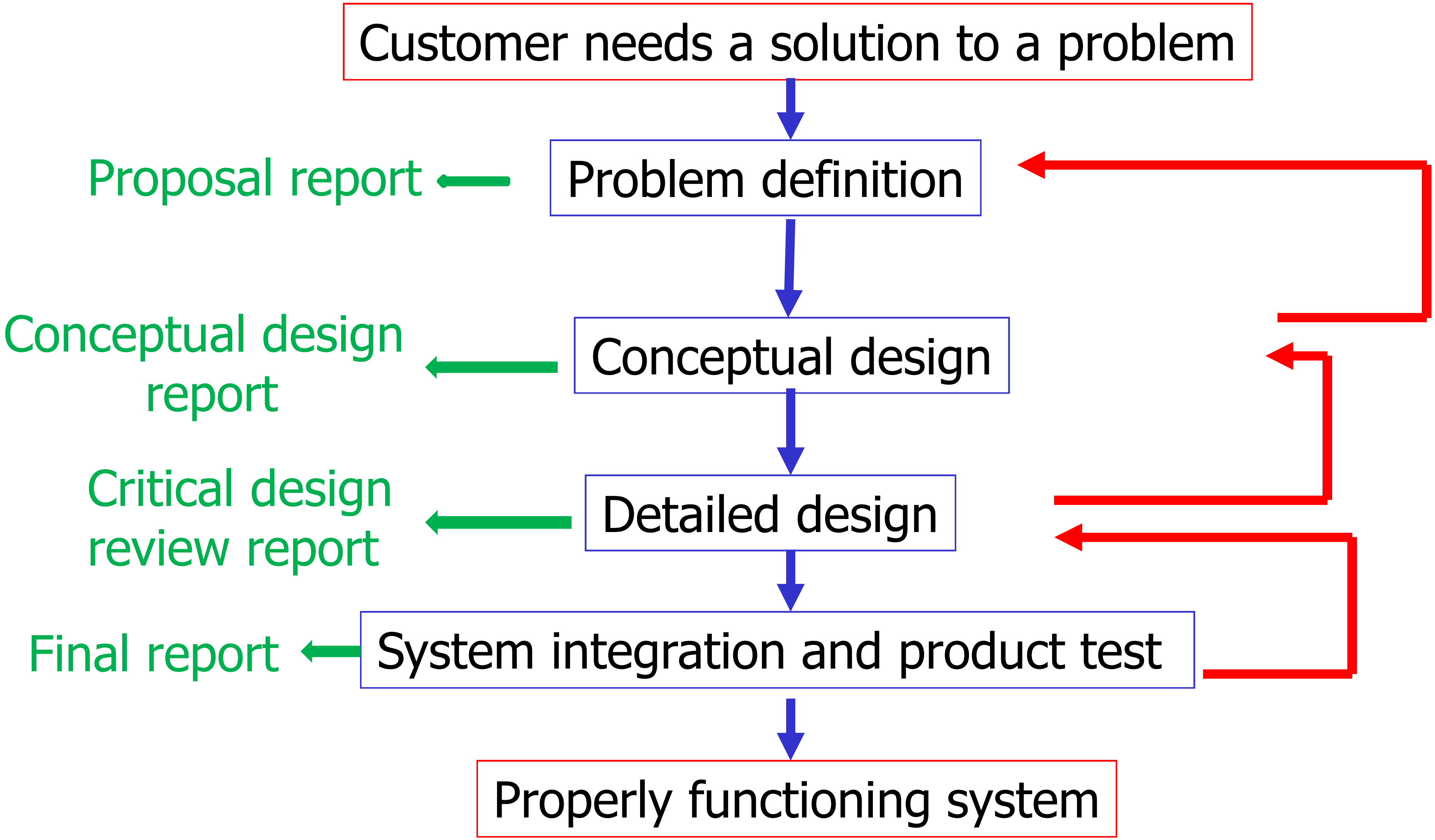
FUNDAMENTALS OF ENGINEERING DESIGN

Best way to learn design is “to design”

Design Process



Problem Definition

- Needs assessment
- Define goals
- Define objectives and metrics
  - Objectives are the desired attributes of the design, what the design will "be" and what qualities it will have
  - Metrics measure how well the objectives are met
- Identify constraints
  - Constraints are strict limits that a design must meet in order to be acceptable
- Specify design requirements
  - A requirement specifies a capability or a condition to be satisfied.
  - Requirements are non-negotiable objectives

Needs Assessment

- The aim is not to solve the problem but to understand what the problem is
  - What does this client want?
  - What is the problem that the design is to solve?

Placing eggs into nests

Define goals

- Detect start signal
- Detect the egg
- Detect the nest
- Align the robot, the egg and the nest
- Push the egg towards the nest by controlling it
- Place the egg into the nest

Define objectives

- Objectives, are the desired attributes of the design, what the design will "be" and what qualities it will have
- They are often adjectives and expressed as "being" statements (not "doing")
- Objectives allow exploration of the design space to choose among alternative design configurations

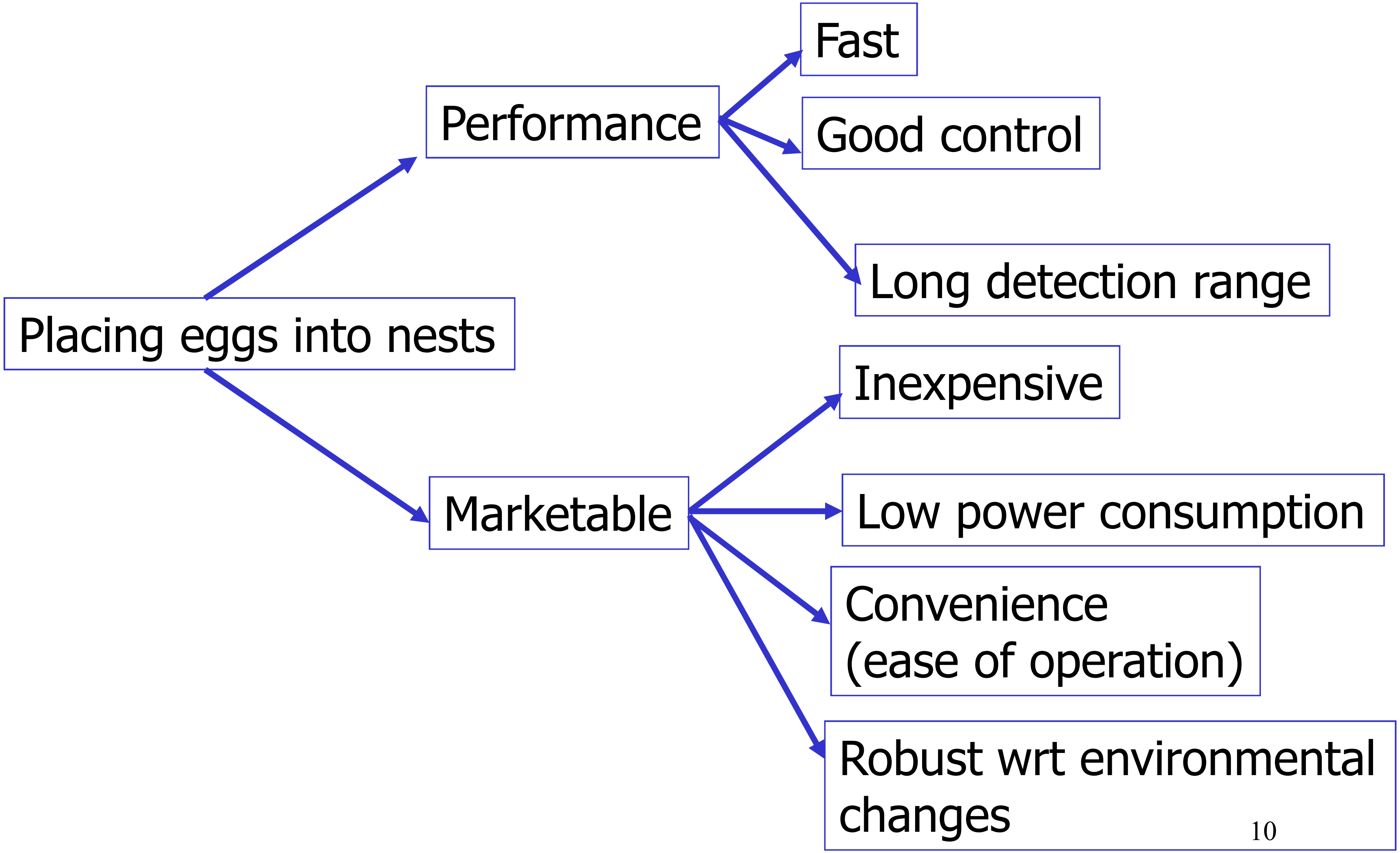
Objective examples

- Performance related
  - Speed
  - Accuracy
  - Resolution
- Cost
- Ease of use
- Reliability, durability
- Power
  - Voltage levels
  - Battery life

Objective trees

- Make a list of objectives
- Group the relevant objectives
- Form a hierarchical tree structure

Objective trees



Define metrics

- Metrics measure how well the objectives are met

	F 0.12	GC 0.10	LDR 0.18	I 0.24	LPC 0.09	C 0.18	R 0.09	Total
S1	8 0.96	6 0.6	10 1.8	4 0.96	2 0.18	0 0	2 0.18	4.86
S2	0 0.0	6 0.6	8 1.44	10 2.4	8 0.72	2 0.36	2 0.18	5.7
S3	2 0.24	8 0.8	0 0.0	2 0.48	6 0.54	10 1.8	4 0.36	4.22

10: Excellent,8: Good, 6: Satis., 4: Av., 2: Unacceptable, 0: Failure

Metrics

	Fast	Long Detection range	Robustness to changes in light conditions
10 Excellent	<5 min.	1-2m	Works in the dark and under sunlight
8 Good	5-10	80-100cm	Works in the dark and in the laboratory lighting
6 Satisfactory	10-15	60-80cm	Works under sunlight and in the laboratory lighting
4 Average	15-20 min	40-60cm	Works everywhere in the laboratory
2 Unacceptable	20-30 min.	20-40cm	Works only at some specific locations in the laboratory
0 Failure	>30 min.	0-20cm	Sometimes works at some specific locations in the laboratory

Identify constraints

- Restrictions or limitations on a behavior, a value, or some other aspect of performance
- Stated as clearly defined limits
- Often the result of guidelines and standards

- Size of robot, pushing plate, nest
- Markers to detect robot and nest
- Start signal: 5kHz sine wave

Specify design requirements

- A requirement specifies a capability or a condition to be satisfied.
- Translating client and user needs into terminology that helps us find ways to realize those needs and measure how well we met them
  - How can I express what the client wants in terms that helps me as an engineer
  - It turns the problem statement into a technical, quantified specification
  - Expressible as numbers and measures

Requirement types

- Functional : Specifies a behaviour that a system or part of system must perform.
  - expressed as "doing" statements
  - typically involve output based on input

- Performance : Refers to a requirement that quantitatively defines a system's or part's required capability.
  - Tells us how well the design will perform

- Physical : Specifies the physical characteristics of a system or system part.

A good requirement is:

- Abstract
  - What the system will do, not how it will be implemented
- Unambiguous
- Traceable
  - To the needs and desires of the user
- Verifiable, measurable
  - Are we building the system correctly?
  - Test plan!!!
- Achievable (realistic, feasible)
  - Research, engineering know-how, system modeling

A good requirement

- The robot must have an average forward speed of 0.5 feet/sec, a top speed of at least one foot/sec, and the ability to accelerate from standstill to the average speed in under one second

A poor requirement

- The robot must employ IR sensors to sense its external environment and navigate autonomously with a battery life of one hour.

- Better one: The robot must navigate autonomously, with the aid of only landmarks in the specified environment, for a period of at least one hour.

Examples of Poor Requirements

- The computer shall process & display the radar information instantly.
- The ship shall carry enough short range missiles.
- The power supply output shall be 28 volts.
- The aircraft shall use stainless steel rivets.
- The power supply unit shall provide 12 V DC with a load regulation of 1% while the line voltage variation is 220 +/- 20 V AC under all load current regimes and vibration and shock profiles within the temperature range.

Placing eggs into nests

- Performance requirement
  - The robot should place the first egg in the nest within at most 20 min.
  - The robot should detect 5kHz sine wave generated by a mobile phone placed 1m from the robot at a signal to noise ratio of 20 dB.
- Functional requirement
  - The nest should signal when the egg is placed in the nest.
  - The robot should distinguish the first egg and the second egg to be placed in the nest.

Objectives versus requirements

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Objectives versus requirements

- S2 and S3 does not satisfy requirement, S1 is the optimum solution

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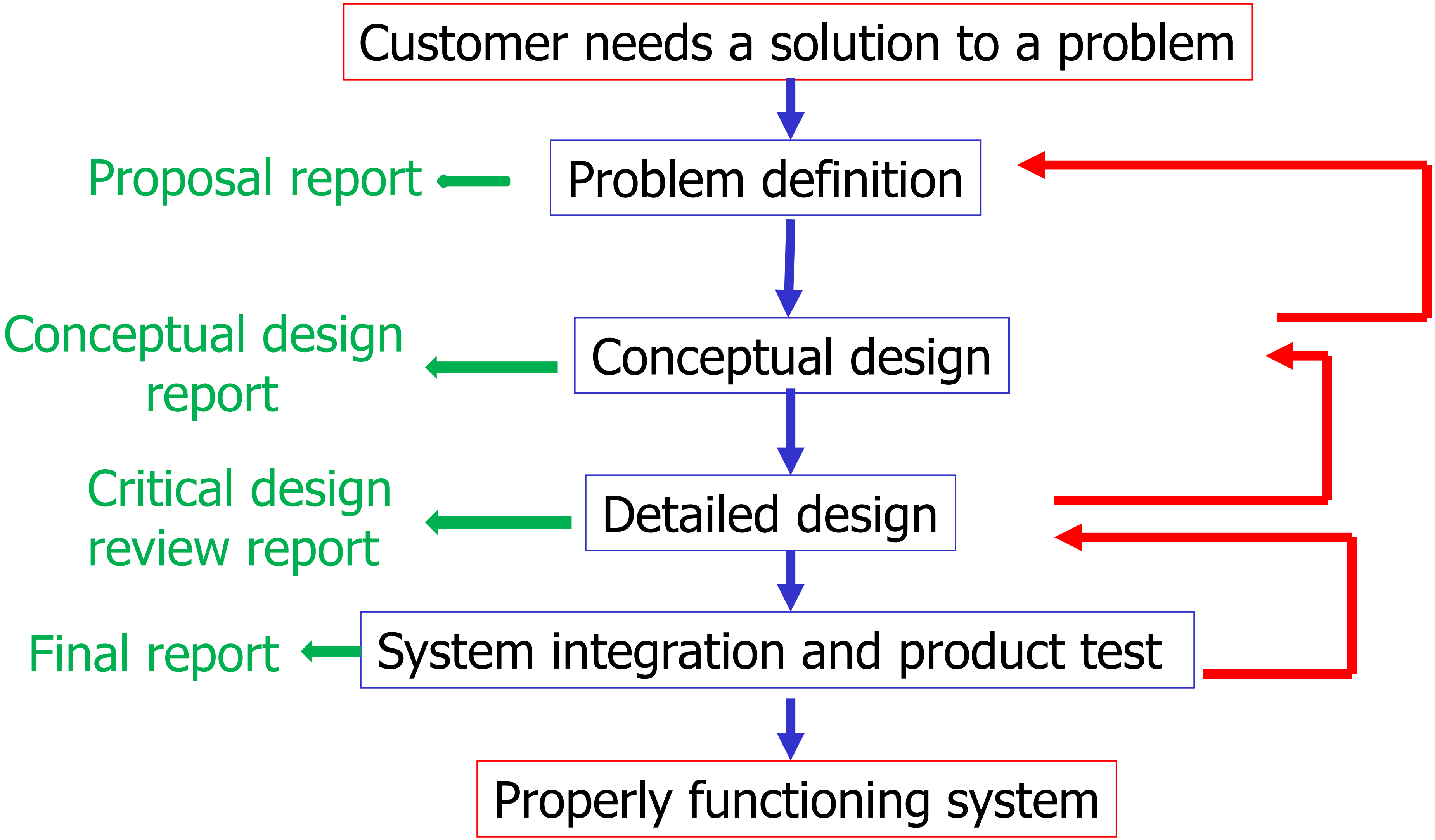
Requirements are non-negotiable objectives

Why requirement analysis is important?

Design Process



System level and sub-system level requirements

- System level requirement (Defined in proposal report)
  - ➢ The robot should place the first egg in the nest within at most 20 min.
- Conceptual Design (CD) ⟹ Subsystems are defined

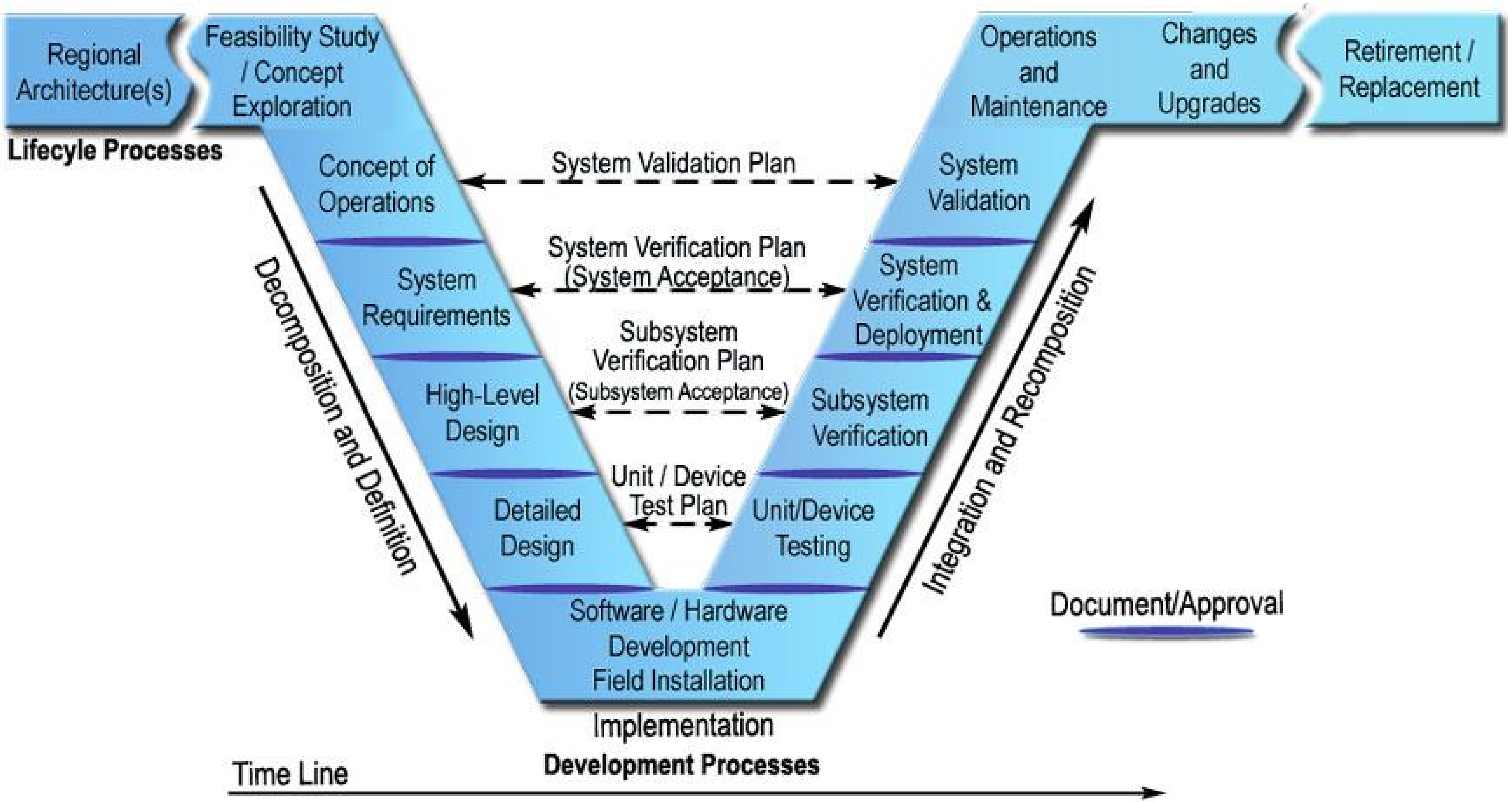
  Sub-system level requirements (Defined in CDR)
  - ➢ At the start of the game, the robot should move to the egg in 10 sec
  - ➢ The speed of the robot while pushing the egg should be at least 5cm/sec
  - ➢ The robot should push the egg without loosing control at least 20 cm
  - ➢ The robot should find the egg within 10 sec after loosing control of it
  - ➢ After detecting the egg and the nest, the robot should align with the egg and the nest within at most 30 sec

Sub-system level and unit level requirements

- Sub-system level requirement (Defined in CDR)
  - ➢ The robot should find the egg within 10 sec after loosing control of it
- Detailed design ➡ Units are defined

  Unit level requirements
  - ➢ The camera should be able to capture 30 frames per second
  - ➢ The microprocessor should be able to process 15 frames per second

V Diagram



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