SYSTEM ENGINEERING
UNIT-I

by

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What is System Engineering ?

What is a System?

- A frequently used definition of a system is " a set of interrelated components working together toward some common objective".
- It is an integrated composite of people, products and processes that provide a capability to satisfy a stated need or objective.
- It is a collection of different elements that interact to produce results that are not obtainable by the elements alone.

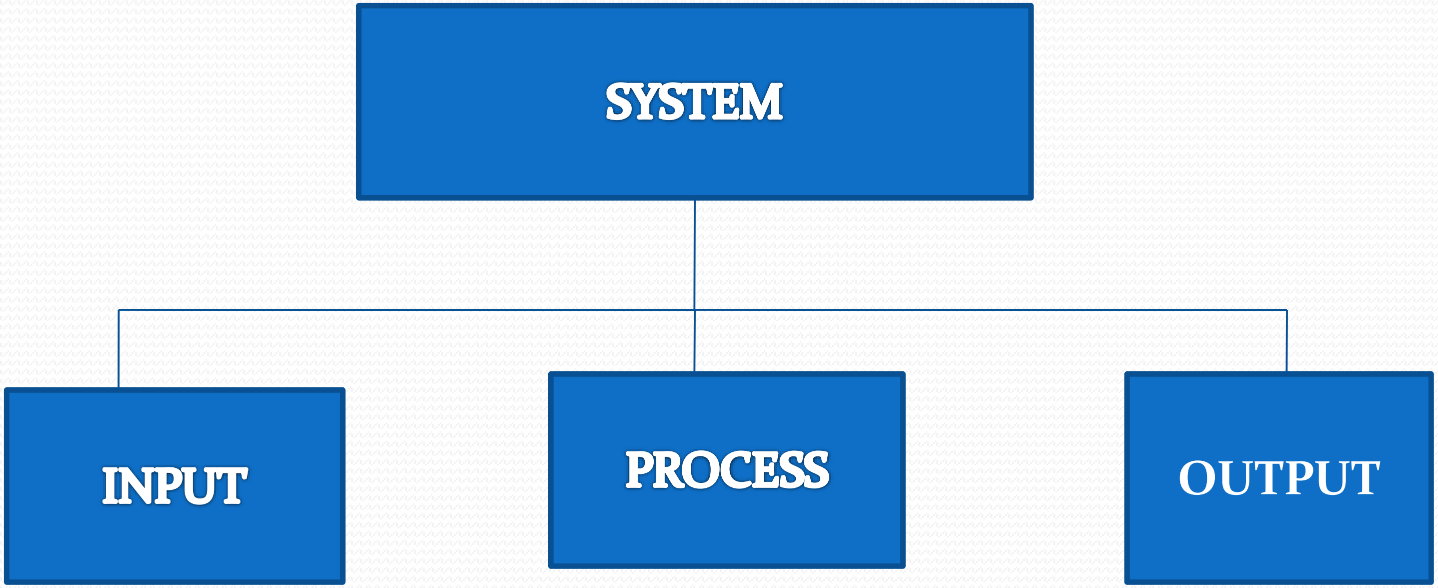
What is a System?

- A system can be NATURAL or ENGINEERED.
- Example of a natural system is our solar system.
- Engineered systems are designed and built to satisfy human needs.(example wireless telephone network, power generation plants and our highways)
- From a functional viewpoint systems have inputs, processes and outputs.
- Feedback is a mechanism to compare goals and outputs.
- Systems have boundaries.
- Everything outside the boundary of a system is part of another system

What is a System?

- Engineered system can be non-complex or complex.
- A non-complex engineered system is a system which does not involve many disciplines of engineering. For example a washing machine, refrigerator, dishwasher, and a vacuum cleaner.
- A complex engineered system involves many engineering disciplines. For example Weather satellite system and Air Traffic control system.

What is a System?



ELEMENTS OF A SYSTEM

What is System Engineering?

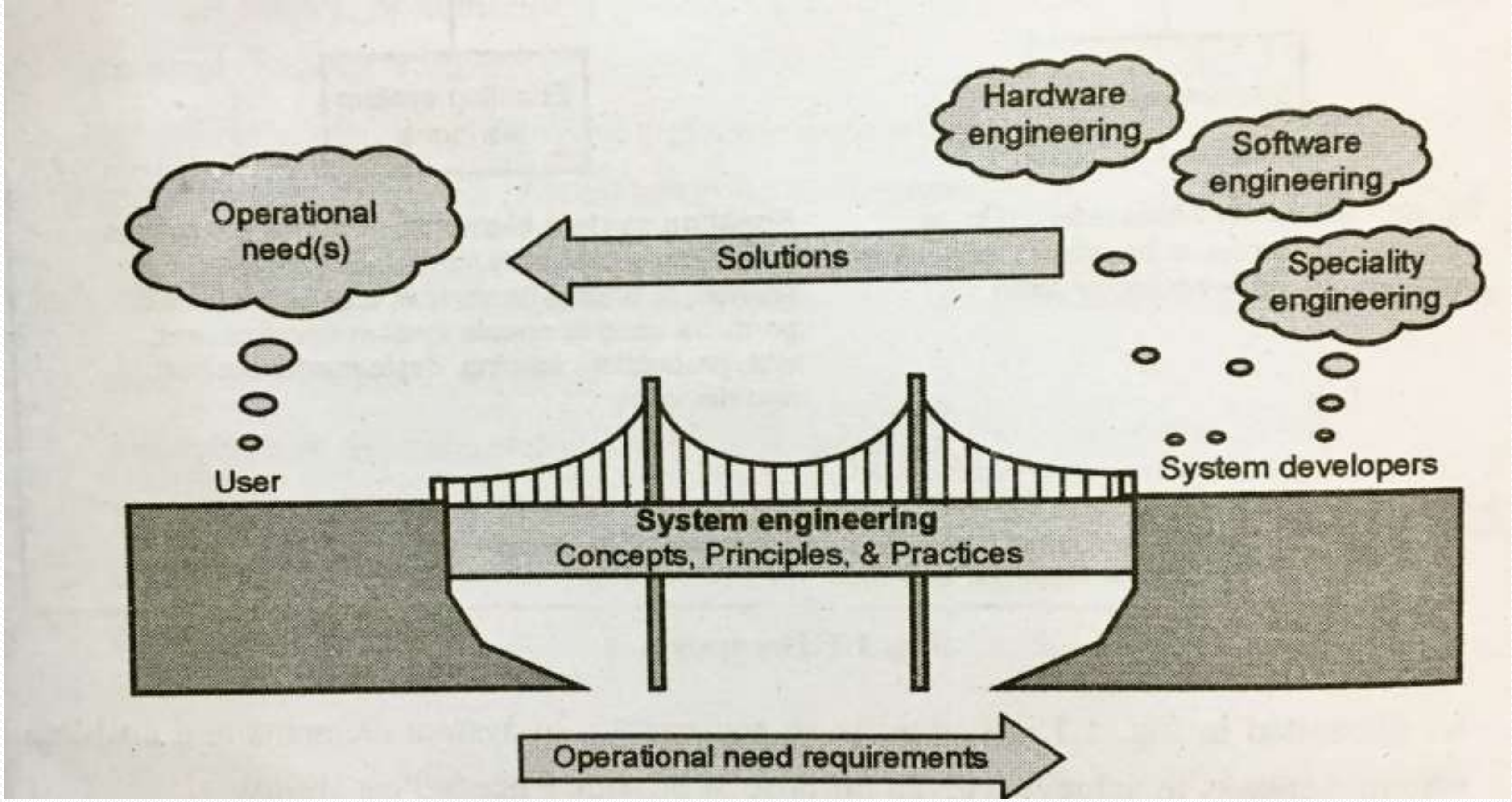
- A logical sequence of activities and decisions transforming an operational need into a description of system performance parameters and a preferred system configuration (MIL-STD-499A, Engineering Management 1974)
- An interdisciplinary approach encompassing the entire technical effort to evolve into and verify an integrated and life cycle balanced set of system people, products and process solutions that satisfy customer needs. (EIA 632 Standard , System Engineering, Dec. 1994)

What is System Engineering?

- An interdisciplinary, collaborative approach to derive, evolve and verify a life cycle balanced system solution which satisfies customer expectations and meets public acceptability.(IEEE P1220, Standard for application and management of the System Engineering Process, Sept 1994)

- The function of systems engineering is to *guide the engineering of complex systems* .

What is System Engineering?



Systems Engineering- Bridging the gap from user needs to system developers

Systems Engineering and Traditional Engineering Disciplines

- Systems engineering differs from mechanical, electrical, and other engineering disciplines in several important ways
- Systems engineering is focused on the system as a whole
- It is focused on its total operation.
- It looks at the system from the outside, that is, at its interactions with other systems and the environment, as well as from the inside.
- While the primary purpose of systems engineering is to guide, this does not mean that systems engineers do not themselves play a key role in system design.
- Systems engineering *bridges the traditional engineering disciplines.*

Systems Engineering and Project Management

- The engineering of a new complex system usually begins with an exploratory stage in which a new system concept is evolved to meet a recognized need
- The magnitude and complexity of the effort to engineer a new system requires a dedicated team to lead and coordinate its execution.
- Such an enterprise is called a " project " and is directed by a project manager aided by a staff.
- Systems engineering is an inherent part of project management — the part that is concerned with guiding the engineering effort itself
- Also concerns with setting its objectives, guiding its execution, evaluating its results, and prescribing necessary corrective actions to keep it on course.

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice”, Wiley India, Chapter-1 (Page numbers 3-5).
- S.L. Gadhave, “Systems Engineering”, Technical Publications, Chapter-1 (Page numbers 1-2 to 1-6)

Origin of System Engineering

Origin of System Engineering

- No particular date can be associated with the origins of systems engineering.
- The Bible records that Noah's Ark was built to a system specification.
- Systems engineering principles have been practiced at some level while building of the pyramids in Egypt.
- The recognition of systems engineering as a distinct activity is often associate with the effects of World War II, and especially the 1950s and 1960s.
- There was a rise in advancement in technology after World War – II in order to gain a military advantage for one side or the other.
- The development of high - performance aircraft, military radar, the proximity fuse, the German V1 and V2 missiles, and especially the atomic bomb required revolutionary advances in the application of energy, materials, and information.

Origin of System Engineering

- These systems were complex, combining multiple technical disciplines, and their development posed engineering challenges.
- The compressed development time schedules necessitated a level of organization and efficiency that required new approaches in program planning, technical coordination, and engineering management.
- Systems engineering, as we know it today, developed to meet these challenges.
- During the Cold War of the 1950s, 1960s, and 1970s, military requirements continued to drive the growth of technology in jet propulsion, control systems, and materials.
- Another development, that of solid - state electronics, has had perhaps a more profound effect on technological growth.

Origin of System Engineering

- The still evolving "information age", in which computing, networks, and communications are extending the power and reach of systems far beyond their previous limits.
- The relation of modern systems engineering to its origins can be best understood in terms of three basic factors
  - *Advancing Technology, which provide opportunities for increasing system* capabilities, but introduces development risks that require systems engineering management.
  - *Competition, whose various forms require seeking superior (and more* advanced) system solutions through the use of system - level trade - offs among alternative approaches.
  - *Specialization, which requires the partitioning of the system into building* blocks corresponding to specific product types that can be designed and built by specialists, and strict management of their interfaces and interactions.

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice, Wiley India, Chapter-1 (Page numbers 5-10)

Examples of systems requiring system engineering

General Examples

- A refrigerator, microwave oven, dishwasher, vacuum cleaner, and radio all perform a number of useful operations in a systematic manner.

- However, these appliances involve only one or two engineering disciplines, and their design is based on well - established technology.

- Thus, they fail the criterion of being ***complex***

Characteristics required

The characteristics of a system whose development, test and application require the practice of systems engineering are that the system

- is an engineered product and hence satisfies a specified need
- consists of diverse components that have intricate relationships with one another and hence is multidisciplinary and relatively complex
- uses advanced technology in ways that are central to the performance of its primary functions and hence involves development risk and often a relatively high cost.

Examples of Complex Engineered Systems

TABLE 1.1. Examples of Engineered Complex Systems: Signal and Data Systems

System	Inputs	Process	Outputs
Weather satellite	Images	• Data storage • Transmission	Encoded images
Terminal air traffic control system	Aircraft beacon responses	• Identification • Tracking	• Identity • Air tracks • Communications
Track location system	Cargo routing requests	• Map tracing • Communication	• Routing information • Delivered cargo
Airline reservation system	Travel requests	Data management	• Reservations • Tickets
Clinical information system	• Patient ID • Test records • Diagnosis	Information management	• Patient status • History • Treatment

Examples of Complex Engineered Systems

TABLE 1.2. Examples of Engineered Complex Systems: Material and Energy Systems

System	Inputs	Process	Outputs
Passenger aircraft	• Passengers • Fuel	• Combustion • Thrust • Lift	Transported passengers
Modern harvester combine	• Grain field • Fuel	• Cutting • Threshing	Harvested grain
Oil refinery	• Crude oil • Catalysts • Energy	• Cracking • Separation • Blending	• Gasoline • Oil products • Chemicals
Auto assembly plant	• Auto parts • Energy	• Manipulation • Joining • Finishing	Assembled auto
Electric power plant	• Fuel • Air	• Power generation • Regulation	• Electric AC power • Waste products

Example: A modern automobile

- It can be considered as a lower limit to more complex vehicular systems.
- It is made up of a large number of diverse components requiring the combination of several different disciplines.
- To operate properly, the components must work together accurately and efficiently.
- Should maintain very close control of engine emissions, which requires sophisticated sensors and computer - controlled mechanisms for injecting fuel and air.
- Antilock brakes are another example of a finely tuned automatic automobile subsystem.

Example: A modern automobile

- Advanced materials and computer technology are used to an increasing degree in passenger protection, cruise control, automated navigation and autonomous driving and parking.
- The stringent requirements on cost, reliability, performance, comfort, safety, and a dozen other parameters present a number of substantive systems engineering problems.
- Thus it fits the criteria discussed previously.
- An automobile is also an example of a large class of systems that require active interaction (control) by a human operator.

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice, Wiley India, Chapter-1 (Page numbers 10-12).

Systems Engineer Career Development Model

Characteristics commonly found in successful systems engineers.

They

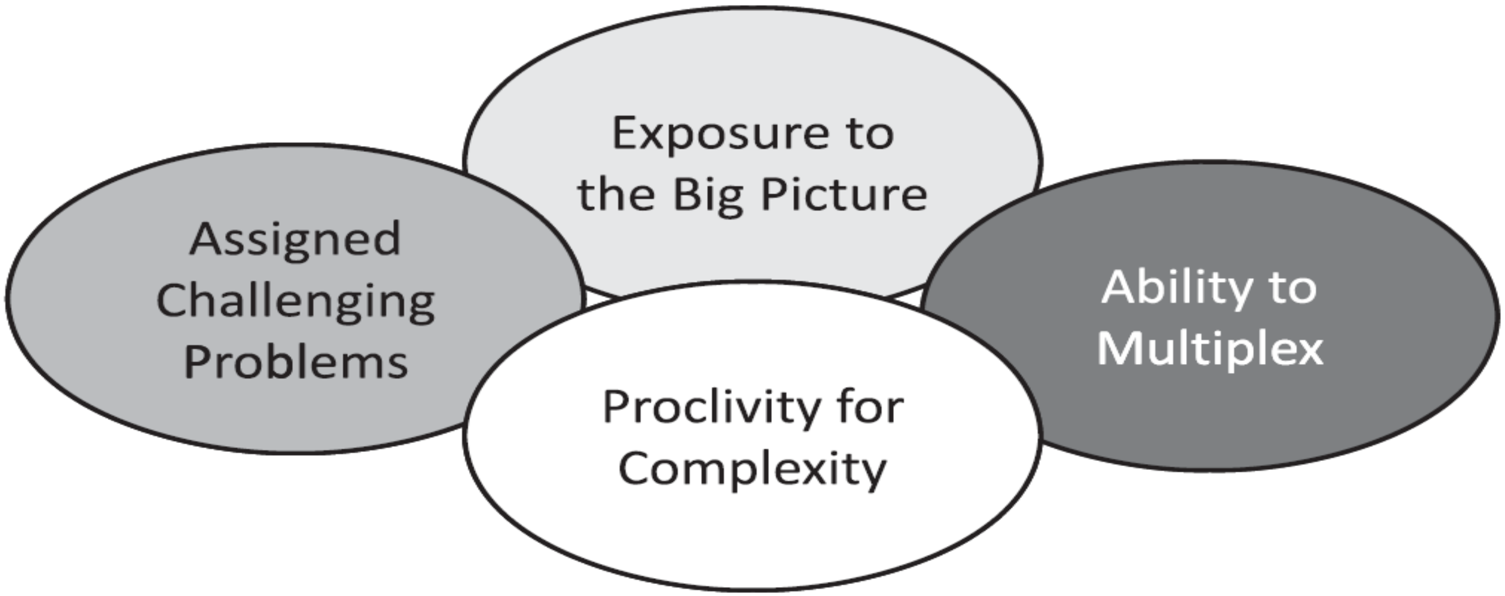
1. enjoy learning new things and solving problems,
2. like challenges,
3. are skeptical of unproven assertions,
4. are open - minded to new ideas,
5. have a solid background in science and engineering,
6. have demonstrated technical achievement in a specialty area,
7. are knowledgeable in several engineering areas,
8. pick up new ideas and information quickly, and
9. have good interpersonal and communication skills.

System Engineer career development model

- In addition to the already discussed attributes a system engineer must have four more qualities
  - one should seek assignments to problems and tasks that are very challenging and are likely to expand technical domain knowledge and creativity
  - Whatever the work assignment, understanding the context of the work and understanding the big picture is also essential.
  - Systems engineers are expected to manage many activities at the same time, have broad perspectives and able to go deeply into many subjects at once.(multiplexing)
  - the systems engineer should not be scared of complex problems since this is the expected work environment.

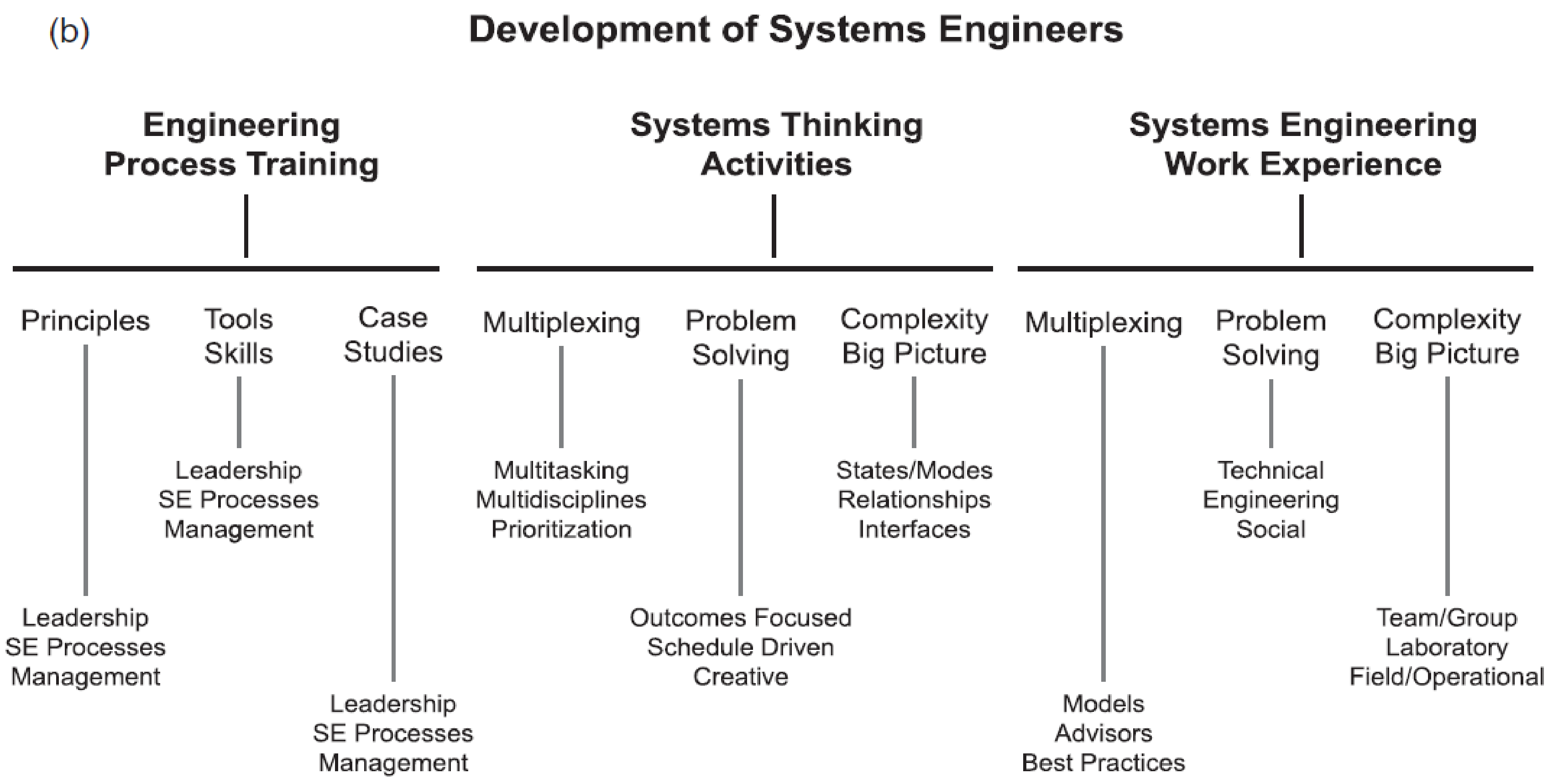
System Engineer career development model

(a)



Systems engineering (SE) career elements derived from quality work experiences.

System Engineer career development model



Components of employer development of systems engineers.

System Engineer career development model

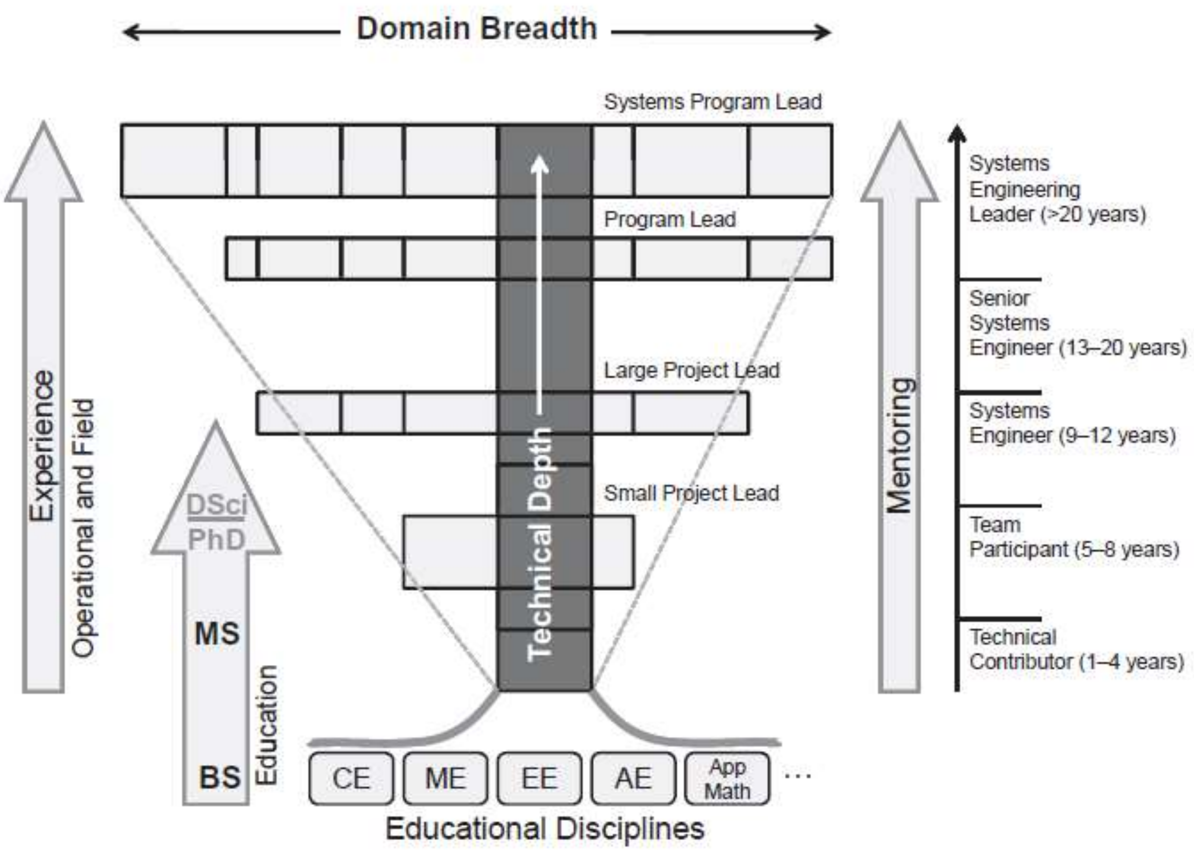


Figure 1.4. "T" model for systems engineer career development. CE, chemical engineering; ME, mechanical engineering; EE, electrical engineering; AE, aeronautical engineering; App Math, applied mathematics.

References

- Alexander Kossiakoff, William N Sweet, "System Engineering Principles and Practice", Wiley India
  Chapter-1 (Page numbers 18-21)

Perspectives of Systems Engineering

Perspectives of Systems Engineering

A perspective that leads to maturity of thinking includes concepts of systems thinking, systems engineering, and engineering systems

- ***System Thinking*** is an approach
  - for understanding the environment, process, and policies of a systems problem requires one to use systems thinking.
  - examining the domain and scope of the problem and defines it in quantitative terms.
  - looking at the parameters that help define the problem and then, through research and surveys, develops observations about the environment in which the problem exists.
  - for finally generating options that could address the problem.
  - appropriate for use in secondary schools so that young students get knowledge of the " big picture " as they learn fundamental science and engineering skills.

Perspectives of Systems Engineering

- ***Systems Engineering*** approach
  - focuses on the products and solutions of a problem, with the intent to develop or build a system to address the problem.
  - tends to be more technical
  - seeks from potential future users and developers of the solution system
    - what are the top level needs, requirements, and concepts of operations
  - for developing design specifications before conducting a functional and physical design.
  - production, and testing of a system solution for the problem.
  - gives attention to the subsystem interfaces and the need for viable and tangible results.
  - is reliable for product development which is evident in many commercial and military sectors.

Perspectives of Systems Engineering

- ***Engineering Systems*** approach
  - tackles some of society's grandest challenges with significant global impact
  - investigates ways in which engineering systems behave and interact with one another including social, economic, and environmental factors.
  - covers engineering, social science, and management processes without the implied rigidity of systems engineering.
  - is applied where critical infrastructure, health care, energy, environment, information security, and other global issues are areas of attention.

Perspectives of Systems Engineering

TABLE 2.1. Comparison of Systems Perspectives

Systems thinking	Systems engineering	Engineering systems
Focus on process	Focus on whole product	Focus on both process and product
Consideration of issues	Solve complex technical problems	Solve complex interdisciplinary technical, social, and management issues
Evaluation of multiple factors and influences	Develop and test tangible system solutions	Influence policy, processes and use systems engineering to develop system solutions
Inclusion of patterns relationships, and common understanding	Need to meet requirements, measure outcomes and solve problems	Integrate human and technical domain dynamics and approaches

References

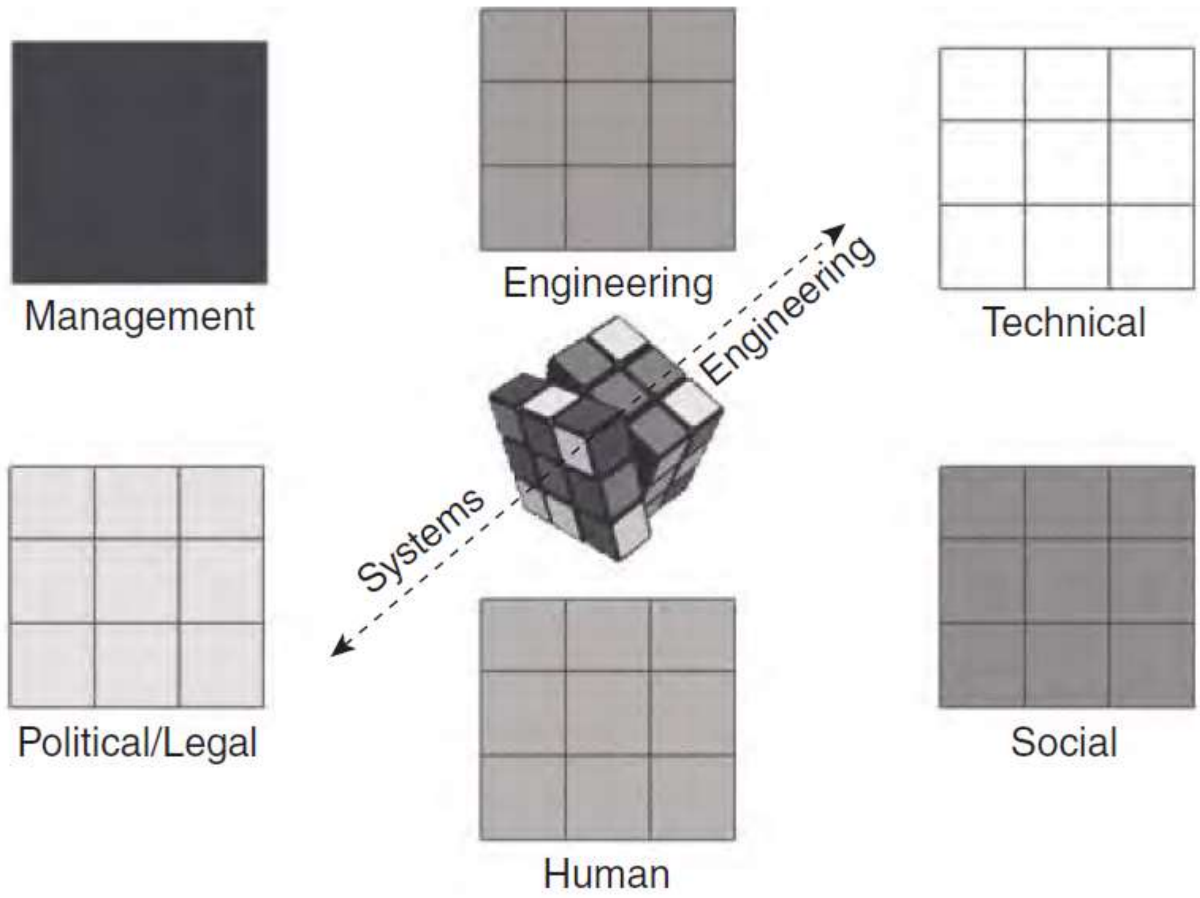
- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice”, Wiley India
  Chapter-2 (Page numbers 32-34)

Systems Engineering Domains

Systems Engineering Domains

- With a broad view of system development, it can be seen that the traditional approach to systems now covers a growing domain breadth.
- Much like a Rubik's Cube, the domain faces are now completely integrated into the systems engineer ' s perspective of the " big (but complex) picture."
- The systems domain faces shown in the Figure include not only the engineering, technical, and management domains but also social, political/legal, and human domains.
- Interesting domains are those that involve scale, such as nano and micro-systems, or systems that operate (often autonomously) in extreme environments, such as deep undersea or outer space.

System Engineering Domains



System Engineering Domains

References

- Alexander Kossiakoff, William N Sweet, "System Engineering Principles and Practice", Wiley India
  Chapter-2 (Page numbers 34-35)

Systems Engineering Fields

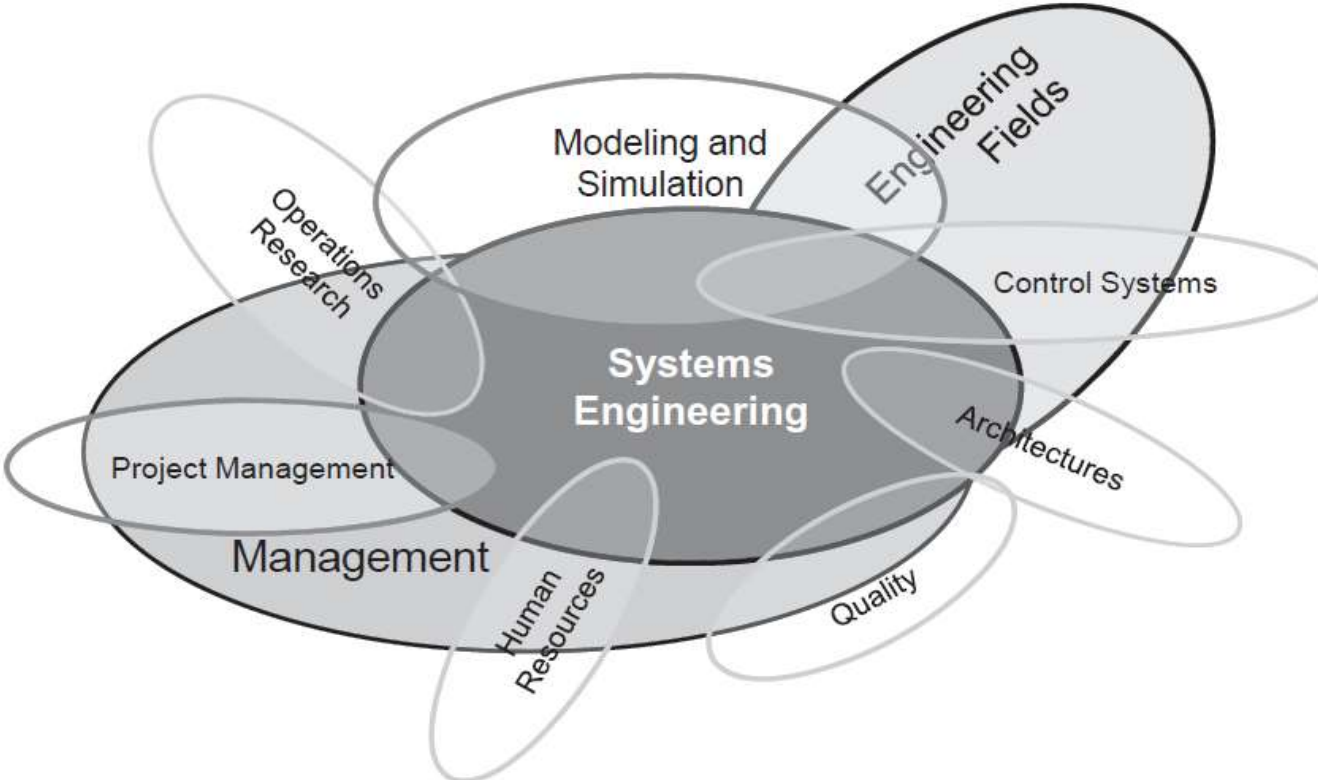
Systems Engineering Fields

- System engineering bridges the traditional engineering disciplines like electrical, mechanical, aerodynamic, and civil engineering among others
- It should be expected that engineering specialists look at systems engineering with a perspective more strongly from their engineering discipline.
- Systems engineering is a guide to design of systems often exercised in the context of a project or program
- Thus functional, project, and senior managers will consider the management elements of ***planning and control*** to be key aspects of system development.

Systems Engineering Fields

- ***Quality management, human resource management***, and ***financial management*** play an important role in system development.
- ***Operation Research*** provides qualitative analysis of alternatives and optimal decisions.
- ***Modeling and simulation*** provides a cost - effective examination of systems options to meet the requirements and needs of the users.
- Professionals also have to focus on the ***structures and architectures*** related to a system.

System Engineering Fields



System Engineering Fields

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice”, Wiley India
  Chapter-2 (Page numbers 35-36)

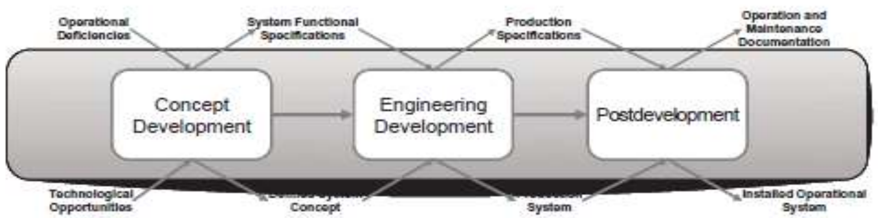
Systems Engineering Approaches

System Engineering Approaches

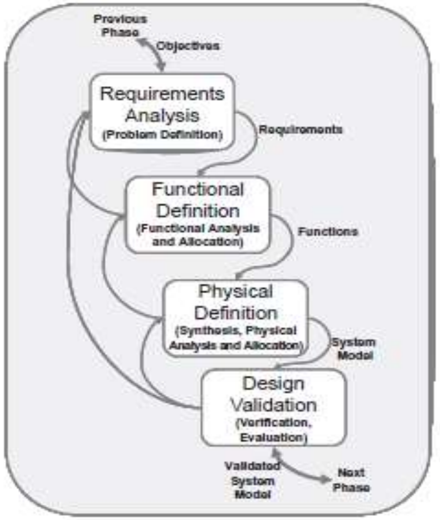
- For depicting the sequence of processes and methodologies used in the execution of the design, development, integration, and testing of a system.
- Early graphics were linear in the process flow with sequences of steps that are often iterative to show the logical means to achieve consistency and viability.
- Small variations are shown in the waterfall charts that provide added means to illustrate interfaces and broader interactions.
- Many of the steps that are repeated and dependent on each other lead to the spiral or loop conceptual diagrams.
- The popular systems engineering " V " diagram provides a view of life cycle development with explicit relationships shown between requirements and systems definition and the developed and validated product.

System Engineering Approaches

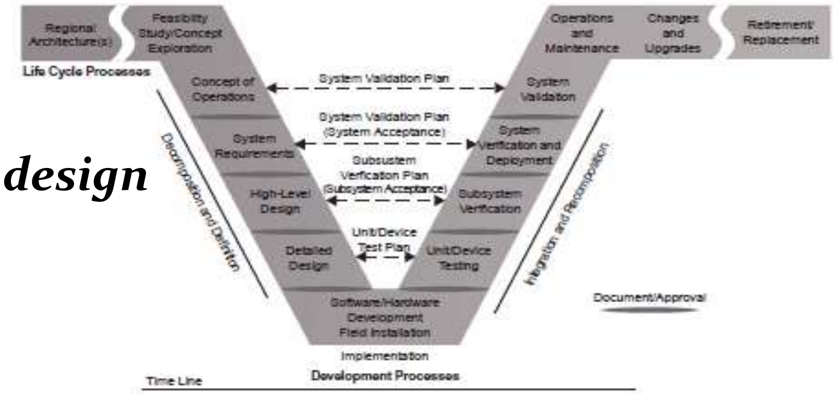
Linear approach



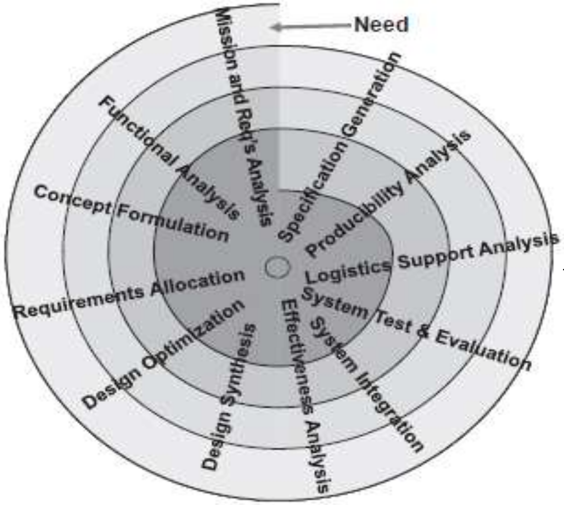
Waterfall Chart



"V" design



Spiral Diagram



System Engineering Approaches

- A broader perspective shown in ***Figure 2.7*** provides a full life cycle view and includes the management activities in each phase of development.
- This perspective illustrates the close relationship between management planning and control and the systems engineering process.

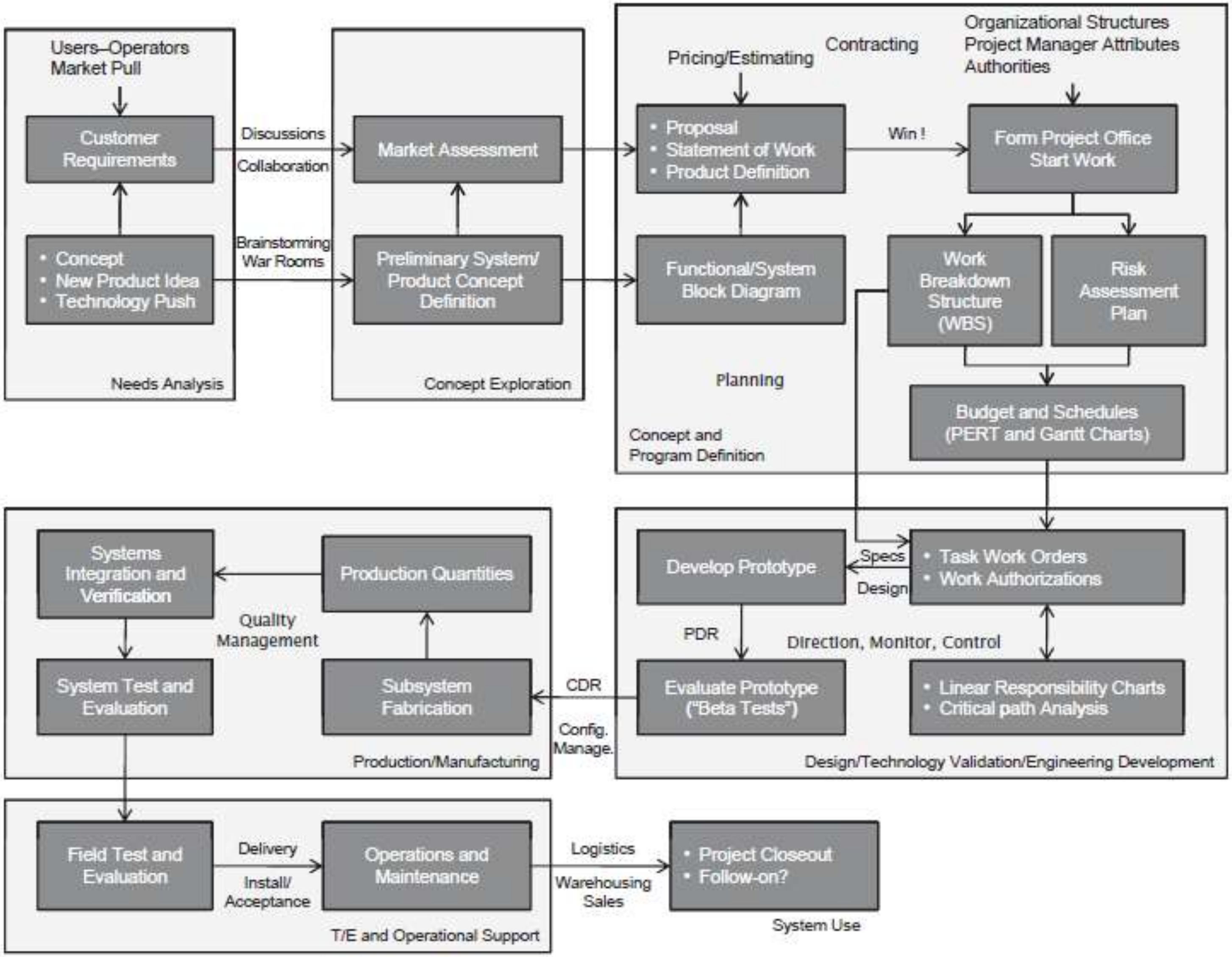


Figure 2.7. Life cycle systems engineering view. PERT, Program Evaluation and Review Technique; PDR, Preliminary Design Review; CDR, Critical Design Review.

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice”, Wiley India
  Chapter-2 (Page numbers 36-37)

THANK YOU