SoSECIE Webinar

Welcome to the
2018 System of Systems Engineering Collaborators Information Exchange (SoSECIE)

We will start at 11 am Eastern Time

Skype Meeting +1 (703) 983-2020, 46013573#

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https://www.acq.osd.mil/se/outreach/sosecollab.html

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NDIA System of Systems SE Committee

- **Mission**
  - To provide a forum where government, industry, and academia can share lessons learned, promote best practices, address issues, and advocate systems engineering for Systems of Systems (SoS)
  - To identify successful strategies for applying systems engineering principles to systems engineering of SoS
- **Operating Practices**
  - Face to face and virtual SoS Committee meetings are held in conjunction with NDIA SE Division meetings that occur in February, April, June, and August
  - SoS Track at NDIA Annual Systems Engineering Conference

NDIA SE Division SoS Committee Industry Chairs:
Mr. Rick Poel, Boeing
Ms. Jennie Horne, Raytheon
OSD Liaison:
Dr. Judith Dahmann, MITRE

Simple Rules of Engagement

- I have muted all participant lines for this introduction and the briefing.
- If you need to contact me during the briefing, send me an e-mail at knharrington@mitre.org.
- Download the presentation so you can follow along on your own
- We will hold all questions until the end:
  - I will start with questions submitted online via the CHAT window in Skype.
  - I will then take questions via telephone; State your name, organization, and question clearly.
- If a question requires more discussion, the speaker(s) contact info is in the brief.

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2018 System of Systems Engineering Collaborators Information Exchange Webinars

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November 27, 2018

Emergence as a Subject of Research, Research Methods, and Engineering Knowledge and Practice

Dr. Timothy L.J. Ferris, Centre for Systems Engineering, Cranfield University, Defence Academy of the United Kingdom

2019 SoSECIE Webinar Dates to Come

Emergence as a Subject of Research, Research Methods, and Engineering Knowledge and Practice

Dr Tim Ferris

21/June/2017

www.cranfield.ac.uk

What is Emergence?

- Emergence is the effects one observes when a system is assembled that are not observed in the parts
  - Parts have properties
  - Wholes have properties which are the result of the parts and the interaction of the parts
- Engineering design is done to cause emergent effects
  - Planned effects are the intention of design
  - Surprises happen because unplanned things happen
  - Some surprises are fortuitous, many are viewed as bad

Classical Epistemological Account of Knowledge

- *S* knows that *p* if and only if
- 1. *p* is true;
- 2. *S* believes that *p*; and
- 3. *S* is justified in believing that *p*
  - Minor variations exist
- Knowledge in the sense of this account is central in science

Knowledge in Engineering

- Engineering is pragmatic
  - Things are done to achieve an end
  - Knowledge is valued as means to enable achievement of an end
    - Knowledge must be sufficiently complete – span of subject matter
    - Completeness demands an appropriate level of detail
    - Knowledge must be sufficiently accurate – or at least a known accuracy so predictions can be bounded
    - The intellectual purity and consistency of the knowledge is not paramount
  - The engineer is concerned to have knowledge which can be relied on to make fair predictions of what will happen when something is built

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- Science is focused on knowledge
  - Theoretical purity and consistency are the focus
    - The goal is the knowledge

Interpretation in Terms of Grammar

- Science is concerned with describing what is
  - Has to do with certainty and confidence, description of extant things
  - Scientific knowledge is expressed in indicative forms
- Engineering is concerned with proposals and realisation with the purpose of producing an effective solution to a need
  - Knowledge begins with the hypothetical space
    - What could, would or should be (this is the subjunctive mood verb form that concerns possible solutions to needs)
  - Engineering expression is actually written in the indicative form
  - But the logic in engineering is subjunctive
    - This concerns proposals to address something which is first hypothetical – followed by a decision to instantiate

Knowledge in Engineering

- Engineering is pragmatic
- Science is focused on knowledge
- How do the two foci interact?
- We are looking for a way of knowing emergence which includes both
  - Knowing about emergence – the ability to describe the general characteristics of emergence
  - Knowing what is emergent in specific project cases

Knowledge of Emergence

- Two kinds
- General description of emergence
  - Focus on characterising the phenomenon of emergence
  - Formulation of precise definition
  - Description of the properties of emergence
  - Methods for abstractly describing emergence (e.g. mathematical formulations that describe the effect)
- Fundamentally a scientific description of emergence as a phenomenon

Knowledge of Emergence

- Research methods applicable to discovery of knowledge in the classical epistemological sense fit
- Commonly recognised methods include:
  - Case studies (general outsider and forensic discovery empowered forms)
  - Post hoc observational studies
  - Experimental studies
  - Investigation of fundamental theory
- These methods enable description of the manifestation of emergence in existing cases
  - Interesting
  - Enlightening about the general character of emergence
  - But does not provide case predictive knowledge related to future systems or events

Knowledge of Emergence

- Second kind
- Predicting and managing the occurrence of emergence
  - Use of scientific knowledge of phenomena and the properties of things to predict the behaviour of design proposals
  - Identification of situations in which interaction effects may be generated
  - Correlation of such situations with prior knowledge of emergent effects
  - Investigation of emergent phenomena not previously understood to improve the knowledge base of emergent effects
- Fundamentally an engineering concern

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- Fundamentally an engineering concern
- The methods required to discover and to use this knowledge need to accommodate uncertainty, hypothetical situations, speculation and other effects not in the ‘indicative space’
  - i.e. The methods must suit the ‘subjunctive space’

Engineering Research into Emergence

- The goal is to discover means to achieve desired outcomes
  - We want to know what will happen if we make a particular intervention in the world
  - We need to know if the proposal is safe
  - We need to know if the proposal will result in untoward or compromising outcomes
  - We want to know if the proposal will generate unplanned affordances
  - We need to know how the proposed intervention will behave in the absence of some service which it assumes will be provided from within or without the system
  - We need to know how the system will behave in the event of changes in the environment around the system

Resilience – a phenomenon involving emergence

- There are several schools of thought about resilience
- My position is that resilience deals with the fact of life that engineered stuff breaks
  - So the concern of resilience is understanding system behaviour under conditions of various failures (singly and in combination)
- Elements of a system may fail:
  - Independently, as random events (a reliability related issue)
  - Dependently, failure of one causes loads that lead to failure of another
  - Sequentially, this expresses time relationship but does not express the physical causal relationship (independent or dependent)

Measurement of resilience

- Most measures of resilience use a relatively simple description
  - ‘Performance’ level – how much of ‘full’ performance is available?
  - Time to recover after insult – but is recovery ALWAYS desirable, for all systems?
- Systems development uses tradeoff analysis to decide between alternative proposals
  - Usually done by a weighted sum of value-to-scale results
  - At this stage the system is seen as static
- Resilience concerns the dynamic of the system performance in the context of its environment and the events in the environment
  - This gives a basis for measuring resilience through the achieved available performance of a system
  - Therefore we have a method to compare the resilience of various alternatives

Lifecycle analysis of resilience

- Proposed method to address measurement of resilience
  - Construct a plurality of alternatives with descriptions of the system elements including random failure statics, failure under threat statistics and dependent failure statistics (when other system elements have failed)
  - Execute a Monte Carlo model of a high plurality of lifecycles of the system to find a distribution of resilience measures achieved
  - Compare the measure distributions to rank the ‘desirability’ of each alternative
- This approach requires means to determine performance of the system with impaired performance of various (specific) system elements
- This approach provides means to compare system proposals with the emergence of diverse systems element impairments – to enable judgement o preference of alternatives

General need

- Resilience is a specific example in which events lead to diverse outcomes, depending on what events have happened
- General need is for means to predict the effect of combinations of elements/effects in general