System Frameworks

System Concepts

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Presentation Goals

Outline and define basic concepts, including system, meta-system,complexity and complexity measures.

Present a systematic approach to system framework development and use

Discuss typical system frameworks, architectures and reference models

Discuss and further define system “meta-models” and system abstraction frames

System Frameworks

Overview

Provide definitions and context

Discuss system application modes

Outline system complexity measures

Define system engineering process as a problem solving activity

Introduce system abstraction frames

CCFRAT concepts (self-similar, recursive) for complexity control

Outline system design engine

Define system context and value network

Discuss system meta-levels and context refinement

System Frameworks

Define Terms

System – "Functional" Definition:

"A system is a constraint on variety."
(Heylighen 1994)

System – "Construction Rule" Definition:

"A system is a non-empty set of objects and a non-empty set of relationships mapped over these objects and their attributes."
(Simpson & Simpson 2003)

System Frameworks

Define Terms

Meta-system:

"A meta-system is a set of value sentences which describe the wanted physical system, and which imply or actually comprise the parts and relationships of the meta-system." (A.D. Hall, 1989)

Meta-system:

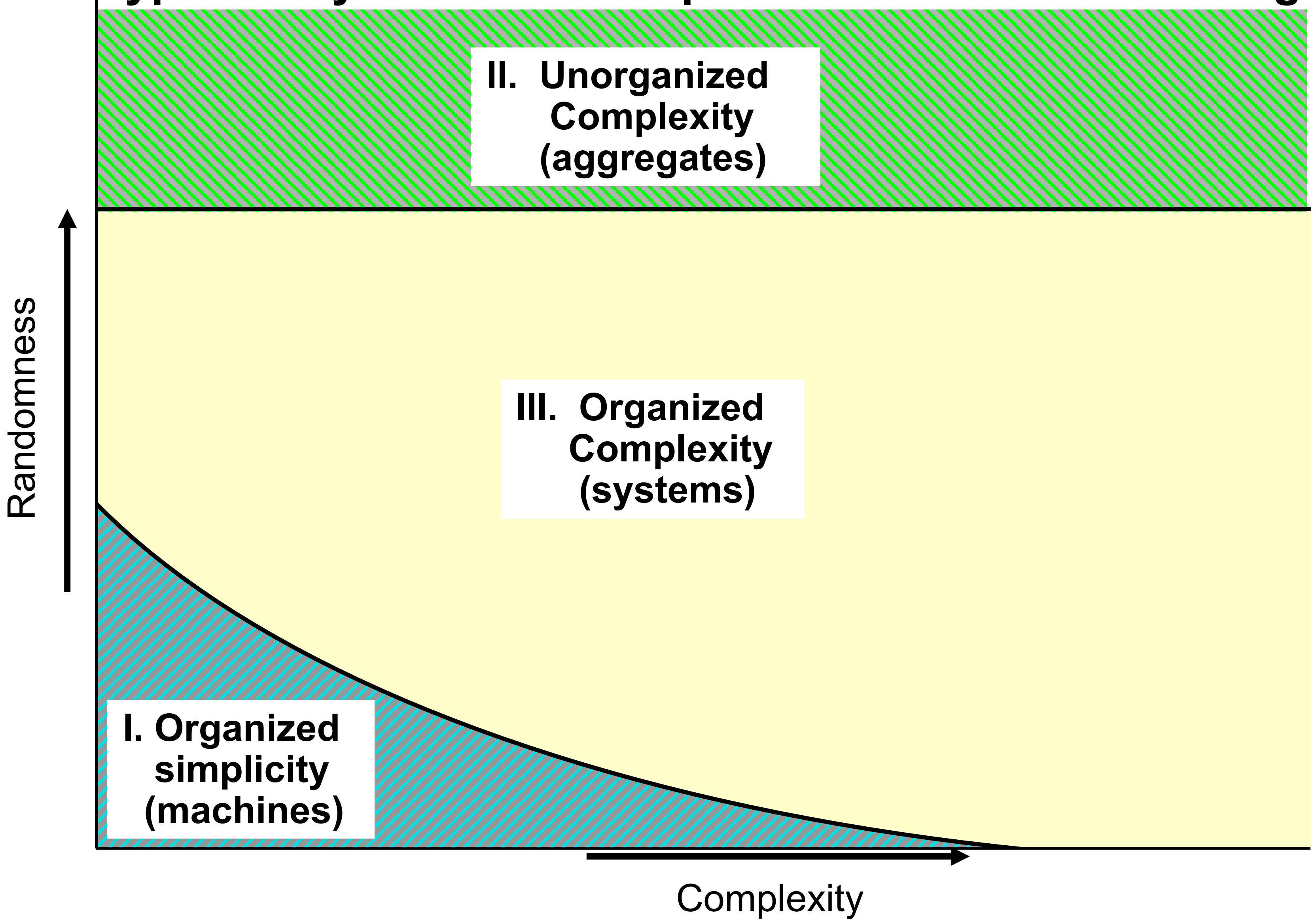
"The meta-system indicates the field within which the system arises and within which it interacts with other systems." (K.D. Palmer, 2000)

Meta-system:

"A meta-system is a constrained variation of constrained varieties." (Heylighen 1994)

System Frameworks

Types of Systems with respect to Methods of Thinking



Adapted from “introduction to General Systems Thinking” G.M. Weinberg

Discovery Mode & Design Mode

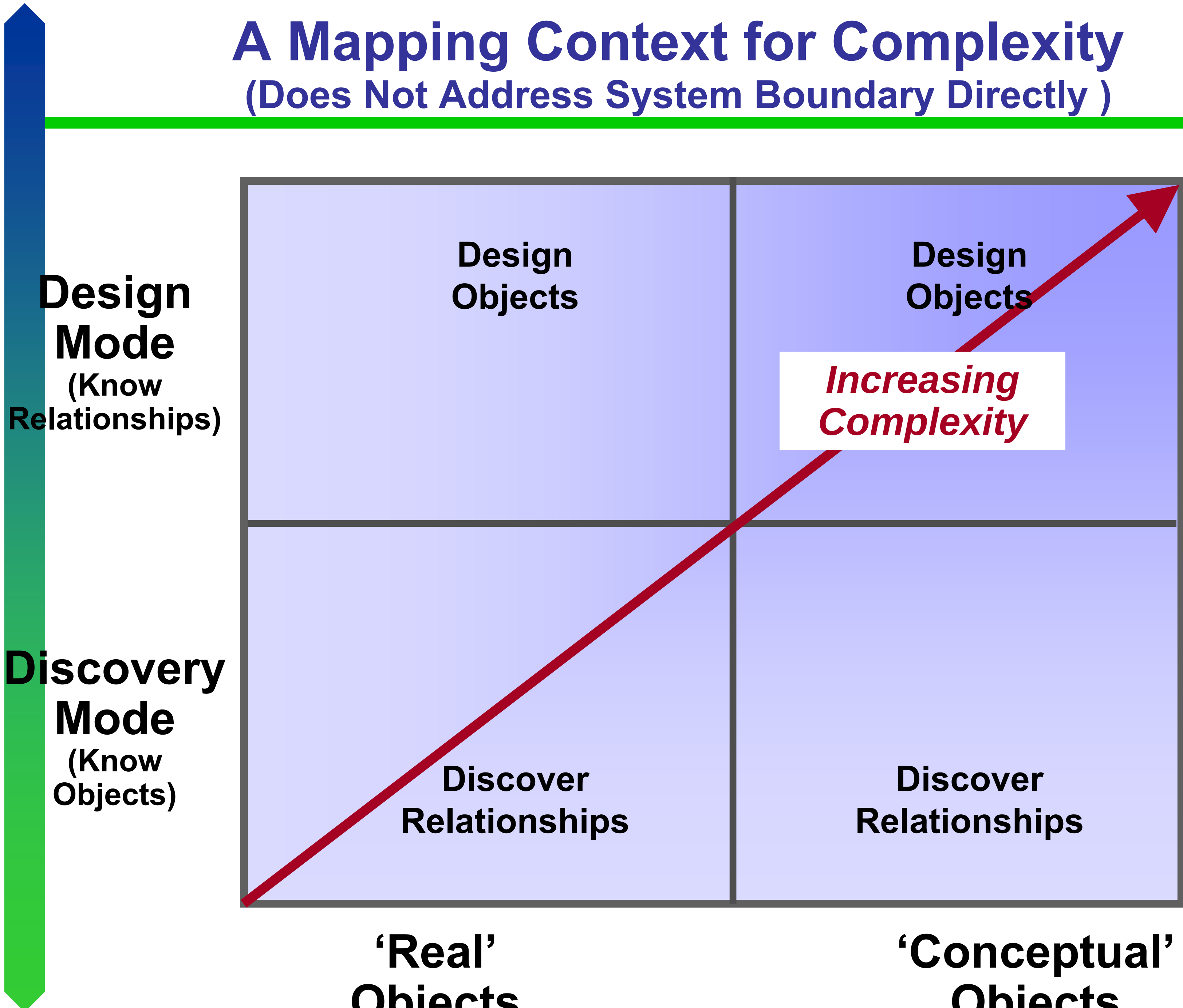
Two Primary System Application Modes

System	*Objects*	*"Over which we map"* *Relationships*
Discovery Mode	**Know the Objects**	**Discover the Relationships**
Design Mode	**Design the Objects**	**Know the Relationships**

Discovery (Kepler)	**Know the Planets**	**Discover the Mathematical Relationships**
Design (Kennedy)	**Design the Objects, Config**	**Know "Man on the Moon"**

A Mapping Context for Complexity

(Does Not Address System Boundary Directly)



Eight Primary System Complexity Metrics

1 – Number of objects – Weinberg

2 – Number of relationships

3 – Number of different types of objects

4 – Number of different types of relationships

5 – Rate of change of objects – Warfield (structure)

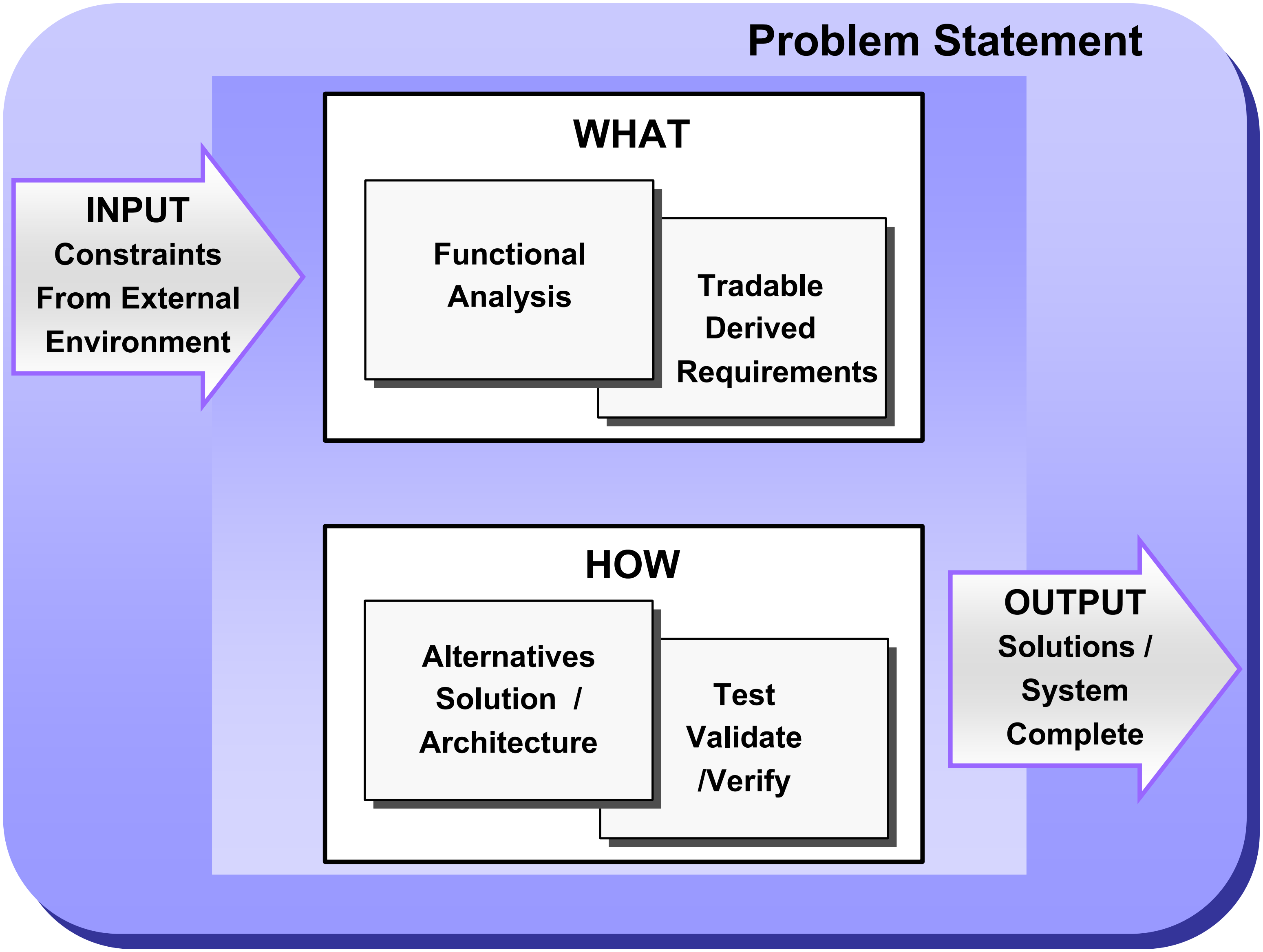
6 – Rate of change of relationships – Warfield (structure)

7 – Rate of change of the environment

8 – Range of variability

System Frameworks

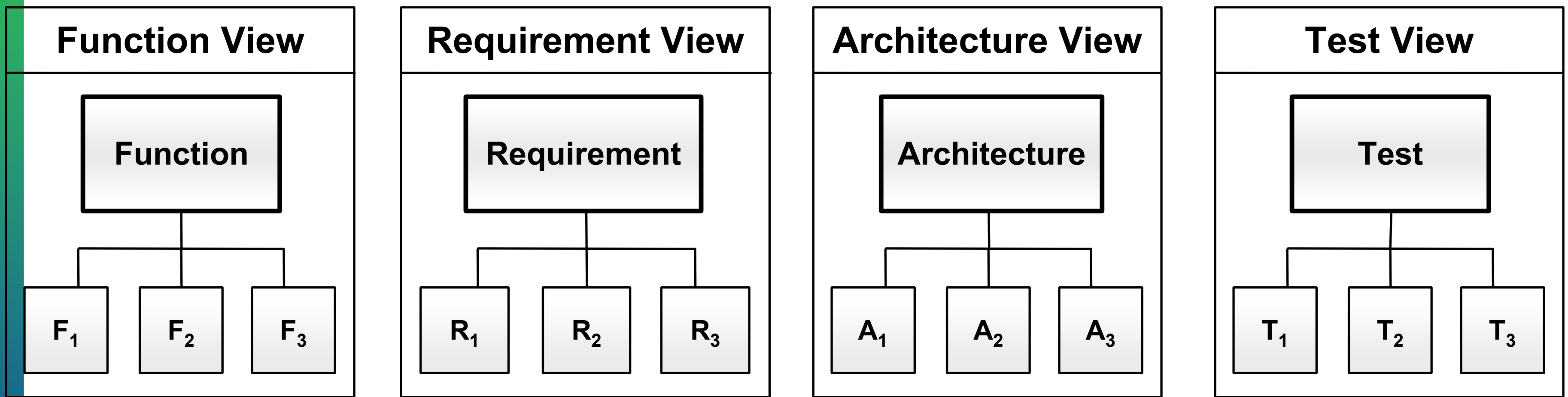
Meta Process in SE Notional Format



System Frameworks

FRAT - System Views*

Any system must be expressed in four views



* **Mar & Morais**

Problem Space Topology

Complexity # of Individuals, # of Variables	Problem Space Well-defined vs Ill-Defined	Solution Space Unique vs Multiple Solution(s)
Simple	Well-Defined	Closed
Simple	Ill-Defined	Closed
Simple	Well-Defined	Open
Simple	Ill-Defined	Open
Complex	Well-Defined	Closed
Complex	Ill-Defined	Closed
Complex	Well-Defined	Open
Complex	Ill-Defined	Open

Increasing Complexity

Deductive

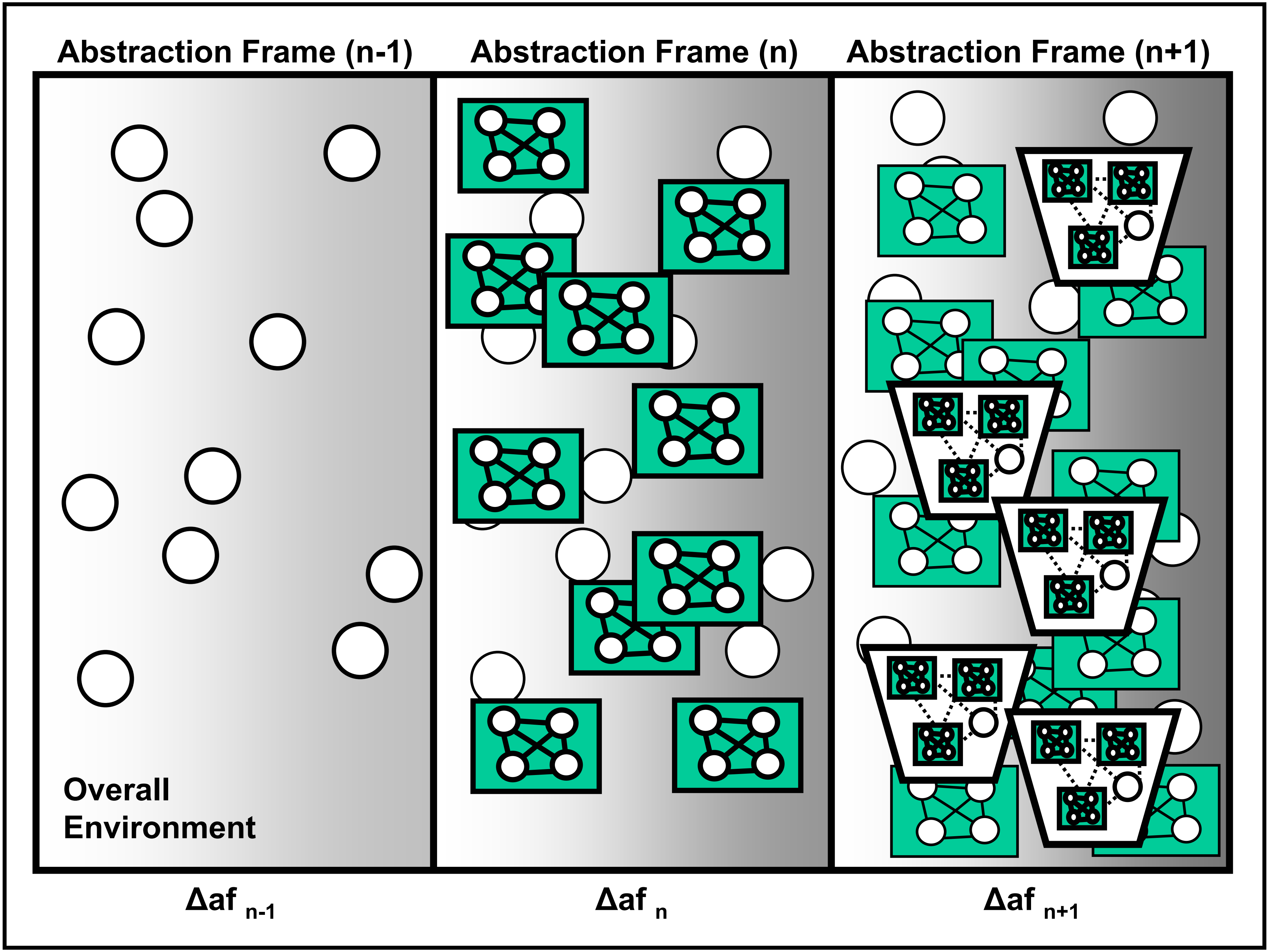
Inductive

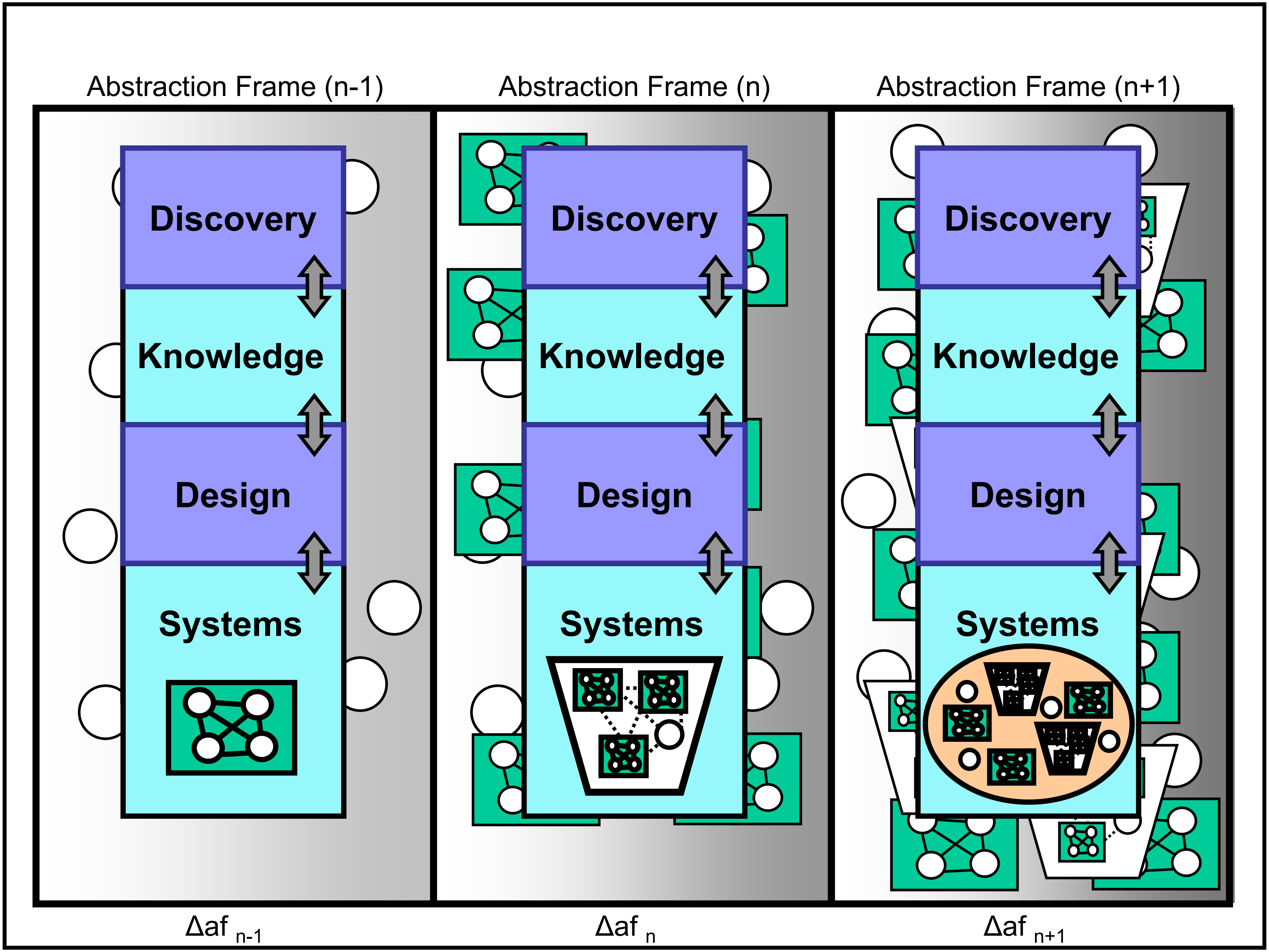
Features of a system are largely driven by its problem space

A systems approach is characterized hierarchically by

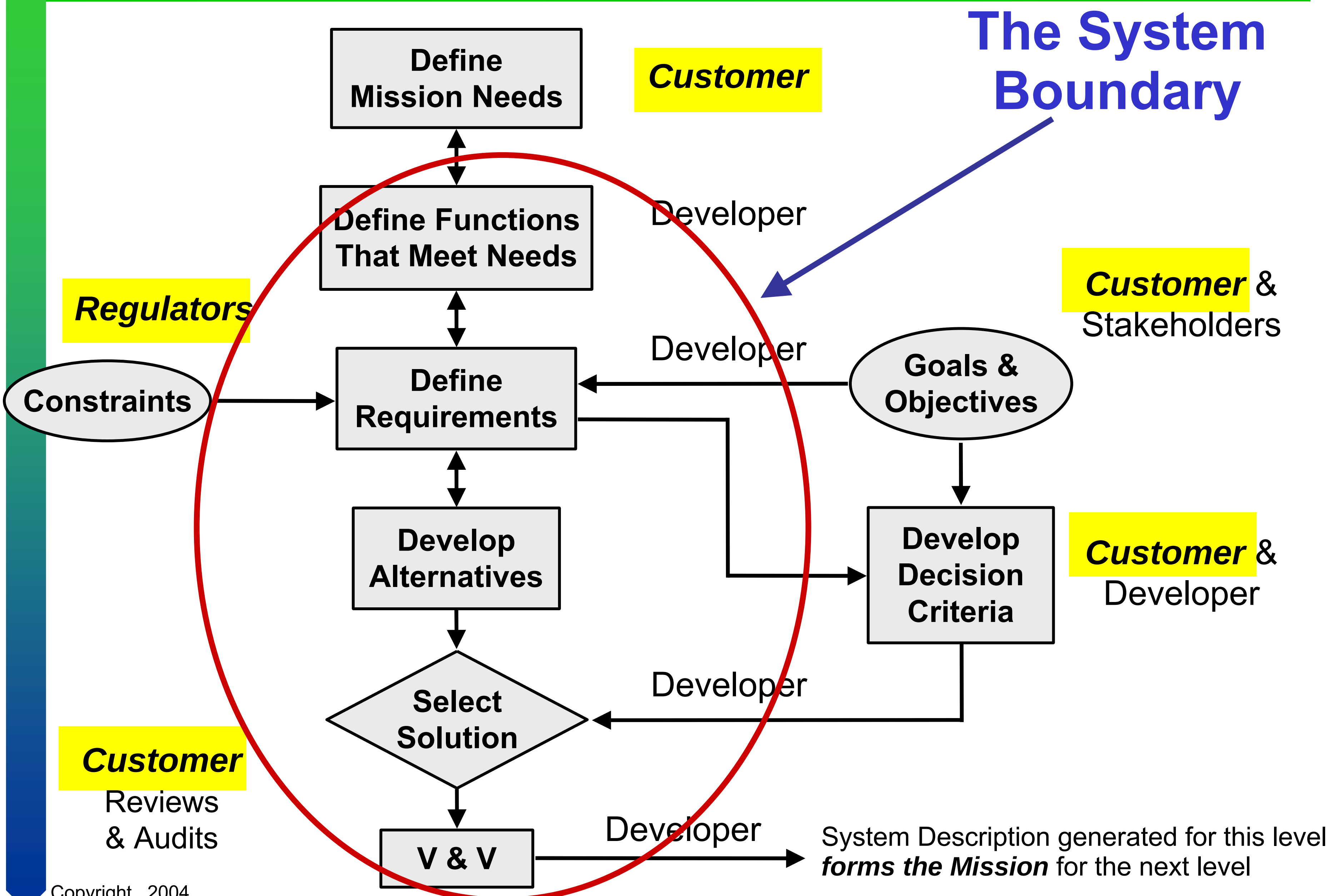
- **Abstraction frames**
- **Degree of complexity**
- **Levels of detail**

Table adapted from Chapter 9 Problem Solving Skills, *Introduction to the Engineering of Complex Systems*, Brian W. Mar, 1996.


Abstraction Frame (n-1)
Abstraction Frame (n)
Abstraction Frame (n+1)
Overall Environment
Δaf_{n-1}
Δaf_{n}
Δaf_{n+1}

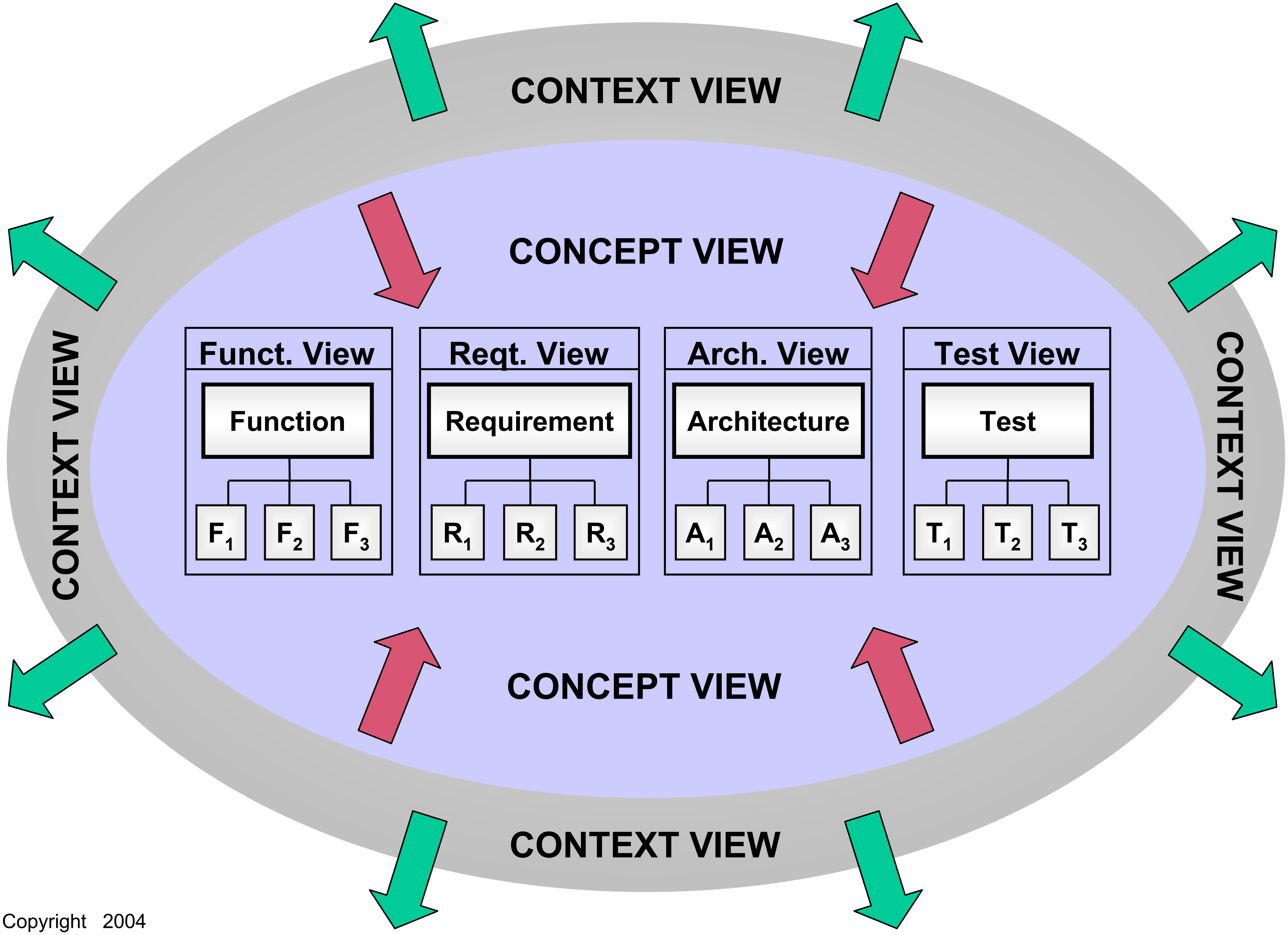

Abstraction Frame (n-1)
Abstraction Frame (n)
Abstraction Frame (n+1)
Discovery
Knowledge
Design
Systems
Discovery
Knowledge
Design
Systems
Discovery
Knowledge
Design
Systems
Δaf n-1
Δaf n
Δaf n+1

System Frameworks

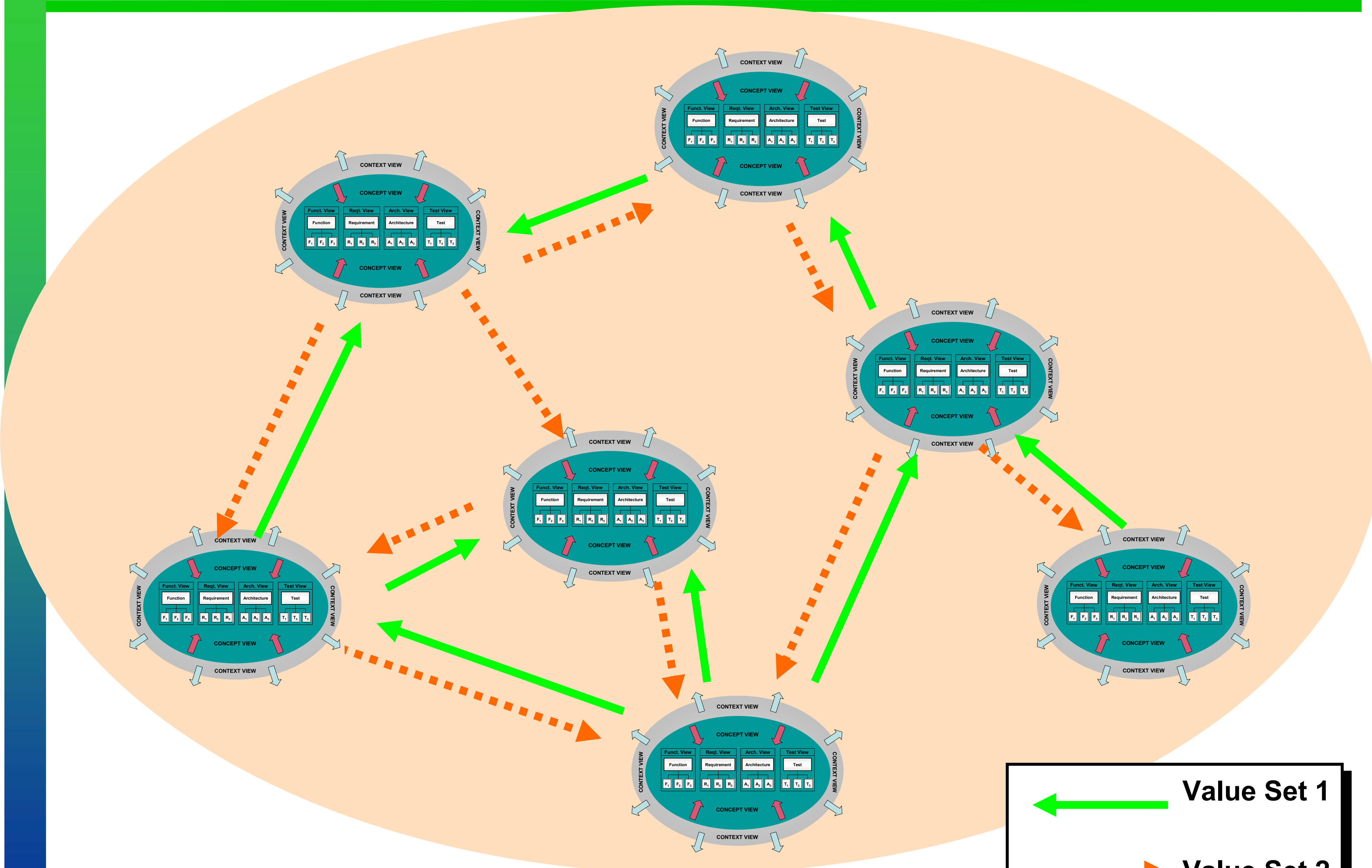


* **"FRAT – A Basic Framework for Systems Engineering," Mar & Morais**

System Frameworks



System Frameworks

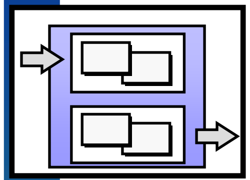


Value Set 1

Value Set 2

Systems Approach: Phases, Hierarchies, Content

Pick One Aspect from Each Axis

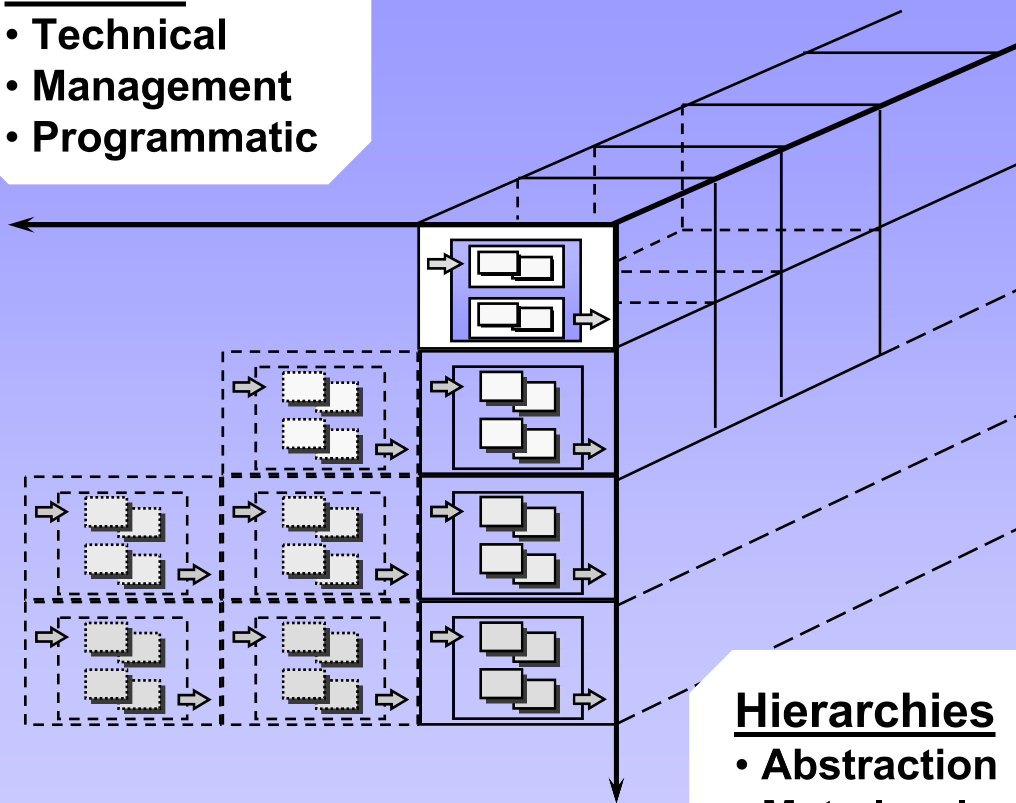


Meta Process

Applies to:

Content
- Technical
- Management
- Programmatic

Phases
- Over time
- Over products
- Over events



Hierarchies
- Abstraction
- Meta-levels
- Levels of detail

System Frameworks

Systems Meta-Levels

	Being's Meta-levels	Bateson's Series	Modalities of Being-in-the-World	Associated Cognitive Abilities	Systems Meta-levels
5	Being meta-level 5 ULTRA	This step into non-Being is ultimately unthinkable	Empty Handedness Emptiness or Void	Cognitive Inability	Rules For Developing Rules
4	Being meta-level 4 WILD	Learning 4 to learn to learn to learn	Out-of-Hand	Encompassing	Rules For Developing Frameworks
3	Being meta-level 3 HYPER	Learning 3 to learn to learn	In-Hand	Bearing	Architectural Frameworks
2	Being meta-level 2 PROCESS	Learning 2 to learn	Ready-to-Hand	Grasping	Architectural System Schema
1	Being meta-level 1 PURE	Learning 1 as an ideal gloss	Present-at-Hand	Pointing	Conceptual System Schema
0	Being meta-level 0 ENTITY	Concrete Instances 0 of learning in world	Orientation toward Things	Thing	Single Physical Instance

- Table from Palmer, Kent D., "Meta-systems Engineering,"
  - 10th Annual Symposium of INCOSE, 2000

Summary and Conclusions

Summary and Conclusions

Increasing system and environmental complexity can be measured and managed.

Systems engineering processes and principles provide a logical framework for evaluation of system complexity.

As product systems grow in size and complexity, system engineering must find and utilize the proper abstraction frame which reduces the system complexity and retains the proper level of system analysis.

The CCFRAT concepts and methods combined with well-defined meta-levels provide a foundation for a specialized systems engineering language.

Questions?