



# Beyond MBSE: Looking towards the Next Evolution in Systems Engineering

David Long  
INCOSE President  
david.long@incose.org  
@thinkse



tools life  
issues deals  
different  
optimization  
difficult  
requirement  
coordination  
disciplines  
System  
reliability  
design  
large  
met  
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risk  
interdisciplinary  
teams become  
large  
design met  
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# Systems Engineering

**Systems Engineering is an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholder's needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system's entire life cycle.**

International Council on Systems Engineering



# Systems Engineering

A word cloud background with various terms related to systems engineering. The most prominent words are 'Systems Engineering' in large, bold, blue letters. Other visible words include 'management', 'interdisciplinary', 'risk', 'complex', 'tools', 'life', 'issues', 'deals', 'different', 'optimization', 'difficult', 'requirement', 'coordination', 'disciplines', 'evaluation', 'dealing', 'field', 'teams', 'become', 'large', 'on', 'methods', 'ability', 'logistics', 'manage', 'focuses', 'interdisciplinary', 'management', 'risk', 'complex', 'tools', 'life', 'issues', 'deals', 'different', 'optimization', 'difficult', 'requirement', 'coordination', 'disciplines', 'evaluation', 'dealing', 'field', 'teams', 'become', 'large', 'on', 'methods', 'ability', 'logistics', 'manage', 'focuses'.

**Systems engineering collects and organises all the information to understand the whole problem, explores it from all angles, and then finds the most appropriate solution.**

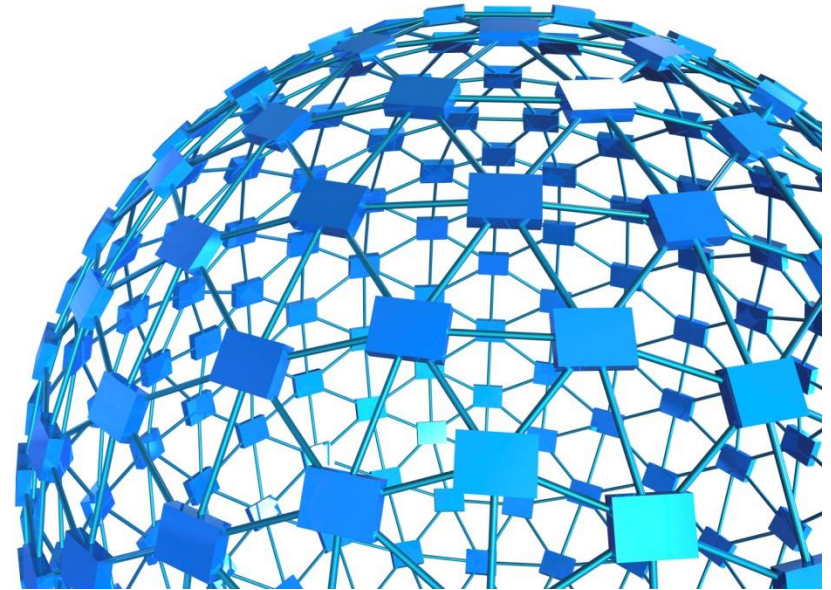
**Richard Beasley, Rolls Royce SE Fellow**

# System Characteristics Our Stakeholders Demand

- Sustainable
- Scalable
- Safe
- Smart
- Stable
- Simple
- Secure
- Socially Acceptable



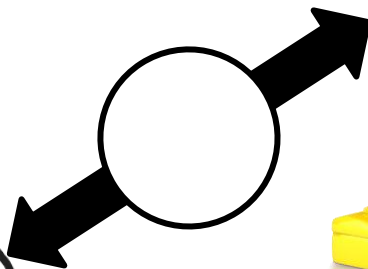
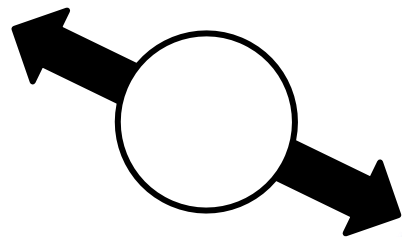
- Interconnected
- Interdependent
- Complex



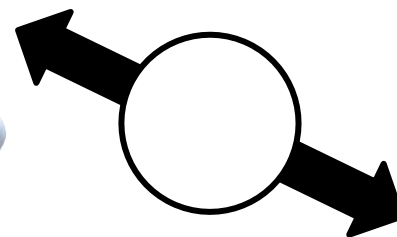
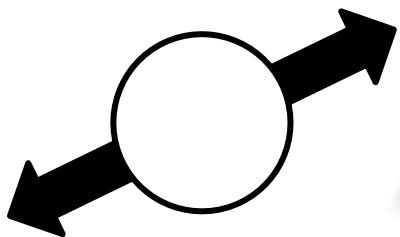
Adapted from Alan Harding, 2014



# Connecting across the Project: Communications, Semantics, Analysis



Requirements  
Architecture



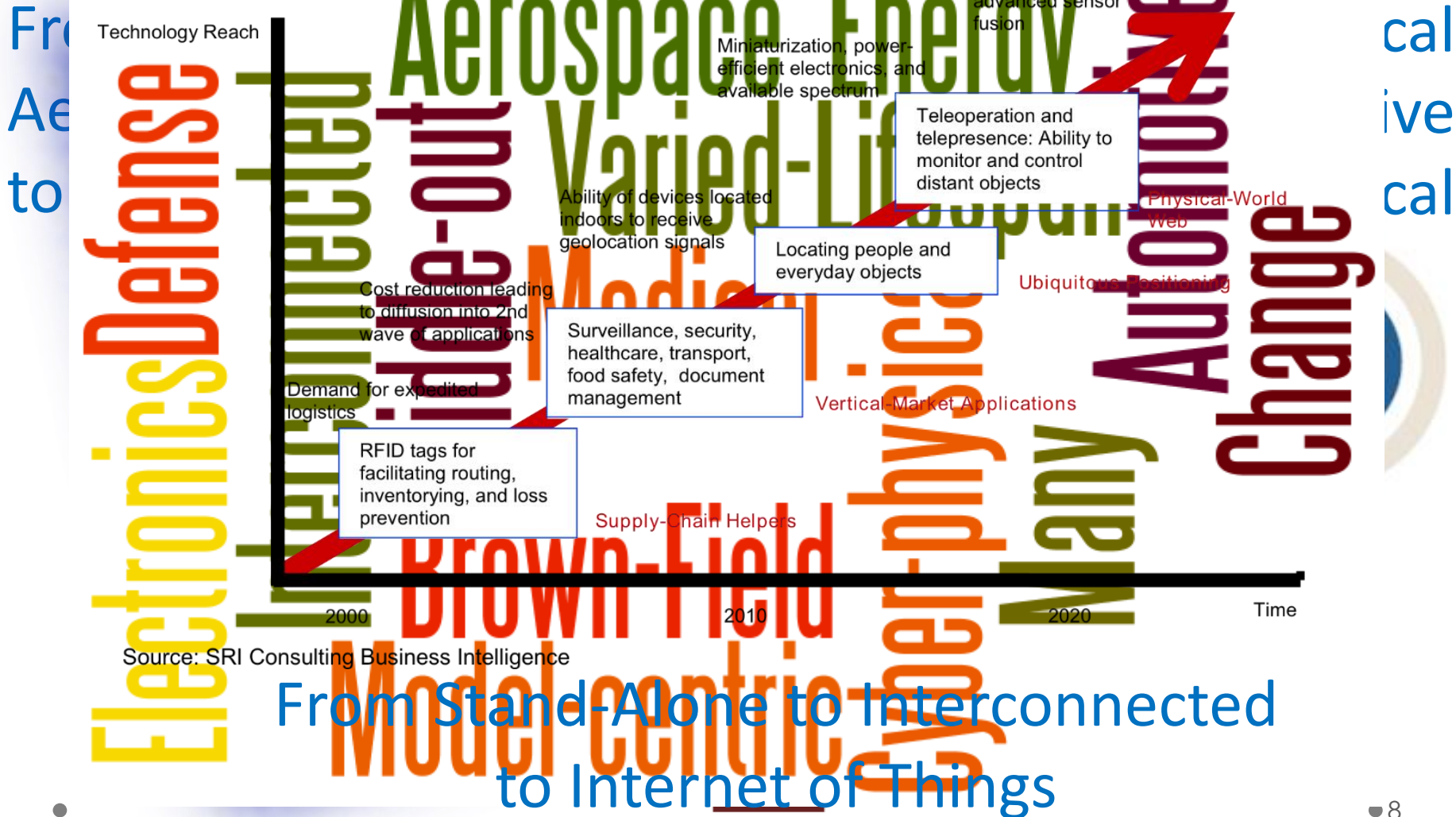
# Origins of “Systems Engineering”





# A Changing Environment for SE

— TECHNOLOGY ROADMAP: THE INTERNET OF THINGS —





# Looking at Challenges in the Energy Domain – Classic and New



Power and Energy EU www.ngpowereu.com

## Smart Grids



Credit Kleineth Oliveros

All sources will be interconnected allowing consumers to access a general and renewable generated source of energy. Energy storage will also be available ensuring none is wasted, and that energy can be tapped at a late date should the need arise.

It is difficult for consumers to see how much electricity they are using, but smart grid devices are quickly being developed. It is hoped that smart grid devices will use less of it, subsequently cutting energy bills and, moreover, pinpointing off-peak hours to run their energy-intensive machines.

Smart grids are designed to transmit and operate more efficiently than traditional grids. They reduce power-flow waste through the use of low-cost generation sources. Smart grids also facilitate inter-regional energy flows which will reduce congestion, reduce grid outages / disruptions.

**Variety of Generation**  
With CO2 emissions on the rise, it is imperative that the current grid system. The current grid system is made up of a variety of technologies, but this is changing.



### Demand Response

Consumers are changing what they need from a power supplier and are moving towards flexible energy, cheaper alternatives and the option for microgeneration, all of which are not currently facilitated by the electricity grid. The development of the Smart Grid and associated "smart" technologies and devices will allow users to have a more direct control over the energy they use on a day-to-day basis.



**Self-healing**  
Smart grids can detect and isolate problems, ensuring that a small portion of the grid is isolated from the main grid to prevent a major disruption to services.

### Electricity Market

Creating an open market where alternative energy sources can be sold to customers regardless of location. Microgeneration of electricity will also be a viable source of energy and will potentially contribute a good source of income to local economies.



Credit Peretz Partensky



# Systems Engineering Challenges in Today's World

1

Mission complexity and inability to manage from inadequate system-level complete verification.

2

System design emerges more than from architectural that are brittle, difficult and expensive to open.

3

Knowledge and investment life cycle phase boundaries, development cost and of design problems



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and investment are lost between increasing cost and risk: dampening potential for true product lines.

Programmatic sides of projects are... hampering effective decision making.

...ers such as Challenger and ... lited from failure to recognize ... The Columbia Accident Investigation determined that the preferred ... pendent technical authority".

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# Turbulence

*'tərbyələns/ noun*

1. violent or unsteady movement of air or water, or of some other fluid.
2. conflict; confusion.

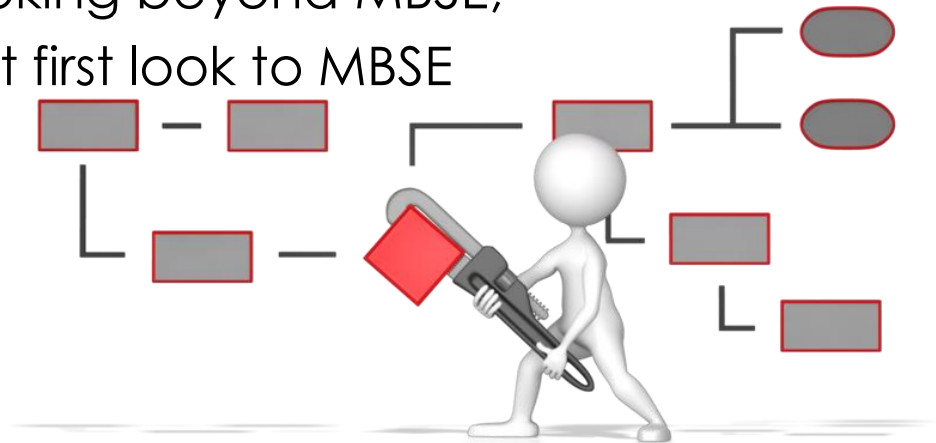
When you come out of the storm, you won't be the same person who walked in.

Haruki Murakami, *Kafka on the Shore*

# Building a Solid Foundation

...

Before looking beyond MBSE,  
we must first look to MBSE





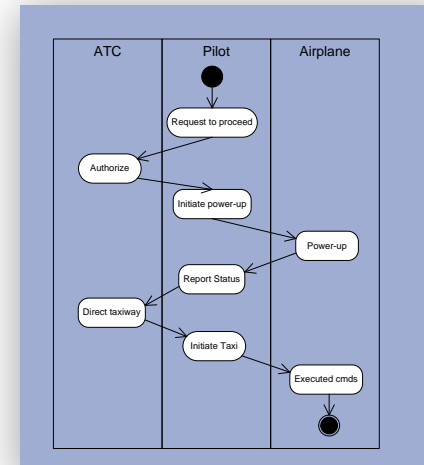
# Towards MBSE: A Practice in Transition

## *Traditional*



- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

## *Future*



Moving from document-centric to model-centric

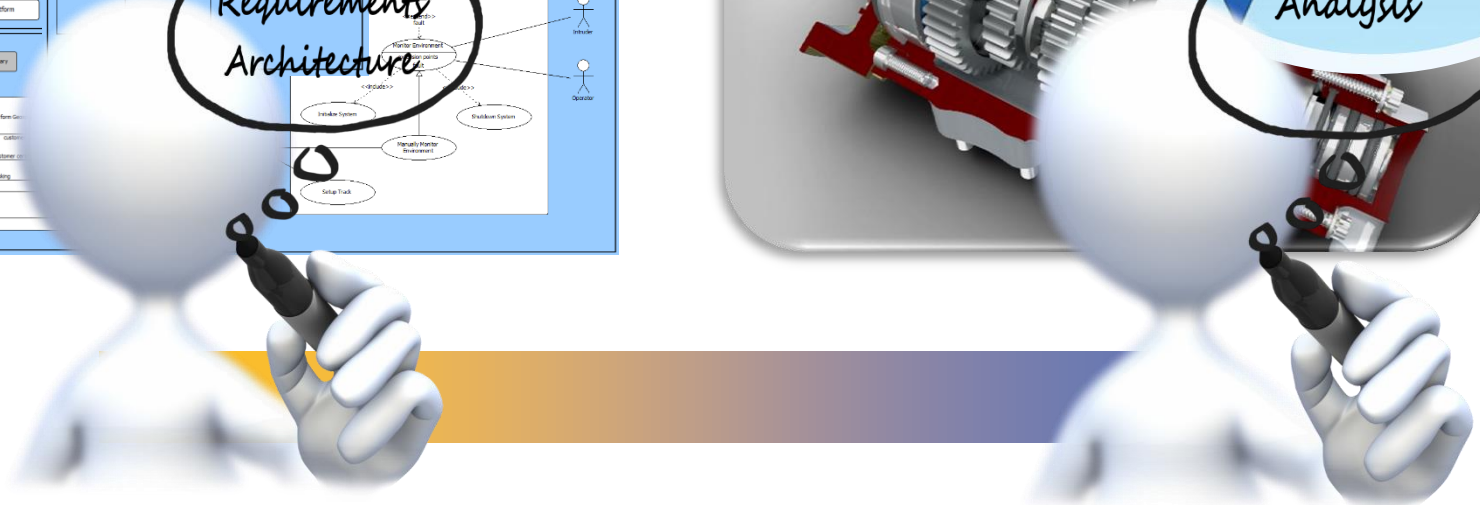
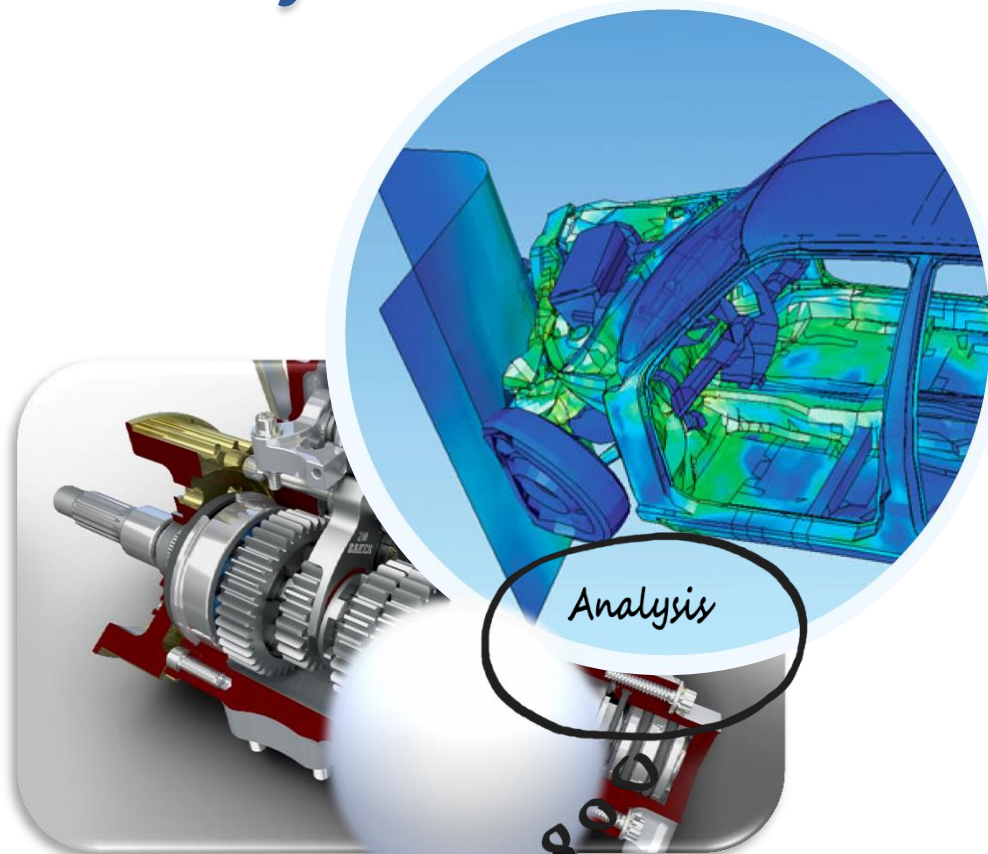
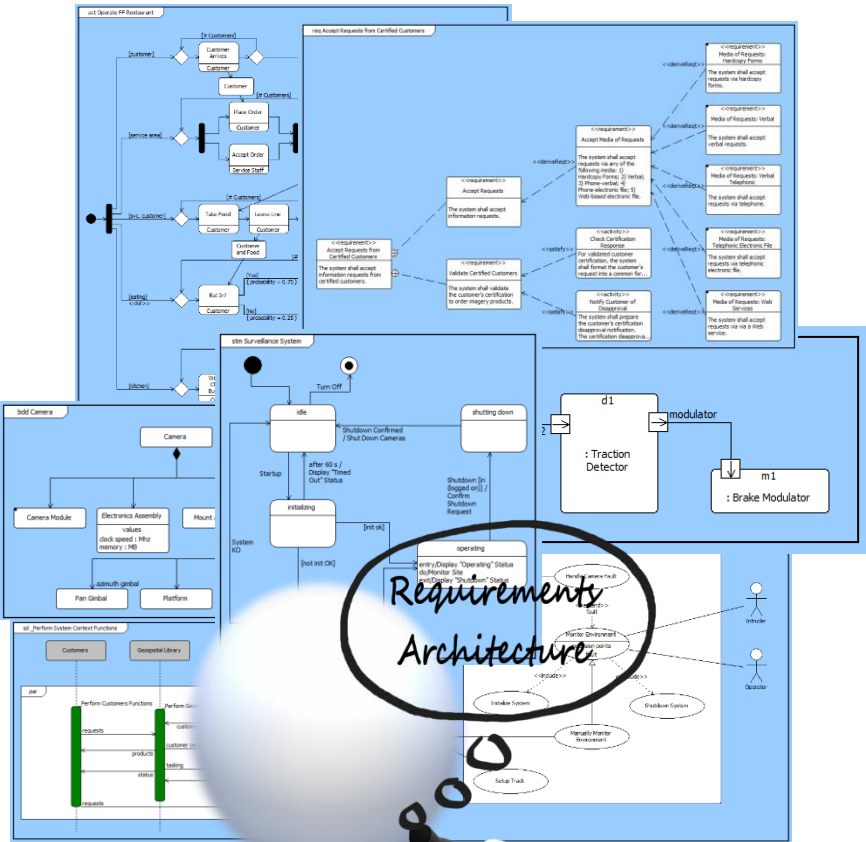


# Step 1 to Improving the Journey: Demystify (and “Demythify”)

- Models are not new
  - Central to engineering, even if they only reside in the engineer’s mind
  - Evolution from low-fidelity representations in documents to higher-fidelity, richer representations
  - Improved granularity of knowledge capture for management, analysis, and learning
- Documents remain a flexible communication mechanism serving a diverse audience
- MBSE requires integration, connectivity, coherence
  - A series of diagrams  $\neq$  a model
  - Models in SE (or modeling & simulation in SE)  $\neq$  MBSE
- Views allow us to construct, communicate, and analyze models
  - Diagrams, tables, documents, dashboards, and more can comprise a fit-for-purpose library from which to draw



# Step 2 to Improving the Journey: Clarify





# Step 3 to Improving the Journey: Remove Roadblocks

- “MBSE requires SysML (or UML or UPDM or UAF).”
  - “Everyone must learn *fill in the blank* for our organization to adopt MBSE.”
- “We’re doing SysML (or UML or UPDM or UAF) so we are already doing MBSE.”
- “We are already doing modeling and simulation.”
- “We must implement the architectural and analytical aspects to get any benefit.”
- “It’s too complex.”
- “We must model everything, and it’s not possible to model everything.”
- “Implementing MBSE is one size fits all.”
- “It’s a technical problem.”
  - “All I need is the right tool.”
  - “I can learn it myself.”
- “We need to avoid ‘tool lock’.”
- “MBSE is the answer...it does everything.”







# Progress in Meeting Today's Systems Engineering Challenges

1

Mission complexity is growing faster than our ability to manage it . . . increasing mission risk from inadequate specifications and incomplete verification.

2

System design emerges from pieces, rather than from architecture . . . resulting in systems that are brittle, difficult to test, and complex and expensive to operate.

3

Knowledge and investment are lost at project life cycle phase boundaries . . . increasing development cost and risk of late discovery of design problems

4

Knowledge and investment are lost between projects . . . increasing cost and risk: dampening the potential for true product lines.

5

Technical and programmatic sides of projects are poorly coupled . . . hampering effective project risk-based decision making.

6

Most major disasters such as Challenger and Columbia have resulted from failure to recognize and deal with risks. The Columbia Accident Investigation Board determined that the preferred approach is an "independent technical authority".

# Plotting the Journey Beyond MBSE



...

Begin with the Added Value of MBSE



Complexity

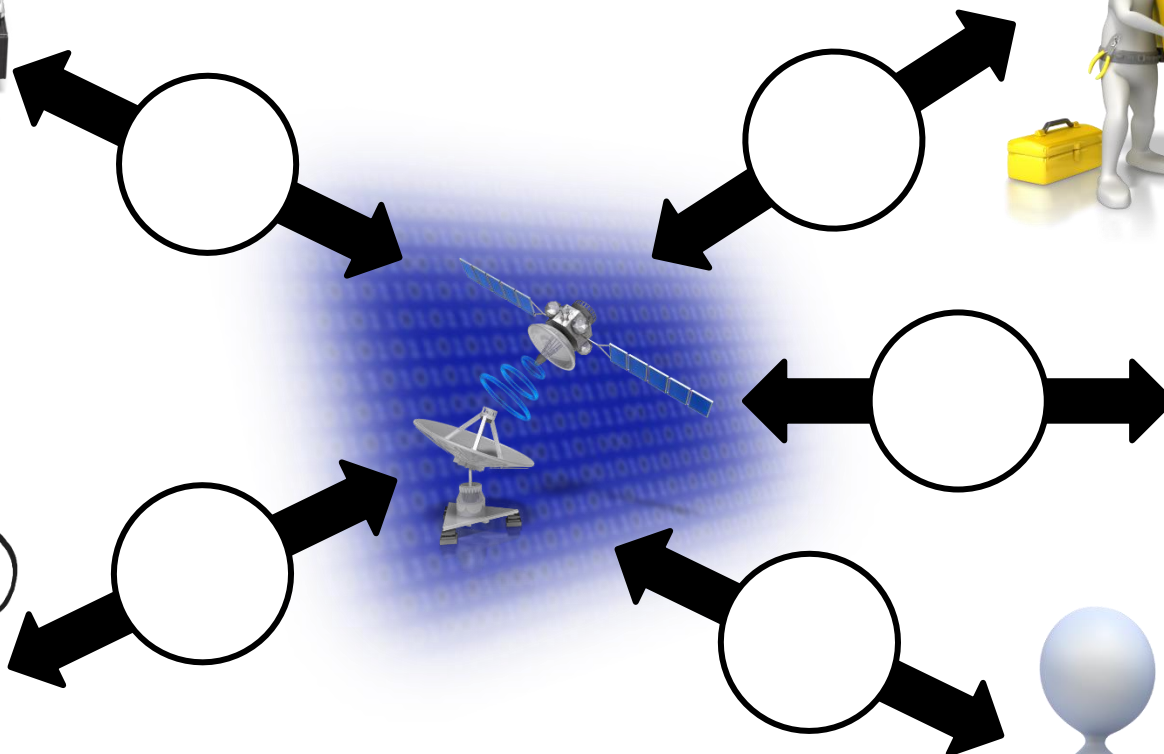
Design

Project Life  
Cycle

Cross-Project  
Learning

SE-PM

# Connecting across MBE: Communications, Semantics, Syntax



Requirements  
Architecture

Complexity

Design

Project Life  
Cycle

“One model to coordinate them all”

SE-PM

# Leveraging Collective Insights while Enabling Alignment



Power and Energy EU

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Smart Grids

Environment

Solution

Regulation

Supplier

Policy

Lifecycle

Problem

Market Threat

System

Technology

Customer

In-service

Developer

Evolution

System of Systems

Complexity

Design

Project Life Cycle

SE-PM



# Aligning and Responding with Reference Architectures



Complexity

Design

Project Life  
Cycle

Cross-Project  
Learning

Image credit Don McCullough



# Accelerating to Meet the Pace of Change

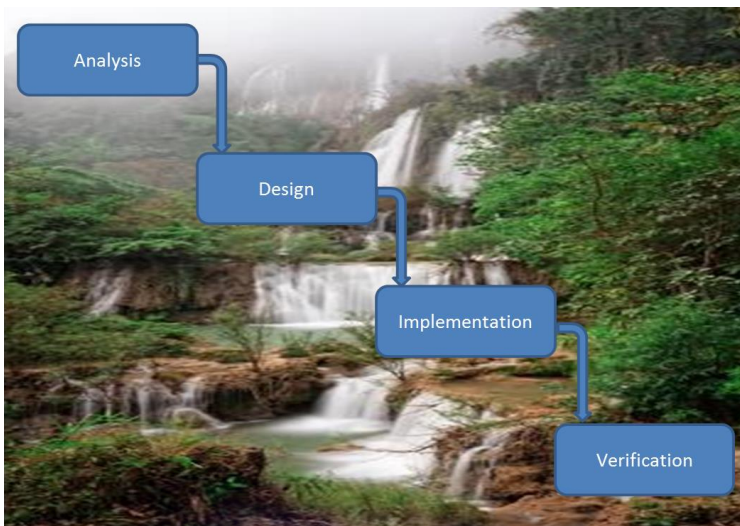


Requirements

Capabilities

Architecture

Test



Integration  
 Sprint  
 Team  
**Change**  
 Value  
 Continuous  
 Build

Complexity

Design

Project Life Cycle

SE-PM







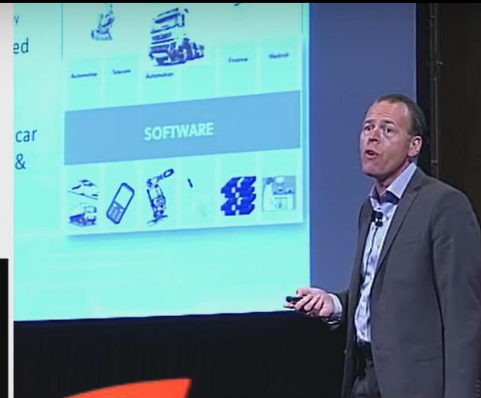
# Incorporating Feedback and Learning: From Built-to-Last to Built-to-Evolve

Jan Bosch keynote presentation at the 25th Anniversary INCOSE International Conference



**25<sup>th</sup>** anniversary  
annual INCOSE  
international symposium

Seattle, WA  
July 13 - 16, 2015



## Nature of Product Innovation is Shifting

- More than 80% of R&D is related to software according to Ericsson
  - The world's 5th largest software company
- 70% of all innovation is related to software according to AB Volvo
- 80-90% of all innovation in a car is related to electronics (HW & SW) according to Volvo Cars



Complexity

Design

Project Life  
Cycle

Cross-Project  
Learning

SE-PM

# Moving from Custom-Built to Composability: SoSE, IoT, Interactions, and Capabilities



Complexity

Design

Project Life  
Cycle

Cross-Project  
Learning





# Enabling Communication, Analysis, Learning, and More



Technical Processes

“Non-traditional domains”

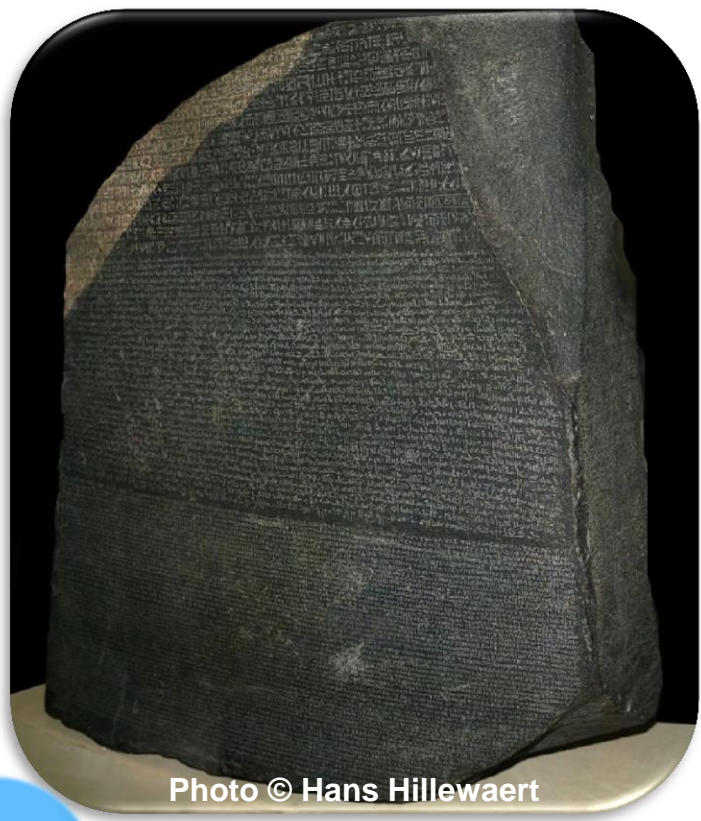


Photo © Hans Hillewaert



SE Management

Soft Systems



Model-Based SE

SE Leadership

Systems Thinking

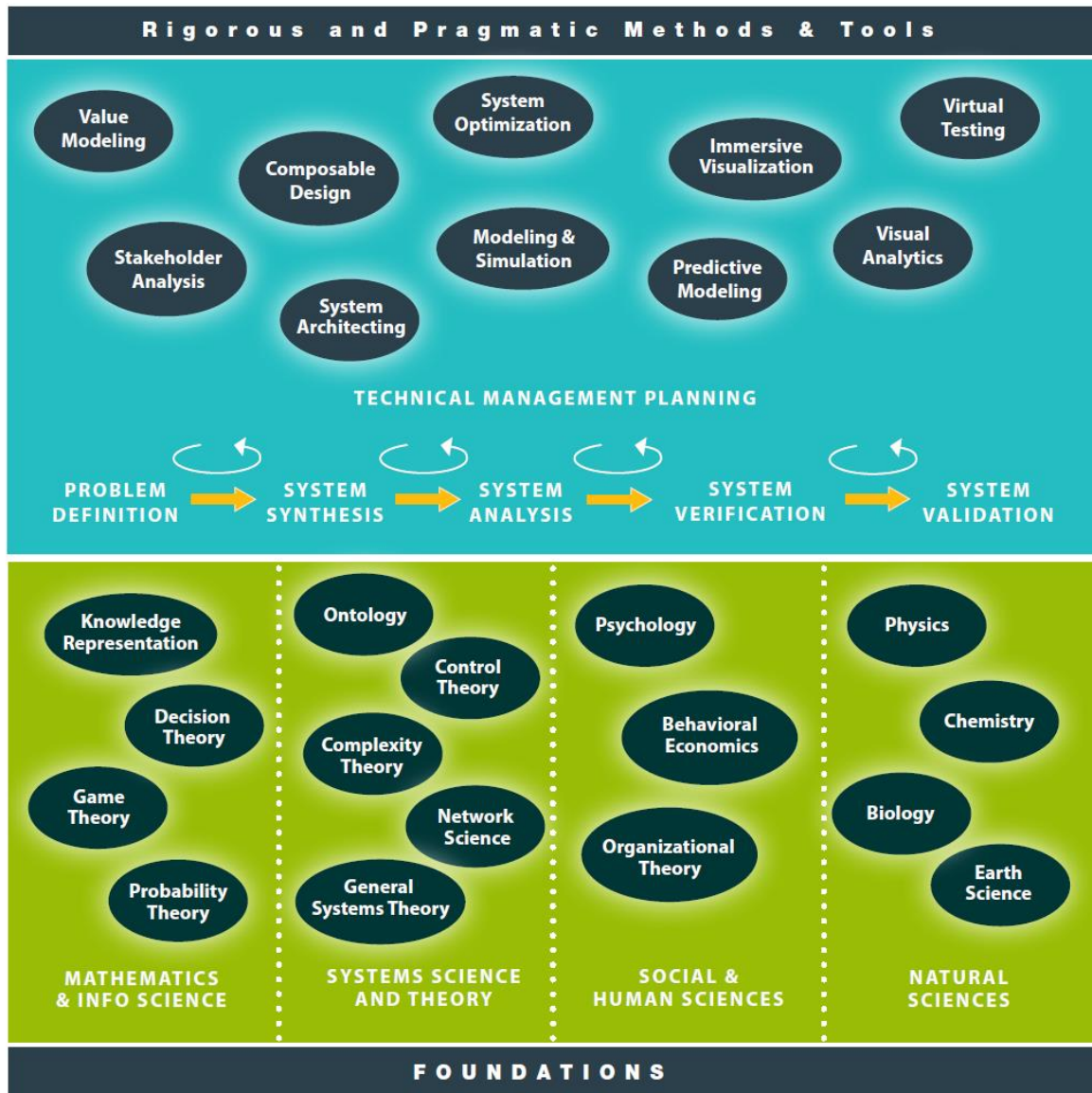
Systems Science

- Complexity
- Design
- Project Life Cycle
- Cross-Project Learning
- SE-PM





# Connecting Supporting Theories



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- Complexity
- Design
- Project Life Cycle
- Cross-Project Learning
- SE-PM

# Recognizing the Future of Systems Engineering

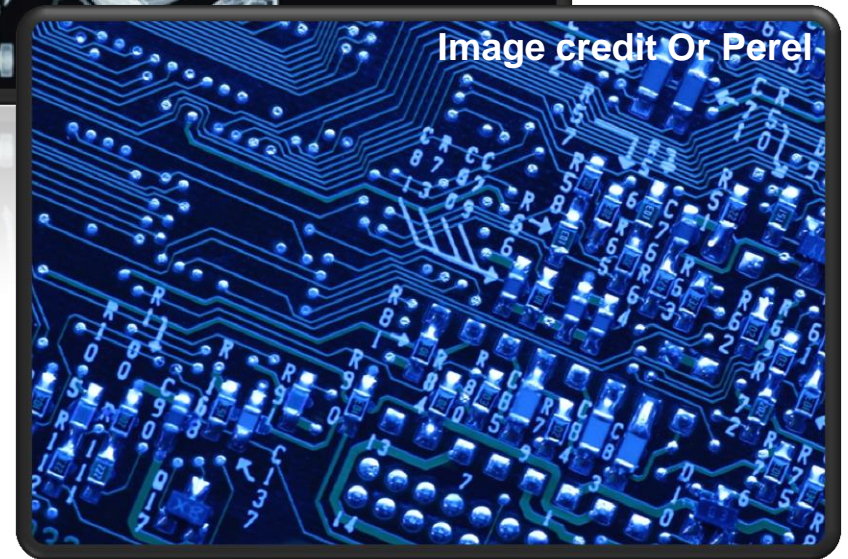
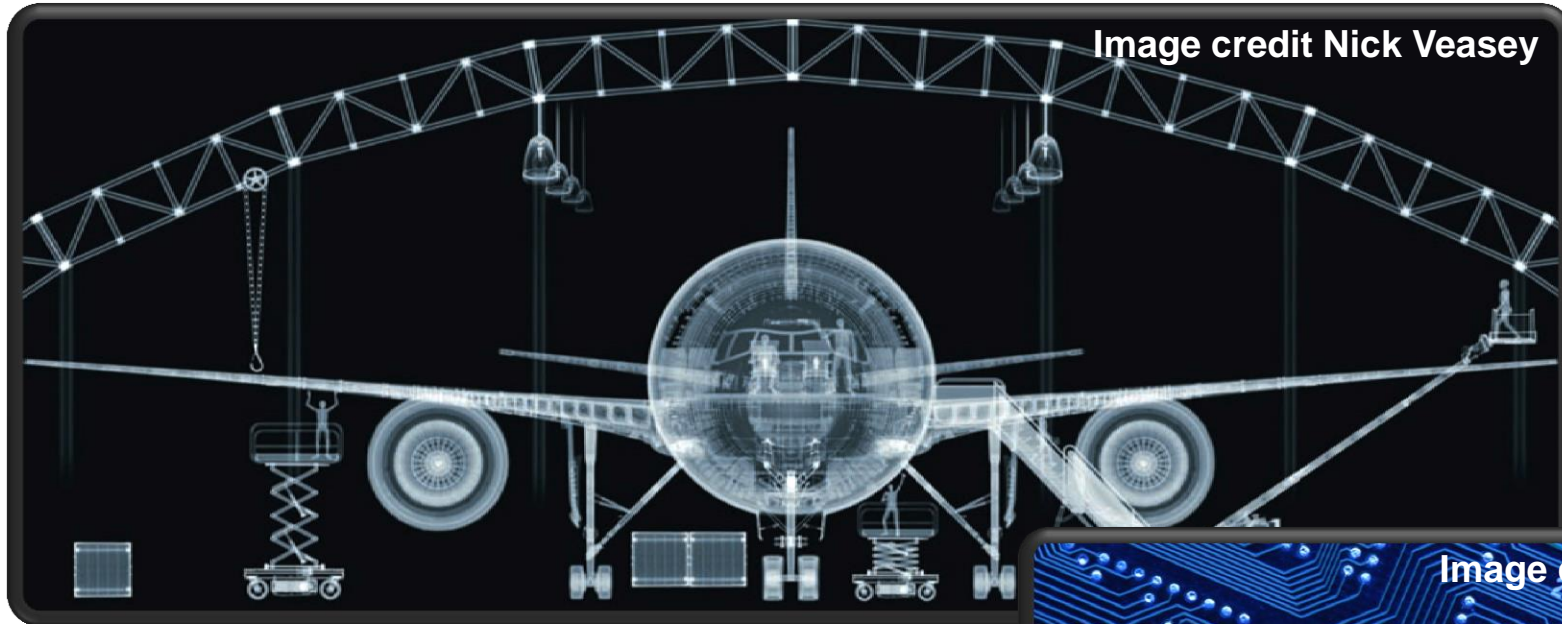
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What Lies Beyond MBSE



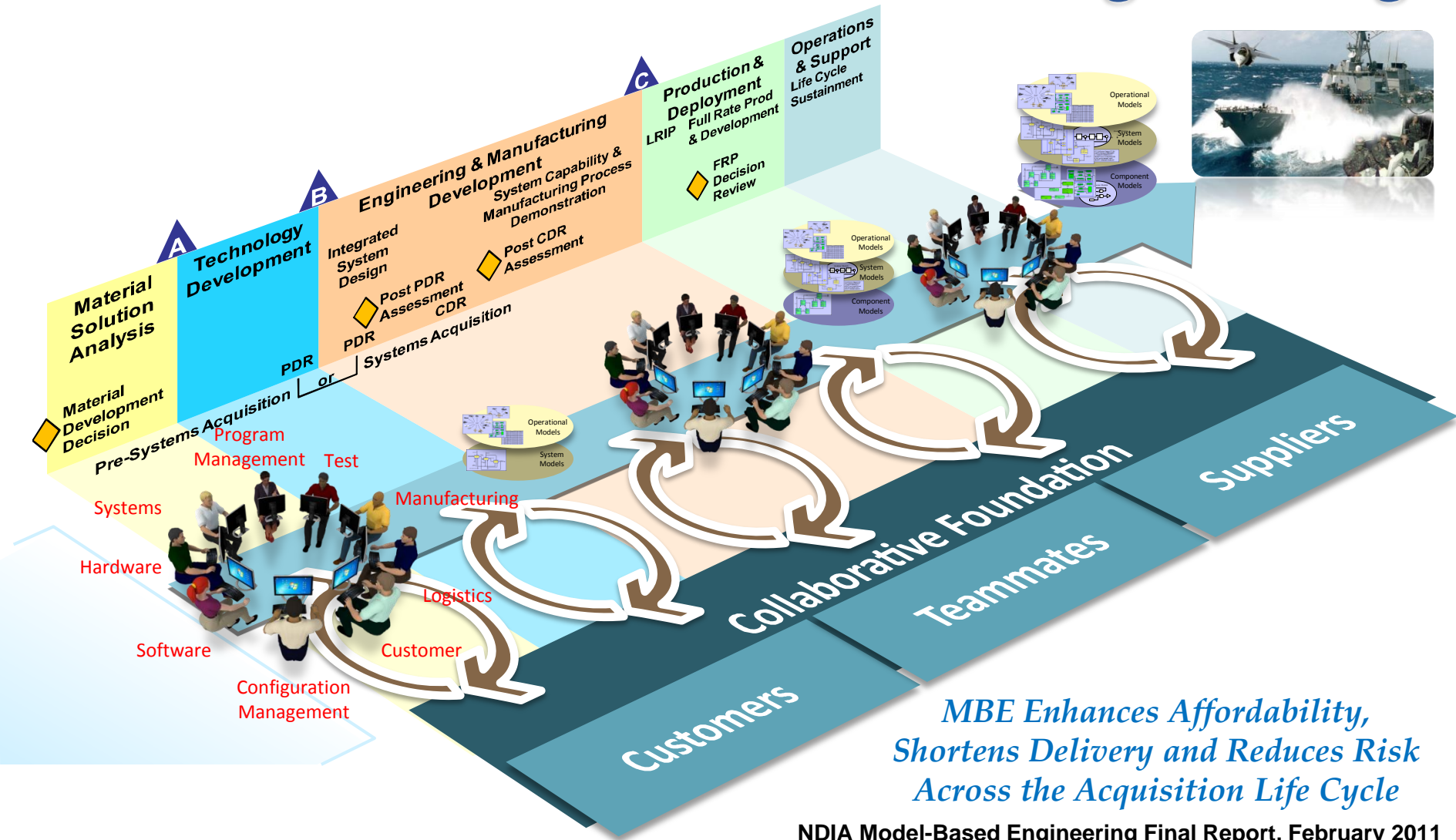


# Learning from Our Colleagues





# Joining Our Engineering Colleagues to Enable Model-Based Engineering



*MBE Enhances Affordability, Shortens Delivery and Reduces Risk Across the Acquisition Life Cycle*

NDIA Model-Based Engineering Final Report, February 2011



# After “Model-Based” Fades Away

Enriched toolbox for communication and analysis

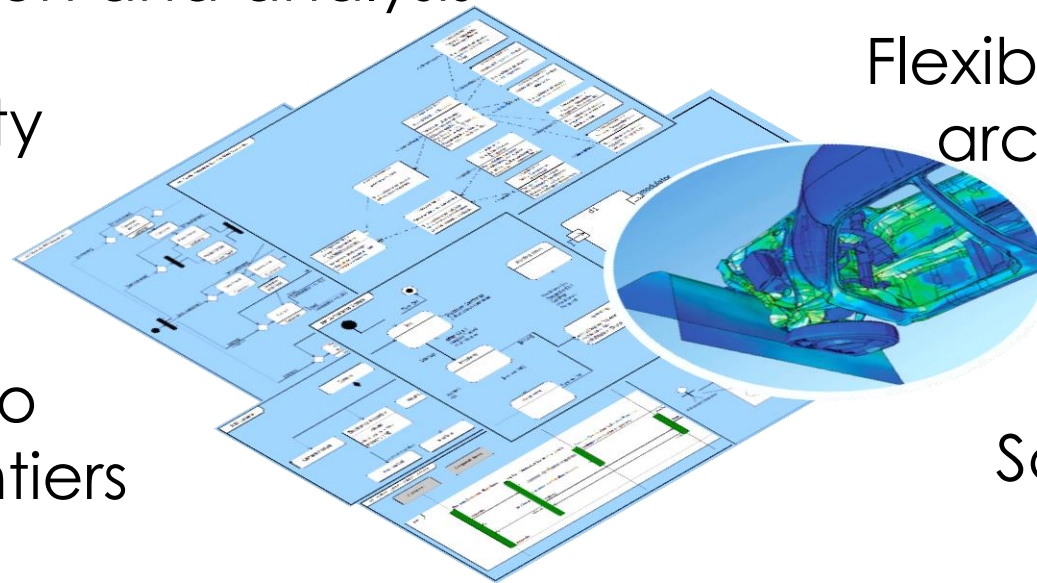
Composability

Tailorability

Flexible reference architectures

Heuristics

Insight into efficient frontiers



Rigor

Scalability

Higher value

Toolbox of theories supporting SE

Progress

# Systems Engineering



# Questions



  
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International Council on Systems Engineering

David Long  
President

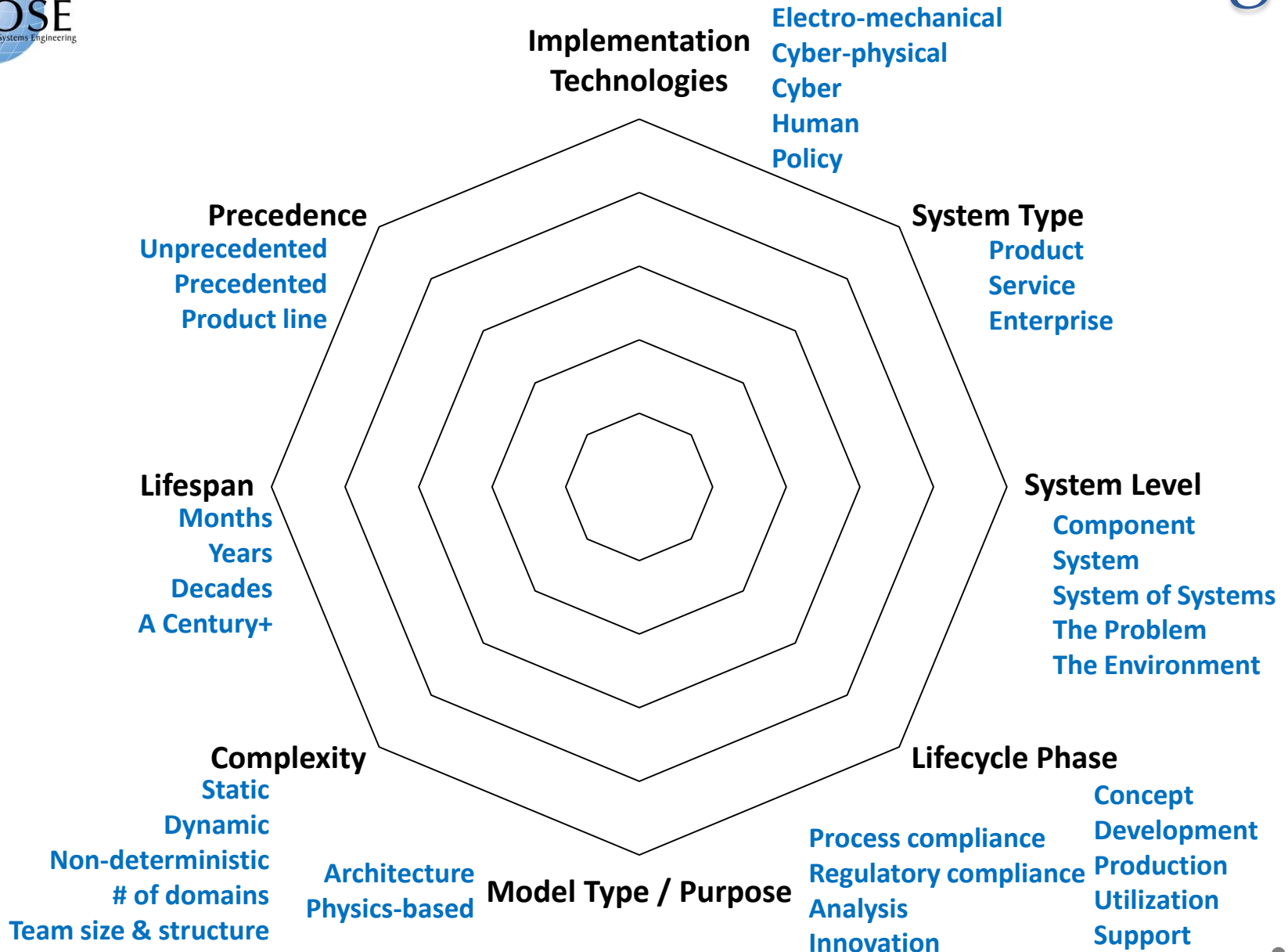
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[david.long@incose.org](mailto:david.long@incose.org)

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# 8 Dimensions to Our Challenge





# Responding to 21<sup>st</sup> Century Needs with 21<sup>st</sup> Century Systems Engineering

Analytics  
 Sustainable Architecture  
 Scalable  
 Affordability Process  
 Integration  
 Resilience  
 Innovation  
 Non-deterministic  
 Technology  
 Holistic  
 Security  
 Responsiveness  
 Agility  
 Standardization  
 People  
 Tools  
 Global  
 Autonomy

• Practice • Practitioners • Opportunity



- As we make the journey to model-based, how must we also adapt and evolve the greater practice of systems engineering in a world dominated by cyber-physical systems with the inherent opportunities, risks, and vulnerabilities they bring?
- Audience is more than systems engineers
- Tie keynote into risk stream
- Threat, threat modeling
- Critical Infrastructure Protection
- Nov 18-19 grid-security exercise run by the North American Electric Reliability Corporation (NERC)
  - Coincidental to timing of the terrorist actions in Paris on Nov 13
  - Many hazards and threats, constantly evolving
  - Cyber attacks, physical attacks – all of which required “a protected period of time to recover” (Gerry Cauley, president and chief executive of SERC)
  - Improvements in communications, inventories of critical replacement parts, preservation of evidence and other forensics