Software Engineering V1.3

Sep 2023

Agenda

- Software Engineering Overview
- Software Project Methodologies
- Software Requirement Analysis
- Software Architecture and Component based Design
- Software Testing and Quality Assurance
- Cost Estimation and Measurement
- References

Software Engineering

Software

Software

- Instructions (Computer Programs) that when executed provide desired features, function and performance

What is a Project?

What is a Project?

- A project is defined as a “temporary endeavour with a beginning and an end and it must be used to create a unique product, service or result”
- End results have specific goals – Time, Cost, Performance & Quality

Software Characteristics

- Software is a logical rather than a physical system element
- Software doesn't wear-out
- Software is not susceptible to the environment maladies
- Software however deteriorates with time mainly due to change
- Software failure rate is high at the beginning but tapers out due to defect fixing

V/S

- Hardware wears out with time due to the effects of environment (dust, vibration, temp….)
- Hardware failure rate shows a bathtub curve
- Hardware failure can be corrected by spare part replacement

Software Application Domains

- **System Software** – A collection of programs written to serve other programs (compilers, editors, Operating system components, drivers, networking softwares…..)
- **Application Software** – Stand alone programs that solve a specific business need
- **Engineering/scientific Software** – number crunching programs, astronomy, CAD, Meteorology)
- **Embedded Software** – Resides within a product or system (Automobile, Medical Equipment, Industrial Automation……)
- **Product Line Software** – Designed to provide specific capability for use of many different consumers
- **Web/Mobile Applications** – Browser based apps and mobile devices
- **Artificial Intelligence Software** – Applications include Robotics, Expert Systems, Artificial neural networks, gaming

Changing Nature of Software

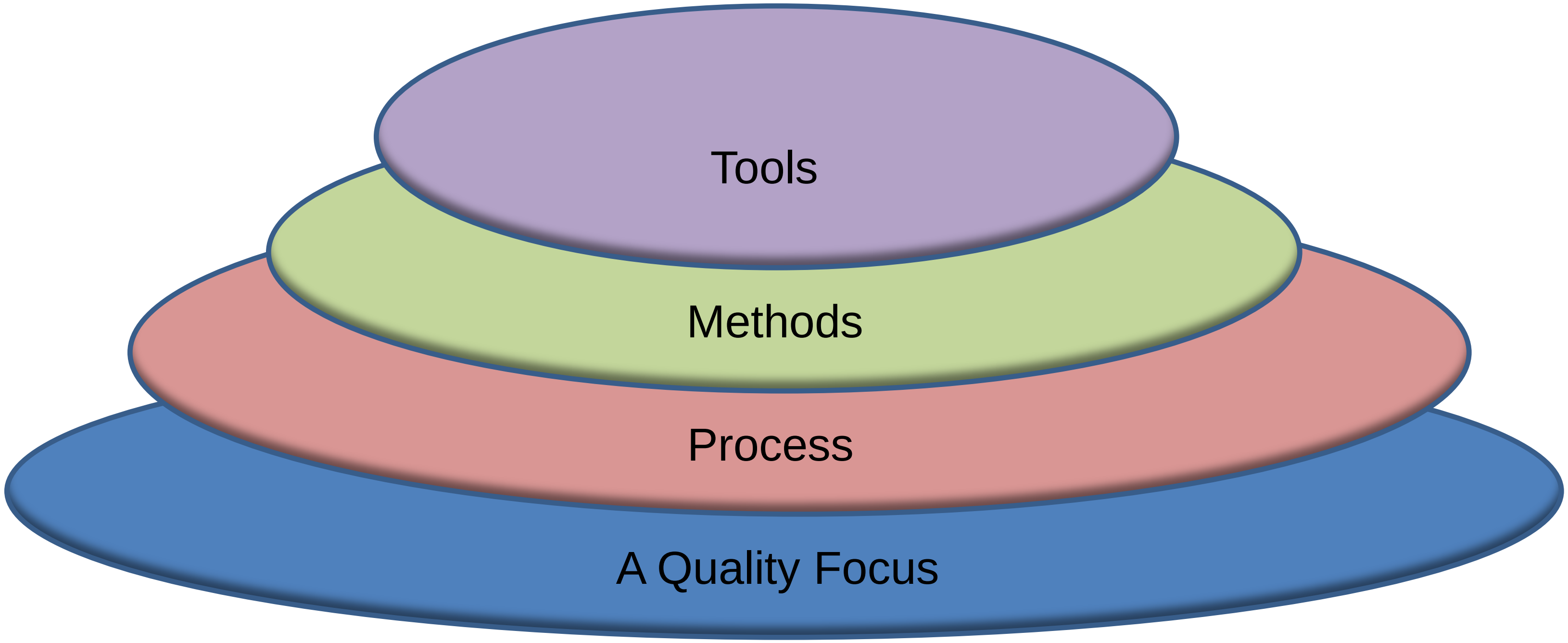
- **WebApps** – Sophisticated computing tools that not only provide stand alone function to the end user but have now integrated with corporate databases and business applications
- **Mobile Applications** – Specifically designed to reside on a mobile platform (IOS, Android) with persistent storage capabilities within the platform
- **Cloud Computing** – Encompasses an infrastructure or ecosystem that enables any user, anywhere, to use a computing device to share computing resources on a broad scale
- **Product Line Software** – A set of software –intensive systems that share a common managed set of features satisfying the specific needs of a particular market segment

Software Engineering

Software Engineering:

- Software engineering is the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software
- Software Engineering is the establishment and use of sound engineering principles in order to obtain economically software that is reliable and works efficiently on real machines

Software Engineering – A layered Technology



- Software Engineering rests on a commitment to Quality
- Process Layer is the foundation
- Engineering methods provide the “how to’s”
- Tools provide automated or semi automated support for the process and the methods

Software Engineering Process

- **The Software Process**:
- A collection of activities , actions , and tasks that are performed when some work product is to be created with a broad objective
- Is applied irrespective of the application domain, size, complexity, efforts
- Not a rigid prescription but an adaptable approach

- **The Process Framework:**
- Communication – Process of understanding Customer requirements, needs, pain areas
- Planning – A map that guides the team – Project Plan
- Modeling – The design of how to implement the requirements
- Construction –Execution or building the product
- Deployment – Delivery to the Customer

Process Framework – Umbrella Activities

- **Monitoring and Control** – Allows the team to assess progress against plan and take corrective actions wherever required
- **Risk Management** – Assess risks that may affect the outcome of the project
- **Quality Assurance** – Define and conduct activities to ensure quality
- **Technical reviews** – Assess engineering work products to uncover and remove errors
- **Measurement** – Defines and collects process, project, and product measures that assists the team to deliver software that meets stakeholders needs
- **Software Configuration Management** – Manages the effects of change throughout the life cycle
- **Reusability Management** – Defines criteria for work product reuse
- **Work product preparation and production** – Encompasses the activities required to creat work products such as models, documents, logs, forms and lists

Software Engineering Practice

- **Understand the problem:**
  - Who are the stakeholders?
  - What are the unknowns? What data functions and features are required to solve the problem
  - Can the problem be compartmentalized? Is it possible to represent smaller problems that may be easier to understand?
  - Can the problem be represented graphically? Can an analysis model be created?

- **Plan the Solution:**
  - Have you seen similar problems before? Have we done a similar project before?
  - Has a similar problem been solved? If so, are elements of the solution reusable?
  - Can subproblems be defined?
  - Can you represent a solution in a manner that leads to effective implementation? Can a design model be created?

Software Engineering Practice

- **Carry out the Plan:**
  - Does the solution conform to the plan? Is source code traceable to the design model?
  - Is each component part of the solution provable correct? Has the design code been reviewed?

- **Examine the Result:**
  - Is it possible to test each component part of the solution? Has a reasonable testing strategy been implemented?
  - Does the solution produce results that conform to the data, functions, and features that are required?

The overall approach is commonsense. In fact, it is reasonable to state that a commonsense approach to software engineering will never lead you astray!

General Principles

- **The reason it all exists –** To provide value to users – To address a pain area
- **Keep it Simple Stupid (KISS) –** All design should be as simple as possible. The payoff is software that is more maintainable and less error-prone
- **Maintain the Vision** – A clear vision is essential to the success of a software project
- **What you produce others will consume** – Always specify design, and implement knowing someone else will have to understand what you are doing. Specify with an eye to the users
- **Be open to the future** – A system with a long lifetime will add more value. Easy to adapt to change
- **Plan ahead for Reuse** – Reuse saves time and effort. Planning ahead for reuse reduces cost and increases the value
- **Think** – Placing clear complete thought before action almost always produces better results

Software Development Myths

Management Myths:

- We already have a book of standards and procedures……Is it being used?
- If we get behind schedule, we can add more programmers and catch up……Adding people to a late software makes it later (Brooks)
- If we decide to outsource the software project to a third party, I can relax……If we cannot understand how to manage and control projects internally, outsourcing will not help

Customer Myths:

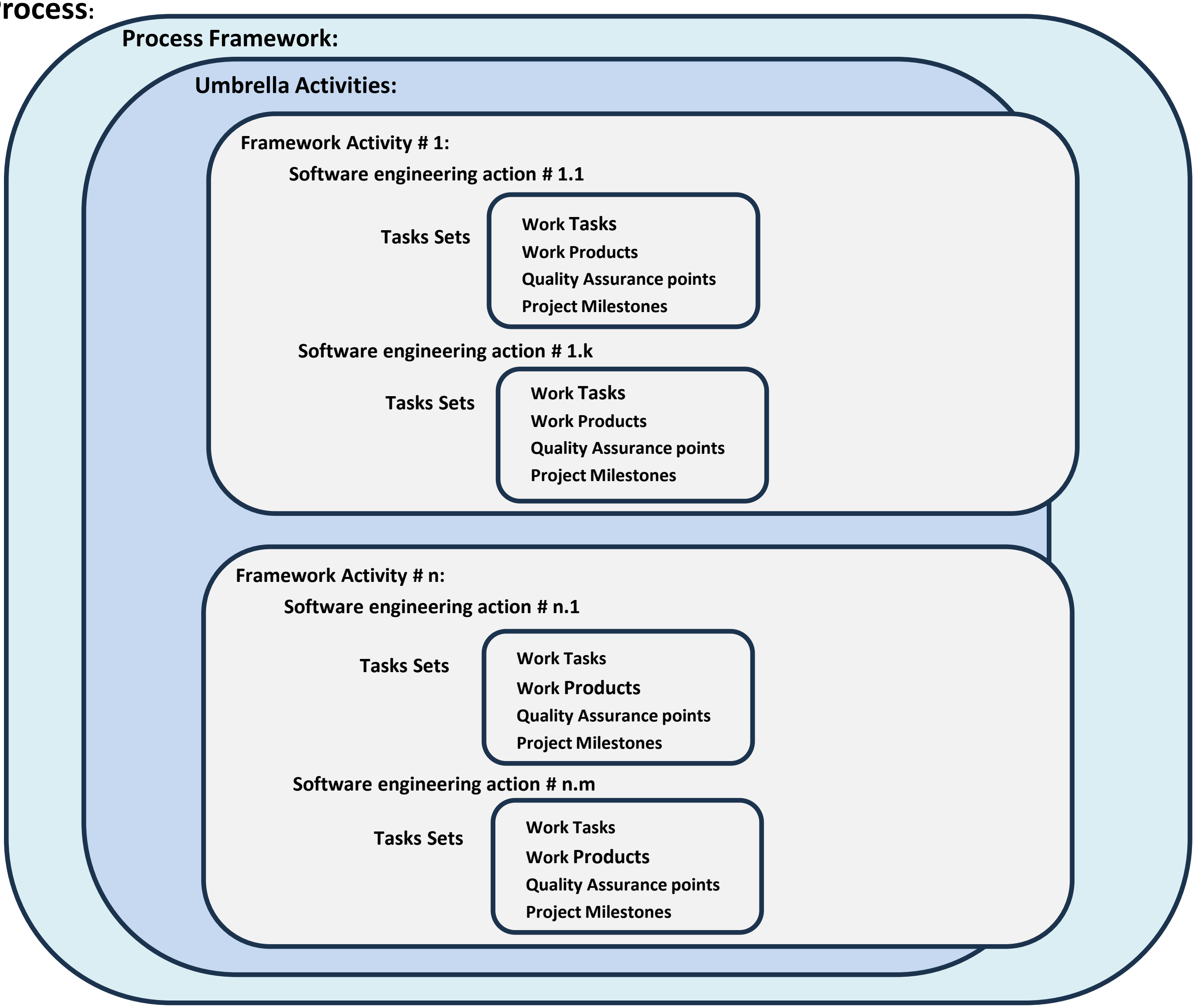
- A general statement of objectives is sufficient to begin writing programs – we can fill in the details later……An ambiguous statement of objectives is a recipe for disaster
- Software requirements continually change, but change can be easily accommodated because software is flexible……Impact of change varies with time. Later the changes in the life cycle, the more it costs

Practitioner's Myths:

- Once we write a program and get it to work, our job is done……The sooner you will begin writing code, the longer it will take
- Until I get the program running, I have no way of assessing its quality……Software reviews are one of the most effective ways for assessing the quality
- The only deliverable work product for a successful project is the working program……A working program is only one part of a software configuration. A variety of work products such as models, documents, plans are included
- Software Engineering will make us create voluminous and unnecessary documentation and will slow us down……Software Engineering is not about creating documents. It is about creating a quality product. Better quality leads to reduced rework and thereby faster delivery times

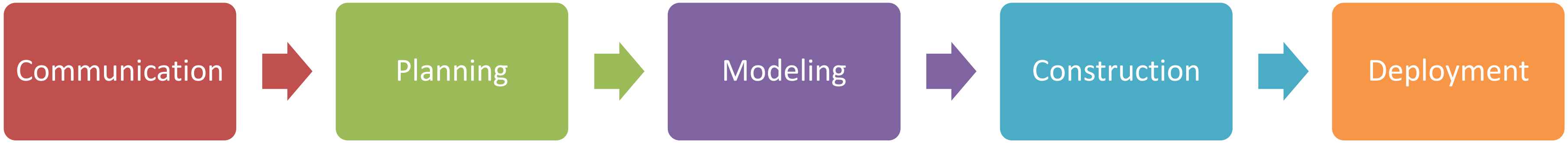
Software Process Structure

Software Process:

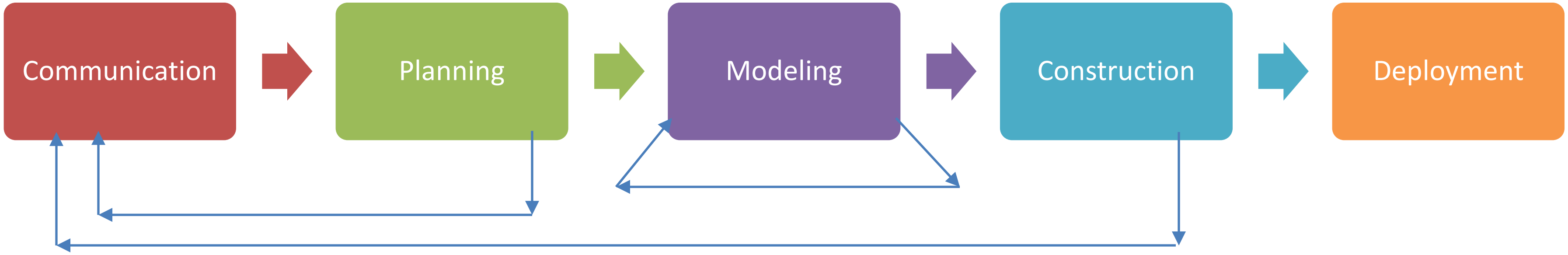


Software Process Flows

Linear Process Flow:

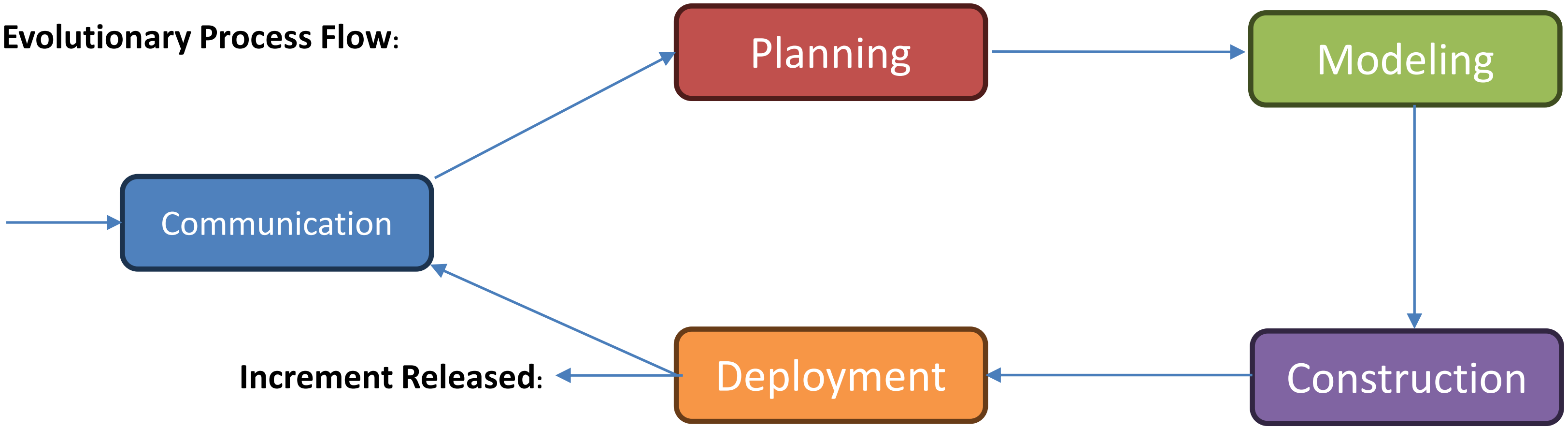


Iterative Process Flow:

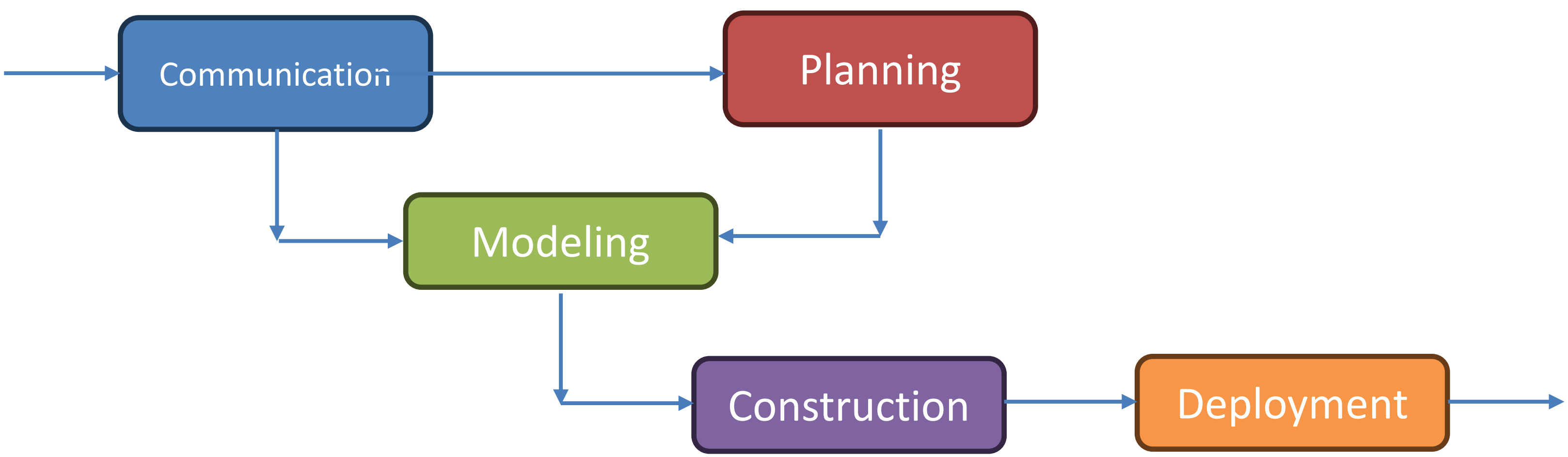


Software Process Flows

Evolutionary Process Flow:



Parallel Process Flow:



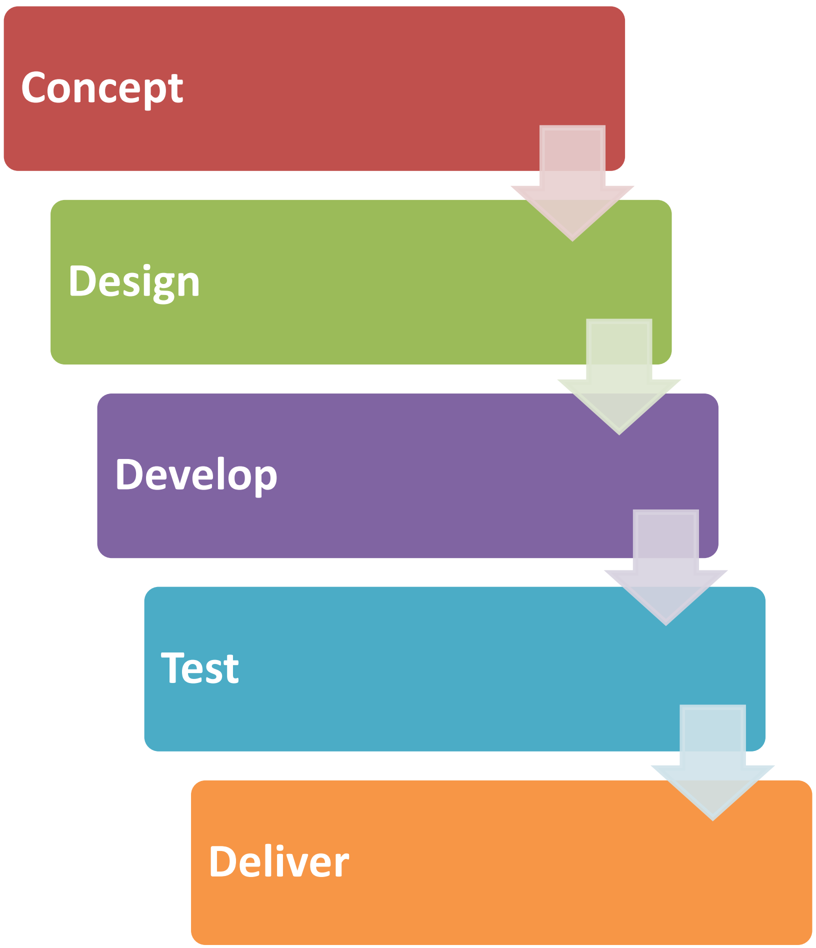
Software Process Models

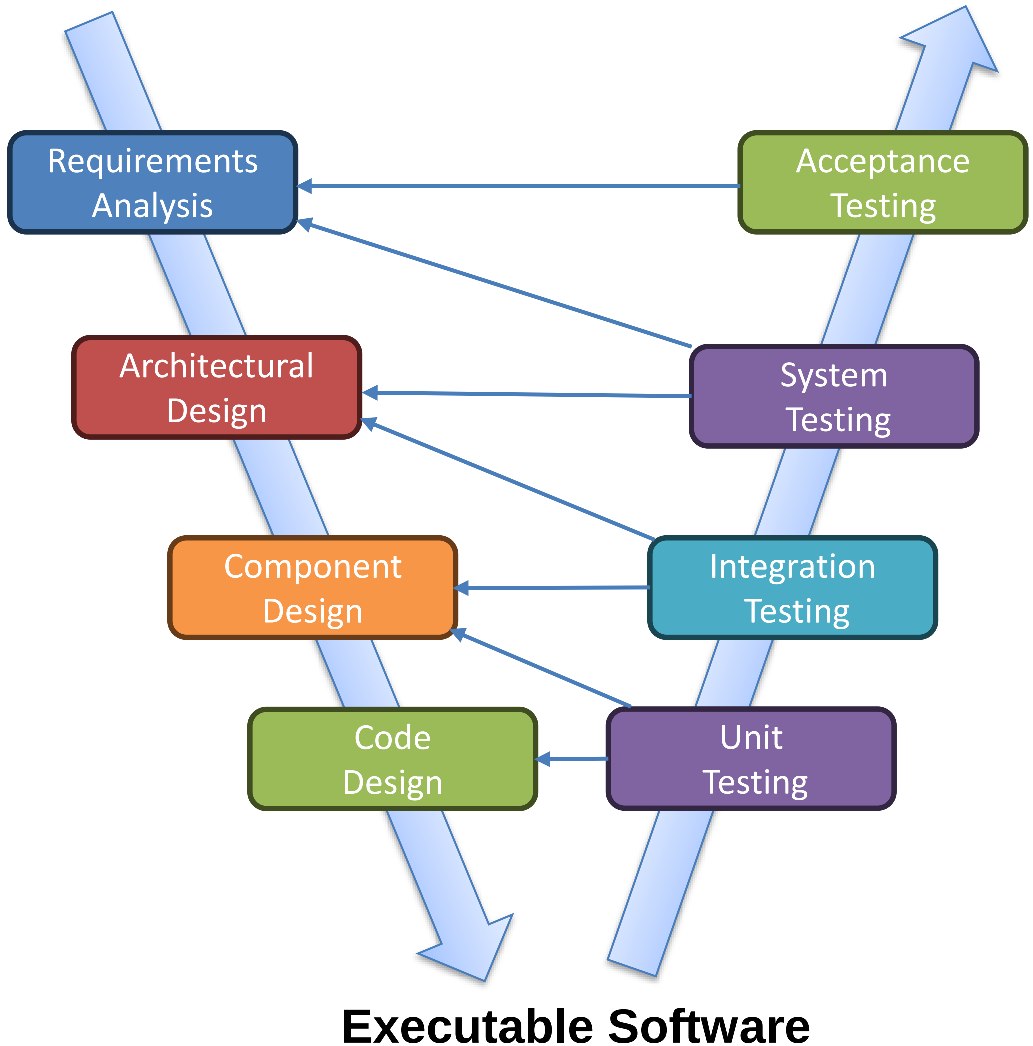
- The word 'Process' emphasizes the idea of a system in action. In order to achieve an outcome, the system will have to execute one or more activities: This is its process
- These activities can be organized in different ways – 'Process Models'

Waterfall	•A classical Model also known as one-shot or once-through model •A sequence of activities working from Top to Bottom •Best suited where the Requirements are well defined & development methods well understood
Spiral	•A Feasibility Study is carried out at the beginning of the project •Greater level of detail is considered at every stage of the project •Portrayed as a loop or a Spiral where the system to be developed is considered in more detail in every step
Atern/DSDM	•The approach is more incremental and iterative •Also called as Dynamic Systems Development Method •8 Core principles: Focus on Business Need, OTD, Collaborate with user, Quality, Iterative Development, Incremental Build, Communicate & Control
RAD	•Also referred to as Rapid Prototyping Model •The major aim is to reduce costs and cycle time and improved Change Management •Increased Customer involvement as feedback is sought on successive developed prototypes which are refined
Agile	•Designed to overcome important disadvantages of the Traditional Methodologies •The approach involves development of one feature at a time and released to the Customer for their use and feedback •Includes various sub methods: Scrum, XP, Kanban

Waterfall

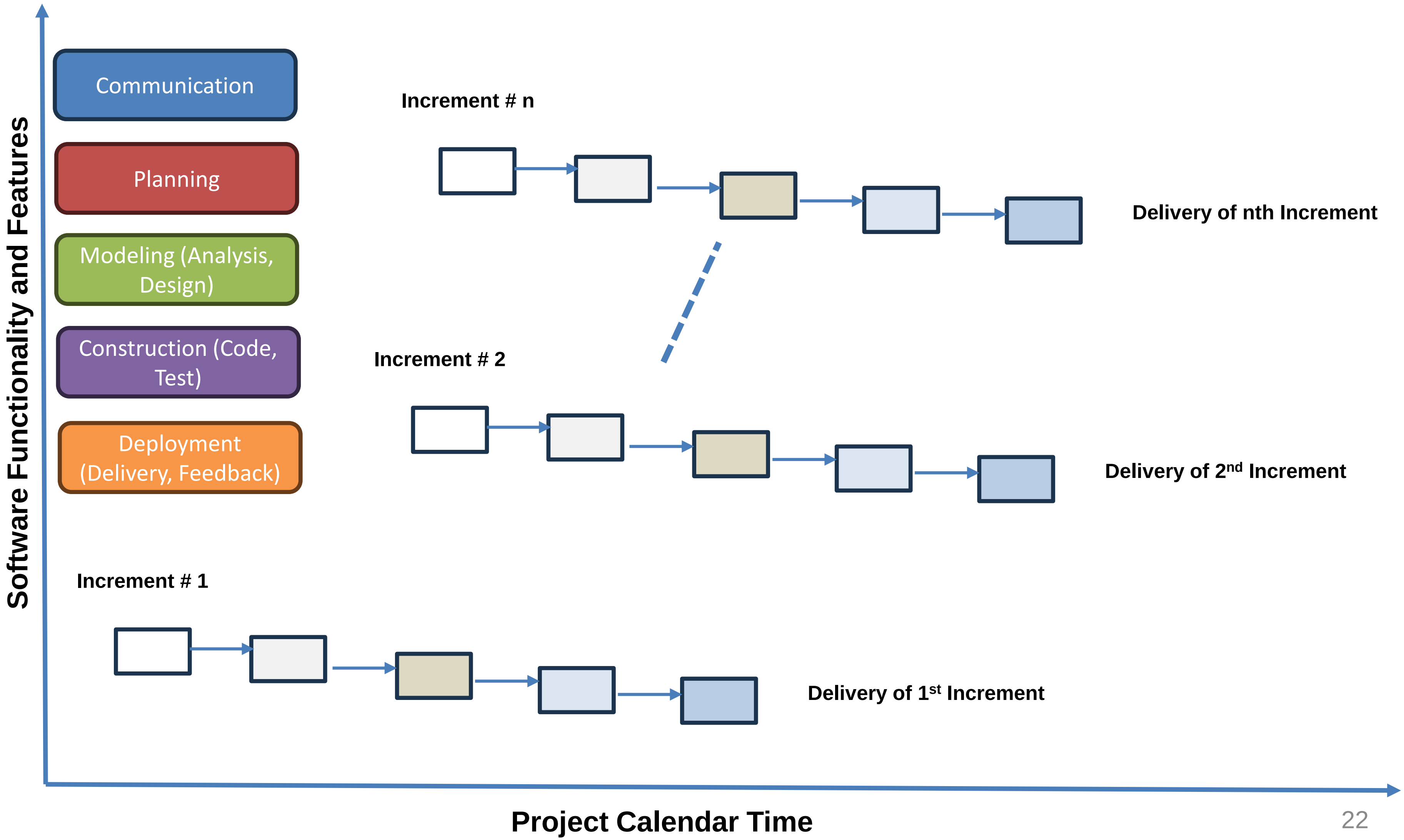
Waterfall





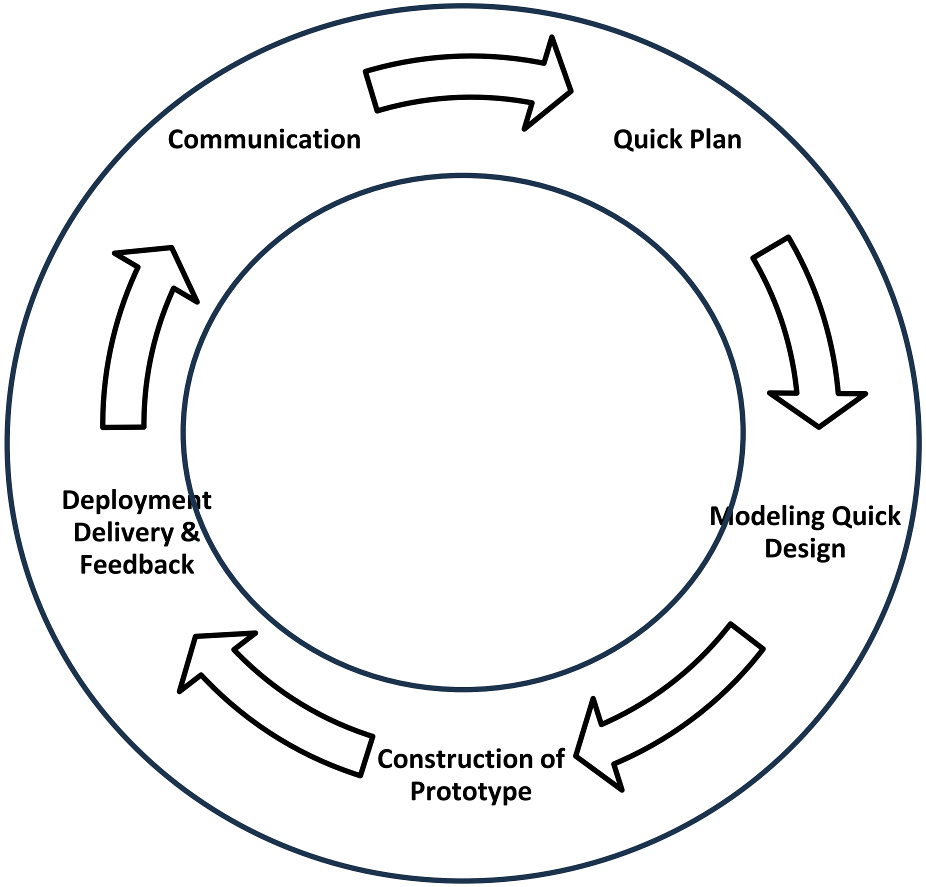
Incremental Process

Incremental Process Model



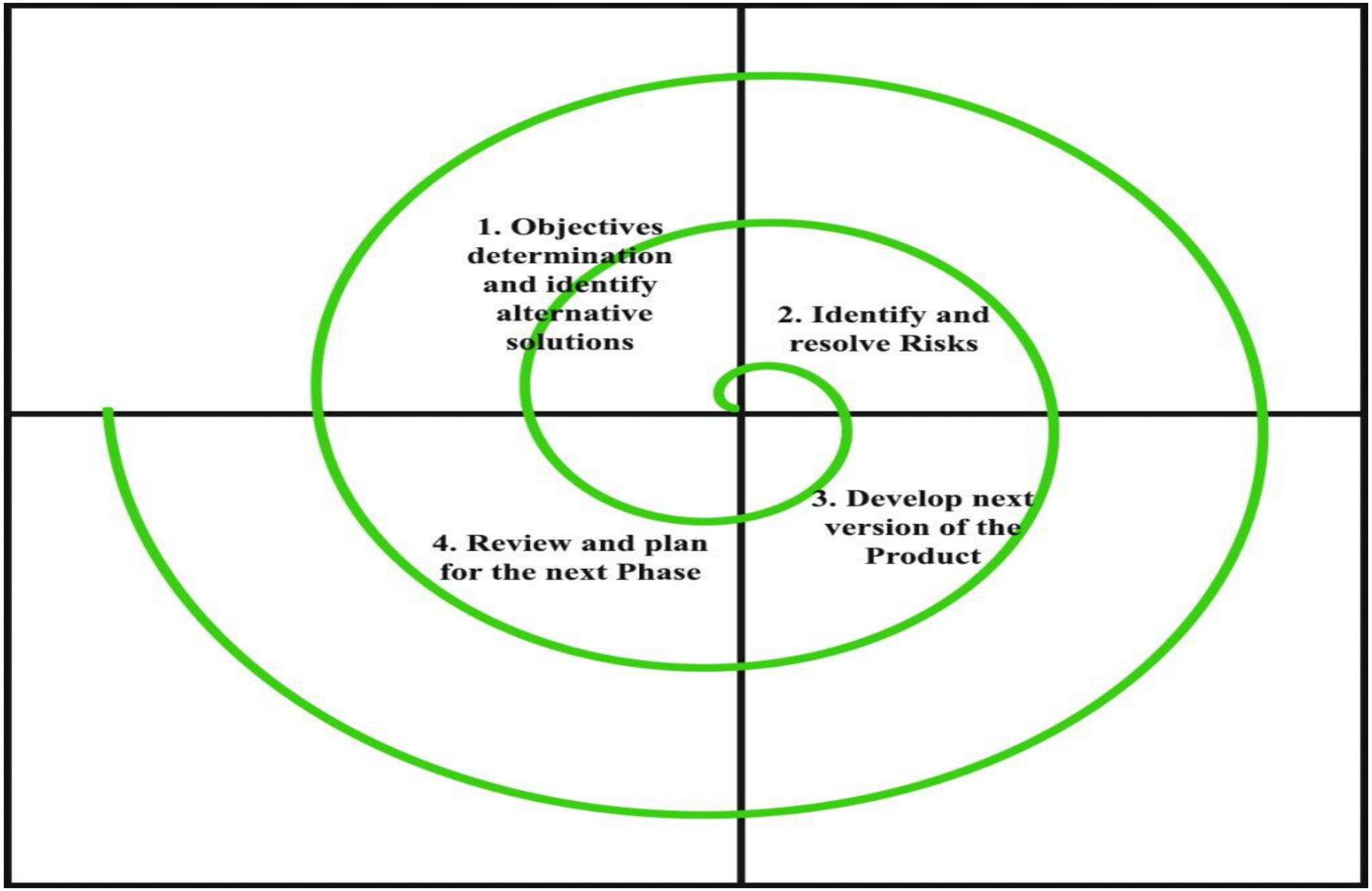
Evolutionary Process Models

Prototyping



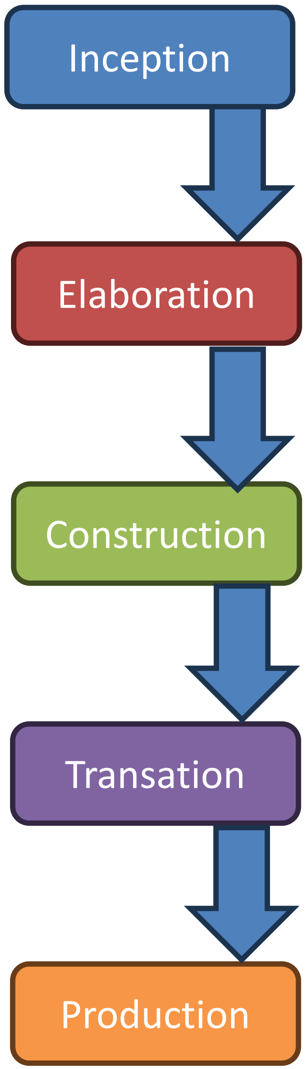
- Best suited when the Customer defines a set of general objectives but does not identify detailed requirements for functions and features
- The developer may be unsure of the efficiency of an algorithm, the adaptability of an operating system or the form that human-machine interaction should take place

Spiral Model – Different Phases



- An evolutionary software process that couples the iterative nature of prototyping with the controlled and systematic aspects of Waterfall model
- The software is developed in a series of evolutionary releases. Early iterations release might be a prototype and later iterations would be more complete versions of the system

The Unified Process



- Encompasses both Customer communication & Planning activities
- Business requirements (Use Cases) are identified and a rough architecture is proposed
- A plan for the iterative, incremental nature of the project is developed

- Use cases that were developed as part of the inception phase are refined and expanded
- Expands the architecture to include Use Case Model, Analysis Model, Design Model, Implementation Model, and Deployment Model
- A first cut executable system representation is done

- Using the architectural model as input, the construction phase develops or acquires the components to make the Use case operational
- Analysis and design models are completed to reflect the final version of the software increment
- All necessary and required functions and features are implemented
- Unit tests are designed and executed and integration activities are conducted

- Encompasses the delivery and feedback activity
- Software is given to end users for beta testing for defects and feedback
- The team creates the necessary support information (User manuals, troubleshooting guides, and installation procedures

- Ongoing use of the software is monitored
- Support for the operating environment (infrastructure)is provided
- Defect reports and requests for changes are submitted and evaluated

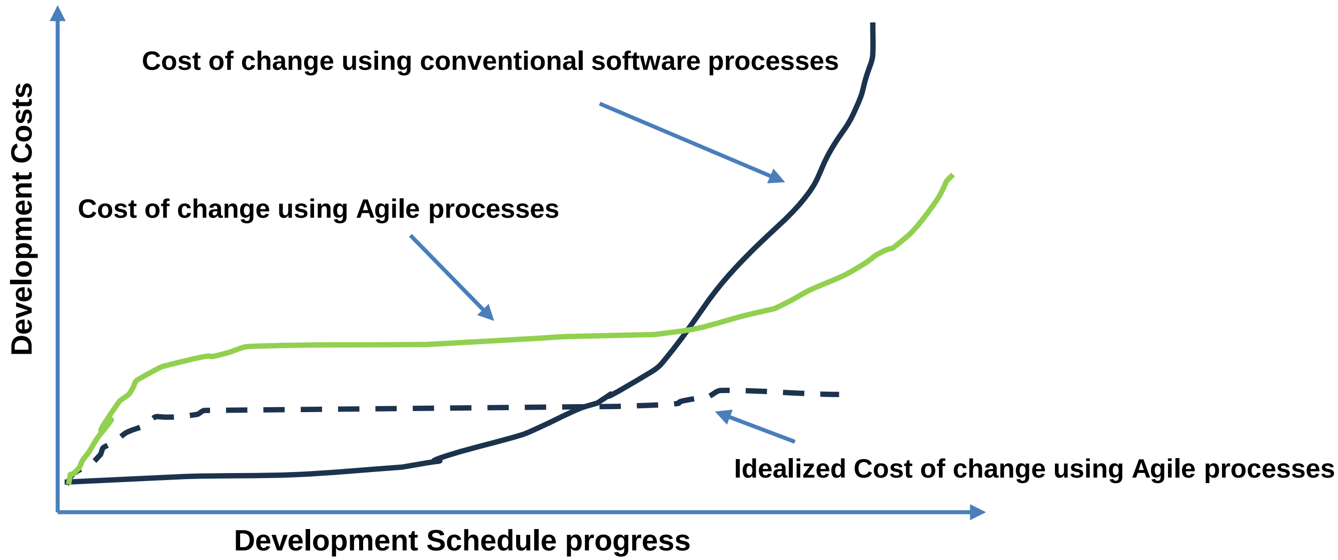
Agile Development

What is Agility?

- Software development today is driven by change. The pervasiveness of change is the primary driver for Agility
- Agility is more than an effective response to change
- It encourages team structures and attitudes that make communication between stakeholders more facile
- It emphasizes rapid delivery of operational software

Agility and the cost of change

- The cost of change increases nonlinearly as the project progresses
- It is easy to accommodate a change during the upper life cycle especially requirements phase
- Changes later in the life cycle require changes across the phases (Requirements, Design, Coding, Testing)
- A well defined Agile process flattens the cost of change curve



Agile Process

Key Assumptions

- It is difficult to predict in advance which software requirements will persists and which will change
- It is difficult to predict how Customer priorities will change as the project proceeds
- For many types of software, the design and construction are interleaved. Both activities should be performed in tandem so that the design models are proven as they are created
- Analysis, Design, Construction, and Testing are not as predictable (from a planning point of view) as we might like

How do we create a process that can manage unpredictability?

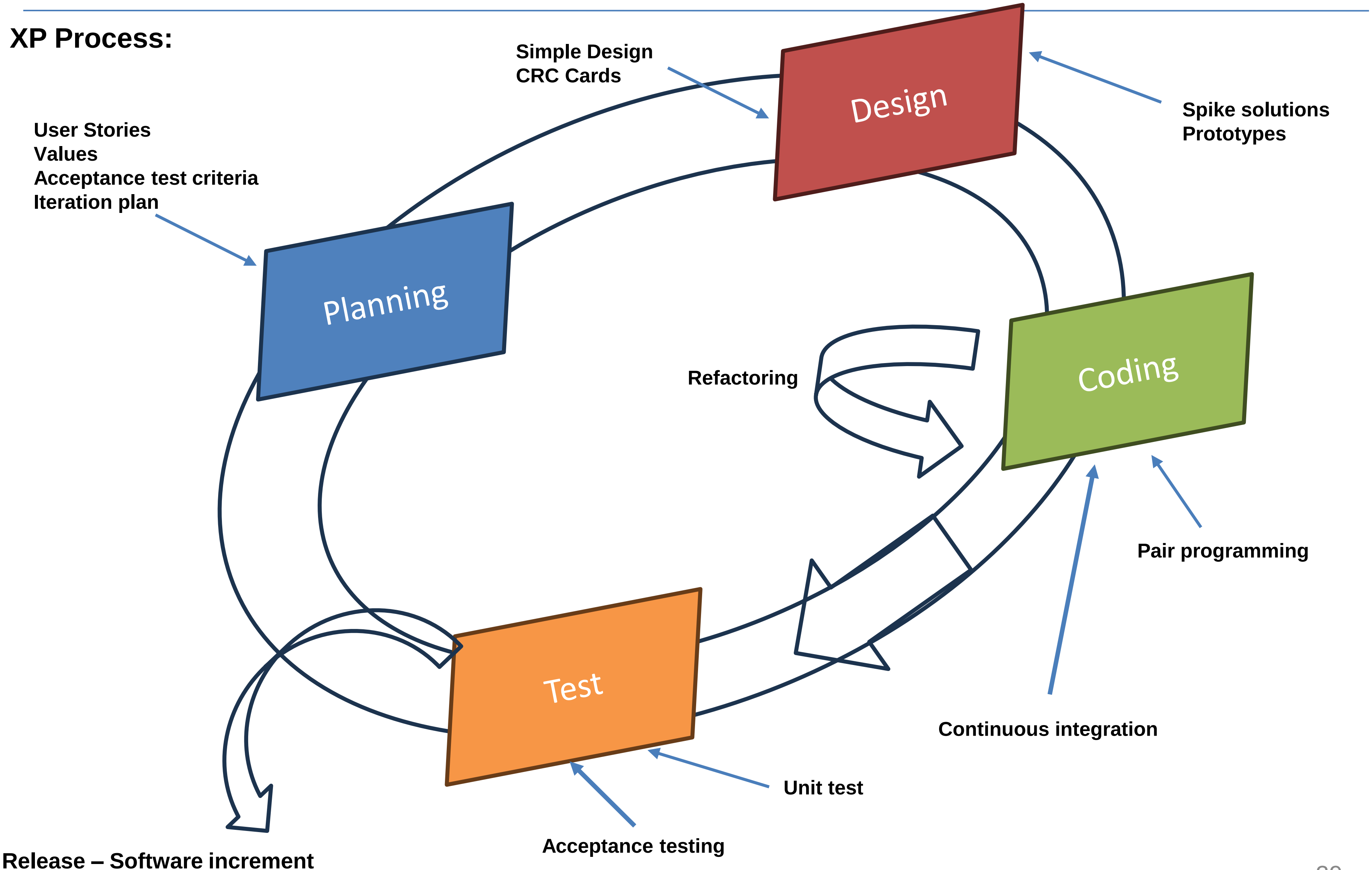
- An incremental development strategy should be instituted!
- Adaptation keeps pace with change (unpredictability)
- This iterative approach enables the Customer to evaluate the software increments regularly, provide necessary feedback to the development team, and influence the process adaptations that are made to accommodate the feedback

Agile Principles

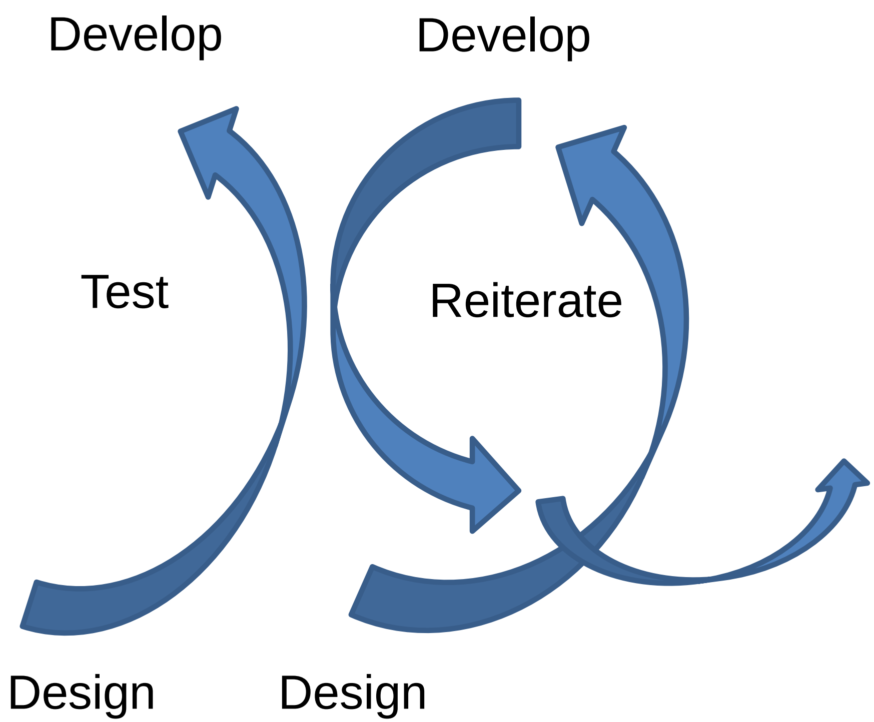
1. Highest priority is to satisfy the Customer through early and continuous delivery of valuable software
2. Welcome changing requirements even late in development. Agile processes harness change for the Customers competitive advantage
3. Deliver working software frequently, from a couple of weeks to a couple of months with a preference to the shorter time scale
4. Business people and developers must work together daily throughout the project
5. Build projects around motivated individuals, Give them the environment and support they need, and trust them to get the job done
6. The most efficient and effective method of conveying information to and within a development team is face-to-face conversation
7. Working software is the primary measure of progress
8. Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely
9. Continuous attention to technical excellence and good design enhances agility
10. Simplicity – the art of maximizing the amount of work done – is essential
11. The best architecture, requirements, and design emerge from self organizing teams
12. At regular intervals the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly

Agile – Extreme Programing

XP Process:

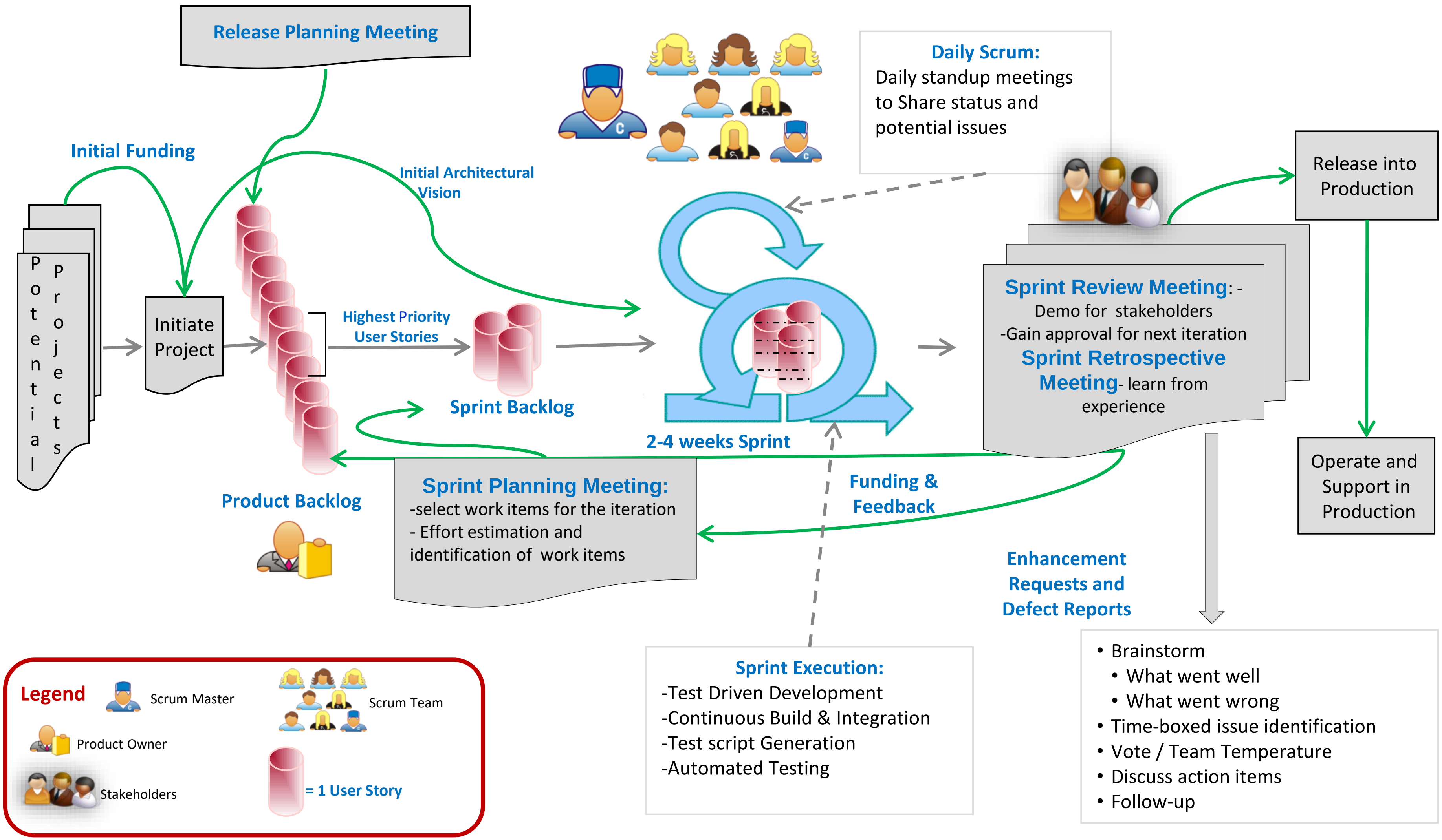


Agile Scrum Model



1. The Project is divided into sprints of 2 to 4 weeks where incremental functionality is completed and delivered
2. Key Role holders – Product Owner, Scrum Master, Team Member
3. Key Artefacts – Product Backlog, Sprint Backlog, Sprint Burn Down and Burn Up Charts
4. Scrum Ceremonies – Sprint Planning, Daily Scrum, Sprint Review Meeting

Agile – Scrum



Rather than doing all of one thing at a time…
…Scrum teams do a little of everything all the time

Agile – Dynamic Systems Development Method

- Provides a framework for building and maintaining systems through the use of incremental prototyping in a controlled environment
- An iterative software process in which each iteration follows the 80% rule. Only enough work is required for each increment to facilitate movement to the next increment

Functional Model iteration

- Produces a set of incremental prototypes that demonstrate functionality to the Customer
- All DSDM prototypes are intended to evolve into deliverable applications
- Intent is to gather additional requirements through feedback from users as they exercise the prototype

Design and Build Iteration

- Revisit and review prototypes that were built during the functional model iteration
- In some cases the functional model iteration and the design and build iteration occur concurrently

Implementation

- Places the latest software increment (An operational prototype) into the operational environment
- The increment may be 100% complete or changes may be requested as the increment is put into place

Agile Unified Process

- AUP adopts a “serial in the large” and “iterative in the small” philosophy for building computer based systems
- By adopting the classic UP phased activities (Inception, Elaboration, Construction, and Transition) – AUP provides a serial overlay (linear sequence of software engineering activities)

Each AUP iteration addresses the following activities:

Modeling	•UML representations of the business and problem domains are created •These models should be just barely good enough to allow the team to proceed
Imlementation	•Models are translated into source code
Testing	•Like XP, the team designs and executes a series of tests to uncover defects
Deployment	•Delivery of software increment and acquisition of feedback from the end users
Configuration and Project Management	•Configuration management addresses change management, Risk Management and control of any persistent work products •Project Management tracks and controls the progress of the team and coordinates team activities

Agile Methods – Basic Principles

- Incremental Delivery after each time box
  - Features are decomposed into small parts that can be incrementally developed
  - Each incremental part is developed over an iteration
  - The Time to develop an iteration is called a time box
- Face-to-Face communication
  - Emphasis on Face-to-Face communication over written documents
  - Daily contact through communication channels
- Customer Interactions
  - Includes Customer representative in the team
  - Customer participates in review meetings and provide feedback
- Minimal Documentation
  - Documents are created on a need to know basis
  - Documentation is light so easy to keep up-to-date and consistent
- Pair Programming
  - In this approach two programmers work together at one station
  - The programmers switch roles every hour or so
  - Lesser defects are expected

Waterfall V/S Agile

Strengths	Weaknesses	Type of projects
Waterfall: 1. Simple projects 2. Clear Requirements 3. Past projects experience 4. Intuitive and logical	1. Requirements frozen early 2. Does not encourage changes 3. Cycle time is too long 4. Late user feedback	1. Projects with very clear requirements 2. Short duration projects 3. Automation of existing manual systems
Agile: 1. Regular deliveries 2. Reduces risks 3. Accommodates changes 4. Quick user feedback 5. Prioritizing requirements	1. Requirements spillover from sprints 2. Backlog bloating 3. Possibility of rework and defects 4. System architecture and structure may suffer as frequent changes are made	1. For projects where time is of essence 2. Risk of long projects cannot be taken 3. Requirements are not known and will be known only with time

Agile Methods – Sub Methods

Extreme Programming (XP)

- Based on Four Core Values: Communication and Feedback, Simplicity, Responsibility, Courage
- Code is developed in iterations of 1 to 4 weeks during which specific features are created. Pair programming is followed
- Small Releases – Time between Releases must be as short as possible
- Simple Design and Testing is done at the same time as coding using automation tools

Scrum

- The Project is divided into sprints of 2 to 4 weeks where incremental functionality is completed and delivered
- Key Role holders – Product Owner, Scrum Master, Team Member
- Key Artefacts – Product Backlog, Sprint Backlog, Sprint Burn Down and Burn Up Charts
- Scrum Ceremonies – Sprint Planning, Daily Scrum, Sprint Review Meeting

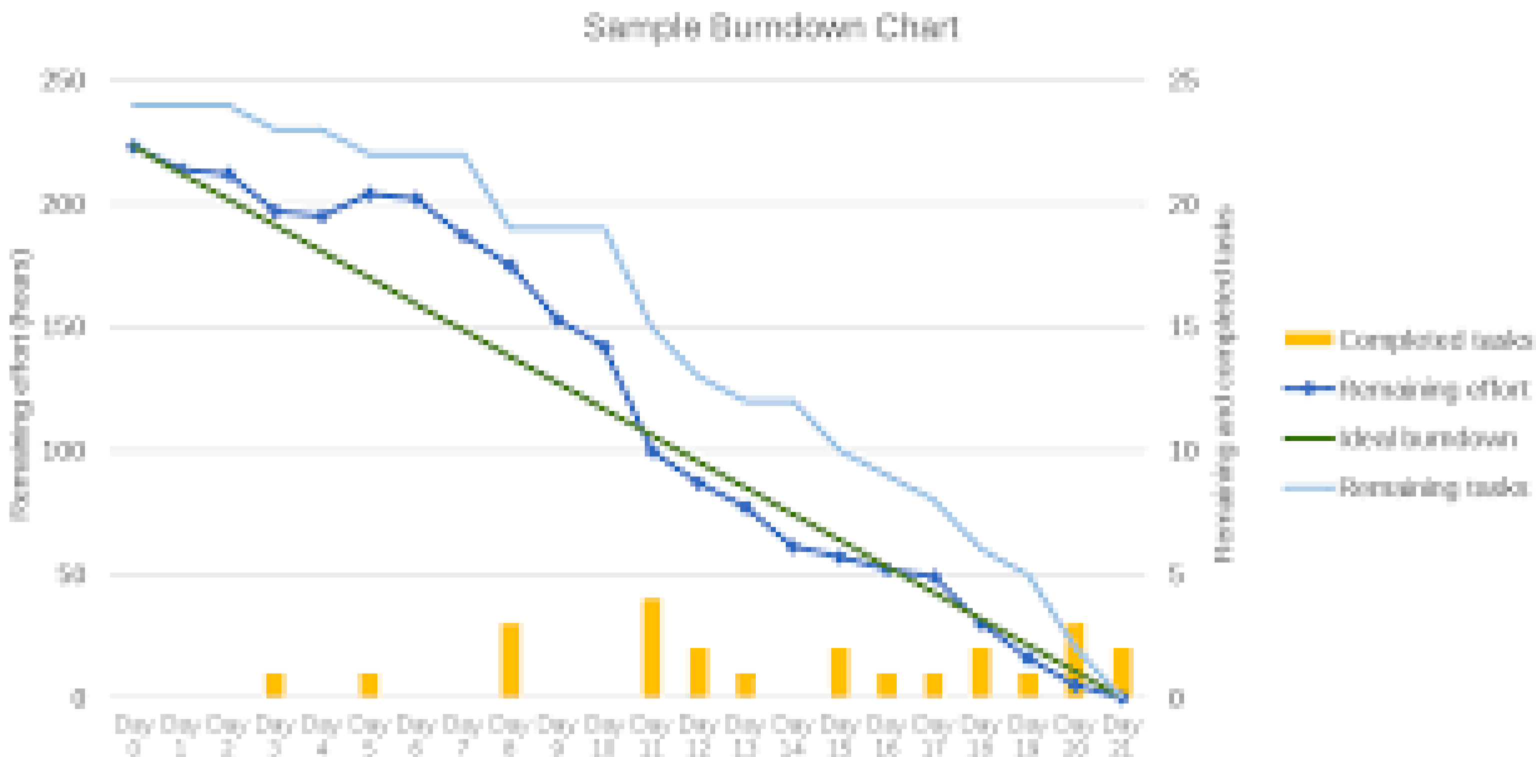
Kanban

- Main Objective is to provide visibility to the workflow. This is expected to debottleneck congestions in the process and minimize delays
- Kanban Board and Kanban Card – Typically a white board on which Kanban Cards are attached to represent the work items. A card is moved on the board as the corresponding work is completed at a stage
- Visibility – It shows work assigned to each developer at any time and the work flow. Bottlenecks get highlighted. Cycle time is tracked and optimized

Agile Methods – Kanban Boards example

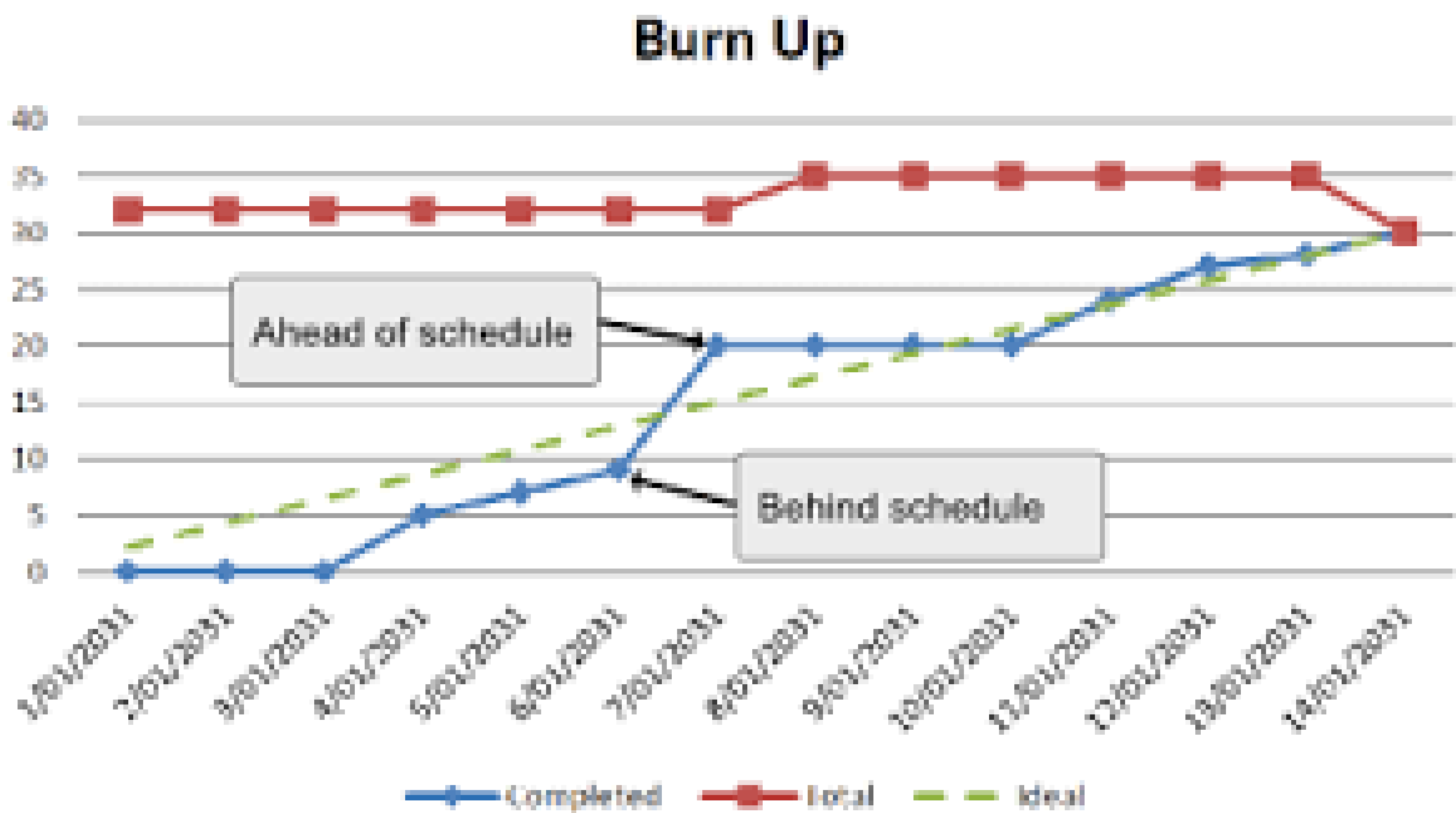
Agile -- Metrics

Burn Down Chart



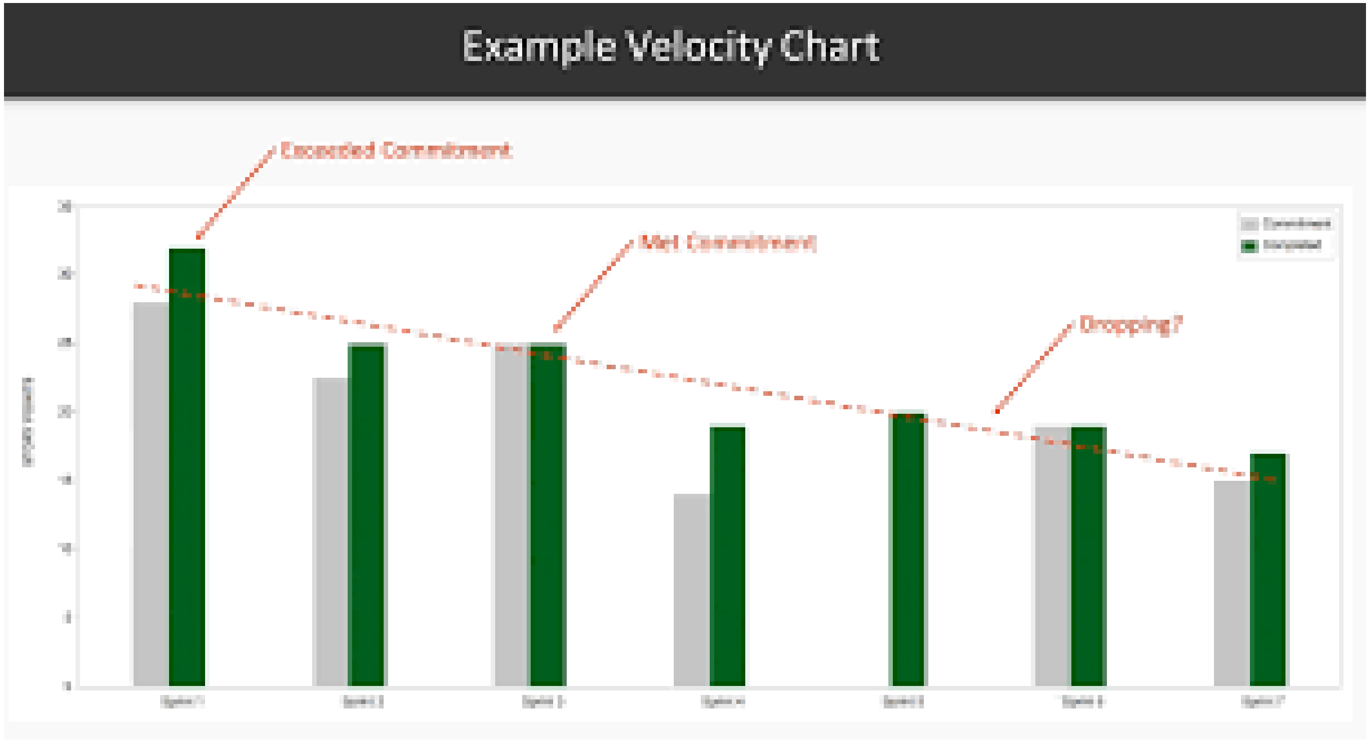
Agile -- Metrics

Burn Up Chart



Agile -- Metrics

Velocity



Agile – Metrics & Challenges

What to measure?

Efforts (Cost), Schedule, Quality of Deliverables, Customer Satisfaction

Traditional Methodology:

Measurements done at phase level

- Size : Function Points, LOC, Use-case Points
- Efforts / Cost – Effort Variance / Cost Variance
- Schedule – Schedule Variance
- Quality –
  - Defect Density, Review Effectiveness, Defect Removal Efficiency
  - Efficiency, Test Case Effectiveness
  - Defect Density – Defects / FP, Defects / KLoc
  - Defect Age, Defect Acceptance Rate
- Critical Chain Concept can be used for effective Buffer Management
- Earned Value can be used for prediction / Forecasts to facilitate Proactive Project Management
- Customer Satisfaction – Customer Satisfaction Survey / Feedback

Agile Methodology:

Measurements done at Sprint and Iteration level

- Size : Story Points
- Efforts / Cost – Effort Variance / Cost Variance
- Schedule – Schedule Variance
- Quality –
  - **Defect Density – Defects/Story Point,** Review Effectiveness, Defect Removal Efficiency
  - Efficiency, Test Case Effectiveness
  - **Defect Density – Defects / Story Points**
  - Defect Age, Defect Acceptance Rate
- Critical Chain Concept can be used for effective Buffer Management
- Earned Value can be used for prediction / Forecasts to facilitate Proactive Project Management
- Customer Satisfaction – Customer Satisfaction Survey / Feedback

Challenges?

- Inconsistencies in Size measurements across projects and inadequate baselines
- Short Turn around time in a sprint leading to process gaps
- Aggressive schedule and stringent deadlines

Agile Methods – Challenges

- Reluctance to Change
  - Difficult to break work habits as teams are used to work with a traditional approach. Need to implement Agile in a phased manner with pilot projects
- Quality, Cost, Time and Scope
  - Agile being flexible allows frequent changes in scope which means that Cost, Quality or Time has to change. In practice, majority of projects have fixed budget and a mandatory deadline
  - Establishing when the scope changes to cease is difficult and hence leads to overruns
- Ready to Use Product
  - An application under agile development process is always evolving and may have functional defects. Hence, performance testing can only be performed after substantial number of deliveries
- Inability to 'design' for future requirements
  - Irrespective of best design models and most experienced design personnel on a project team, it is very hard to design a system on the basis of unseen requirements. This often leads to 'rework' at various stages in development and testing
- External and Internal Dependencies
  - Majority of projects have external dependencies which are out of control of core project team and they are discovered only during development
  - The selection of work items is dependent on internal teams, hence planning each iteration becomes tough and needs huge coordination efforts

Requirements Analysis and Specification

"I know you think you understand what I said, but what you don't understand is what I said is not what I meant"

For large Software systems, requirements analysis is perhaps the most difficult and intractable activity and is it is error-prone

Why is Requirements Analysis difficult?

- The needs of the system are in the minds of the Customer organization
- The analyst has to identify the requirements by interacting with the Customer and understanding their needs……visualize
- As the information which is visualized, is not formally stated or organized, the input of the requirements phase is inherently informal and imprecise, and is likely to be incomplete
- When inputs from multiple people are to be gathered, these inputs are likely to be inconsistent as well
- User needs keep changing as the environment in which the system is to function changes with time

The requirement process

- The requirements phase translates the ideas in the minds of the Customer (the input) into a formal document (the output)
- The output is hopefully complete and consistent, while the input has non of these properties
- Any formal translation process producing a formal output must have a precise and unambiguous input

Software Requirements

Requirement

- A condition of capability needed by a user to solve a problem or achieve an objective
- A condition or capability that must be met or proposed by a system…… to satisfy a contract, standard, specification, or other formal imposed document

- Requirements of the proposed system, that is the capabilities that the system, which is yet to be developed should have
- Even while accepting that some requirement change requests are inevitable, it is imperative to have a high quality and stable SRS (Software Requirement Specification)

Why do we need a high quality and stable SRS?

- An SRS establishes the basis for agreement between the Customer and the Supplier on what the software product will do
- An SRS provides a reference for validation of the final product
  - A defect in the SRS will most likely manifest itself as a defect in the final system implementing the SRS
- A high quality SRS is a prerequisite to high quality software
  - Cost of fixing a defect increases almost exponentially as time progresses
- A high quality SRS reduces the development costs

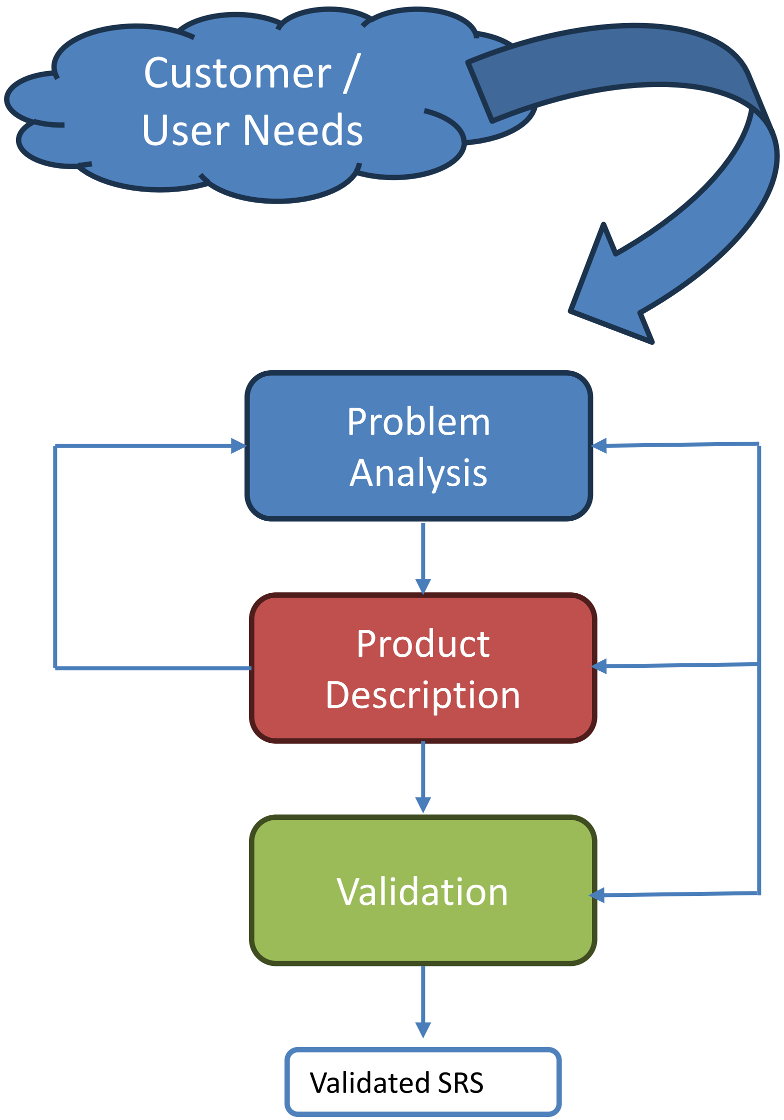
High quality SRS – High quality & Reduced costs

Phase	Cost (Person-hours)
Requirements	2
Design	5
Coding	15
Acceptance Test	50
Maintenance	150

- Invest an additional 100 person-hours in the requirements phase, an average of 50 new requirement defects will be detected and removed
- Distribution of defects that remain after the requirements phase:
- 65% in design, 2% in coding, 30% in Testing, 3% in maintenance
- Assuming that the 50 defects are detected in the later phases after requirements, the cost of fixing the defects will be:
- (32.5*5) + 1*15) + (15*50) + (1.5*150) = 1152 person hours!!
- By investing additional 100 person hours in the requirements phase, the development costs could be reduced by 1152 person hours – a net reduction in cost of 1052 person hours

- It is estimated that 20% to 40% of the total development effort in a software project is due to rework (mainly due to change in requirements
- Cost of requirements phase is roughly 6% of the total project cost. Consider a project with 50 person months of total effort
- Requirements phase consume 3 person months
- If by spending an additional 33% effort in the requirements phase, we reduce the total requirement change requests by 33%
- Total effort due to rework will reduce from 10 to 20 person months resulting a total saving of 5 to 11 person months i.e a saving of 10% to 22% of the total cost!!

Requirements process



- The problem domain and the environment are modelled in an effort to understand the system behaviour, constraints, inputs & outputs

- Focus is on clearly specifying the requirements in a document
- Issues such as representation, specification languages, and tools are addressed to organize and describe the requirements

- Focusses on ensuring that what has been specified in the SRS are indeed all the requirements of the software
- Making sure that the SRS is of a good quality

Problem Analysis

- The basic aim of problem analysis is to obtain a clear understanding of the needs of the clients and the users, what exactly is desired from the software and what the constraints on the solution are
- The basic principle used in analysis is the same as in any complex task: divide and conquer!
- Partition the problem into subproblems and then try to understand each subproblem and its relationship to other subproblems in an effort to understand the total problem

Methods of Analysis:

Informal Approach

- An approach where no defined methodology is used
- The information about the system is obtained by interaction with the client, end users, surveys, study of existing documents, brainstorming

Data Flow Modeling

- Also referred to as the structured analysis technique uses function based decomposition while modeling the problem
- Data Flow diagrams (DFD) and Data Dictionary are created. The system is viewed as a function that transforms the inputs into desired outputs

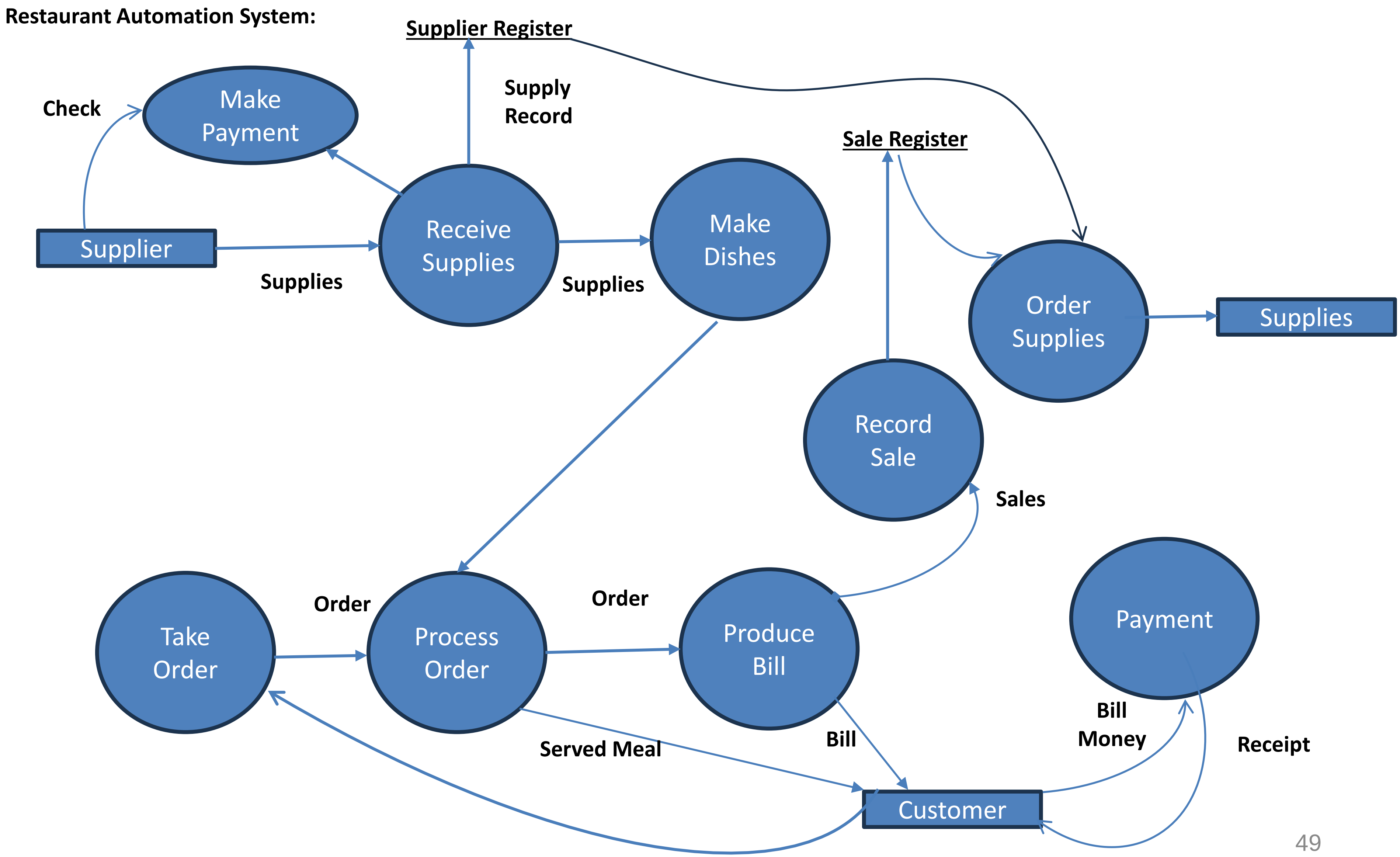
Object Oriented Modeling

- The system is viewed as a set of objects (Object Classes). The objects interact with each other through the services they provide
- Define the classes by specifying what state information they encapsulate and what services they provide
- Identify relationships that exist between objects of different classes

Prototyping

- A partial system is constructed which is used by the clients, users , and developers to gain a better understanding of the problem and the needs
- Two approaches – throwaway and evolutionary prototypes

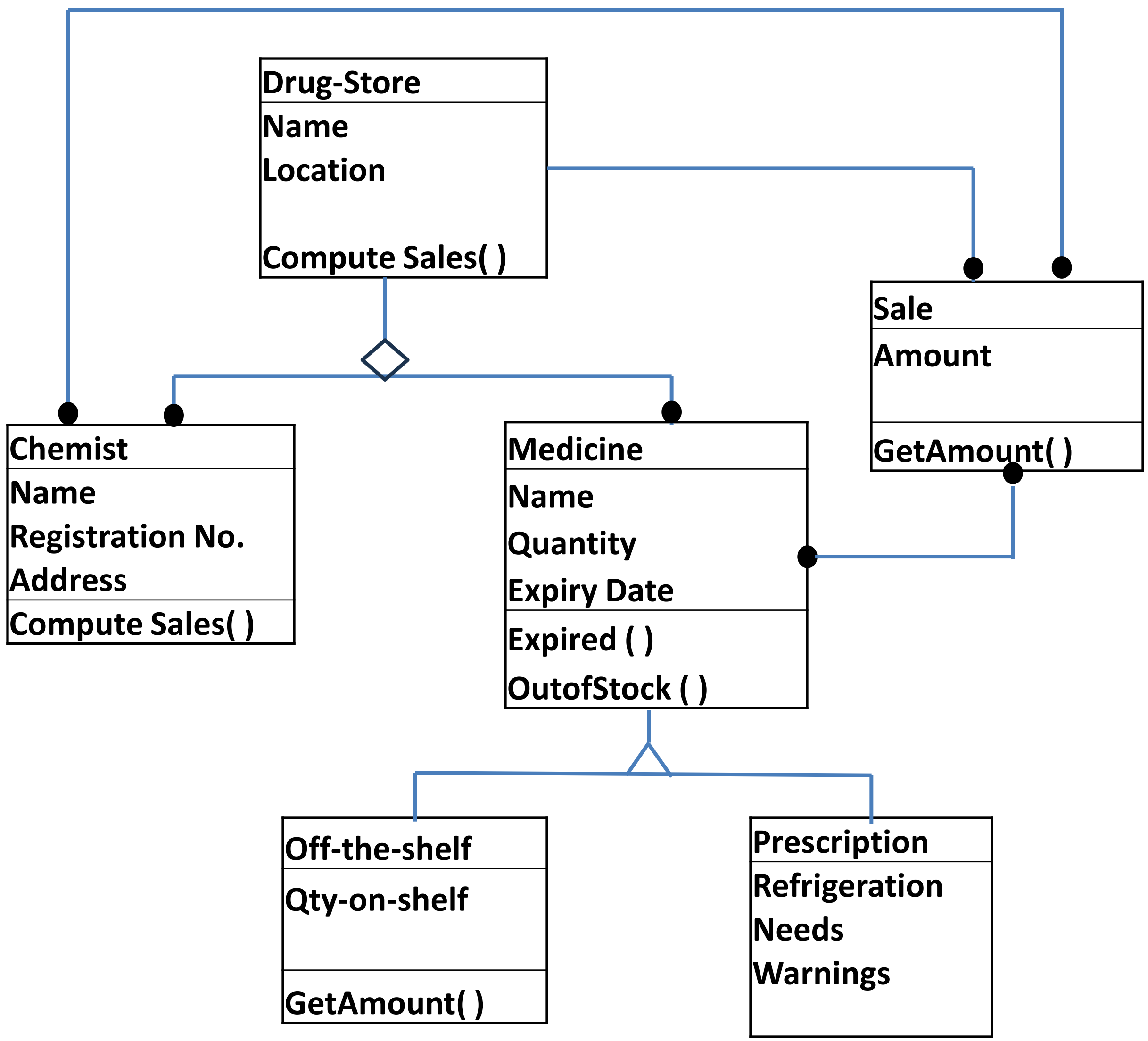
Data Flow Diagram (DFD)



Data Dictionary

- Supplies_file = [date + [item_no + quantity + cost]*
- Order_file = [date + [menu+item_no + quantity + status]*]*
- Status = satisfied | unsatisfied
- Order = [menu_item_no + quantity]*
- Menu = [menu_item_no + name + price + supplies_used]*
- Supplies_used = [supply_item_no + quantity]*
- Bill = [name + quantity + price]* + total_price + sales_tax + service_charge + grand_total
- Discrepancy_report = [supply_item_no + amt_ordered + amt_left + amt_consumed + desr]*

Object Oriented Modeling



Software Requirements Specifications (SRS)

Characteristics of an SRS:

Correct	• An SRS is correct if every requirement in the SRS represents something required in the final system
Complete	• An SRS is complete if everything the software is supposed to do and the response of the software to all classes of input data are specified in the SRS
Unambiguous	• An SRS is unambiguous if and only if every requirement stated has one and only one interpretation
Verifiable	• An SRS is verifiable if and only if every stated requirement is verifiable. The requirements should have as little subjectivity as possible
Consistent	• An SRS is consistent if there is no requirement that conflicts with another
Ranked for importance and /or stability	• Some requirements are core requirements which are not likely to change as time passes while others are more dependent on time • SRS is ranked for importance and /or stability. Stability of a requirement reflects the chances of it changing in future
Modifiable	• An SRS should be easy to modify. This is possible if the structure and style are such that any necessary changes can be made easily while preserving completeness and consistency
Traceable	• An SRS is traceable if the origin of each of its requirements is clear and if it facilitates the referencing of each requirement in future development

Components of an SRS

Functionality

- Functionality requirements specify which outputs should be produced from the given inputs
- They describe the relationship between the input and output of the system
- For each functional requirement, a detailed description of all the data inputs and their source, the units of measure, and the range of valid inputs must be specified
- All operations to be performed on the input data to obtain the output should be specified.
- Specifying the validity checks on the input and output data, parameters affected by the operation, and equations or other logical operations that must be used to transform the inputs into corresponding outputs
- The functional specifications must clearly state the system behavior for invalid inputs and invalid outputs

Components of an SRS

Performance

- This part of the SRS specifies the performance constraints on the software system
- All the requirements relating to the performance characteristics of the system must be clearly specified
- There are two types of performance requirements – Static and Dynamic
- Static requirements are those that do not impose constraints on the execution characteristics of the system. These are also called capacity requirements (No. of terminals to be supported, No. of simultaneous users……)
- Dynamic requirements specify constraints on the execution behavior of the system (Response time and throughput……)
- The functional specifications must clearly state the system behavior for invalid inputs and invalid outputs

Components of an SRS

Design Constraints

- **Standards Compliance** – This specifies the requirements for the standards the system must follow. For e.g. report format, accounting procedure, audit tracing requirements
- **Hardware Limitations** – The software may have to operate on some existing or predetermined hardware, thus imposing restrictions on the design
- **Reliability and Fault Tolerance** – Requirements about system behavior in the face of certain kinds of faults is specified
- **Security** – Security requirements place restrictions on the use of certain commands, control access to data, different kinds of access requirements for different users, maintain log of activities.

Components of an SRS

External Interface Requirements

- All the interactions of the software with people, hardware, and other software should be clearly specified
- For the user interface, the characteristics of each user interface of the software product should be specified
- For hardware interface requirements, the SRS should specify the logical characteristics of each interface between the software product and the hardware components. For e.g. memory restrictions, load characteristics……
- The interface requirement should specify the interface with other software the system will use or that will use the system

Structure of an SRS

1. Introduction
    - 1.1 Purpose
    - 1.2 Scope
    - 1.3 Definitions, Acronyms, and Abbreviations
    - 1.4 References
    - 1.5 Overview
2. Overall Description
    - 2.1 Product Perspective
    - 2.2 Product Functions
    - 2.3 User Characteristics
    - 2.4 General Constraints
    - 2.5 Assumptions and Dependencies
3. Specific Requirements

Functional Specifications with Use Cases

- A use case is a written description of how users will perform tasks on the system
- It outlines, from a user's point of view, a system's behavior as it responds to a request
- Each use case is represented as a sequence of simple steps, beginning with a user's goal and ending when that goal is fulfilled.

Term	Definition
Actors	A person or a system which uses the system being built for achieving some goal
Primary Actor	The main actor for whom a use case is initiated and whose goal satisfaction is the main objective of the use case
Scenario	A set of actions that are performed to achieve a goal under some specified conditions
Main success scenario	Describes the interaction if nothing fails and all steps in the scenario succeed
Extension scenario	Describe the system behavior if some steps in the main scenario do not complete successfully

Use Case Example

* **Use Case 1: Put an item for auction**

  Primary Actor: Seller

  Precondition: Seller has logged in

  Main Success Scenario:

  1. Seller posts an item (its category, description, picture, etc.) for auction
  2. System shows past prices of similar items to seller
  3. Seller specifies the starting bid price and a date when auction will close
  4. System accepts the item and posts it

  Exception Scenarios:

  - 2 a) There are no past items of this category
    * System tells the seller this situation

* **Use Case 2: Make a bid**

Validation of the SRS

- The basic objective of Validating the SRS is to ensure that the SRS reflects the actual requirements accurately and clearly

- The SRS is of a good quality

Types of errors:

- Omission : Some user requirement is simple not included in the SRS

- Inconsistency : Contradictions within the SRS or incompatibility of the stated requirements with the actual requirements

- Incorrect fact : Some fact recorded in the SRS is not correct

- Ambiguity : Some requirements have multiple meanings i.e. their interpretation is not unique

Software Architecture

- At a top level, architecture is a design of a system which gives a very high level view of the parts of the system and how they are related to form the whole system

- Architecture partitions the system in logical parts such that each part can be comprehended independently, and then describes the system in terms of these parts and the relationship between these parts

Important uses of architecture:

- Understanding and communication :
    - To communicate the system to the various stakeholders (Users, Clients, developers)
    - The stakeholders gain an understanding of some macro properties of the system and how the system intends to fulfill the functional and quality requirements

- Reuse :
    - One of the main techniques by which productivity can be improved, thereby reducing the cost of the software

- Construction and Evolution:
    - Some architecture provided partitioning can be used for constructing the system

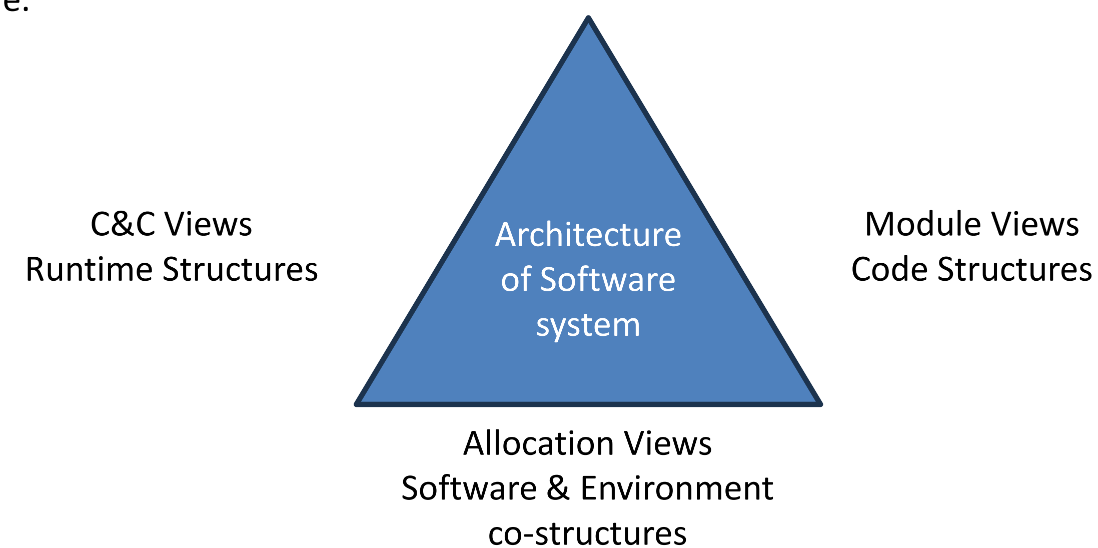
- Analysis:
    - It is highly desirable if some important properties about the behaviour of the system can be determined before the system is actually built (analyse the response time and throughput for a web site to be developed)

Architecture Views

- Module:
  - The system is viewed as a collection of code units, each implementing some part of the system functionality
  - These views are code based and do not explicitly represent any runtime structure of the system (Packages, a class, a procedure, a method……)

- Component and connector :
  - The system is viewed as a collection of runtime entities called components. A component is a unit which has an identity in the existing system (Objects, a collection of objects, a process……)
  - Components provide means for interaction with others (shared data, middleware……)

- Allocation:
  - Focuses on how the different software units are allocated to resources like hardware, file systems, and people.



Function Oriented Design

- A design methodology is a systematic approach to creating a design by applying of a set of techniques and guidelines

- The design process has two levels:
    - At the first level, the focus is on deciding which modules are needed for the system, the specifications of these modules and how the modules should be implemented – system design or top level design
    - In the second level, the internal design of the modules, or how the specifications of the module can be satisfied is decided – detailed design or logic design

Design Principles:

- Efficiency:
    - Proper use of scarce resources by the system – cost considerations
    - If some resources are scarce and expensive, it is desirable to use them efficiently (Processor time and memory)

- Simplicity :
    - Most important quality criteria for software systems
    - Maintainability of the software is one of the established goals

Design Principles

- Problem partitioning and Hierarchy:
  - The goal is to divide the problem into manageable small pieces that can be solved separately
  - The cost of solving the entire problem is more than the sum of the cost of solving al the pieces
  - The design produced by using problem partitioning can be represented as a hierarchy of components

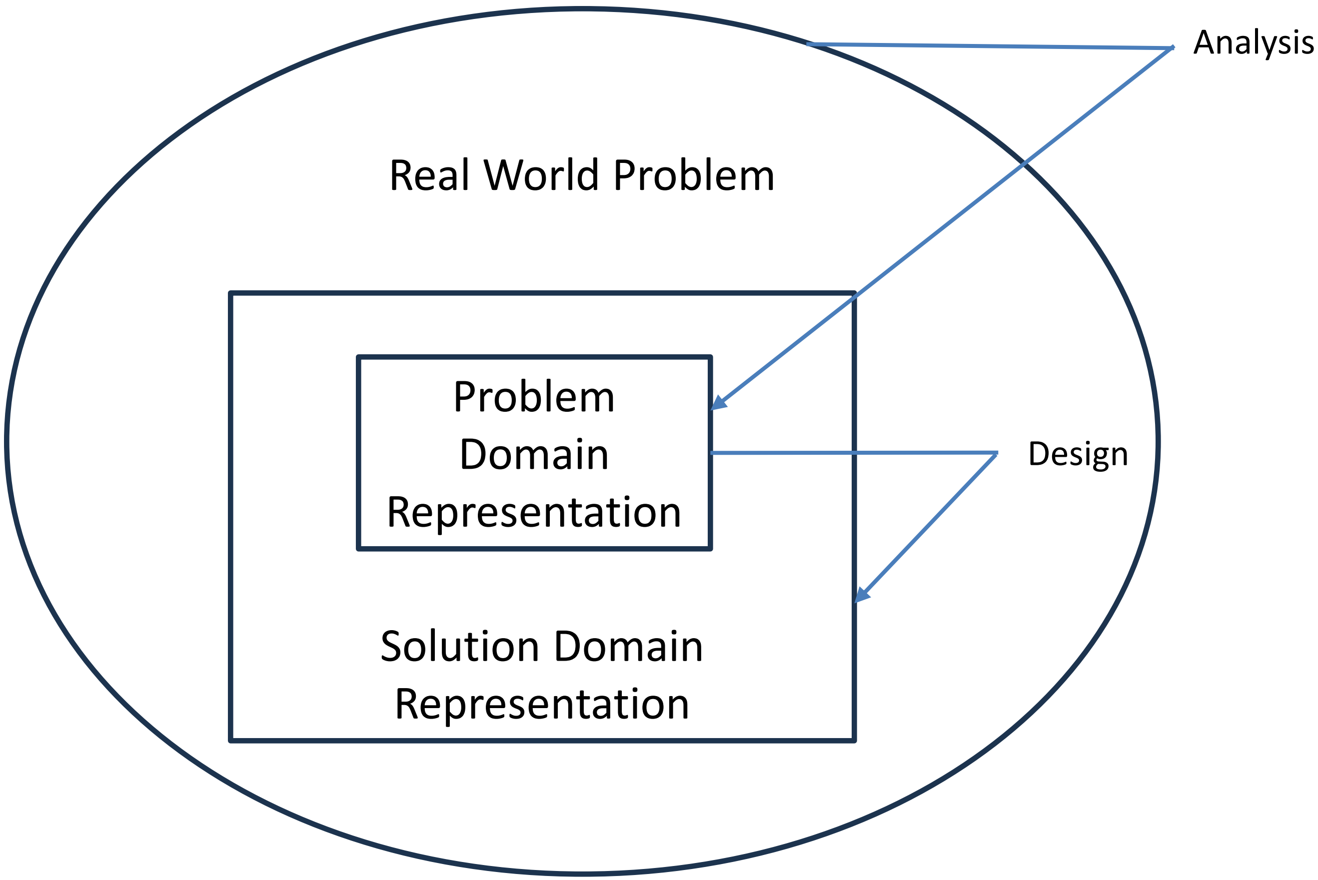
- Abstraction :
  - An abstraction of a component describes the external behaviour of the of that component without bothering with the internal details that produce the behaviour
  - Functional and Data abstraction are common abstraction mechanisms:
    - In functional abstraction, a module is specified by the function it performs (A module to compute the log of a value can be abstractly represented by the function log
    - In data abstraction, the system is viewed as a set of objects providing some services

- Modularity:
  - A system is considered modular if it consists of discrete components so that each component can be implemented separately, and a change to one component has minimal impact on other components

- Top-Down and Bottom-Up Strategies:
  - The top-down approach starts from the highest level component of the hierarchy and proceeds through to lower levels
  - The bottom-up approach starts with the lowest level component of the hierarchy and proceeds through progressively higher levels to the top level component

Object Oriented Design

- OOA and OOD:
  - The Analysis deals with the problem domain while design deals with the solution domain
  - OOA models the problem domain leading to an understanding and specification of the problem, while OOD models the solution to the problem



Relationship between OOA and OOD

Unified Modeling Language (UML)

- Unified Modeling Language is a graphical notation for expressing object oriented designs . UML helps build designs that are more likely to satisfy all the requirements of the system

- UML is an aid for understanding the system, designing the system, as well as a notation for representation design

Key concepts:

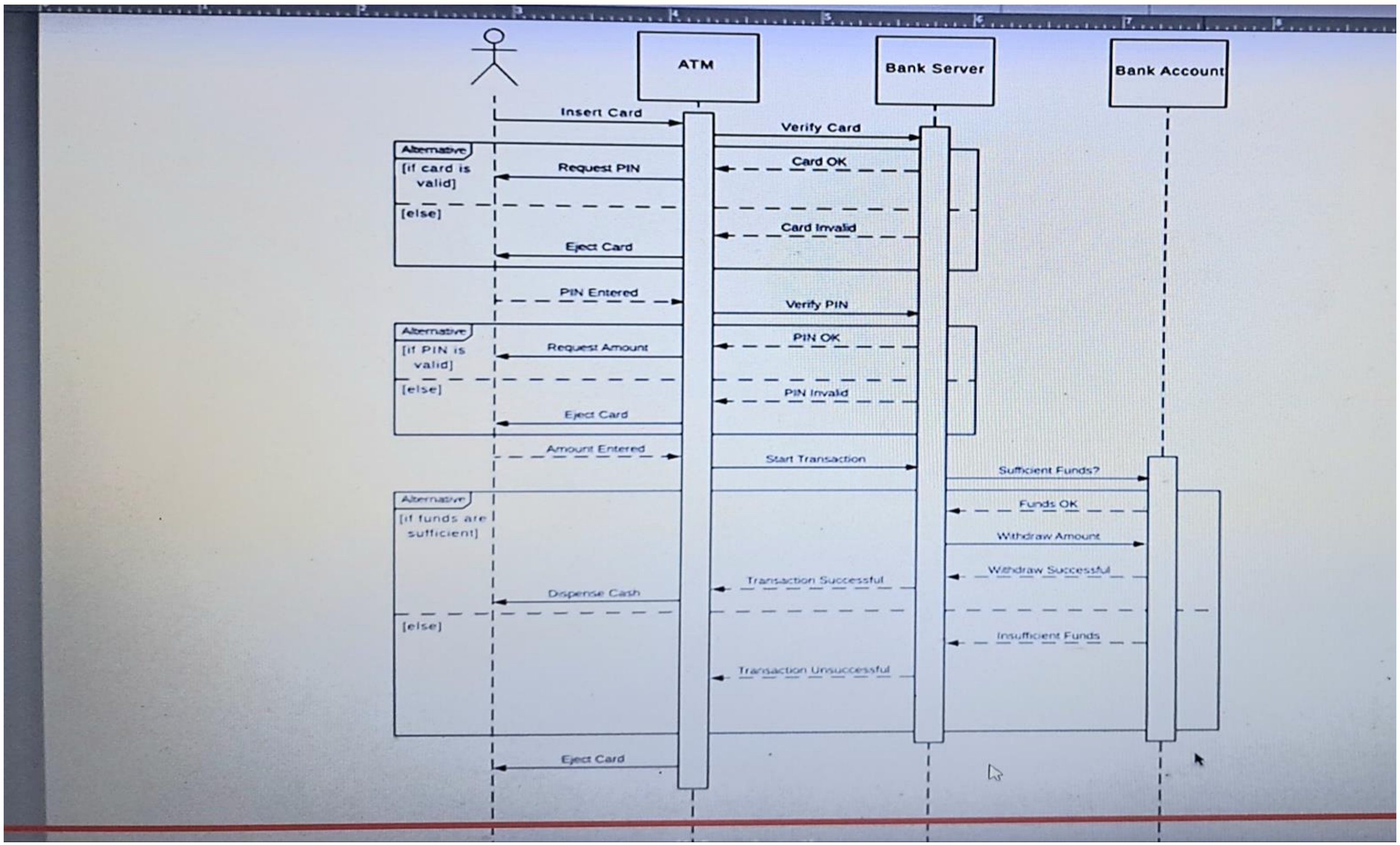
- Class Diagram:
    - Represent the static structure of the system or capture what is the structure of the code that will implement it and how the classes in the code are related
    - Defines the classes that exist in the system – key fields as well as the methods of the classes
    - Association between classes
    - Subtype, subtype relationship – classes may also form subtypes giving type hierarchies

- Sequence and Collaboration Diagrams:
    - Also called as interaction diagrams, it represents how the system behaves when it performs some of its functions
    - Captures the behaviour of the use case and models how the different objects in the system collaborate to implement the use case
    - Drawn to model the interaction between the objects for a particular use case

- Other diagrams and Capabilities:
    - Apart from Static and Dynamic behaviour, there are many other aspects that might need to be modelled such as specifying notation for components
    - Also provide a notation for a subsystems, and packages (collection of many elements)

Sequence Diagram

ATM Cash withdrawal:



Design Methodology

- The design methodology for producing an OO design consists of the following steps:

Sequence of steps:

- Produce the class diagram:
- Produce the dynamic model and use it to define operations on classes:
- Produce the functional model and use it to define operations on classes:
- Identify internal classes and operations
- Optimize and package

Design Verification

- The output of the design phase should be verified before proceeding with the next phase
- Tools can be used to check internal consistency, data usage is consistent with declaration……
- Most common approach for verification is design reviews or inspections. The purpose of design reviews is to ensure that the design satisfies the requirements and is of a good quality

Sample Checklist:

- Is each of the functional requirements taken into account?:
- Are there analyses to demonstrate that performance requirements can be met?
- Are all assumptions explicitly stated, and are they acceptable?
- Are there any limitations or constraints on the design beyond those in the requirements?
- Are external specifications of each module completely specified?
- Have exception conditions been handled?
- Are all the data formats consistent with the requirements?
- Are the operator and user interfaces properly addressed?
- Is the design modular, and does it conform to local standards?
- Are the sizes of data structures estimated? Are provisions made to guard against overflow?

Software Testing

What is Software Testing:

Testing is the process of executing a program with the intent of finding errors

Black Box Testing:

- The program is viewed as a black box. Also called a data driven testing
- The goal is to be completely unconcerned about the internal behavior or structure of the program
- concentrate on finding circumstances in which the program does not behave according to its specifications

White Box Testing:

- permits you to examine the internal structure of the program. Also called as Logic driven testing
- This strategy derives test data from an examination of the program's logic

Software Testing Principles

Sr. No.	Principle
1	A necessary part of a test case is a definition of the expected output or result
2	A programmer should avoid attempting to test his or her own program.
3	Test cases must be written for input conditions that are invalid and unexpected, as well as for those that are valid and expected
4	Examining a program to see if it does not do what it is supposed to do is only half the battle; the other half is seeing whether the program does what it is not supposed to do
5	Avoid throwaway test cases unless the program is truly a throwaway program
6	Do not plan a testing effort under the tacit assumption that no errors will be found
7	The probability of the existence of more errors in a section of a program is proportional to the number of errors already found in that section
8	Testing is an extremely creative and intellectually challenging task

Test Design Techniques

- Testing, however creative and seemingly complete, cannot guarantee the absence of all errors
- Test-case design is so important because complete testing is impossible
- The obvious strategy, then, is to try to make tests as complete as possible

What subset of all possible test cases has the highest probability of detecting the most errors?

Black Box	White Box
Equivalence partitioning	Statement coverage
Boundary value analysis	Decision coverage
Cause-effect graphing	Condition coverage
Error guessing	Decision/condition coverage
	Multiple-condition coverage

Test Design Techniques (Black Box)

Equivalence Partitioning:

- when testing a program, you are limited to a small subset of all possible inputs
- you want to select the ‘‘right’’ subset, that is, the subset with the highest probability of finding the most errors
- you should try to partition the input domain of a program into a finite number of equivalence classes such that
  - you can reasonably assume (but, of course, not be absolutely sure) that a test of a representative value of each class is equivalent to a test of any other value
  - if one test case in an equivalence class detects an error, all other test cases in the equivalence class would be expected to find the same error
  - Conversely, if a test case did not detect an error, we would expect that no other test cases in the equivalence class would fall within another equivalence class

External Condition	Valid Equivalence Classes	Invalid Equivalence Classes

- The equivalence classes are identified by taking each input condition (usually a sentence or phrase in the specification) and partitioning it into two or more groups
- valid equivalence classes represent valid inputs to the program, and invalid equivalence classes represent all other possible states of the condition (i.e., erroneous input values)

Test Design Techniques (Black Box)

Examples of Equivalence Classes:

1. If an input condition specifies a range of values (e.g., ‘‘the item count can be from 1 to 999’’), identify one valid equivalence class (1<item count<999) and two invalid equivalence classes (item count<1 and item count>999)

2. If an input condition specifies the number of values (e.g., ‘‘one through six owners can be listed for the automobile’’), identify one valid equivalence class and two invalid equivalence classes (no owners and more than six owners)

3. If an input condition specifies a set of input values, and there is reason to believe that the program handles each differently (‘‘type of vehicle must be BUS, TRUCK, TAXICAB, PASSENGER, or MOTORCYCLE’’), identify a valid equivalence class for each and one invalid equivalence class (‘‘TRAILER,’’ for example).

4. If an input condition specifies a ‘‘must-be’’ situation, such as ‘‘first character of the identifier must be a letter,’’ identify one valid equivalence class (it is a letter) and one invalid equivalence class (it is not a letter)

Test Design Techniques (Black Box)

Boundary Value Analysis:

- Boundary conditions are those situations directly on, above, and beneath the edges of input equivalence classes and output equivalence classes
- Boundary value analysis requires that one or more elements be selected such that each edge of the equivalence class is the subject of a test

Examples of Boundary Value Analysis:

1. If an input condition specifies a range of values, write test cases for the ends of the range, and invalid-input test cases for situations just beyond the ends. For instance, if the valid domain of an input value is –1.0 to 1.0, write test cases for the situations –1.0, 1.0, –1.001, and 1.001.

2. If an input condition specifies a number of values, write test cases for the minimum and maximum number of values and one beneath and beyond these values. For instance, if an input file can contain 1–255 records, write test cases for 0, 1, 255, and 256 records

Test Design Techniques (Black Box)

Cause Effect Mapping:

- One weakness of boundary value analysis and equivalence partitioning is that they do not explore combinations of input circumstances
- The testing of input combinations is not a simple task because even if you equivalence-partition the input conditions, the number of combinations usually is astronomical
- Cause-effect graphing aids in selecting, in a systematic way, a high-yield set of test cases. It has a beneficial side effect in pointing out incompleteness and ambiguities in the specification

Process:

- The specification is divided into workable pieces
- The causes and effects in the specification are identified. A cause is a distinct input condition or an equivalence class of input conditions
- An effect is an output condition or a system transformation
- You identify causes and effects by reading the specification word by word and underlining words or phrases that describe causes and effects
- The semantic content of the specification is analyzed and transformed into a Boolean graph linking the causes and effects – Cause-effect graph
- By methodically tracing state conditions in the graph, you convert the graph into a limited-entry decision table. Each column in the table represents a test case

Test Design Techniques (Black Box)

Example of Cause Effect Mapping:

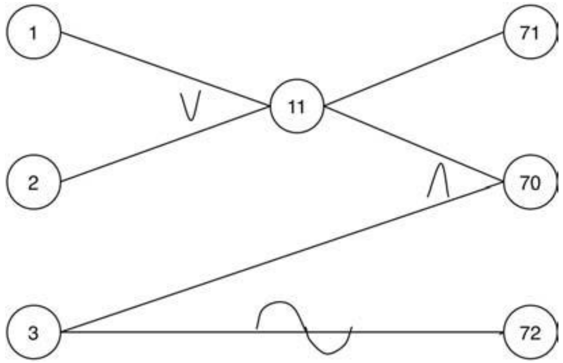
- The character in column 1 must be an ‘‘A’’ or a ‘‘B.’’
- The character in column 2 must be a digit. In this situation, the file update is made
- If the first character is incorrect, message X12 is issued. If the second character is not a digit, message X13 is issued

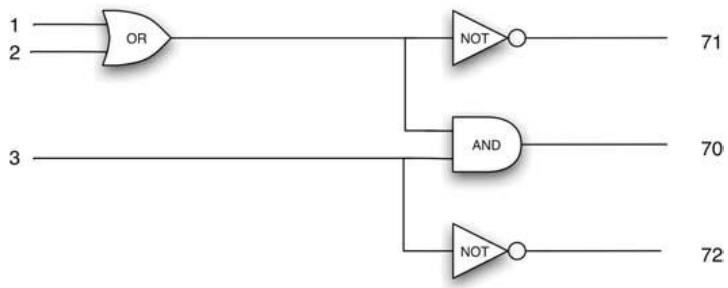
The Causes:

1. character in column 1 is ‘‘A’’
2. character in column 1 is ‘‘B’’
3. character in column 2 is a digit

The Effects:

1. 70—update made
2. 71—message X12 is issued
3. 72—message X13 is issued





Test Design Techniques (Black Box)

Error Guessing:

- It has often been noted that some people seem to be naturally adept at program testing. Without using any particular methodology such as boundary value analysis of cause-effect graphing, these people seem to have a knack for sniffing out errors

- One explanation for this is that these people are practicing—subconsciously more often than not—a test-case design technique that could be termed error guessing

- Given a particular program, they surmise—both by intuition and experience—certain probable types of errors and then write test cases to expose those errors

Software Reliability

- It is desirable to know, in quantifiable terms, the reliability of the software being delivered
- As testing directly impacts the reliability, most reliability models use data obtained during testing to predict reliability
- Reliability of software depends considerably on the quality if testing. By assessing reliability we can also judge the quality of testing
- Reliability of a product specifies the probability of failure-free operation of that product for a given time duration
- Reliability is a probabilistic measure that assumes that the occurrence of failure of software is a random phenomenon
- If X is the random variable that represents the life of a system, the Reliability of a system is the probability that the system has not failed by time t.
    - $R(t) = P(X>t)$
- The reliability of a system can also be specified as the mean time to failure (MTTF). MTTF represents the expected lifetime of the system

Project Planning -- Estimation

What is Estimation?

Estimation is a process of forecasting or ... tion of the project

Why Estimating T

- Estimat
- E
-
- Es
- E
- Es

Project Estimation is indeed a yardstick for project cost control. If the yardstick is faulty, you start on the “wrong Foot”

Do not Underestimate the Estimate!!

Consider this:

- Inaccurate Estimates lead ... lse exp ... Customer dissatisfaction
- Accuracy is improved w ... ater efforts, but is it worth the time and costs? Estimating costs money!
- Project Estimates become a trade-off balancing the benefits of better accuracy against the costs for securing increased accuracy
- Cost, Time, and Budget estimates are the lifeline for control

Factors Influencing the Quality of Estimates

- **Planning Horizon:**
  - Estimates of current events are close to 100% accurate but are reduced for more distant events
- **Project Duration:**
  - Longer the project it is difficult to estimate accurately
- **People:**
  - Accuracy of estimates depends on the skills of the people making the estimates
- **Project structure and Organization:**
  - Estimates are influenced by the project structure and Organization culture
- **Padding Estimates:**
  - Estimates are padded for safety and Risks. The project costs and schedule may be seriously overstated
- **Other Factors:**
  - Equipment down time
  - National Holidays
  - Vacations
  - Legal Limits
  - Industry specific Standards and Guidelines

Estimating Guidelines

- **Responsibility:**
  - Estimates should be done by people most familiar with the task. Draw on their expertise
- **Several people to Estimate:**
  - Better chance of being reasonable and realistic when several people with relevant experience and knowledge of the task are used (Crowdsourcing)
- **Normal Conditions:**
  - Estimates should be based on normal conditions, efficient methods and a normal level of resources
- **Time Units:**
  - Need to have consistent time estimates (PD, MM, etc......)
- **Independence:**
  - Treat each task as independent of the other tasks
- **Contingencies:**
  - Do not include allowances for contingencies in work package estimates
- **Add Risk Assessment:**
  - Include Risk assessment and plan for them to increase accuracy

Estimation – Top Down v/s Bottom Up

Top Down Approach: These are usually derived from someone who uses experience and /or information to determine project duration and total costs

Bottom up Approach: Done at the work package level and then rolled up to major deliverables

Top Down Different Approaches:

1. **Consensus Methods:**

   This method uses the pooled experience of senior and/or middle managers to estimate the total project duration and costs

2. **Ratio Methods**

   This method uses ratios or surrogates to estimate project times and costs (Rate per sq. Ft.)

3. **Apportion Methods:**

   This is an extension to the Ratio Method. Refer to historical data with customization for variations

4. **Function Point Method:**

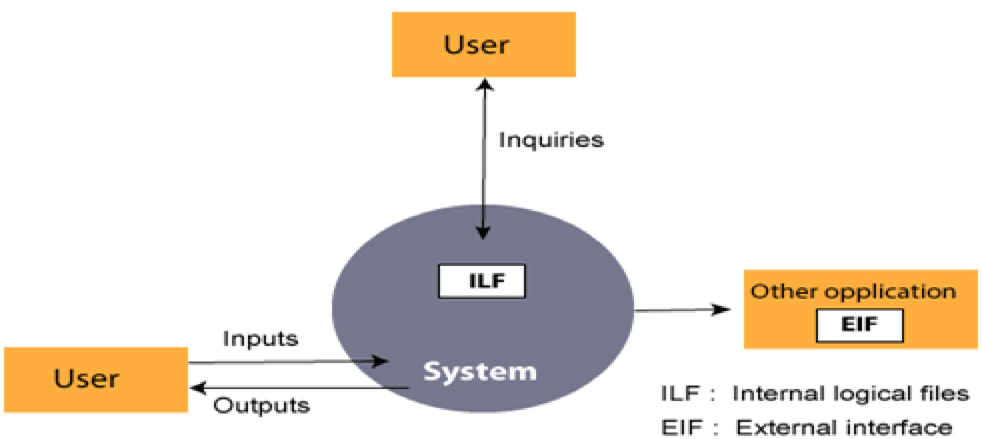
   Function point analysis is the process of sizing software based on the number of business functions an application must accomplish. Derive costs based on the unit costs

5. **Learning Curves:**

   For repetitive tasks, the productivity is expected to improve

Estimation – Size by Function Points

Measurements Parameters	Examples
1.Number of External Inputs(EI)	Input screen and tables
2. Number of External Output (EO)	Output screens and reports
3. Number of external inquiries (EQ)	Prompts and interrupts.
4. Number of internal files (ILF)	Databases and directories
5. Number of external interfaces (EIF)	Shared databases and shared routines.



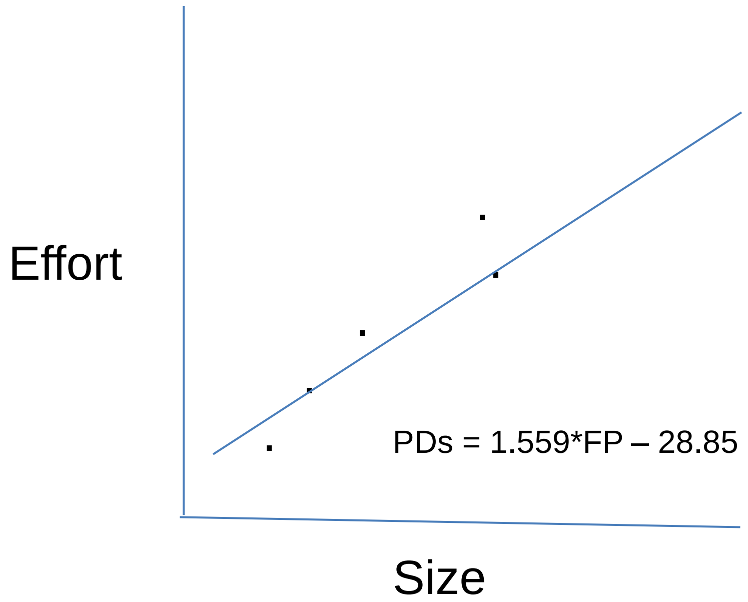
FPAs Functional Units System

- Weighting Factors
- Unadjusted FP
- Complexity Adjustment Factor

FP = UFP * CAF

Planning by Use of Baselines

Projects	Size (FP)	Actual Efforts (PDs)	Defects
Pr1	100	118 (0.84)	200
Pr2	150	183 (0.81)	330
Pr3	175	224 (0.78)	420
Pr4	200	267 (0.74)	540
Pr5	250	329 (0.75)	725
Pr6	500	602 (0.83)	1000
Pr7	750	1071 (0.70)	2250
Pr8	1000	1471 (0.67)	3200
Pr9	1500	2419 (0.62)	5250
Pr10	4000	7273 (0.54)	14400



Pr1 100/118 = 0.847 Pr7 750/1071 = 0.7
Pr2 150/183 = 0.819 Pr10 4000/7273 = 0.549

If the Size is 1200 FPs, How many PDs will I need?

Regression Equation
PDs = 1.559*FP – 28.85 = (1.559*1200 – 28.85)
= 1890 PDs

Estimation – Size by Function Points

International Function Points Users Group   IFPUG
Size = 1000 FPs

Productivity = Size / Efforts   = FP / PD

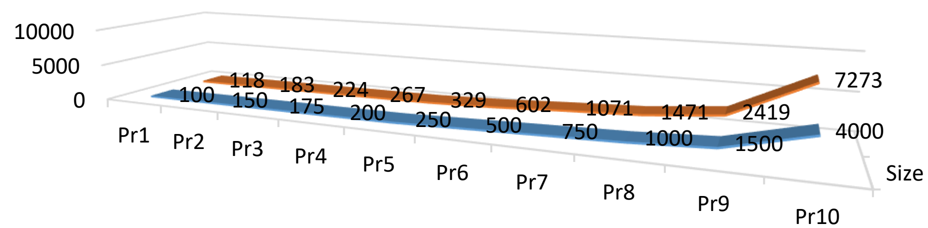
0.7 FP in 1 PD of effort = 0.7/1 FP / PD Baselines (Historical Data)

Effort = Size / Productivity

= 1000 / 0.7
= 1428.57 = 1429 PDs   (Efforts spread across the life cycle)

Planning by Use of Baselines

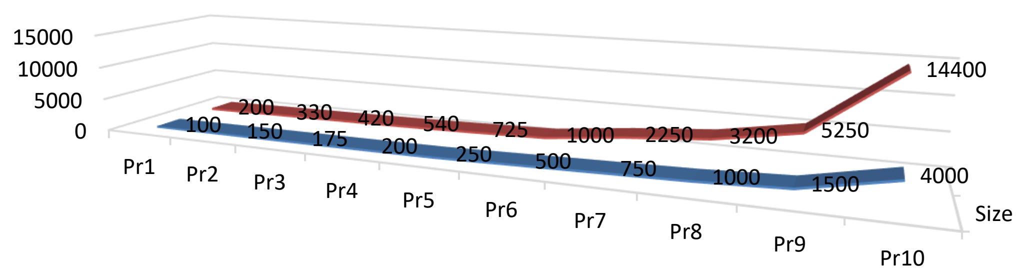
Productivity



	Pr1	Pr2	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	Pr10
Size	100	150	175	200	250	500	750	1000	1500	4000
Actual Efforts	118	183	224	267	329	602	1071	1471	2419	7273

Size Actual Efforts

Defect Density



	Pr1	Pr2	Pr3	Pr4	Pr5	Pr6	Pr7	Pr8	Pr9	Pr10
Size	100	150	175	200	250	500	750	1000	1500	4000
Defects	200	330	420	540	725	1000	2250	3200	5250	14400

Size Defects

Thank You