System Engineering
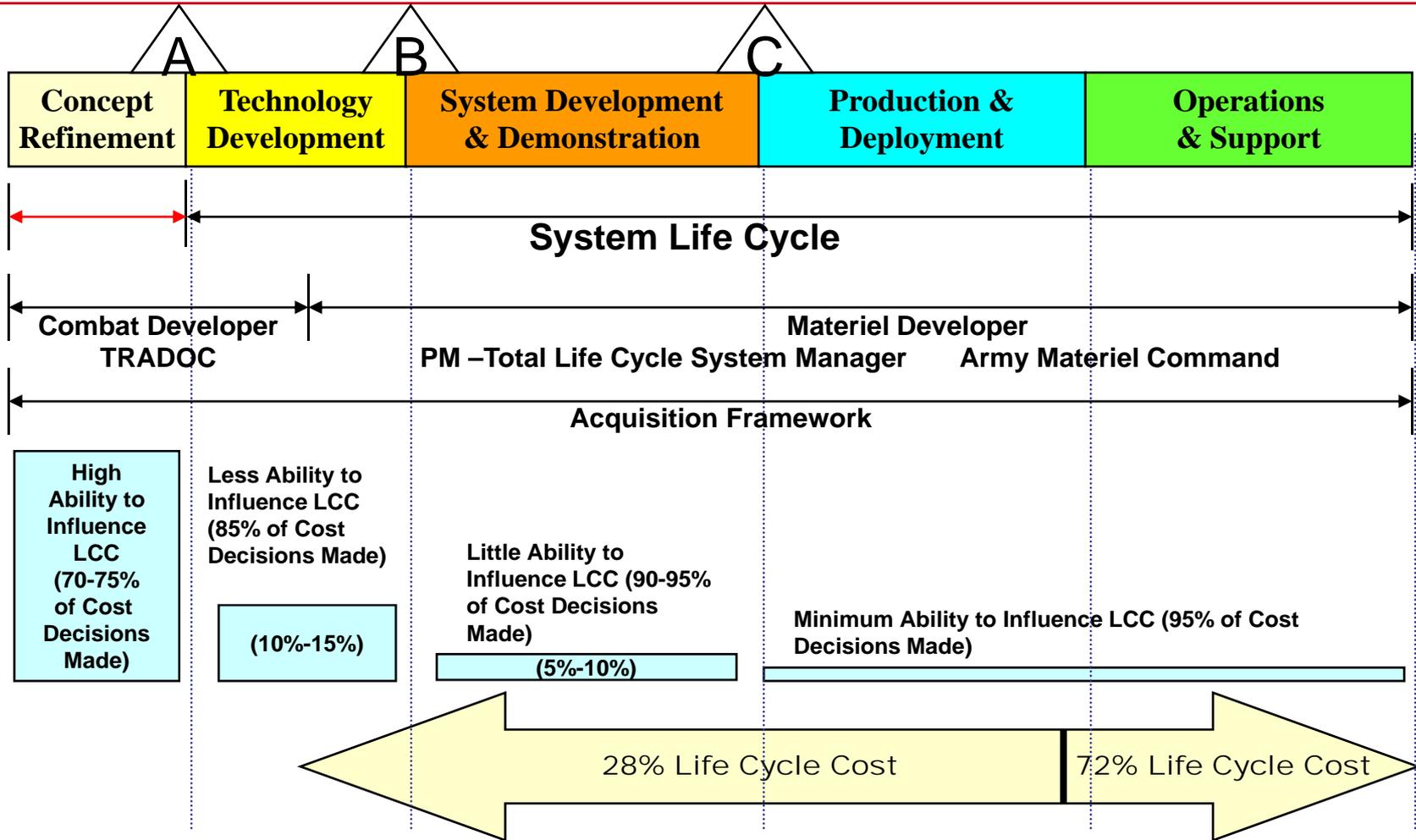
- What is it? Why System Engineering?

- How is it used in industry?

- How do you prepare yourself for a successful career as a System Engineer?

A Consensus of the International Council on System Engineering (INCOSE) Fellows

- System 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.**

- The process is usually comprised of the following seven tasks, SIMILAR:
  - State the problem,
  - Investigate alternatives,
  - Model the system,
  - Integrate,
  - Launch the system,
  - Assess performance,
  - Re-evaluate

The Schedule and Cost are largely determined in the system definition phase of the program

A	B	C		
Concept Refinement	**Technology Development**	**System Development & Demonstration**	**Production & Deployment**	**Operations & Support**

System Life Cycle

Combat Developer TRADOC

Materiel Developer

PM –Total Life Cycle System Manager   Army Materiel Command

Acquisition Framework

High Ability to Influence LCC (70-75% of Cost Decisions Made)

Less Ability to Influence LCC (85% of Cost Decisions Made)

(10%-15%)

Little Ability to Influence LCC (90-95% of Cost Decisions Made)

(5%-10%)

Minimum Ability to Influence LCC (95% of Cost Decisions Made)
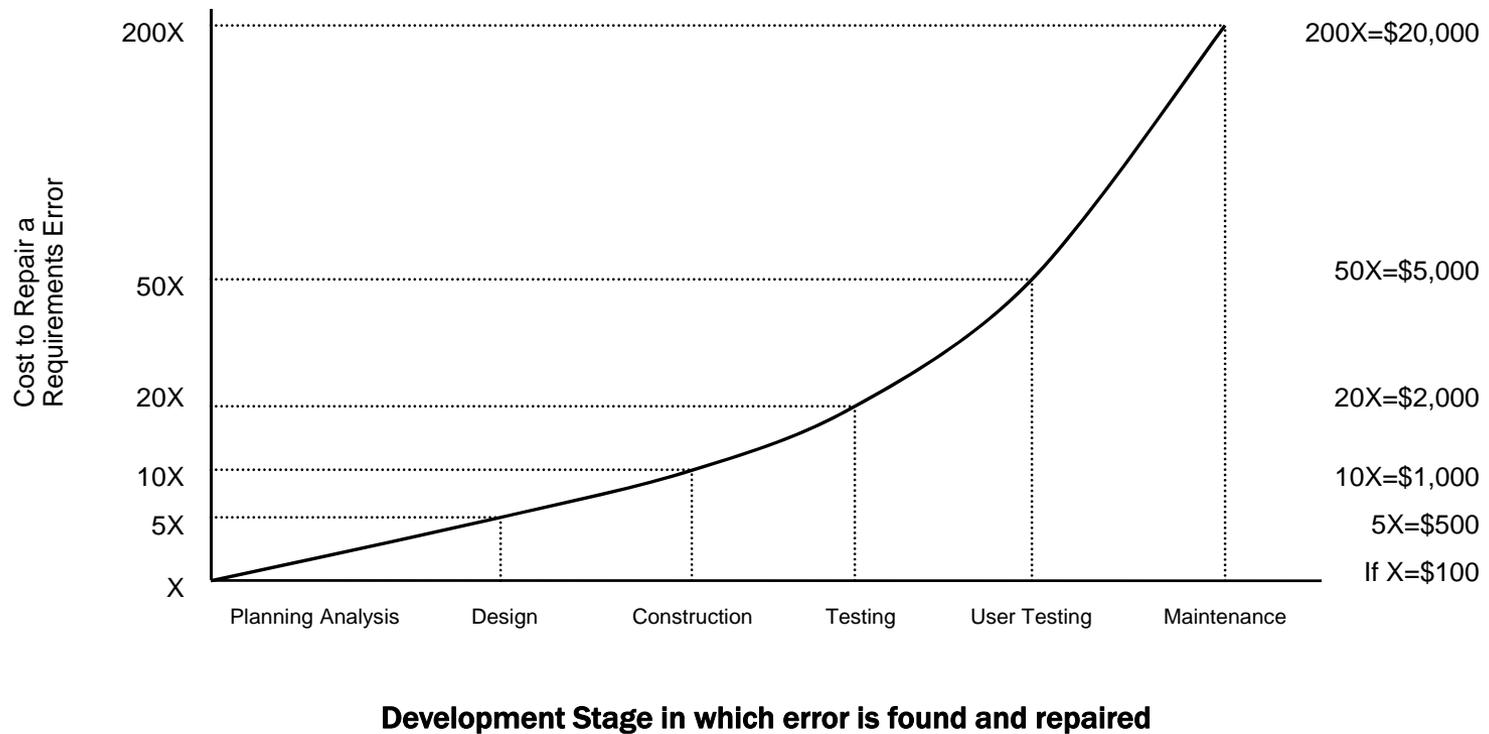
28% Life Cycle Cost   **72% Life Cycle Cost**

System Engineering translates the use's needs into a system and its architecture through an iterative process that results in an effective system design.

Cost Risk: Requirements Errors

The cost to repair a requirements error found during *Analysis* is x.

The cost becomes 200x if the error is not found until *Maintenance*.

Cost to Repair a Requirements Error (y-axis)

y-axis labels: 200X, 50X, 20X, 10X, 5X, X

x-axis labels: Planning Analysis, Design, Construction, Testing, User Testing, Maintenance

Right-side labels: 200X=$20,000, 50X=$5,000, 20X=$2,000, 10X=$1,000, 5X=$500, If X=$100

Development Stage in which error is found and repaired

Source: Davis, Alan. *Software Requirements: Objects, Functions & States.* 1993.

Most of the Program Failures in A & D Sector can be traced to System Engineering

- 2003 and 2005 Government Accountability Office (GAO)
  - Separate technology development from systems acquisition. Commit to a program only if the technology is sufficiently mature
  - **Stabilize the requirements early**
  - **Employ system engineering techniques before committing to product development**
- 2003 National Defense Industrial Association (NDIA)
  - **Increase SE awareness and recognize SE authority in the program formulation and decision process**
  - **Incentivize career SE positions within the government**
- 2003 Defense Science Board (DSB)
  - **Overhaul requirements process**
  - **Establish a robust SE capability**

System Engineering Is Becoming Increasingly Important to Commercial Industry

- **Commercial industry has been practicing system engineering based on common sense and experience**
    - **Air traffic control systems and Commercial airplanes**
    - **Wireless communication**
    - **Net computing**
    - **Civil engineering programs such as Big Dig and Yangtze River Dan**

- **Due to globalization, outsourcing, and international competition, the system integration and system engineering capabilities are becoming important competitive edge of US businesses.**

The System Engineering are done differently in different markets!

System Engineering is the "Front End " of Businesses

It defines what to be done.

During product definition phase (conceptual design), system engineers:

- – Identify customers and stakeholders
- – Understand their needs
- – Understand and develop the operational concept
- – Identify the constraints
- – Translate it into a system specification (procurement spec)
- – Make sure the system is feasible
- – Identify risks and development risk mitigation plans
- – Develop product test and evaluation strategies

*It is a bit of marketing, a bit of management,
whole lot of engineering, and it is about risk management.*

System Engineers frame the solution

During product development phase, system engineers:

- Develop the architecture of the solution
  - Major building blocks (subsystems), internal and external interfaces
  - Detailed operational concept
  - Building code - Standard and conventions
- 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 balanced all life cycle system issues
  - Cost, System deployment, reliability, maintainability, supportability, human interfaces

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

System Engineers are the system integrator!

System Engineering "is" and "is not"….

- Processes are important, but knowing the processes **does not** make one a system engineer.

- Following system engineering processes increases the odds of program success. But it **does not** replace sound engineering judgments.

- Reviews and documentations are important steps in system engineering process. But system engineering **does not** encourage buarcracy

System engineering is an inter-disciplinary. Team work is necessary!

Attributes of System Engineers

- See the big picture, and think system-strategically
- Have broad knowledge and experience
- Understand the tools and methods
- Equipped with good communication and leadership skills

But don't forget

Good system engineers must have strong domain knowledge!

- System engineer in Communication
- System engineer in Information Based Systems
- System engineer in Airborne and Space Systems
- System engineer in Civil Systems