SYSTEM ENGINEERING
UNIT-III

by

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Originating a new system

Place of needs analysis in system development life cycle

- Refer to the figure 6.1
- Inputs are operational deficiencies and/or technological opportunities
- The need for a new system arises because of following reasons
  - Serious deficiency in the present system designed to meet a specific need
  - Technological development which promises a better solution than the present system
- Outputs to the following phase of concept exploration
  - Estimated operational effectiveness
  - System capabilities

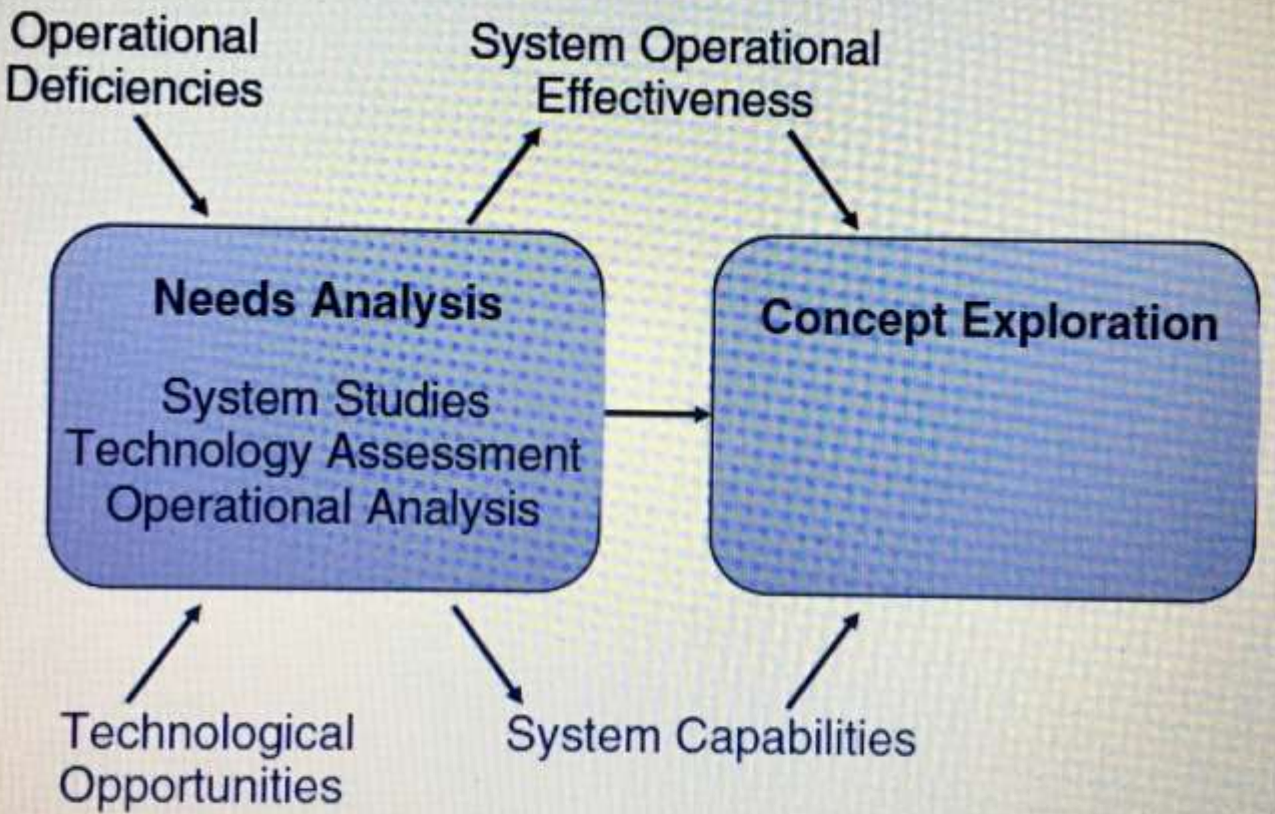

Figure 6.1. Needs analysis phase in the system life cycle.

Examples of new system needs

- The most common example is automobile industry
- Government laws require manufacturers to make substantial improvements in
  - Fuel economy
  - Safety
  - Pollution control
- The above factors render many present designs obsolete overnight
- Examples of technology driven new systems are applications of space technology to meet public and military needs such as
  - Powerful propulsion systems
  - Lightweight materials
  - Compact electronics
  - GPS

Competitive issues

- Regardless of the source of funding there may be a competition for resources necessary to demonstrate a bona fide need
- One question considered in the military is
  - Should maritime superiority be primarily a domain of the surface or the air navy or a combination of two?
- One question considered in automobile industry is
  - Should cleaner air be achieved by more restrictions on the automobile engine combustion process or on the chemical composition of the fuel?
- The answers to the above questions play an important role in the development of a new system

Design Materialization status

- The focus of attention in this phase is on the system operational objectives
- It goes no deeper than the subsystem level
- The activity is listed as "visualize" rather than definition or design
- The term "**Visualize**" refers to "forming a mental image or vision"
- It implies conceptual rather than the material view
- At this level, most designs first originate , drawing on analogies from existing system elements
- Refer to the table in next slide

TABLE 6.1. Status of System Materialization at the Needs Analysis Phase

	Phase					
	Concept development			*Engineering development*		
Level	Needs analysis	Concept exploration	Concept definition	Advanced development	Engineering design	Integration and evaluation
System	Define system capabilities and effectiveness	Identify, explore, and synthesize concepts	Define selected concept with specifications	Validate concept		Test and evaluate
Subsystem		Define requirements and ensure feasibility	Define functional and physical architecture	Validate subsystems		Integrate and test
Component			Allocate functions to components	Define specifications	Design and test	Integrate and test
Subcomponent		Visualize		Allocate functions to subcomponents	Design	
Part					Make or buy	

Applying System Engineering method in needs and requirement analysis

- **Operational Analysis (Requirement analysis)**

  Focus is on

  - Projected needs of the system
  - Understanding the value of fulfilling projected needs
  - Defining quantitative operational objectives and the concept of operation

  Products are

  - Operational objectives
  - System capabilities

Applying System Engineering method in needs and requirement analysis

- **Functional Analysis**

  Focus is on

  - Translating operational objectives into functions that must be performed
  - Allocating functions to subsystems by defining functional interactions and organizing them into a modular configuration

  Product is

  - List of initial functional requirements

Applying System Engineering method in needs and requirement analysis

- **Feasibility Definition (Physical definition)**

  Focus is on

  - Visualizing the physical nature of subsystems conceived to perform the needed system functions
  - Defining a feasible concept in terms of capability and estimated cost

  Product is

  - Initial physical requirements

Applying System Engineering method in needs and requirement analysis

- **Needs Validation (Design Validation)**

Focus is on

- Designing or adapting an effectiveness model (analytical or simulated) with operational scenarios, including economic (cost, market etc.) factors.
- Defining validation criteria
- Demonstrating cost effectiveness of the postulated system concept after suitable iteration or adjustment
- Formulating the case for investing in the development of a new system to meet the projected need

Product is

- List of operational validation criteria

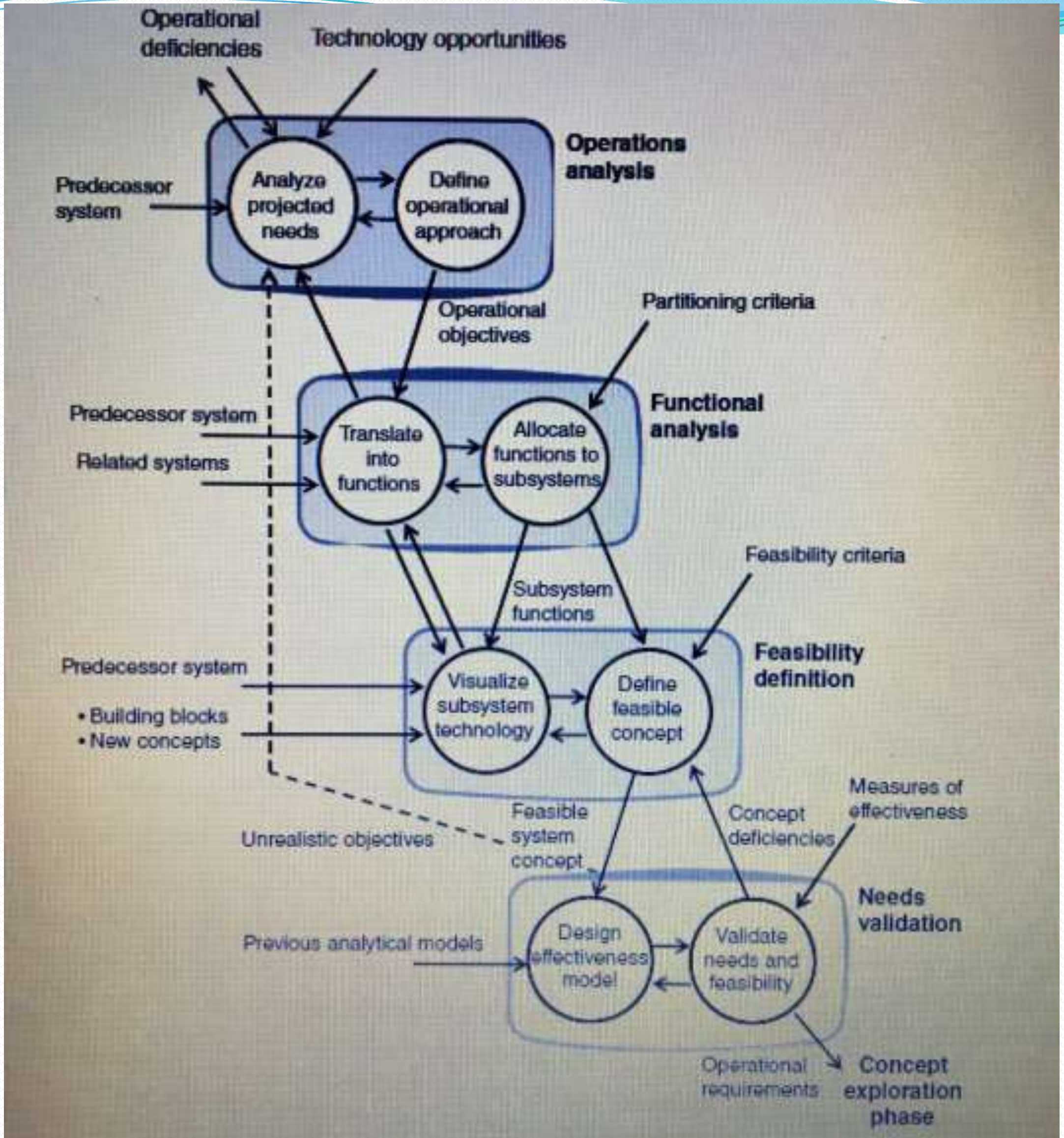

Figure 6.2 Needs analysis phase flow diagram.

Types of requirements

- **Operational Requirements**
  - Refer largely to the mission and purpose of the system
  - Will describe the end state of the world after the system is deployed and operated
  - Give a broad view of objectives
- **Functional Requirements**
  - Focus on what a system should do?
  - Action oriented and should describe the tasks or activities that the system performs during its operation
  - Largely quantitative

Types of requirements

- **Performance Requirements**
  - How the system should perform and affect its environment
  - Minimal numerical thresholds
  - Objective and quantitative
- **Physical requirements**
  - **C**haracteristics and attributes of the physical system and physical constraints placed upon the system design
  - Concerns with appearance, general characteristics as well as volume, weight, power and material
  - Relates with constraints or even system requirements

References

- Alexander Kossiakoff, William N Sweet, "System Engineering Principles and Practice", Wiley India, Chapter-6(Page numbers 139-145).

Operations Analysis

Analysis of projected needs

- Market studies are continuously carried out
- Reaction of customers is monitored
- Reason for lagging sales are mathematically probed
- Strength and weaknesses of competing systems and their likely future growth are analyzed

Deficiencies in the current system

- Is development needed or an upgrade?
- Must focus on ten years in the future
- Accumulated test data with analysis often using system simulations
- Benefits
  - Consistent and accurate evaluation of system's operational performance
  - Documented history of results

Operational Objectives

- Are outcome of operational studies
- Should address the end state of the operational environment
- Should address the purpose of the system
- Answers “WHY” question
- Start with “Provide”

Objective Analysis

- Refining the set of objectives
- Objective tree is used
- Automobile as example (GREEN)
  - Clean means good mileage and comfortable

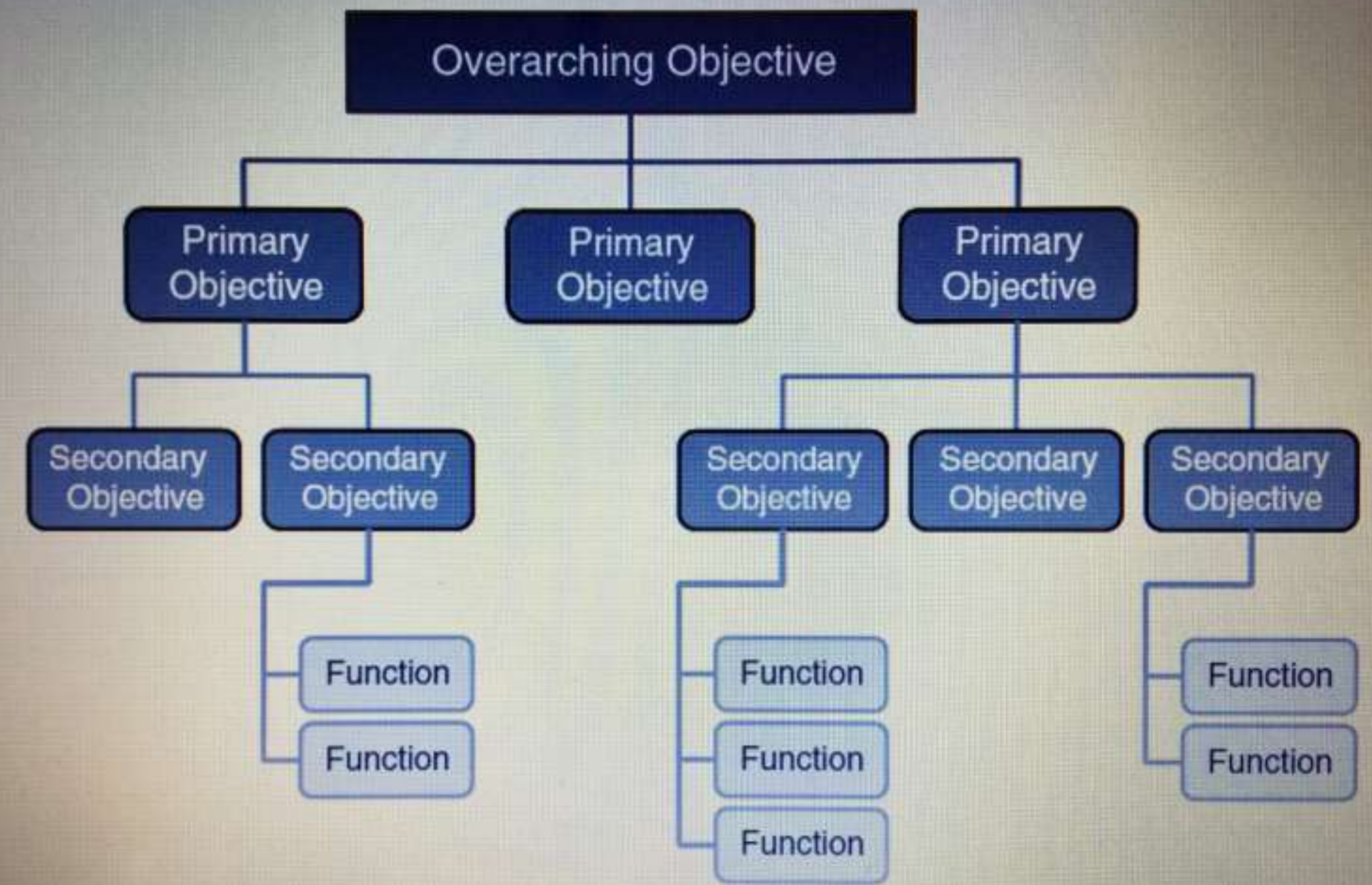

Figure 6.3. Objectives tree structure.

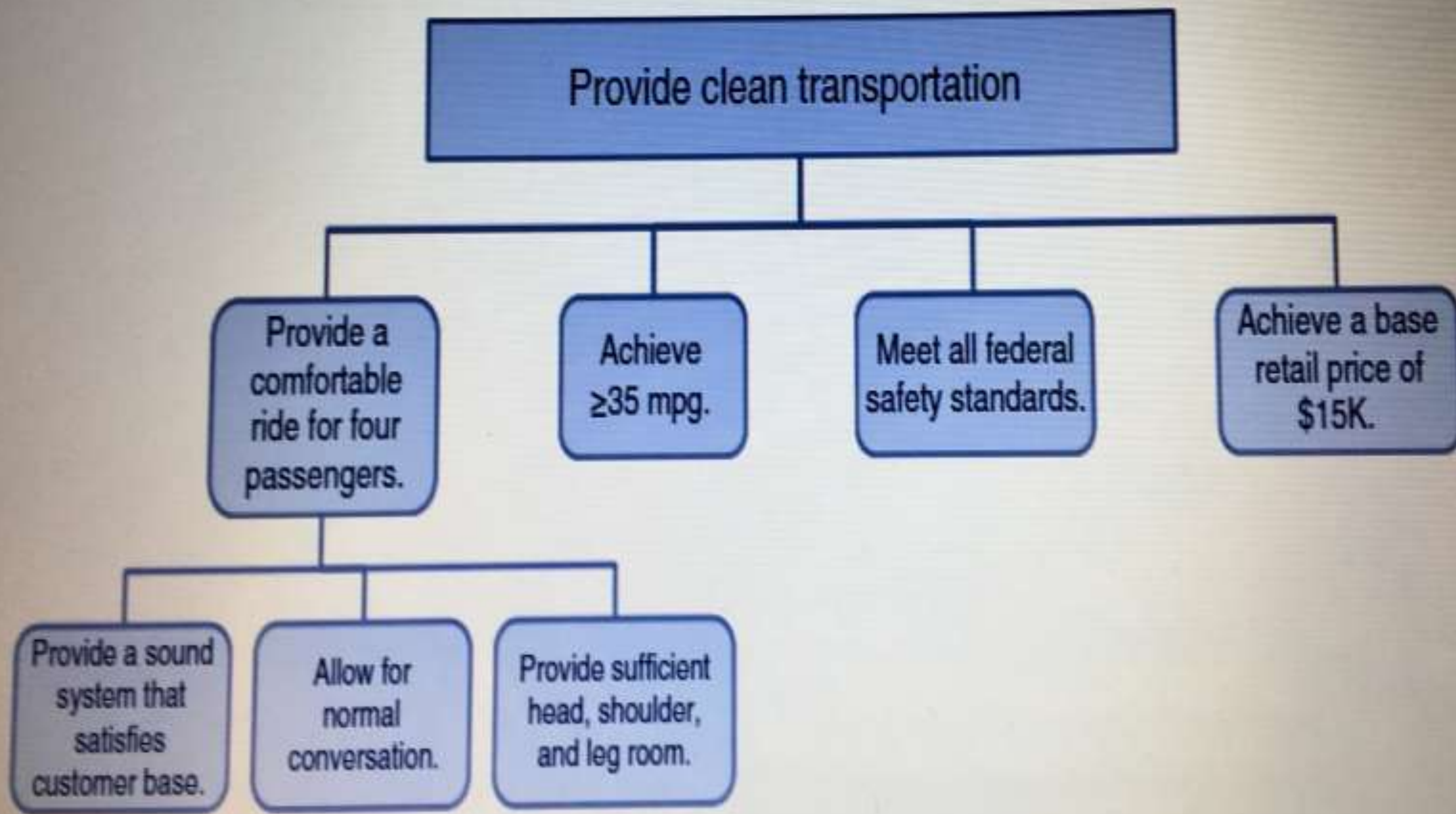

Figure 6.4. Example objectives tree for an automobile.

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice”, Wiley India, Chapter-6(Page numbers 146-151).

Functional Analysis

Translation of operational objectives into system functions

- Visualize the feasible type of system concept
- Visualization is an abstract process
- In needs driven systems operational objectives are considered
- In technology driven systems technological developments are considered
- A helpful approach is to consider the type of media (data, signal, material and energy) involved
- All the elements of the concept should be functionally related to the elements of the real system

Allocation of functions to subsystems

- Visualize- How they might be allocated, combined and implemented in a new system
- A top level system concept should be visualized which implements all the prescribed functions to obtain a plausible solution
- All interactions and interfaces, both internal and external, should be identified and associated with system functions
- Trade-off process should be employed to check that the consideration of various system attributes is thorough and properly balanced

References

- Alexander Kossiakoff, William N Sweet, "System Engineering Principles and Practice", Wiley India, Chapter-6(Page numbers 151-152).

Feasibility

Feasibility Definition

- System cost is a dominant factor especially compared to other alternatives
- Visualization of subsystem implementation
  - At this stage it is only necessary to find examples of similar functional units in existing systems
  - The identification of media involved in each major function (signal, data, material and energy)
  - Relation to the current system
    - Existing models and simulations of current system are useful tools
    - Analysis answers “What if” question
    - Effectiveness model can be used for effectiveness analysis

- Application of advanced technology
  - Analysis done on the basis of theoretical and experimental data available
  - Data available from the research done on the candidate system in consideration
  - Sometimes a particular technology may offer a substantial gain but may lack maturity
- Cost
  - Cost assessment is very important
  - Task is particularly complicated when there is a mix of old, new and modified subsystems, components and parts
  - Cost models and maintenance records of the current system combined with inflation factors can be helpful

Definition of a feasible concept

- The system description should include
  - Discussion of the development process
  - Anticipated risks
  - General development strategy
  - Design Approach
  - Evaluation methods
  - Production issues
  - Concept of operations

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice”, Wiley India, Chapter-6(Page numbers 153-154).

System Operational Requirements

Operational Scenarios

- **Mission Objectives**
  - The scenario should identify the overall objectives of the mission represented
  - The purpose and role of the system(s) in focus in accomplishing those objectives
- **Architecture**
  - The scenario should identify the basic system architecture involved
  - Includes a list of systems, organizations and basic structural information
  - Includes basic information on system interfaces

Operational Scenarios

- **Physical Environment**
  - The scenario should identify the environment in which it takes place
  - Includes physical environment (eg. Terrain, weather, transportation grid and energy grid)
  - Business environment (eg, recession and growth period)
  - Neutral entities (eg. Customers and their attributes, neutral nations and their resources)

Operational Scenarios

- **Competition**
  - The scenario identify competition to the efforts
  - Identify elements directly opposed to the mission's success (eg. Software hacker or other types of "enemy")
  - Consider natural disasters such as tsunami or hurricane
  - Consider outside market forces that may influence the target customers
- **General Sequence of the events**
  - Sequence should be within the mission context
  - There should be freedom of action on the part of the players
  - Should not "script" the system, they are analysis tools, not shackles to restrain the system development.

Operational Requirements Statement

- Described in terms of operational outcomes rather than system performance
- Should not be stated in terms of implementation
- Should not be biased towards a particular conceptual approach
- All requirements must be mentioned in measurable (testable) terms
- Time factor should be considered
  - Not readily derived from operational factors but may be critical in certain cases when obsolescence of current system and schedule of platforms

Feasibility Validation

- Build a convincing case by analogy with already demonstrated applications of the projected technique
- Comparison should be quantitative rather than only be qualitative
- Experimental investigations should be conducted
- Experience of the engineering staff is an important factor
- The investigation should be extensive
- This approach is often referred to as "critical experiments"

References

- Alexander Kossiakoff, William N Sweet, "System Engineering Principles and Practice", Wiley India, Chapter-6(Page numbers 158-162).

Implementation of concept exploration

Alternative implementation concepts

- At one end predecessor system should be explored for
  - Operational deficiencies
  - Modifications (if required)
  - developmental risks
- At the other end
  - Innovative technical approaches featuring advanced technology
  - Generally more risky and difficult to implement
  - Brainstorming is one of the oldest technique
  - Mind Maps is a prominent technique which helps in brainstorming (the figure in the next slide shows a mind map for favorite pastime)


cycling on the country roads
watching Discovery channel
swimming
reading
OUTDOORS
INDOORS
hiking in the hills
playing mahjong
My favourite pastimes
standing in the rain
skating on the lake
in the summer
in the winter
lying on the beach
building snowmen
eating strawberries in the garden

Concept exploration for a new aircraft

- Automation has become more widespread, especially in autopilots and navigation systems
- Changes in safety requirements must be examined to identify the performance characteristics
- While exploring alternative implementations, the main features of each candidate system must first be analyzed to see if they are conceptually achievable
- At this stage of development, a detailed design analysis is usually not possible because the concept is not yet sufficiently formulated
- Based on previous experience and engineering judgment, system engineer must decide whether or not the concept is proposed is likely to be achievable within given bounds of time, cost and risk

Technology Development

- Many of the new systems have been brought into being because of technological developments
- It is important for system engineers to understand the nature and sources of technological advances that concerns with proposed system development
- System oriented exploratory R & D can be distinguished according to
  - **Needs driven system** which aims at gaining a firm understanding of the operational environment and factors responsible for the increasing need of a new system
  - **Technology driven systems** which is focused on extending and quantifying the knowledge base for the new technology and its knowledge base for the new system objectives

Preferred System

- In most cases it is best to refrain from picking a superior system concept prematurely
- There are instances where it is permissible for the requirements definition effort to identify a so-called preferred system
- Preference for a system or subsystem may be set forth when significant advanced development work has taken place and has produced very promising results
- Such work is often conducted or sponsored by the customer
- Another factor is major technological breakthrough which promises high gains in performance at an acceptable risk
- The idea of this approach is that subsystem analysis can start building on this concept, thereby saving time and cost

Performance Characteristics

- **Performance analysis**
  - Used to derive a set of relevant performance characteristics for each candidate system concept that has been found to satisfy the effectiveness criteria
  - The issue of relevance arises because a full description of any complex system will involve many parameters
  - Must extract from the identified system characteristics only those that directly affect the system's operational effectiveness
  - The defined set of characteristics must be both necessary and sufficient to facilitate a valid determination for each candidate system concept

Constraints

- Interfaces and interactions with other system or part of systems cannot be overlooked, which will invariably place the constraints on the new system
- May affect the physical form and fit, weight and power, schedules(eg. Launch date), mandatory software tools, operating frequencies, operator training etc.
- The immediate benefit of early attention to such problems is that the conflicting concepts can be filtered out
- More time can be given for the analysis of more promising approaches
- The whole system life cycle should be considered
- Constraints like environmental conditions of temperature, humidity, shock vibration etc. are often same for any candidate system concept irrespective of their architecture

References

- Alexander Kossiakoff, William N Sweet, “System Engineering Principles and Practice”, Wiley India, Chapter-7(Page numbers 185-189).
- http://baibasvenca.blogspot.in/2013/01/using-mind-maps-with-students.html

THANK YOU