9th Nordic Systems Engineering Tour 2021

Key Skills for Moving Beyond Greenfield Systems Engineering

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Abstract

Systems Engineering Practitioners need to move beyond their traditional Document-Centric, Greenfield (Clean/Blank-Sheet) Systems Engineering heritage as we move forward to tackle the ever-increasing complexities of the future. This talk will discuss how transitioning beyond Greenfield Systems Engineering, such as Brownfield/Legacy Systems Engineering, Product Line Engineering, Systems of Systems Engineering, and Social Systems Engineering, requires additional Systems Engineering hard skills and soft skills to help ensure success.

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Topics

- **Purpose/Introductions**
- Greenfield/Traditional Systems Engineering (TSE)
- Moving Beyond TSE
  - Brownfield/Legacy Systems Engineering
  - Product Line Engineering (PLE)
  - System of Systems Engineering (SoSE)
  - Social Systems Engineering
- Wrap-up/Summary

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Purpose/Introductions

- Systems Engineering Practitioners need to move beyond their traditional Document-Centric, Greenfield (clean/blank- sheet) Systems Engineering heritage as we move forward to tackle the ever-increasing complexities of the future.
- This talk will discuss how transitioning beyond Greenfield Systems Engineering requires additional hard skills and soft skills to help ensure success.

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What do we Mean by Soft Skills?

- Definition
  - "Soft skills are the skills that really count. They are the skills that employers look for, that promotions are made of, and by which families thrive. Soft skills are interpersonal skills that demonstrate a person's ability to communicate effectively and build relationships with others in one-on-one interactions as well as in groups and teams." (Kamin, 2013)
- Also known as
  - People Skills
  - Applied Skills
  - Life Skills
  - (Real) World Skills
  - Interpersonal Skills
  - Professional Skills
  - Behavioral Skills
  - Personal Growth Skills
  - Emotional Intelligence

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Adapted from: (Kamin, 2013)

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Soft Skills are a Participatory Activity!

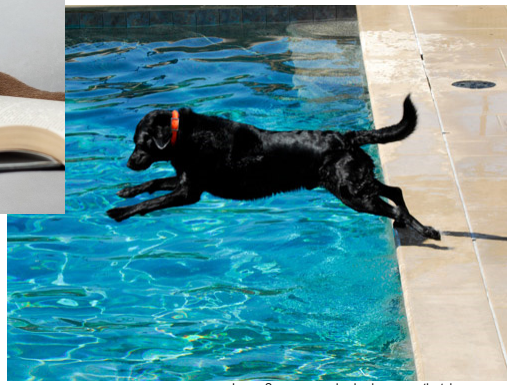

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Image Sources: www.londonderry.org, atlantahumane.org

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Topics

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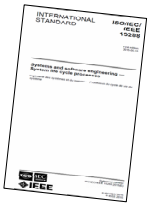
Traditional Systems Engineering (TSE)

- Traditional Systems Engineering is characterized by:
  - A Greenfield (or clean-sheet
  - or blank-sheet) environment
  - "Make" the system elements
  - Primarily a single pass – albeit, with concurrency, iteration, and recursion
  - Document-centric – with requirements the "source of truth"
  - A (single) product-centric solution
  - A complicated (vs complex) system
  - Social considerations important, but ancillary



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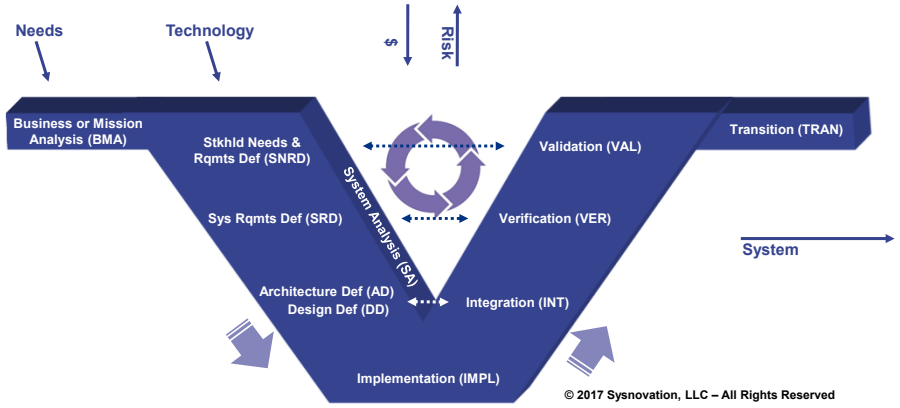
V - The "Vee" Model



Adapted from: (INCOSE SEH, 2015) (Forsberg et al., 2005) (Rook, 1986)

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Traditional Systems Engineering (TSE): The Systems Engineer as Craftsman

- The TSE System Engineer
  - Understands the customer's needs
  - Translates them into requirements and a system architecture & design
  - Allocates & derives system element requirements
  - Verifies & validates continually

- Key Hard Skills
  - Requirements Analysis
  - Architecting & Design
  - Integration, V&V
  - Decision & Risk Mgmt
  - "-ilities" (e.g., affordability, reliability, safety, usability)
- Key Soft Skills
  - Communication
  - Asking Questions
  - Teamwork
  - Culture (Internal/External)

Adapted from: (Walden, 2007) (Walden, 2020)

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Beyond Traditional Systems Engineering

- Traditional Systems Engineering is characterized by:
  - A Greenfield (or clean-sheet or blank-sheet) environment — Brownfield SE
  - ~~"Make" the system elements~~ — ~~COTS-Based SE~~
  - ~~Primarily a single pass – albeit, with concurrency, iteration, and recursion~~ — ~~Agile SE~~
  - ~~Document-centric – with requirements the "source of truth"~~ — ~~MBSE~~
  - A (single) product-centric solution — PLE
  - A complicated (vs complex) system — SoSE
  - Social considerations important, but ancillary — Socio-Technical

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Greenfield vs. Brownfield

"**Greenfield** land is undeveloped land in a city or rural area either used for agriculture, landscape design, or left to evolve naturally."

"**Brownfield** land means places where new buildings may need to be designed and erected considering the other structures and services already in place." "The land may be contaminated … and has the potential to be reused once it is cleaned up."

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Quotes and Images sources: Wikipedia and (Baley and Belcham, 2010)

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Greenfield vs. Brownfield Systems Engineering

- **Greenfield** Systems Engineering
  - No or limited legacy system constraints other than system interfaces
  - No or limited continuity considerations
  - Also known as “clean-sheet” systems engineering
- **Brownfield** Systems Engineering
  - Significant modification, extension, or replacement of an existing system in an existing environment
    - Maintenance
    - Modernization
    - Replacement
  - Typically explicit continuity requirements
  - Also know as “legacy” or “in-service” systems engineering

“Brownfield is much, much harder than Greenfield, whether [systems] or house remodeling.”
Fred Brooks

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Adapted from: (Seacord et al., 2003) (Hopkins and Jenkins, 2008)

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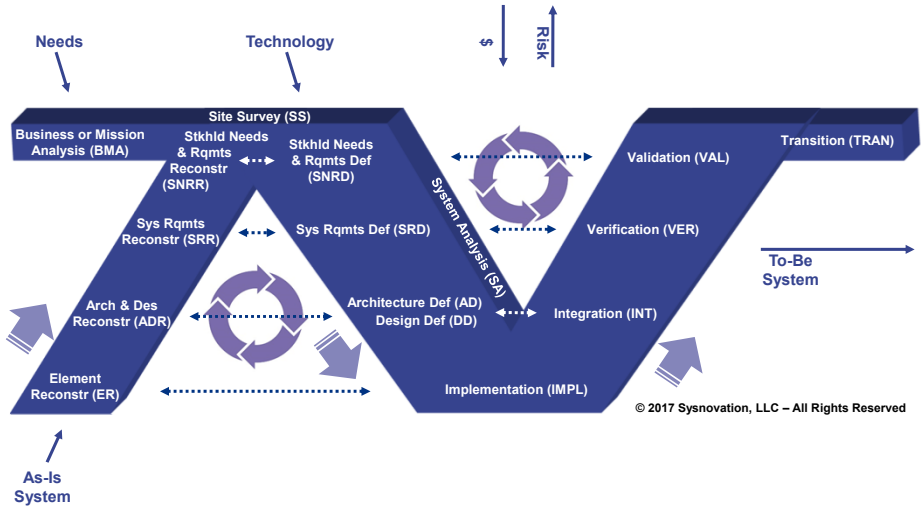
N – The “N” Model for Brownfield



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Adapted from: (Walden, 2019)

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Brownfield SE: The Systems Engineering as Archeologist

- The Brownfield System Engineer
  - Studies the past to design the future
  - Envisions and moves from the "as-is" to the "to-be" solution

- Key Hard Skills
  - Site Survey
  - Reconstruction
  - Gap Analysis
  - Reuse
- Key Soft Skills
  - Investigating
  - Inquisition
  - Discernment
  - Culture (Legacy/New)

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Adapted from: (Walden, 2019) (Walden, 2020)

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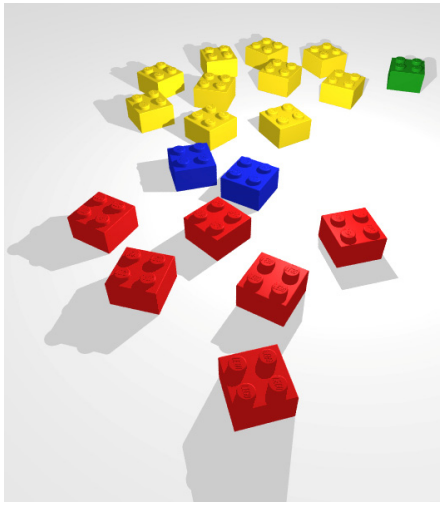
Application of Systems Engineering for Product Lines

SEHv4 §8.3



- Product line engineering (PLE) is a combination of product, process, management, and organization to migrate from single-system engineering to a product line approach
- PLE can support the goal of improved organizational competitiveness
  - Decreases the development cost
  - Increases the quality
  - Enlarges the product catalog

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Adapted from: (INCOSE SEH, 2015)

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Product Line Engineering (PLE) Driving Challenge – Product Variability

So many variants – what is the best architecture(s)?

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Source: Volvo

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The Feature-based PLE Factory

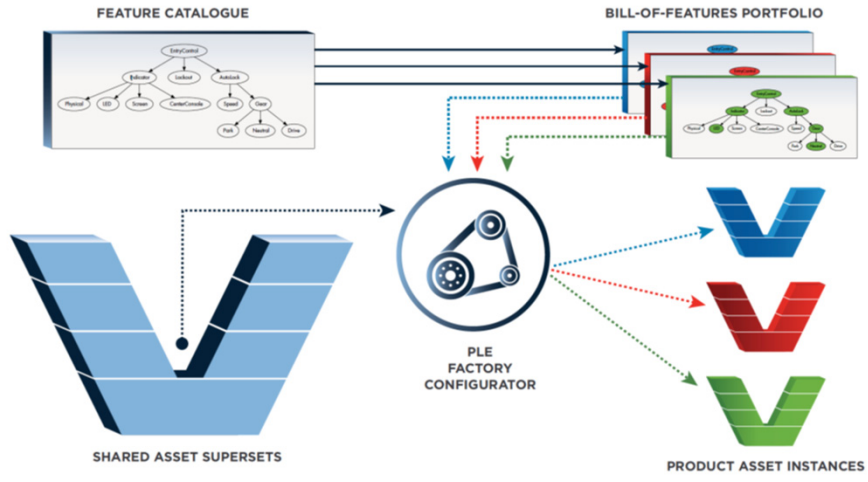

Image Source: (ISO/IEC 26580, 2021)

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Product Line Engineering (PLE): The Systems Engineer as "Lego Master"

- The PLE System Engineer
  - Uses features to express product differences across the life cycle
  - Uses variation management in artifacts from across the full life cycle to engineer a portfolio of products

- Key Hard Skills
  - Feature Point Specification
  - Variability Analysis
  - Architecting Product Lines
  - Composable Design
  - Non-Hierarchical Integration
- Key Soft Skills
  - Abstraction
  - Life Cycle Value Formulation and Communication

Adapted from: (INCOSE SEH, 2015) (Clements 2019)

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Complicated vs. Complex

Complicated system

Modern transit vehicles exhibit:

- Large numbers of interacting systems – fuel, electrical, engine, transmission, safety, etc.
- Aggregate properties, reasonably predictable emergence – range, top speed, handling, etc.
- Unexpected outcomes still possible, but origin is different
- Transit systems may be complex

Complex system

Traffic jams exhibit:

- Self-organization and unpredictable emergence – local actors and decisions interact to create larger patterns
- Memory – even after an obstacle is removed the jam can persist for hours
- Counter-intuitive outcomes (e.g., Braess' Paradox – adding capacity to the network can degrade network performance)

The opposite of "complex" is "decomposable" – not "simple"

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Adapted from: (INCOSE CxP4SE, 2015)

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Characteristics of SoSs

SEHv4 §2.4

SoS Characteristic	Elaboration
Operational Independence of the Constituent Systems	The SoS is composed of systems that are independent and useful in their own right. When removed from the SoS, the systems can (and do) usefully operate separately.
Managerial Independence of the Constituent Systems (Governance)	The SoS is composed of systems that are separately acquired and maintain a continuing operational existence separate of the SoS.
Geographic Distribution	The geographic extent of the constituent systems is large. Constituent systems can easily exchange only information and not substantial quantities of mass or energy.
Emergent Behavior	The SoS has emergent properties that cannot be localized to any constituent system. The principal purposes of the SoS are fulfilled by these behaviors.
Evolutionary Development	The SoS does not appear fully formed. Its development and existence are evolutionary with purposes and functions added, modified, and removed with experience.

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Adapted from: (INCOSE SEH, 2015) (Maier, 1998)

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Types of SoS

Type of SoS	Definition/Features
Virtual (Example: The Internet)	No central authority No centrally agreed-upon explicit, recognized SoS purpose SoS behavior emerges Relies on standardized formats or protocols
Collaborative (Example: An Electrical Grid)	No overall directing authority Constituent systems interact voluntarily Agreed-upon SoS purposes, which can evolve Collective means of enforcing and maintaining standards
Acknowledged (Example: Air Traffic Control System)	Designated SoS manager and dedicated SoS resources SoS objectives recognized the by constituent systems Constituent systems retain their independence Changes based on SoS/constituent system collaboration
Directed (Example: Integrated Air Defense)	Integrated SoS built and managed to fulfill specific purposes Operations are centrally managed to ensure goals are met Integrated SoS maintained and upgraded Constituent systems can operate independently Normal operation is part of the SoS

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Adapted from: (ISO/IEC/IEEE 21841, 2019) (INCOSE SoSP, 2018) (DUSD, 2008) (Maier, 1998)

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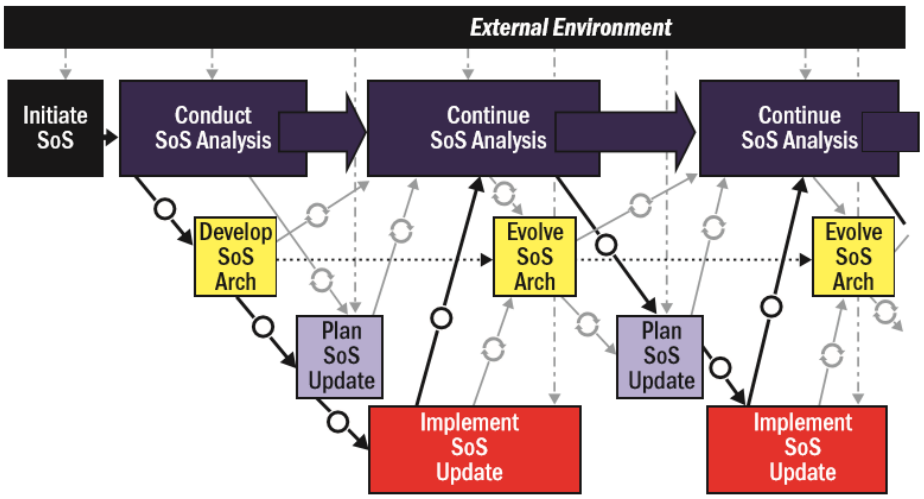
W - The "Wave" Model for SOS



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Source: (Cook 2016) Adapted from: (Dahmann et al. 2011)

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System of Systems Engineering (SoSE): The Systems Engineer as Conductor

- The SoSE System Engineer
  - Balances the process flow between parties
  - Manages the interdependencies of the constituent systems to produce global behavior that they cannot produce alone

- Key Hard Skills
  - Capabilities & Requirements
  - Iterative Development
  - SoS Integrator
- Key Soft Skills
  - Leadership
  - Collaboration
  - Influencing

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Adapted from: (Walden, 2007) (Walden, 2019) (Walden, 2020)

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Socio-Technical Systems

Image Source: (INCOSE Vision 2025, 2014)

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Social Systems Engineering

- Social systems engineering is a reciprocal relationship between systems engineering and the social sciences
  - Adapting/applying systems engineering methods/tools in a range of social policy areas in industry, government and academia
  - Developing/applying social science theory and methods for the integration of teams and communities that are engineering systems

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Adapted from: (Palmer, et al., 2021)

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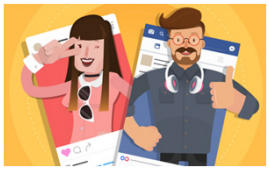
Social Systems Engineering: The Systems Engineer as Influencer

- The Social System Engineer
  - Understands the overall social objectives for the system
  - Develops system elements that facilitate much more complex social functions
  - Leverages the "-ologies" (e.g., sociology, psychology, geography, history, political science, economics, anthropology) in addition to the "-ilities"



- Key Hard Skills
  - Policy
  - Iterative Development
  - Continuous Co-Design
  - "-ologies"
- Key Soft Skills
  - Ethics
  - Empathy
  - Conflict Management
  - Politics

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Adapted from: (Palmer, et al., 2021) (Donaldson, 2017)

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Wrap-up/Summary

- This talk discussed why and how Systems Engineering Practitioners need to move beyond their traditional Document-Centric, Greenfield (clean/blank-sheet) Systems Engineering heritage as we move forward to tackle the ever-increasing complexities of the future.
- This talk also discussed how transitioning beyond Greenfield Systems Engineering requires additional hard skills and soft skills to help ensure success.

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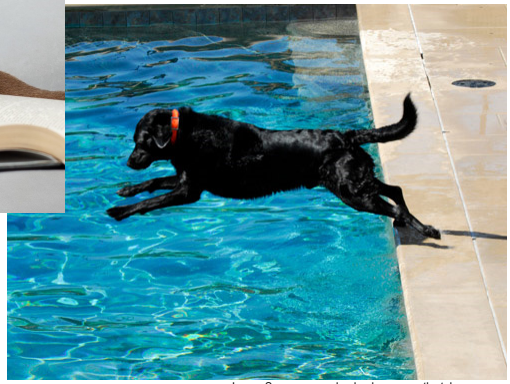
Remember – Soft Skills are a Participatory Activity!



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Thank You!

Comments?
Questions?

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