International Council on Systems Engineering
A better world through a systems approach

Relationship between Adaptability and Resilience

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Today's Agenda

- Introduction
- Relationships between Adaptability and Resilience
- Value of Applying Applicable Resilience and Adaptability Techniques towards Systems Engineering
- Future Work and Conclusions
- References

Introduction

Adaptability

Dictionary Meaning

"adapt":

"to make fit (as for a new use) often by modification" (Merriam-Webster, Inc.).

Traditionally

Adaptation is the "modification of an organism or its parts that makes it more fit for existence under the conditions of its environment" (Martín, de Lope, & Maravall, 2009).

Systems Engineering

Adaptability:

The ability to satisfy mission and requirement changes, with or without modifications.

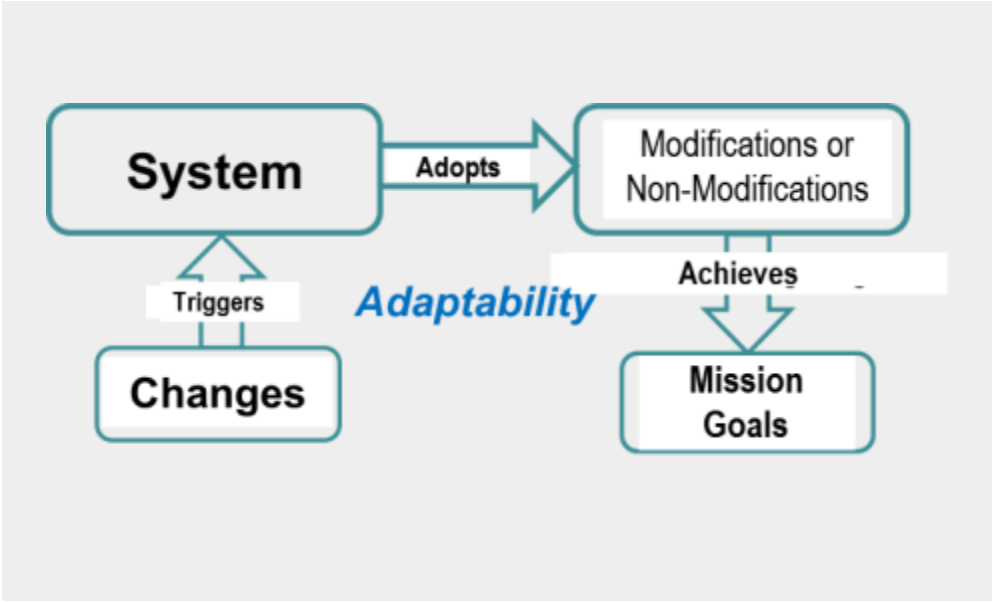
(IEEE, INCOSE, & Steven Institute of Technology, Systems Engineering Body of Knowledge - SEBoK).

Examples:

- Real-Time Adaptation: robot respond to environmental changes
- Non-Real-Time Adaptation: adapt a previous product design to a new product design.

Adaptability: Objectives

- Anticipate - view into the future to inform current design choices (e.g., to take advantage of future options or future opportunities).
- Reuse – repurpose the system (or modular components) for new situations.



- Endure – withstand fluctuations in the environment, system conditions, and needs (requirements).
- Afford & Satisfice –optimize costs (including system value) and risks associated with changes.

Resilience: Objectives

The objectives of resilience, in order to achieve required capability when facing adversity are to:

- **Avoid**: eliminate or reduce exposure to stress, or degradation due to adversity
- **Withstand**: resist capability degradation when stressed or subjected to adversity
- **Recover**: replenish lost capability after degradation to achieve at least required capability

Examples:

- **Adaptability/flexibility/agility**—ability to react appropriately and dynamically to a situation to avoid degradation of system capability
- **Architecture, design, and operational techniques** for achieving resilience objectives: e.g., fault tolerance—the ability to continue functioning with certain faults present.

Relationships Between Adaptability and Resilience

Adaptability vis-à-vis Resilience Engineering

Topic	Adaptability		Resilience
What is it?	A characteristic of the system	=	A characteristic of the system
Item of interest	Engineered systems	=	Engineered systems
Value of interest	Optimizing or satisficing value & capability	>	Provide required capability
Trigger	Differing situations, existing or new (not just adversity)	>	Adversity, existing or new
Typical relation to potential situations	Engages and resolves the situation	<	Includes the possibility of avoiding the situation all together
Item response	Item may or may not change	=	Item may or may not change
Proactive vs. Reactive	Both	=	Both
Considerations	Opportunity, issues and risk	>	Issues and risk
Difference of scope	Considers non-adverse situations in design and operational techniques	≠	Considers avoidance of adversity in design and operational techniques
Frequently used set theory type	Fuzzy	≠	Crisp (pass/fail, binary)

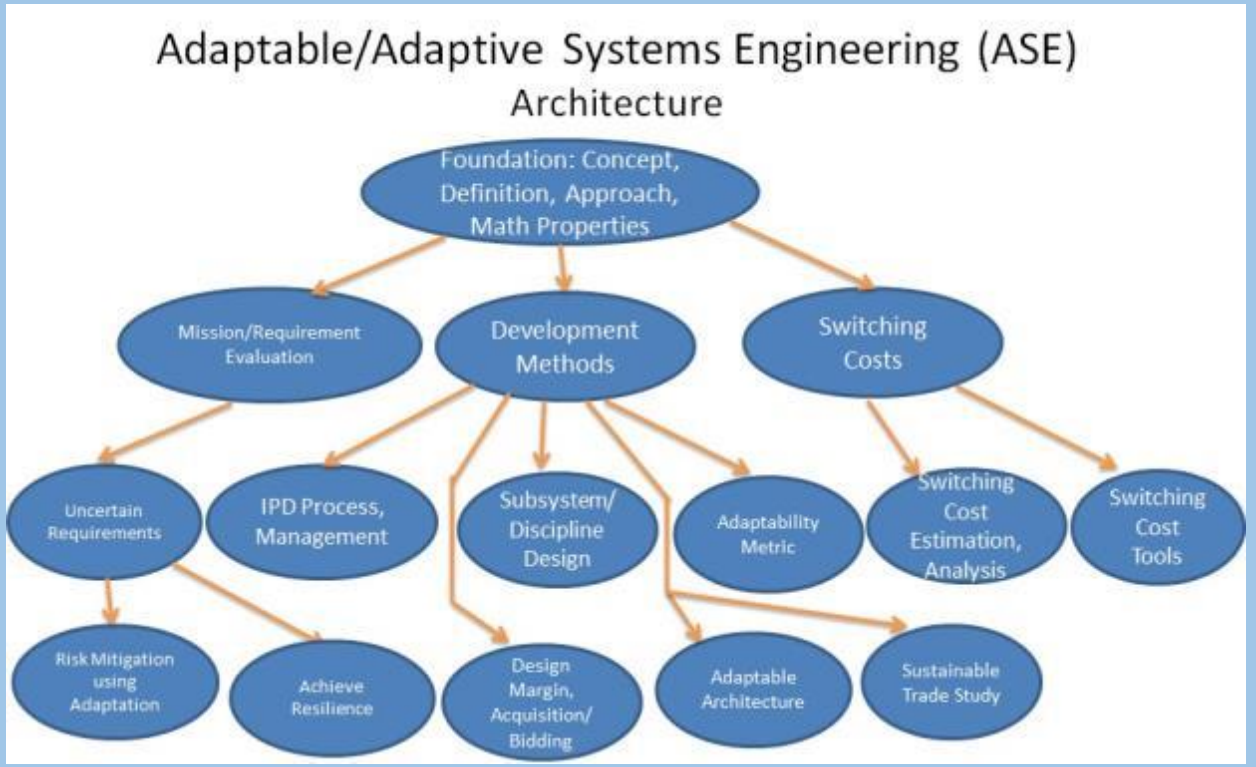
Relationship Venn diagram

Value of Applying Applicable Resilience and Adaptability Techniques towards Systems Engineering

Adaptive Systems Engineering

Theory and Methods.

Each bubble has publications or projects developed or demonstrated.



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System Adaptability Usages/Adoptions

Cross Domains

- Aerospace and Defense
- Communication Network Systems
- Climate Change
- Supply Chains
- Financial Investment
- …

Examples

- Boeing standard design practice guidelines (SEBoK Media 2023)
- Raytheon Mission Systems (Hershey, Paul C., et al.2022, 2025)
- California Precipitation Systems (Brooks, et. al. 2024)
- UAS Air Traffic Systems (SysCon 2025)
- Adaptive City Planning (Review in IEEE ISSE 2025)

Examples – Cont'

- Pratt & Whitney: Aircraft Engine Design (IS 2016)
- Risk Management (CAS 2025)
- Adaptive Entrepreneurship (Barton, et. al., 2025)
- Green Communications Systems (Yeh, et. al. 2023)
- Tool Selection (Boeing, 2024)
- Lifecycle Switching Cost Tools (Henry Zhu, 2024, 2025)
- ….

E.g. Boeing adopted it as Standard Design Practice :
Ref: SEBoK Social Media:
https://www.linkedin.com/feed/update/urn:li:activity:7159262285008437249/

Resilience Systems Engineering

Possible means of achieving fundamental objectives to *Avoid*, *Withstand*, and *Recover* from adversity:

- *Adapt*
- *Anticipate*
- *Constrain*
- *Continue*
- *Degrade gracefully*
- *Disaggregate*
- *Evade*
- *Evolve*
- *Fortify*
- *Manage complexity*
- *Minimize adversity*
- *Minimize faults*
- *Monitor*
- *Preserve integrity*
- *Prevent*
- *Reduce vulnerability*
- *Repair Replace*
- *Tolerate*
- *Understand*

Examples of Architecture, Design, and Operational Techniques:

- *Absorption*
- *Adaptability*
- *Anomaly detection*
- *Redundancy*
- *Fault tolerance*
- *Defense-in-depth*
- *Diversification*
- *Modularity*
- *Human participation*
- *Loose coupling*
- *Segmentation*
- *Shielding*
- *Substitution*
- *Buffering*
- *Coordinated defense*
- *Distributed privilege*
- *Error recovery*
- *Maintainability*
- *Protection*
- *Virtualization*

50+ techniques are commonly used– many are domain-specific

Future Work and Conclusions

Future Work

Potential relationships among resilience, adaptability and other quality attributes (e.g., Reliability-Availability-Maintainability (RAM), Affordability, Survivability, Safety, and System Security)

- Reducing engineering effort by eliminating redundant efforts
- Helping to ensure a comprehensive consideration of multiple specialty viewpoints
- Ensuring cohesion and elimination of conflicts among potential solutions
- Identifying highly effective solutions that address the interests of multiple specialty areas
- Providing a holistic viewpoint addressing the multiple perspectives
- Reducing the load of data generated by multiple specialty areas to a minimal, non-redundant set
- Mutual learning and sharing of selected appropriate best practices, processes, and tools among the specialty areas

Conclusions

- Answered a frequently asked question on the differences, relationships, and causality of system adaptability and system resilience.
- Provided areas that are potentially unique to each concept, and the significant common areas.
- Depicted the relationship through a comparison chart and a Venn Diagram
- Identified the value of applying applicable resilience and adaptability techniques for stakeholders, demonstrated the value of this work to systems engineering community, and showed directions for further investigations and subsequent studies

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