ENGINEERING DESIGN PROCESS AND PROJECT MANAGEMENT

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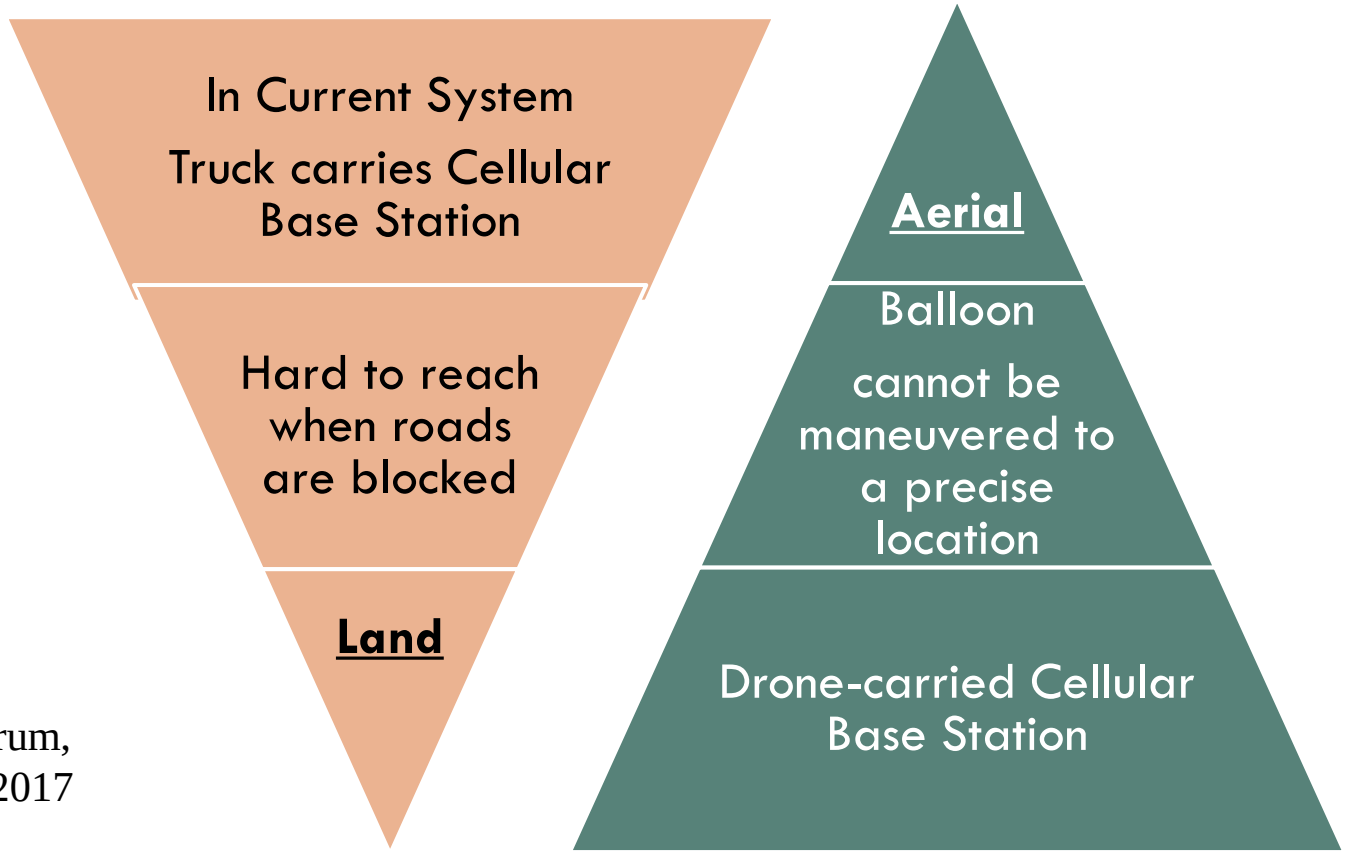
Engineering Design Process

A Story – First Responder Communication System

The Disaster Area Experiences Complete or Partial Communication Breakdown

Japan Earthquake 9.0 – NTT sustained damage to 6,700 pieces of Base-station equipment and 65,000 telephone poles



IEEE Spectrum, September 2017

Drone

Portable Base Station

Handset

Aerial Deployable Communication System

Drone

Constraints: 25 Kg weight (US regulation), 2Kg payload, commercial Drone stays afloat for 45 minutes

Choice: AR200 Drone from AirRobot

Base Station

Constraints: Less than 2Kg weight, LTE Band 14 in 700 to 800 MHz

Choice: GreenCell picocell LTE, weight 2kg, 128 user, 2km cell, 12.5cmx12.5cm

Mobile Phone &SW

Constraints: LTE phone in Band 14

Choice: Sonim LTE phone configured for Band 14, NICS from MIT

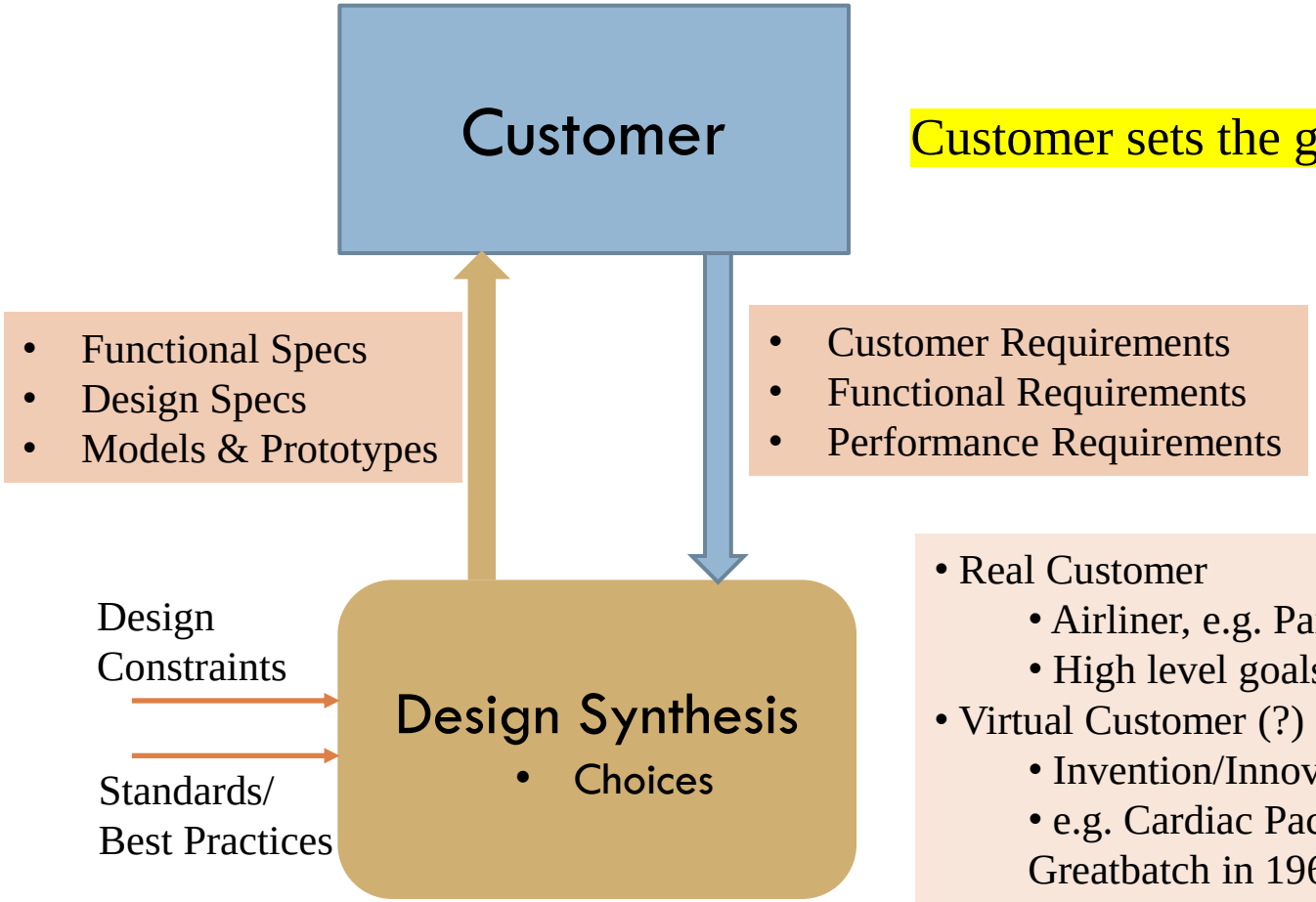
Test & Deployment

* WiFi on a balloon from 12m to 21m height
* Base-station on a Tabletop to test video communication in Band 14
* Full-scale deployment: transmit power 250mW, altitude 120m, coverage 2km

Engineering Design

- Design
  - It is an open-ended process where more than one feasible solution may exist. The goal of a design is to meet a set of pre-determined specifications.
  - More elaborate definition from Canadian Engineering Accreditation Board:
    - Engineering design integrates mathematics, basic sciences, engineering sciences and complementary studies in developing elements, systems and processes to meet specific needs. It is a creative, iterative, and often open-ended process subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may relate to economic, health, safety, environmental, social, or other pertinent factors.

Design – Customer



Customer – Visionary Goals

Boeing's CEO launched 747 project to introduce airliner that can carry large number of passengers for long distance

McDonald's CEO launched Digital Acceleration project in 2017. His *vision: "I have absolutely no doubt that our industry will get disrupted by technology," he warned. "Our discussions within McDonald's are 'Why don't we be the ones to disrupt ourselves rather than wait to be disrupted?' You have a choice to either be the disrupter or the disrupted."*

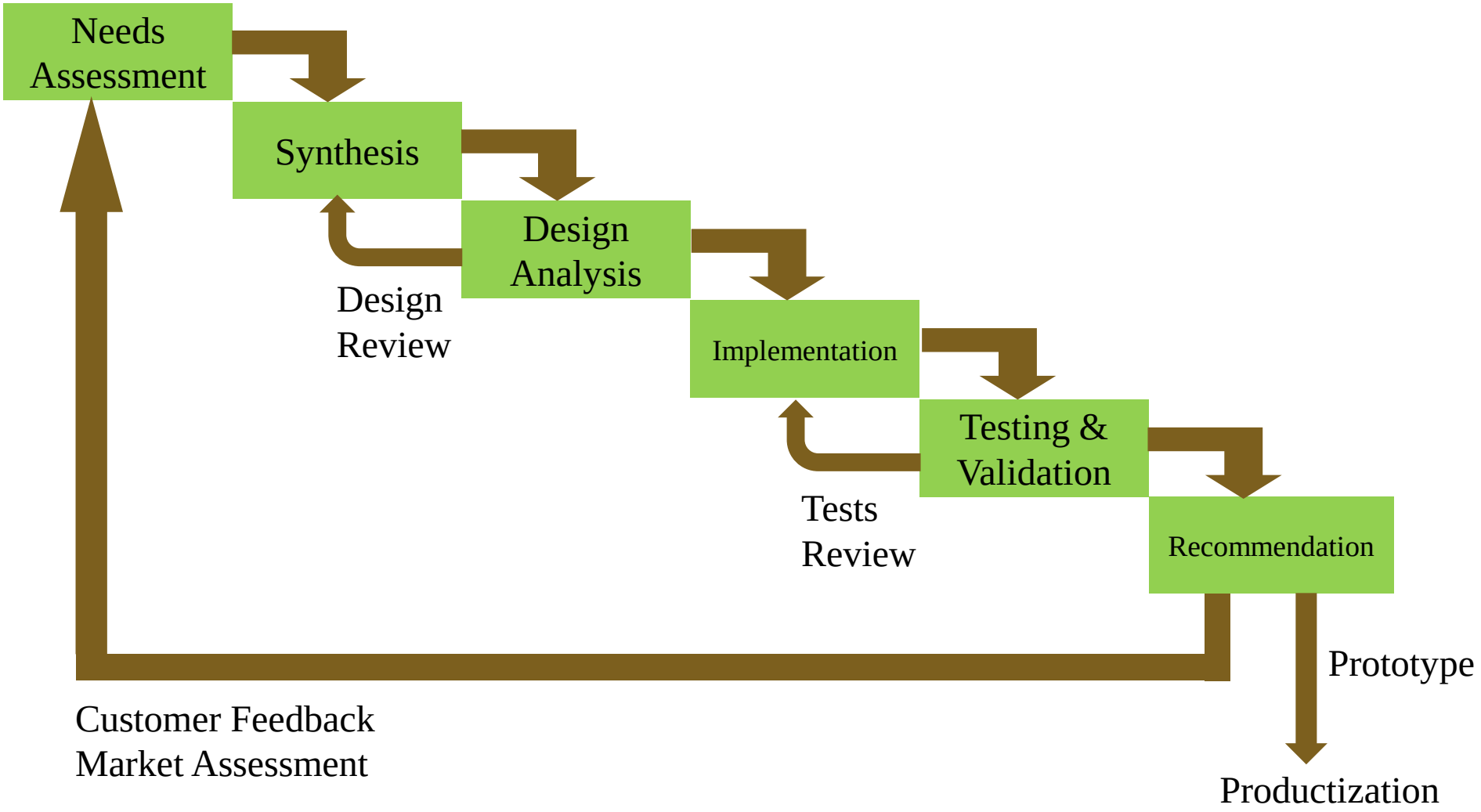
Design Types

- Evolutionary design (re-design)
  - Improvements to existing solutions, for instance due to technological improvements
    - For example, passenger cars have come a long way from Henry Ford's Model T, yet the basic functions remain same: propulsion, steering, braking, seating, and others.
  - Competitive Analysis
    - Comparing with similar design or product
    - It helps in establishing design criteria
  - Benchmarking
    - It is the process of determining how well a function is performed
    - Often for later competitive analysis
  - Reverse Engineering
    - It is the process of decomposing an existing solution to understand how it has been constructed and where its design limitations are

Design Types

- Innovative design (original design)
  - Original idea
  - Novel way of solving a problem
  - Invention – is the realization of a new and useful product, process, or system
  - Invention is the result of applying innovation to technology
  - E.g., Cellular Network in early 70's
- Combining evolution and innovation
  - Much complex design involves a combination of re-engineering and innovative design
  - E.g., Generational evolution of Cellular network, smart phone era

Design Process – Waterfall Model



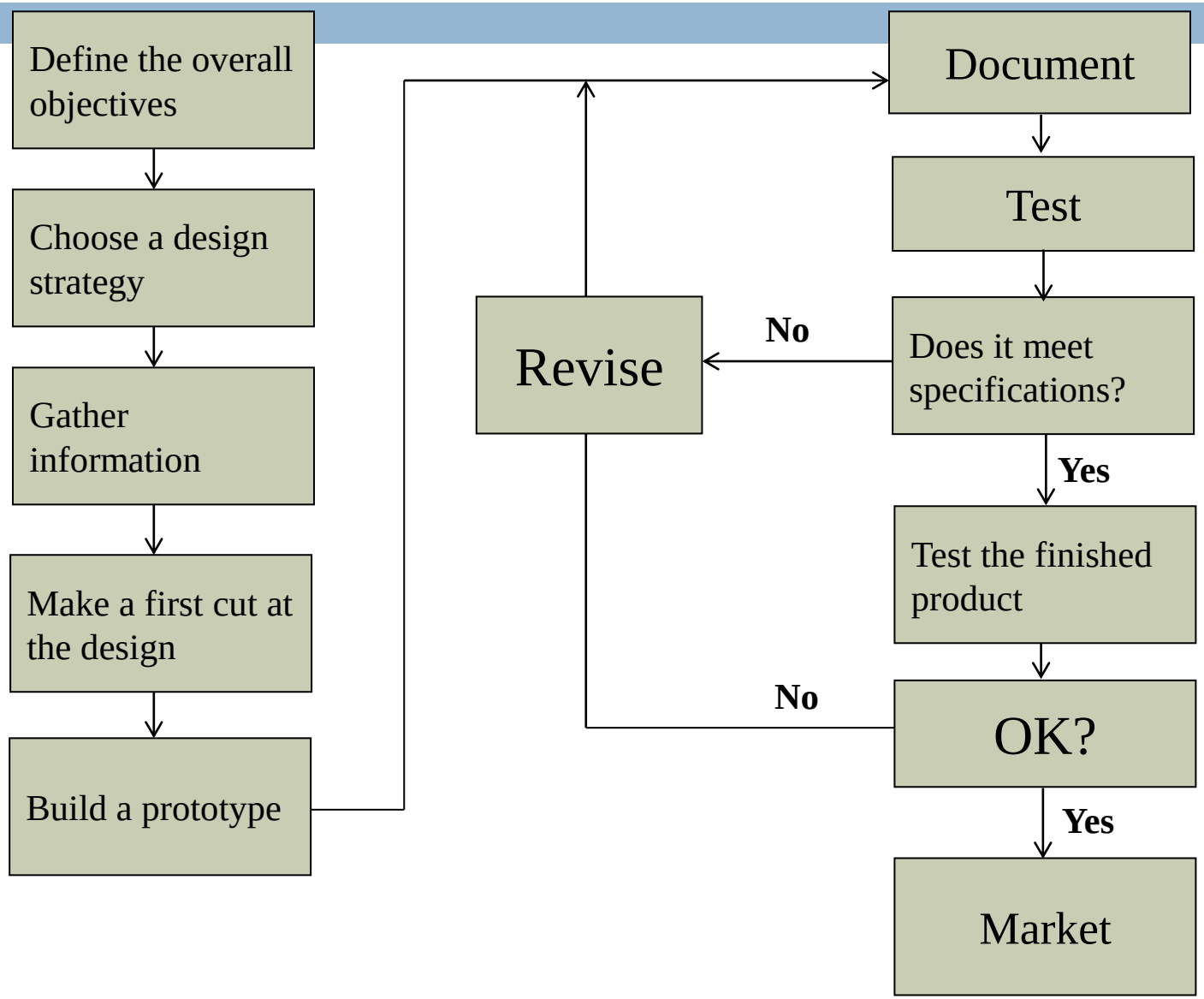
Design Process Concepts

- Needs Assessment
  - Problem, stake holders, existing solutions and their suitability, requirements, constraints, additional criteria
  - Customer Requirements – Performance, Time, Cost and Quality
  - Quality – Performance, Features, Reliability, Durability, Serviceablity, Conformance
  - Customer Requirements Classification – Expecters, Spoken, Unspoken, Exciters
- Synthesis
  - Ideas for solving the problem, creative ways of addressing limitations, solution alternatives and their priority
- Design analysis
  - Whether design idea is feasible, whether it incorporates best practice, predicted performance

Design Process Concepts

- Implementation
  - How to build the solution? Prototype or simulation for testing the solution
- Testing and Validation
  - Evaluation process or steps, test measures, acceptable outcomes
- Recommendation
  - Whether design specification for manufacturing can be generated, or it needs further improvements

Engineering Design – Design Cycle



Engineering Design

- Design skills
  - Clearly defining the problem with Requirements → Reference document ETSI-ITS-ICRW.pdf (https://www.etsi.org/deliver/etsi_ts/101500_101599/10153902/01.01.01_60/ts_10153902v010101p.pdf) [pages: 7,8,10,11,16,17,26,27]
  - Generating solutions
    - Explain the problem
    - Brainstorming
      - Formal Brainstorming
        - Phase-1: Idea Generation Phase
        - Phase-2: Idea Trigger Phase → Tension and Relaxation Technique
        - Phase-3: Compilation Phase
    - Assumption smashing
- Building models, simulations, and prototypes
  - Prototype
    - Fidelity
    - Functionality

Good Design

- Criteria – general factors
  - Requirements (Objectives)
    - E.g. the sports car must cruise at 200 kmph
    - Functional and Performance
      - The most important requirement of a product is that it should work, that is it should perform one or more functions
      - "Must" functions are demands and "Should" functions are wants
      - Importance weight
    - Operating Environment, Safety, Economic
  - Constraints – limitations
    - E.g. the product must not exceed certain budget
    - Maximum and Minimum limitations on performance of specific functions or sub-functions
    - Specific limitations regarding size, shape, materials, or manufacturing processes
  - They are refined as the design progresses

Good Design (contd…)

- Identify users and their tasks
- Identify effects on the environments
- Generate multiple solutions
- Select optimal solutions
  - Design requires the use of resources including materials, procedures, or human resources
- Defensible decisions
  - Complex process of selling ideas to the customer
  - Multiple stakeholders are involved, e.g. design team, marketing team etc.
- Best practice
  - Design should be based on recognized methods, procedures, codes, and standards

Engineering Design – Documentation

- Project plan and milestones
  - Milestones
    - Control points, Deliverables + dates
- Project budget
- Functional specification
  - States functions in quantitative terms and in the order of priority
- Design specification
  - Detailed blueprint of the design solution – Block Diagram
  - It is in the form of the discipline, e.g. circuit diagrams for HW and entity-relationship for SW
- Test and validation plan
- Design reviews, design logbook, progress reports, final reports

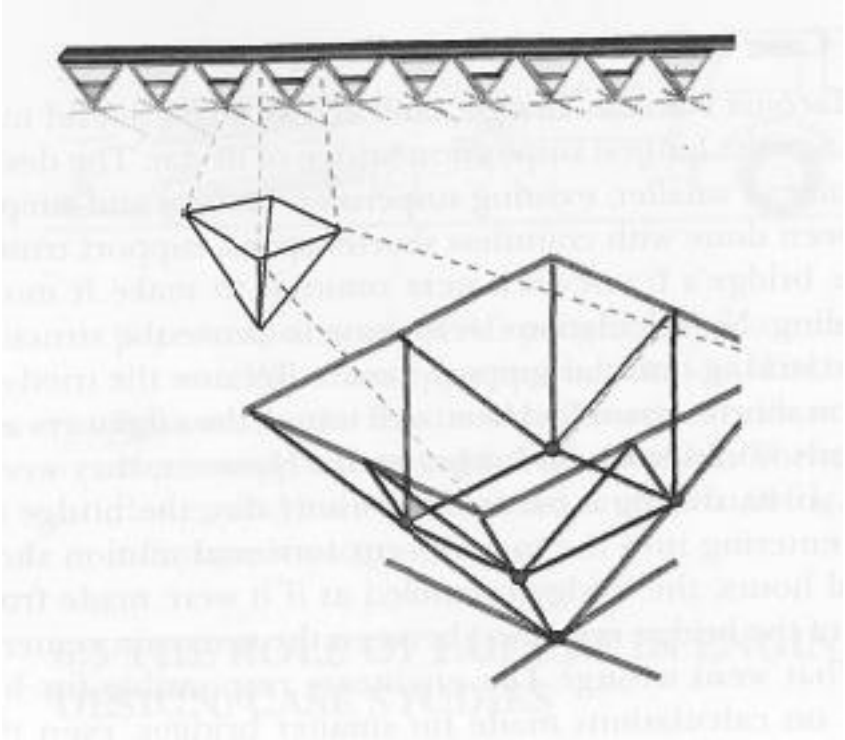
Design Analysis – Charles De Gaulle Airport Terminal 2E Collapse

- The Charles de Gaulle airport was inaugurated in May 2004, and soon after, a huge portion of the roof of Terminal 2E collapsed.
- The 1475 ft (450 mt) long terminal building is an elliptical tube constructed of concrete rings.
- The official investigation report found that the structure had failed due to a lack of detailed feasibility analysis, a number of design flaws were not caught during construction. These included a lack of redundant supports; poorly placed reinforcing steel; weak outer steel struts; weak concrete support beams; and low resistance to temperature fluctuations.

[Source: https://interestingengineering.com/23-engineering-disasters-of-all-time]

Testing – Hartford Civic Centre

- Built in mid-1970's
- Innovative design
- Instead of convention I-beam structure, they used frame structure of interconnected trusses and joints to form visually appealing patterns
- Used computer model for load computation
  - Ignored derating factors at the structural joints to account for slight changes in the layout



Software Failure – Fastly CDN Outage

- Fastly – a major Content Distribution Networking service provider
- Outage – June 8, 2021 (for approx. one hour)
  - Major websites were down – Amazon, Spotify, Airbnb etc.
  - Nick Rockwell, Fastly's senior vice president of engineering, said the hour-long outage happened because a customer pushed a configuration change that triggered the undiscovered software bug (https://www.fastly.com/blog/summary-of-june-8-outage).
  - Rockwell doesn't explain what exactly happened, other than saying that on May 12, the company deployed a software update that "introduced a bug that could be triggered by a specific customer configuration under specific circumstances."
  - Then yesterday, June 8, a customer pushed a configuration change that met the conditions to trigger the bug, which caused 85% of its network to return errors. End users visiting affected sites saw the "Error 503 Service Unavailable" error message in browsers.

[Source: https://www.zdnet.com/article/fastlys-global-outage-heres-what-went-wrong/]

Engineering Design

- References
  - G. Andrews et al, Introduction to Professional Engineering in Canada, Second Edition, Pearson-Prentice Hall, 2006. [This presentation is mostly based on chapter 15]
  - Mark Horenstein, Design Concepts For Engineers, Third Edition, Pearson-Prentice Hall, 2006. [chapters 2 and 3]
  - Joe Sutter, *747 Creating the World's First Jumbo and Other Adventures from a Life in Aviation*
  - Karl Sabbagh, Twenty-First Century Jet: The Making and Marketing of the Boeing 777

Project Management

2018 PMI Project of the Year Finalist: McDonald's Customer Digital Experience

- McDonald operates restaurants in 37000 locations in 120 countries across the globe
- McDonald launched Digital Acceleration project in January 2017 – It's CEO wanted to use digital technology for completely overhauling the *customer delivery experience and achieve this change within a year*
- *CEO's vision: "I have absolutely no doubt that our industry will get disrupted by technology," he warned. "Our discussions within McDonald's are 'Why don't we be the ones to disrupt ourselves rather than wait to be disrupted?' You have a choice to either be the disrupter or the disrupted."*

McDonald's Digital Acceleration Project

- Launched in January 2017
- Completion Time Target: Less than a year
- Budget: $155 million
- Scope: Deployment in 20,000 stores in USA, Canada, UK, France, Australia, China and Hong Kong
- Objective: Custom mobile ordering and payment platform that lets customers order meals via in-store kiosks or a mobile app and pick up their orders as soon as they arrive at the restaurant. The system uses geofencing technology to direct orders to the proper restaurant based on customer's location that reduces the delivery time by giving a lead time for food preparation.
- Risks: Pace to complete the project on a short time and Change that overhauls the order and delivery process

Digital Acceleration Project Management

- Global Project Management Office (PMO)
  - Previous global projects had siloed plans for each market that slowed progress and prevented consistent communication and delivery
  - Centralized governance
    - ensured same level of quality and reliability in deployment
    - accelerated delivery with short release cycle
    - allows local customization
- Change Control Board (CCB)
  - Local markets needs to tweak the system for their unique needs and customers
  - Local franchise owners want the system to accommodate their ideas and features
  - The CCB was created to prioritize stakeholder demands, provide a firewall for developers and mitigate the risk of scope creep
  - The board approved no changes unless they met a valid business purpose, aligned with the strategic vision and had a defined budget
- Robust Change Management
  - Local franchise owners need to roll out training for staff to learn new technology and delivery process, make counter-design changes, create space to install kiosks and adapt parking lots for curb side pickup
  - Experts were brought to counsel stakeholders how to plan changes and deployment, and communicate the value of transformation
  - Held technology demonstrations, set strict deadlines and captured learning lessons

McDonald's Achievements

Achieved the goal of 20,000 deployment in November 2017

One month ahead of schedule

Nearly $10 million under budget

The Platform allows customers

To place orders, access special offers and pay through their devices

To pick up their food at the counter, in the drive through, or at the curbside

Project Management

Project Management

Teamwork

Communication

Leadership

Why do projects fail so often?

Among the most common factors:

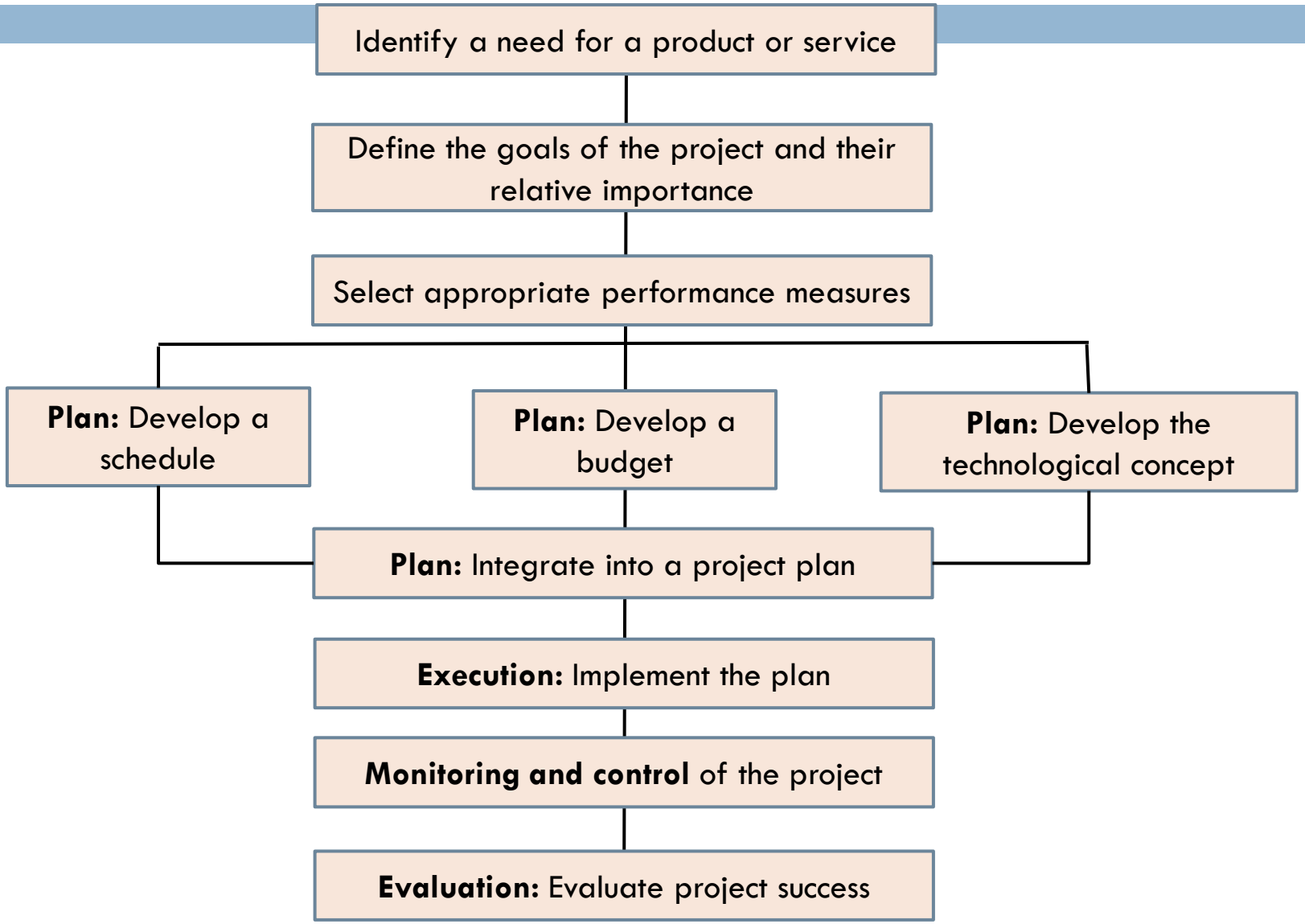
- Unrealistic or unarticulated project goals
- Inaccurate estimates of needed resources
- Badly defined system requirements
- Poor reporting of the project's status
- Unmanaged risks
- Poor communication among customers, developers, and users
- Use of immature technology
- Inability to handle the project's complexity
- Sloppy development practices
- Poor project management
- Stakeholder politics
- Commercial pressures

[Source: Why Software Fails? By Robert N. Charette, IEEE Spectrum, September 2005]

Definition and Features of a Project

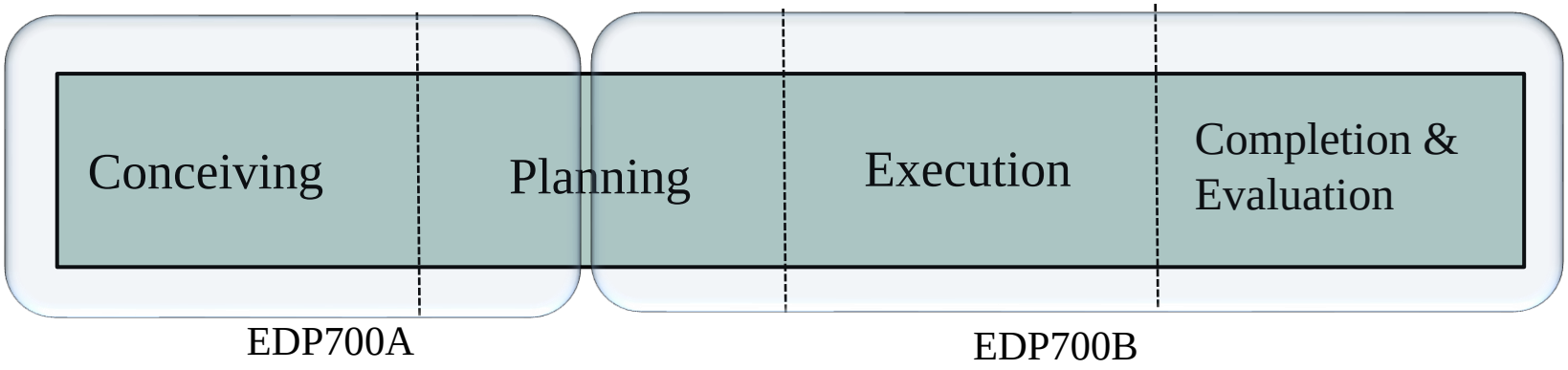
- Definition
  - A temporary endeavour undertaken to produce a unique product, service or result – PMI definition (www.pmi.org)
  - A project is a combination of human and non-human resources pulled together in a temporary (specified start and end time) organization to achieve a specified purpose
- Features
  - Definable purpose with established goals
  - Project Requirements – Performance, Cost, Time and Scope (PCTS) targets
  - One-time activity (defined start and end time) – a repetitive activity is not a project
  - Temporary activity
  - Multiple resources across organizational lines
  - Element of risk
  - Process of phases/project life cycle

Process Approach to PM

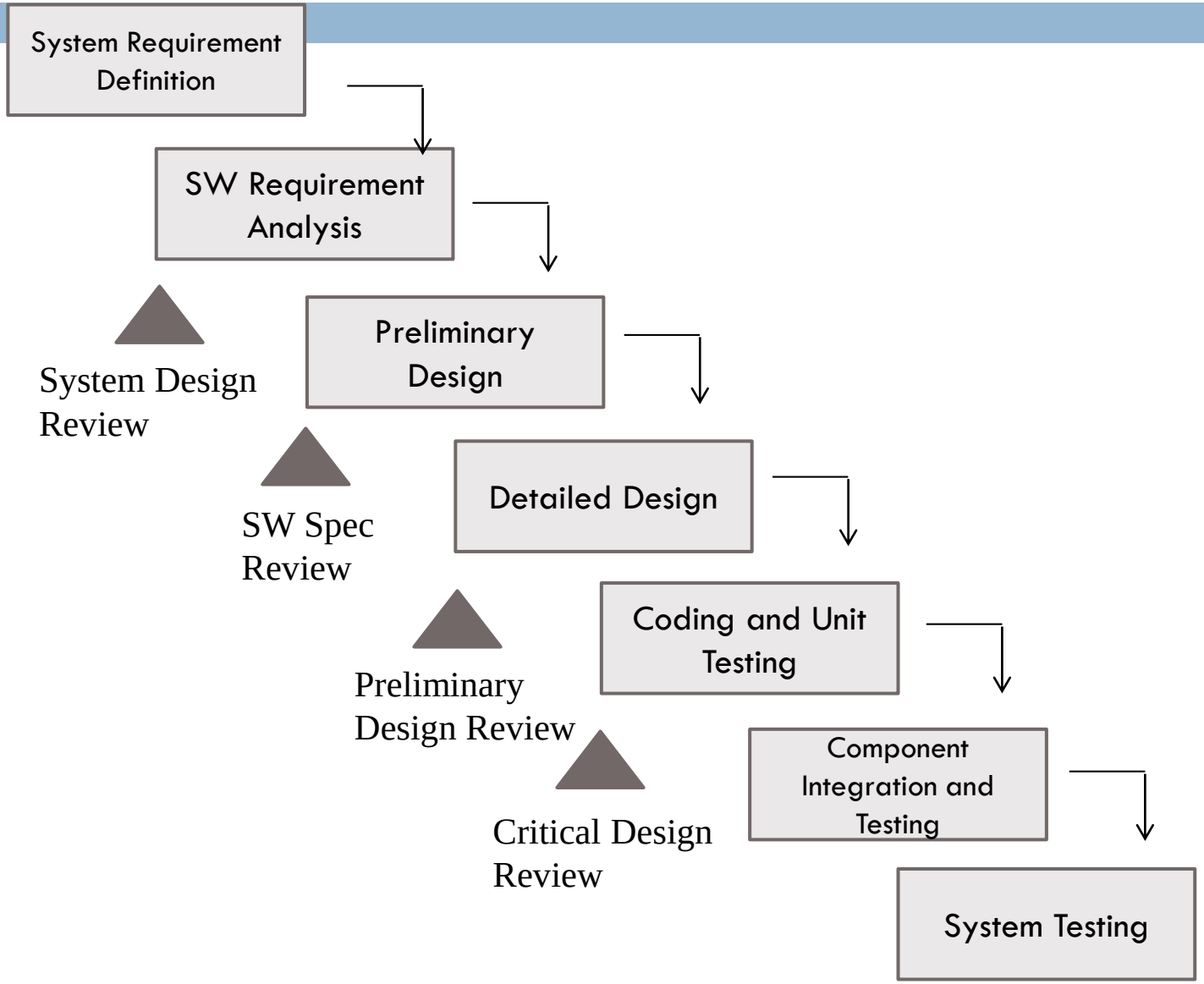


Project Lifecycle

- Conceiving and defining the project
- Planning the project
- Implementing the plan
- Completing and evaluating the project
- Operating and maintaining the project
- Life-cycle Model – Project phases

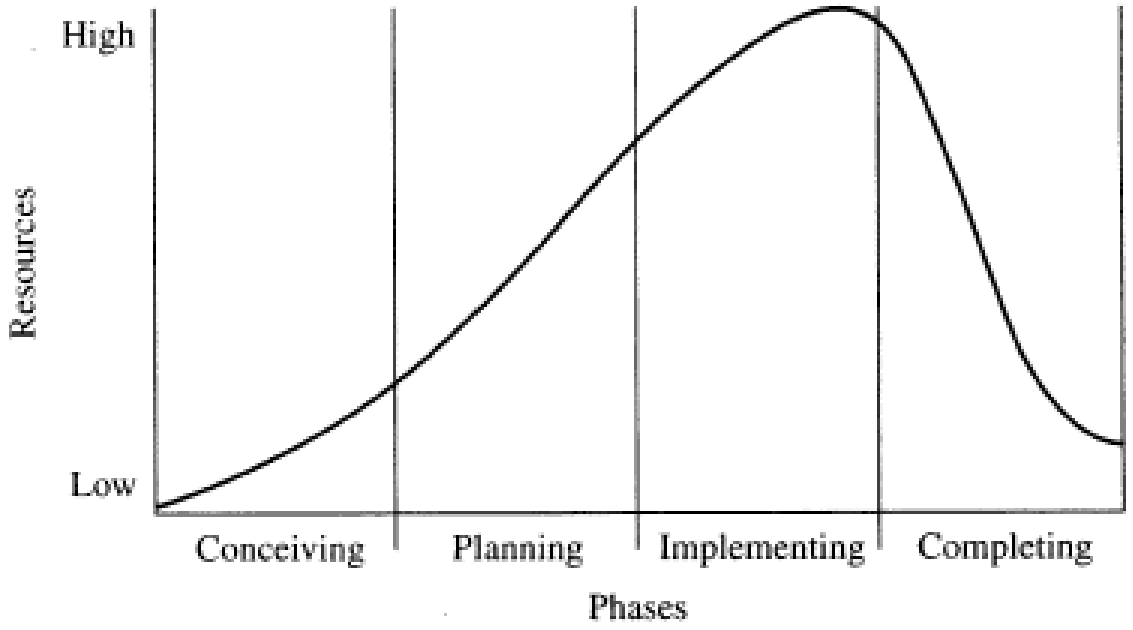


Waterfall Model – Software System



Resource Distribution

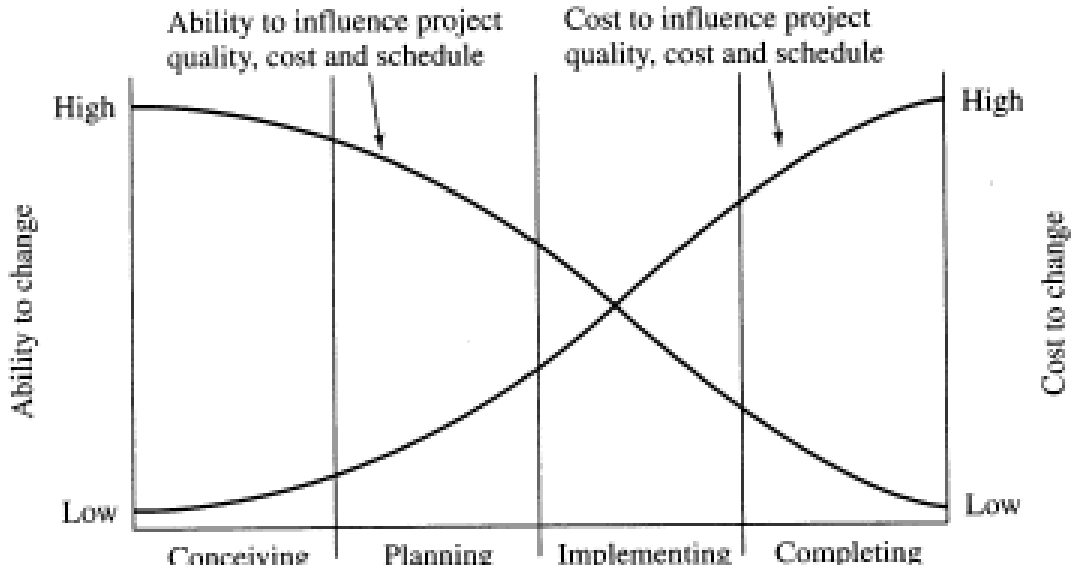
Figure 4.3 Resource Distribution over the Project Life Cycle



Ability and Cost of Changes

Phases

Figure 4.4 Ability to Change, and Cost to Make Changes, over the Project Life Cycle



Project Planning

- Overview
  - Brief description of project, Deliverables and Milestones
- Objectives
  - Detailed description of project deliverables
- General Approach
- Contractual Aspects
  - Reporting requirements , Technical specifications, Project review dates
- Schedules
  - Outline of all schedules and milestones – Tools e.g. WBS, CPM, Gannt chart
- Resource Requirements
  - Estimated project expenses, overhead, material requirement
- Personnel
  - Necessary skills and training
- Evaluation Methods
  - Standards, benchmarks, testing
- Potential Problems

Role of Project Manager

- Planning
- Organizing
  - Develop WBS (Work Breakdown Structure)
  - Scheduling, Budgeting, and distribution of responsibilities
- Staffing
- Directing
  - Coordinating project components, investigating potential problems and taking steps to resolve them including allocation/reallocation of resources
- Controlling
  - Communicating with team members; measuring project performance; planning, monitoring progress of and completing milestones; convening and documenting meetings

A Project Manager needs both management and leadership skills : management skill to administer above tasks and leadership skill to get the staff do the work on their own will

Characteristics of Effective Team

- **Positive Interdependence**
  - Team is focused on a common goal
  - Team goals are as important as individual goals
- **Individual and Group Accountability**
  - The team understand the goals and is committed to achieving them
  - Each person takes responsibility to the success of the team
  - Each person delivers on commitments
- **Promotive Interaction**
  - Trust replaces fears and people feel comfortable taking risks
  - Respect, collaboration and open-mindedness are prevalent
- **Teamwork Skills**
  - Each member has the skill for and practices effective communication, decision making, problem solving, conflict management, and leadership
  - Team members adopt tools to effectively manage teamwork
- **Group Processing**
  - The team reflects on its processing, celebrates its achievements and take correctional steps in case of problems

Team Dynamics – Stages

- **Orientation or Forming**
- **Dissatisfaction or Storming**
  - Challenges of forming a cohesive team
  - Differences in personalities, working and learning styles and habits, logistics etc
- **Resolution or Norming**
  - The team establishes group norms to guide the process, resolve conflicts and focus on common goals
- **Production or Performing**
  - The team is working co-operatively with few disruptions
  - Effective project planning and project management is a major reason for team's performance, e.g. missing or tight deadlines cause tension within the team.
- **Termination or Adjourning**
  - Joint reflection and evaluation of team performance, and celebration

Individual Essentials of Teamwork

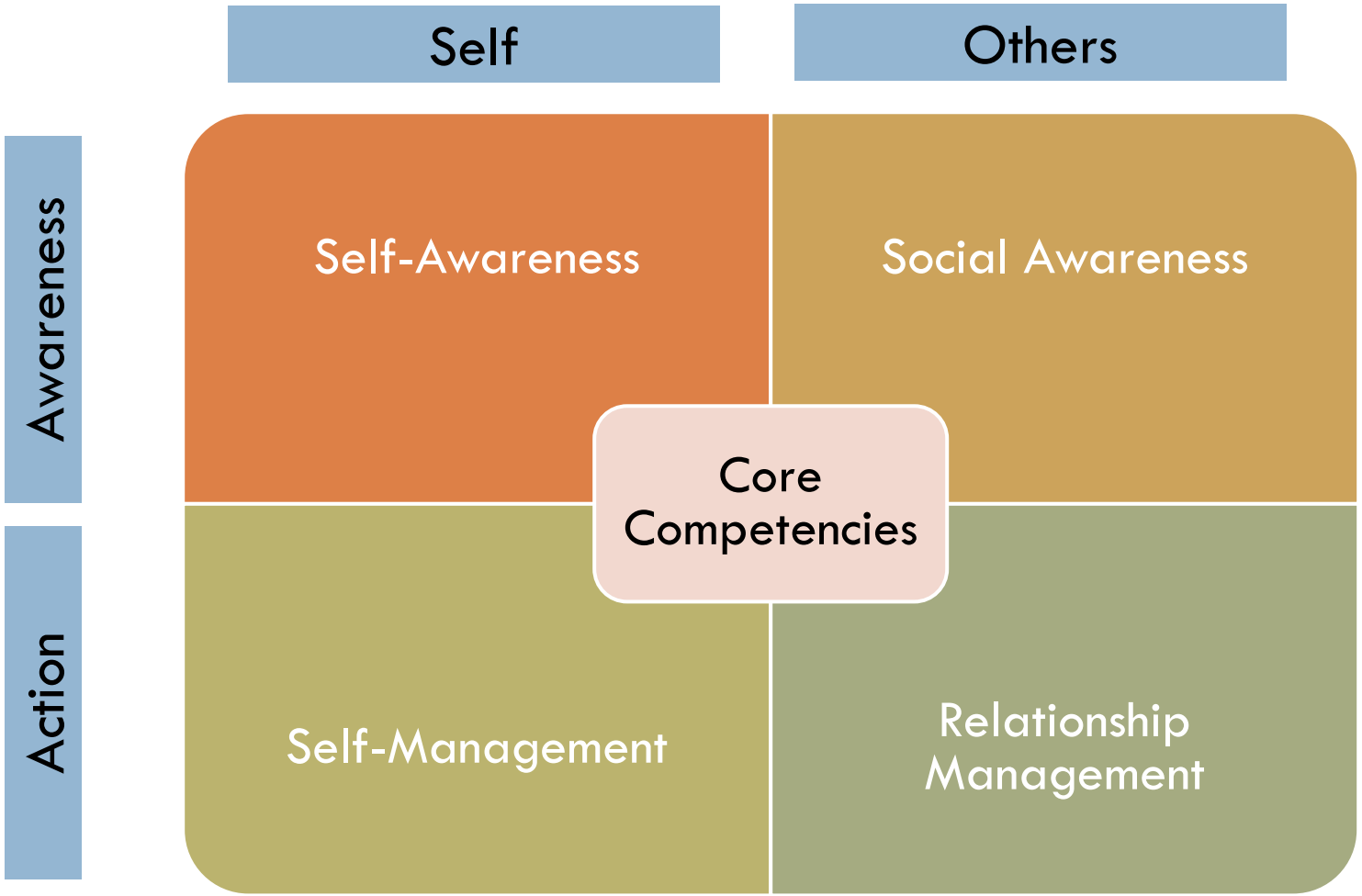
- Energy
- Enthusiasm
- Passion
- Punctuality
- Integrity
- Good Behaviour
- Understanding
- Respect

Emotional Intelligence (EQ)

- "Emotional intelligence is defined as the ability to understand and manage your emotions, as well as recognize and influence the emotions of those around you." (Harvard Business Review Online)
- EQ is a strong predictor of performance
- Employees with high EQ can manage stress, resolve conflict, build effective collaboration, and respond to co-workers concerns with empathy
- Technical Skills and IQ are entry level requirements … EQ is important for effective leadership

Source: Harvard Business Review (https://online.hbs.edu/blog/post/emotional-intelligence-in-leadership)

Core Competencies of Emotional Intelligence



Source: Harvard Business Review (https://online.hbs.edu/blog/post/emotional-intelligence-in-leadership)

Communication

- **Basics of Communication**
  - Listening and Speaking
  - Honesty and Fairness
  - Respect
  - Say What You Mean and Mean What You Say
- **Meeting**
  - Plan, Inform, Prepare, Structure and Control, Summarize and Recall
  - Hold at least one meeting every week
  - Record the minutes in a logbook
- **Conflict Management**
- **Decision Making**
  - Decision by authority, Expert, Majority and Consensus

Conflict Management

Conflict: The situation in which an action of one person prevents, obstructs, or interferes with the actions of another

- Withdrawal or Avoiding
- Forcing
- Smoothing
- Compromise
- Confrontation
- Competing
- Collaborating

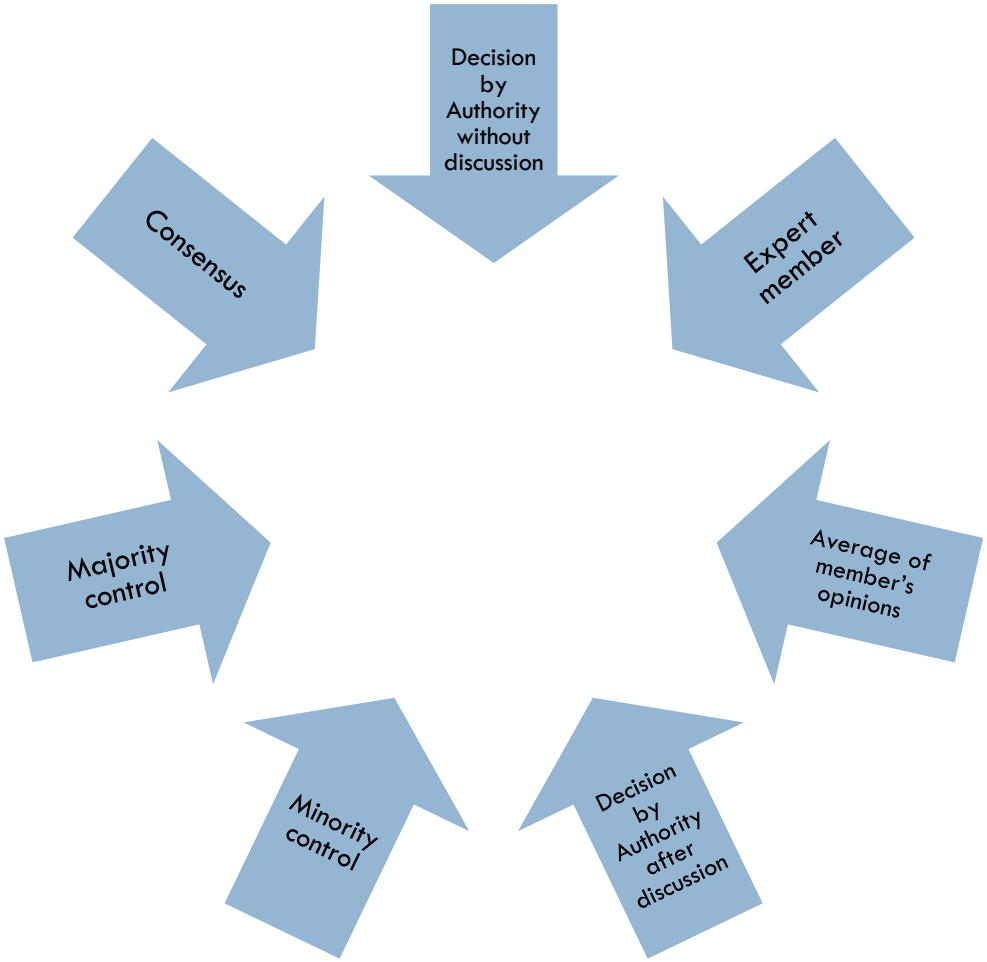
The Process of Building Collaboration

- Manage Your Feelings
- Create a Supportive Climate
  - Coming Together on Mutual Ground
  - Having a Sense of Openness
- Focus on the Facts – data driven approach
- Describe the Goals
- Create Solutions – solution oriented approach

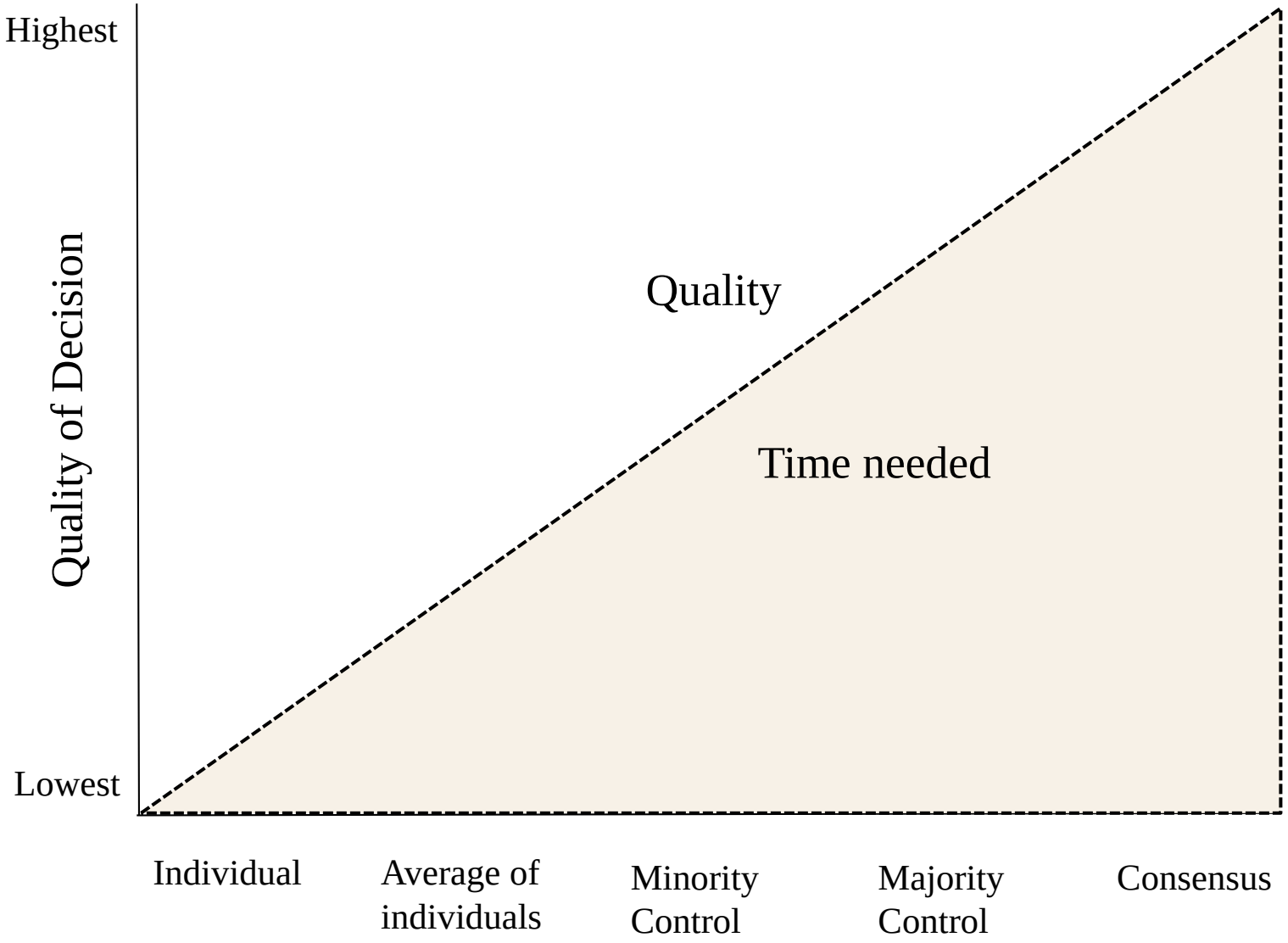
Decision Making Process

- **Frame**
  - Decide (Define) what you are going to decide and what you are not going to decide
- **Gather intelligence**
  - Gather real intelligences, not just information that will support your biases
- **Come to conclusions**
  - Determine how your team will act on the intelligence it gathers
- **Learn from experience**

Types of Decision Making



Decision Making: Time – Quality Graph

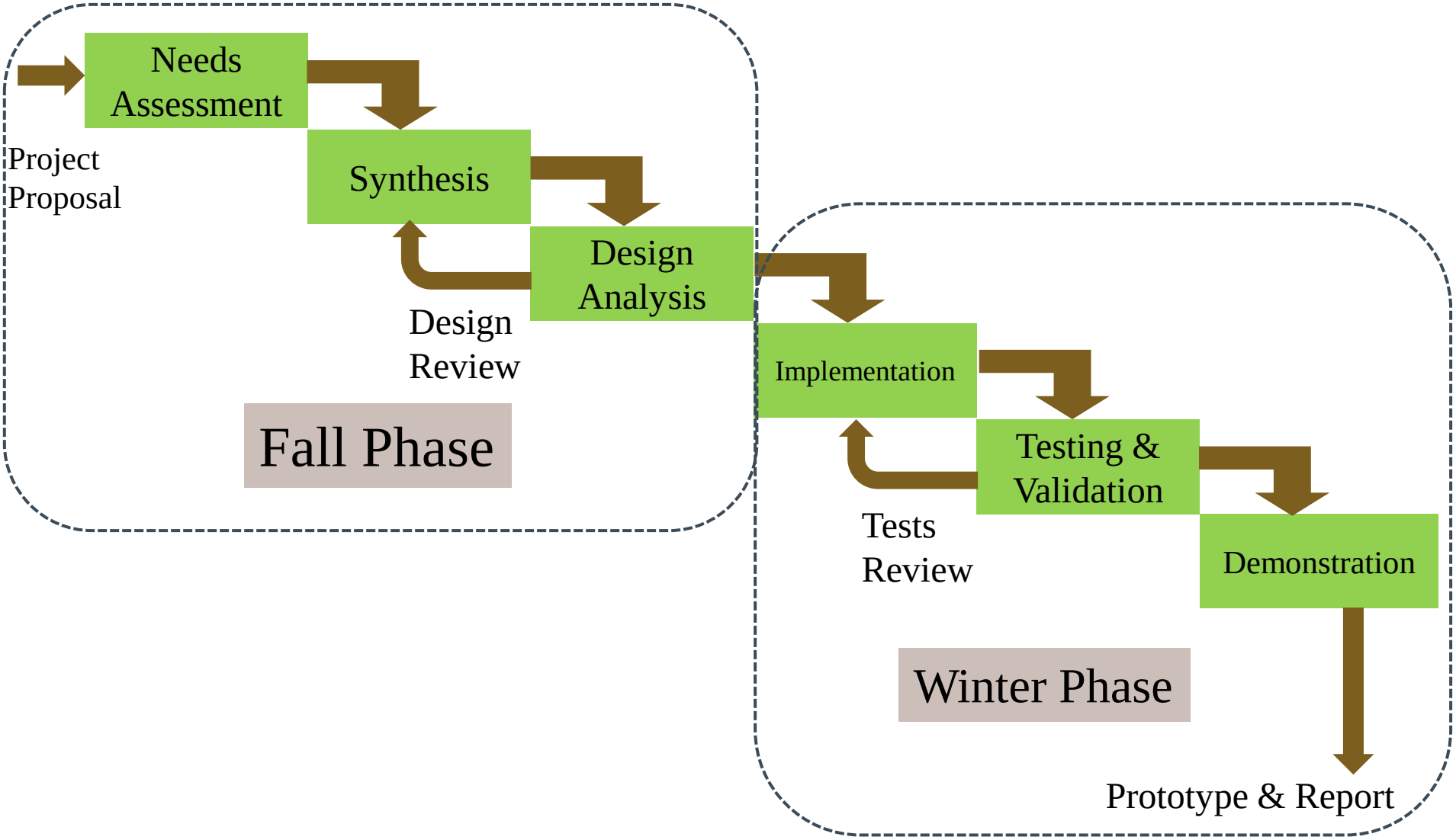


Leadership

- Plan
- Organize
- Control
- Lead – show innovation and open-mindedness
- The Engineering Leader
  - Is Proactive, Has Vision, Creates Alignment, Promotes Growth, Promotes Continuous Improvement, Prevents or Put Out Fires, Leads by Example
- The Engineering Manager
  - Is Responsive, Stays Focused and Maintains Control, Provides Resources, Manages the Firehouse

Capstone Design Project

Capstone Design Project



EDP Targets in the Fall Term

- Fall Term: Design Phase
  - Complete Functional Specification
    - Problem Definition
    - User and Functional Requirements
    - Design Constraints
  - Complete Design Specification
    - Background literature review
    - Design Analysis
    - Evaluation of alternative design solutions
  - Complete Part List and Budget Plan
    - Part list is optional but highly recommended, so that you can order parts before Christmas and year-end break

EDP Targets in the Winter Term

- Winter Term: Prototype Implementation Phase
  - Complete Implementation Plan
  - Define Important Milestones
    - Four milestones, one at the end of every third week
      - M1: Week-3, M2: Week-6, M3: Week-9 and M4: Week-12
  - Complete Test and Validation
  - Complete Performance Measurement
  - Prepare for Open-House Demonstration

Project Management Exam Topics

- We prescribed the following textbook: TeamWork and Project Management by Karl Smith and P.K. Imbrie, Third Edition, McGraw Hill, 2004. [page numbers in the 4th edition]
- Following topics in the book are prescribed for the reading:
  1. Groups and Teams, page 27 [45]
  2. Characteristics of Effective Teams, page 30 [47, 54]
  3. Stages of Team Development, page 31 [52]
  4. Teamwork Skills, page 39 [62]
  5. Decision Making, page 45 [69]
  6. Conflict Management, page 48 [72]
  7. Project Life Cycle, page 64 [159]
  8. Skills Necessary for Effective Project Managers, page 78 [175]
  9. Project Manager's Role over the Project Life Cycle, page 81 [179]
  10. Work Breakdown Structure, page 88 [185]
  11. Critical Path Method, page 89 [186]
  12. Project Resource and Cost Consideration, page 97 [194]
  13. Meetings, page 103 [201]
  14. Project Evaluation, page 113 [218]
  15. Project Documentation, page 121 [226, 233]
- An Examination from the above topics will be conducted as per schedule. The examination may include case study on the application of some of the above topics.
- Supplemental Reading (Not mandatory): Fundamentals of Project Management 5th edition by Joseph Heagney – Ch1, Ch2, Ch7, Ch8, Ch9, Ch13 and Ch14; and Managing Teams For Dummies by Marty Brounstein

PM Exam – Case Study

WSB Team of X-Network

Team Lead: Lisa

Team members: Mark and Govi

Project: The team is assigned the task of designing sensor board and implementing its prototype

Situation:
-Lisa has called a meeting to decide the communication interface.
- She asked the team to consider wireless interface because that requires no attachment to the board.
- Mark suggested Zigbee interface because he thinks that is very popular in the embedded market.
- Govi countered that proposal by suggesting Bluetooth. He didn't provide any rationale for his suggestion, but the tone of his suggestion caused Mark to withdraw his proposal.
- Lisa asked them to prepare small presentations on their proposals that should include power consumption, robustness of device driver software, and per unit cost of the interface.

Evaluation of the situation in terms of:
-Leadership
-Communication
-Decision making
-Conflict management