



System Design and Engineering (2IMP30)

WEEK6 USER NEEDS, MISSION ANALYSIS, REQUIREMENTS

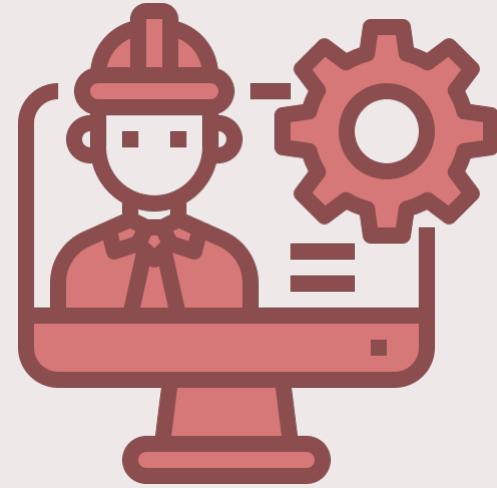
- Ion Barosan – i.barosan@tue.nl
- Mathematics and Computer Science – SET

Content



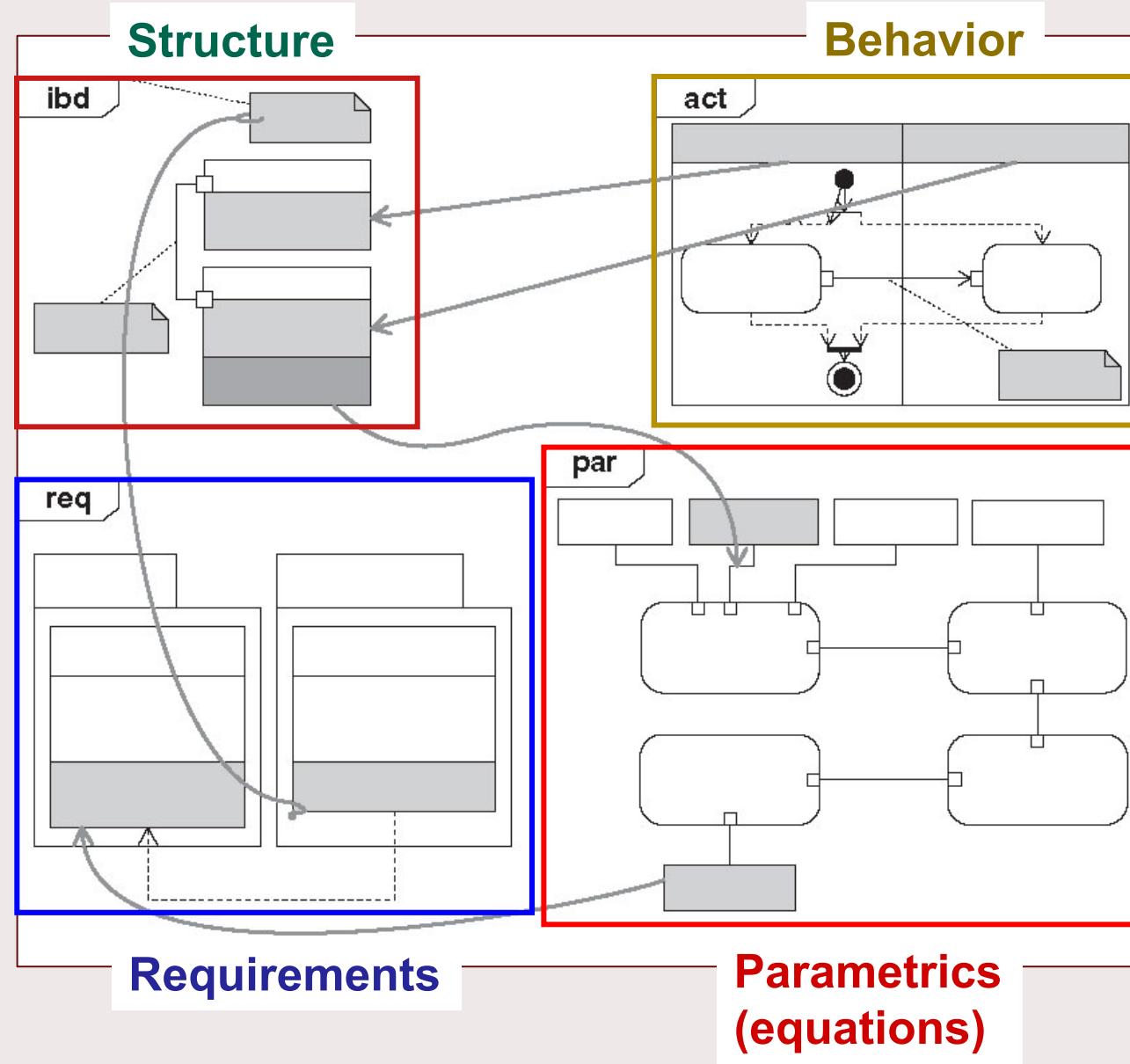
1. System Model
2. User Enterprise Roles and Missions
3. User Roles and Missions
4. Understanding the user's problem, opportunity, and solution spaces
5. Understanding the user's problem, opportunity, and solution spaces
6. Defining the Problem Statement
Translating Problem Space into an SE Solution
7. *How to Solve Problems? -Time*

1



System Model - Summary

What is a System Model?



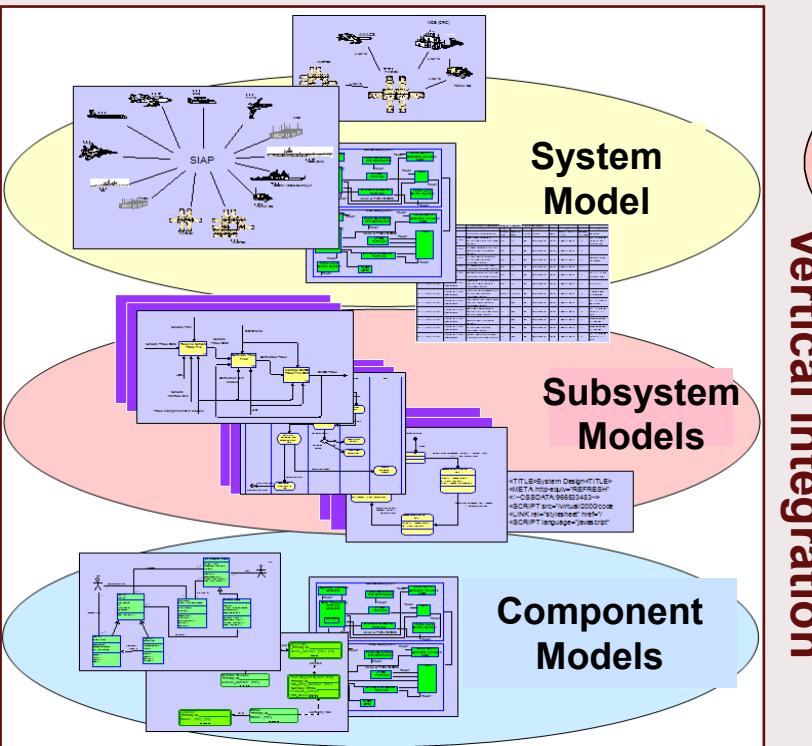
A **system model** is an interconnected set of model elements that represent key system aspects including:

- structure,
- behavior,
- requirements, and
- parametrics

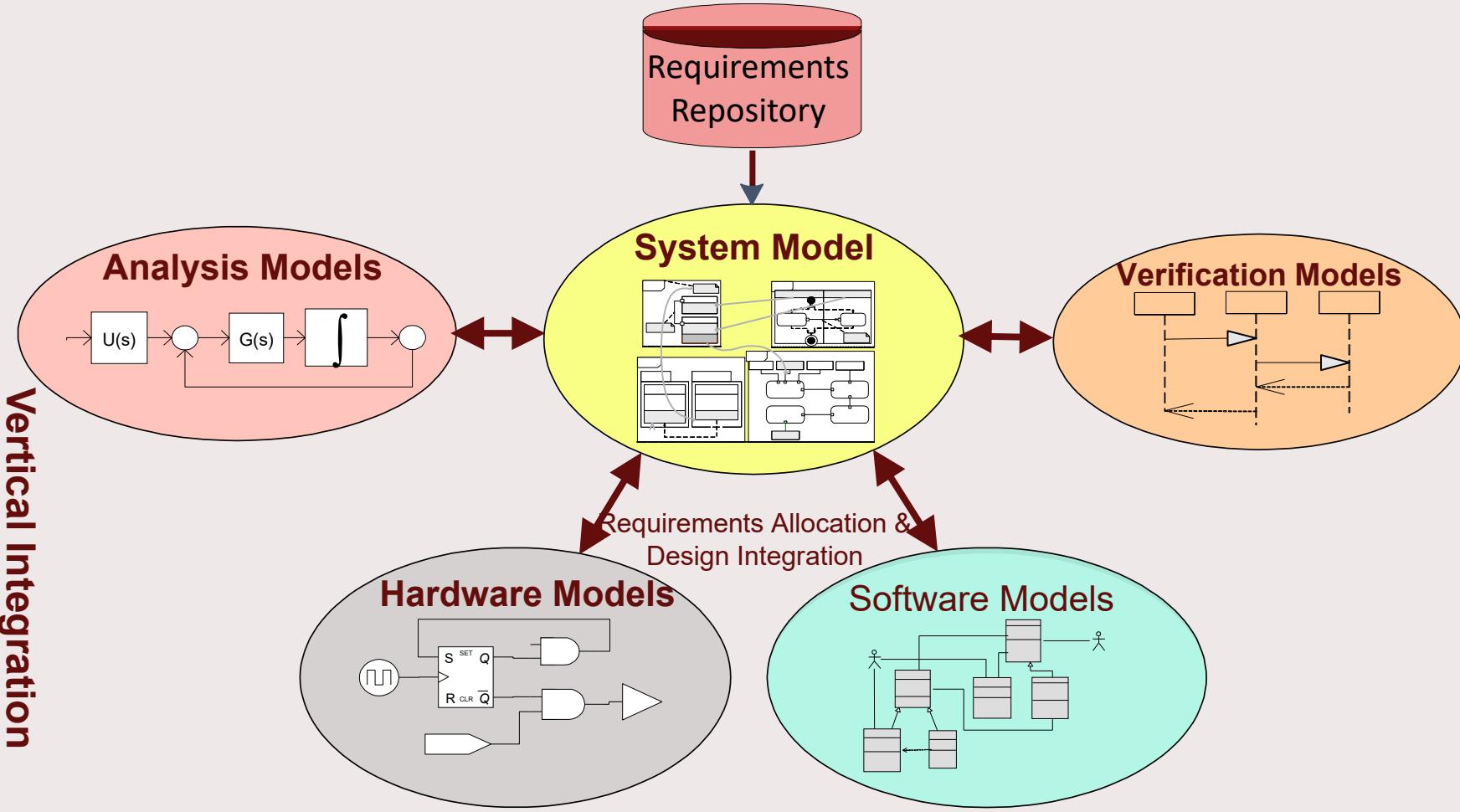
A **system model represents** logical relationships among requirements, design, analysis and verification elements

System Model as Integrator

The system model exchanges information with discipline models to form an authoritative, up-to-date source of information at a system level



Vertical Integration



© Copyright Lockheed Martin Corporation All Rights Reserved

Activities in MBSE



Context
Usage
Realization
Execution

DEFINE CONTEXT

Describe the system and the people and systems who interact with it (actors).

DEFINE USAGE

Describe how the actors use the system to produce the results and purposes of the system

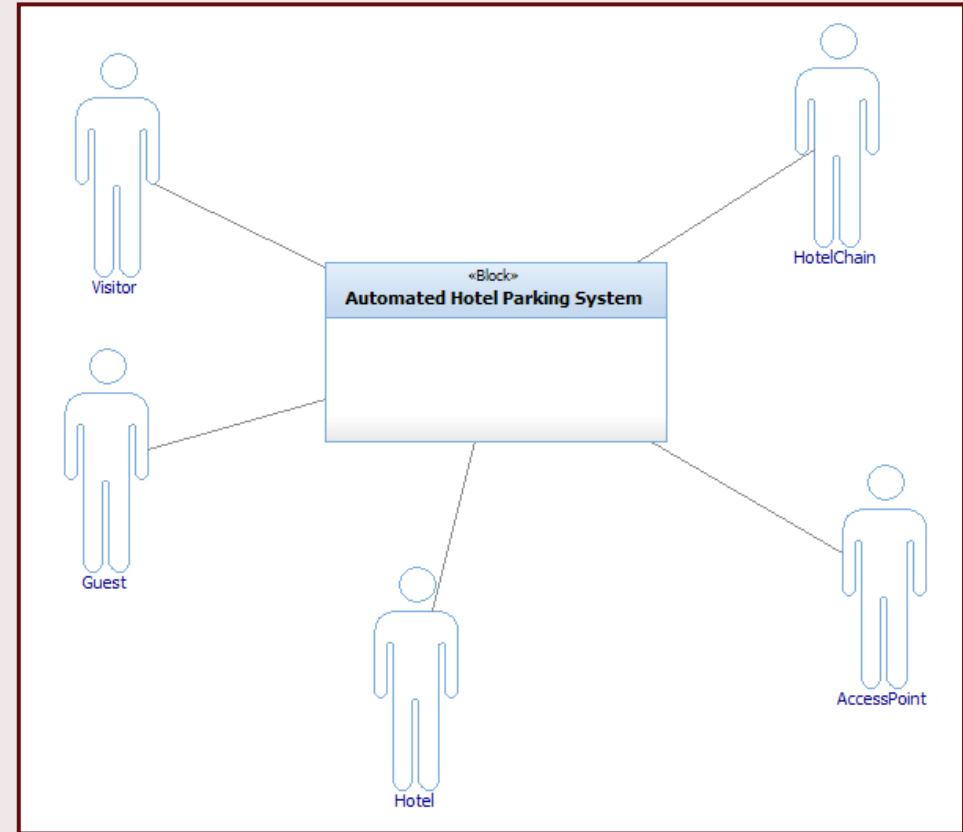
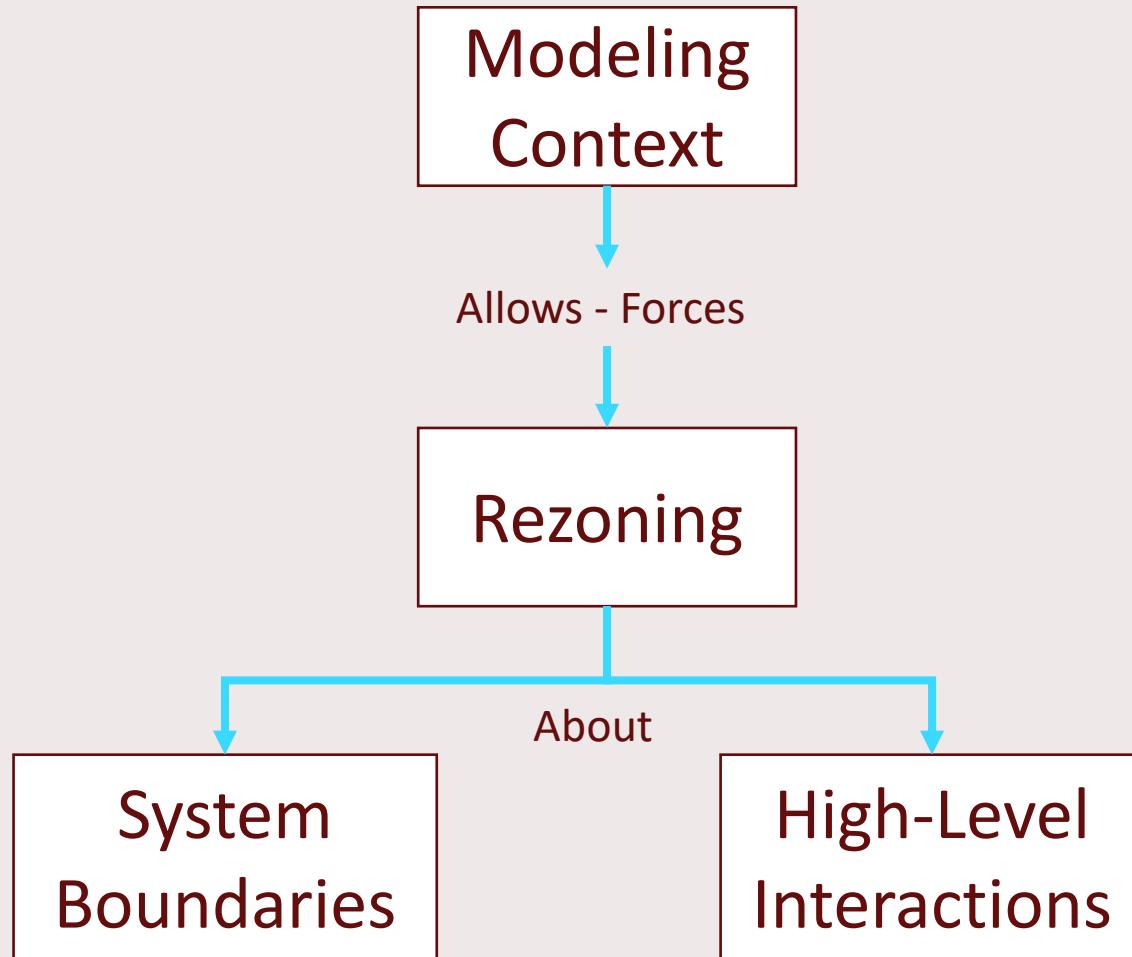
DISTRIBUTE REALIZATION

Describe how each usage is accomplished by a collaboration of system elements

VALIDATE through EXECUTION

Enable demonstration and proof of the model through execution

Context



Modeling Usage

Foundation for

Ensures

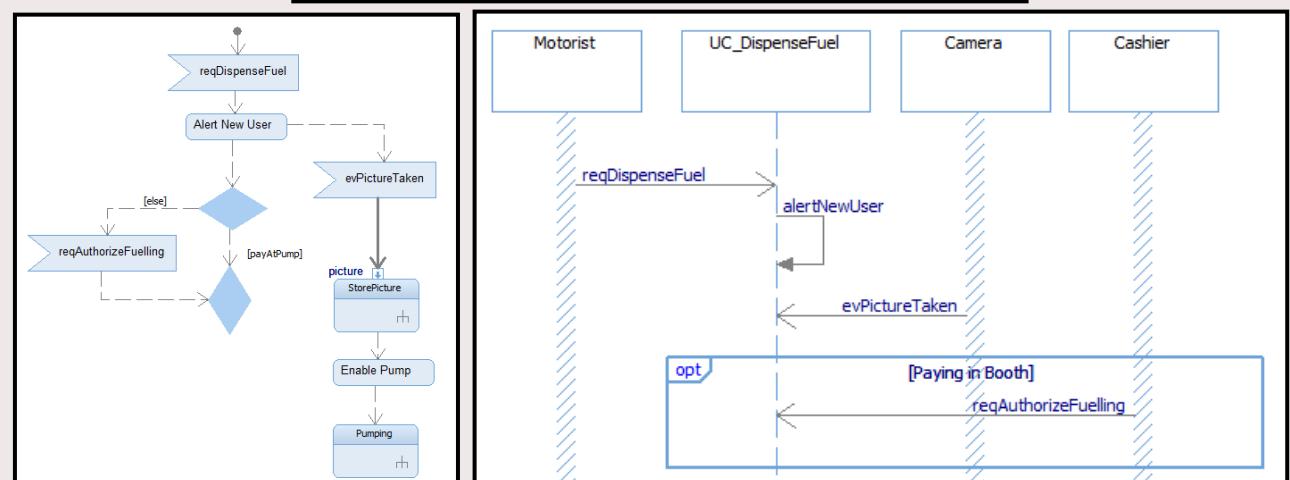
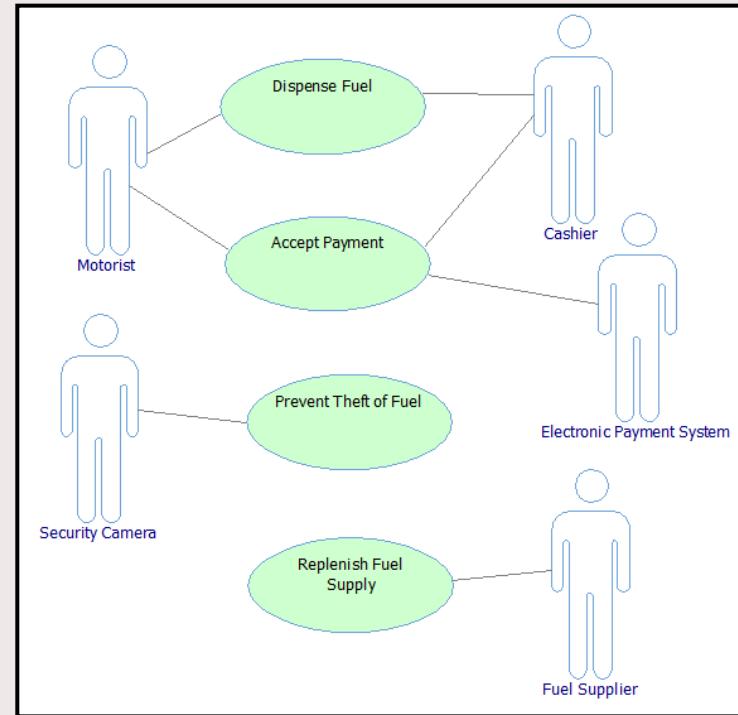
Architecture

Design

Serves for

System's Intended
Purposes

Usage



Modeling Realization

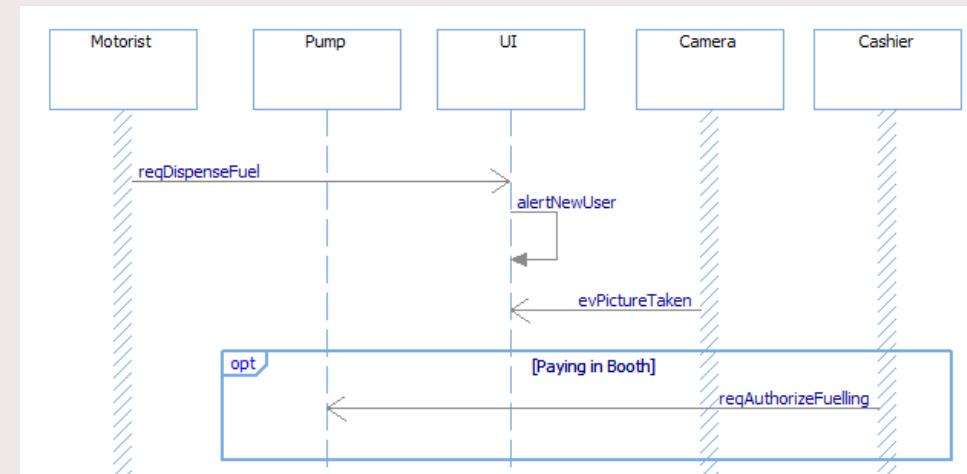
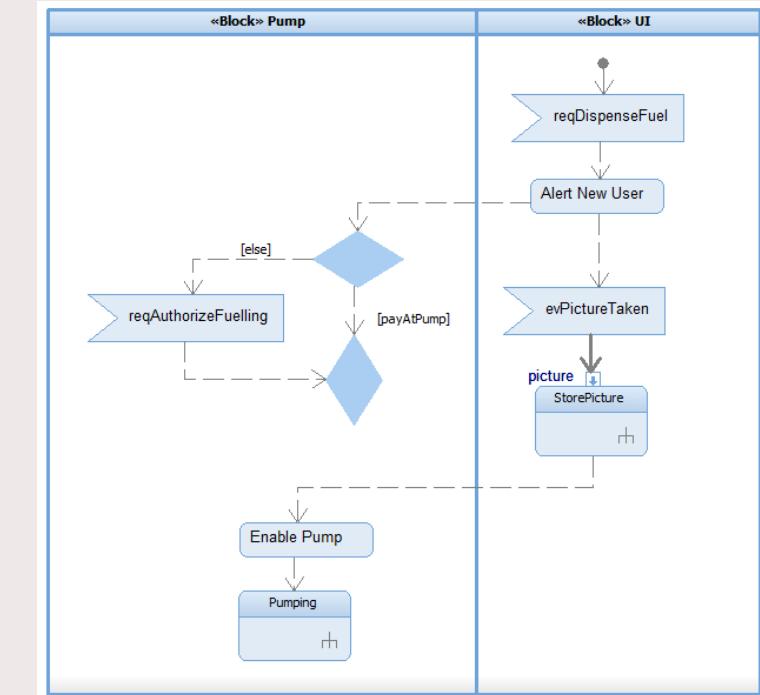
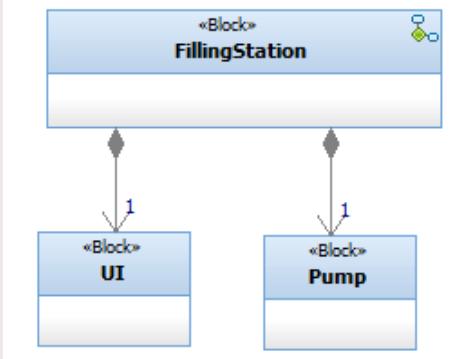
Connects

Architecture

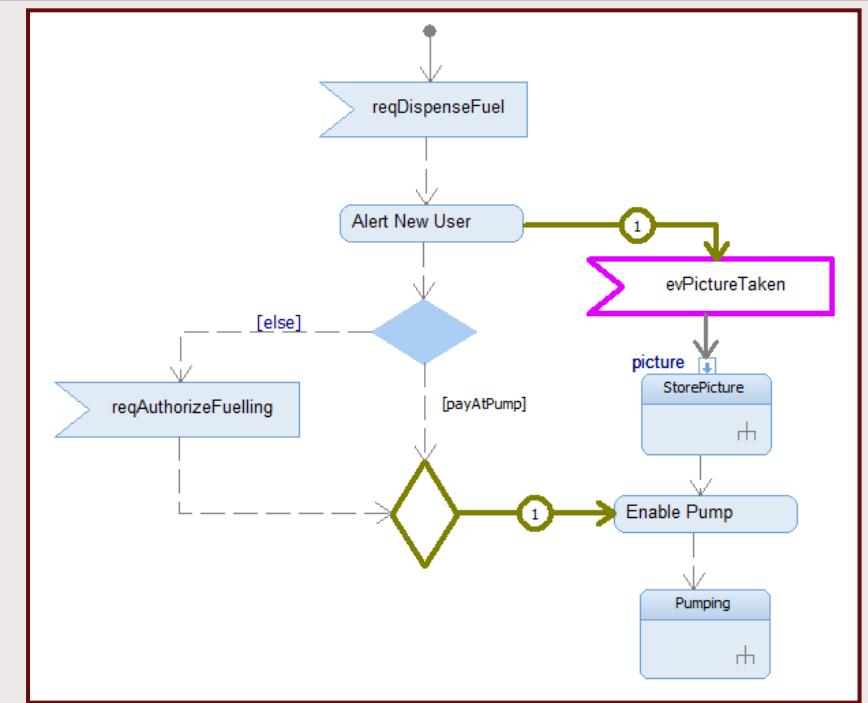
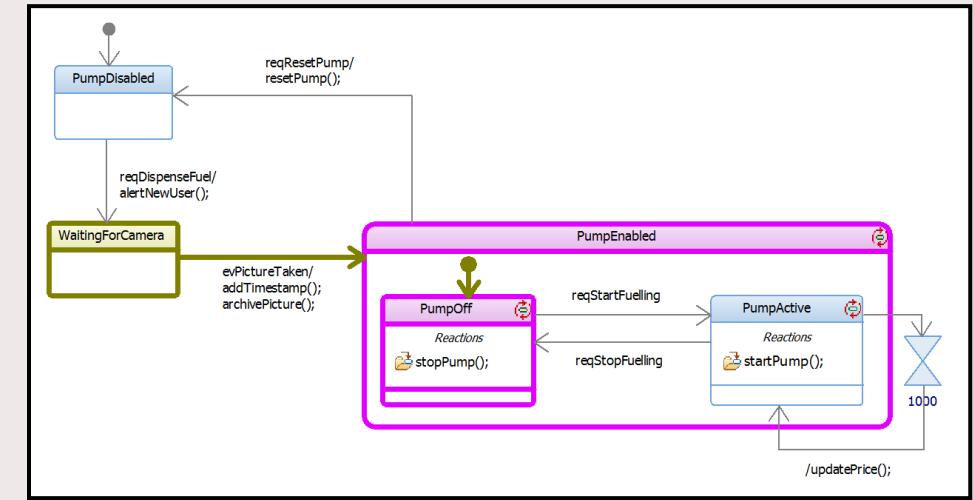
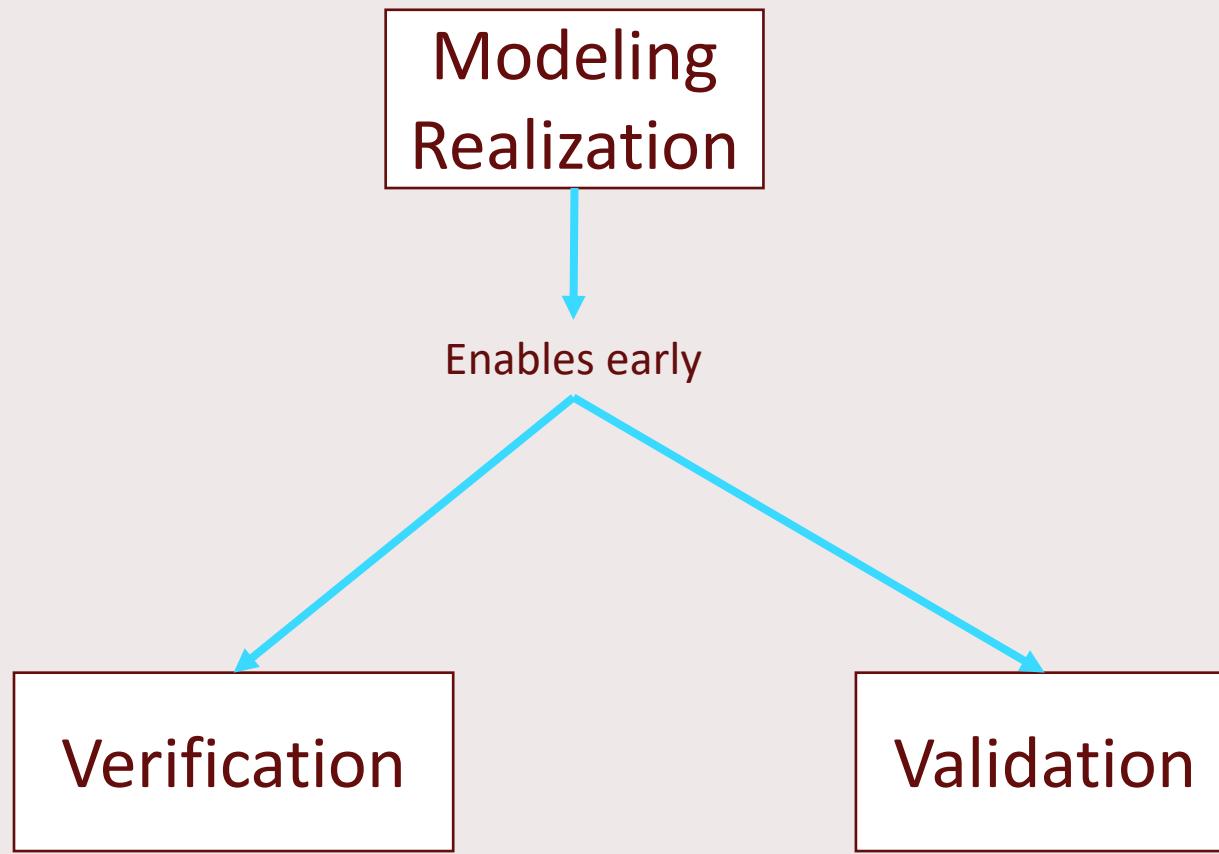
Allocate

Behavior

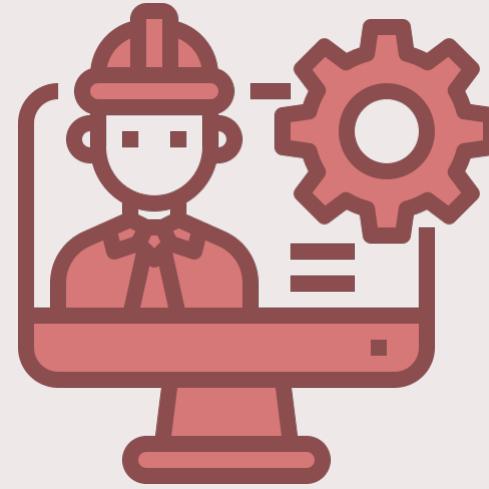
Realization



Execution



2



User Enterprise Roles and Missions

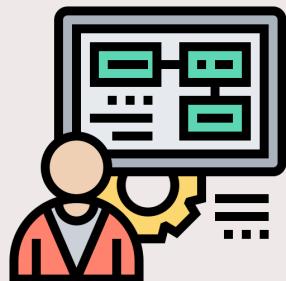
User Enterprise Roles and Missions – Take Away

Engineers

Wrong

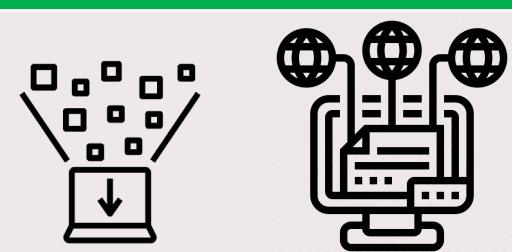
Reality

Do not understand how their
System Requirements Originate



Engineers perceive that the Customer sits down one day with a word processor and writes a few requirements for a new system “off the top of their head.”

Customers do not magically decide one day to acquire a new system, product, or service and start writing requirements.



Key Terms [1]

Mission

An intentional activity or assignment aimed at achieving a specific outcome and level of performance based on defined objectives.

Mission Needs Statement (MNS)

A general description of the operational capabilities required for a new system, product, or service or upgrade to meet mission requirements.

Mission Objectives

Performance-based outcomes to be achieved by a mission within a specified timeframe and operating constraints.

Mission Profile

A time phased description of operational events and environments an item experiences from beginning to end of a specific mission.

It identifies the tasks, events, durations, operating conditions and environment of the system for each phase of a mission.

Key Terms [2]

Solution Space

A bounded abstraction that represents a capability that, when implemented, is intended to satisfy all or a portion of a higher-level Problem Space.

Problem Space

An abstraction within a system's Operating Environment that represents an actual, perceived, or evolving gap, hazard, or threat to an existing capability. One or more lower-level Solution Space systems, products, or services resolve the problem space.

Problem Statement

A brief, concise, statement of fact that clearly describes an undesirable event, issue, state, or condition without identifying the source or actions required to solve the problem.

Opportunity Space

A gap or vulnerability in a system, product, or service capability that represents an opportunity for
(1) a competitor or adversary to exploit
(2) a supplier to offer solutions

Key Terms [3]

Strategic Plan

A forward-looking document, applicable to either a global or specific business domain, that articulates an Enterprise's vision, mission, and objectives. It defines (1) the desired future state the organization aims to achieve and (2) the long-term accomplishments it seeks, typically spanning five years or more. Challenge: determine the current and desire LOBs.

Strategic Threats

Threats—External systems that have long-term plans to exploit opportunities that leverage or enhance an Enterprise's reputation or equity to achieve a long-term vision and upset the “balance of power.” Example: An Enterprise has a long-term vision to predominate a software market.

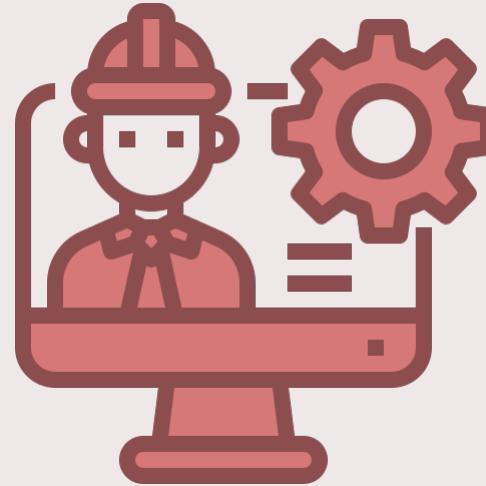
System Threat

An external entity that possesses the capability to cause harm to another entity, impacting its mission, capabilities, or performance to varying extents. A system threat refers to any hostile or adversarial interaction from an external system that hinders the operation and performance of your system, preventing it from accomplishing its intended mission.

Tactical Plan

A short-term, purpose-oriented strategy that outlines how the leadership of the Enterprise intends to utilize and maintain current resources, including personnel, products, processes, and tools, in order to accomplish specific organizational goals assigned from the overall strategic plan, while adhering to time and resource limitations, usually within a year or less

3



User Roles and Missions

System Existence Principle

Every system, product, or service has a purpose and exists for the benefit of performing missions for its Stakeholders—User(s) and End User(s).



Retire And Appropriately Dispose Of A System

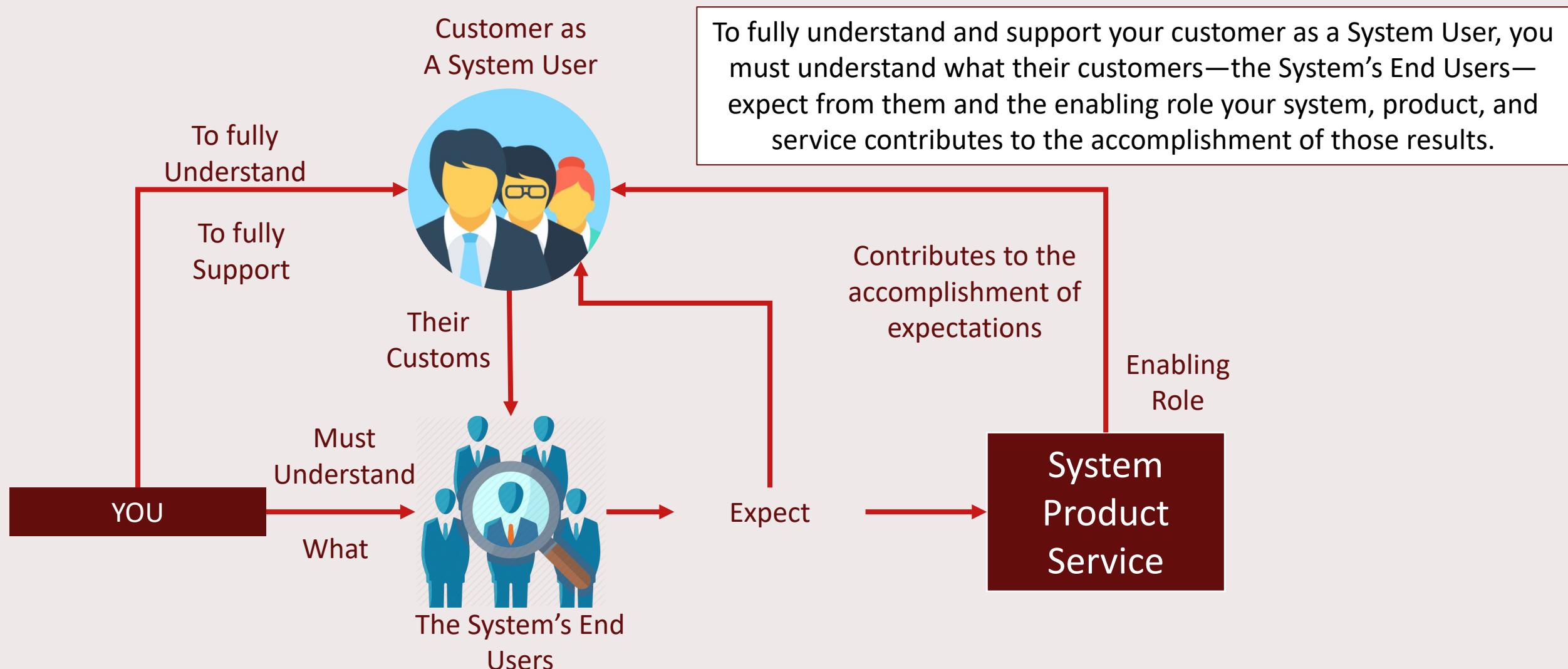
No longer has a mission.

Becomes cost prohibitive to operate, maintain, or sustain (OM&S).

Is no longer efficient or effective in accomplishing Enterprise performance-based mission outcomes.

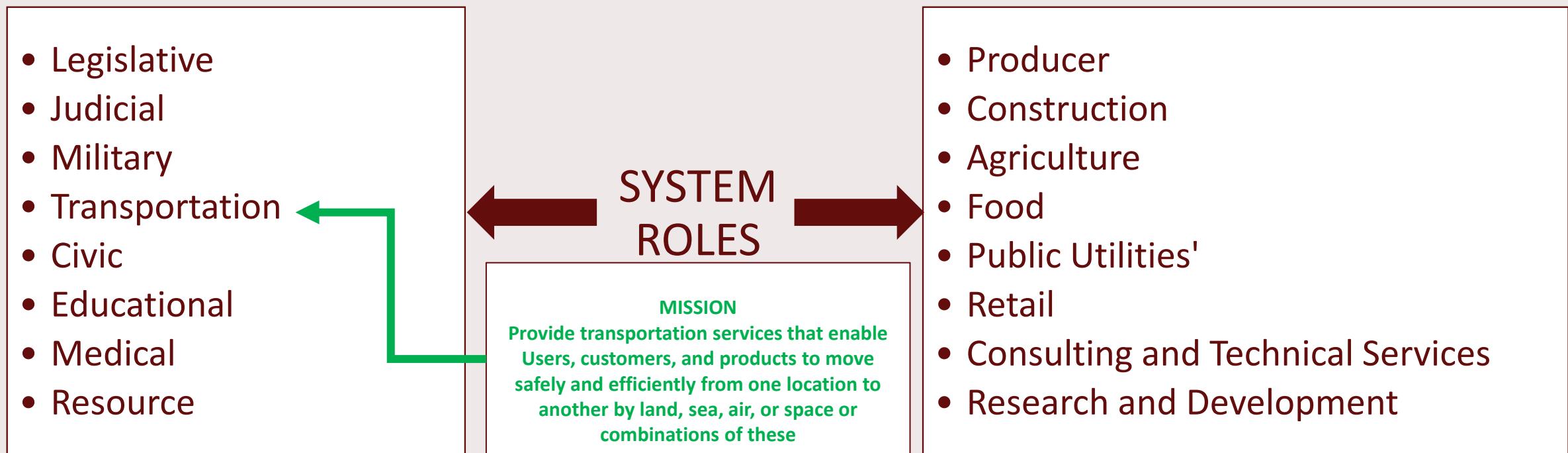
It serves no one and no longer provides value.

The Customer and Customer's Customer Principle



User and End User Organizational Roles and Missions

User and End User Enterprises, along with their systems, fulfill roles that align with their designated missions and objectives

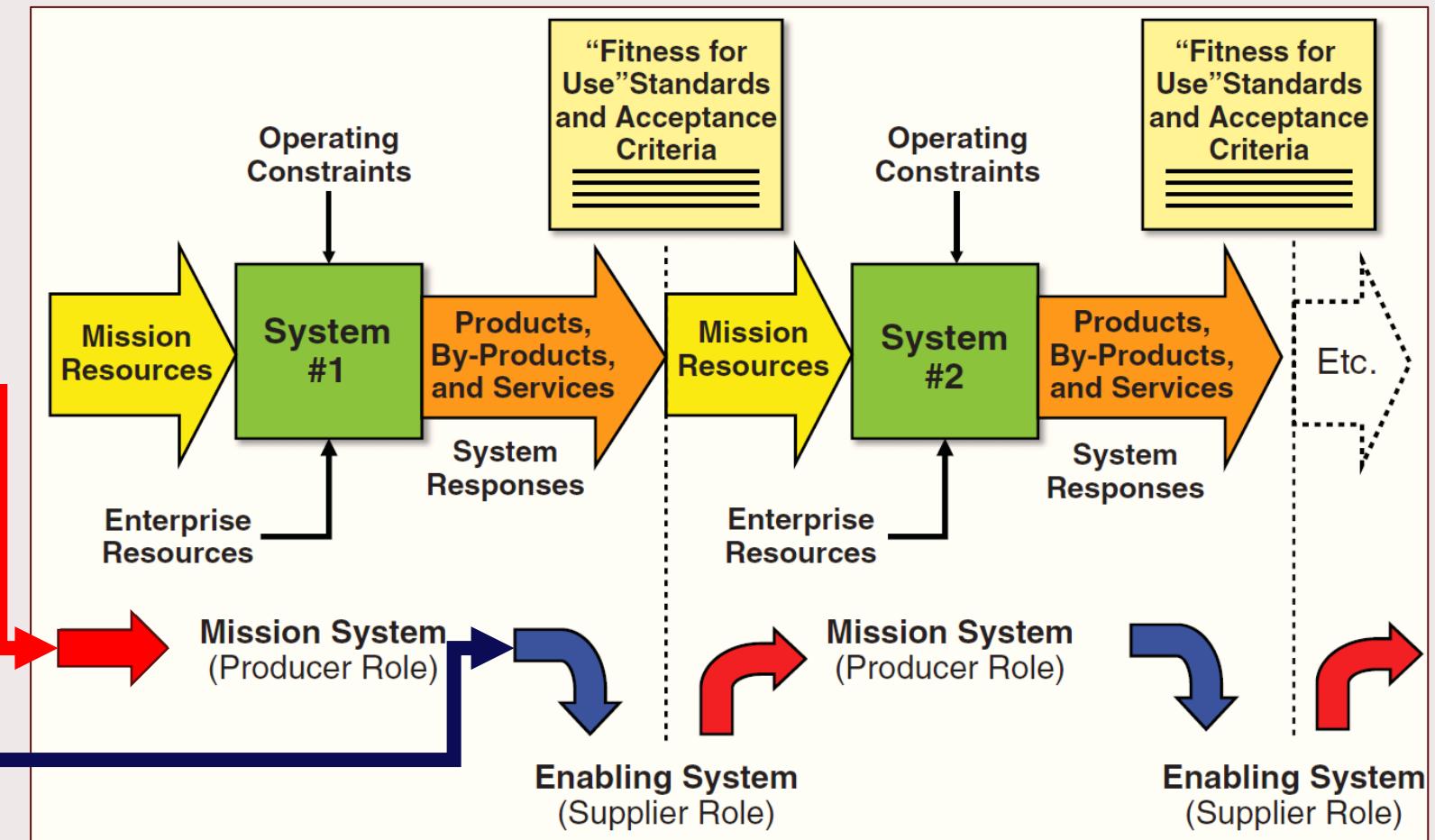


Enterprise Supply Chain Roles

Every system, product, or service performs two contextual roles

A Mission System (Producer) role

An Enabling System (Supplier) role.





System Stakeholder Role Definitions [1]

System Advocate or Proponent

An individual, organization, or Enterprise that champions the system's cause, mission, or reason for existence. The System Advocate may derive tangible or intangible benefits from their support of the system, or they may simply believe the system contributes to some higher level cause the System Advocate supports

System Shareholder

An individual, organization, or Enterprise that "owns" all or equity shares in the system and its development, operation, products, and by-products—either directly or indirectly

System Owner

An individual, organization, or Enterprise that is legally and administratively responsible and accountable for the system; its development, operation, products, and by-products; outcomes; and retirement

System User(s)

An individual, organization, or Enterprise that operates, commands and controls (C2) a system or provides inputs data, consumables and expendables, raw materials, or pre-processed materials. Users control system outputs provide results such as information, data, reports, and End Users to perform their tasks or make decisions.

System End Users

An individual, organization, or Enterprise that derives direct benefits directly or indirectly from a system and/or its products, services, or by-products. End Users may or may not require training.

System Acquirer

An agent or agency selected by the User to serve as their acquisition and technical representative



System Stakeholder Role Definitions [2]

System Developer

An individual, organization, or Enterprise responsible for developing and delivering a verified system solution based on operational capabilities and performance bounded and specified in a System Performance Specification (SPS)

System Architect

An individual, organization, or Enterprise that visualizes, conceptualizes, and formulates the system, system concepts, missions, goals, and objectives. Since SE is viewed as multi-disciplined, the system architect role manifests itself via hardware architects, software architects, and instructional architects

Services Provider

An individual, organization, or Enterprise chartered or contracted to provide services to operate the system or support its operation

Independent Test Agent/Agency (ITA)

An individual, organization, or Enterprise responsible for verifying and/or validating that a system will meet the User's documented operational mission needs for an intended and prescribed operating environment

System Administrator

An individual, organization, or Enterprise responsible for the general operation, configuration, access, and maintenance of a system

Mission Planner

An individual, organization, or Enterprise that: 1. Translates mission objectives into detailed tactical implementation plans based on situational analysis and system capabilities and performance relative to SWOT; 2. Develops a course of action, countermeasures, and required resources to achieve success of the mission and its objectives (SWOT Strengths, Weaknesses, Opportunities, and Threats)



System Stakeholder Role Definitions [3]

System Analyst

An individual, organization or Enterprise that applies analytical methods and techniques (e.g., scientific, mathematical, statistical, financial, political, social, cultural) to provide analysis and meaningful data to support informed decision-making by Mission Planners, System Operators, and System Maintainer personnel

System Support

An individual, organization, or Enterprise responsible for supporting the system, its capabilities, and/or performance at a sustainment level that ensures successful achievement of the system's mission and objectives. System support includes activities such as maintenance, training, data, technical manuals, resources, and management

System Maintainer

An individual, organization, or Enterprise accountable for ensuring that the Equipment System Element is properly maintained via preventive and corrective maintenance and system upgrades

System Instructor

An individual or organization accountable for training system operators or maintainers to achieve a standard level of performance based on proficiency in achieving the system mission and its objectives



System Stakeholder Role Definitions [4]

System Critic

An individual, organization, or Enterprise with competitive, adversarial, or hostile motivations to publicize or promote the shortcomings of a system to fulfill its assigned missions, goals, and objectives in a cost effective, value-added manner and/or believes the system is a threat to some other system for which the System Critic serves as a System Advocate

System Competitor

An individual, organization, or Enterprise whose missions, goals, and objectives compete to capture similar mission outcomes. Example - Examples include market share and physical space

System Adversary

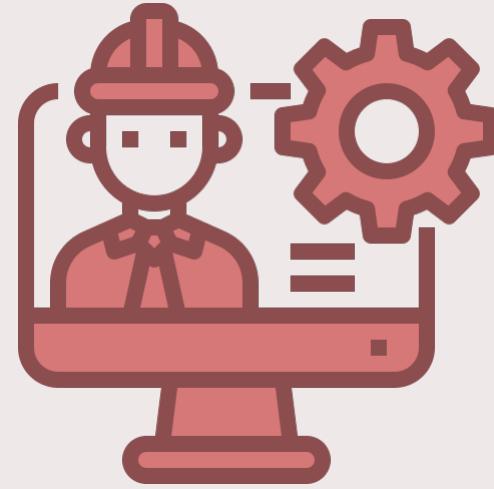
An individual, organization, or Enterprise that exhibits hostile behavior or actions whose interests, ideology, goals, and objectives are to:

1. Counter to another system's missions, goals, and/or objectives;
2. Exhibit behavioral patterns and actions that appear to be threatening

System Threat

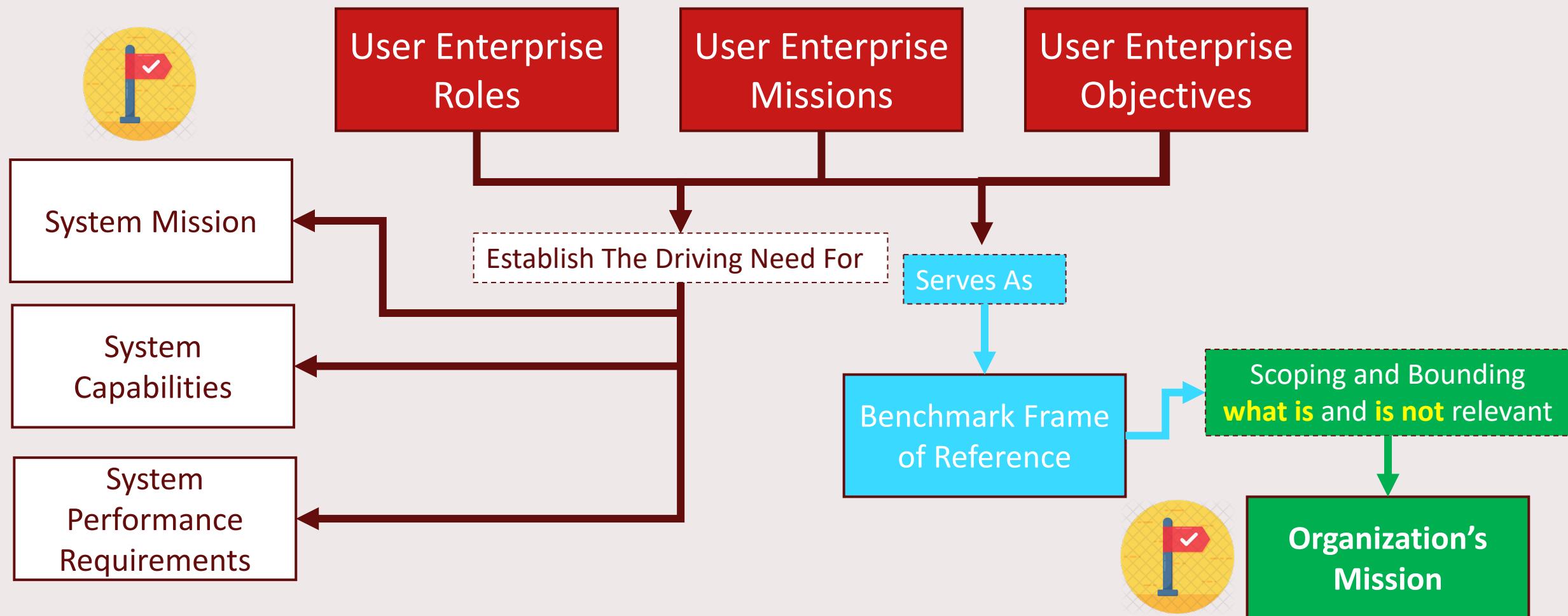
A competitive, adversarial, or hostile individual, organization, or Enterprise actively planning and/or executing missions, goals, and objectives that may be counter to another system's missions, goals, and/or objectives

4

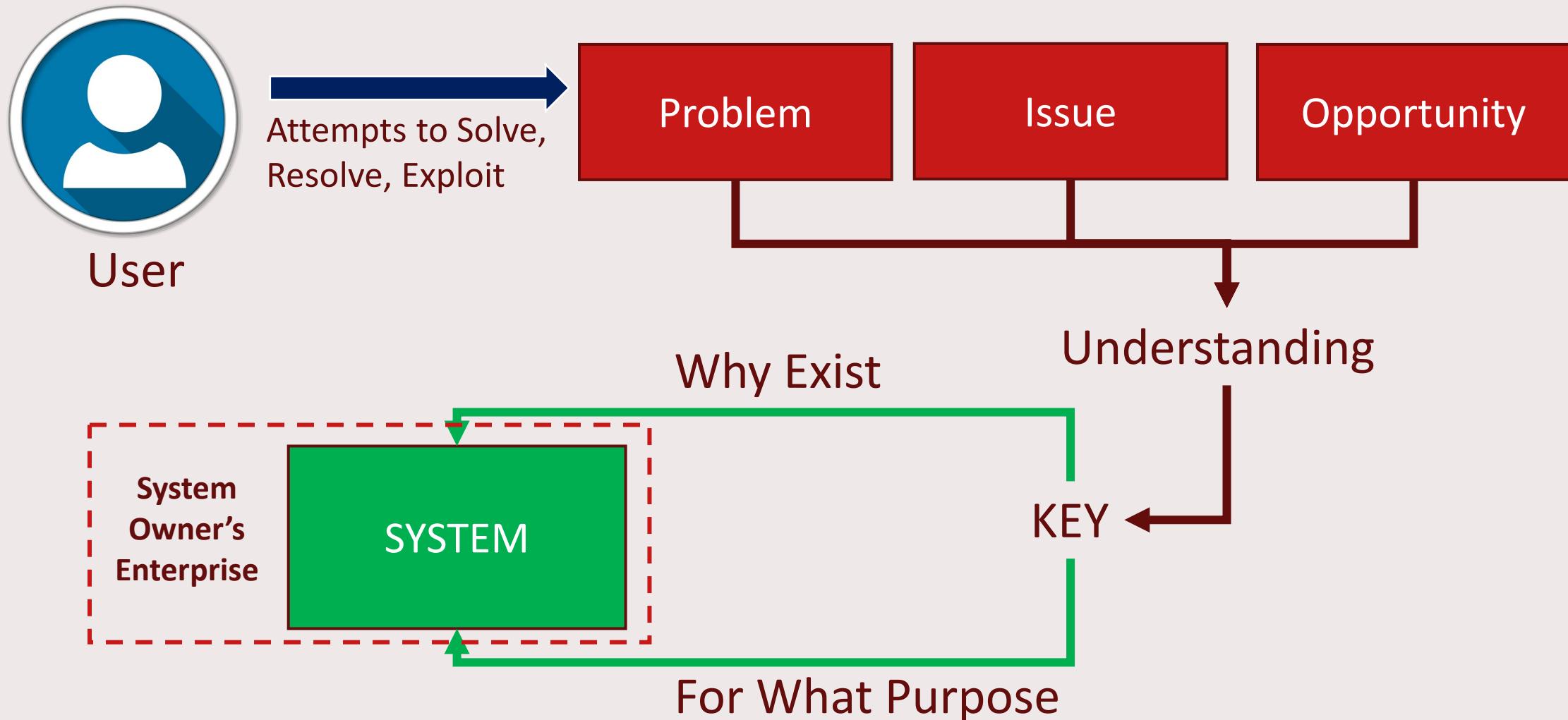


Understanding and Defining User Missions

Understanding And Defining User Missions [1]



Understanding And Defining User Missions [2]



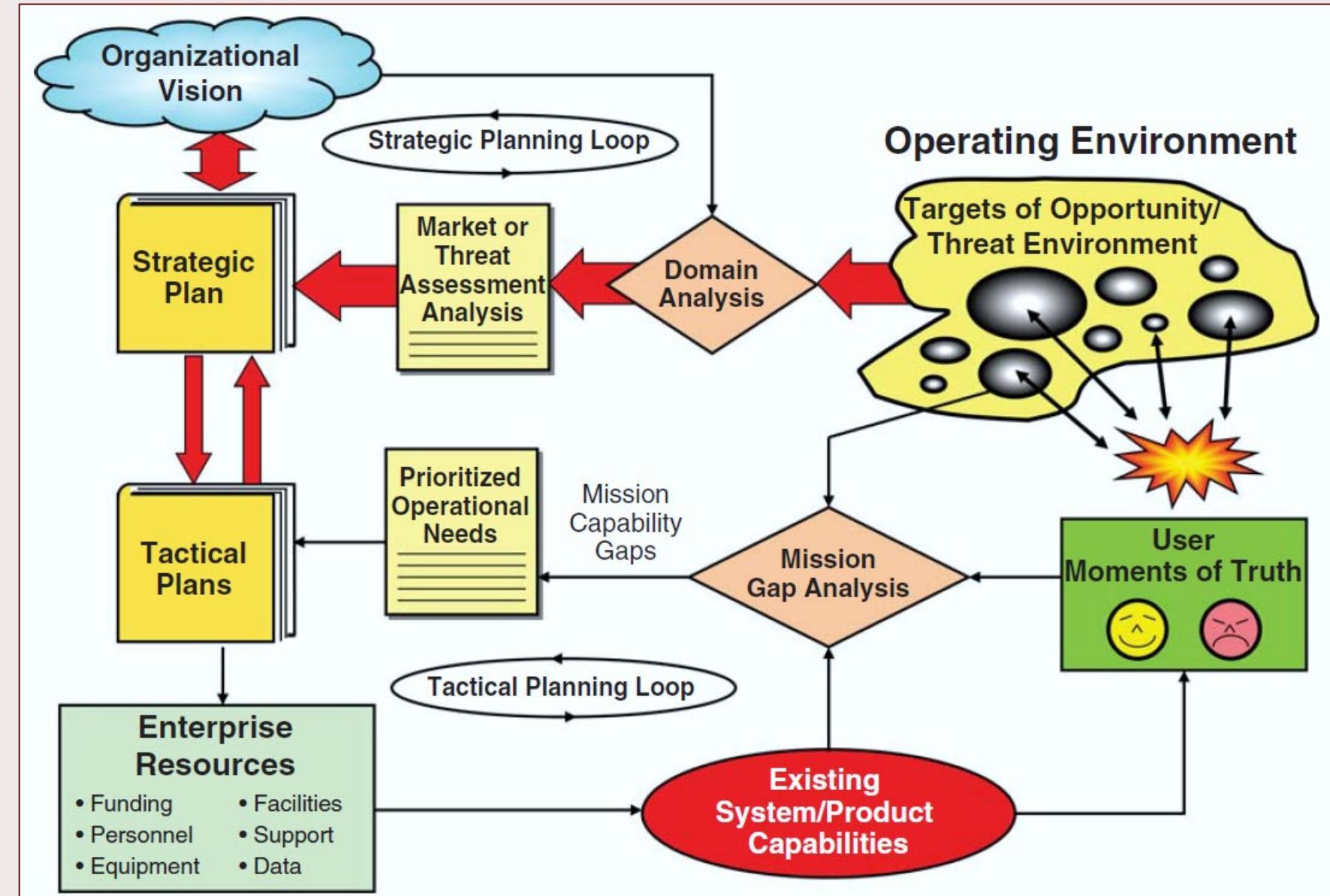
Types of Enterprise Missions

Organizations conduct various **types of missions** that require assets such as *systems, products, or services* to fulfill mission objectives

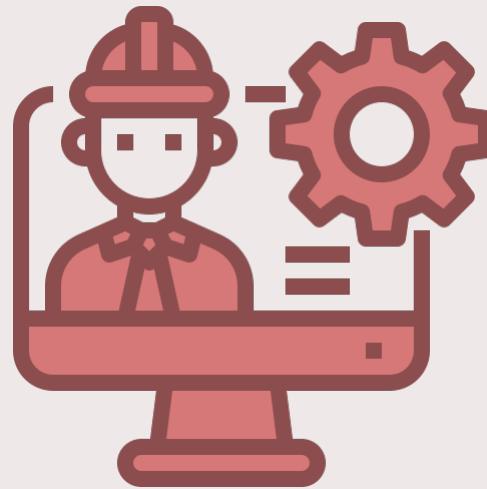


- High Level Types Of Missions**
 - Educational
 - Humanitarian
 - Medical
 - Transportation
 - Government
 - Educational
 - Delivery Services
- Military Organizations Missions**
 - Search and Assist
 - Search and Rescue
 - Search and Retrieve or Recover
 - Search and Destroy

Operational Needs Identification Process



5



Understanding the user's problem, opportunity, and solution spaces



Understanding The User's Problem, Opportunity, And Solution Spaces

NECESSARY

Understand the User's Problem/ Opportunity and Solution Spaces.

WRONG

Writing perfectly stated specification requirements for the wrong problem

SUCCESSFUL

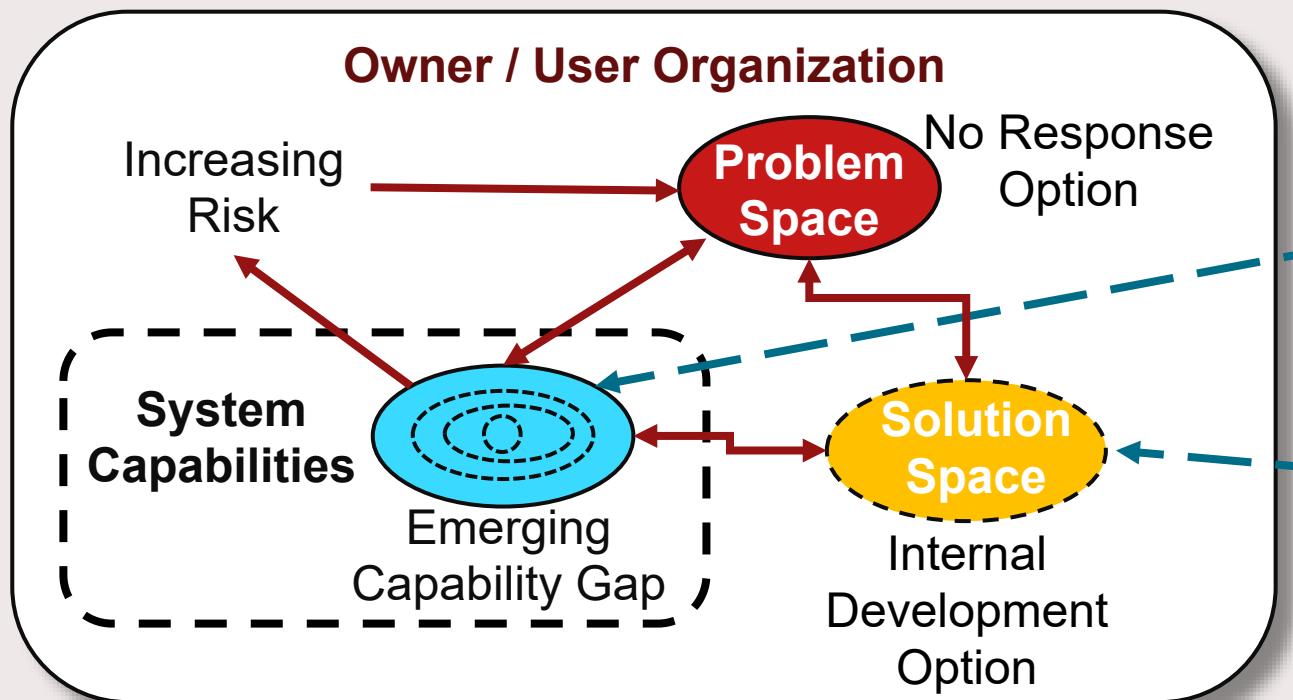
Thorough identification and understanding of the Problem, Opportunity, and the Solution space(s)

PROBLEM SPACE → OPPORTUNITY SPACE

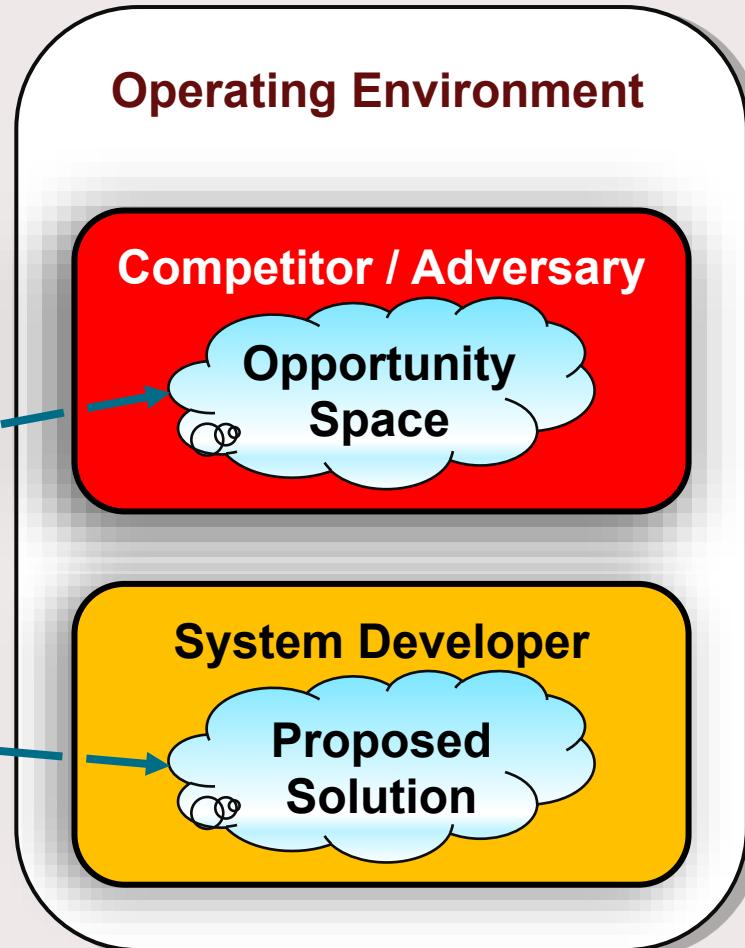
One system's Problem Space may be an Opportunity Space for another that desires to capitalize on the potential or emerging weakness



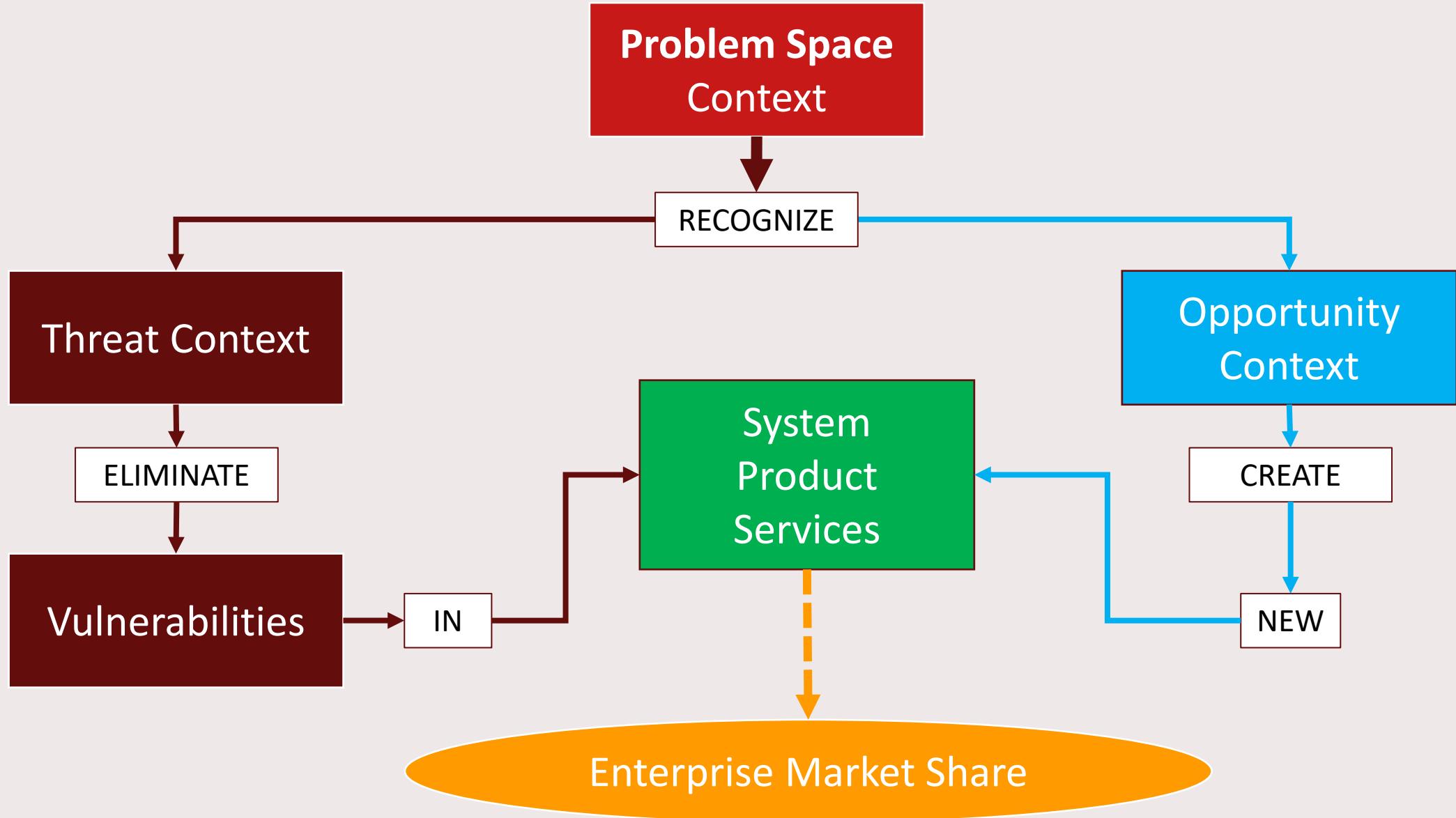
Relationships of Problem, Opportunity, and Solutions Spaces



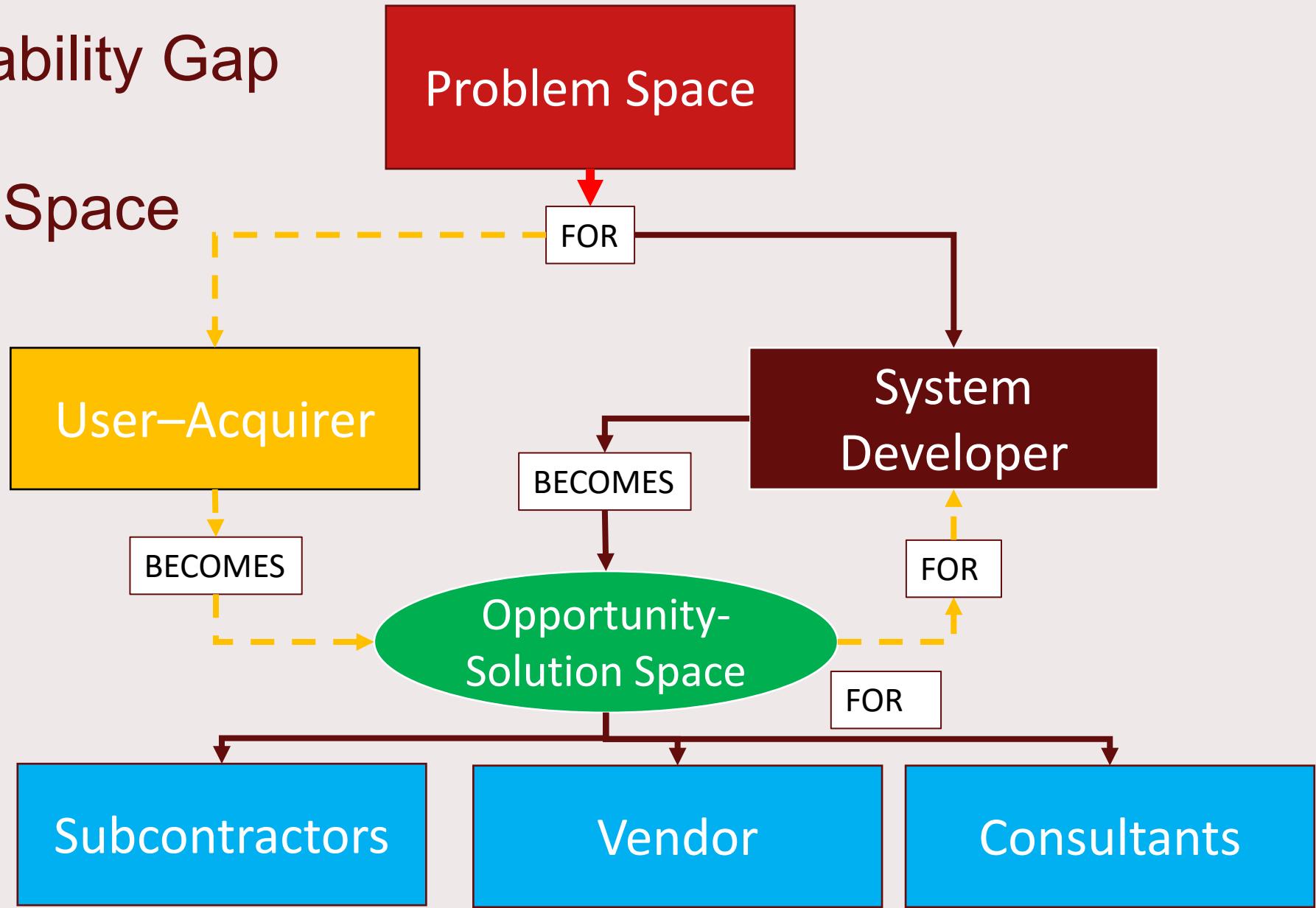
TOO - Target
of Opportunity



Internal and External Development Combination Option



Emerging Capability Gap as A Problem Space



Dynamics of the Problem Space

THE ROOT CAUSES FOR PROBLEM SPACES

System neglect.

Improper oversight or maintenance.

System degradation through normal wear.

Ineffective training of the User Operators.

Improper use, abuse, or misapplication.

Product or technology obsolescence.

Budgetary constraints.

MANAGEMENT FAILS TO SEE THE PROBLEM SPACE

Operationally, the source of the Problem Space goes away.

The Enterprises management becomes distracted or enamored by other priorities.

Enterprise objectives change.

Catastrophic (worst-case) events force corrective action.

Forecasting the Problem Space



How do we translate a forecast of a potential Problem Space in terms of system capabilities with some level of confidence?



Enterprise Strategic and Tactical Plans establish

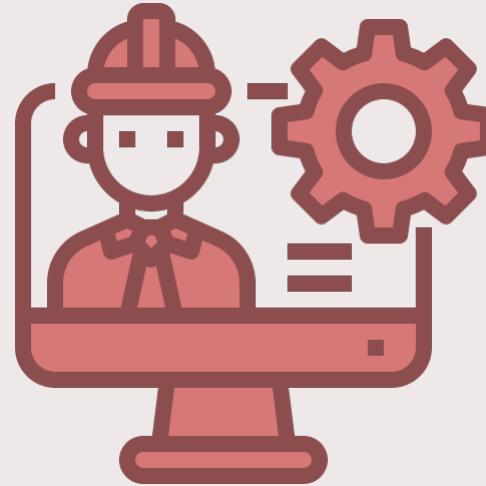
- The reference framework for evaluating potential organizational weaknesses—**current capabilities versus planned capabilities**.



If you cannot eliminate the Problem Space

- Try to control it until you can resolve and eliminate it

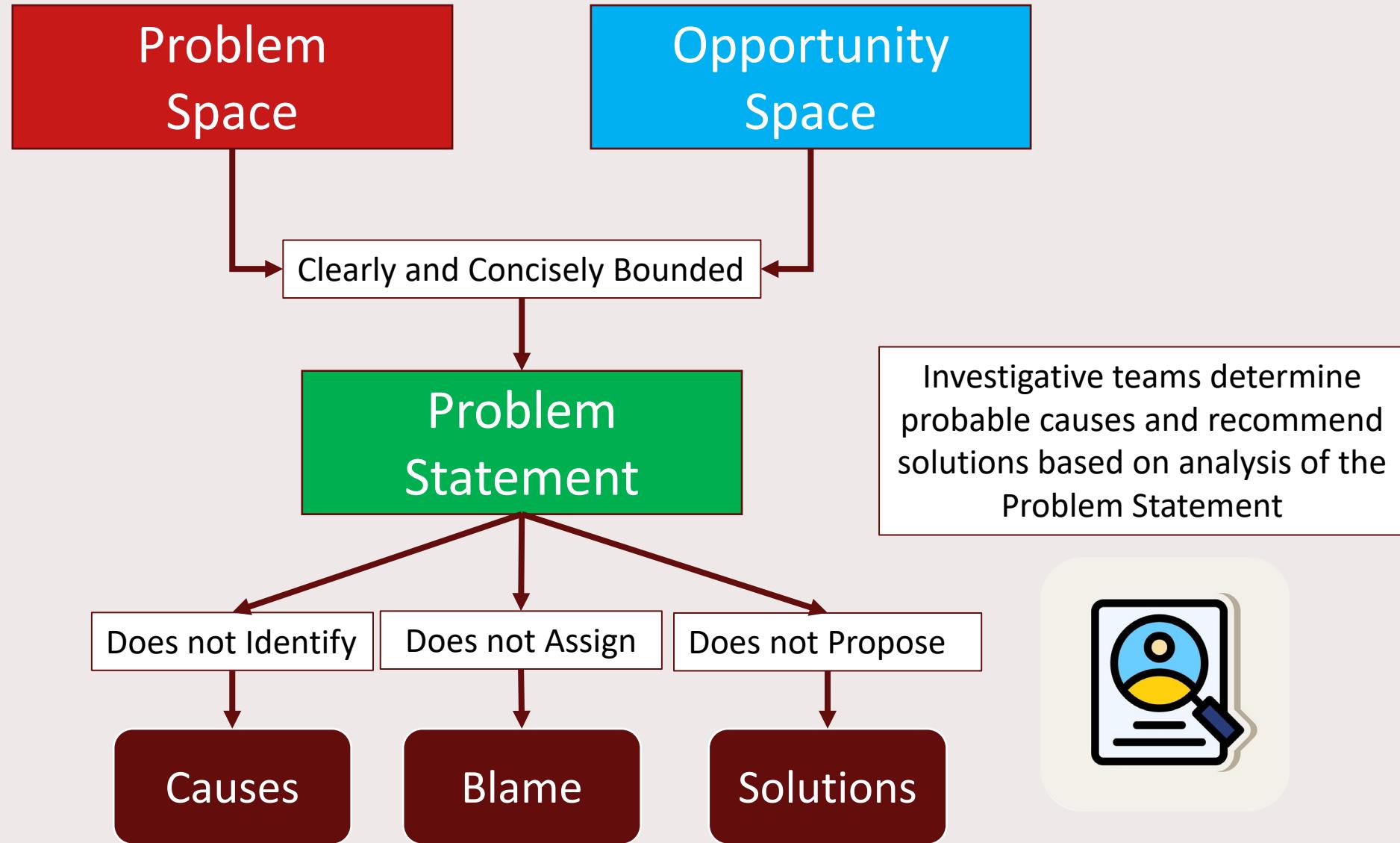
6



Defining the Problem Statement Translating Problem Space into an SE Solution



Problem Statement Principle





Problem Statement

What problem or issue is the User attempting to solve?

How should a problem statement be written?

Viruses are corrupting computers connected to our Local Area Network (LAN).

The TUe students are misusing the 2IMP30 course streaming facilities.

A Problem Statement

Clearly
Concisely
Succinctly
One sentence

No Source
No Root

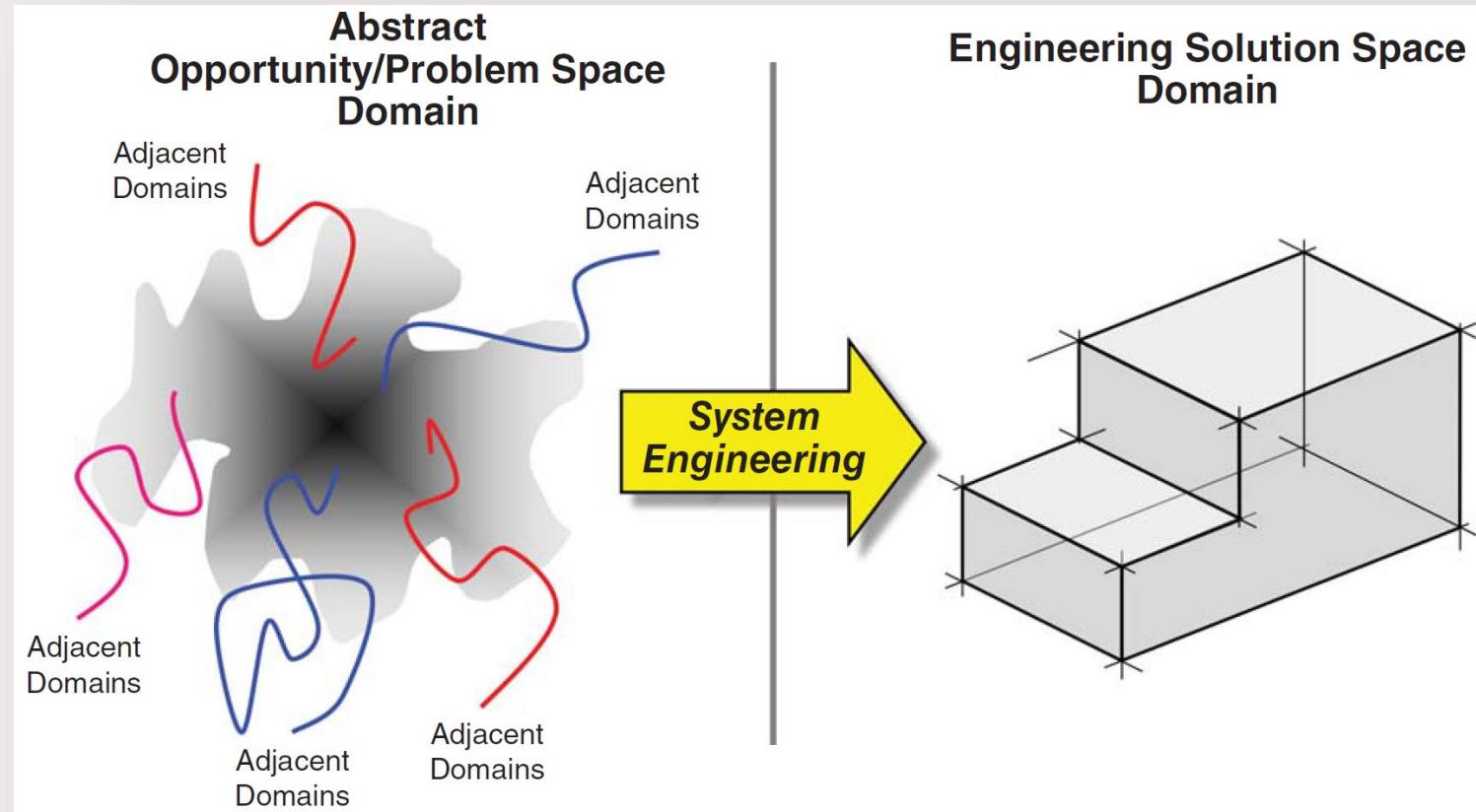
Identify
operational scenario
operating conditions

No Solutions

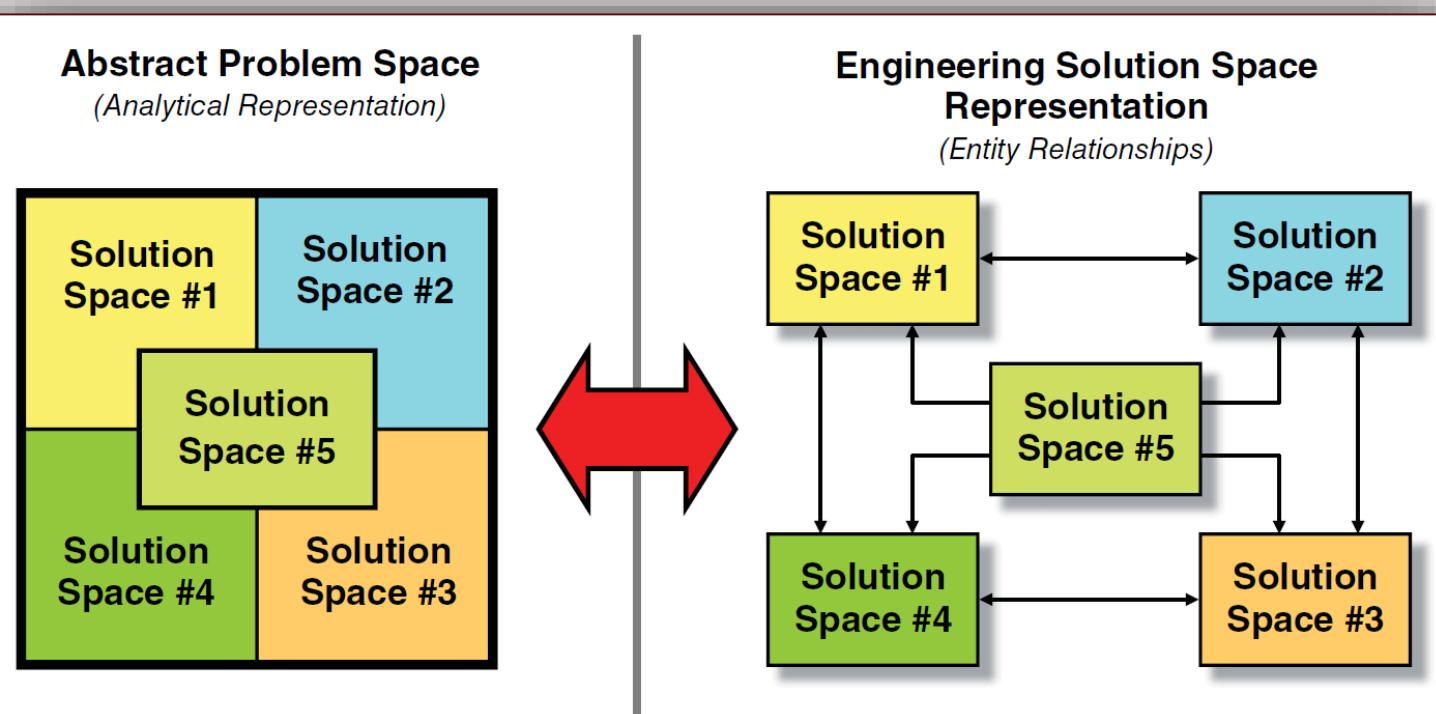
No
Responsibility
Blame

At our hospital, there are patients who endure a waiting time of at least four hours for a medical laboratory assistant to perform an electrocardiogram (ECG).

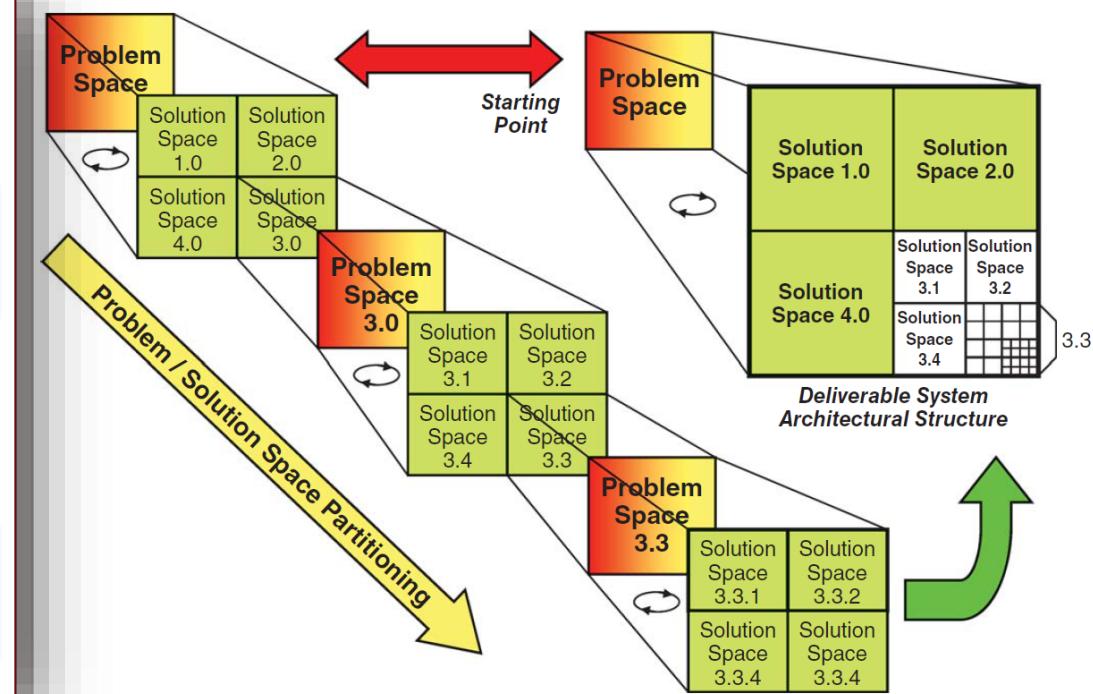
SE—Translating the Abstract Opportunity/Problem Space into an SE Solution Space



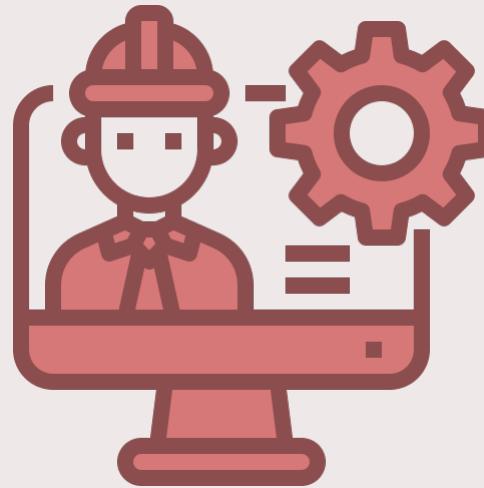
Partitioning the Problem Space into an SE Solution Space Representation



Partitioning (decomposing) the Problem Space into Manageable Pieces



7



How To Solve Problems? TRIZ – Short Introduction

Invention Of Civilization[1/3]

WE ASSUME THAT TODAY THE PRODUCTIVE AGE OF AN INDIVIDUAL IS UP TO 40 YEARS

*more than 800 generations lived without **artificial shelters in woods and caves**;*

*only 120 generations have known and used **the wheel**;*

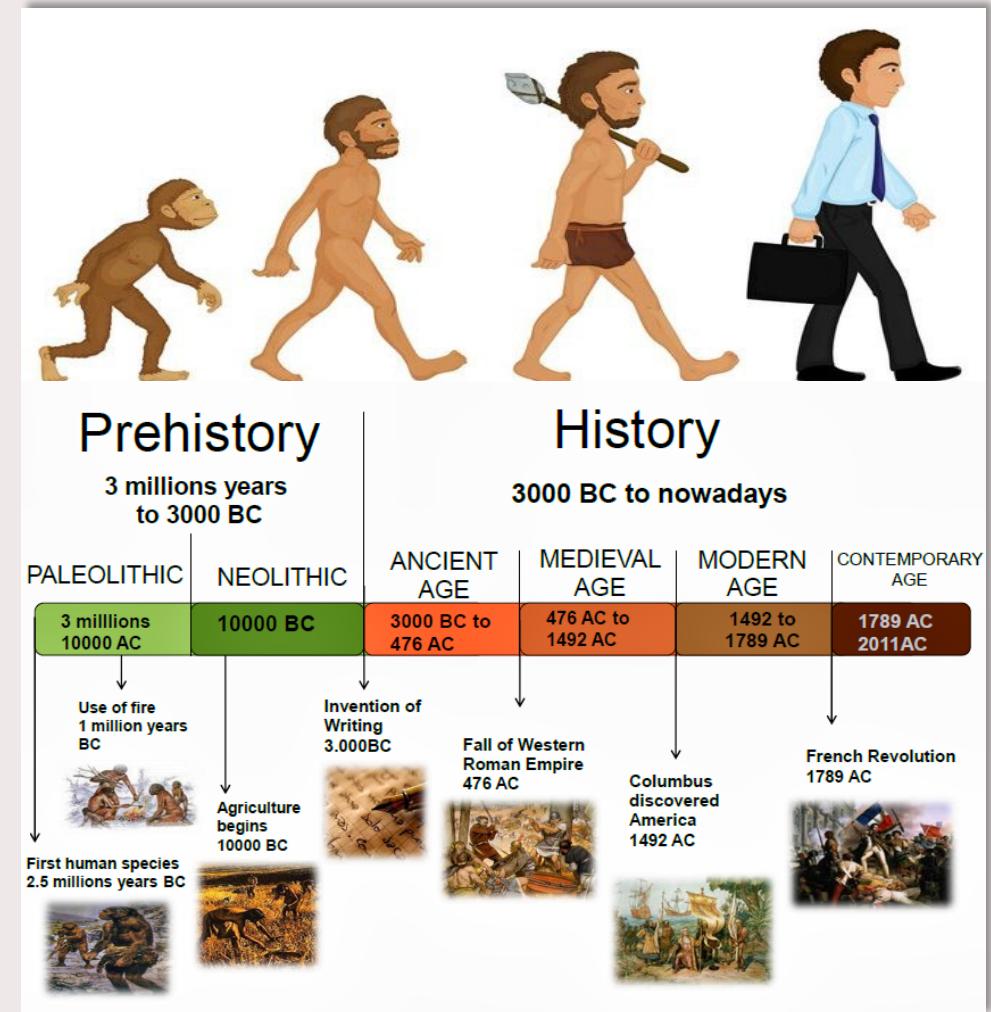
OF 1000
GENERATIONS
IN THE LAST
40,000 YEARS

*about 55 generations have known and used the **Archimedes' law**;*

*about 40 generations have used **windmills and watermills**;*

*about 20 generations have known and used **timepieces**;*

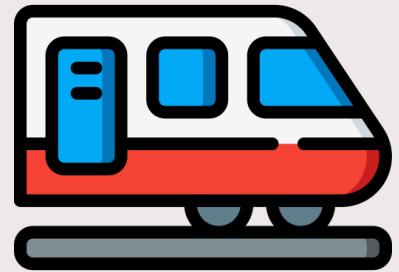
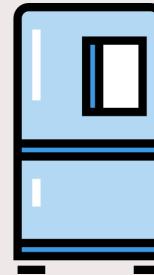
*about 10 generations have known **printing**;*



Invention Of Civilization[2/3]

OF 1000
GENERATIONS
IN THE LAST
40,000 YEARS

5 generations have travelled with **ships** and **trains**;



4 generations have used **electric lights**;



3 generations have travelled with **automobiles**,
have used **telephones** and **vacuum cleaners**;



2 generations have travelled with **aircraft** and
used **radios** and **refrigerators**;

Invention Of Civilization[1/3]

**OF 1000
GENERATIONS
IN THE LAST
40,000 YEARS**

*only today's generation
travelled in outer space
used atomic energy
Used PCs and notebooks*

*uses artificial satellites to transmit audio, video and other
information around the globe*

90 % of the knowledge and all material values
that have been arisen in the history of humanity
were developed in the 20th century!



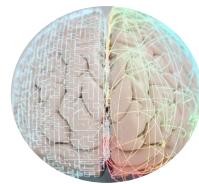
HUMAN BRAIN [1/2]



The **human brain**, as a biological entity, **has remained unchanged** not only in recent decades but also over thousands of years.



The **organization** and apparently the **working principles** of the brain **are the same** as they were 50.000 years ago.



The **purely biological over-capacity** of the brain does not lead **to quality thinking**



Quality thinking can **change in many ways** and **depends** on the **quality of learning** and the **subjects learned**.



Modern technology and the **subjects learned by individuals** are **not without essential faults**.

Where Do Good Ideas Come From? [1/2]

**Genrikh Saulovich
Altshuller (1926-1998)**

THE ENTIRE CIVILIZED WORLD CANNOT
THINK PROPERLY

People waste their intellectual potential
because of poorly organized thinking

People don't suspect that they think
ineffectively!

**THE METHOD OF TRY AND ERROR IS THE
BASIS OF THINKING**

ABANDON TRY AND ERROR

WOULDN'T IT BE MORE LOGICAL TO LEARN
FROM SUCCESS?

**CONDENSE THE EXPERIENCE GATHERED FROM
THE BEST SOLUTIONS INTO CONCRETE RULES**

**DEVELOP A METHODOLOGY WITH COMPLETE
MODELS OR EVEN AS A PRACTICAL THEORY**

Common Features of Good Solutions

Resolve

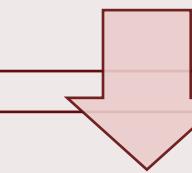
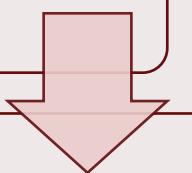
- Resolve Contradictions

Increase

- Increase “the Ideality” of a System

Use

- Use Idle, easily available resources



**A UNIQUE,
RIGOROUS
AND
POWERFUL
TOOLKIT**

TRIZ

Guides engineers to understand and solve their problems by accessing the immense treasure of past engineering and scientific knowledge.

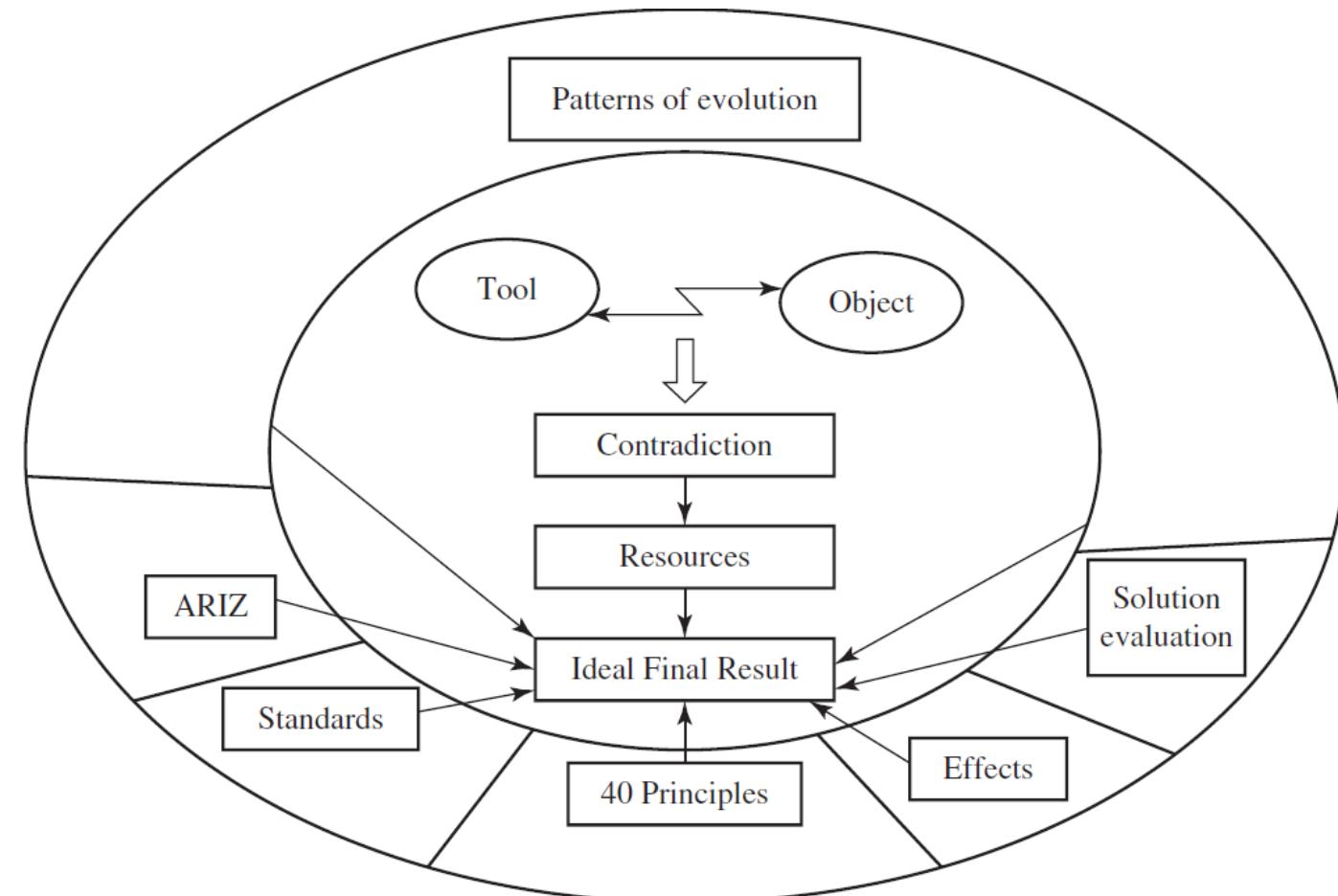
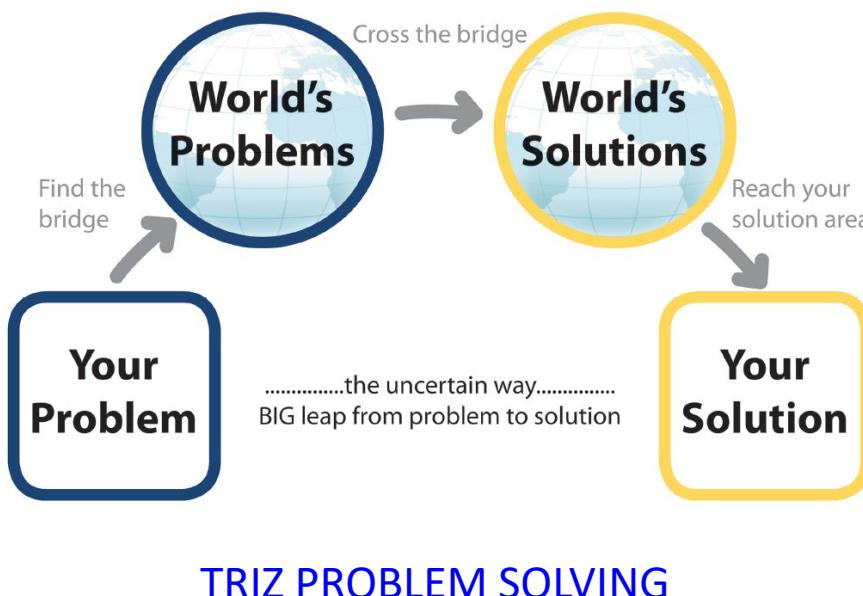
HELPS US FIND THE SURPRISINGLY FEW RELEVANT AND PRACTICAL ANSWERS TO OUR REAL PROBLEMS.



Summarize of all the conceptual answers to engineering and scientific problems.

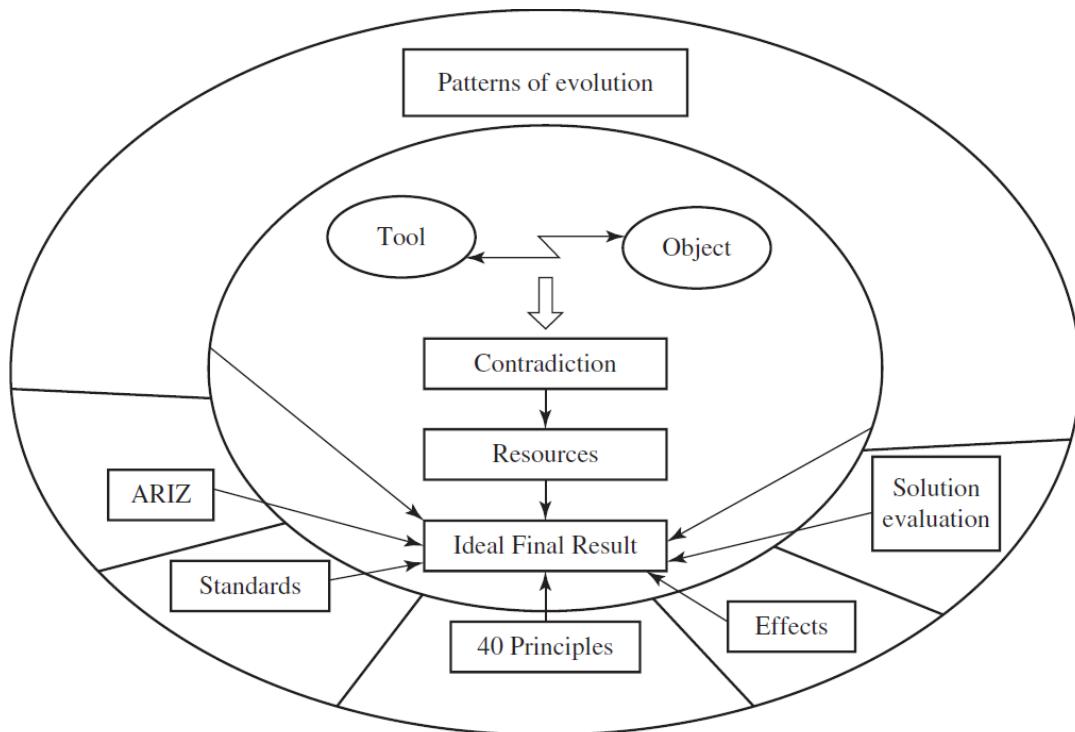
Model for Problem Solving

ARIZ is the central analytical tool of TRIZ



Model for Problem Solving

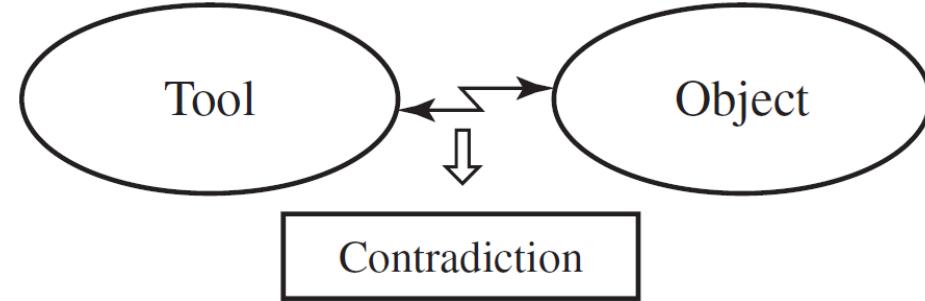
ARIZ is the central analytical tool of TRIZ



PROBLEM SOLVING MODEL FOR
TECHNICAL APPLICATIONS

- **ARIZ (algorithm for inventive problem solving)**
 - a long step-by-step guide for the analysis and resolution of contradictions.
- **Standard solutions**
 - list the ways of transforming the system, based on Altshuller's 1985 publication of a list called the "76 Standard Solutions."
- **Effects**
 - a technical database of physical, chemical, mechanical, biological, geometrical, and other technical phenomena that can be used for inventive problem solving.
- **Solution Evaluation techniques**
 - can be used to rate and order your solutions.
 - As an example, solution concepts can be graded against quality (how well does the solution concept solve the problem without creating conflicts?)
- **40 Principles**
 - General principles of solving contradictions
 - Your business situation will determine which criteria should be used for the evaluation
 - Standard solutions, principles, and effects are lists of recommendations and examples that can be easily captured within computer software

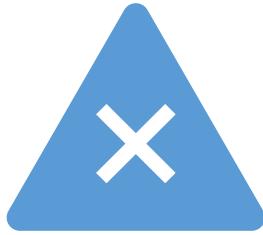
Contradiction



- **Difficult Problems Contain Contradictions**
- A contradiction **is a conflict in the system**
- **We meet contradiction everywhere**
 - *Digital camera* – we want small pixels (better resolution) **but** this gives us increased noise.
 - *Cooling fan* – how can we get good airflow, **but** without noise?
 - *A larger heat sink dissipates more heat but is bigger.*
 - *I enjoy eating cream cakes, but they are bad for me.*

Contradictions between tools and objects are the moving force of evolution

Three Basic Concepts for Reaching the Best Solution [1]



A good solution resolves the contradiction that is the cause of the problem.

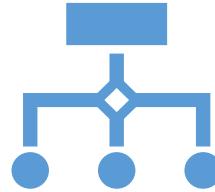


There are two kinds of contradictions:

“**Tradeoff contradiction**” means that if something good happens, something bad happens, too.

“**Inherent contradiction**” means that I need one thing that possesses two opposite properties.

Three Basic Concepts for Reaching the Best Solution [2]



The “ideality” of a system is the measure of how close it is to the perfect system.

The perfect system (called the “Ideal Final Result” in TRIZ) has all the benefits the customer wants, at no cost, with no harmful effects.

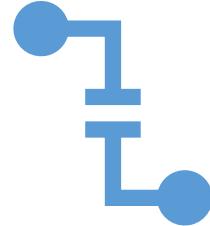


A system **increases** in ideality when

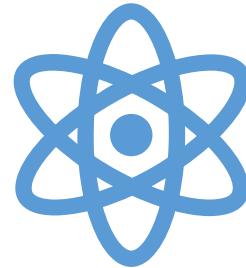
it gives you more of what you want, or less of what you do not want

does it at a lower cost and does so usually with less complexity.

Three Basic Concepts for Reaching the Best Solution [3]



Unseen, idle resources of the system are used to reach these seemingly incompatible goals.



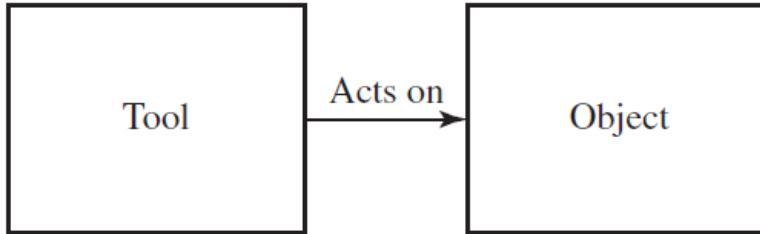
Resources include

Energy, Materials, Objects, Information
Things that can be made easily from the resources that are in the system or nearby.

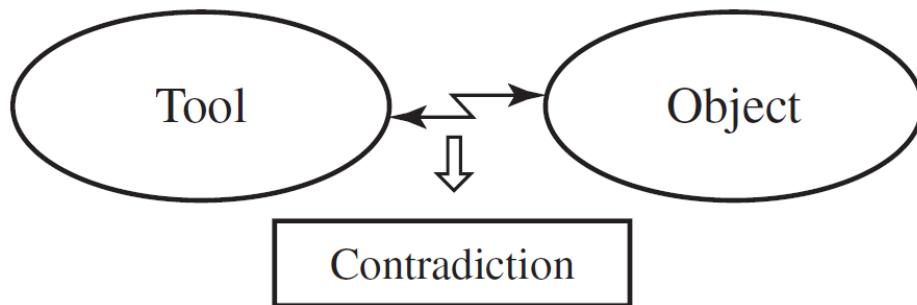
Tradeoff Contradiction - Technical

- When something good happens, something bad happens
- Something good gets better, something else gets worse
- Examples
 - The product gets stronger (good) but the weight increases (bad).
 - Software is made easier to use (good) but versatility decreases (bad).
 - The hot coffee is enjoyable to drink (good) but can burn the customer (bad).
 - Training gets more thorough (good) but requires more time (bad).
 - The faster the automobile airbag deploys, the better it protects the occupant (good), but the more likely it is to injure or kill small or out-of-position people (bad).

Tradeoff Contradiction



1. Use the words **IF**, **THEN**, and **BUT** in the statement.
2. **IF** describes a situation or relationship about the problem being analyzed.
3. **THEN** states what is good about the situation or relationship.
4. **BUT** states what is bad about the situation or relationship.



**Contradictions between tools
and objects are the moving
force of evolution**

- IF a lawnmower uses a muffler for noise suppression
- THEN noise levels are reduced (good)
- BUT backpressure on the engine is increased (bad)

- IF carrot seeds are sewn by hand
- THEN the work “tools” are simple (good)
- BUT cultivation requirements are increased (bad)

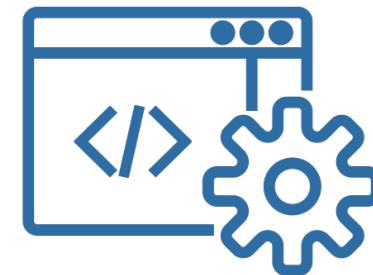
Inherent Contradiction – Physical

- One thing has two opposite properties
- There are always inherent contradictions behind tradeoffs— sometimes they are obvious and sometimes they are hidden
- Examples:
 - *The product should be thick (to get needed strength) and should be thin (to be light).*
 - *Software should have very few options for ease of use and should have numerous options to be effective*
 - *Coffee should be hot for enjoyable drinking and should be cold to prevent burning the customer.*
 - *Training should be lengthy to ensure good learning and should be very short to minimize demands on time.*
 - *The automobile airbag should deploy quickly to save the driver or passenger and should deploy slowly to minimize harm to small drivers or passengers.*

How to Identify the right problem to Solve?

- Instead of subjective or arbitrary formulations, using TRIZ, we have a precise definition
- A real problem contains tradeoffs → Analysis of Tradeoffs
- Consider the available time and resources → Find the hidden ones
- The problem appears between certain components
→ Select the components touched by problems
- To get the solution, it is very important to state the right problem → “a problem well stated is half-solved”

Questions?



תודה

Dankie Gracias

Спасибо شکرًا

Köszönjük Merci Takk

Grazie Terima kasih

Dziękujemy Děkujeme

Ďakujeme Vielen Dank Paldies

Kiitos Täname teid 谢谢

Thank You Tak

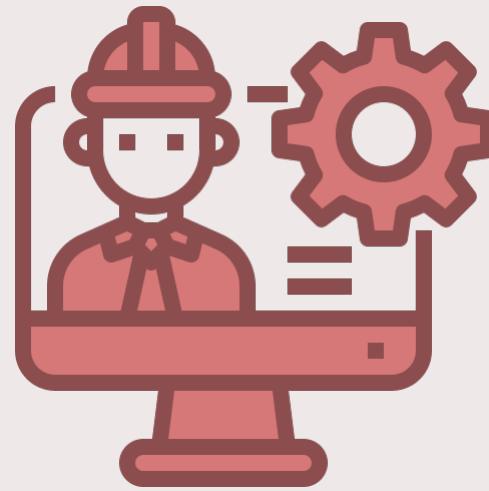
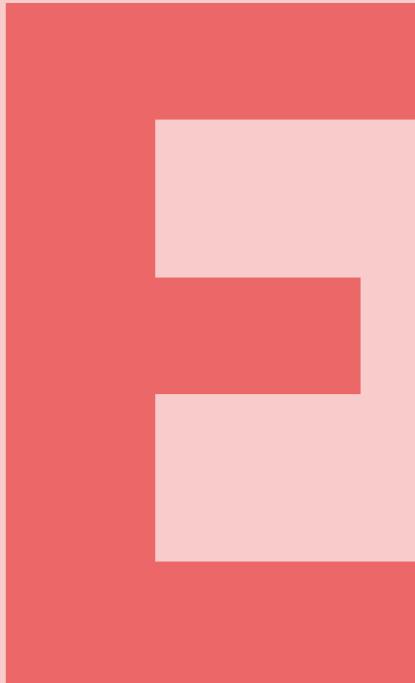
感謝您 Obrigado Teşekkür Ederiz

Σας Ευχαριστούμ 감사합니다

Bedankt Děkujeme vám

ありがとうございます

Tack



Extra Slides

Key Terms

Mission

A purposeful action or task directed toward accomplishing a specific **objective-based outcome and level of performance**

Mission Needs Statement (MNS)

A general description of the **operational capabilities** required for a new system, product, or service or upgrade to meet mission requirements.

Mission Objectives

Performance-based outcomes to be achieved by a mission within a **specified timeframe and operating constraints**.

Mission Profile

A time phased description of **operational events and environments** an item experiences from beginning to end of a specific mission.

It identifies the tasks, events, durations, operating conditions and environment of the system for each phase of a mission.

Key Terms

Opportunity Space

A gap or vulnerability in a system, product, or service capability that represents an opportunity for
(1) a competitor or adversary to exploit
(2) a supplier to offer solutions

Problem Space

An abstraction within a system's Operating Environment that represents an actual, perceived, or evolving gap, hazard, or threat to an existing capability.
One or more lower-level Solution Space systems, products, or services resolve the problem space.

Problem Statement

A brief, concise, statement of fact that clearly describes an undesirable event, issue, state, or condition without identifying the source or actions required to solve the problem

Solution Space

A bounded abstraction that represents a capability that, when implemented, is intended to satisfy all or a portion of a higher-level Problem Space.

Key Terms

Strategic Plan

An outcome-based, global or business domain document that expresses an Enterprise's vision, mission, and objectives of:

(1) where it wants to be at some point in time

(2) what it wants to accomplish in the long term, typically five years or more hence.

The challenge for most organizations is:

What business or Line of Business (LOB) are you currently in versus what do you want to be in five years from now versus what LOB you should be in?

Strategic Threats

External systems that have long-term plans to exploit opportunities that leverage or enhance an Enterprise's reputation or equity to achieve a long-term vision and upset the "balance of power."

System Threat

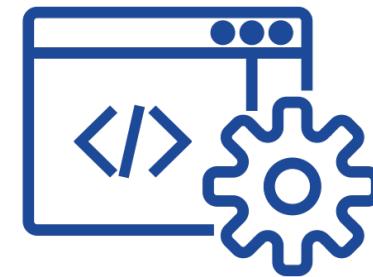
An external entity that has the potential to cause or inflict varying degrees of harm on another entity and its mission, capabilities, or performance.

A system threat is any interaction by an external system that is hostile or adversarial and impedes the operation and performance of your system in accomplishing its intended mission

Tactical Plan

A short-term, purpose-oriented strategy that outlines how the leadership of the Enterprise intends to utilize and maintain current resources, including personnel, products, processes, and tools, in order to accomplish specific organizational goals assigned from the overall strategic plan, while adhering to time and resource limitations, usually within a year or less

Questions?



תודה

Dankie Gracias

Спасибо شکرًا

Köszönjük Merci Takk

Grazie Terima kasih

Dziękujemy Děkujeme

Ďakujeme Vielen Dank Paldies

Kiitos Täname teid 谢谢

Thank You Tak

感謝您 Obrigado Teşekkür Ederiz

Σας Ευχαριστούμ 감사합니다

Bedankt Děkujeme vám

ありがとうございます

Tack