Requirements Engineering Overview

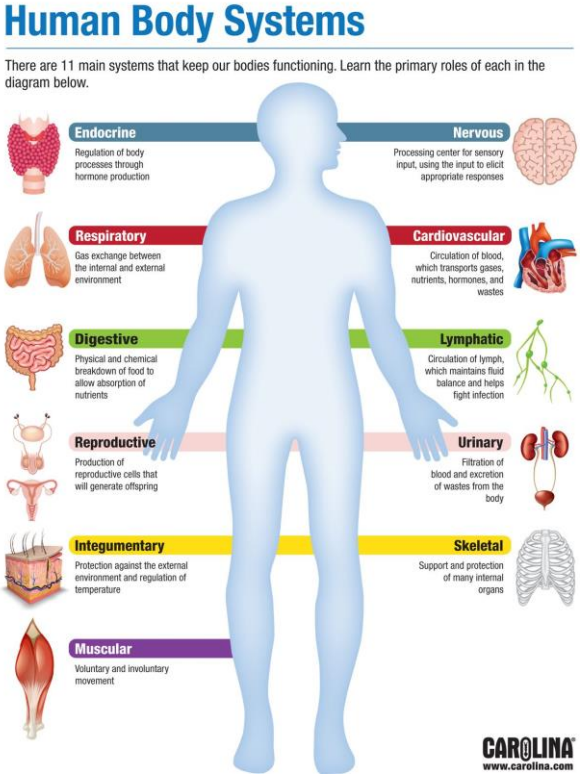
Outline

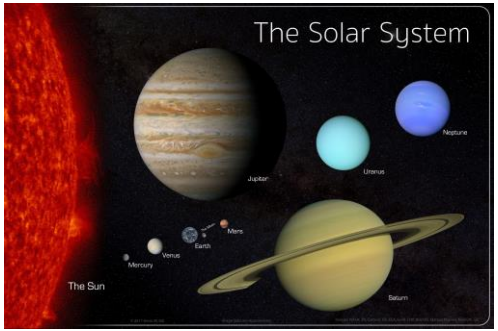
- What is a System?
- The Need for Systems Engineering
- What is Systems Engineering?
- System Lifecycle
- Understanding the Problem
- Greenfield and Brownfield Projects
- Requirements Engineering

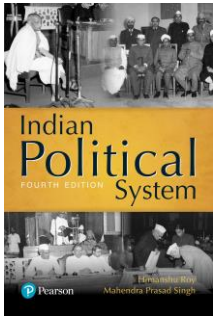
What is a System?

What were some “**systems**” that you were first familiar with?

Familiar Systems







Identify “**systems**” in this room

What qualifies these to be “**systems**”?

A System

is

- a set of elements in interaction.
  (von Bertalanffy 1968)

- an arrangement of parts or elements that together exhibit behaviour or meaning that the individual constituents do not.
  (INCOSE, ISO/IEC/IEEE 15288)

An Engineered System

is

- a system designed or adapted to interact with an anticipated operational environment to achieve one or more intended purposes while complying with applicable constraints.
  (INCOSE)

An Engineered System

has

- a structure (system elements, attributes, hierarchy)
- an intended behaviour (function, state)
- a boundary (physical or conceptual; static or dynamic)
- a life / lifecycle
- a context or environment within which it exists and operates
(operating environment)

The Need for Systems Engineering

Challenges in Current Landscape

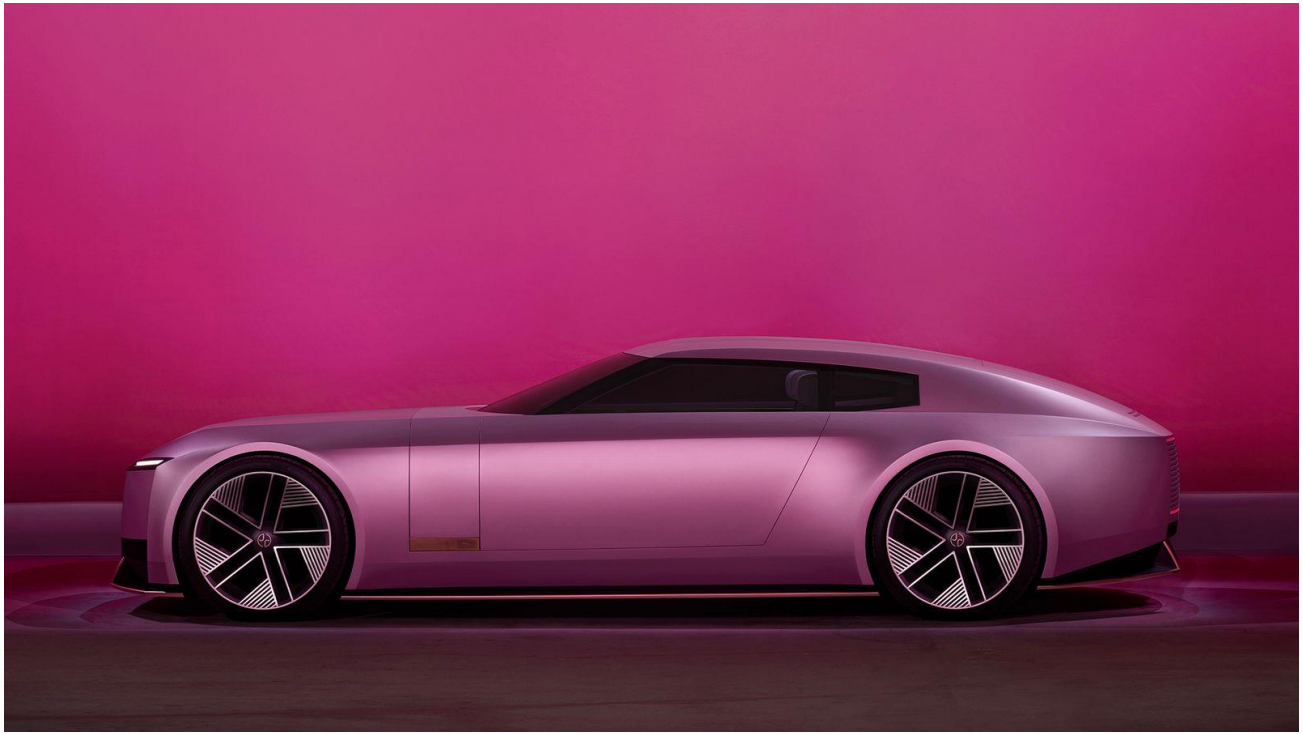
- Quicker, Better, Cheaper
  - Lesser time-to-market; no time for testing
  - Demand for more feature and capabilities
  - Lesser Cost
- Rapidly changing technology
- Dwindling resources, limited budget
- Constantly changing requirements
- Greater international competition

What's the Difference?

What are some things that developers of the **New-Gen Ambassador** must consider that developers of **Old-Gen Ambassador** did not have to?

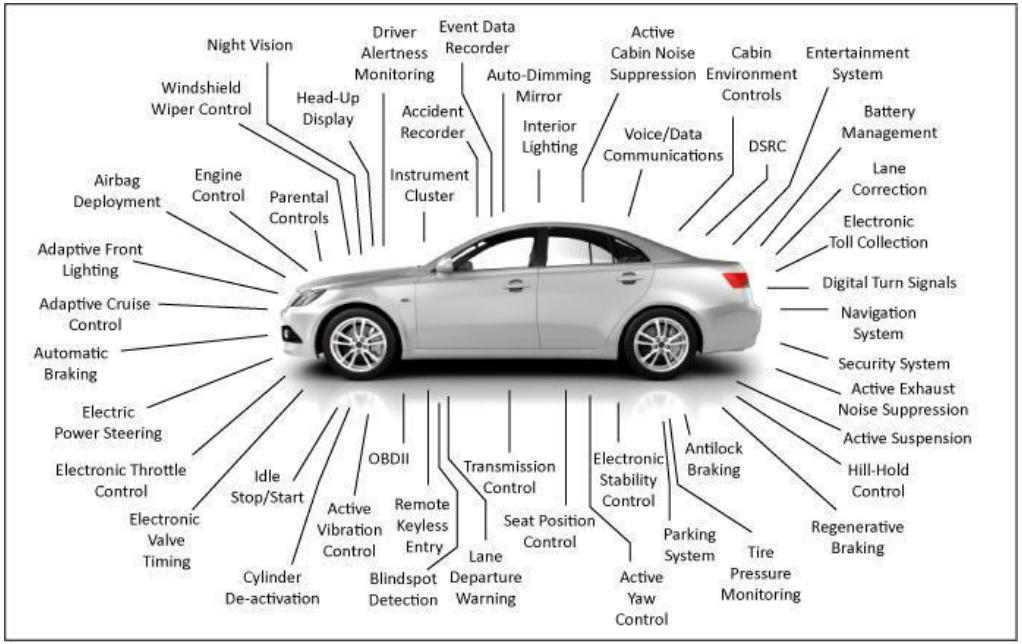
New Cars

New Concept Car



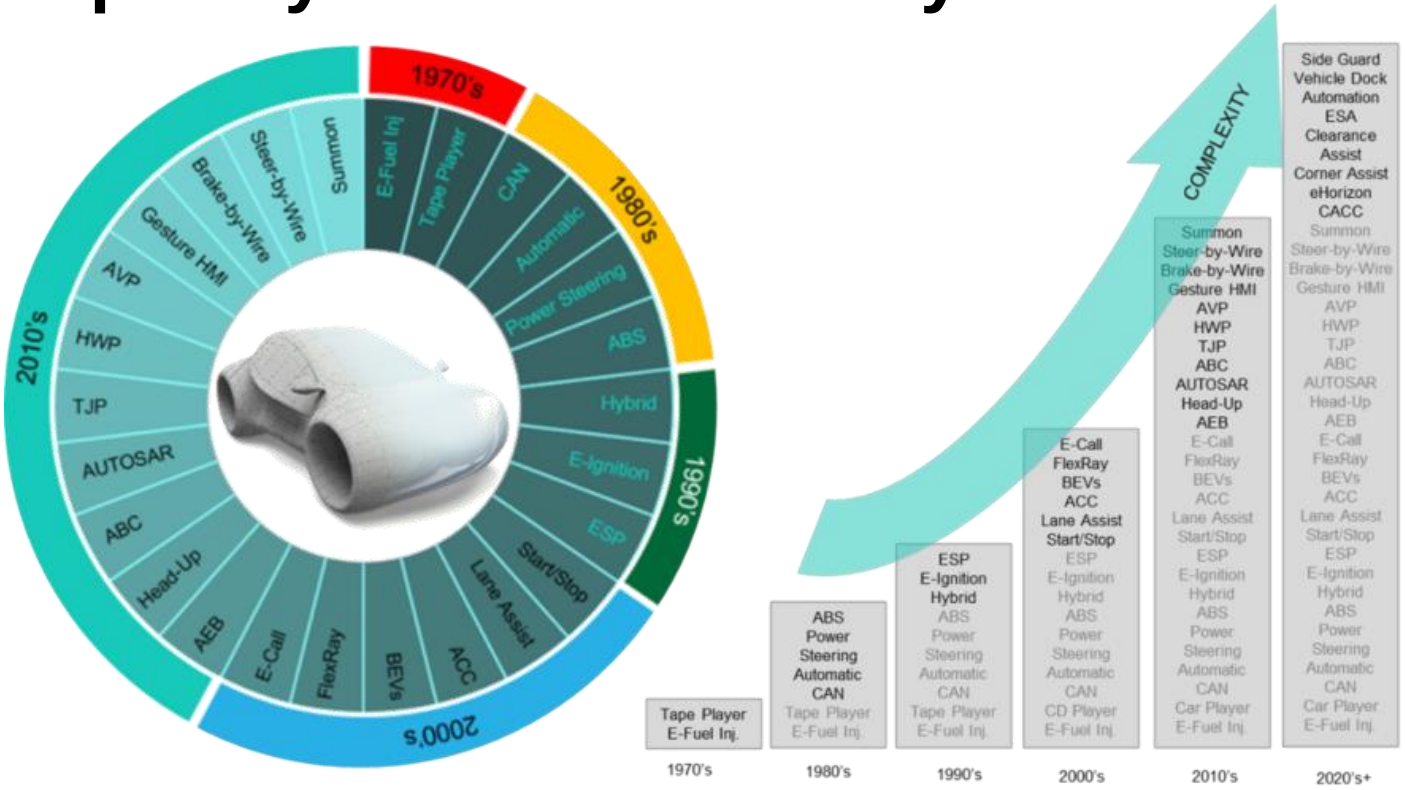
Today's Complex System

- Today's car is a multidimensional aggregation of multiple, complex electromechanical functions – each a complex system in itself – which must work closely and seamlessly with each other, and whose details are invisible to the vehicle driver.



https://www.eeworldonline.com/todays-complex-system-systems-driving-need-sophisticated-tools-detailed-modeling-data-continuity/

Complexity of Automotive Systems Overtime



https://www.theengineer.co.uk/content/in-depth/applying-systems-engineering-to-complex-connected-vehicles/

Global Automotive Trends

Population Growth and Urbanization

Aging population

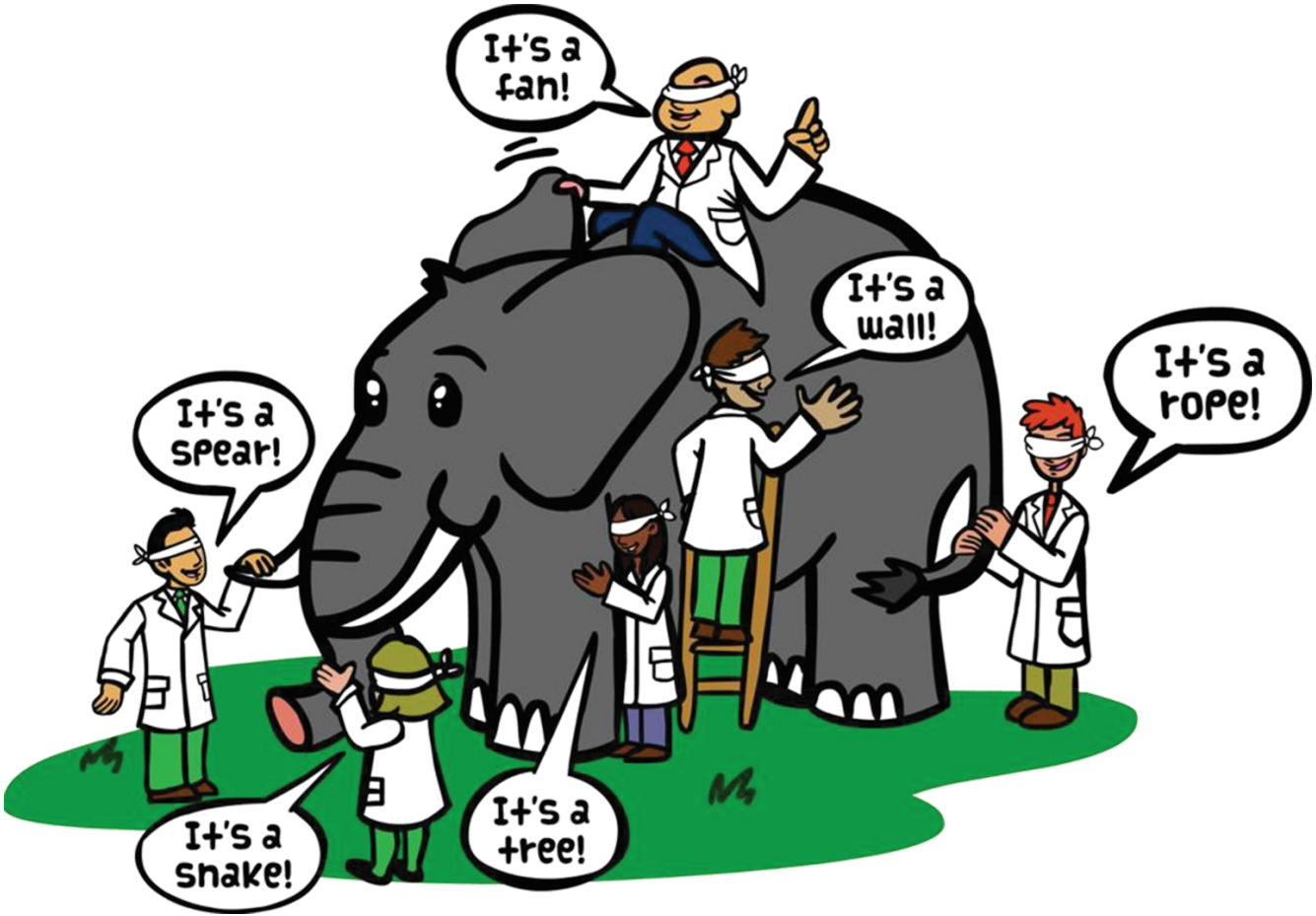
Environmental factors such as air quality

Consumer attitude shift from ownership to services

Changing workforce demographics

Ubiquitous connectivity and cybersecurity

What is Systems Engineering?



“Systems Engineering focuses on ensuring the pieces fit and work together to accomplish the objectives of the whole, across the system’s lifecycle.”

Source: Systems Engineering Book of Knowledge

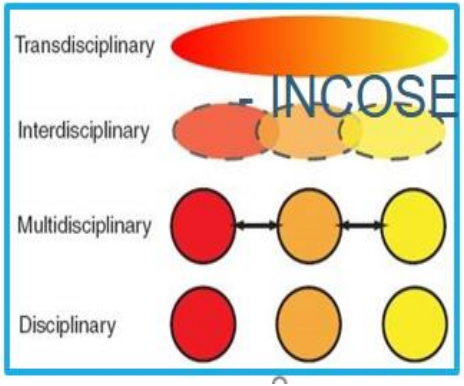
Systems Engineering

*A **transdisciplinary** and integrative approach to enable the **successful** realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods.* (INCOSE)

Adopting an SE Approach (for system development)

Significantly Increases the Likelihood of…

- Higher success rates (First time right)
- Overall Cost & Time benefits



How SE benefits

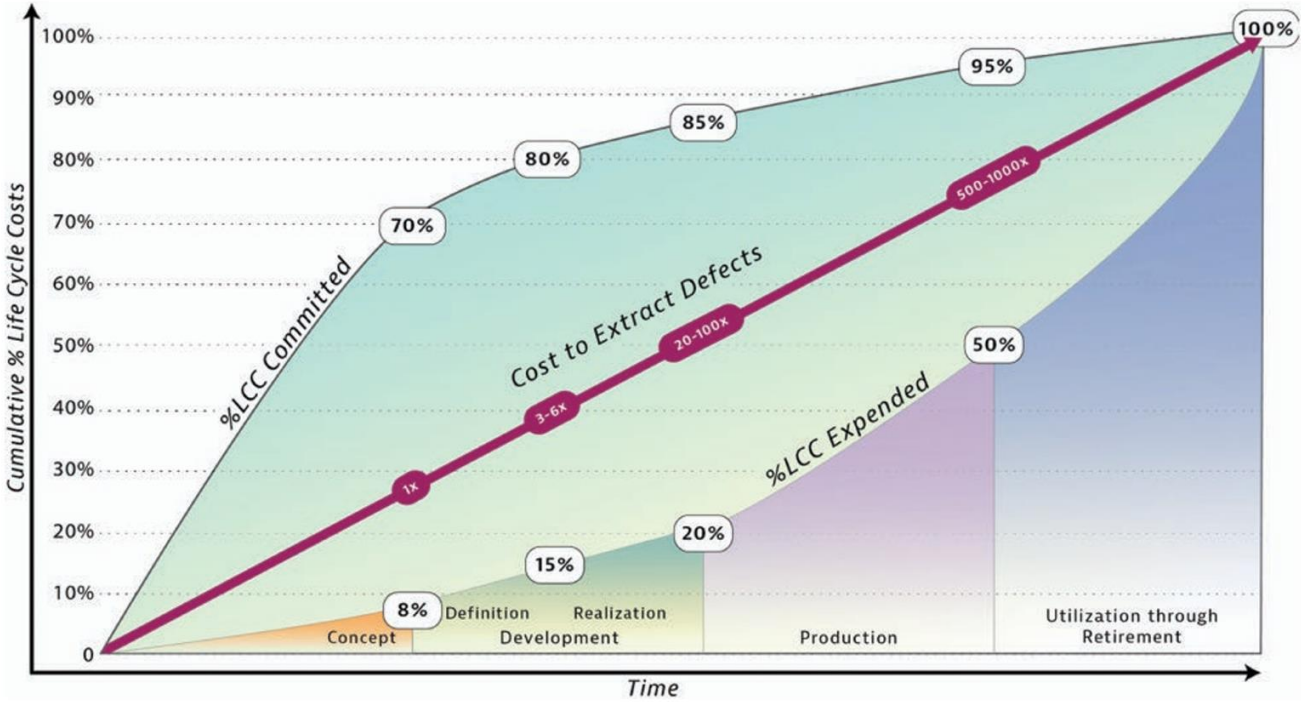
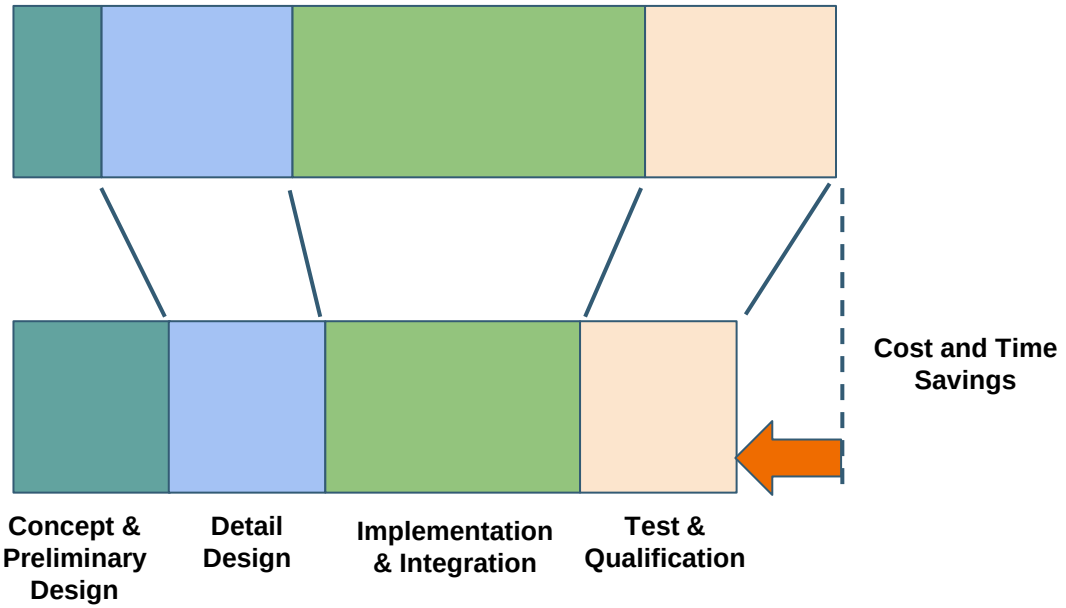


FIGURE 1.4 Life cycle costs and defect costs against time. INCOSE SEH original figure created by Walden derived from DAU (1993). Usage per the INCOSE Notices page. All other rights reserved.

Source: SE Handbook

Systems Engineering Impact



System Life Cycle

Life Cycle Stages

- To effectively manage the progress of a system, its overall life is broken into stages

Generic life cycle (ISO/IEC/IEEE 15288:2023)

<table>
<tr><td rowspan="2">Concept stage</td><td rowspan="2">Development stage</td><td rowspan="2">Production stage</td><td>Utilization stage</td><td rowspan="2">Retirement stage</td></tr>
<tr><td>Support stage</td></tr>
</table>

- Life cycle stages can be executed multiple times, in parallel, and in an overlapping manner.
- Decision Gates are introduced between the life cycle stages

Life Cycle Models

The framework within which the individual life cycle stages and transitions between them are planned and implemented

- Waterfall
- DevOps
- V model (Sequential)
- Incremental
- Evolutionary

WATERFALL MODEL

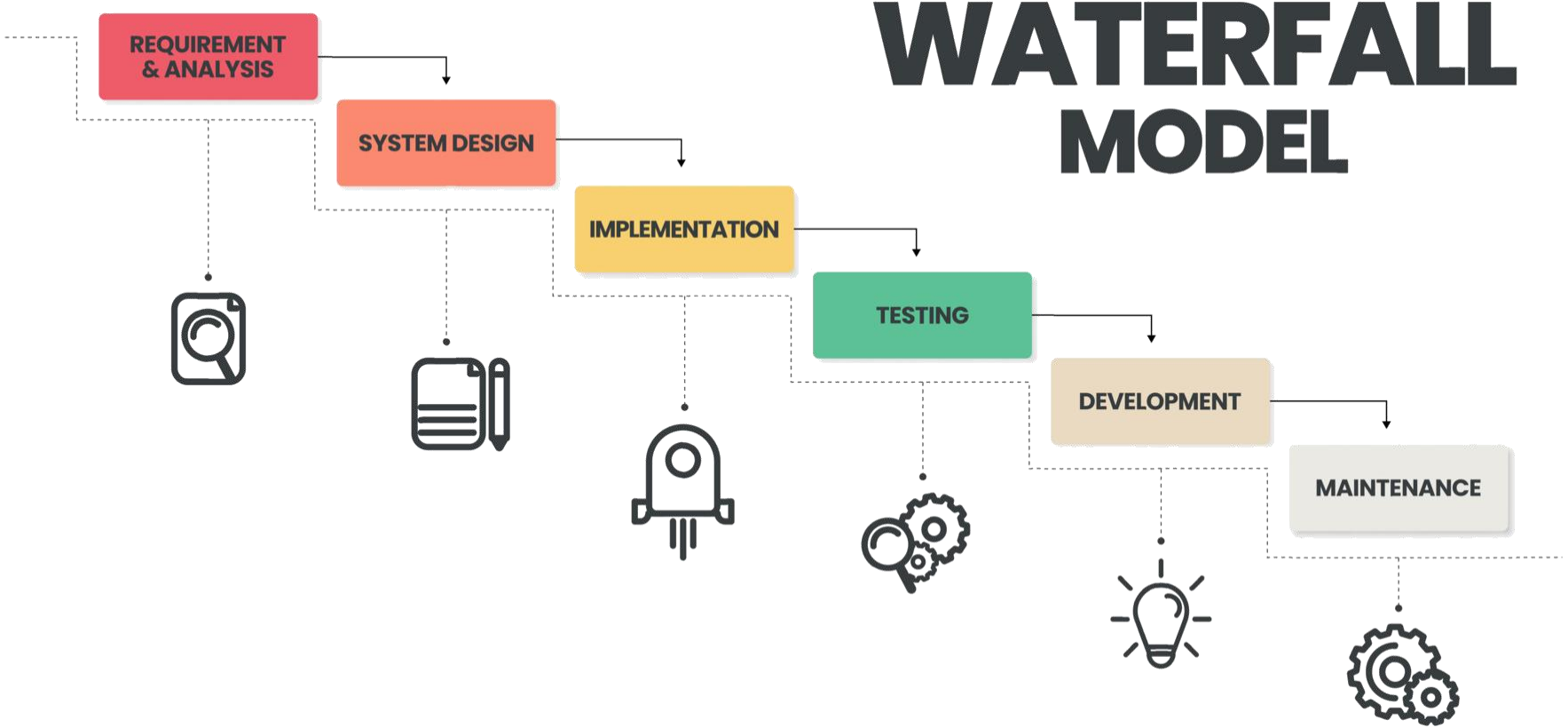
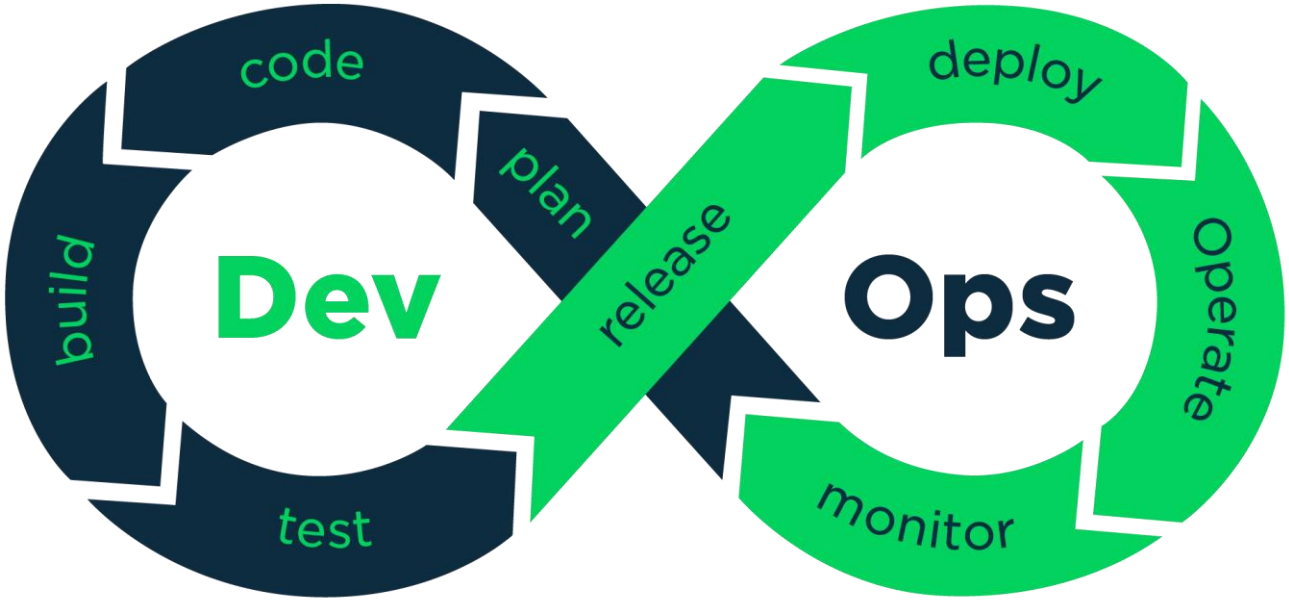


Image Source: Vecteezy

DevOps



Systems Engineering V

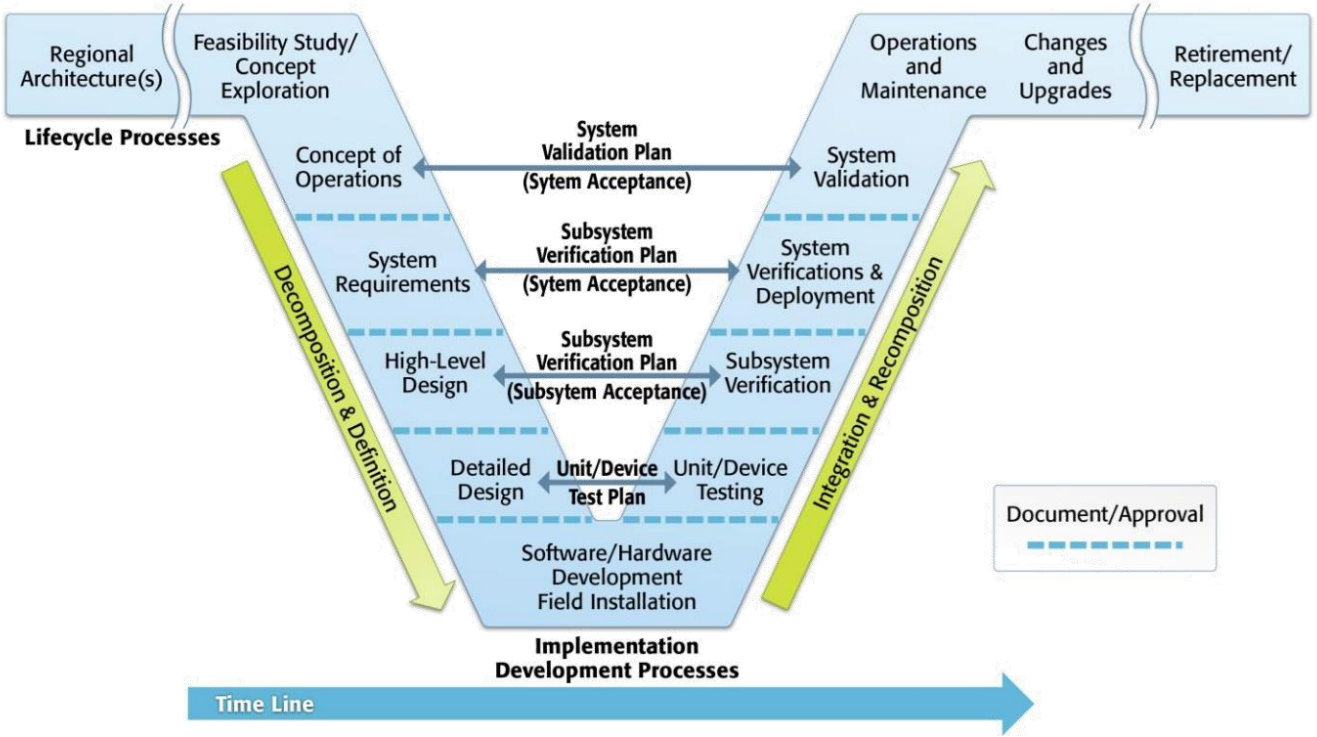
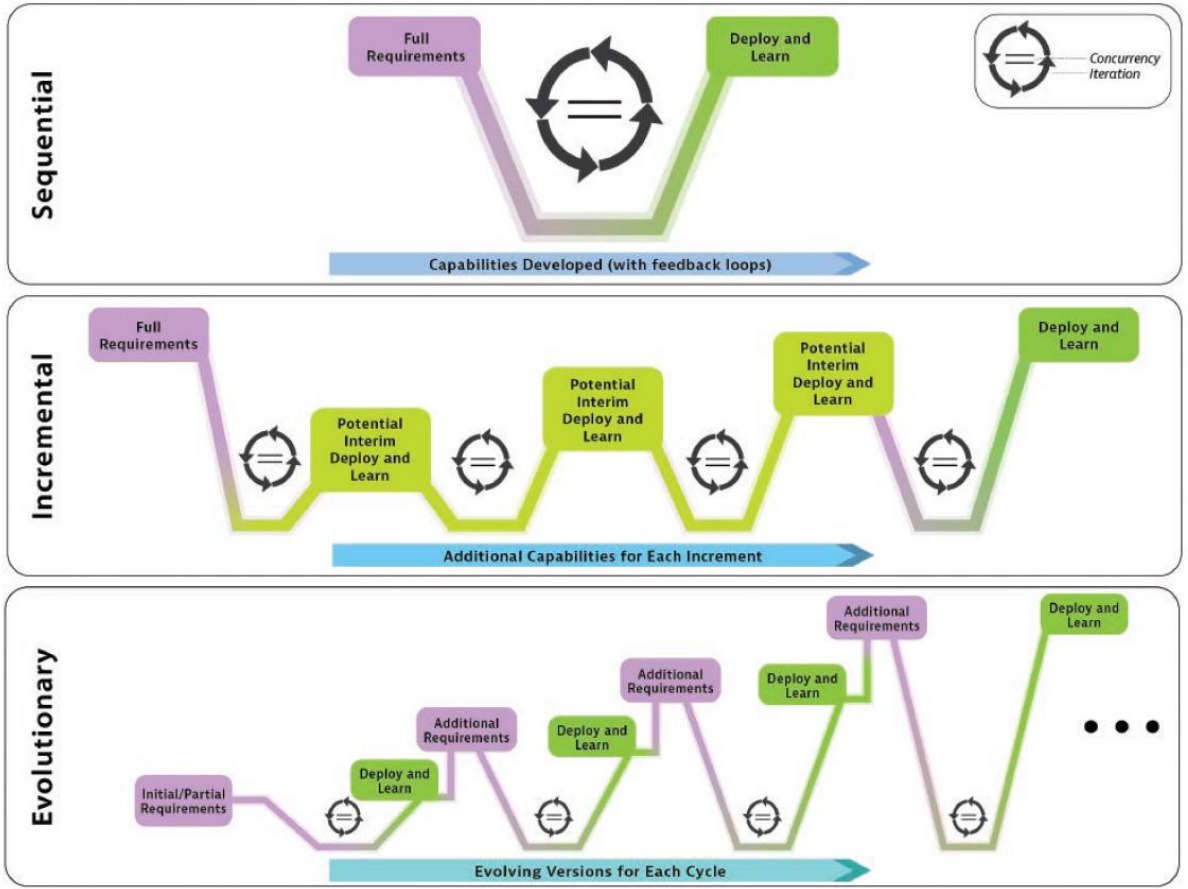
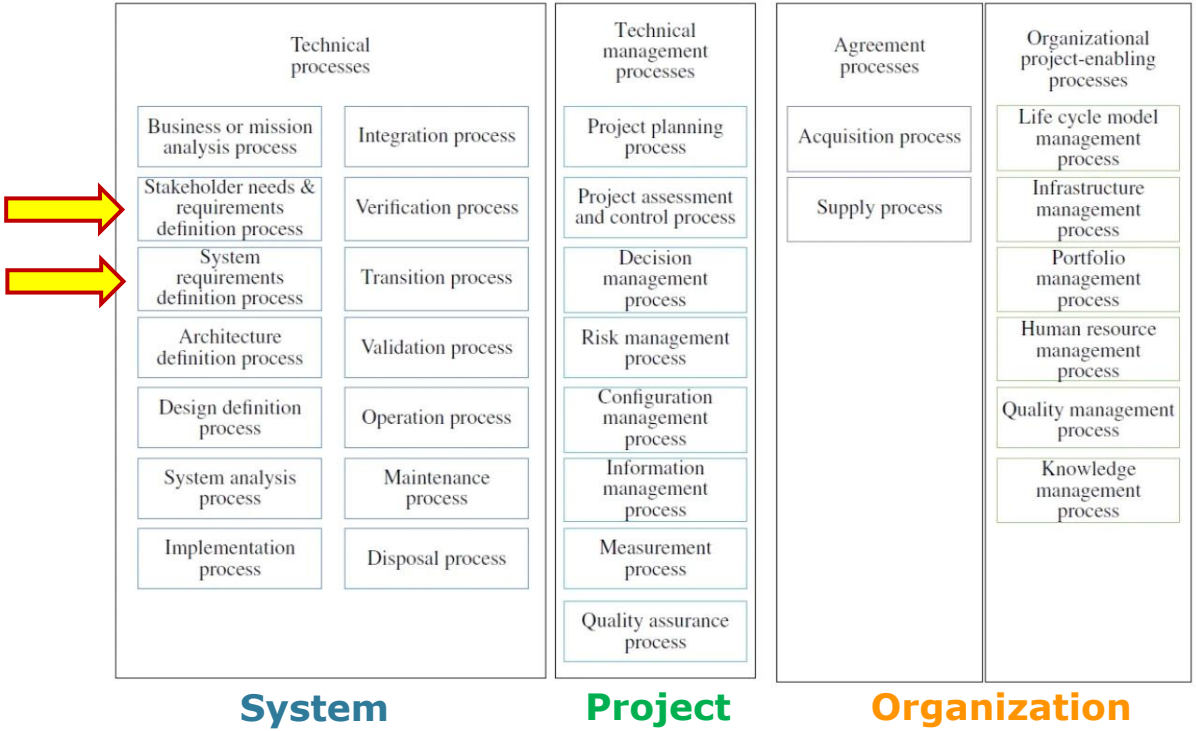


Image source: USDOT



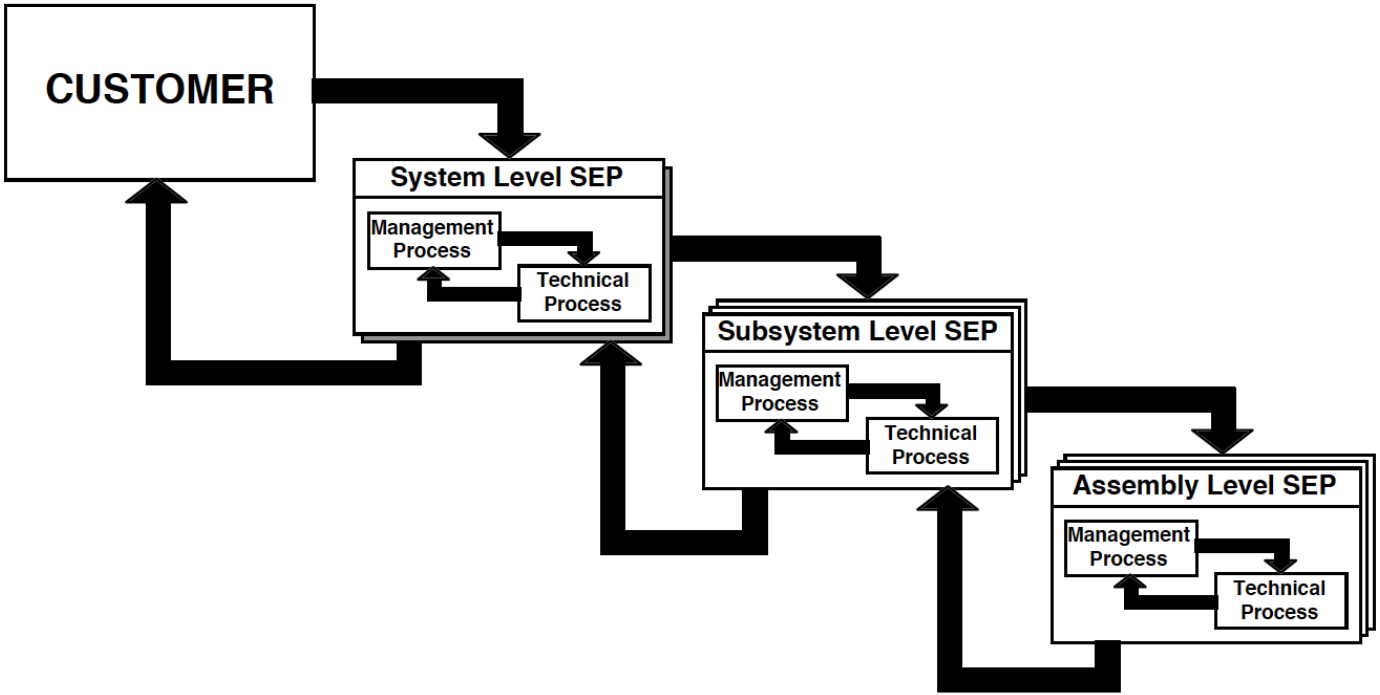
Source: INCOSE Systems Engineering Handbook, 5th edition

Systems Engineering Lifecycle Processes



Source: INCOSE Systems Engineering Handbook v4

SE Process



Lockheed Martin Corporation

Automotive SPICE process reference model

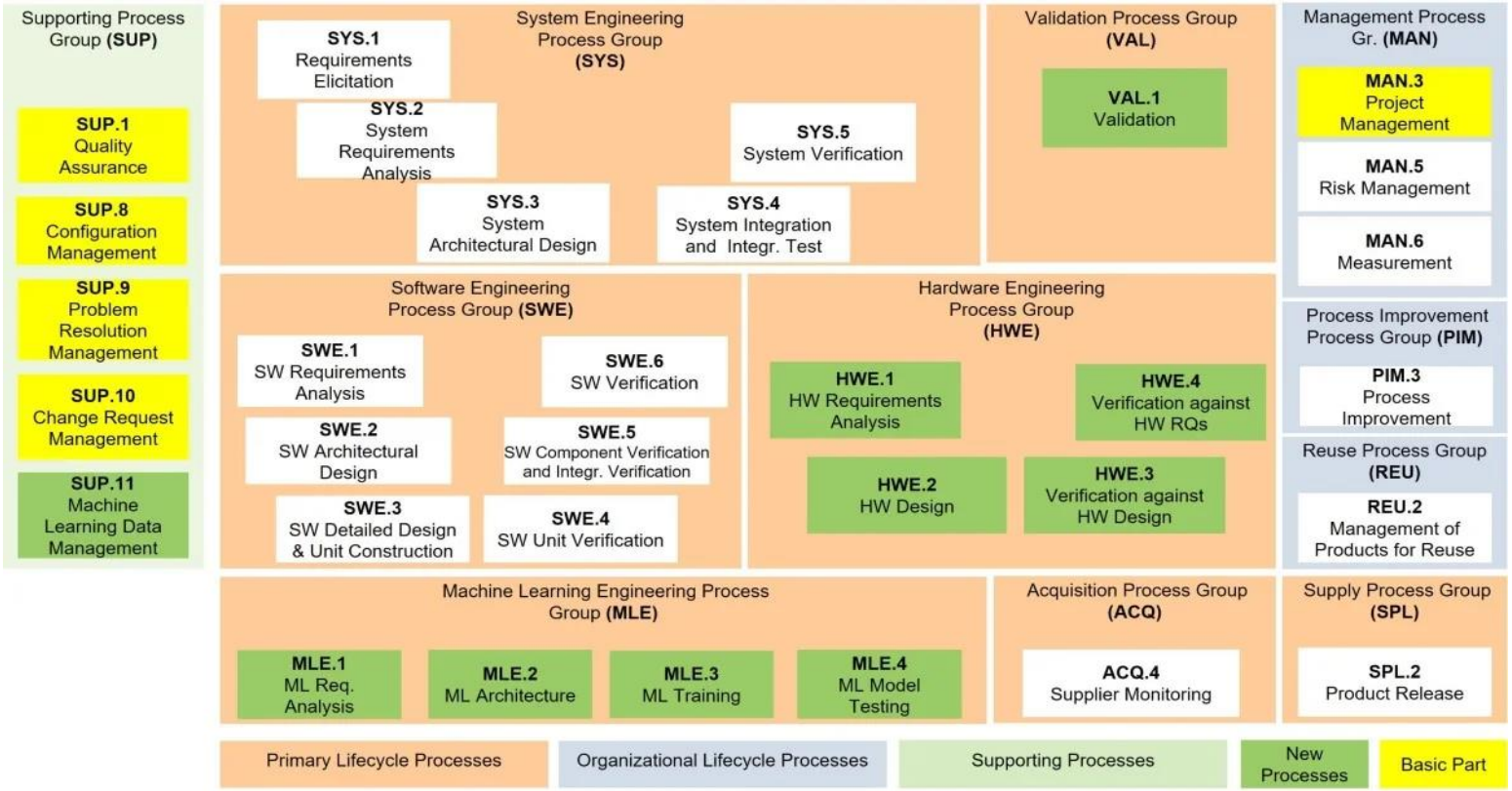
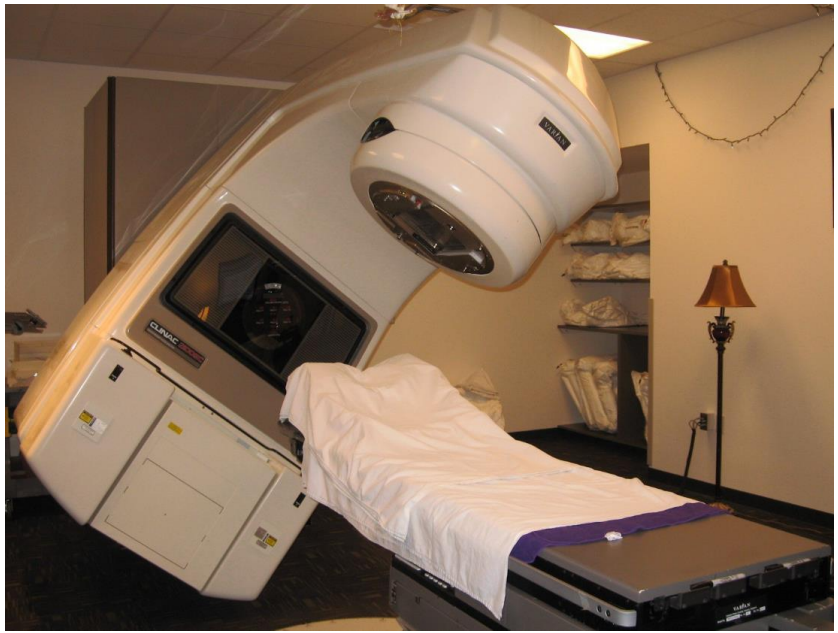


image source: Invensity

SE Case Study – Therac-25



Source: Wikipedia

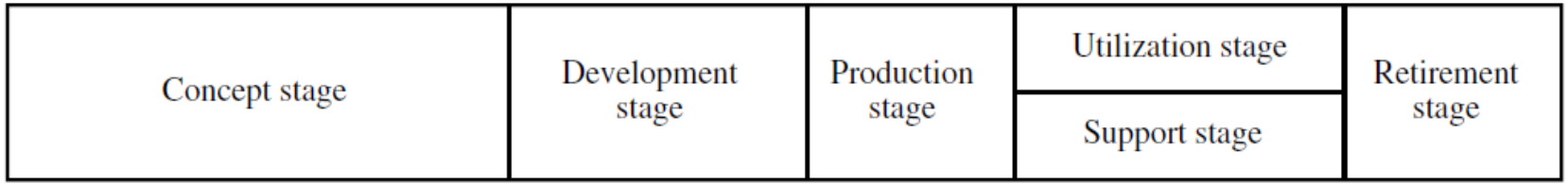
Team Formation

https://tinyurl.com/Bosch-Hyd-Dec2024

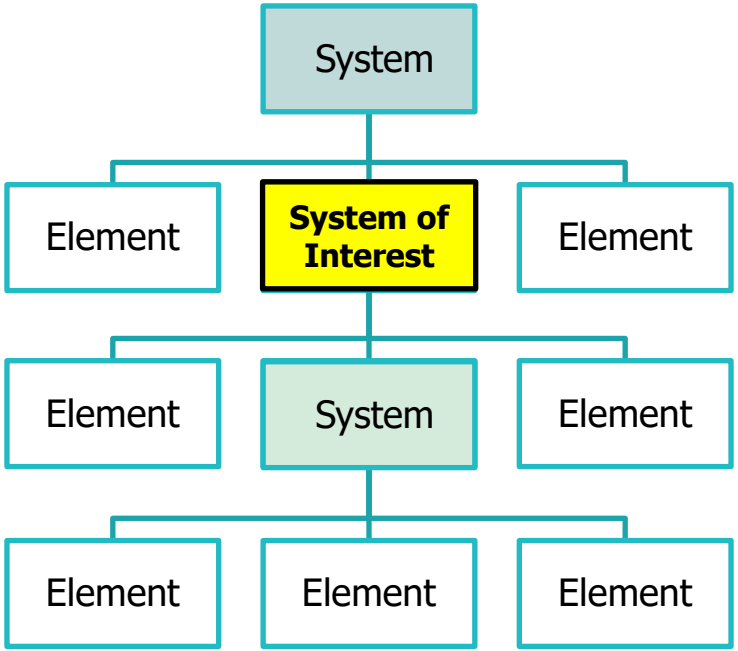
Exercise 1.1

*Read "**SE_CaseStudy_Therac25**"*

1. What life cycle stages can you identify?
2. Which stages were done well? Which not so well?
3. How does this case study relate to your work?

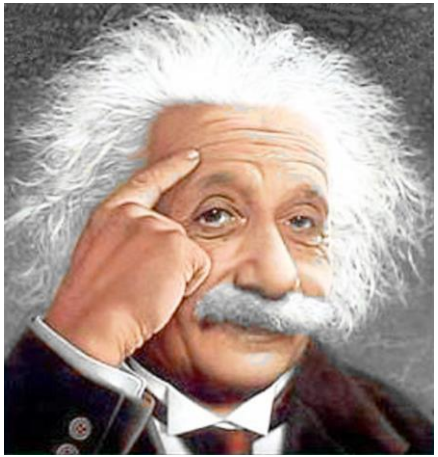


System of Interest



Understanding the Problem

“If I had an hour to solve a problem, I’d spend 55 minutes thinking about the problem and 5 minutes thinking about solutions.”



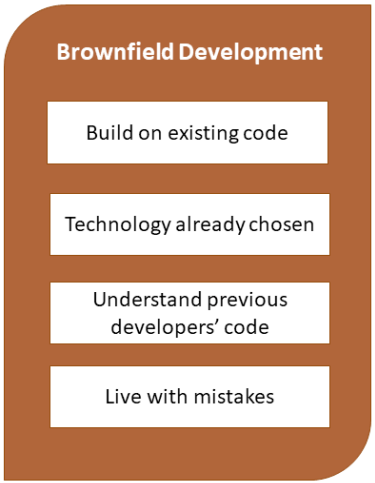
- **Albert Einstein**

The “Problem”

- Establishing and understanding the problem, is the first step for performing systems engineering
- The problem establishes the need and context for an engineered solution
- A problem can be defined internally (by an organization) or externally (that an organization may respond to)
- Good understanding of the problem is essential to developing an effective solution

Greenfield and Brownfield Projects

Greenfield project	Brownfield project
A greenfield project is one, where the land on which the project is developed, has never been used and there is no need to rebuild or demolish an existing structure.	A brownfield project is one, where the development work is carried out in a place where prior work has been done. It refers to a project, where an existing one is rebuilt, modified or upgraded.



Greenfield vs Brownfield Projects

- Today's systems often include existing elements. It is rare to find a true "greenfield" system, in which the developers can specify and implement all new elements from scratch.

- "Brownfield" systems, wherein legacy elements constrain the system structure, capabilities, technology choices, and other aspects of implementation, are much more typical (Boehm 2009).

Discussion

1. What are some examples of Greenfield and brownfield projects in your context?

2. How are requirements managed in these two cases?

3. What are some common challenges of Product Development in these two cases?

Requirements Engineering

What are “Requirements”?

- Criteria to be met
- Documented needs of what a particular product or service should be or do
- “To-Do” list for the project / development team
- Desired attributes of a system

Requirement

- Every requirement represents an engineering decision as to what the SoI must do, or a quality the system must have, to meet the needs from which they were transformed.

- Determination of what the system must do to meet a need is through a process of detailed requirement analysis, which can include the development and use of models, simulations, and prototypes.

- A requirement statement is the result of a "formal transformation of one or more needs or parent requirements into an agreed-to obligation for an entity to perform some function or possess some quality within specified constraints with acceptable risk." (INCOSE NRM 2022).

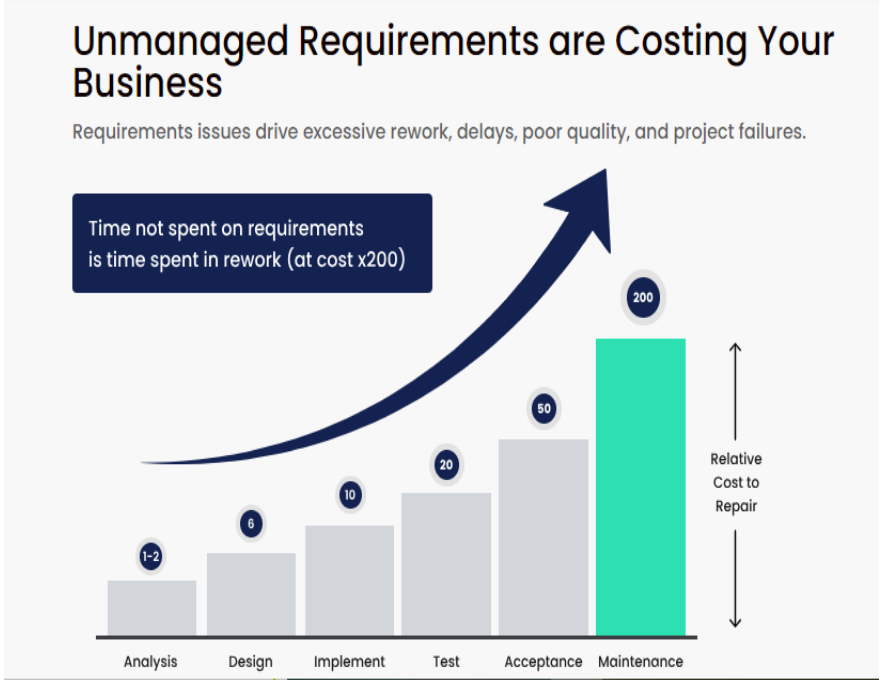
SEBOK WIKI

Why do we need Requirements?

Requirements

- Requirements are vital
- Missing requirements have a cascading effect on the entire lifecycle of the project
- Most requirements errors will NOT be discovered during design

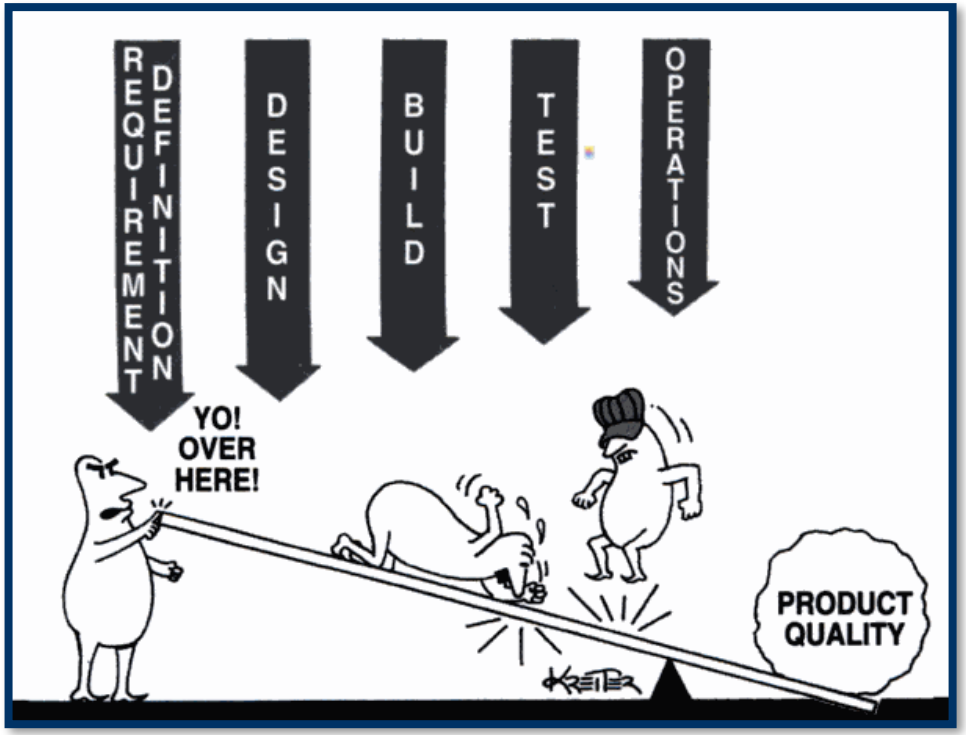
Requirements Rework Impact



- Errors, detected late in the maintenance phase can cost up to 200 times more than detected early in Requirement Analysis phase
- More than 40% of development budget can be consumed by poor requirements.
- 41% of projects fail to deliver the expected business value and ROI
- 49% of projects overrun original estimates
- Being late to market by 6 months or more will cost organizations 33% of the 5-year ROI

https://mgtechsoft.com/blog/complete-guide-on-digital-requirements-management/

Importance of Requirements Engineering in the early lifecycle stages



Requirements Engineering Process

1. Requirements Elicitation
2. Requirements Analysis
3. Requirements Communication
4. Requirements Management

Requirements process is applicable at every level of system development