Systems and Objects

Joseph J. Simpson, The Boeing Company

Mary J. Simpson, System Concepts

Systems and Objects

1. System Definition and Application Modes
2. System Boundary Development and Complexity Map
3. System Design and SE Process as Problem Solving Activities
4. Impact of Environment Changes on the Problem Statement
5. FRAT Concepts (Self-similar, Recursive) for Complexity Control
6. Lack of Common Semantics Increases System Complexity
7. Standard "System Language" Will Reduce System Complexity

System Meta-Model Definition

Systems Science

"A system is a set of things (objects or components) and a relation among the things." (Klir, 1991)

General Systems

"A system is a set of objects together with relationships between the objects and between their attributes." (Hall and Fagen, 1956)

"A system most generally implies the idea of elements forming an ordered whole, with the relations among these elements forming the structure of the system. The systemic character appears only as the elements function within the system." (Noth, 1995 - semiotics community)

Definition for Systems and Objects Context

A system is a non-empty set of objects and a non-empty set of relationships mapped over these objects and their attributes.

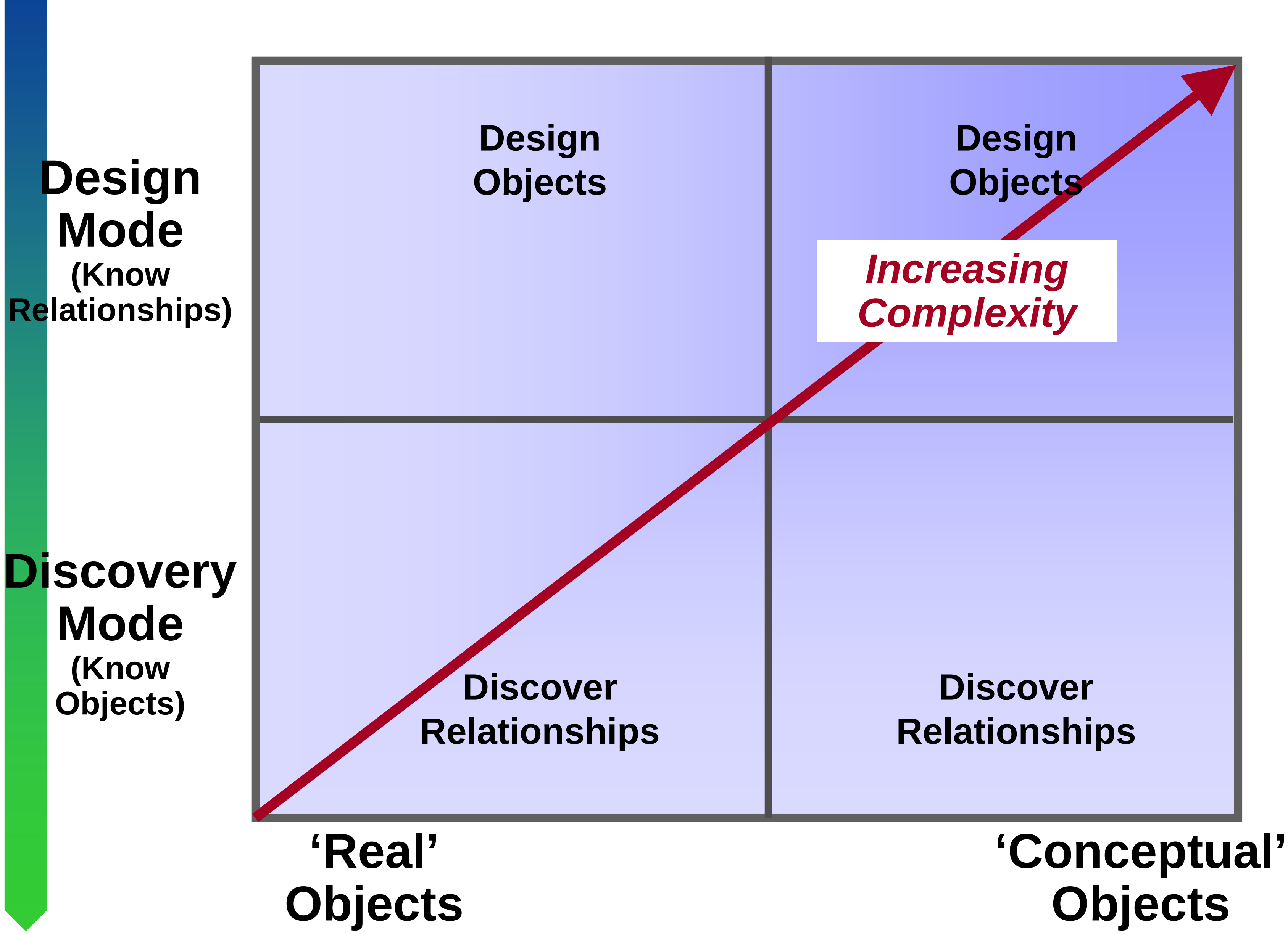
Discovery Mode & Design Mode

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)



Phases in Integrating System Design *
(Starts to Address System Boundary Definition)

Initiation Phase – Initiates the Project

- ***Exterior*** portion concerns itself with things outside of the system: requirements on the system and its environment
- ***Interior*** portion concerns itself with design choices relative to equipment, procedures and people: the system itself

Problem is outside the System

Solution is inside the System

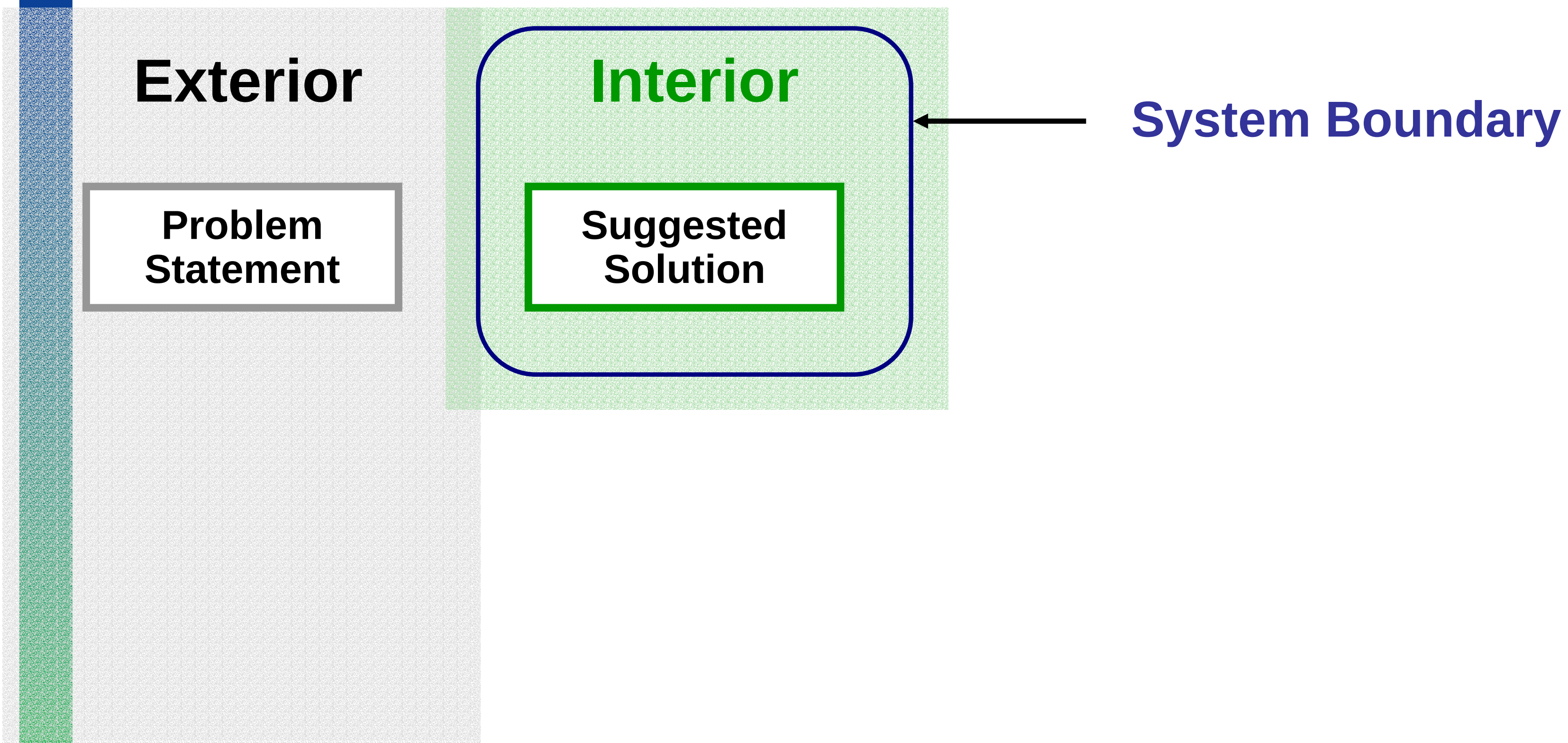
Preliminary Design Phase – Achieves 'First' System

- Answers questions which have only equivocal answers, iterates and documents the reasoning for choices made
- Describes overall system operation in considerable detail
- Delineates each subsystem by (a) inputs and outputs, (b) its functioning (operation on its input to produce its output), (c) limiting specifications concerning allowable sizes, weights, etc., and (d) at least one method of physically realizing proposed function within these limitations

Creates the Initial System Boundary

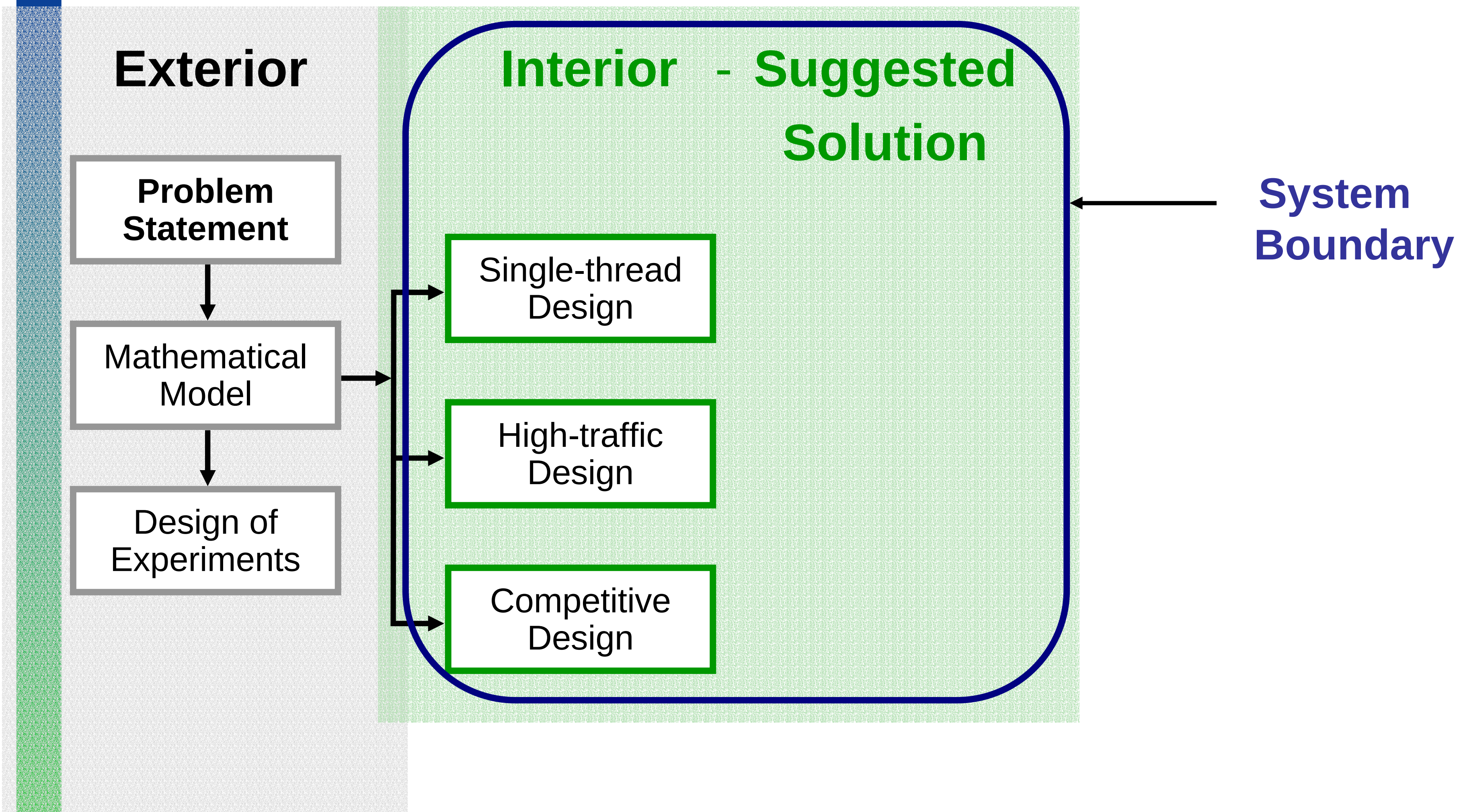
* Goode, Harry H. and Machol, Robert E., *System Engineering,* McGraw-Hill Book Company, Inc, 1957

Steps in System Design – Initiation Phase *



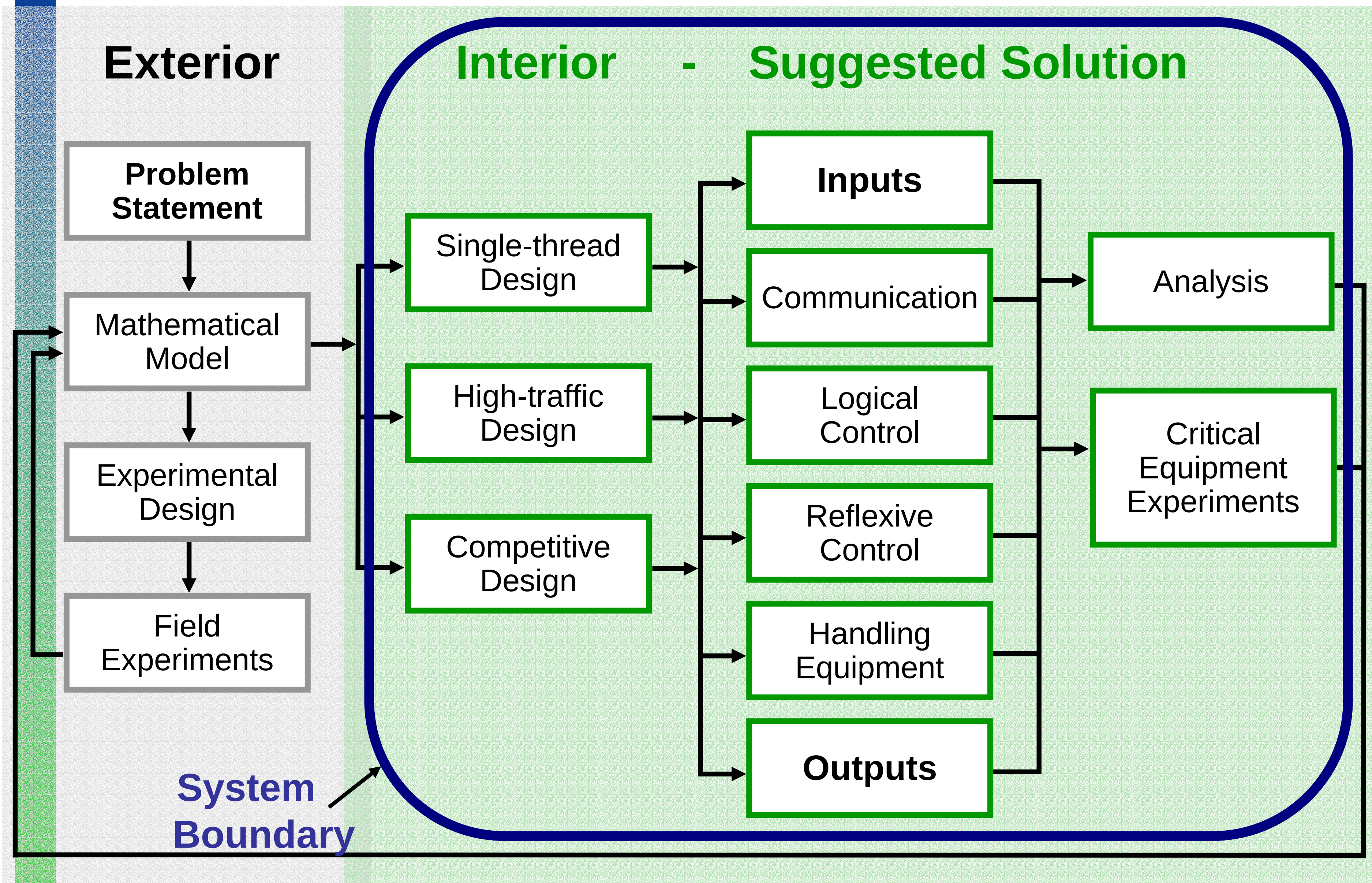
* Goode, Harry H. and Machol, Robert E., *System Engineering,* McGraw-Hill Book Company, Inc, 1957

Steps in System Design – Organization Phase *



* Goode, Harry H. and Machol, Robert E., *System Engineering,* McGraw-Hill Book Company, Inc, 1957

System Design Steps– Preliminary Design Phase*



* Goode, Harry H. and Machol, Robert E., *System Engineering,* McGraw-Hill Book Company, Inc, 1957

Scientific Approach to Problem Solving

Steps to Apply Scientific Method to Problem Solving	Early Man Developing Cultural Patterns	Basic Research	Operations Research	System Design
1 Recognize problem	Unsatisfied Physiological Need	Identify gap in body of scientific knowledge	Identify operational objective to be achieved	Describe mission or use requirements
2 Describe problem	Discover alternative ways to increase satisfaction of need	Develop theory of probable cause and effect relationships	Define situation & resources which can be used to attain objectives	Define req'd operation and logistic functions to attain use objectives
3 Select hypothesis for solving problem	Select favored way of satisfying need	Select hypothesis for investigation	Describe tailorable variables to achieve desired objectives	Specify the system performance / design requirements
4 Develop model for testing hypothesis	Devise implements & techniques to practice favored way	Describe experimental model to test hypothesis	Construct statistical model to interrelate variable conditions	Accomplish detail design & qualification testing of components
5 Conduct tests under controlled conditions	Use selected techniques for some period of time	Conduct controlled lab/field investigation to obtain data	Perform computation to obtain statistical values	Build, assemble, test complete prototype system
6 Analyze and evaluate test data	Decide if techniques result in tolerable satisfaction of need	Analyze and evaluate collected data	Analyze and evaluate summary statistical data	Analyze and evaluate test data
7 Derive conclusions to confirm, deny, modify hypothesis	Transmit techniques to others & establish cultural pattern	Derive conclusions to confirm, deny, modify hypothesis	Recommend actions to achieve desired objectives	Recommend modifications for production system

* Chase, Wilton P., *Management of System Engineering,* Robert E Krieger Publishing Company, Inc., 1974

A Problem Solving Meta Process

Define problem (Exterior) **INPUT**

Constraints, External Environment

- What is the problem?
- Who needs to have it fixed?
- Why does it need to be fixed?

Determine WHAT is needed to fix problem (Interior) **WHAT**

Functional Analysis, Requirements

- What has to be done?
- How well does it have to be done?

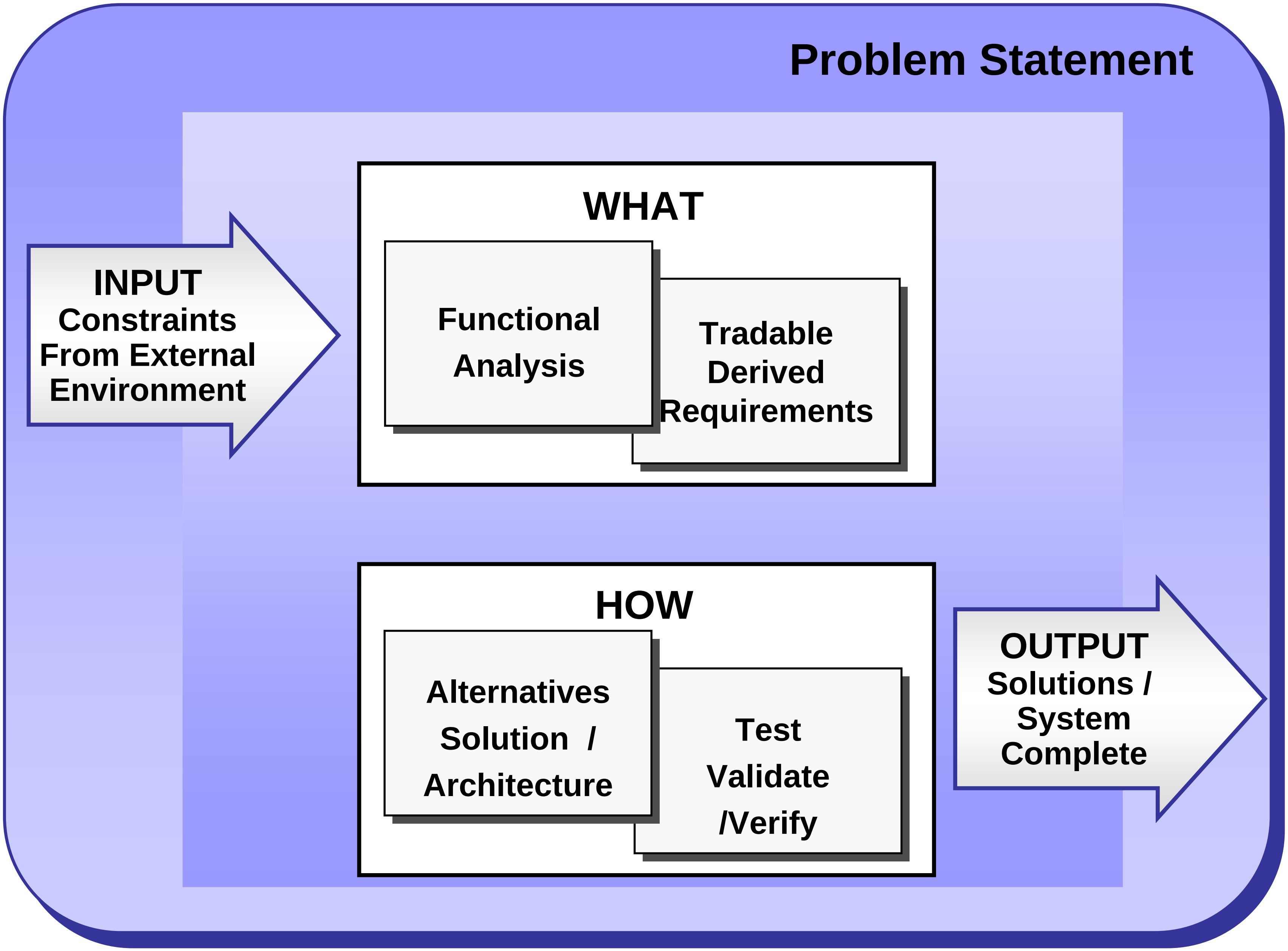
Decide HOW to fix the problem **HOW**

Alternatives/Solution Verification, Validation

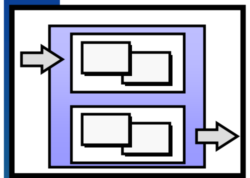
- What are various ways to do it?
- What way will you use to fix the problem?
- When done, is the original problem fixed?
- Has the best way been used to fix the problem?

Solve problem; provide solution to customer **OUTPUT**

Meta 'Process' in SE Notional Format



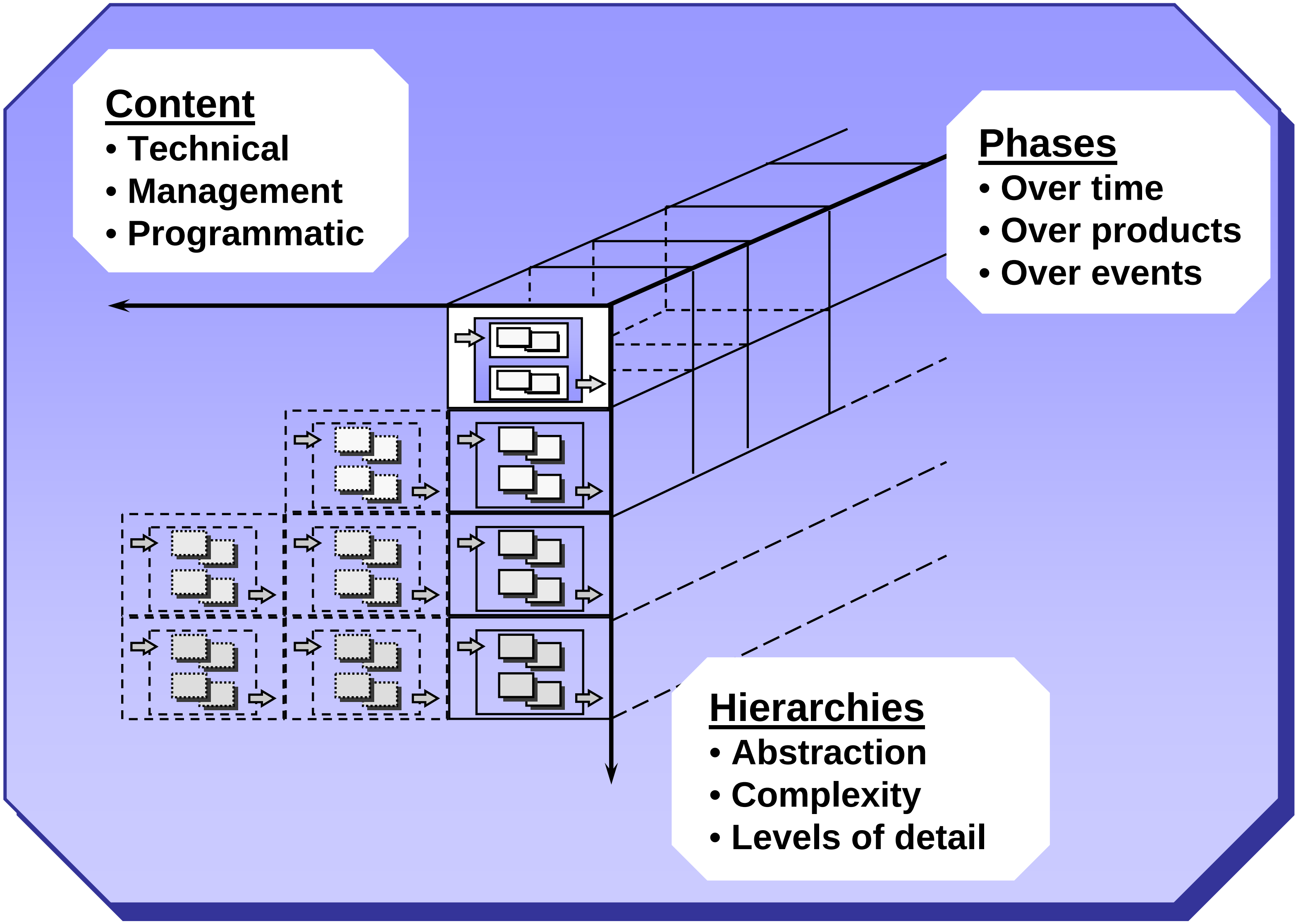
Systems Approach: Phases, Hierarchies, Content



Meta Process

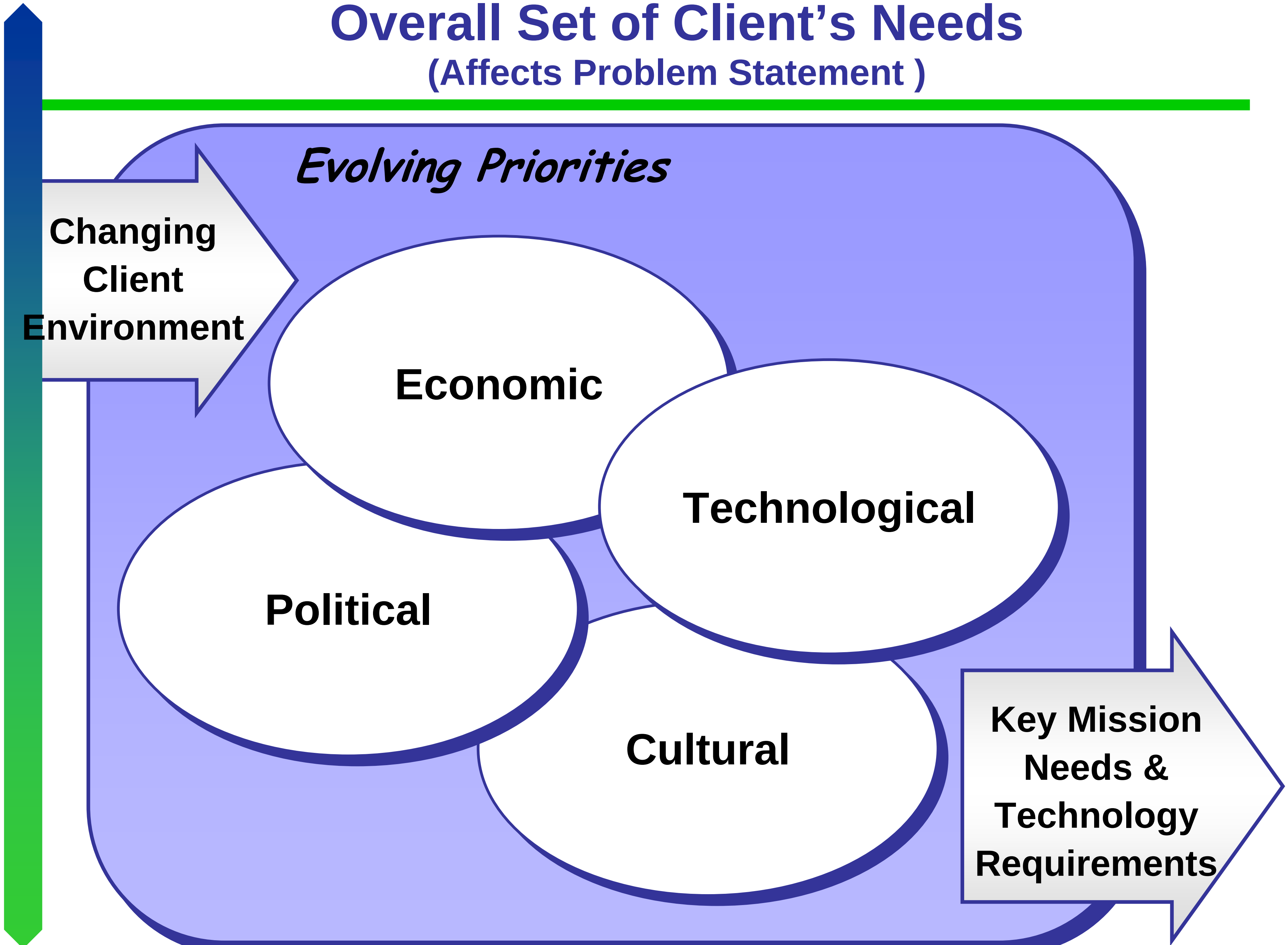
Applies to:

Pick One Aspect from Each Axis



Overall Set of Client's Needs

(Affects Problem Statement)



Considerations: Client Needs & Requirements

Key Aspects of a 'Changing Environment'

1 **Political**
- Regulatory Infrastructure
- Legal Infrastructure
- Political Infrastructure

2 **Economic**
- Economic Structure of Customers
- Distribution of Resources

3 **Technological**
- Existing Base
- Operational Practices
- State of Technology

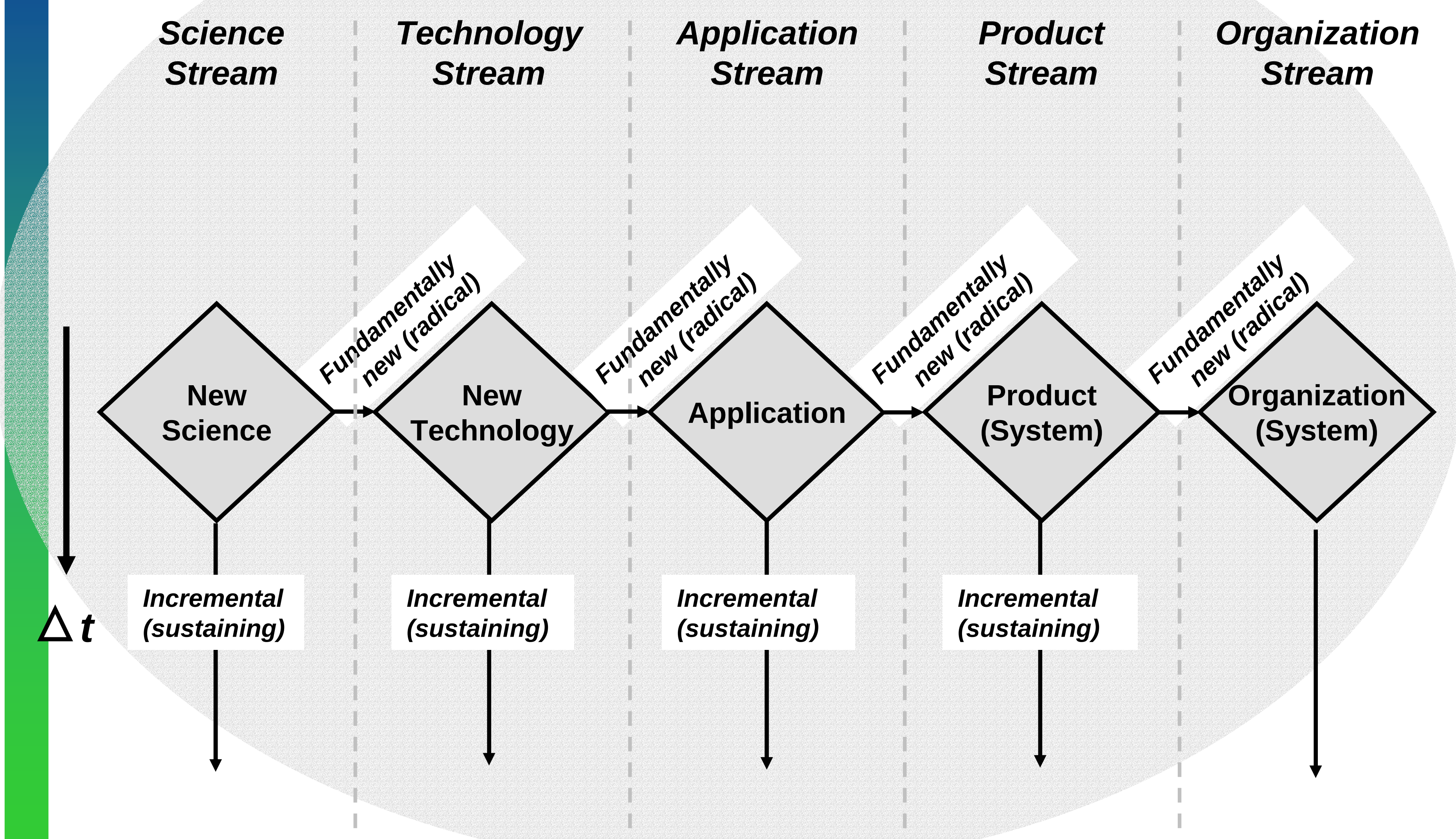
4 **Cultural**
- Public consciousness
- Demographic features
- Views/biases of power brokers

Considerations

1. ***Are all four kinds of client needs addressed?***
2. ***Are these needs prioritized (between each other) by the client? by provider?***
3. ***Are there specific organizational components already assigned to incorporate these needs?***
4. ***Since each aspect requires different kind of client/provider interface, is there infrastructure to handle?***
5. ***How are the interfaces between the political, economic, technological and cultural values/aspects handled internal to unit? to enterprise?***

‘Streams of Change’ in the Environment

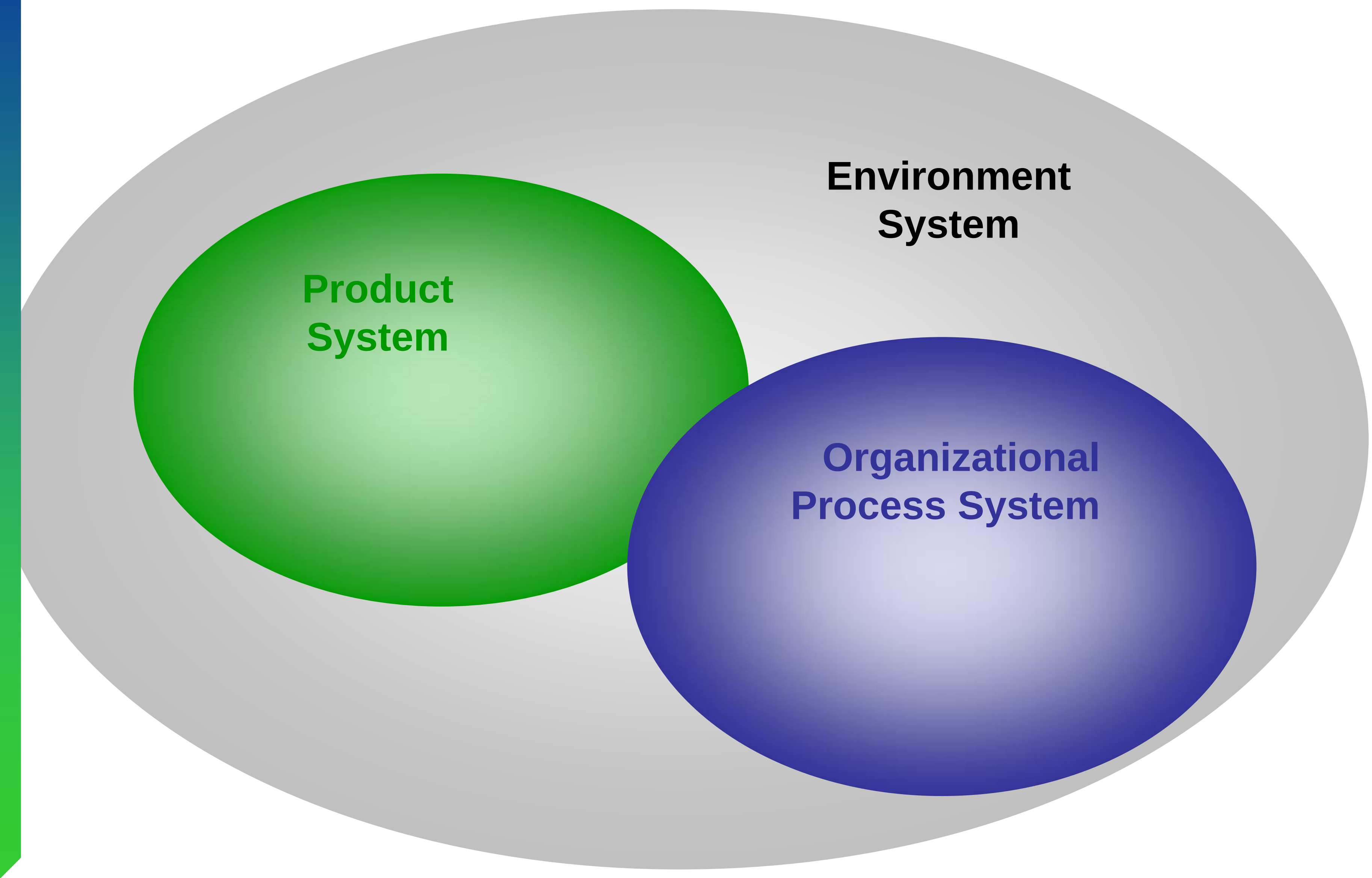
(How the Problem Changes)



* Simpson, Joseph J., “Innovation and Technology Management,” INCOSE 12th Annual International Symposium, Las Vegas, NV, 2002

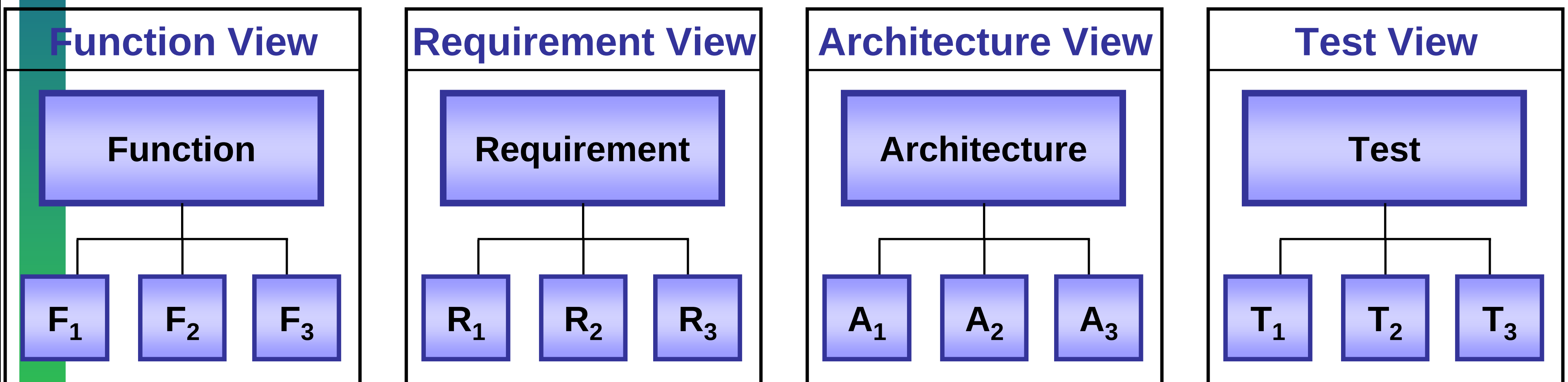
FRAT Concepts

(Highlights Two of the Five Streams – A Snap Shot in Time)



FRAT - System Views*

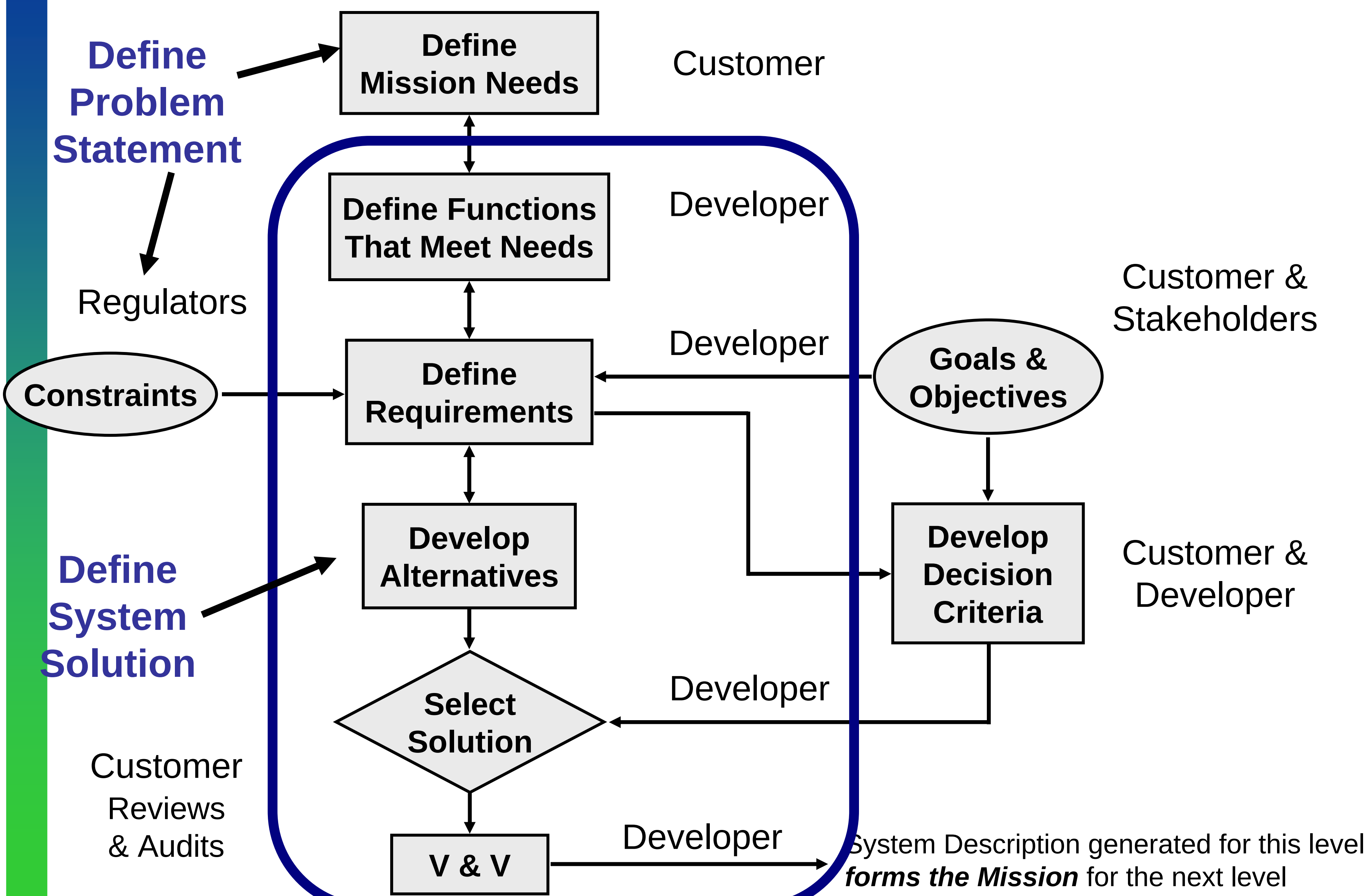
Any system must be expressed in four views



**Further Refines System Boundary,
at any Specific Level of Abstraction**

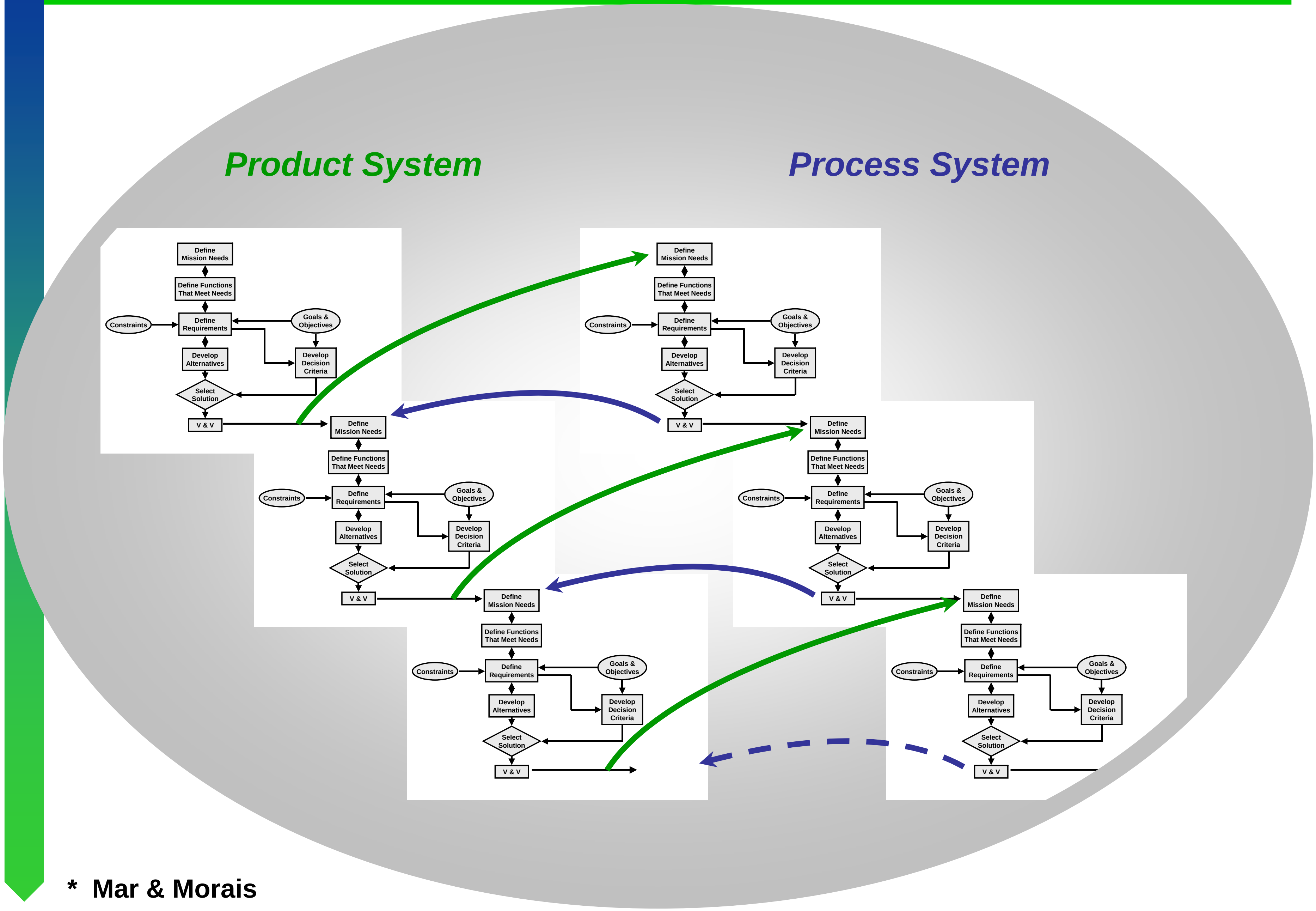
* Mar & Morais

The FRAT Design Engine*



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

Recursive Application of FRAT Design Engine



* Mar & Morais

System Definition

Set of Objects over which Relationships Are Mapped

System Boundary Definition

- Problem is outside the system
- Solution is inside the system

SE Meta Process

- Used for System Design

System Approach

- Hierarchical decomposition over specific phases and dimensions

System Design

- Accomplished by a large distributed group of people
- Requires structured technical communication and design feedback

General Recommendation

Interactive system meta-models needed to facilitate system design and technical communication

Formal systems models in an executable format are required for distributed large-scale design

Use of semi-formal and formal system and software object models is strongly recommended

Software Object Model Types

Informal Object Models

- Free form implementation
- Compiler enforces language rules
- No domain application logic enforcement

Semi-Formal Object Models

- Patterns of code implementation
- May be enforced by software application
- Example: XML, Integrated Development Environments

Formal Object Models

- Code patterns enforced by software application
- Application domain ontology enforced by software application

System Object Models

Semi-Formal System Object Models

- System classes and behavior known
- Patterns of system interaction known
- System behavior and interaction rules may be enforced by the executable model

Formal Object Models

- Code patterns are enforced by the model and application
- System domain ontology enforced by the model
- System domain rules enforced by the model
- System design process enforced by the model

Summary and Conclusions

- A formal executable SE model is needed
- System object models provide one aspect of the formal model
- Computer based SE tools provide the basis for “shared SE practice” and a shared system vision.
- A shared system vision is essential for large-scale system design success
- Questions