Systems Engineering as a Data-Driven and Evidence-Based Discipline

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To protect the health and safety of our community, the 30th Annual INCOSE International Symposium (IS2020) will be held virtually July 20-22, 2020. Below you will find important information and expectations for your participation in the Symposium virtual technical program.

Your paper, "Systems Engineering as a Data-Driven and Evidence-Based Discipline", will be presented at the following session:
Session Number: 8.2
Session Title: Technical Leadership III
Date: Wednesday, 22 July
Time: 14:00-14:40 UTC+2

Introduction

In this paper, we present opportunities for Systems Engineering (SE) to evolve towards a data-driven and evidence-based discipline, thereby making better systems and engineering decisions. We discuss how systems engineers can apply data-driven and evidence driven characteristics through systems engineering processes and programs.

“We stand on the brink of technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before.”

Klaus Schwab
Founder and Executive Chairman,
World Economic Forum

This is an opportunity for analytics, statistics and data science

Systems Engineering as a Data-Driven Discipline

DESIGN AND MANUFACTURE

Governance: Well-managed manufacturing based on data

Digitization: Latest manufacturing technologies driven by big data

Metadata: Inventory management

* Kenett and Redman (2019) The Real Work of Data Science, Wiley

Systems Engineering as a Data-Driven Discipline

- SE is based on engineering requirements, engineering calculations, testing, modelling & simulations- all of them are based on data or data generation
- However, too often systems engineers make decisions based on intuition, previous experience and/or qualitative assessments

The traits of being data driven (1)

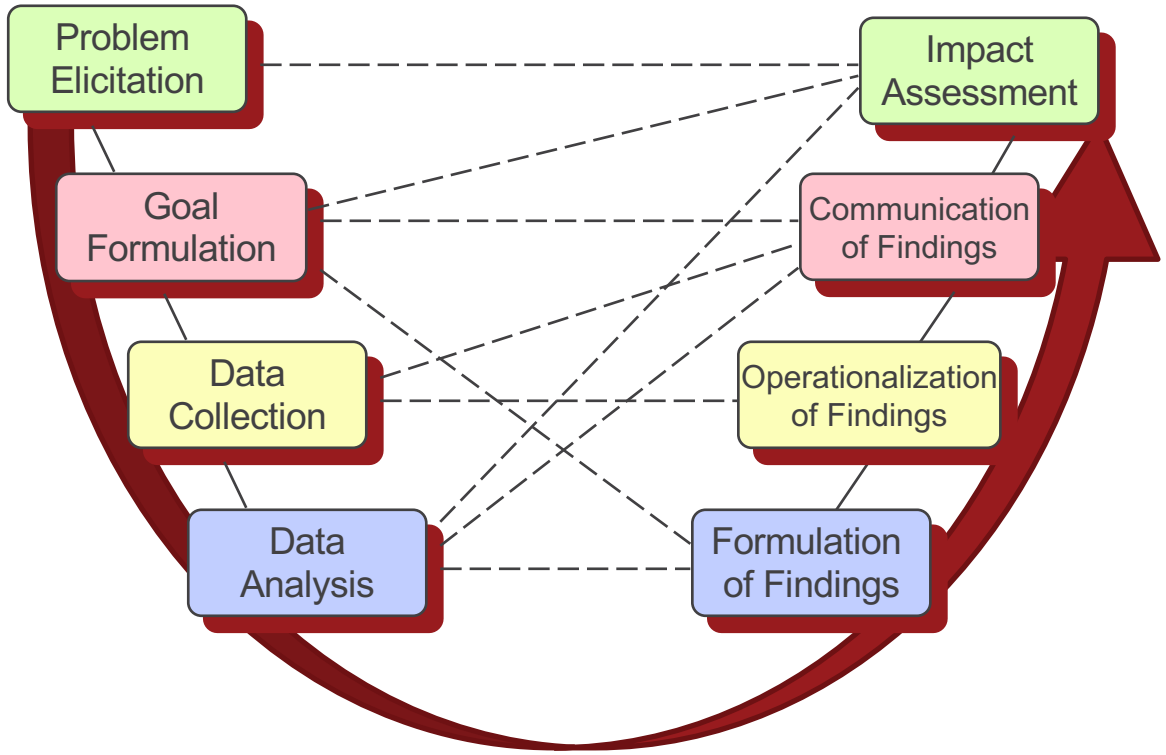
- Bring as much diverse data and as many diverse viewpoints to any situation as SE possibly can
- Use data to develop deeper understanding of the business context and the problem at hand
- Develop an appreciation for variation, both in data and in the overall business

The traits of being data driven (2)

- Deal reasonably well with uncertainty
- Recognize the importance of high-quality data and invest in trusted sources and in making improvements
- Conduct good experiments and research to supplement existing data and address new questions
- Recognize that the criteria on which a decision is based can vary with circumstances

Applying a Data Life-Cycle View to Systems Engineering (1)

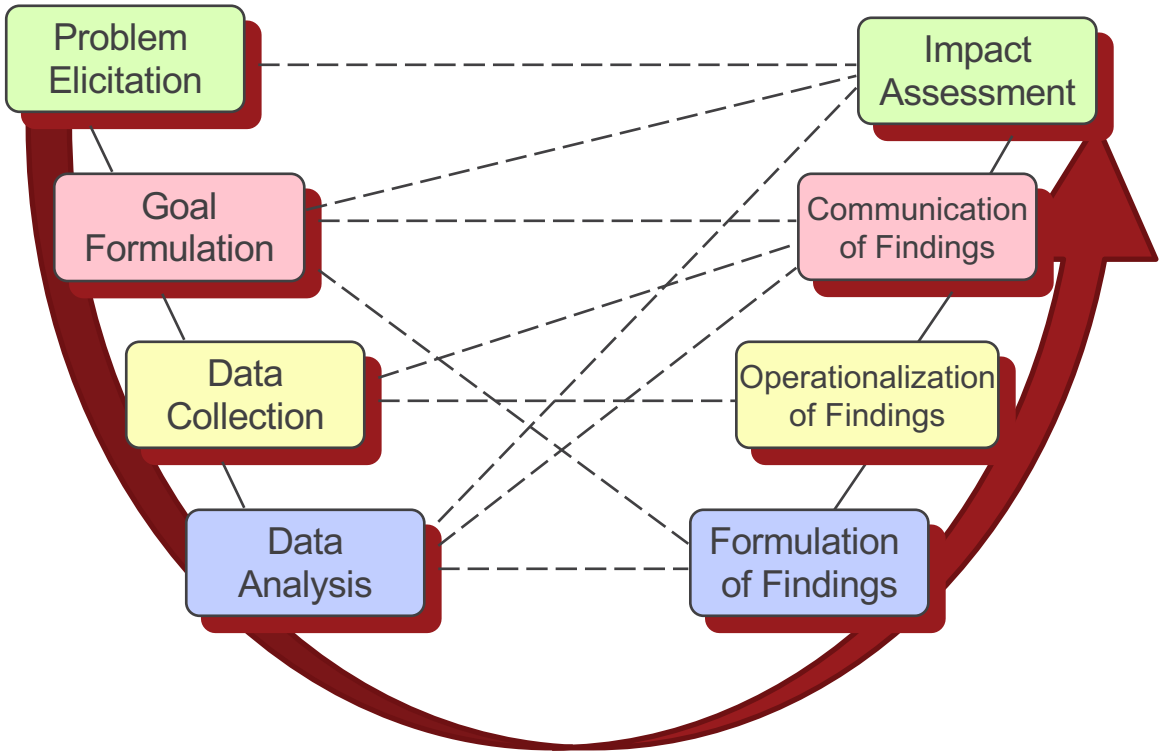
- Problem elicitation- defining the problem to be resolved by the developed system
- Goal formulation- the goal and the mission of the system
- Data collection- gathering data on similar systems solutions and performances, collect data on the planned environment for the system



* Kenett (2015) Statistics: A Life Cycle View *Quality Engineering* (with discussion), Vol. 27, No.1, pp. 111-129

Applying a Data Life-Cycle View to Systems Engineering (2)

- Data analysis- apply the appropriate descriptive, explanatory and predictive methods with systems view
- Formulation of findings- present the results and recommendations for decisions which are relevant to the systems design and engineering
- Operationalization of findings- implement the findings through the systems engineers and decisions makers
- Communication of findings



* Kenett (2015) Statistics: A Life Cycle View *Quality Engineering* (with discussion), Vol. 27, No.1, pp. 111-129

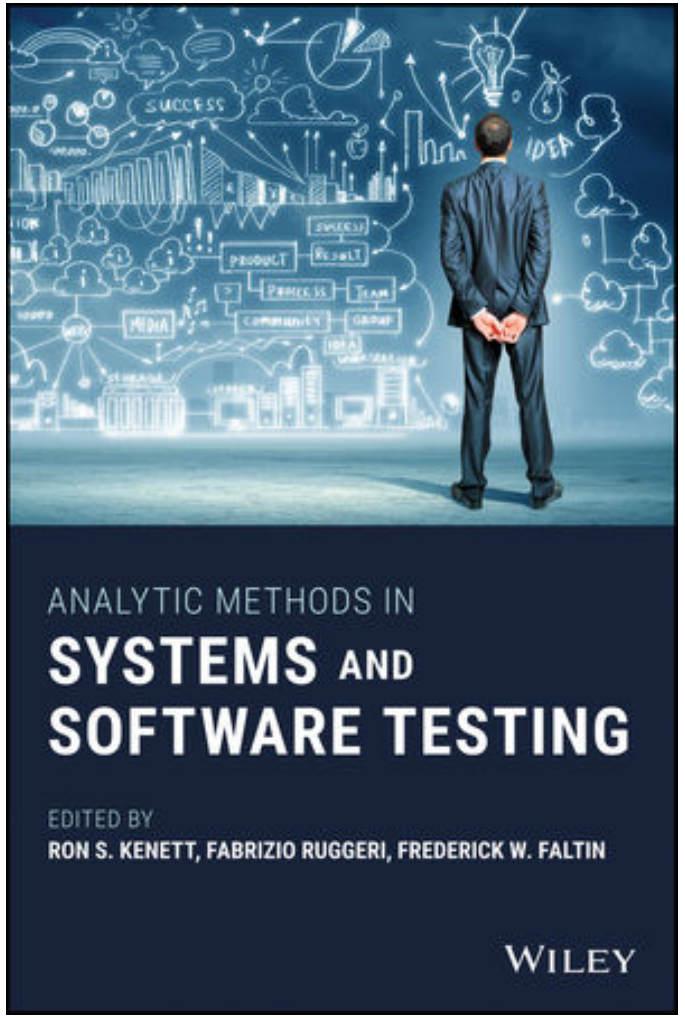
Model-Based Systems Engineering

- Adapting Models (in plural) Based Systems Engineering approach, by applying different modelling and simulations tools and methodologies.
- The Models Based Systems Engineering approaches are powerful tool to collect, generate and analyse data about the systems under development.
- The models provide systems engineers with quantitative data on the performances of the systems

Advantages of using Models & Simulations

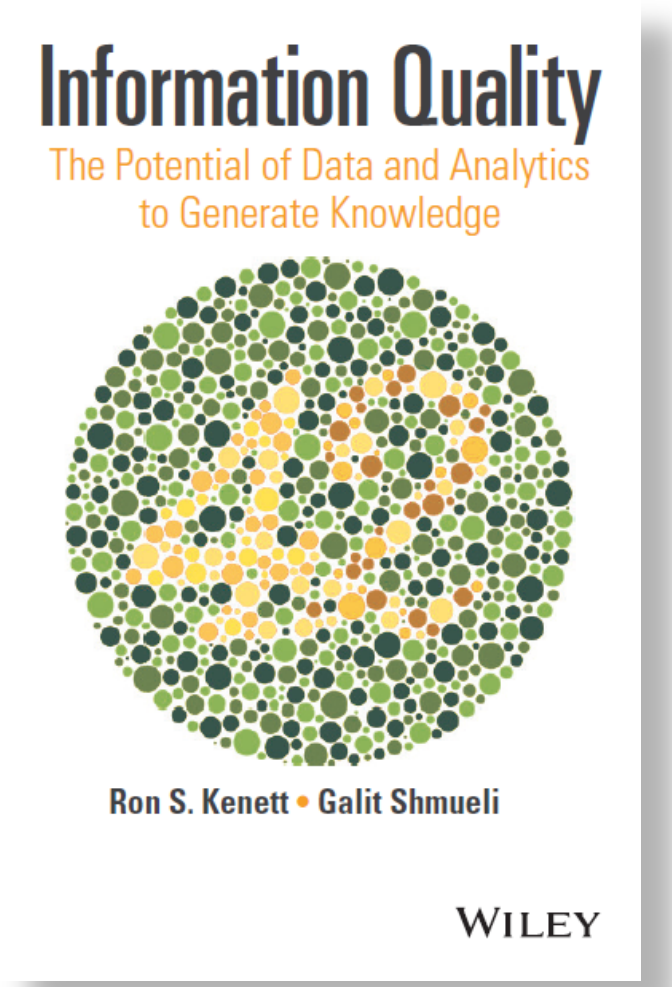
- Models document the “truth” on the system parameters and behaviour
- Models based on data analytics create valuable data through simulations
- Models represent a unique source of information for manufacturing, integrating and deploying systems
- Models support and ease the possible changes

Evidence-Based Systems Engineering



- Research and Development of Validated Systems Engineering Processes
- Using Statistical Techniques in the Design of System Tests and the Analysis of Resulting Data
- Model-Based Systems Engineering as a Source for Evidence-Based Engineering Decisions

Information Quality



$$InfoQ(U,f,X,g) = U(f(X|g))$$

InfoQ Dimensions

1. Data resolution
2. Data structure
3. Data integration
4. Temporal relevance
5. Chronology of data and goal
6. Generalizability
7. Operationalization
8. Communication

Applying data analytics

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15th Global Conference on Sustainable Manufacturing

A road map for applied data sciences supporting sustainability in advanced manufacturing: the information quality dimensions

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The Maturity Ladder for Systems Engineering as a Data-Driven and Evidence-Based Discipline

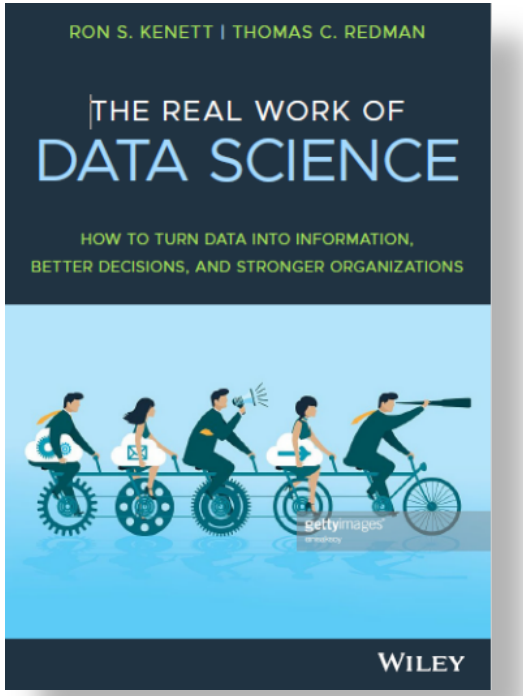
Level 5: *Learning and discovery* - This is where attention is paid to information quality. Data from different sources is integrated. Chronology of Data and Goal and Generalization is a serious consideration in designing analytic platforms. **Leverage causality models.**

Level 4: *Quality by Design* - Experimental thinking is introduced. The data scientist suggests experiments, like A/B testing, to help determine which website is better. **Develop causality analysis**.

Level 3: *Process focus* - Probability distributions are part of the game. The idea that changes are statistically significant, or not, is introduced. Some attention is given to model fitting. **Introduce causality analysis.**

Level 2: *Descriptive statistics level* – Management asks to see histograms, bar charts and averages. **Models are not used, data is analyzed in rather basic ways.**

Level 1: *Random demand for reports driven by firefighting* - New reports address questions such as: How many components of type X did we replace last month or how many people in region Y applied for a loan?



Implementation Systems Engineering as a Data Driven and Evidence Based Discipline

- Traditionally SE is process and procedure oriented, so the transformation to a data driven and evidence-based discipline is not an easy task
- Transformation lead by top management
- Initiating by data analytics maturity assessment and measuring information quality and assessing the SWOT of the organization in these areas
- Launching data science education

Case Study A:Complex Missiles Systems

Demonstrating Data-Driven Systems Engineering: Case Study A

- The Mission: Developing, engineering and delivering of a complex system with innovative technologies
- Advanced systems engineering
- Lessons learned and data collection from previous projects
- Extensive systems testing
- Extensive modelling and simulations of subsystems
- Reliability and Safety Analysis based on data and evidence
- Design Reviews focused reviewing engineering decisions based on data, modelling and simulation

Case Study B: UAV System

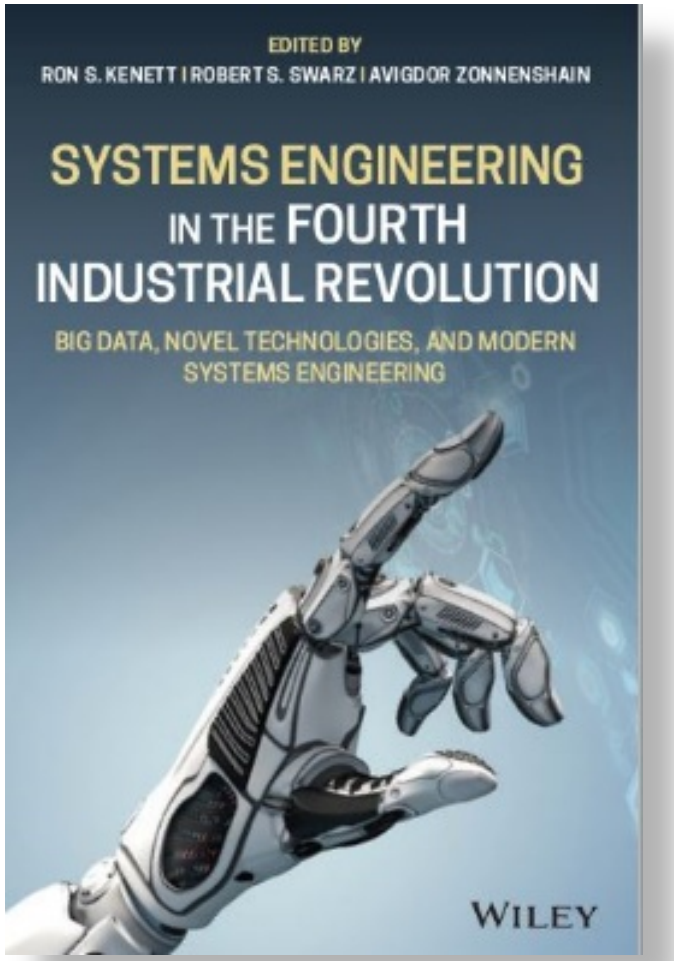
Demonstrating Data-Driven Systems Engineering: Case Study B

Kinematic models for flight control of a coaxial Un-manned Arial Vehicle (UAV)

This case was developed by S. Yehezkel, A. Bachnoff from RAFAEL LtD.

This case study demonstrates how systems engineering can benefit from data driven models by using digital-twin-simulations to produce simplified models from which one can easily produce insights, evaluate and improve the design of complex mechanical systems.
It validates the decision-making process, improve engineering communication and shorten the TTM

Systems Engineering in the 4th IR



- A new edited book on Advanced SE
- 22 chapters by 30 leading international contributors on diverse modern topics
- A study guide is planned

Conclusions

- This paper is about the promise of data-driven and evidence-based systems engineering
- The 4th Industrial Revolution is based on digital transformation and the Big Data revolution, which can be applied to all SE life-cycle domains
- It is recommended that systems engineers should be educated in data science programs through academia, companies & professional societies

COVID-19 EFFECT

- Coping with COVID-19 crisis through the health , economics & social aspects should implement systemic approach driven by data and based on evidences
- It is an opportunity and a challenge for the systems engineering discipline
- Keep yourselves healthy and safe

THANKS!

QUESTIONS?