Chapter 2

System Life Cycle and Design Processes

Rocks and Bucket

- There is a bucket, some big rocks just enough to fill it, some small stones, some sands and water.
- Let us first fill the bucket with big rocks
- Then we put the small stones around the big rocks in the bucket,
- We then can put sands in the bucket
- Finally, we can still put water in the bucket

- now the bucket is full.
- What does this story tell us?
  - In order for us to fit all the things (big rocks, small stones, sand and water) in the bucket, you have to follow the order in the story, and if you reverse the order, then you will never be able fit the big rocks!
  - Top-down processing

Top-Down Processing

- Top down processing means “big pictures” first
  - Designing the system from a life cycle perspective
  - Consider everything involved in system life cycle from the very beginning of the system design
  - Doing things right in the beginning
  - Minimize the cost associated with late changes

Overview

- In this chapter, we will
  - Introduce systems life cycle;
  - Describe the elements that are involved in system design process, including system need, requirements, functions, components, prototypes and models, and their relationships with regard to different phases in systems life cycle;
  - Describe the system engineering process, define the main objectives for each of the phases in the design processes;
  - Review the most common models for the systems design process, including the waterfall model, Vee model, spiral model and concurrent model.

2.1 System Life Cycle

- Life Cycle:
  - *“a series of stages through which something (as an individual, culture, or manufactured product) passes during its lifetime*.”

- Life Cycle of Engineering Systems
  - sequence of stages/phases in the life of the systems.

2.1 System Life Cycle

- Different Terms Used
  - Clark, Cramer et al (1986) defined systems life cycles as stages of “planning, definition, design, integration acceptance, delivery product”
  - Blanchard and Fabrycky (1996) used need identification, conceptual design, preliminary design, detailed design, production and construction, utilization and support, and systems phase-out and disposal.
  - Chapanis (1996):operational need for the systems, system concept, system concept exploration and validation, engineering model development; systems production, deployment and distribution; systems operation and maintenance and finally system phase-out and retirement

2.1 System Life Cycle

- We adopt Chapanis(1996)'s Life Cycle Definition
  - Focus on system status and state
  - Not on design activities

- Two fundamental characteristics
  - System life cycle starts with a need
  - System life cycle evolve from general to specific

Operational Need

- Define WHY do we need this system and
- WHAT is needed for this system
- Source of needs
  - Government customers
    - Request for Proposal (RFP)
    - Respond with Statement of Work (SOW)
  - Other customers
    - Strategic planning: market survey, customers feedback, new technologies/resources change.

Operational Need

- Typical Operational Needs Format
  - Introduction
  - Missions
  - Technical Objectives
  - Constraints

PARAMETER	DESCRIPTION
Range:	200 statute miles, with 30 min. reserve, day VFR at ≥4000' MSL over non-mountainous, sparsely-populated coastal terrain
Efficiency:	≥200 Passenger-MPGe energy equivalency
Speed:	≥100 mph average on each of two 200 mile flights
Minimum Speed:	≤ 52 mph in level flight without stall, power and flaps allowed
Takeoff Distance:	≤2000 feet from brake release to clear a 50 foot obstacle
Community Noise:	≤78 dBA at full power takeoff, measured 250 feet sideways to takeoff brake release
Handling Qualities:	Acceptable on all 7 basic handling qualities. Listed Below.

System Concepts

- Or conceptual model : An abstract representation of the system to be developed
- Models have important values in systems design
- Operational Concepts
  - Usually in narrative format
  - Scenarios: Story telling of the systems operations
  - Graphical profiles, charts and diagrams

System Concepts

- Scenario for ATM machine

“Customers (including walking and driving through type of customers, they might also be visually and hearing challenged) request service, by pressing start, or insert their debit card, receive feedback from ATM that their request was accepted, ATM system read the card and request pin; customers input pin, system process the pin, if pin is correct, ATM proceed to the next selection menu, if pin is not correct, ATM provide feedback, go back to request pin again, repeat 3 times, and block the card and provide feedback.”

Systems Concepts

- Results of concept lead to system functions
- Defines WHAT actions system needs to take
    - what the system should do in order to accomplish the requirements, to fulfill the customer needs

Systems Concepts Exploration and Validation

- Conceptual Model to Component Model
- Allocation concepts to components
- Verification vs. Validation
  - Verification: system built correctly, according to design specification, “do things right”
  - Validation: system built is what customer wants, “do the right thing”

  - Not exactly the same

Engineering Model Development

- Validated Functional Model to Engineerning Model
- System evolve from requirements → functional baseline (Type A specification) → Allocation baseline (Type B specification) → Product baseline (Type C specification) → Process and Material baseline (Type D and E specifications)
- Engineering Model Format
  - Part list
  - Material list
  - Blueprint
  - Computer aid design (CAD) data

System Production, Distribution and Deployment

- Full scale production, distribution of systems and deployment of systems
- Components selection for systems
  - Commercial Of the Shelf (COTS)

System Operation and Maintenance

- Different class of customers
  - Users
  - Operators
  - Maintainers

- Follow-up tests and evaluations

System Phase Out and Retirement

- Many reasons for retirement
  - New technology
  - New supply of materials
  - Change of regulations and legislation
  - New trend of customer demands

Sustainable development

recycle, reuse and remanufacturing

2.2 Systems Design Process: Introduction

- Parallel to system life cycle, there are a series of activities that bring systems into being → systems engineering processes
- Characteristics
  - Requirement driven
  - From general to specific
  - Design activities are iterative

2.2.2 Basic Concepts and Terminologies for Design Process

- Requirement
  - single formal statement containing "***shall***" to define a need that a system must provide or perform.
  - syntax: system (or sub-system or component) + shall + verb + noun (i.e. provide a specific function) + (applicable parameters that this requirement pertains) + (applicable environmental or contextual information for the requirement).

2.2.2 Basic Concepts and Terminologies for Design Process

- Functions
  - A function is a specific action or activity that a system does or provides, it is a meaningful purpose for which the system is developed or designed for.
  - syntax for a function is **verb + noun**.
  - Functions vs. Tasks
    - tasks are supporting functions
    - any user task should relate to one or more system functions, without a function, there are no tasks needed
    - functional analysis usually comes before the task analysis for the system.

2.2.2 Basic Concepts and Terminologies for Design Process

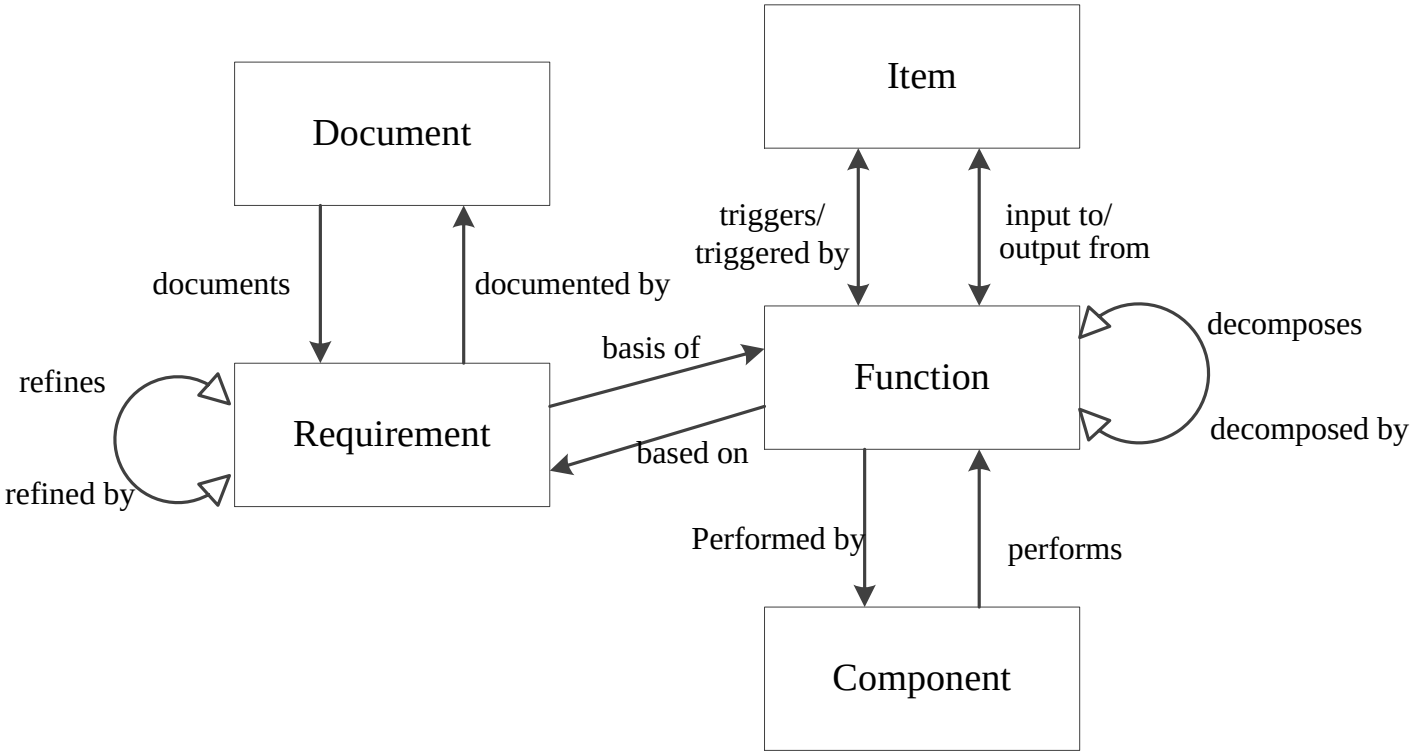
- Components
- Input/Output
- Baseline

2.2.2 Basic Concepts and Terminologies for Design Process

- Comparison of CORE terms with Systems Engineering
- Table 2.2

System Engineering	CORE	Examples
Document, Report,	Document	Files that contain requirements and specifications
Requirements	Requirements	Originating requirements, decision decisions
Functions	Functions	System actions
Components	Components	Hardware, software and people
Input, Output	Item	Materials and information

CORE Relations



2.2.3 Systems User Classes

- System Users/Operators
- System Maintainer/Supporters
- System Designers

2.3 Systems Design Processes

- Conceptual Design process
- Preliminary Design process
- Detailed Design Process
- Production and Construction

2.3.1 Conceptual Design

- Identify system users and system needs
- Conduct feasibility analysis to identify the technical, social, environmental and economical issues for the system design approach
- Develop system operational requirements that describe the system functions and their contextual information.
- Define hierarchical structure of the functions, and their operational relationship among the functions;
- Perform a system level analysis and trade-off studies using a number of systems analysis technique and modeling;
- Produce the Type A specification of the system, which is the functional baseline, documenting the results for the above activities;
- Conduct conceptual design review;

2.3.1.2 Feasibility Analysis

- Provides an answer to the question of “is it beneficial to design the system?” and “can we do it?”
- provide the information of strength and weakness of the organization.
- technical feasibility
- economical feasibility
- operational feasibility

2.3.1.3 Systems Planning

- Systems Engineering Management Plan (SEMP)
  - the top-level plan for managing the Systems Engineering effort. The SEMP defines how the project will be organized, structured, and conducted and how the total engineering process will be controlled to provide a product that satisfies customer requirements
  - Ch10 focuses on SEMP

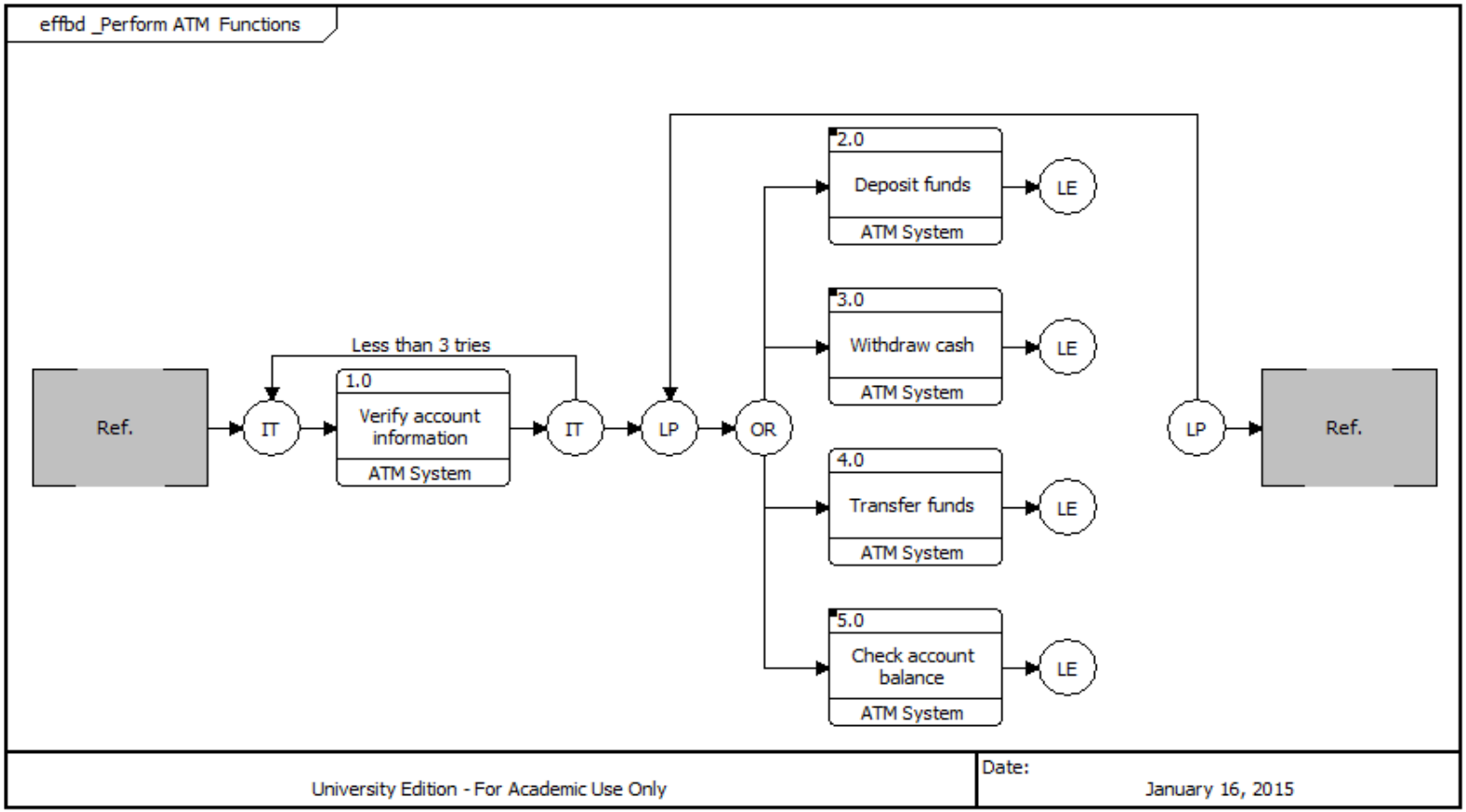
2.3.1.4 Requirement Analysis

- Systems Requirements Analysis is to
  - Define system mission
  - Define system stakeholder
  - Define system performance and physical parameters
  - Define the system life cycle and utilization requirement
  - Define the system effectiveness factors.
  - Define the environment factors.

2.3.1.5 Functional Analysis

- A function is an action of system, it emphasizes the action by using an appropriate **Verb** in the short phrase, such as “withdrawn cash from checking account” function for ATM system or “transport passengers to desired floor” function for an elevator system.
- Functional analysis : identifying systems functions and their hierarchical structure and operational sequences

Functional Analysis

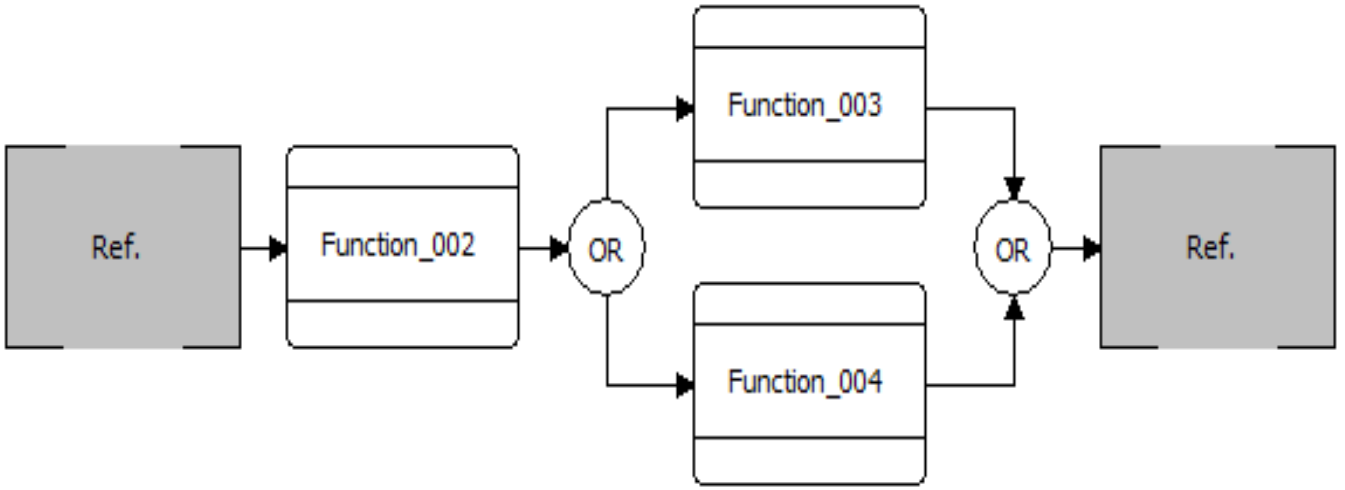


2.3.2 Preliminary Design Process

- Extends the results from conceptual design stage to a more detailed level, namely, sub-system level and component level
  - Performing the functional analysis at the sub-system and component level.
  - Developing the specifications for the subsystem and components
  - Documenting the design results using engineering design tools and software, including the design data, drawing and prototype;
  - Perform trade-off analysis for the system configuration;
  - Conduct the system design

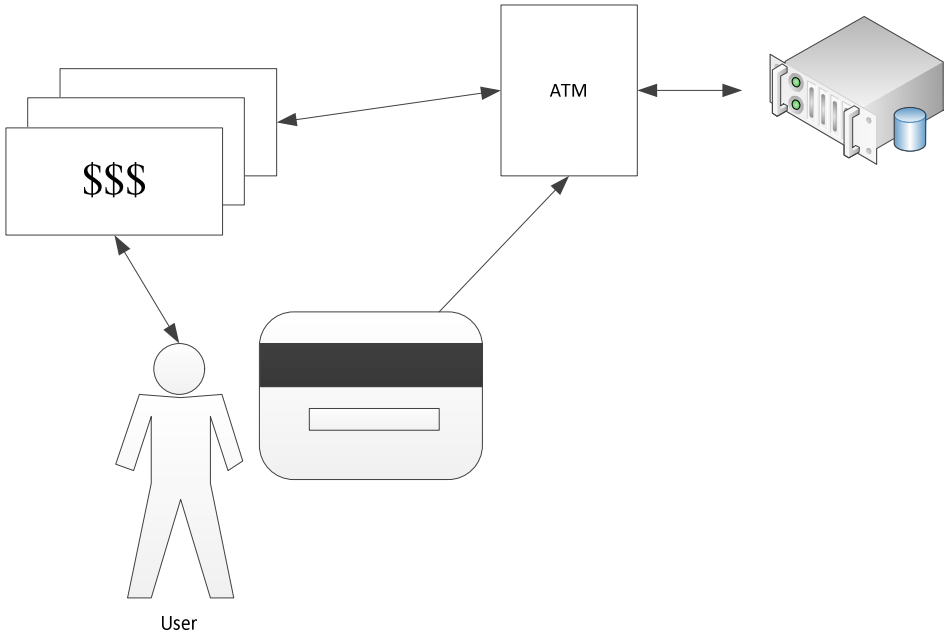
Three Design Models

- Operational Model



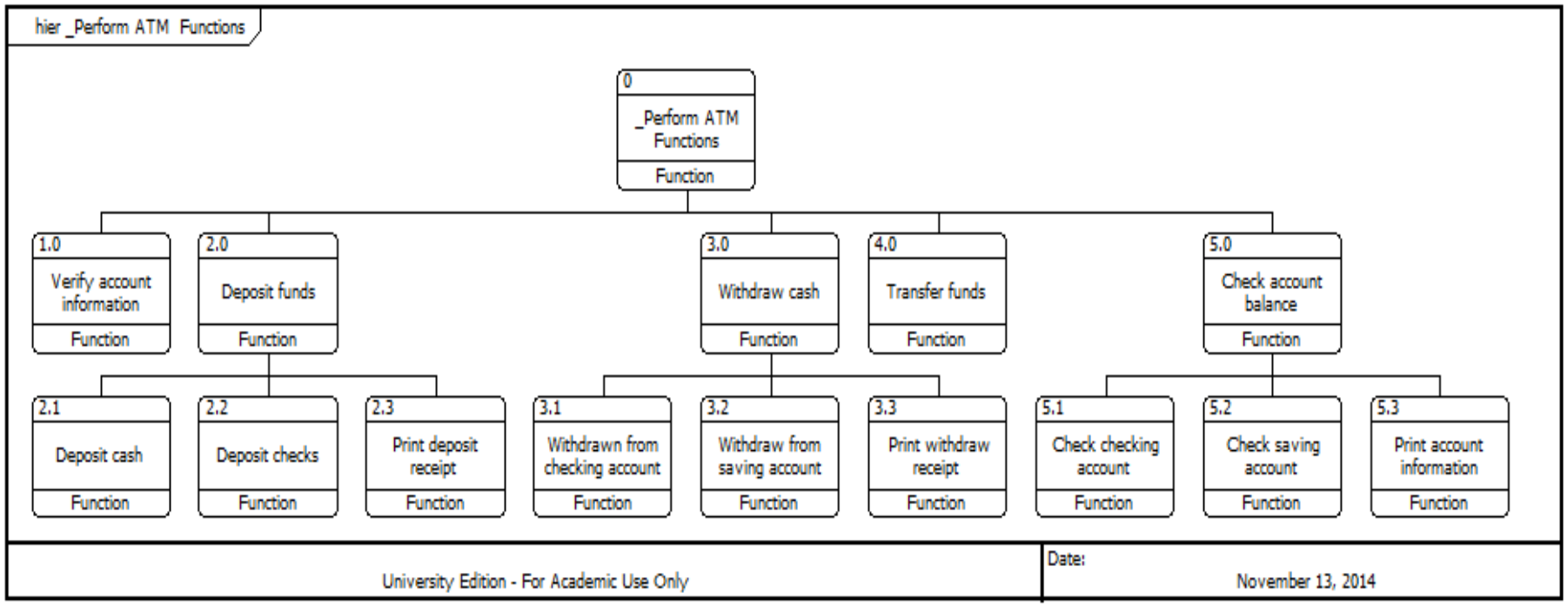
Three Design Models

- Physical Model



Three Design Models

- Functional Hierarchical Model



2.3.2.1 Functional Allocation

- Allocation the system functions to components, so that the system functional model can be translated to physical model.
- Functional analysis stops at the basic configuration level, that is, at the level that the configuration items can be obtained, either from a supplier or from commercial off the shelf (COTS) items.
- From Type A Functional baseline to Type B allocation baseline
- Design Tools
  - CAD, CAM, DOORS, CORE etc.
  - Advantages

2.3.3 Detailed Design

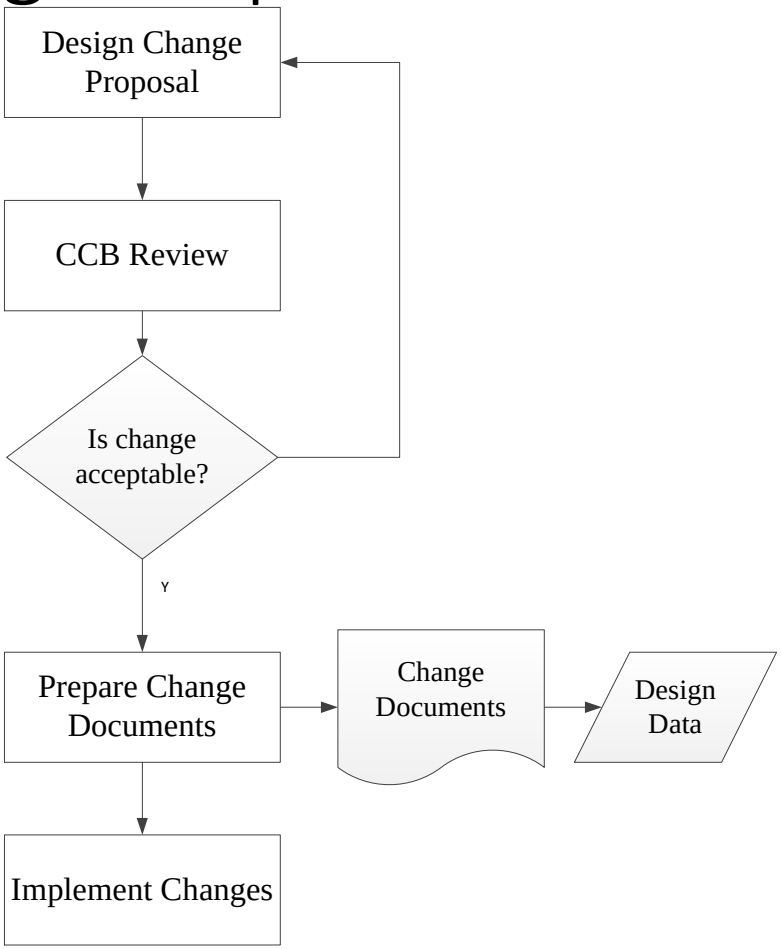
- Develop design specification for all the lower level components and items
- Develop, procure and integrate the system components into final system configuration
- Conduct critical system review,

2.3.3.1 Detailed Design Requirements

- From Functional baseline and allocation baseline to product, process and materials baseline (type C, D and E specification)
- A comprehensive description of the system configuration, in terms of system components and operations. With these descriptions, it should be easy to build or install the system with minimum confusion.
- Computer Design Tools
- Components Selection
  - COTS→ Modified COTS → Manufacturing

2.3.3.1 Detailed Design Requirements

- Change Protocol

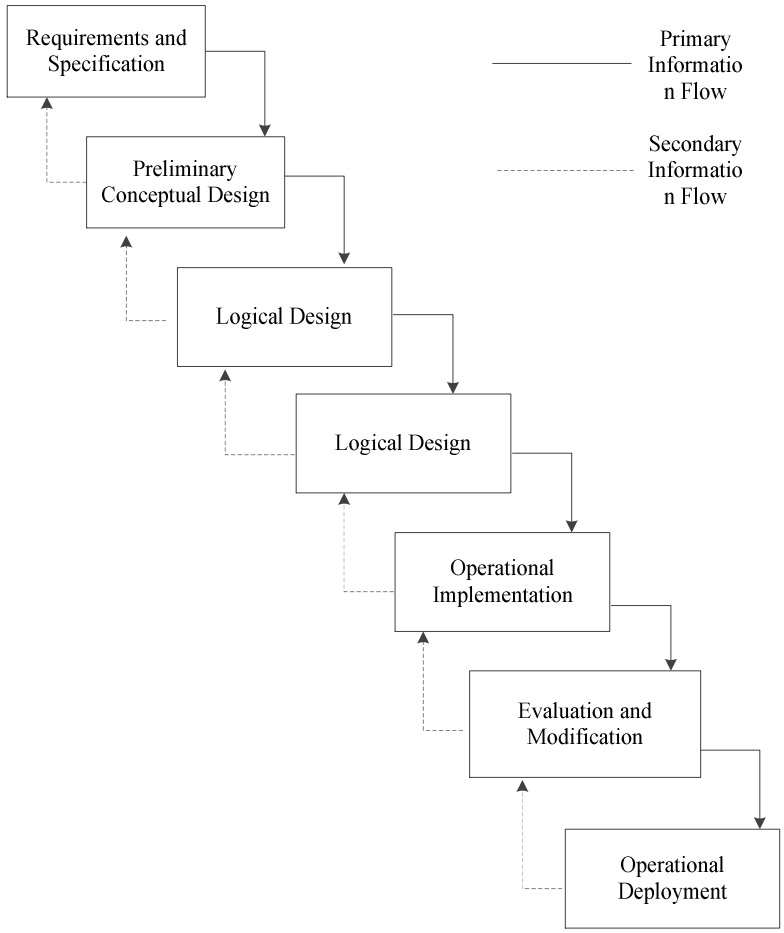


2.3.4 Systems Operation and Maintainence

- The focus of system installation is on the efficiency and effectiveness of the manpower and cost.
- Supply chain management (SCM) plays a more significant role
- follow up evaluation and feedback from the users, to find out how well the system performs at the user's site and what difficulty users have for the systems.

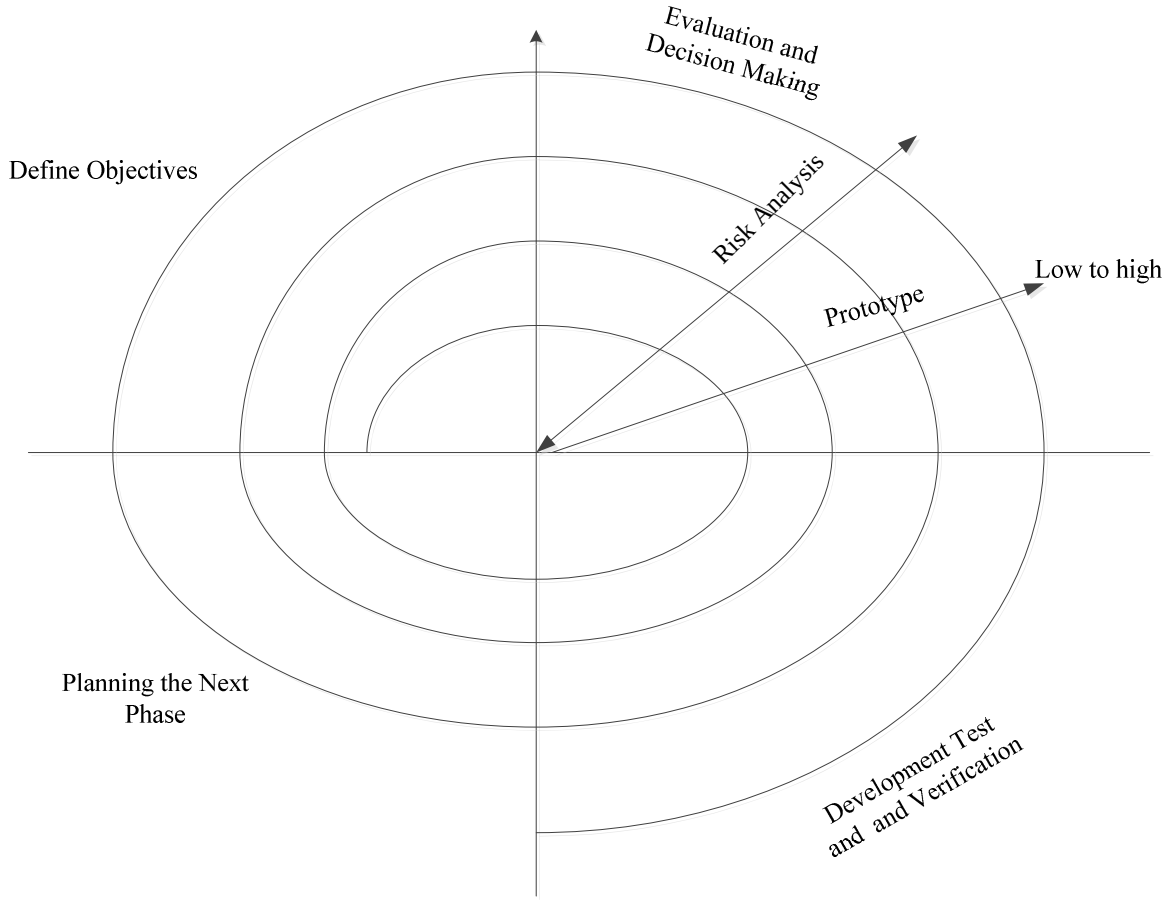
2.4 Systems Engineering Design Process Models

- Waterfall



2.4 Systems Engineering Design Process Models

- Spiral Model



2.4 Systems Engineering Design Process Models

- VEE model