Systems Engineering and Integration

Technology Transition to Target (T4)

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Overview

Definitions

Systems Engineering Approach

Systems Integration Approach

- Organizational - People
- Program, Project and Process
- Technology

Major Systems Engineering Process

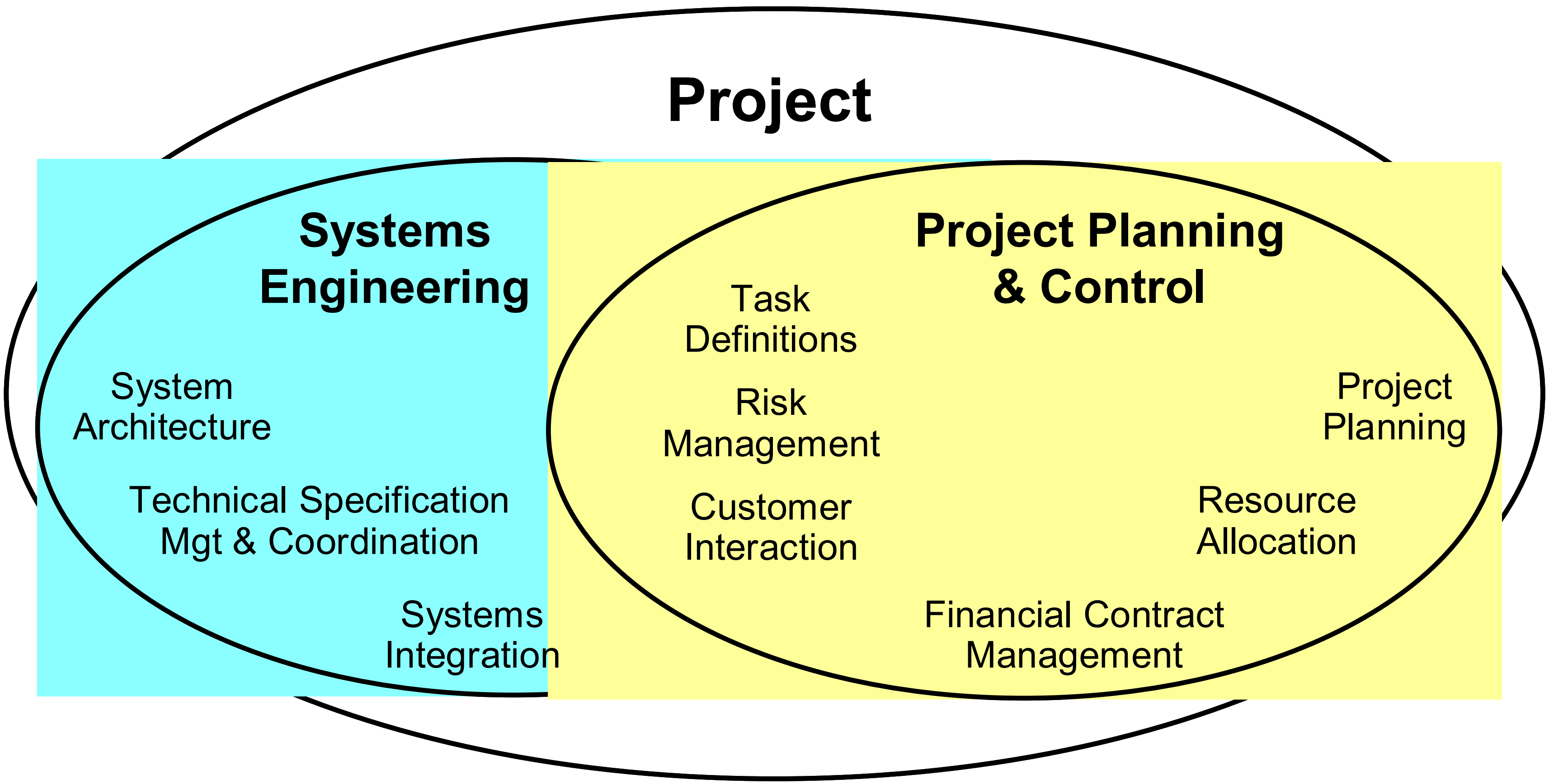
Technology Development Activities and Process

- Science and Technology Streams of Change
- Science and Technology Development
- Technology Target Analysis
- Technology Transition Example
- Rapid Technology Development

Summary

Systems Engineering - Definition

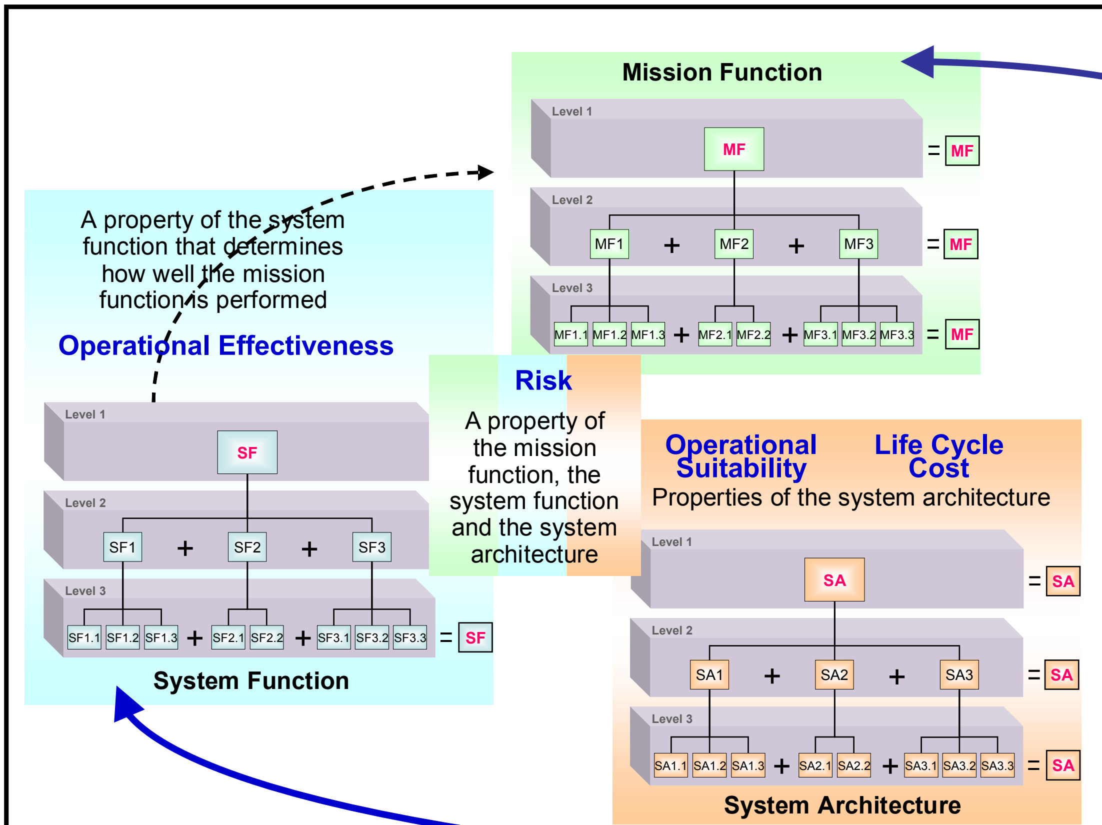
Systems Engineering (SE) is an interdisciplinary approach and means to enable the realization of successful systems.



(Adapted from INCOSE SE Handbook, v. 3.2, January 2010)

Systems Integration - Definition

*“**Systems Integration –** is the art and science of facilitating the marketplace of ideas that connects the many separate solutions into a system solution.”



Mission:

Explosives Detection

Candidate Systems:

- **Dogs**
- **Technical Sensors**
- **Behavioral Observation**
- **Combination of above**

*Jeffrey O. Grady, *System Integration*, 1994

Technology Readiness Levels - Definition

Technology Readiness Levels (TRLs) – provide a scale composed of nine measures that indicate a program's risk and potential for success.

Technology metrics are associated only with technology attributes and characteristics

Technology metrics are more likely to be associated with the performance of a given mission in a given environment

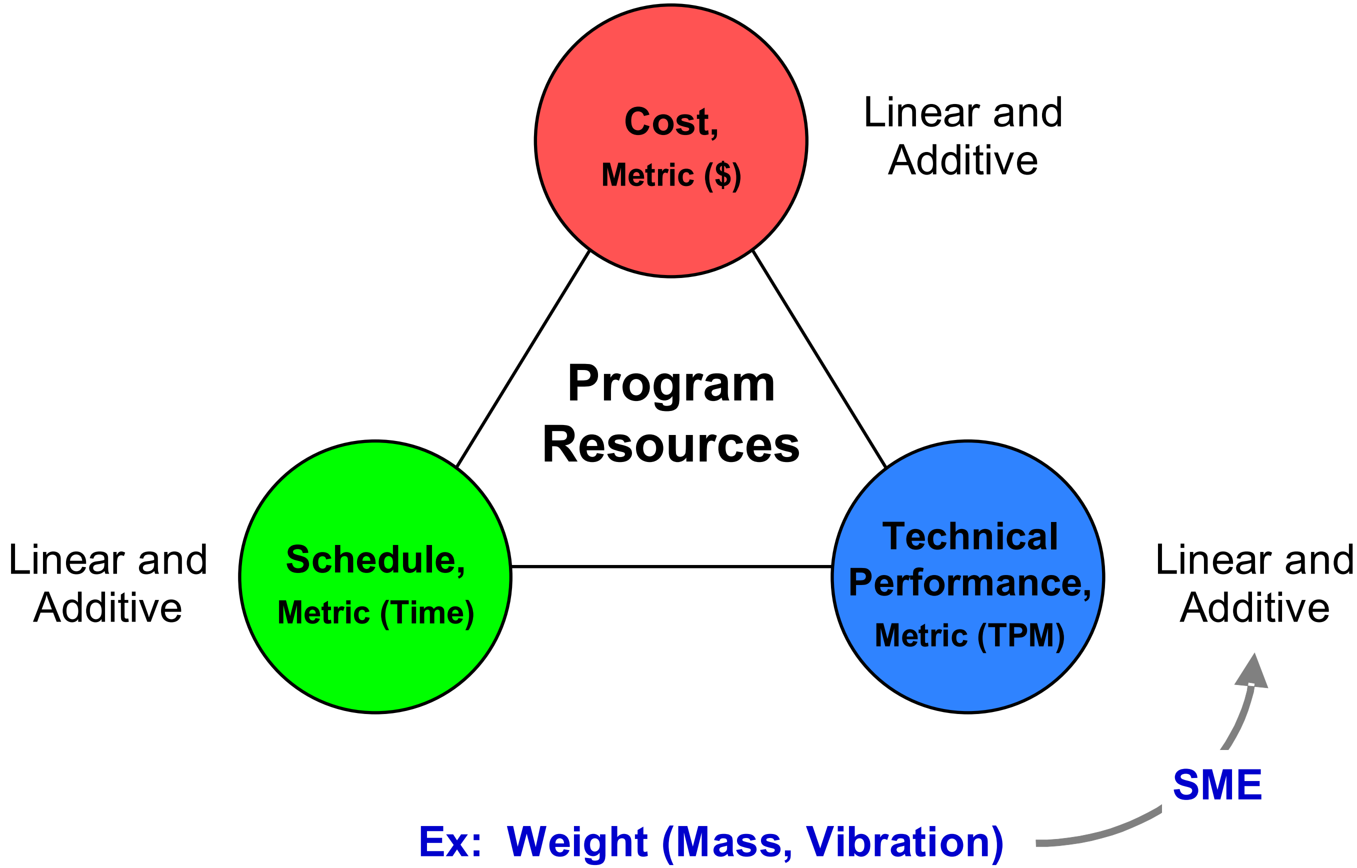
TRL1 —— (in laboratory) ——→ TRL4 TRL5 —— (in relevant environment) ——→ TRL9

Examples
- **Weight (Mass, Vibration)**
- Processing capacity
- Processing speed
- Volume
- Power consumption
- Resolution

For **M** [Mission Accomplishment]
on a scale of 0 to 1

M = f Σ (Technical Performance Measures)
and is the probability of mission success

Presentation Point of View and Organization

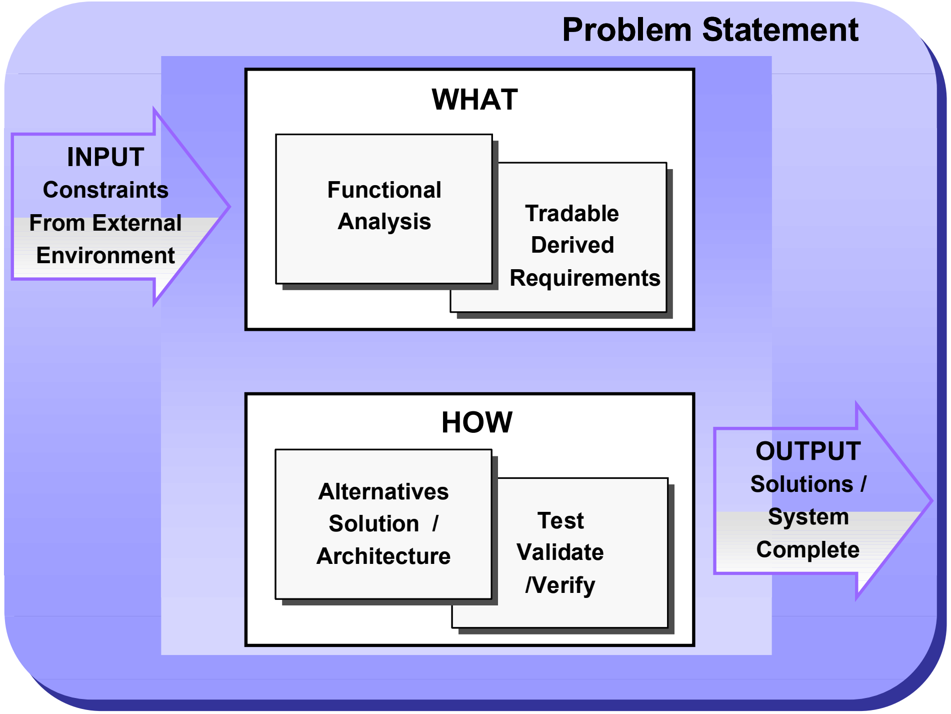


Subject Matter Experts (SMEs) – are used to convert nonlinear technical metrics to the required linear and additive metric for technical performance measure (TPM)

Systems Engineering Processes

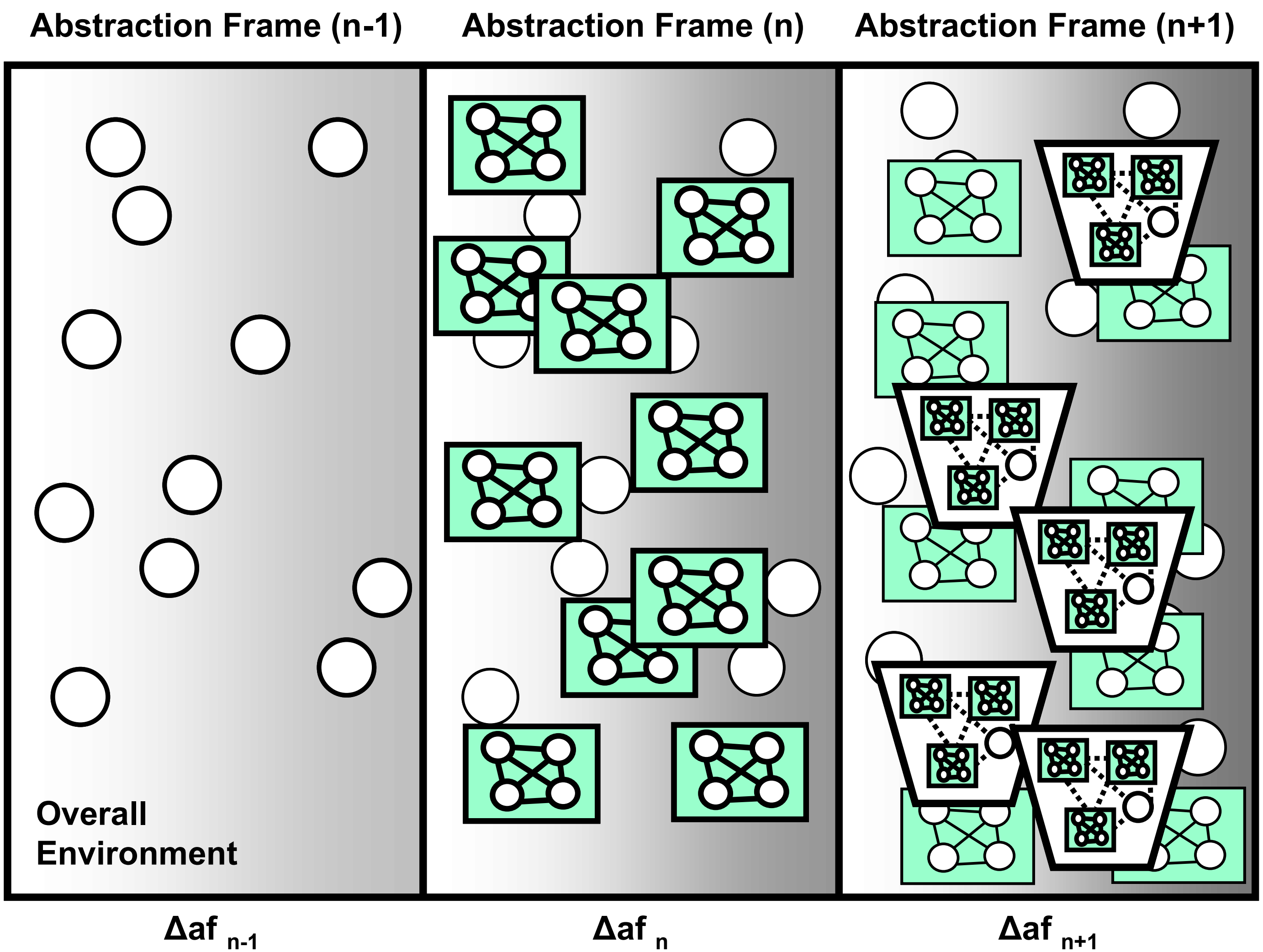
*The systems engineering approach is based on the following:

- **Define** problems before seeking solutions
- **Search** for solutions that examines tradeoffs between alternative solution sets
- **Utilize** traceable integration process that verifies that the product meets requirements and performs needed functions
- **Deploy** information management system that can provide each team member **and the customer** with any information concerning the system that has been generated.



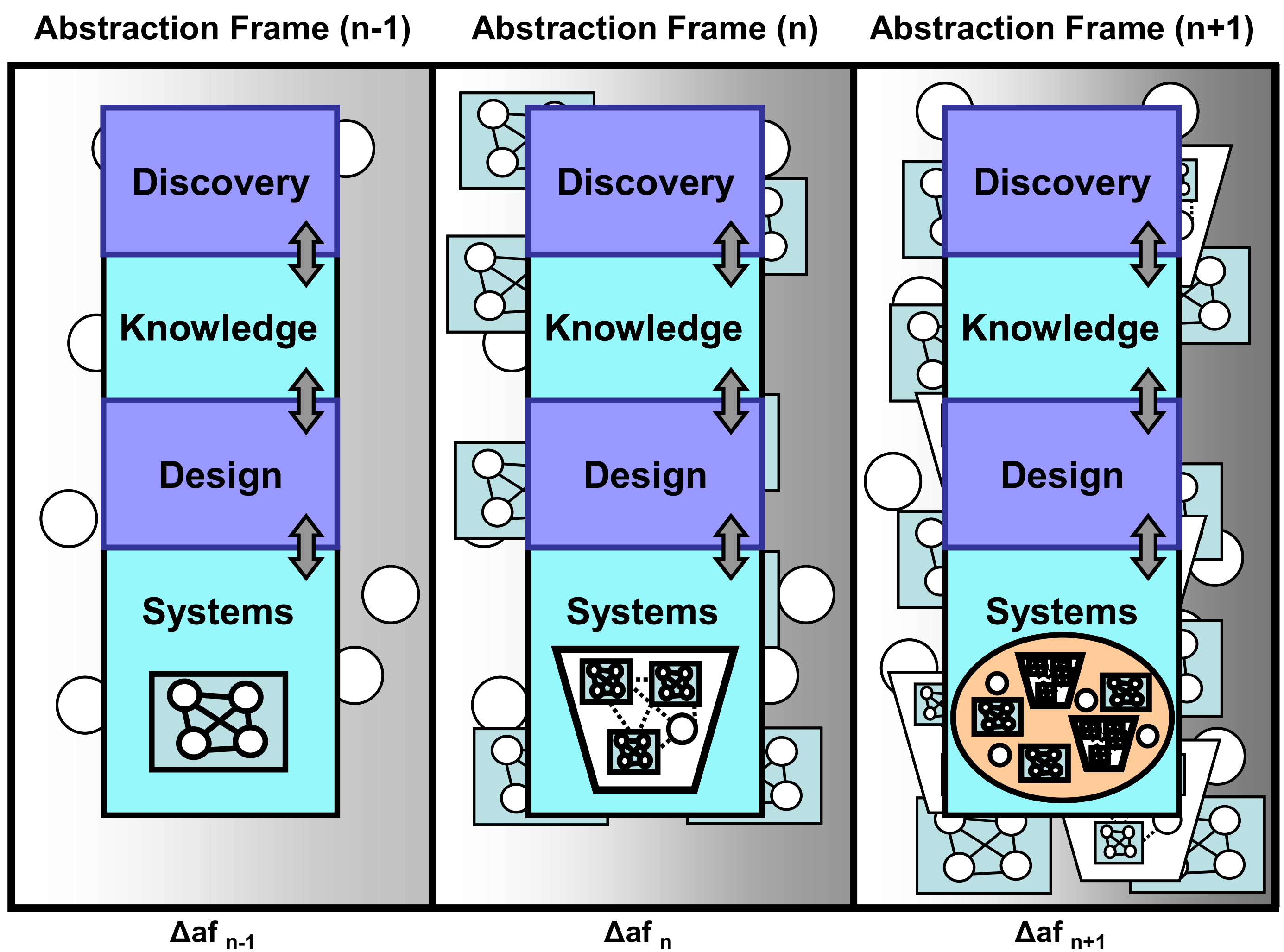
* Adapted from Brian W. Mar, "Back to Basics," 1992

Systems Engineering Processes



Example: DARPA large-scale integration

Systems Engineering Processes



Similar processes; different focus and systems

Systems Engineering Processes

LIFE CYCLE 'PHASES'

Initialization	Implementation	Operations

Typical High-Tech Commercial Systems Integrator

Study Period				Implementation Period			Operations Period		
User Reqts Definition Phase	Concept Definition Phase	System Specification Phase	Acq. Prep. Phase	Source Select. Phase	Development Phase	Verification Phase	Deployment Phase	Operations & Maintenance Phase	Deactivation Phase

Typical High-Tech Commercial Manufacturer

Study Period			Implementation Period			Operations Period		
Product Requirements Phase	Product Definition Phase	Product Development Phase	Engr. Model Phase	Internal Test Phase	External Test Phase	Full-Scale Production Phase	Manufacturing, Sales & Support Phase	Deactivation Phase

ISO/IEC 15288

Concept State	Development Stage	Production Stage	Utilization Stage / Support Stage	Retirement Phase

US Department of Defense (DoD) 5000.2

A: Pre-systems Acquisition	B: Systems Acquisition	C	IOC	FOC: Sustainment
Concept and Technology Development	System Development & Demonstration	Production & Deployment		Operations & Support (including Disposal)

US Department of Energy (DOE)

Project Planning Period			Project Execution			Mission	
Pre-Project	Preconceptual Planning	Conceptual Design	Preliminary Design	Final Design	Construction	Acceptance	Operations

Typical Decision Gates

New Initiative Approval	Concept Approval	Development Approval	Production Approval	Operational Approval	Deactivation Approval

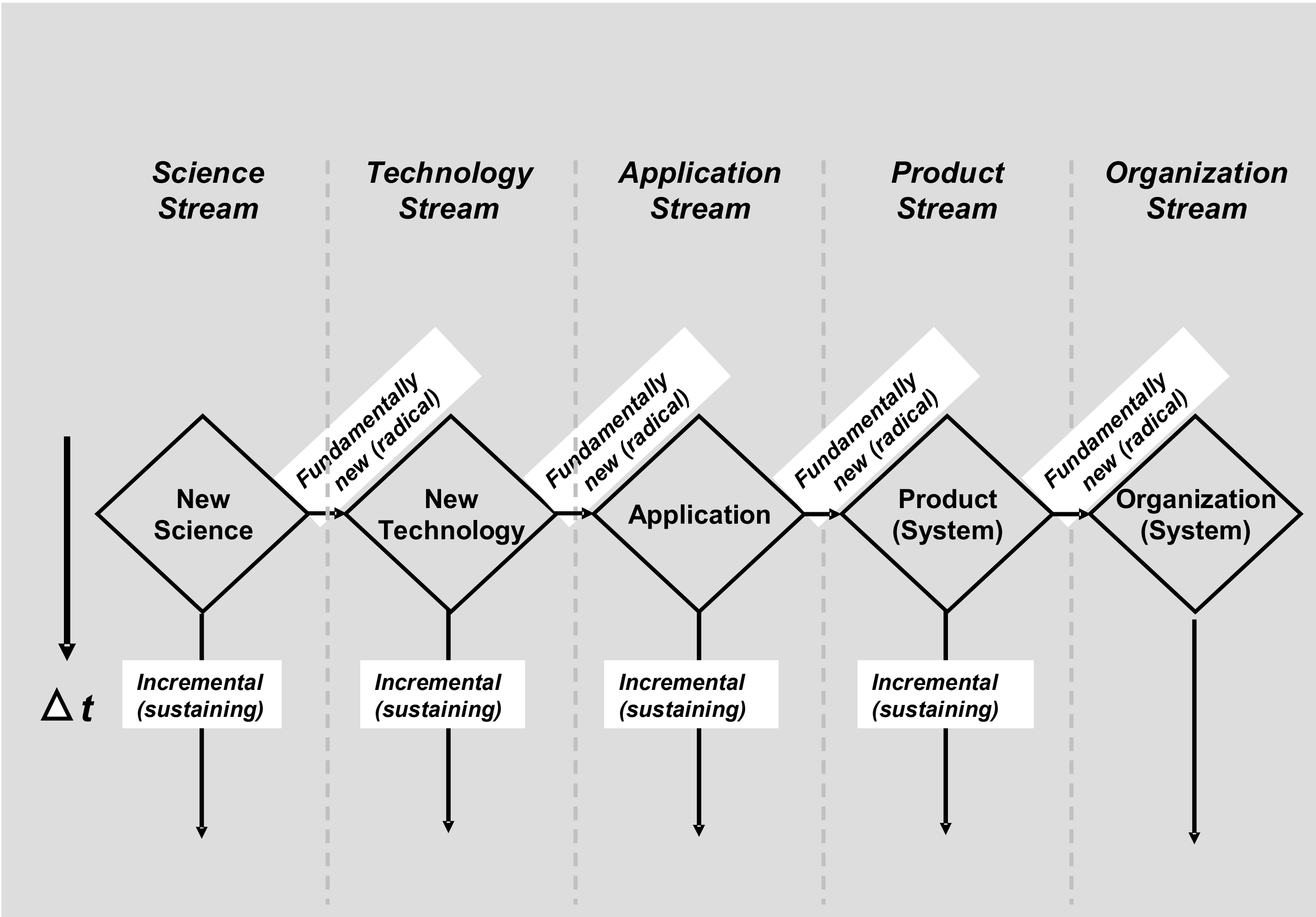
Adapted from INCOSE SE Handbook v. 3

Systems Engineering Processes

- SE Life Cycle Phase processes are based on **relatively stable** types of problems, technologies and organizations
- Changes drive technology and system risk higher
  - New organizations and organizational controls
  - Processes
  - Technology frameworks
- Established technology metrics facilitate management of technology risk
- Operational environments, customer operational needs and technology interfaces impact the system design, technology risk and integration processes

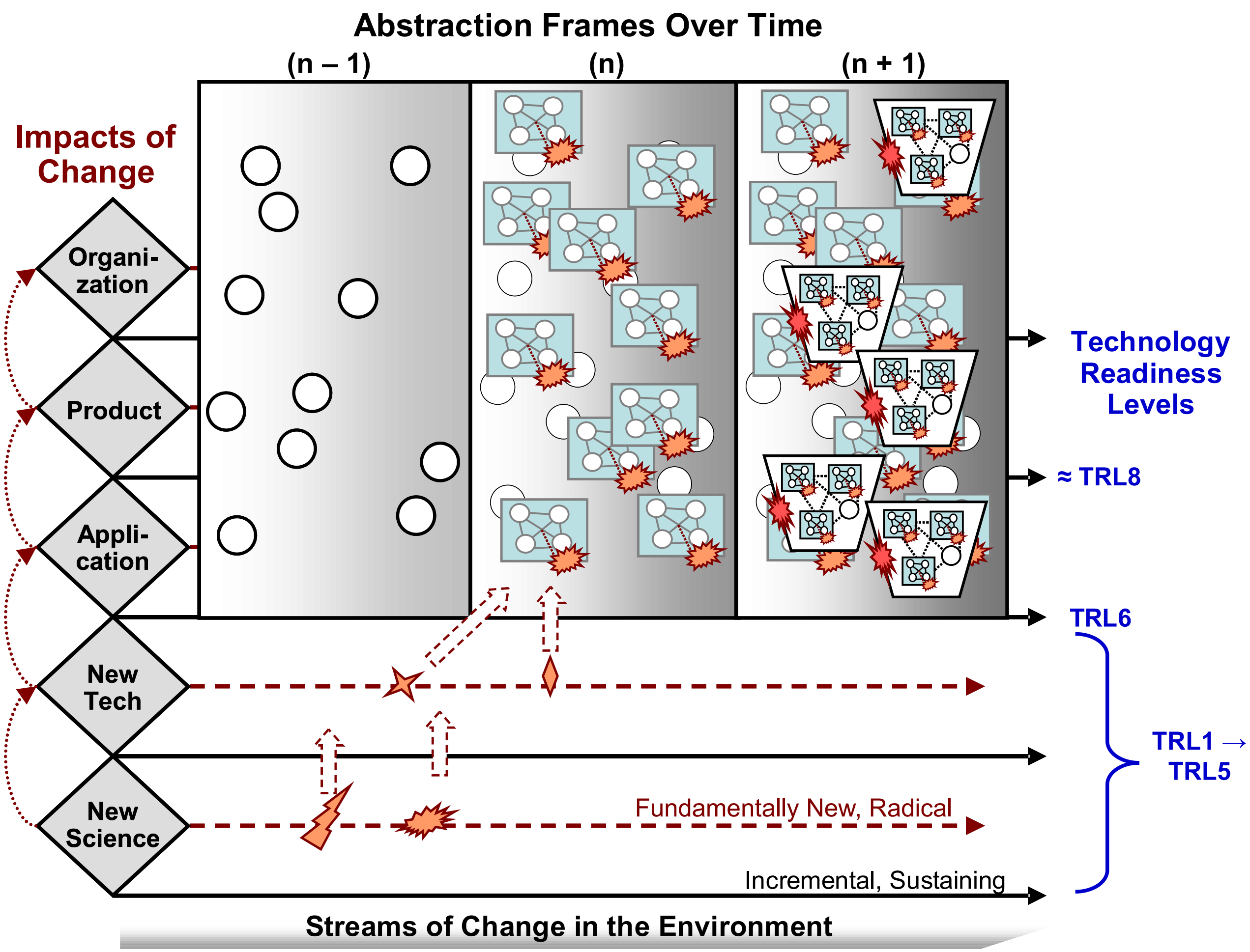
This represents an opportunity to develop a set of system and integration readiness levels that can be used to reduce program/organizational risk

Streams of Change



Example: BMW parts obsolescence; standard interfaces

Impact of Change on Systems Development



New science/technology NOT impacted by change in customers; Specific applications ARE impacted by changes in customers

Impact of System and Technology Changes

- Change impact is structured based on the customer mission
- Changes can be addressed by new technology, applications and/or systems
- Cost impacts are minimized when the new systems and technology solutions are compatible with existing systems and/or system standards and frameworks
- Attributes of organizational support and the deployed environment must be effectively handled to reduce total system life cycle cost
  - Often lifecycle support and operational costs are much greater than the initial capital system cost

Technology Transition To Target

Given the domain of a sensor technology, what is a target?

A target is defined as a specific sensor technology developed for a specific customer and deployed in a specific environment.

Target customer attributes and characteristics:

- Technology acquisition process
- Technology support and operation processes

Target environmental attributes and characteristics:

- Temperature range of operation
- Vibration range of operation
- Electromagnetic interference range of operation

All aspects of the target must be considered for a successful technology deployment

Technology Transition Requirements

Given a specific target, how are the requirements determined?

The target customer requirements are determined from:

- Customer systems engineering process
- Customer logistics
- Operational support concepts

The target environmental requirements are determined from:

- Customer system operational profile
- Assigned area of operation
- Similar existing system solutions
- Operational standards

The system functional requirements are determined from the customer system technology request and/or specification.

Technology Transition Example
Integration, Initialization, and Checkout

Given a ***bio-chemical reactor design*** *that was designed, manufactured and shipped to an installation site*

- Three reactor sections: batch reactor, power, and control sections
- Assembled system (integration); initialized system; system failed…
- Started trouble shooting programmable logic controller and system sensors (for oxygen, CO2, and dissolved oxygen)
- Sensor reading variability was greatly reduced by placing the sensors in a temperature controlled environment (small refrigerator)
- Strip chart variations were traced to proximity and schedule of diesel electric trains. When a diesel electric locomotive passed the installation, the chart needles would literally "go off the chart"
- Attention to the relevant environmental factors at the installation site provided the key to creating an effective operational system`

Technology Transition Example

*Given a **ground vehicle** with the requirement to locate, identify and classify specific types of physical objects at a given range with a given probability of success*

- First the **system level** (vehicle level) requirement must be evaluated, decomposed and assigned to system segments and then to subsystems and components.
- A **technical budget** must be designed to specifically allocate the controlling technical performance measures to each of the components and subsystems. The technical budget also includes a technical measure reserve or margin amount that is available for allocation as necessary at the system level.
- If all of the technical budget (**including margin**) is allocated to the sensor component then total system cost may be increased because of segment and system level considerations.

Technology Transition Example

Given the selection of a **optical sensor** *that uses mature optics technology, analog electric circuits and propriety software*

- Mass and weight associated with optical sensors creates the need to suppress and isolate vibrations in the operational environment
- Analog circuits create the need for a digital to analog interface
- Propriety software drives the need for a new software to interface with the existing software.

A **sensor solution that employed less weight**, direct digital circuits and open software architecture would reduce the total system design and operation cost. All aspects of the system, process integration, logistical support, and operational effectiveness must be considered in the transition of technology to any given target.

Rapid Technology Development

Need an **organizational level plan and process** to address technology development and packaging for specific targets:

- Understand the customer SE process needs
- Understand the customer logistics and operational needs
- Establish techniques that create the necessary design and support artifacts
- Understand the operational environments
- Create an adaptable technology 'packaging' capability

Recognize that **different organizations need different types of support**

Recognize that **different operational environments need different technology 'packaging' techniques**

Summary

Systems Engineering and Integration are organizational level activities that, while closely connected, **vary in detail and application** from organization to organization.

Technology Readiness Levels are a useful general metric, but **must be tailored** for specific application in any given context.

Connecting Technology Readiness Levels with a specific Systems Engineering project activity **creates operational tension** because the two process are focused on different aspects of technology and systems development

Development and application of an **adaptive technology production process** will increase the probability of the development and deployment of successful systems.

Questions?

1- Good Question

2- Excellent Question

3- Interesting Question

Backup

Systems Engineering - Definition

Systems Engineering (SE) is an interdisciplinary approach and means to enable the realization of successful systems.

It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and scheduling, performance, training and support, test, manufacturing, and disposal.

SE considers both the business and technical needs of all customers with the goal of providing a quality product that meets the user needs.

(INCOSE SE Handbook, v. 3.2, January 2010)

Systems Integration - Definition

"**Systems Integration –** is the art and science of facilitating the marketplace of ideas that connects the many separate solutions into a system solution. Systems integration is a component of the systems engineering process that unifies the product components and the process components into a whole. It ensures that the hardware, software, and human system components will interact to achieve the system purpose or satisfy the customer's need."

(Jeffrey O. Grady, *System Integration*, 1994)

Technology Readiness Levels - Definition

Technology Readiness Levels (TRLs) – provide a scale composed of nine measures that indicate a program's risk and potential for success. These nine levels are:

TRL1: Basic principles observed and reported

TRL2: Technology concept and/or application formulated

TRL3: Analytical and experimental critical function proof-of-concept

TRL4: Component, breadboard validation in laboratory environment

TRL5: Component and/or breadboard validation in relevant environment

TRL6: System model, prototype demonstrated in a relevant environment.

TRL7: System prototype demonstration in a relevant environment.

TRL8: System completed and qualified through test and demonstration

TRL9: System verified through successful mission operations

Presentation Point of View and Organization

These observations provide a point of view based on:

- The type of technology development performed at PNNL
- The general tension between technology development and major systems acquisition and engineering activities
- The assumption that PNNL will develop a technology product that will be deployed to different customer types
- The assumption that the technology product will be deployed in a variety of environments by the same or different customers

Systems Engineering Approach

The systems engineering approach is based on the following:

1) A structured and disciplined process that defines problems before seeking solutions
2) A systematic search for solutions that examines tradeoffs between alternative solution sets
3) A traceable and disciplined integration process that verifies that the product system meets the original requirements and performs the needed functions
4) An effective information management system that can provide each team member and the customer with any information concerning the system that has been generated.

(Brian W. Mar, “Back to Basics,” 1992)

Validation and Verification

System **validation** confirms that the system, as built (or as it will be built), satisfies customer's needs (i.e., "you built the right thing").

System **verification** addresses whether the system, its elements, and its interfaces satisfy their requirements (i.e., "you built it right"). Basic verification activities are:

Inspection: an examination of the item against applicable documentation to confirm compliance with requirements.

Analysis: use of analytical data or simulations under defined conditions to show theoretical compliance.

Demonstration: a qualitative exhibition of functional performance, usually accomplished with no or minimal instrumentation.

Test: an action by which the operability, supportability, or performance capability of an item is verified when subjected to controlled conditions that are real or simulated.

Certification: verification against legal or industrial standards by an outside authority without direction to that authority as to how the requirements are to be verified.

Adapted from INCOSE SE Handbook v. 3

Verification Activity Design

Design of the verification activity involves **choosing the most cost-effective mix** of simulations and physical testing, and **integrating test results** to avoid unnecessary redundancy

Four basic test categories are:

Development Test: Conducted on new items to demonstrate proof of concept or feasibility

Qualification Test: Conducted to prove the design on the first article produced, has a predetermined margin above expected operating conditions, for instance by using elevated environmental conditions for hardware

Acceptance Test: Conducted prior to transition such that the customer can decide that the system is ready to change ownership status from supplier to acquirer

Operational Test: Conducted to verify that the item meets its specification requirements when subjected to the actual operational environment

Adapted from INCOSE SE Handbook v. 3