SYSTEMS ENGINEERING OF THE FUTURE

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Evolution of Our Systems Environment

OBSERVED TRENDS
The Value of SE: Relevancy


E. Honour Study

E. Honour, "Understanding the Value of Systems Engineering," INCOSE, 2004

NASA data


Current Situation: Practices and 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”.
Trend: Increasing Complexity of Systems

Number of Components
Number of Functions
Number of Interactions

Systems Engineering Tools

5000 BC  1200 AD  1750 AD  1850 AD  1900 AD  1980 AD  2010 AD

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Trend: Increasing Rate of Technology Adoption

“With technology infusion rates increasing, the pressure of time to market will also increase, yet customers will be expecting improved product functionality, aesthetics, operability, and overall value.”
Example: **Smart Phone Adoption**

Smart Phone is the most quickly adopted consumer technology in history.
Example: **Recent technology adoption with increasing complexity**

**Autonomy / AI**
- Embedding into many of our systems
- Driverless cars
  - Uber - Pittsburgh
  - Google – Palo Alto
- Deliveries
  - Amazon
  - Budweiser – Otto - [Video](#)
- **Hotels** ([CNN](#))
- **Google DeepMind**
- Advanced Robotics ([Sophia](#))
- DoD
  - Autonomous Learning Systems
  - Human-machine Collaborative Decision Making
  - Assisted Human Operations
  - Advanced Manned-Unmanned System Operations

Effects of Autonomy

Effects of Autonomy - 2

However, autonomy creates other issues:
- Emergent behavior
- Continuous change
- Human/machine interfaces
- How to do V&V
- Trust
- Attack vulnerabilities
- Unemployment
- Unintended changes to other businesses
- Ethics
- Issues from new interfaces
- Information overload

Are we ready to deal with these new issues?
But Do We Know How to Manage AI?

Disruption certainly. Deep AI is the real risk, though, not automation.  

*Musk on Automation versus AI*

— Elon Musk (@elonmusk) *June 9, 2017*

Disruption may cause us discomfort, but it’s not a threat in and of itself. However, Musk and others do see the potential for deep AI to be world-shattering, at least for humans.  

*Futurism, June 2017*

Computers are going to take over from humans, no question. If we build these devices to take care of everything for us, eventually they'll think faster than us and they'll get rid of the slow humans to run companies more efficiently.” (Steve Wozniak)

...perhaps most disturbing, scientists working with Google’s DeepMind AI tested whether or not AI are more prone to cooperation or competition — and found that it can go either way ...

*Futurism, June 2017*

The development of full artificial intelligence could spell the end of the human race.” (Stephen Hawking)
Example: Internet of Things

THE INTERNET OF THINGS
AN EXPLOSION OF CONNECTED POSSIBILITY

YEAR
1992
1995
1998
2000
2002
2005
2008
2010
2012
2015
2017
2018
2020

BILLIONS OF DEVICES
1
2
3
4
5
6
7
8
9
10
11
12

- 1.000,000
- 0.5 BILLION
- IoT INCEPTION
- 2020
- 50.1 BILLION
- 2018
- 34.8 BILLION
- 2016
- 42.1 BILLION
- 2014
- 14.4 BILLION
- 2012
- 8.7 BILLION
- 2010
- 2.2 BILLION
- 2008
- 1.8 BILLION
- 2006
- 1.4 BILLION
- 2004
- 1.0 BILLION
- 2002
- 0.5 BILLION
- 2000
- 0.1 BILLION
- 1998
- 0.05 BILLION
- 1995
- 0.01 BILLION
- 1992

February 28, 2018
Other technology trends in systems

Brain-Machine Interface Systems

Intelligent Systems, Intelligent Sensing, and Intelligent Learning in Systems

Digital Engineering / Digital Twins

Cognitive Computing

Applied Artificial Intelligence - Cognitive Assistants and Human Augmentation

Interactive and Wearable Computing and Devices

Cyber physical systems

Biometrics, Bio-mechatronics, and Bio-robotics

Augmented Reality / Virtual Reality

Big Data and Data Analytics

Cyber Resilient Systems

...
Evolution is Needed

- Evolve our systems

- Evolve our systems engineering approaches (processes, methods, tools, perspectives, ...)

- Evolve our people

“When the rate of external change exceeds the rate of internal change, the end of your business is in sight.” [Jack Welch]
INCOSE Focus on Evolving the Discipline

Systems Engineering needs to evolve practices to address:
- Faster pace of change
- Increasing complexity
- Affordable solutions
- Agile, adaptable, and resilient solutions
- Challenges of tomorrow

Move SE to a cohesive discipline

- Need to place emphasis on transforming our SE practices
  - Model Based Systems Engineering / Digital Systems Models
  - System of Systems / Complex Systems
  - Agile Systems Engineering
  - Product Line Engineering
  - Composable Architectures and Designs
  - Resilient and Adaptable Systems
  - ...
Overview of SE Vision 2025 and the Need for Change

Are we ready for the Future?
SE Vision 2025

“Inspiring and guiding the direction of systems engineering across diverse stakeholder communities”

A WORLD IN MOTION*

*Systems Engineering Vision 2025

Note: Chapter and Domain versions of the Vision are being developed (e.g., Dutch Chapter and Automotive)

18 December 2018
Vision Objectives

- Align SE initiatives, including SE research, SE standards, methods, tools, and curriculum
- Promote SE research and organizational investment
- Identify SE capabilities to support future challenges and needs
- Broaden the base of practitioners across industry domains

The purpose of the Vision 2025 is to inspire and guide the direction of systems engineering across diverse stakeholder communities, which include:

- Engineering Executives
- Policy Makers
- Academics & Researchers
- Practitioners
- Tool Vendors

This vision will continue to evolve based on stakeholder input and on-going collaborations with professional societies.

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SE Vision Systems Engineering Imperatives

- Expanding the APPLICATION of systems engineering across industry domains.

- Embracing and learning from the diversity of systems engineering APPROACHES.

- Applying systems engineering to help shape policy related to SOCIAL AND NATURAL SYSTEMS.

- Expanding the THEORETICAL foundation for systems engineering.

- Advancing the TOOLS and METHODS to address complexity.

- Enhancing EDUCATION and TRAINING to grow a SYSTEMS ENGINEERING WORKFORCE that meets the increasing demand.
Global Context of SE

Global trends:
• Increasing stress on natural resources
• Increasing globalization
• Environmental changes
• Increasing population growth and urbanization
• Increasingly interdependent economies
Today’s Global Challenges

Food and Shelter
Clean water
Health environment
Access to healthcare
Transportation and mobility
Economic security & equity
Security and safety
Access to info, communications, education
Application of Systems Engineering - Systems Engineering Across Industry Domains

- Biomedical
- Transportation
- Consumer Products
- Automotive
- Energy

Sharing of practices and knowledge across domains (and adding value to each domain)
Transforming Systems Engineering

Leveraging Technology for SE Tools

- Cloud-based high performance computing supports high fidelity system simulations
- Advanced search query, and analytical methods support reasoning about systems
- Immersive technologies support data visualization
- Net-enabled tools support collaboration

Tailoring and Scaling Practices for Best Value

- TAILORED TO THE DOMAIN
- SCALED TO PROJECT SIZE
- SCALED TO SYSTEM COMPLEXITY

Value Driven Practices for Developing Systems in 2025 and Beyond
Collaborative Engineering
Complex System Understanding
System of Systems Engineering
System Architecting for multiple viewpoints
Composable Design
Design for Resilience
Design for Security – system integrity
Decision Support
Virtual Engineering and MBSE – part of the digital revolution
Change of process implementation to address technology & application
Tailoring and scaling practices for value
### What Does SE Look Like in This Environment? (1)

<table>
<thead>
<tr>
<th>Dynamic, non-deterministic, evolutionary</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Emergent Behavior is common</td>
</tr>
<tr>
<td>• Capabilities continue to evolve</td>
</tr>
<tr>
<td>• Learns and adapts to new needs</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Cybersecurity and assurance need to be integral, not “bolt-on”</th>
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<tbody>
<tr>
<td>• Integrity, Availability, and Confidentiality (resistance to access)</td>
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<tr>
<th>New approaches to V&amp;V</th>
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<tr>
<td>• Current methods are inadequate for testing systems that learn and adapt</td>
</tr>
<tr>
<td>• Behavior changes as data and models are changed by system</td>
</tr>
<tr>
<td>• V&amp;V needed throughout life cycle – especially when state changes</td>
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</tbody>
</table>
### What Does SE Look Like in This Environment? (2)

| Ongoing modeling and simulation challenges | • Robust modeling and simulation capabilities are needed, but ...
|                                          | • How is M&S kept current and controlled when system learns and adapts? |
| Ongoing operational changes              | • Less human dependent, changing Rules of Engagement and Concept of Operations |
|                                          | • Changes to training and mission/business parameters |
| Changes required for a literate workforce | • Much greater man-machine interface, and machine may have the leading role |
|                                          | • Need for skilled personnel at all lifecycle phases |
|                                          | • Adaptable workforce, as roles will change more quickly - get past culture change issues |
What Does SE Look Like in This Environment? (3)

Technology will continue to influence

- But at potential faster rates ...
- “Tech watch” programs are necessary, but not sufficient

Governance may present issues

- Different “ownership” of the interacting systems (System of Systems issue)
- Control of the learning and changing system
- Management of the changing operational areas
- Preventing unintended use or consequences
SHORING UP THE THEORETICAL FOUNDATION OF SYSTEMS ENGINEERING
Essential Systems Engineering Competencies

- Systems and Specialty Engineering Methods
- Technical Leadership
- Socio-technical Competency
- Software-based Tools
- Full System Life-cycle Experience
- Domain-specific Application and Technical Knowledge
Back-up Charts