The Development of an Architecture Framework for Systems Engineering Process Simulators

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Agenda

- Introduction & motivation
- Key terms
  - Systems Engineering (SE) process simulators
  - Framework
  - Architecture
  - Architecture framework
- SE process simulator architecture framework overview
- Elements of SE process simulator architecture framework
- Summary

Motivation

- As systems become more complex, systems engineering becomes more critical
- "Demand is soaring for systems engineers, as **what was once a niche job** in the aerospace and defense industries **becomes commonplace** among a diverse and expanding universe of employers, from medical device makers to corporations like Xerox and BMW."

  (CNN Money 2009)
- Greater demand + workforce retirement expected → long term shortage of systems engineers
- Necessary to accelerate development of senior systems engineers

Motivation

- Increasing complexity of systems can lead to greater project and management complexity
- A systems project can be as "complex as the engineering solution with behavior that is extremely dynamic in nature" (Stupples 2002)
  - Projects can have a significant quantity of dynamic and interacting process and socio-technical factors
- SE process decisions impact important project success indicators related to cost, schedule, quality, and risk
  - Important to understand the impact of process and policy decisions & to provide tools and methods that can support such decisions

Motivation

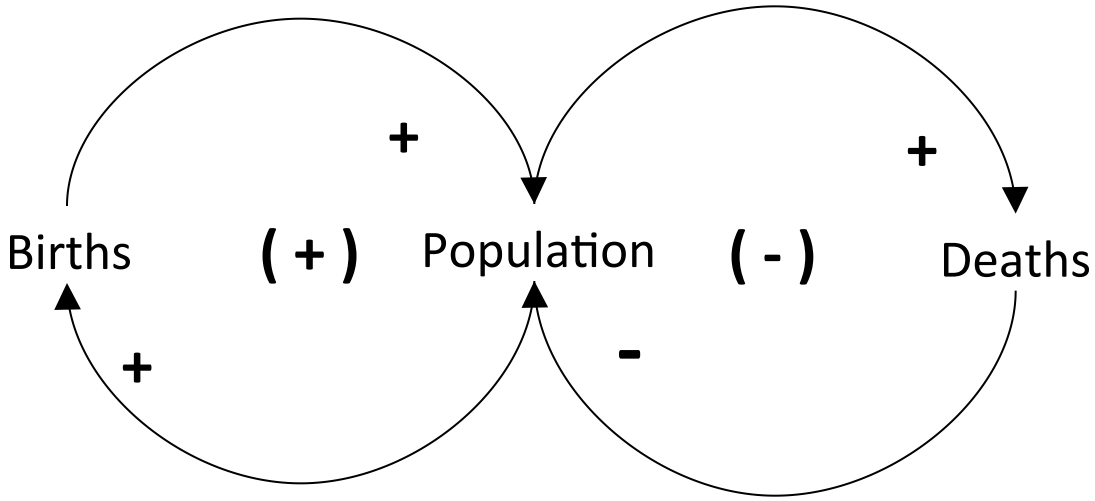
- "Systems Thinking" is an important skill/ability required by systems engineers
- Systems Thinking: an ability to see the world as a complex system and understanding its interconnectedness (Sterman 2000)
- Understanding a system's dynamics can promote "systems thinking"

System Dynamics

- System dynamics can help in understanding the complicated and nonlinear relationships between the many socio-technical factors and measures related to engineering projects
- Developed by Jay Forrester in 1950's
- Considers cause-effect relationships and feedback control
  - Feedback or causal loop occurs when an element of a system influences itself over time
- Causal loops can be represented by factors with relationships shown as links between factors

System Dynamics

- Simple example (Hitchins 2007)



- Models consist of multiple related causal loops

SE Process Simulators

- Can incorporate understanding of a system's dynamics in a simulator
- Simulation can be used to:
  - Study & understand complex situations
  - Evaluate "what-if" scenarios with low risk
  - Explore dynamic consequences of various decision alternatives
  - Provides exposure to scenarios and results that might be difficult to obtain in the real work situation
  - Educate and cross-train current and engineers-in-training
    - Accelerate understanding of important factors and their interconnectedness/relationships and impact

SE Process Simulators

- No impact to real system & environment
- Use as a foundation for further research to explore risks and issues related to systems engineering
- Methods and enablers required for the development and organization of SE process simulators

Definition: Framework

- "a basic conceptual structure (as of ideas)“ (Merriam-Webster 2010)
- Can be used to understand, organize, and manage complex areas
- Useful for the development of systems engineering process simulators
  - Provide a means to characterize and capture critical aspects of simulators
  - Provide guidance and a common structure to support the development of an architecture for SE process simulators

Definition: Architecture

- “the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution” (IEEE 2000)
- “the organizational structure of a system or component” (IEEE 1990)
- Provides a bridge from requirements to design
- Allows a developer to verify important system properties before significant resources are invested to construct a system (Ferreira et al. 2010)

Definition: Architecture Framework

- "conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders" (ISO/IEC 2011)
- Existing architecture frameworks:
  - DODAF
  - MODAF
  - Zachman Framework

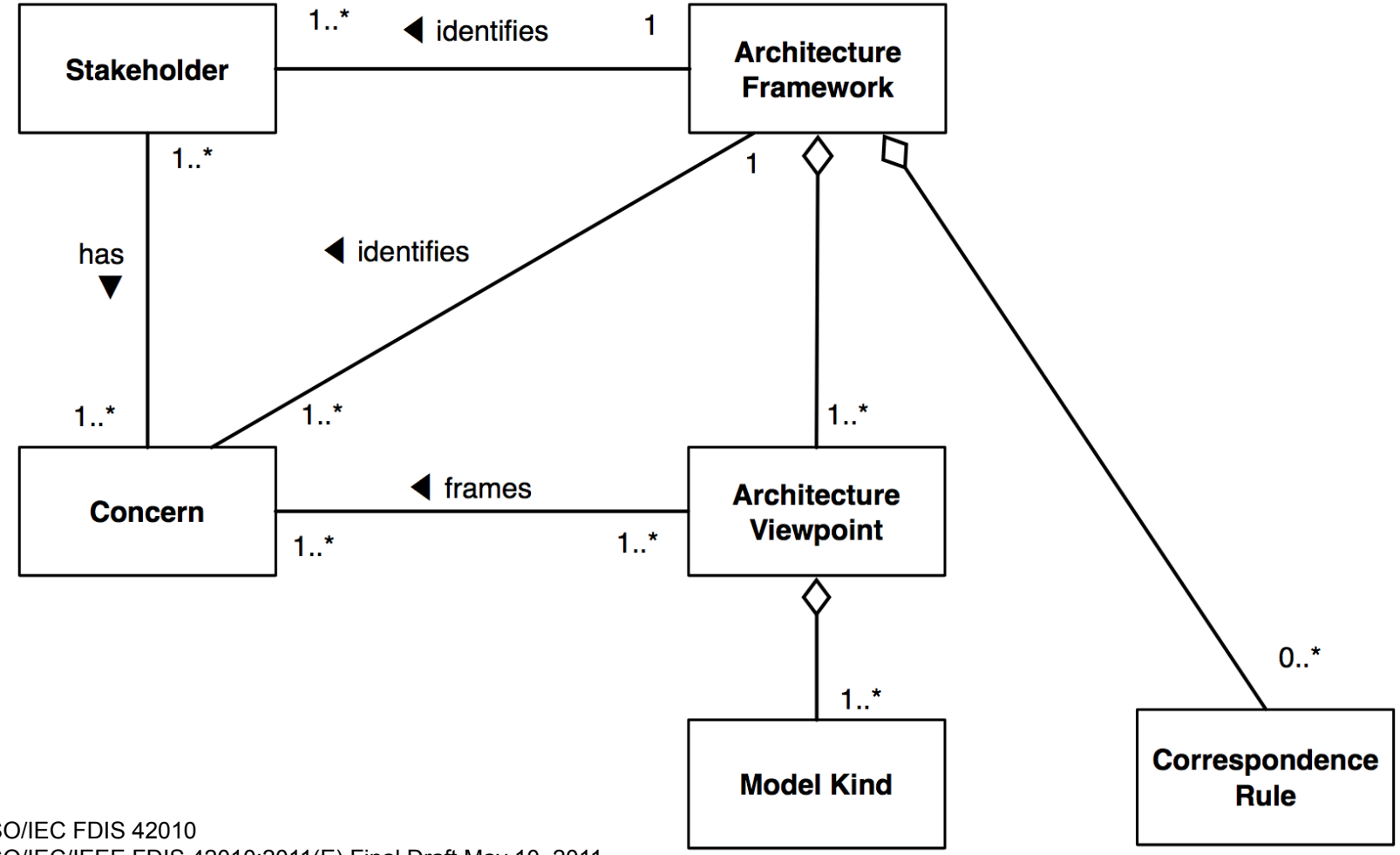
Why Develop a New Framework?

- An architecture framework provides a basis for specifying the architecture description for systems engineering process simulator models
- Evaluated existing software engineering simulator frameworks
  - Existing software engineering process simulator frameworks primarily focus on particular modeling concerns such as:
    - Modularity
    - Reuse
    - Software engineering processes

SE Process Simulator Architecture Framework Overview

- The ISO/IEC/IEEE FDIS 42010 (ISO/IEC 2011) standard (working document – final draft) provides a larger conceptual perspective for architecture descriptions than currently exists for software process simulator frameworks
  - Codifies the current "architectural thinking" to "facilitate common application and evolution of available and emerging architectural practices“
  - Considers both systems and software engineering viewpoints

Architecture Framework Conceptual Model



ISO/IEC FDIS 42010
ISO/IEC/IEEE FDIS 42010:2011(E) Final Draft May 10, 2011

Elements of Architecture Framework

- Elements of this standard applied to develop an SE process simulator architecture framework
  - Architecture Description
  - Simulator Stakeholder
  - Simulator System Concern
  - Simulator Architecture View
  - Simulator Architecture Viewpoint
  - Simulator Model Kind
  - Simulator Correspondence Rule
- Framework can be used as a basis to develop an architecture description for individual simulator instantiations

Architecture Description

- "Work product used to express an architecture" (ISO/IEC 2011)
- Defines an architecture
  - Instantiates an architecture framework
- The architecture description is specific to the simulator to be developed and contains
  - Version
  - Simulator identification information

Simulator Stakeholder

- A stakeholder is any individual, group, or organization that has an interest in the system (ISO/IEC 2011)
- The primary stakeholders of the systems engineering process simulator are
  - Simulator user(s)
  - Simulator developer(s)
- Simulator users are the end users
  - Utilize and gain benefit from the systems engineering process simulator
- Simulator developer creates the simulator

Simulator System Concern

- A system concern is an "interest in a system relevant to one or more of its stakeholders" (ISO/IEC 2011)
- System concerns would include
  - Purposes of the simulator
  - Suitability of architecture to achieve purposes
  - Feasibility of creating the simulator
  - Risks to the stakeholders and its effects on the simulator
  - Maintainability and flexibility of the simulator

Simulator System Concern

- System concerns can relate to any influence on a system in its environment. These influences can include
  - Development, technology, business, operation, organization, politics, regulatory, or social.
- Can use the model purpose and scope referenced in Kellner, Madachy, and Raffo (1999) to express some of the system concerns which should be considered in each architecture description

Simulator Architecture View

- An architecture view refers to the architecture of a system with respect to specific system concerns (ISO/ IEC 2011)
- Each view is directed and ruled by an architecture viewpoint
- Architecture views describe the architecture of the simulator in accordance with the simulator system concerns and the simulator architecture viewpoint
- A view is an outcome of applying a viewpoint to a system & there can be multiple views for the simulator architecture
  - For example: physical and logical views are two different views of the simulator architecture

Simulator Architecture Viewpoint

- An architecture viewpoint determines the conventions used to describe an architecture view (ISO/IEC 2011).
- Viewpoint conventions can include
  - Notations, model kinds, and/or modeling methods, as well as analysis techniques, among other items

Simulator Architecture Viewpoint

- Can encompass a variety of categories of information including
  - Product
    - Includes a single product or multiple products
    - Considers product factors such as system size, complexity, as well as other product measures
  - Process/function
    - Represent different processes or functions within various systems engineering lifecycles such as ISO-15288 (ISO/IEC 2008) or EIA 632 (GEIA 1999)
  - Resource
    - Contains information about people resources as well as other resources used in a project
  - People
    - Includes quantities of various categories of personnel, their skill level, etc.
  - Organization
    - Considers organizational policies and constraints
  - Environment
    - Considers impacts from externally represented factors or groups

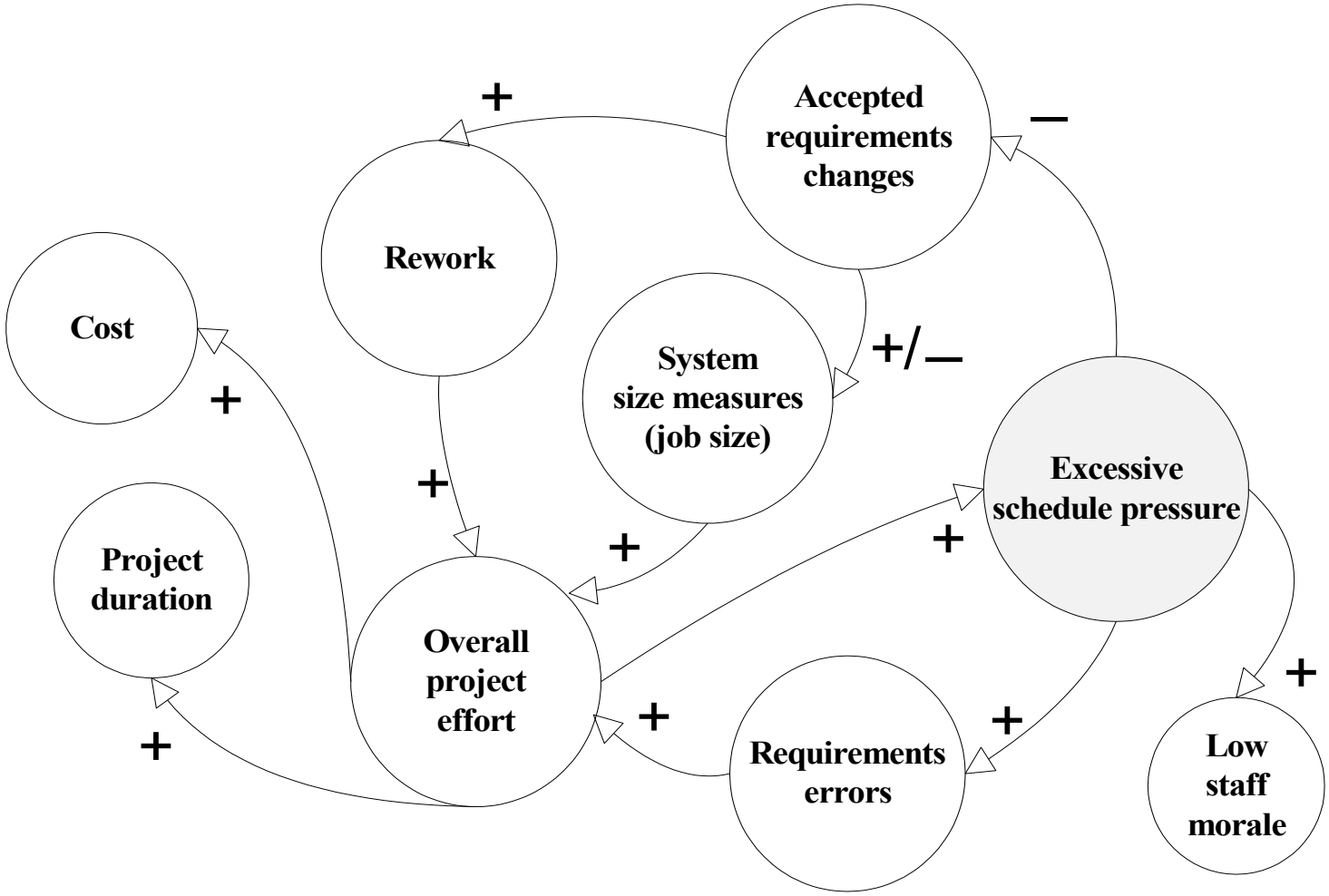
Simulator Model Kind

- ‘a convention associated with one type of modeling’. (ISO/IEC 2011)
  - Examples include: data flow diagrams, class diagrams, Petri nets, and state based models
- SE process simulator model kinds may include causal models, class diagrams, state models, process flows, and other architecture diagrams as appropriate

Simulator Model Kind – Causal Model

- Causal models are a very important enabler for system dynamics models
- System dynamics uses causal models to represent cause and effect relationships between factors
- Causal models provide an understanding of the behavior of a system

Excessive Schedule Pressure Causal Model

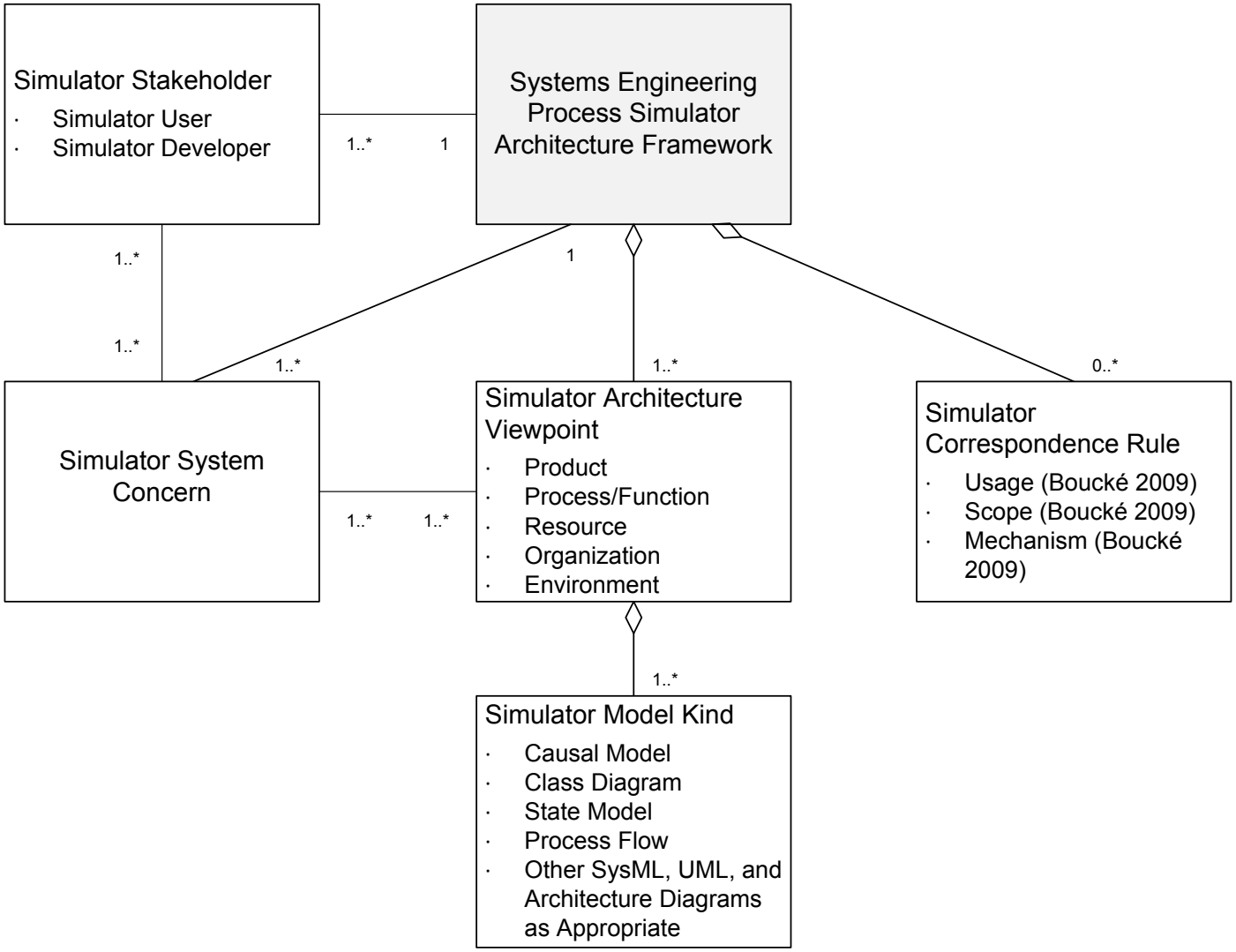


Ferreira (2010b) and Houston (2000)

Simulator Correspondence Rule

- Correspondences identify relationships between various architecture description elements including architecture viewpoints
- Boucké (2009) characterizes relationships between architecture views using three categories:
  - Usage
    - Defines use cases considering the relations between views
      - » For example, in the SE process simulator framework, this correspondence rule category pertains to how different architecture viewpoints like process and resource can be used in a combination
  - Scope
    - Represents the range of the relationships between different architecture views
      - » In the simulator architecture framework, each architecture viewpoint can have a relationship within the viewpoint and with other viewpoints such as within various types of resources and also with other viewpoints.
  - Mechanism
    - The mechanism category provides a way to represent the relationships between views

SE Process Simulator Architecture Framework



Summary

- Systems engineering process simulators allow users to explore risks and evaluate the consequences of various project and process related decisions
- These types of simulators can provide a means to reason about and explore alternative options
- An architecture framework is presented as an enabler for the development of systems engineering process simulators

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