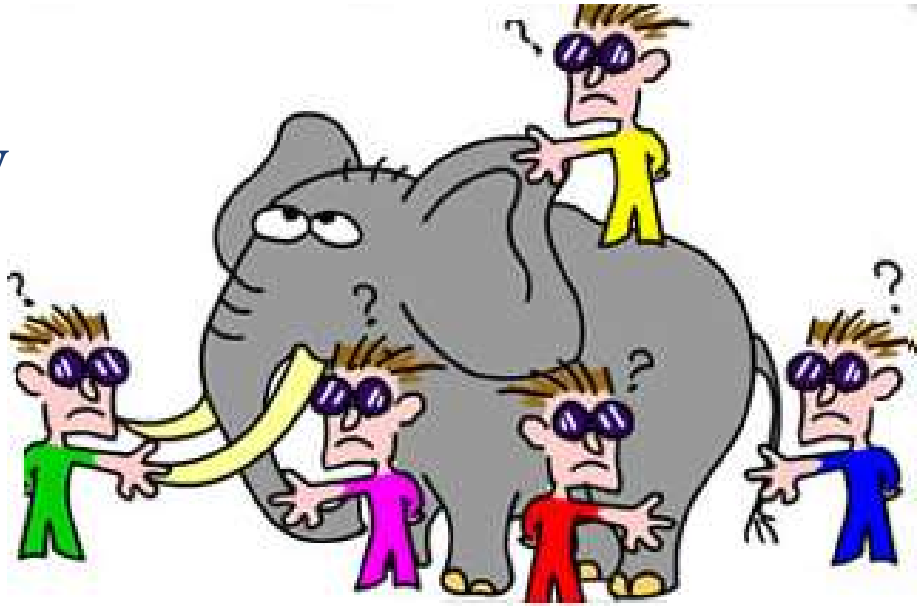
- History of this course
  - No specific discipline focus until late 1970's
  - ABET recommendations – resulted in today
  - Need for "cross discipline" education
- Professor Peter Pao
- Professor Neil Siegel

Outline

- Define Systems Engineering
- Why is Systems Engineering Important?
- What do Systems Engineer Do?
- Systems Engineer Career

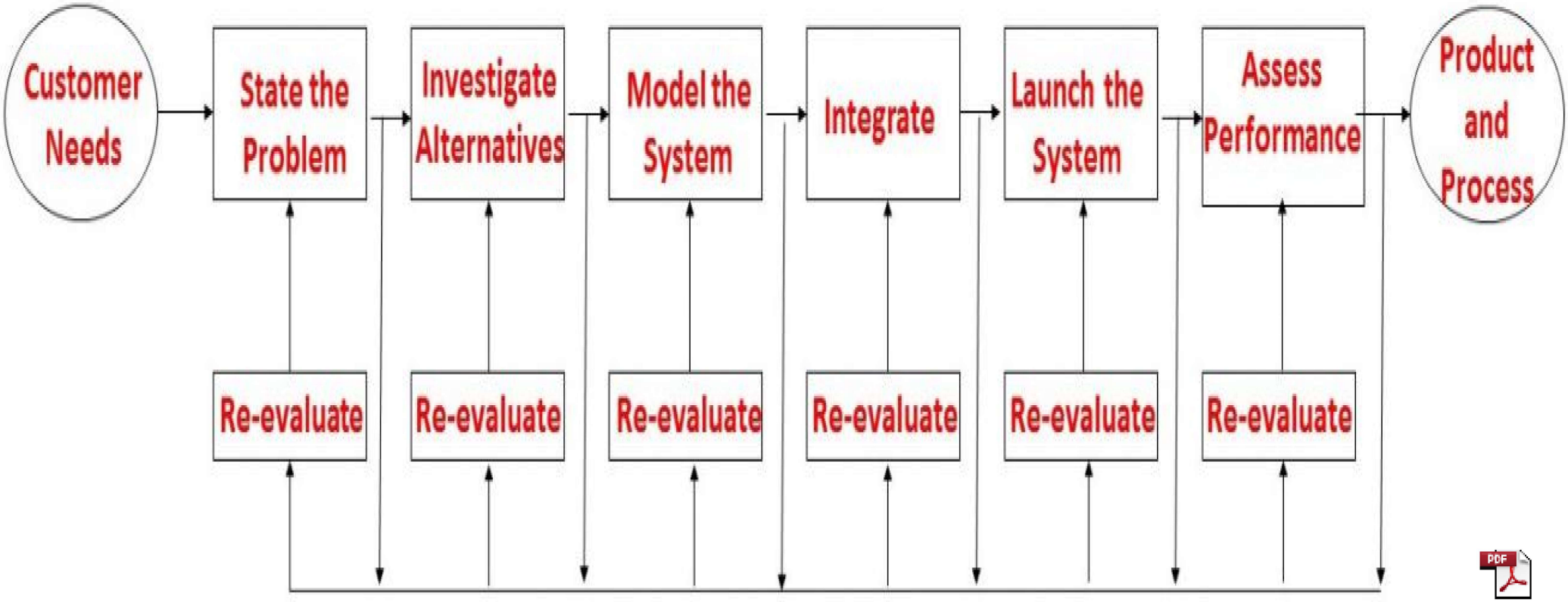
What is Systems Engineering?

- A Consensus of the International Council on Systems Engineering (INCOSE) Fellows
  - Systems Engineering is an engineering discipline whose responsibility is creating and executing an **interdisciplinary process** to ensure that the customer and **stakeholder's needs** are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system life cycle



INCOSE Systems Engineering Process

- The process is usually comprised of the following seven tasks (SIMILAR)

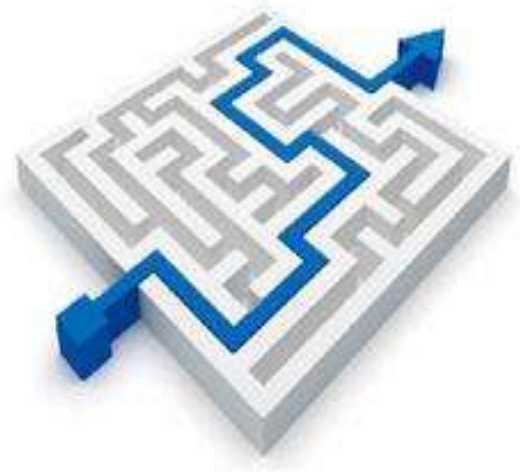


SIMILAR reference

Source Auburn University

History of Systems Engineering before 1950

- The term of "systems engineering" can be traced back to Bell Lab in 1940's
- In 1950, it was recognized by DOD, as an important skill to manage the development of complex systems, where:
  - The requirements are not well understood
  - Traditional "Design evolution" method is no longer feasible (*why*?)
    - A self-contained system that typically had relatively stable requirements, a sound scientific base, and numerous previous precedents
    - Sequential activities



History of Systems Engineering before 2000

- SE has been a hot topic for DOD and NASA during the last 40 years
  - Most of the program overruns and terminations can be attributed to the failures in systems engineering implementation

"Sometimes I get the crazy feeling that he blames us for the budget overrun."

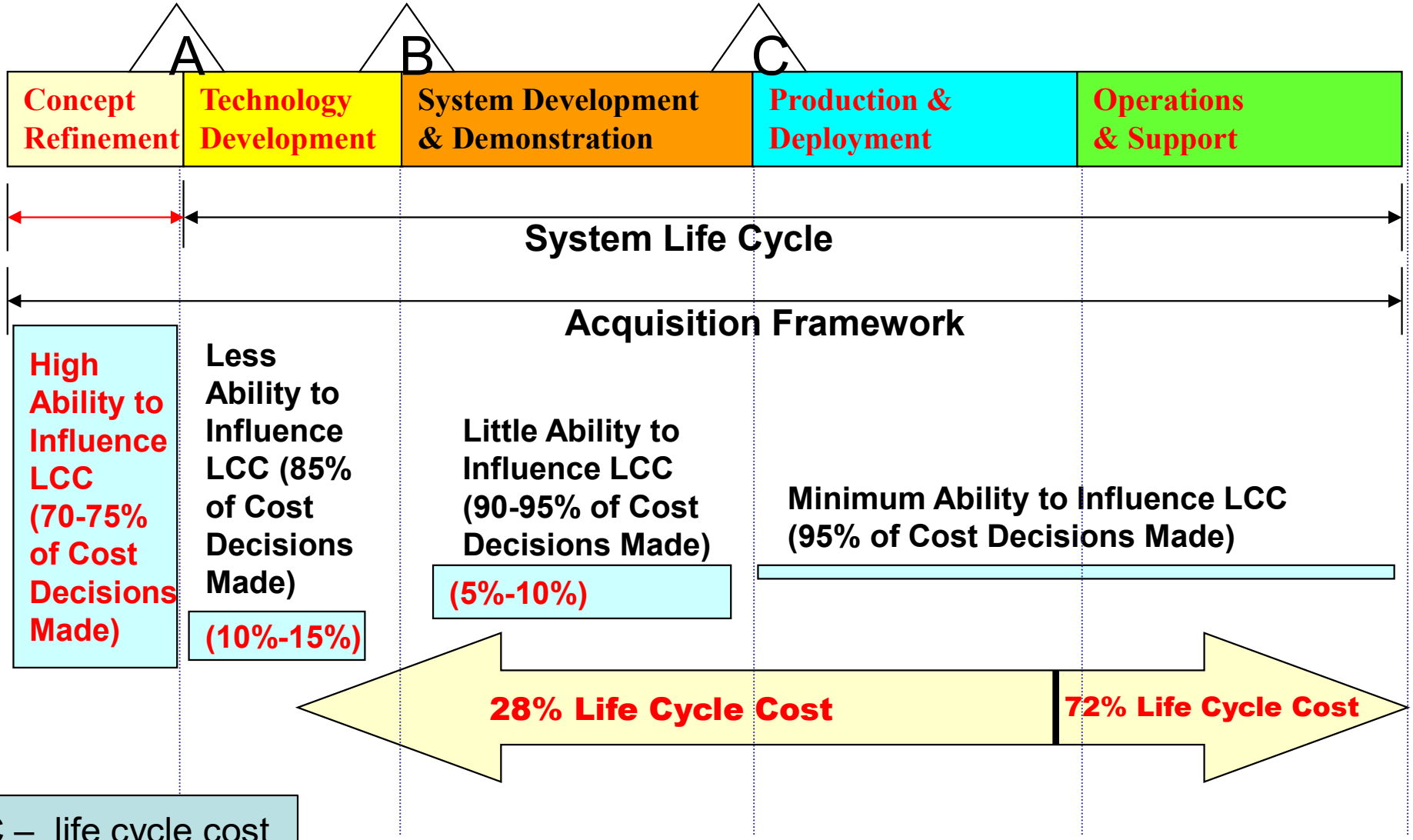
History of Systems Engineering before 2000 (cont)

- During the 90's, as a result of the growth of system complexity and the acceleration of technology evolution, **commercial sector** also started to recognize the importance of Systems Engineering
  - MIL-Spec versus commercial practices
- There has been continuous effort to expedite SE training, and to improve SE processes and tools
  - But we are still far from meeting this challenge!

Why is System Engineering Important?

Any thoughts?

90% of the life cycle costs are determined by the systems engineering effort in the early phases of the program



LCC – life cycle cost

Systems Engineering in the Commercial Sector

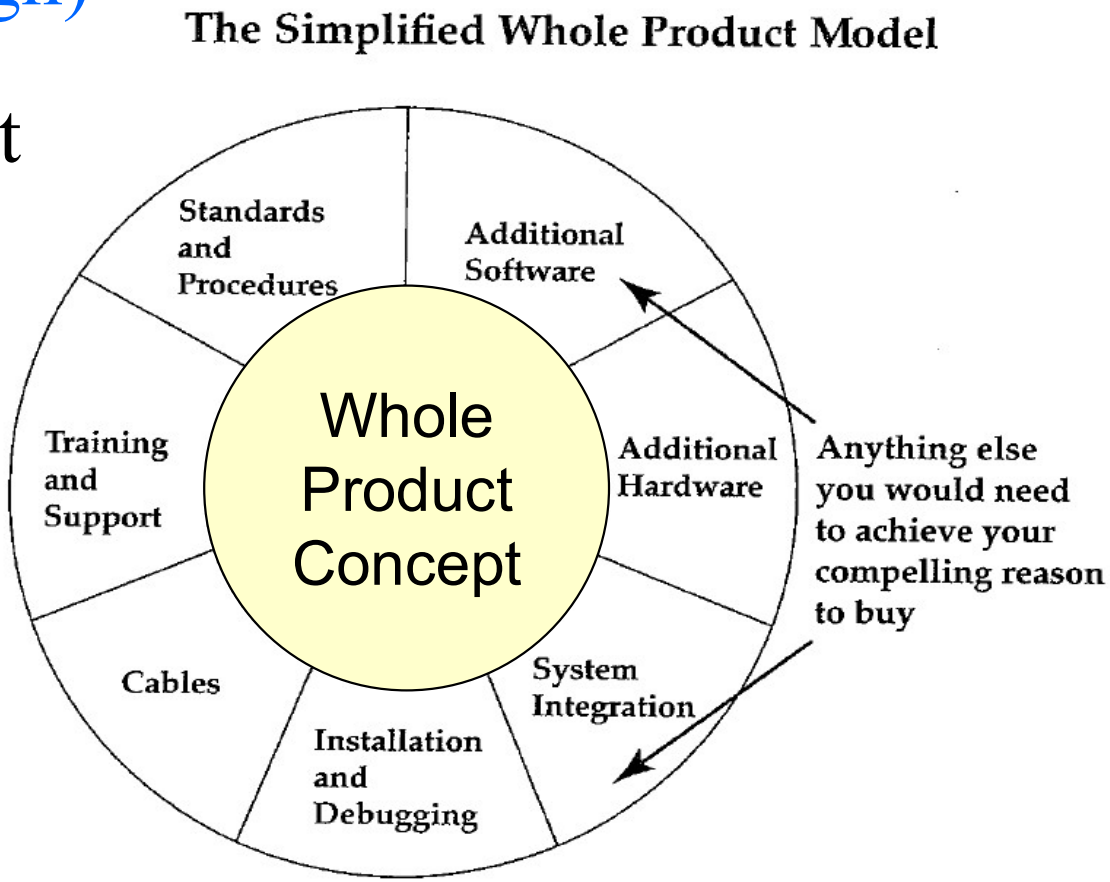
- Commercial companies that sell complex products have the same problems as the companies in the defense sector:
  - System complexity, uncertain requirements, rapid technology evolutions
- Companies that are in custom system business (Contracted projects) use similar SE processes as in the defense sector
  - Highway tolling system

Systems Engineering in the Consumer Products

- Consumer product companies have different business models. They identify products with market potential Design and built; and then sell them in the open market.
  - When the products are complex, systems engineering functions are also performed (sometime implicitly)
  - "Whole product", one of the most useful marketing concept developed in the last few years, is a good example of systems engineering in disguise
  - E.G., cell phone → smart phone

The "Whole Product" Concept

- For a product to be successful in the mainstream market, companies must understand the ecosystem of that product, and make sure all the products and services in the ecosystem are easily accessible to the customers
- The identification (or design) of an ecosystem and its elements is one of the most important parts of systems engineering
- Example: Intel Core processors



In Class Discussion

- Think about a product that you are familiar
  - If your team cannot come up with a product, then consider an autonomous vehicle for this exercise
- Consider the whole product model
  - What are some of the specifics for the figure on the last page?
  - You may expand the categories of the whole product model

What Do Systems Engineer Do?

Any thoughts?

What do systems engineers do during the program definition phase?

- Define the problem:
  - Identify customers and stakeholders
  - Understand their needs
  - Understand and develop the operational concept
  - Identify the constraints
- Define the system (or product) to be procured or built
  - Build the system specification (procurement spec)
- Make sure the problem is solvable. Identify risks and risk mitigation plans
- Develop product testing and evaluation strategies

It is marketing, it is management,
It is a lot of engineering, and it is about managing risk

What do systems engineers do during the development phase?

- Frame the solution
  - Develop the system architecture
    - Identify subsystems
    - Identify internal and external interfaces
    - Develop detailed operational concept
  - Validate the design using modeling and simulations
- Develop the subsystem specifications (requirement flow down), and support the make-buy decision and subcontract management
- Optimize design and balance all life cycle system issues
  - Cost, System deployment, reliability, maintainability, supportability, human interfaces

It is about system architecture, modeling and simulation, system optimization, logistics and supply chain management

What do systems engineers do during the integration and test phase?

- **Systems Engineers are the system integrators!**
  - Need to understand the system inside out to be a good system integrator
  - System integration needs to be planned, and is usually done in stages
- System tests and evaluations are performed at the completion of system integration
  - Three categories of test of evaluation:
    - Developmental test and evaluation (DT&E)
    - Acceptance test and evaluation (AT&E)
    - Operational test and evaluation (OT&E)
- There are also tests for other different purposes:
  - Performance level test
  - Environmental test
  - Reliability and supportability test, …

Systems Engineer Career

Career Path for Systems Engineers

UCLA SYSTEM ENGINEERING

- **Technical path** - Lead engineer, lead architect, lead system integrator
  - Systems engineers are at the center of product development. They understand the requirements, the architecture, the interfaces, and they are the system integrators. Their responsibilities could make them well prepared to be the technical leaders
- **Management** - Program manager, product line manager
  - Systems engineering is the "technical side of program management". Good systems engineers need to have good leadership and communication skills. By the nature of their responsibilities they will acquire market knowledge, and experience of working with customers. By adding some management training, systems engineers will be ideal candidates to manage programs and product lines.
- **Marketing**
  - Systems engineering and marketing overlap. Background in systems engineering could also be important for marketing functions.

My experience

Attributes of a Good Systems Engineer

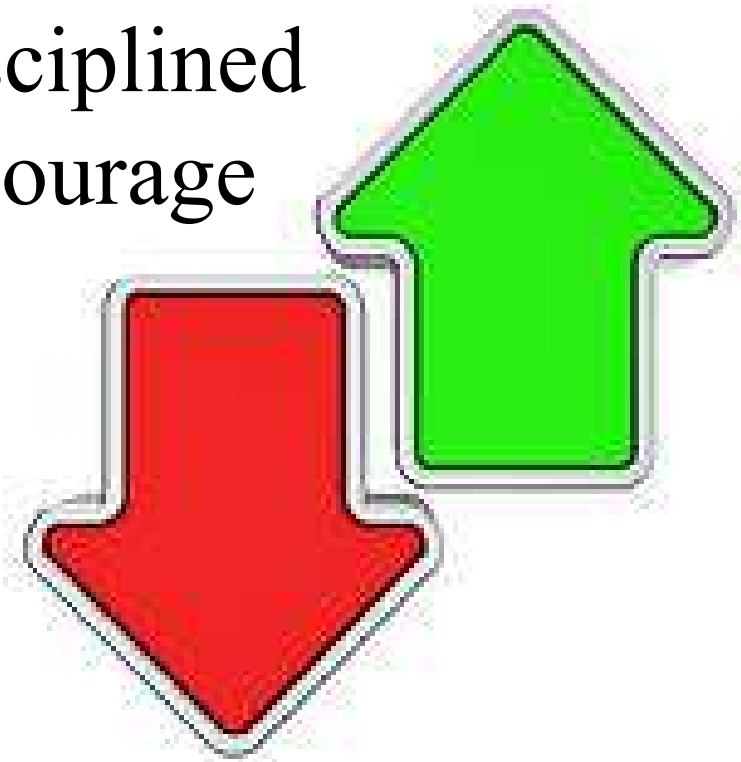
- Understand systems engineering processes, tools and methodologies
- Have strong domain knowledge: See the big picture and also pay attention to details
  - Ability to recognize which part of the system to pay attention
- Think logically, and strategically
- Be observant and always have the desire to learn
  - Ask the right questions
- Have broad technical background and experience
  - This can be gained by working a variety of assignments
- Be a good communicator
- Be a team player
- Have strong leadership skills

How to prepare yourself to be a good systems engineer?

- Have strong domain knowledge
  - A good systems engineer needs to be a good engineer first!
  - You have to start from somewhere – It is your domain area
- Understand the systems engineering processes, tools and methodologies
- Improve communication and leadership skills
- Become a life time learner
- You have to "care …" to be a good systems engineer
  - Always want to make "it" better
  - Don't tolerate loose ends
- Learn how to be a team player
- Find a mentor, and learn from work experience

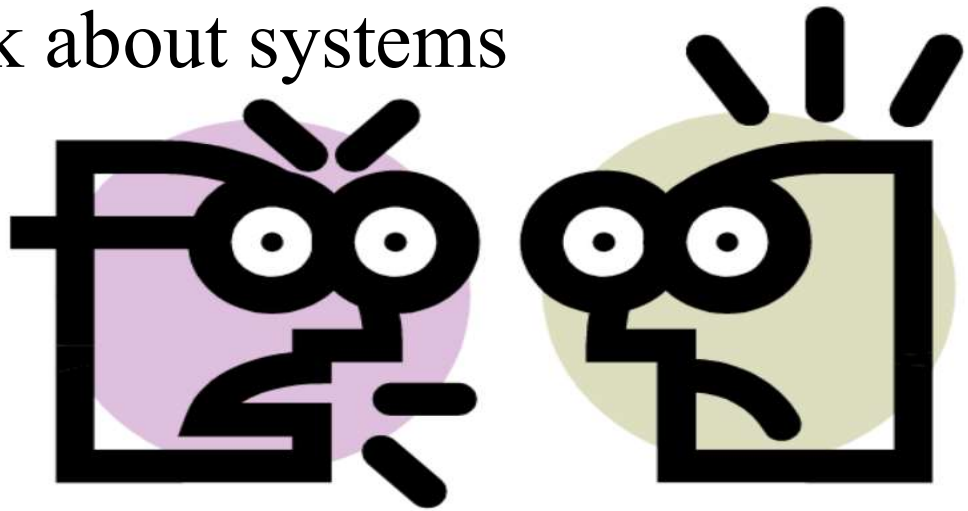
Systems Engineering "is" and "is not"…

- Following systems engineering processes increase the odds of program success
  - But it **does not** replace sound engineering judgments
- Systems Engineering uses disciplined processes, but it **does not** encourage bureaucracy
  - Flexible



Systems Engineering "is" and "is not"… (cont)

- Systems Engineering is interdisciplinary
  - Requires broad knowledge
  - It **does not** make any sense to talk about:
    - Systems Engineering in EE, CS, or …
- Systems Engineering is about building systems:
  - You must be an expert in the systems you are building
  - It does make sense to talk about systems engineering in communication systems, commercial airplanes, mass transportation systems, or …



Group Discussion

In-class Group Exercise

- What, in your view, is the most significant event in all of human history?

- Break into groups. Take 15 minutes, write down one event, with a couple justifications
  - About half a page

Dr Siegel Answer

- ***The doubling of the average length of human life***
- For hundreds of thousands of years, human life averaged around ***40 years***
  - . . . Until around 100 years ago
  - . . . When it started going up
  - . . . Reaching recently around ***80 years***

Dr Neil Siegel – Professor for Engineering 201

. . . and engineers deserve most of the credit

- Water treatment and delivery
- Sewage treatment and transport
- Motor-powered tractors
- Motorized transport and delivery
- Large-scale electricity generation and delivery
- Affordable, mass-scale refrigeration
- Canning and other food storage / preservation techniques
- And so forth

The National Academy rates these sorts of items as responsible for ***~80%*** of the addition to human life expectancy

Not medicine or medical care

My Answer

- Ability to exchange information quickly
  - Mainly via the communication networks
  - 50 year anniversary of ARPANet (2019)
    - Node Number 1 – UCLA 1969, Labor Day September 1
- A few hundred years ago
  - Few pages of week old events in newspaper
  - Information moved at the pace of a horse
  - Smoke signals, mirror to reflect sun lights, etc.
- Now …

Now We Have

- Lots of Methods to exchange information
  - Instant Messages
  - Tweeter
  - Facebook
  - Instagram
  - Tik Tok
  - Etc.
- Few thousand of books get published – daily
- According to Google
  - 41 Zetta Byte in 2019
  - 64 Zetta Byte in 2020
  - 79 Zetta Byte in 2021
  - 97 Zetta Byte in 2022
- Transmitted at the speed of light (fiber)

1 zettabyte = 10^{21} bytes

Most if not all of these improvements result from or can benefit from systems engineering

Aspire to be the best engineer