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Beyond MBSE: Looking towards the Next Evolution in Systems Engineering

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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.

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Systems Engineering

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

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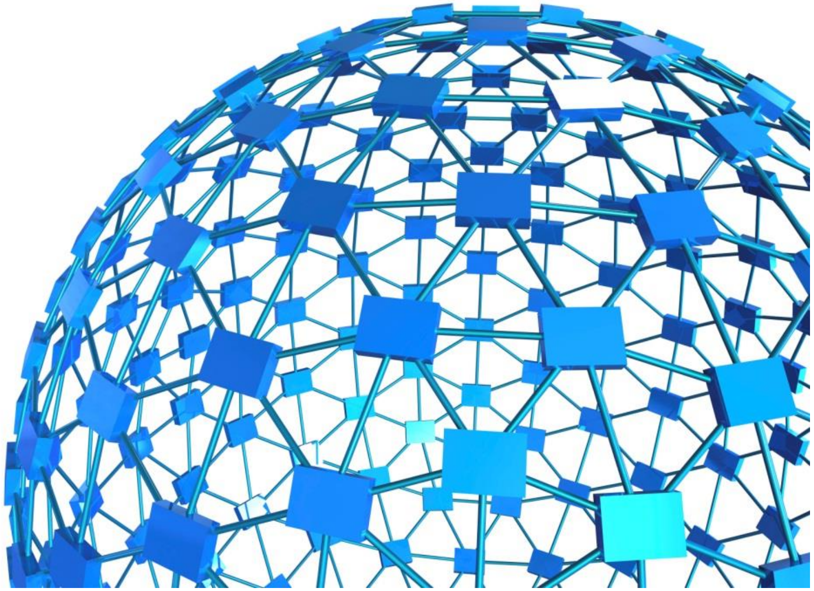
System Characteristics Our Stakeholders Demand

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

- Interconnected
- Interdependent
- Complex



Adapted from Alan Harding, 2014

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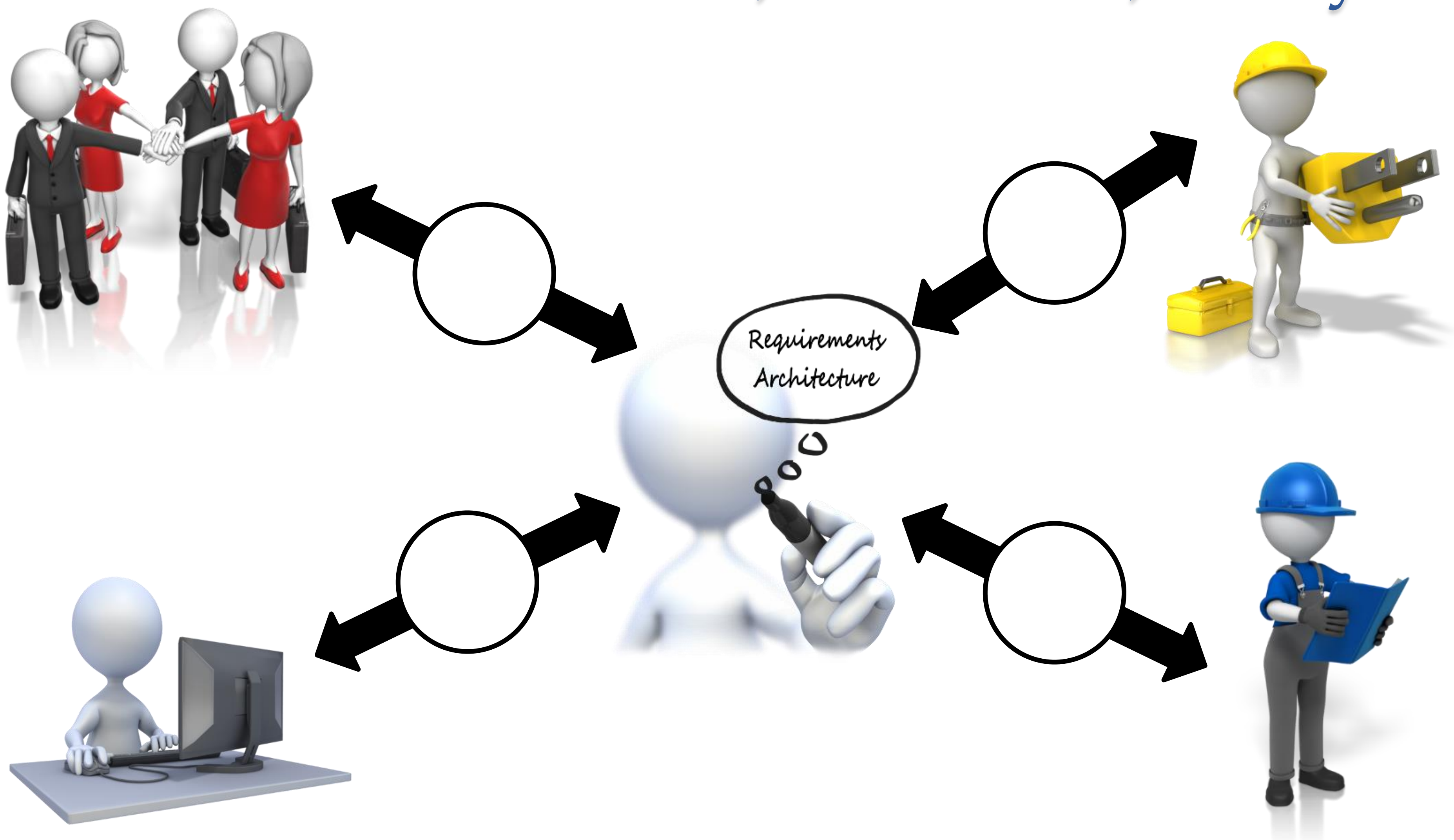
Connecting across the Project: Communications, Semantics, Analysis



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Origins of "Systems Engineering"

A Changing Environment for SE

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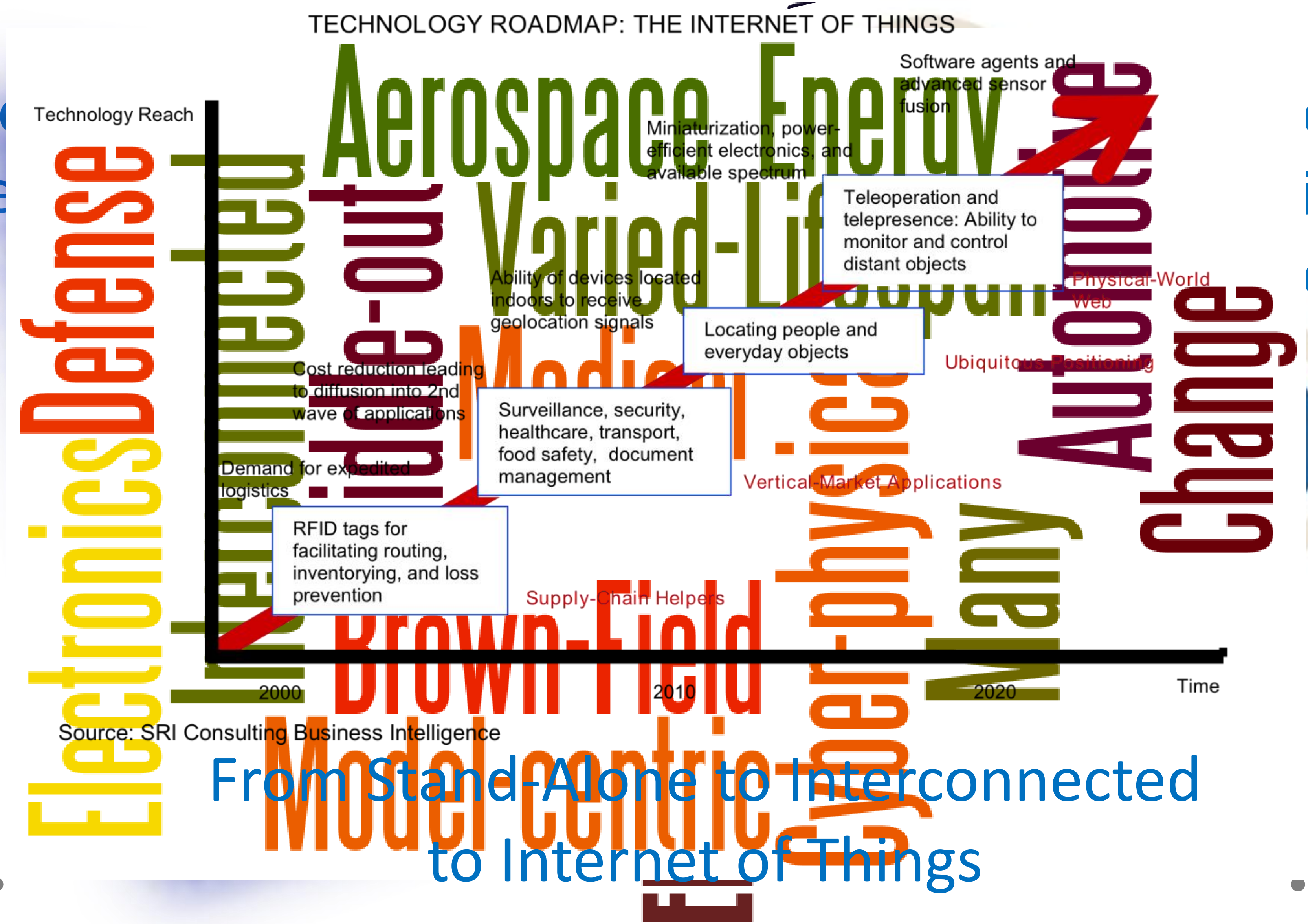
Ae ive
to cal



From Stand-Alone to Interconnected
to Internet of Things

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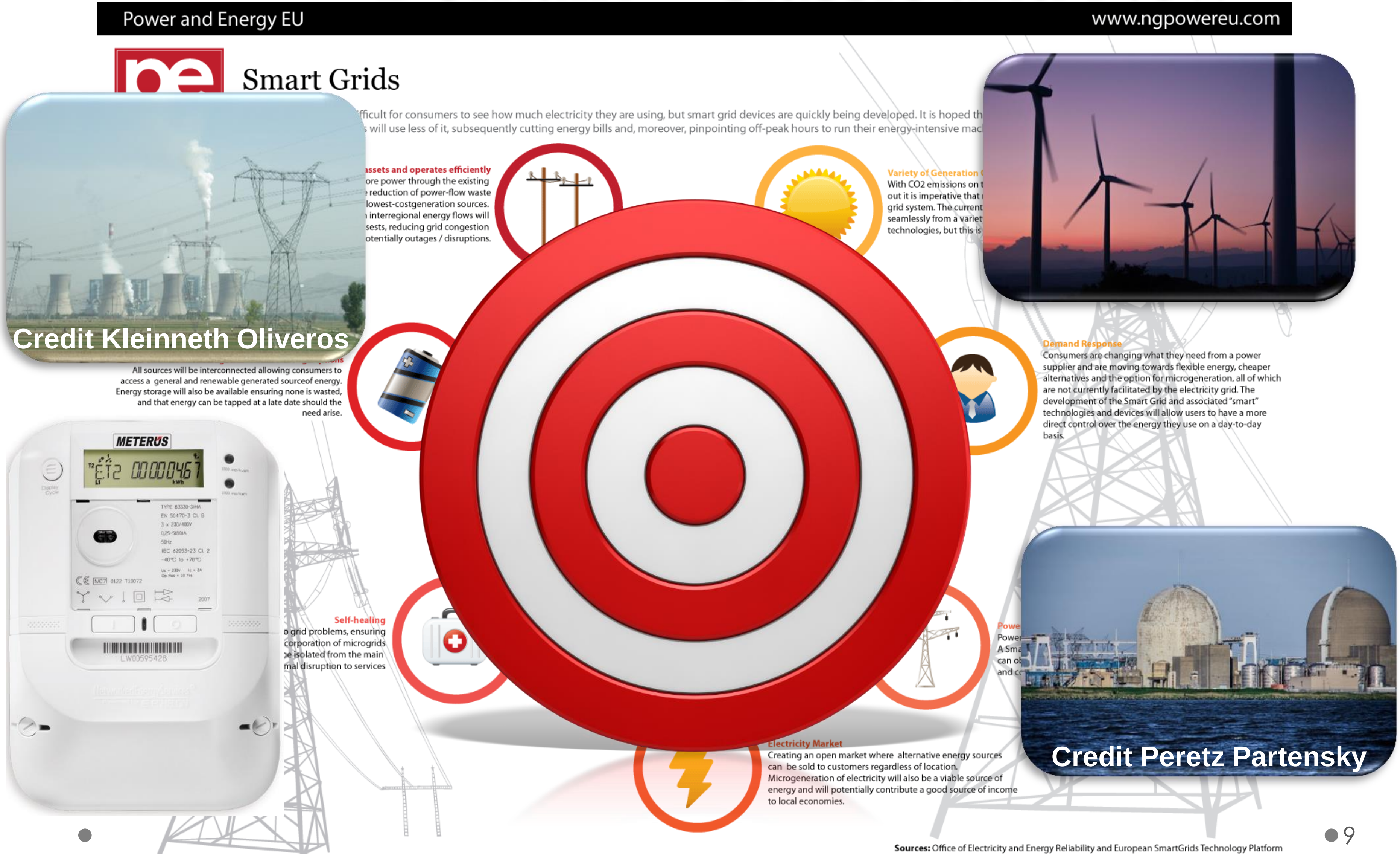
Looking at Challenges in the Energy Domain – Classic and New



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Systems Engineering Challenges in Today's World

1 | Mission complexi
ability to manage
from inadequate s
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nd investment are lost between
creasing cost and risk: dampen-
ial for true product lines.

2 | System design emer
than from architectu
that are brittle, diffic
and expensive to ope

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3 | Knowledge and invest
life cycle phase bound
development cost and
of design problems

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The Columbia Accident In-
etermined that the preferred
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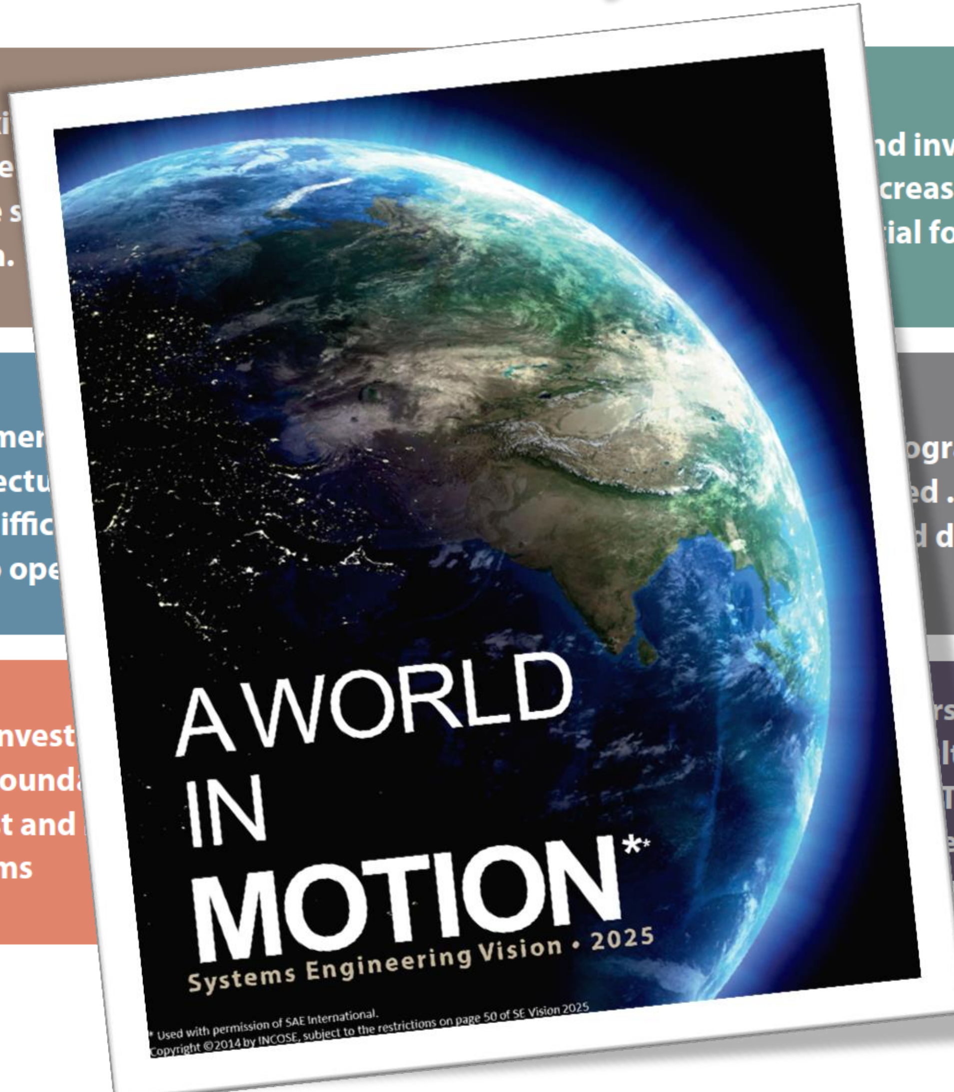

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Turbulence

ˈtərbyələns/ *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*

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Building a Solid Foundation

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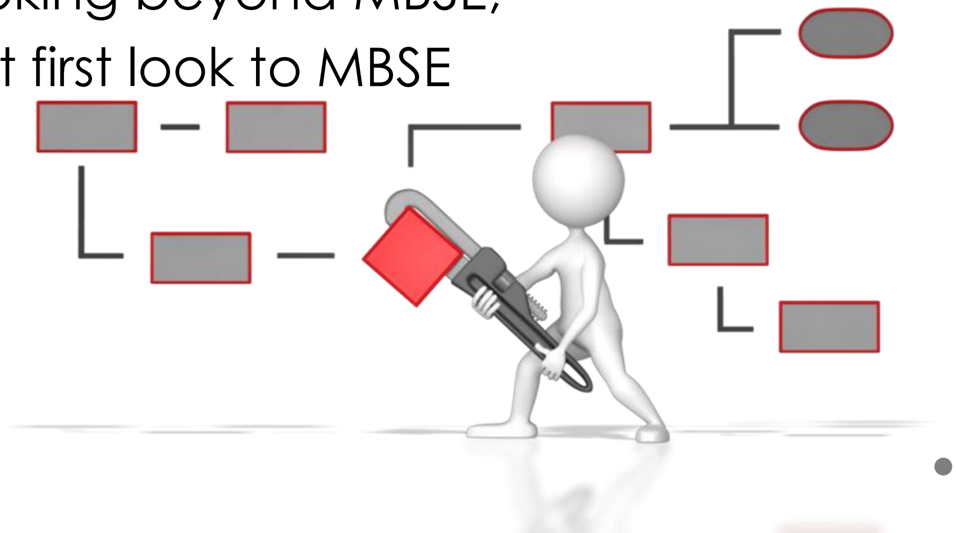
Before looking beyond MBSE,
we must first look to MBSE



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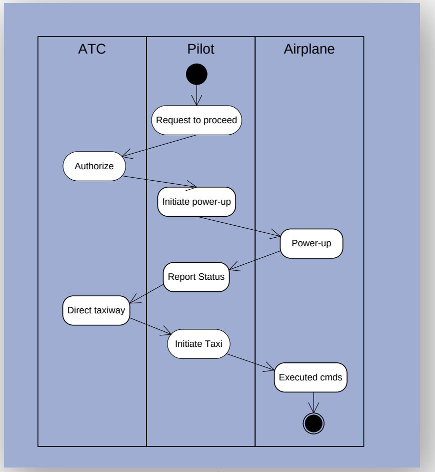
Towards MBSE: A Practice in Transition

Traditional

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

Future



Moving from document-centric to model-centric

Reprinted from INCOSE Model-Based Systems Engineering Workshop, February 2010

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 ≠ a model
  - Models in SE (or modeling & simulation in SE) ≠ 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

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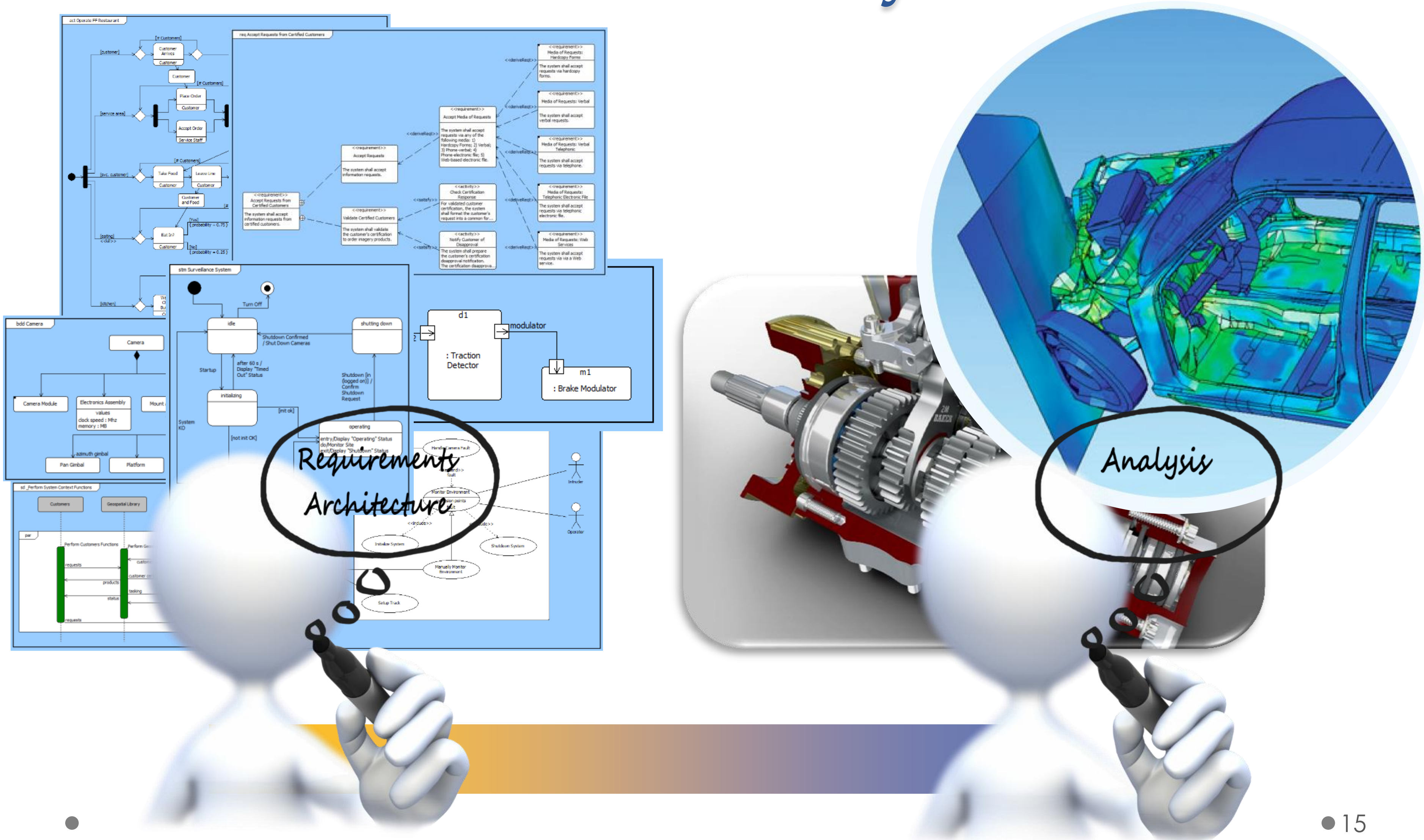
Step 2 to Improving the Journey: Clarify



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."

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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".

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Plotting the Journey Beyond MBSE

. . .

Begin with the Added Value of MBSE

Complexity

Design

Project Life Cycle

Cross-Project Learning

SE-PM

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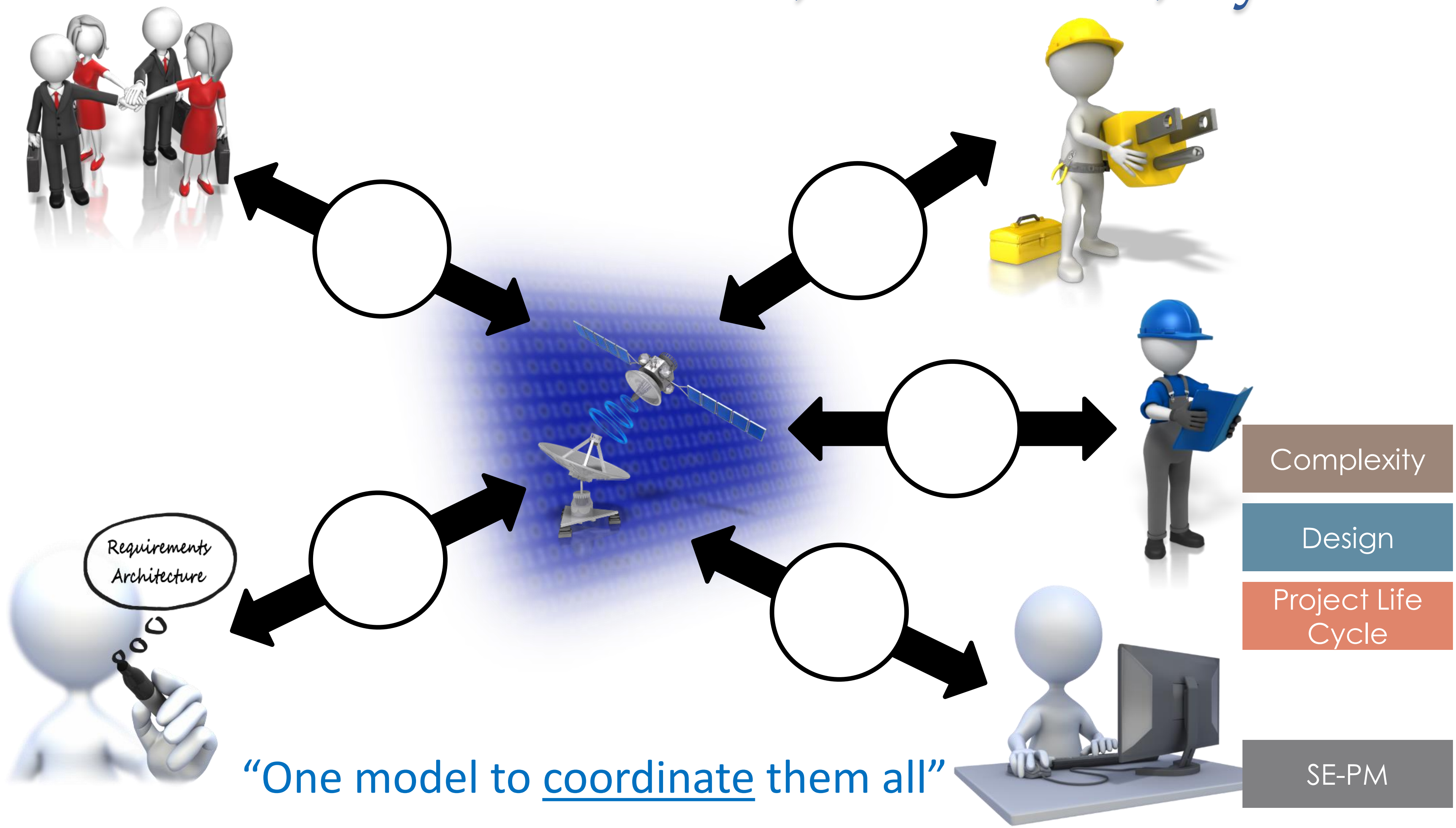
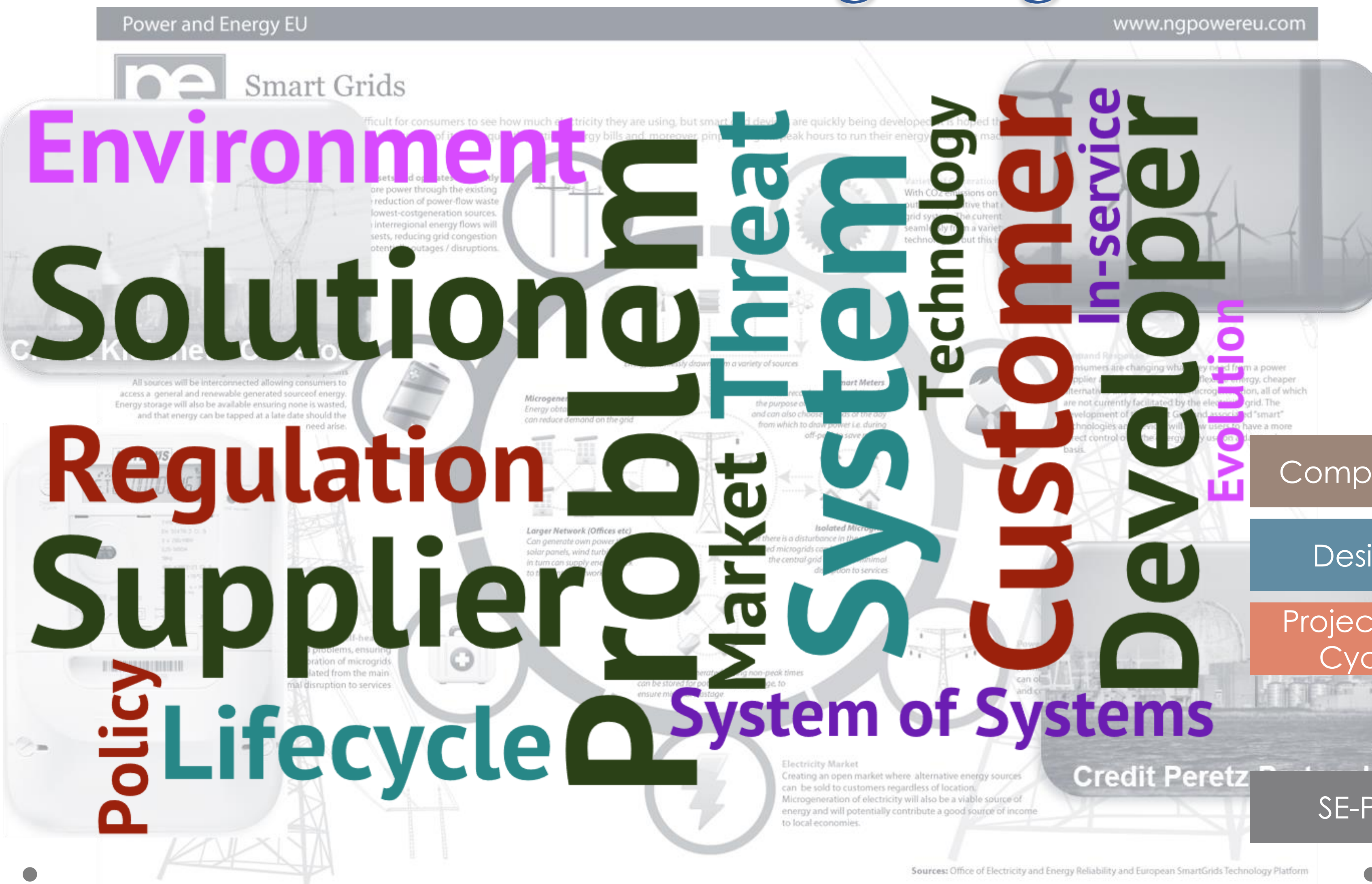
Connecting across MBE: Communications, Semantics, Syntax



"One model to coordinate them all"

Leveraging Collective Insights while Enabling Alignment



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

Aligning and Responding with Reference Architectures

Image credit Don McCullough

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

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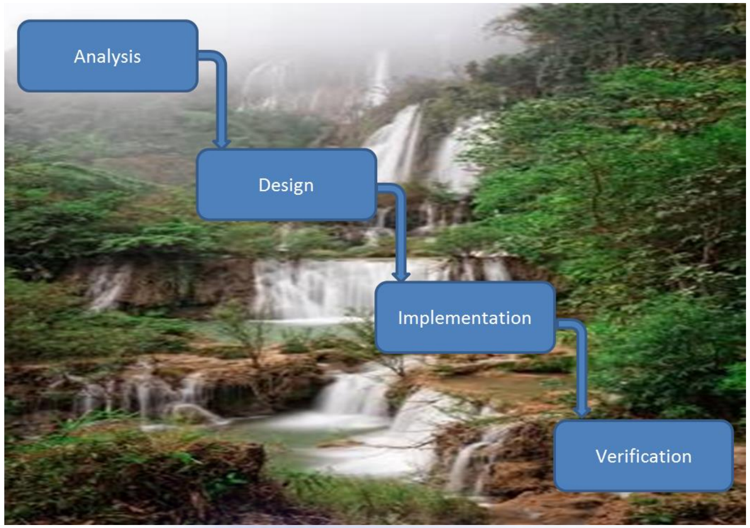
Accelerating to Meet the Pace of Change

Requirements

Capabilities

Architecture

Test



Integration
Sprint
Team
Change
Value
Build
Continuous

Complexity

Design

Project Life Cycle

SE-PM


Image credit Local Motors

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

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

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

Complexity

Design

Project Life Cycle

Cross-Project Learning

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Enabling Communication, Analysis, Learning, and More

Technical Processes

"Non-traditional domains"

Model-Based SE

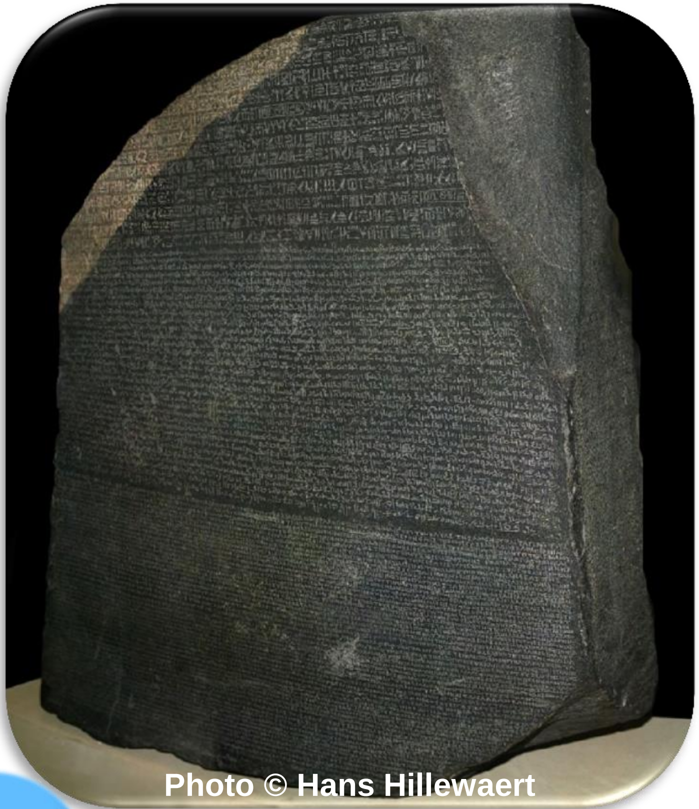
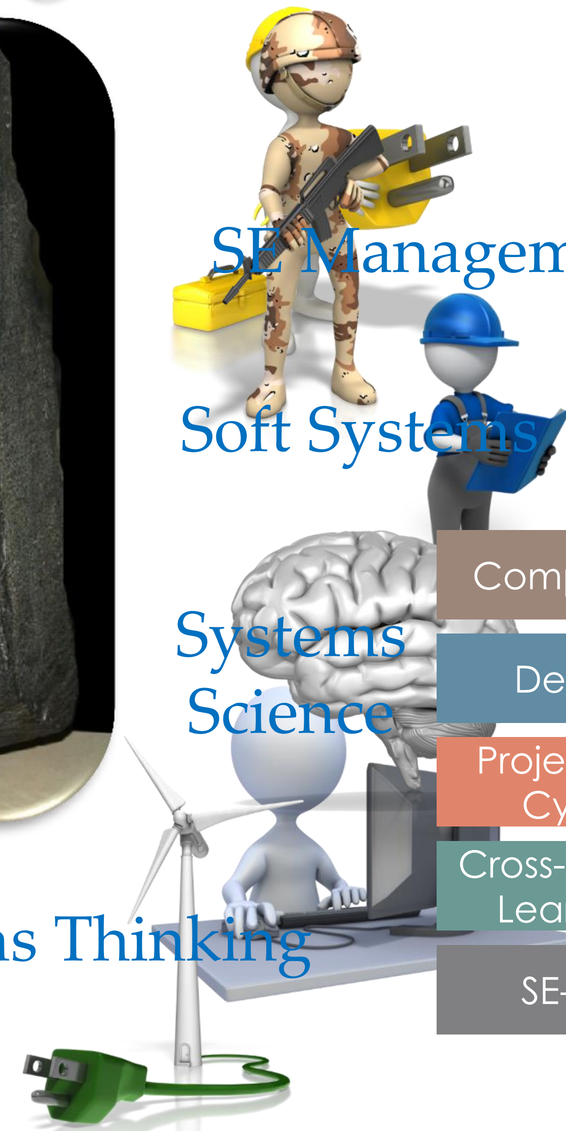


Photo © Hans Hillewaert

SE Leadership

Systems Thinking



SE Management

Soft Systems

Systems Science

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

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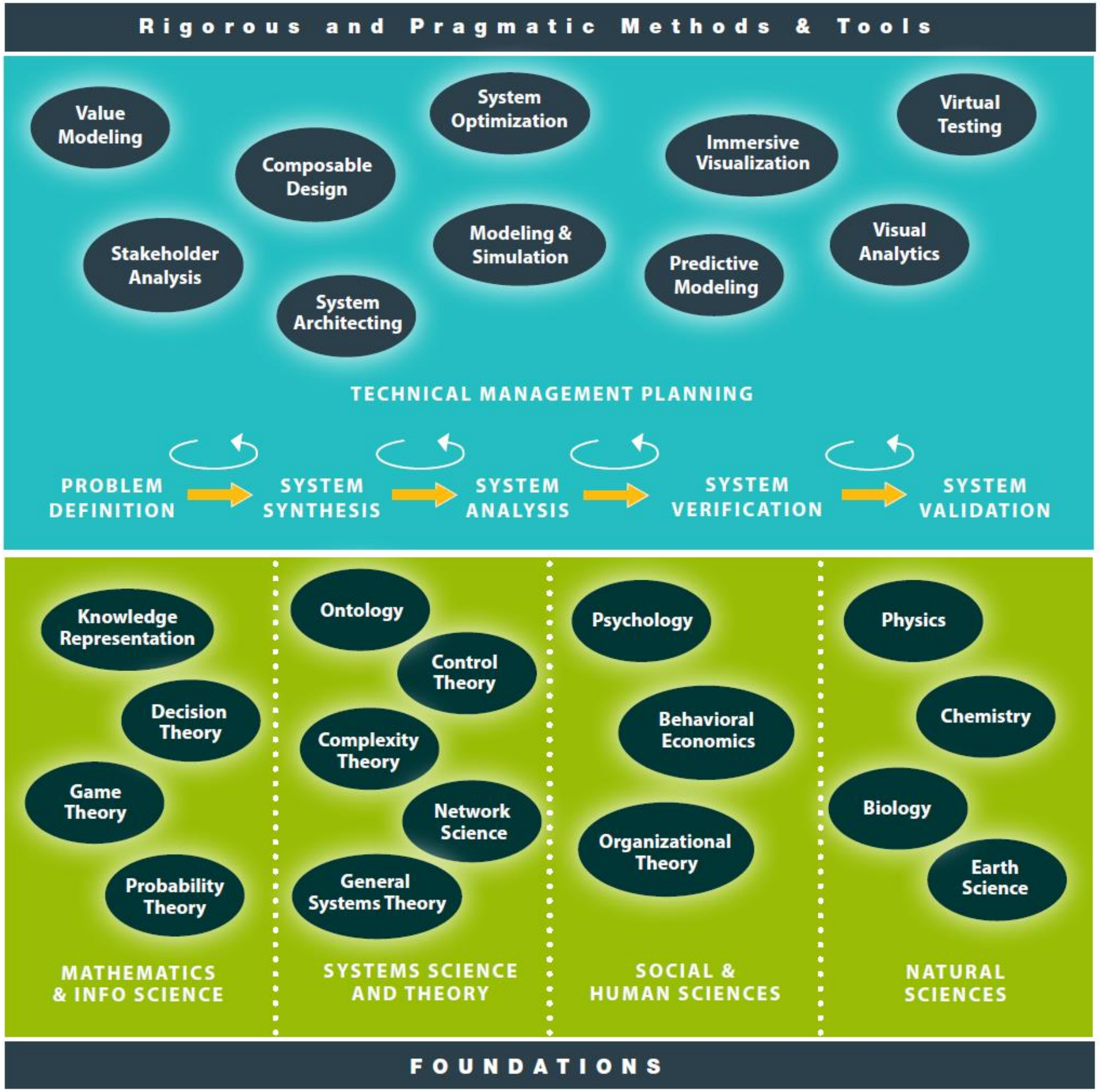
Connecting Supporting Theories



SE Vision 2025.

Complexity

Design

Project Life Cycle

Cross-Project Learning

SE-PM

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Recognizing the Future of Systems Engineering

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What Lies Beyond MBSE

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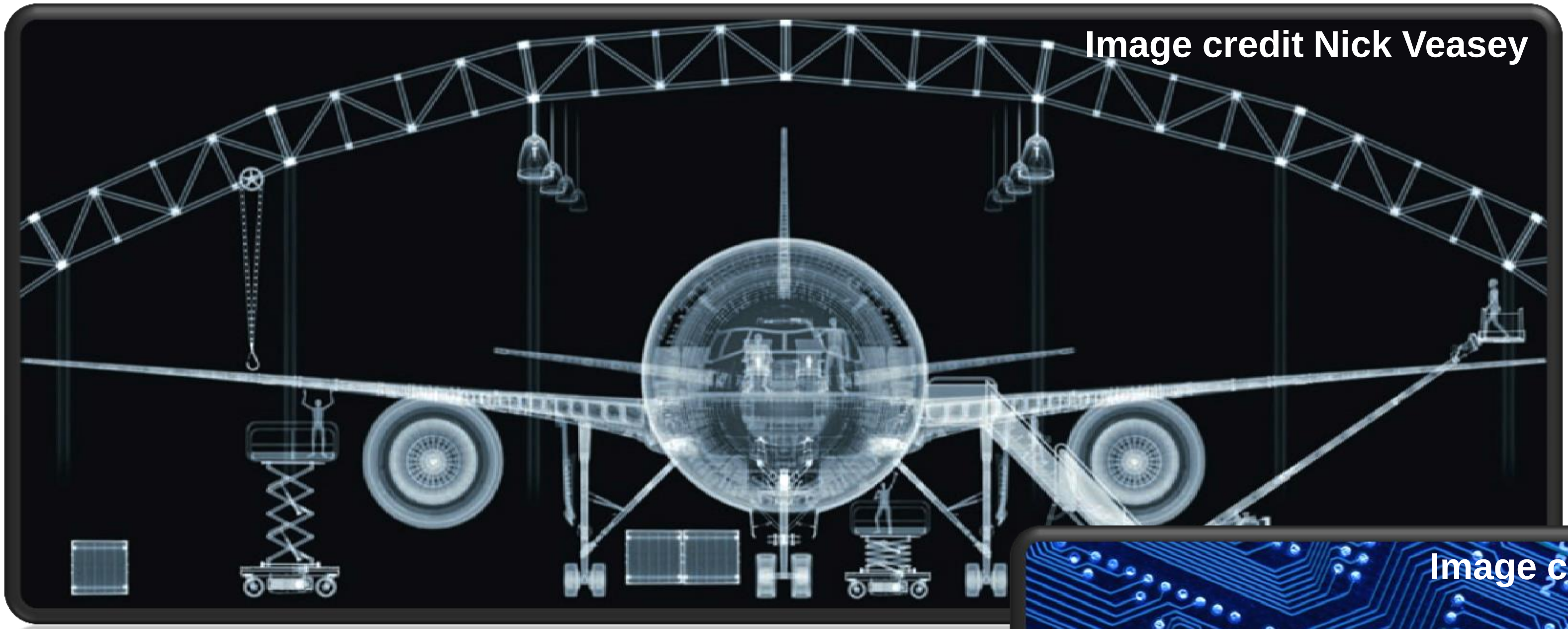
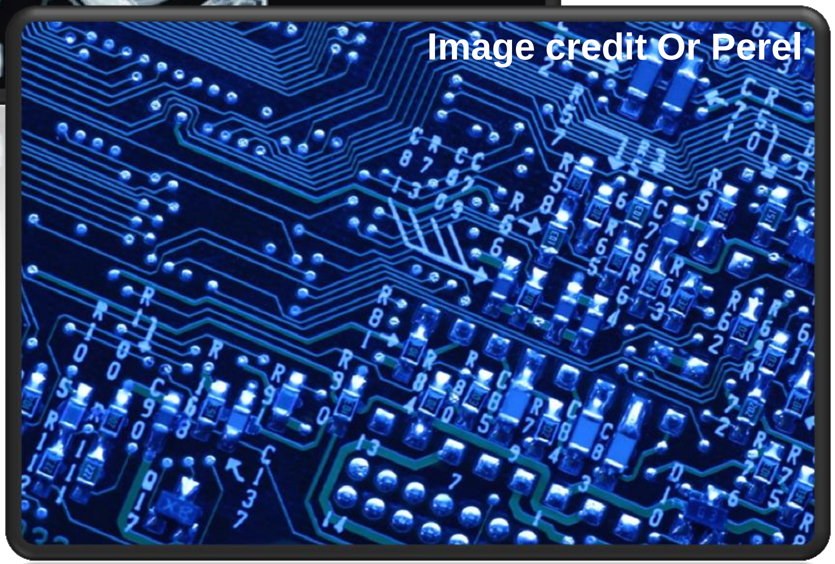
Learning from Our Colleagues





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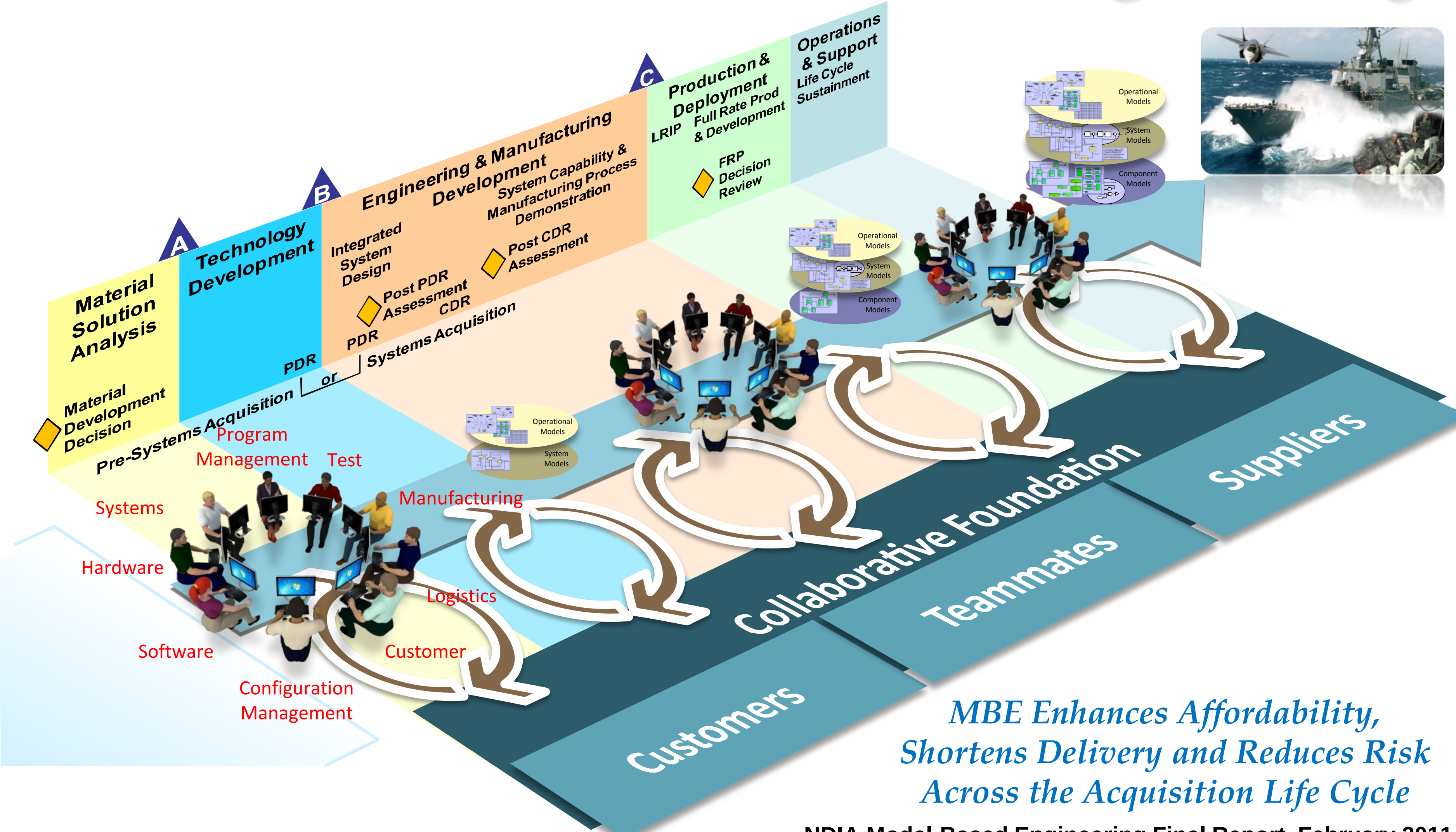
Joining Our Engineering Colleagues to Enable Model-Based Engineering



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

NDIA Model-Based Engineering Final Report, February 2011

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After "Model-Based" Fades Away

Enriched toolbox for communication and analysis

Composability

Flexible reference architectures

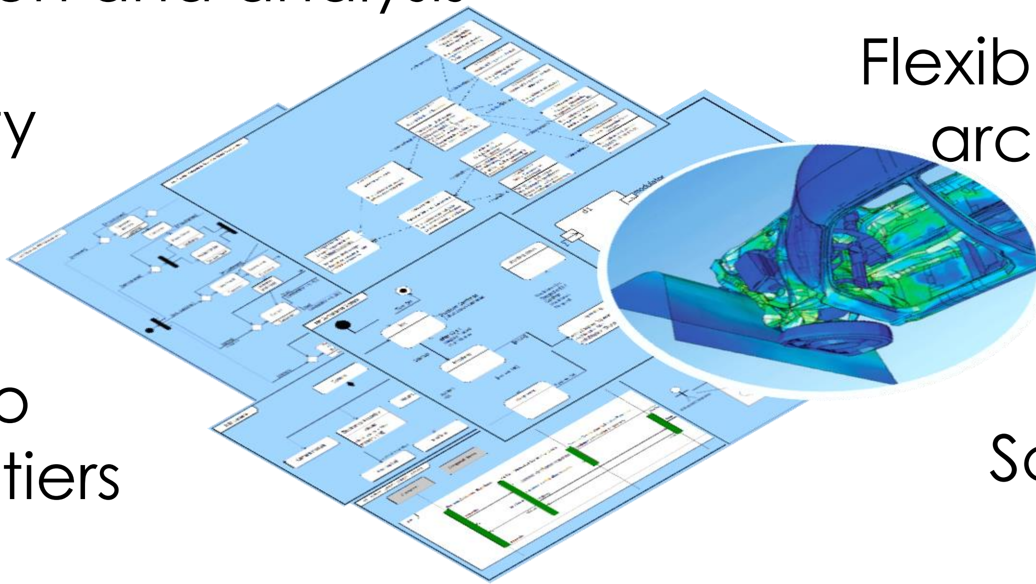
Tailorability

Heuristics

Rigor

Insight into efficient frontiers

Scalability



Higher value

Model-Based

Toolbox of theories supporting SE

Progress

Systems Engineering

Questions

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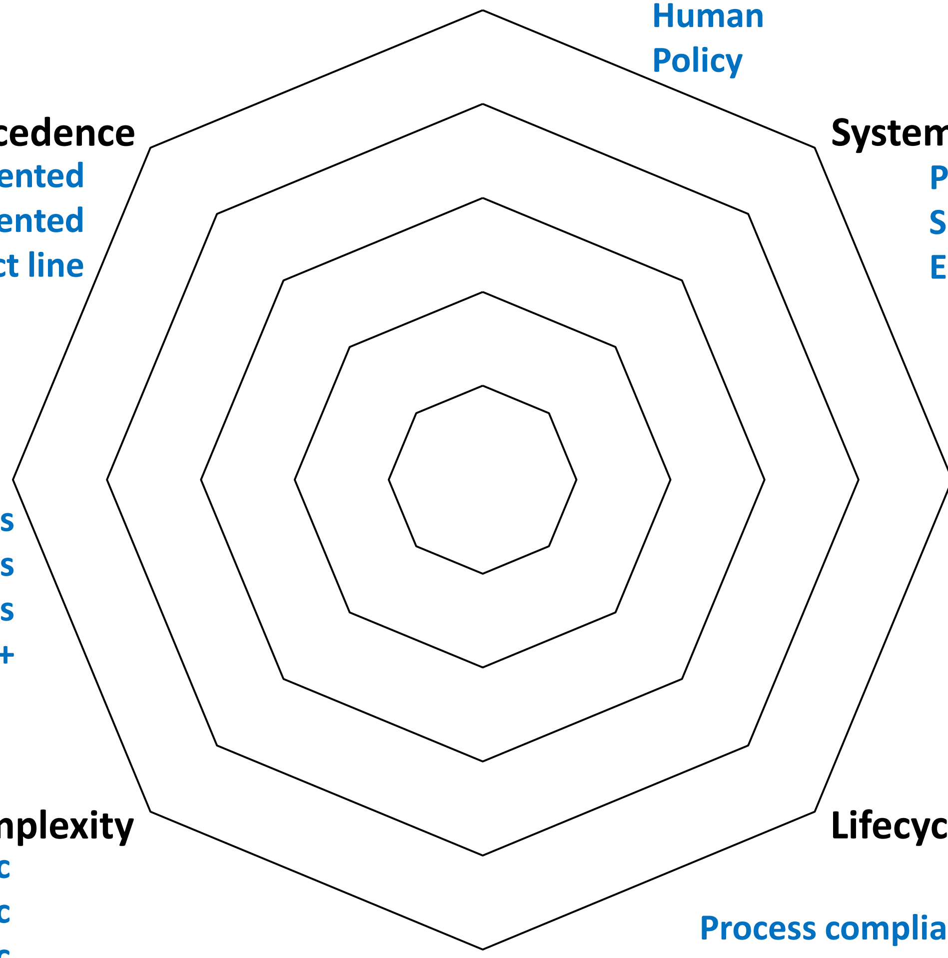
8 Dimensions to Our Challenge



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Responding to 21st Century Needs with 21st Century Systems Engineering

- 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 protacted 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