SYSTEMS ENGINEERING OF THE FUTURE

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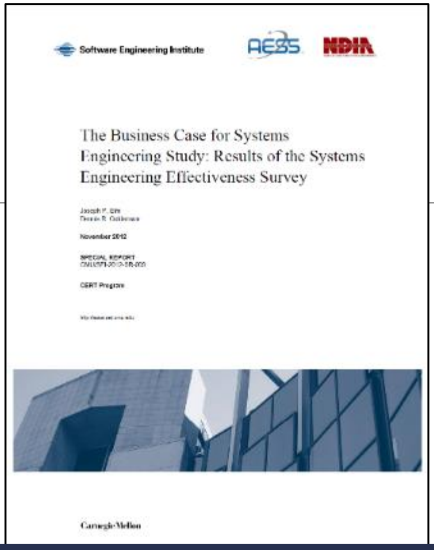
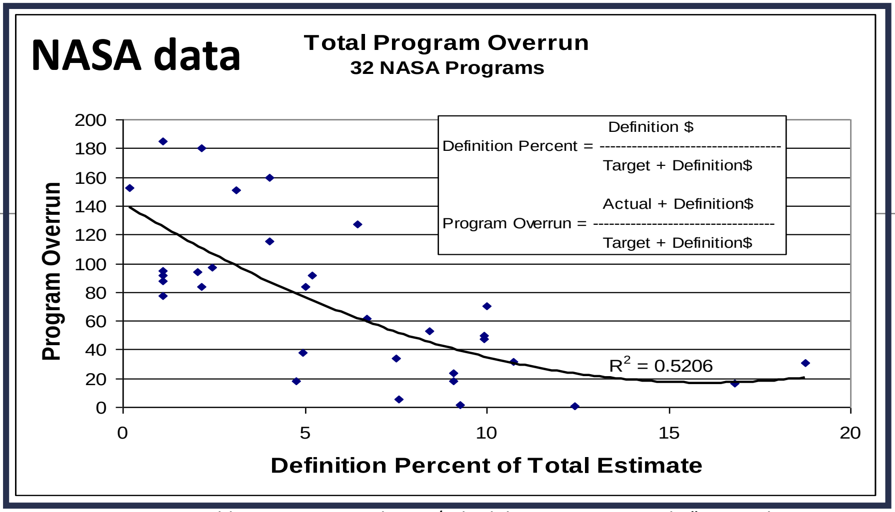
Evolution of Our Systems Environment

OBSERVED TRENDS

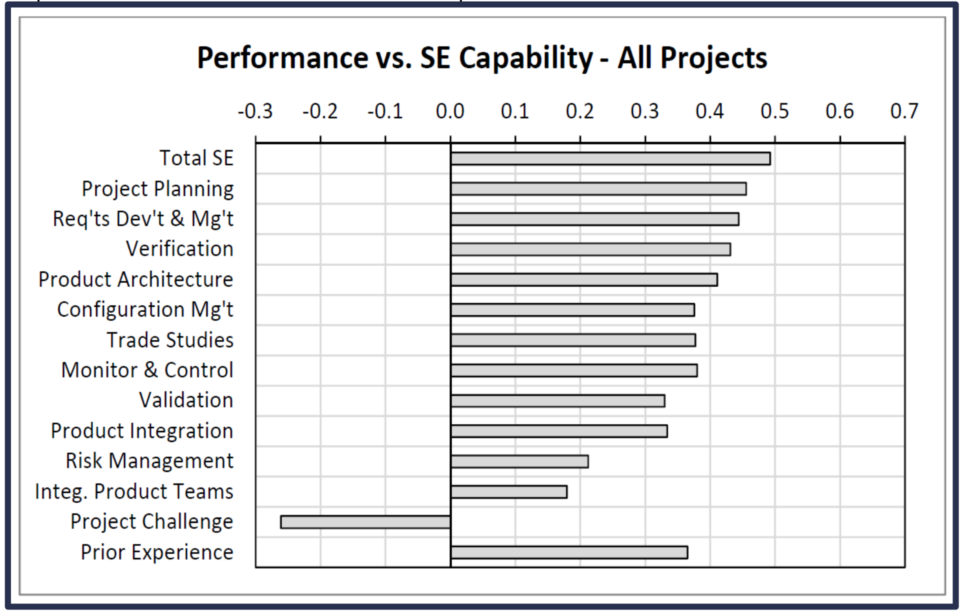
The Value of SE: Relevancy

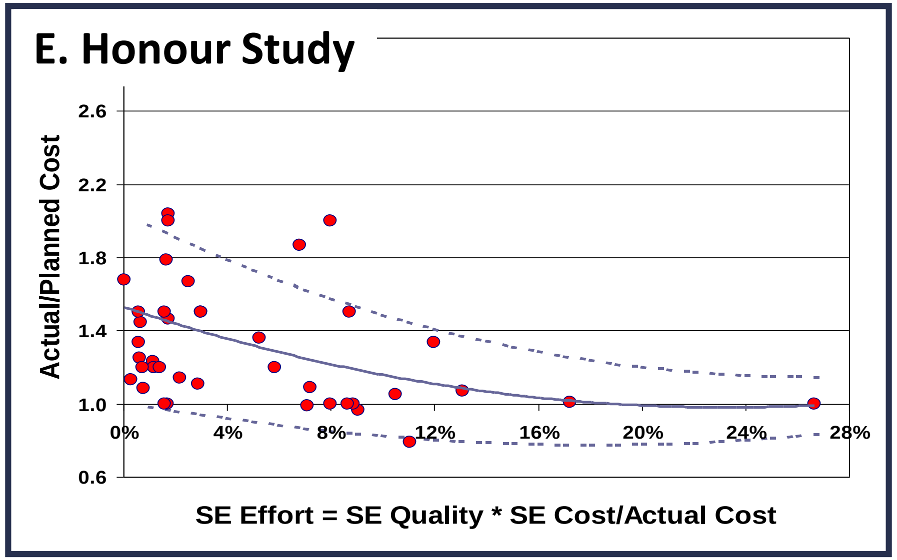


Elm, Joseph, et al "The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey", CMU/SEI-2012-SR-009, November 2012



W. Gruhl, Lessons Learned, Cost/Schedule Assessment Guide," Internal Presentation, NASA Comptroller's Office, 1992





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

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.

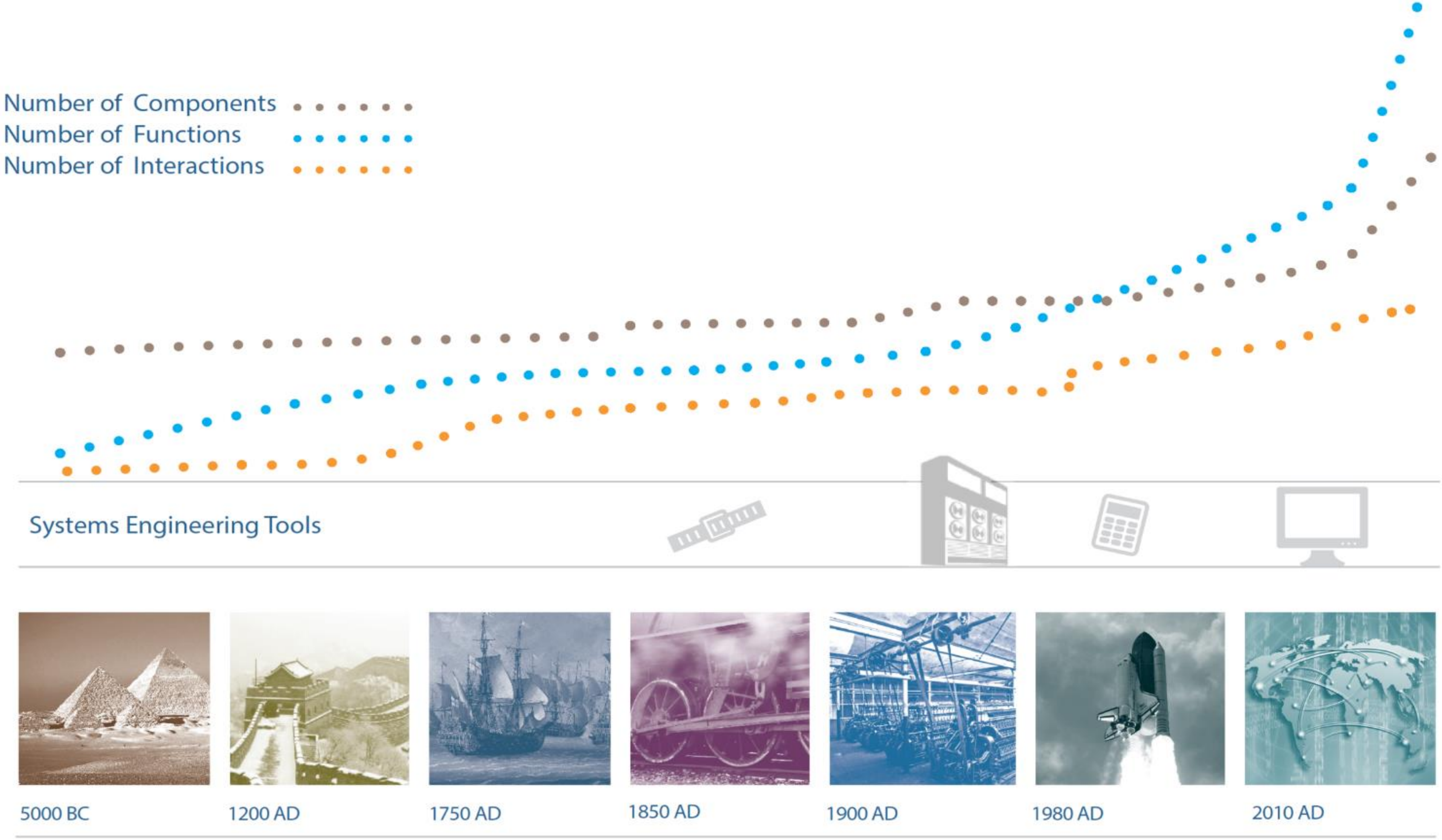
3 Knowledge and investment are lost at project life cycle phase boundaries . . . increasing development cost and risk of late discovery of design problems

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".

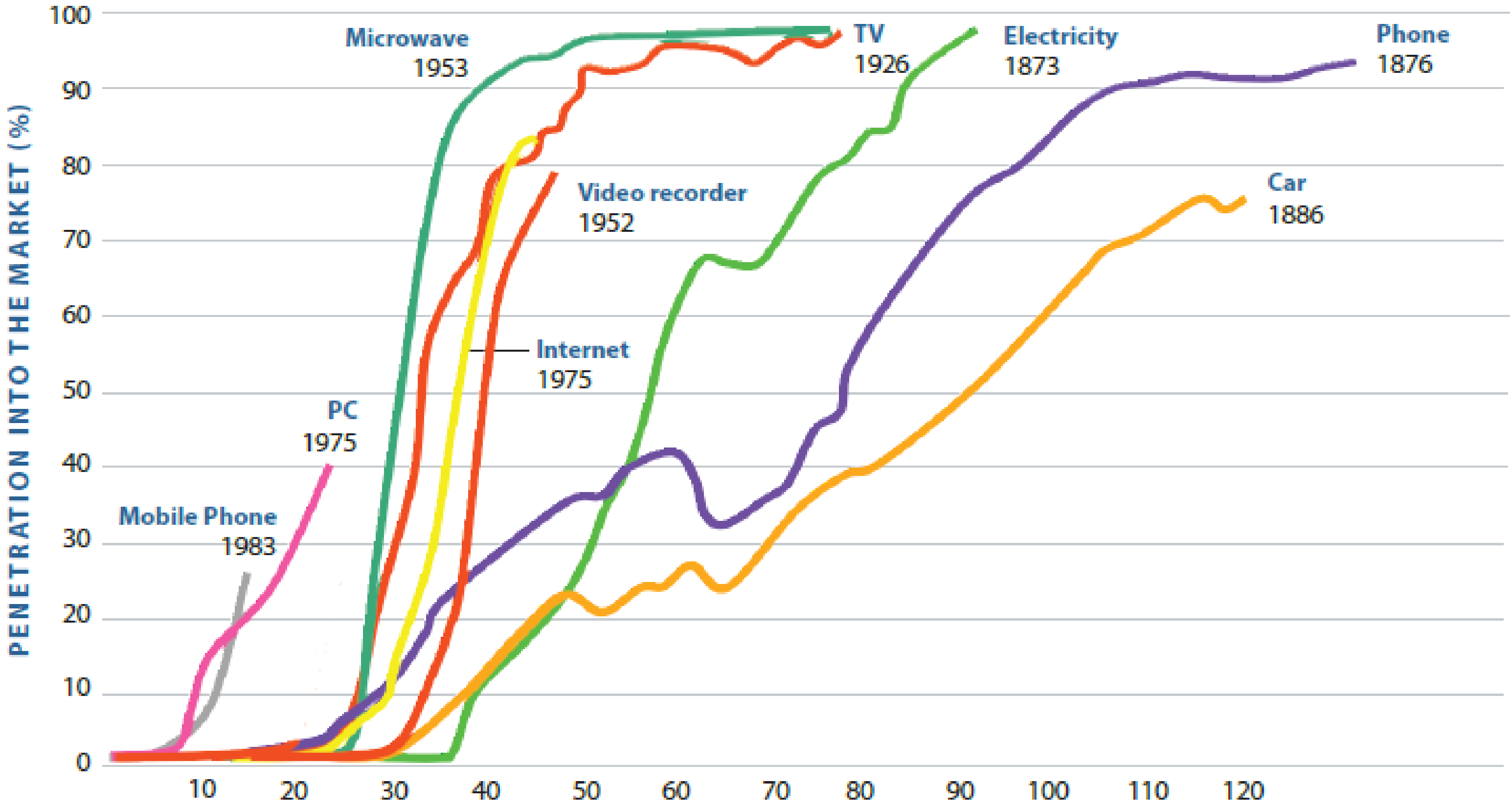
Trend: Increasing Complexity of Systems



Trend: Increasing Rate of Technology Adoption

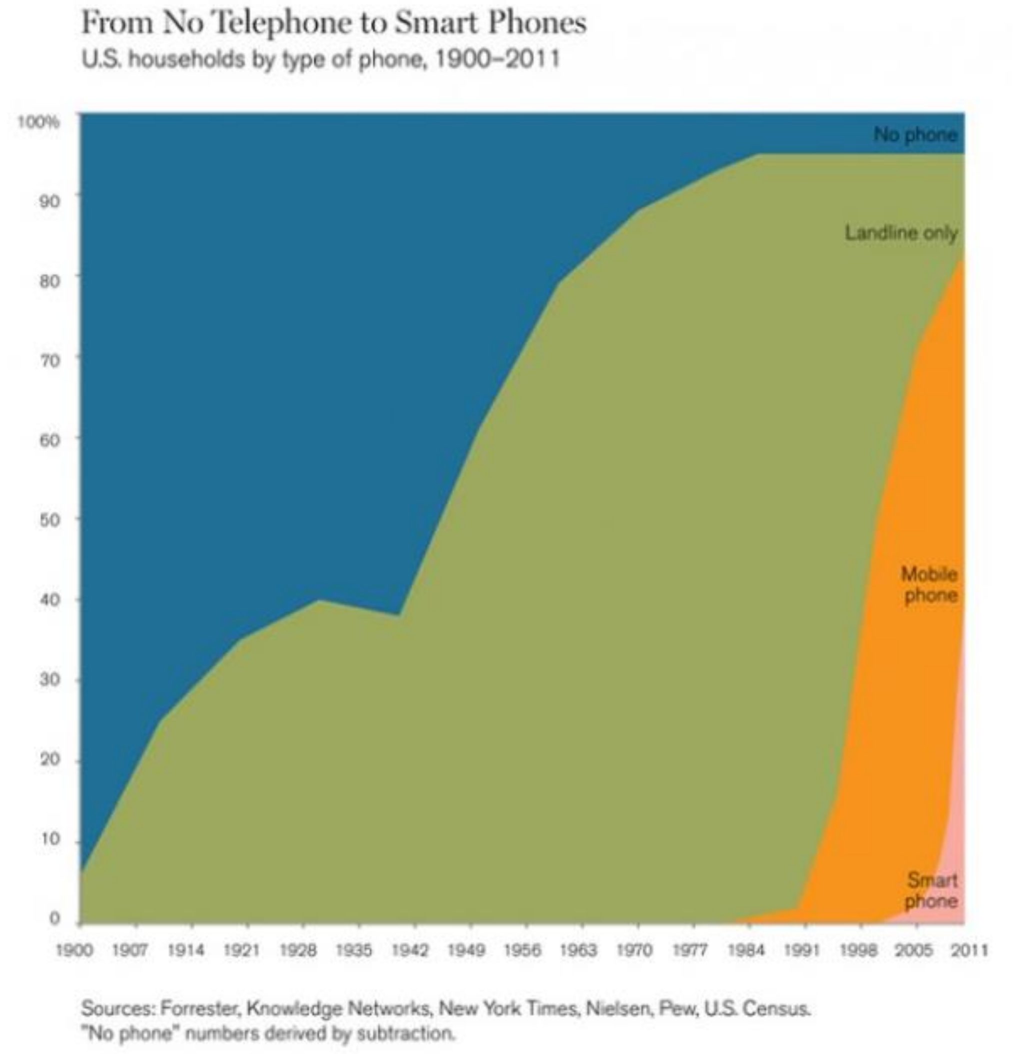
NEW TECHNOLOGIES CHANGE OUR DAILY LIFE AT AN EVER INCREASING RATE

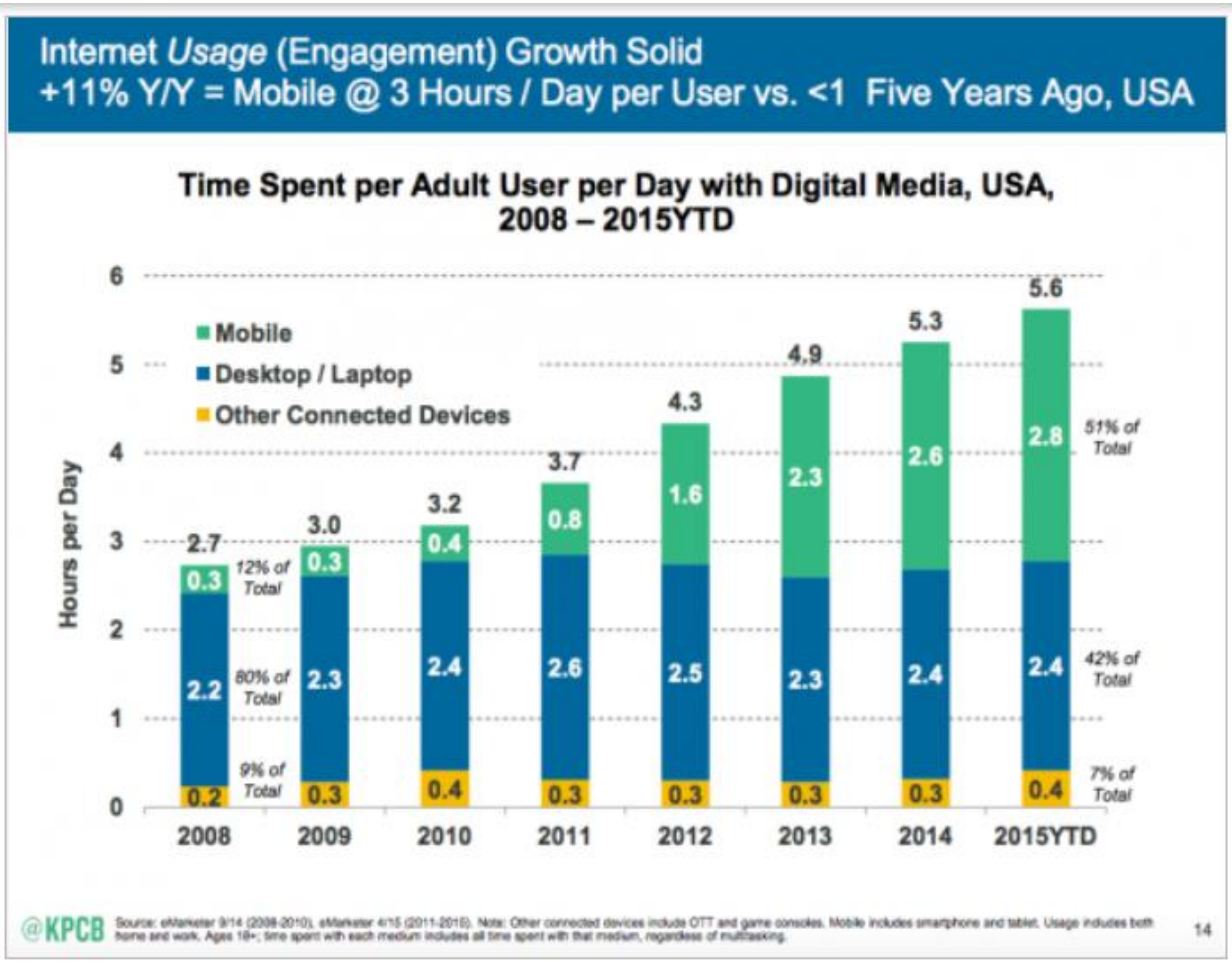
Source: Forbes magazine



"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





Jun 28, 2017
Source: KPCB mobile technology trends by Mary Meeker

Smart Phone is the most quickly adopted consumer technology in history

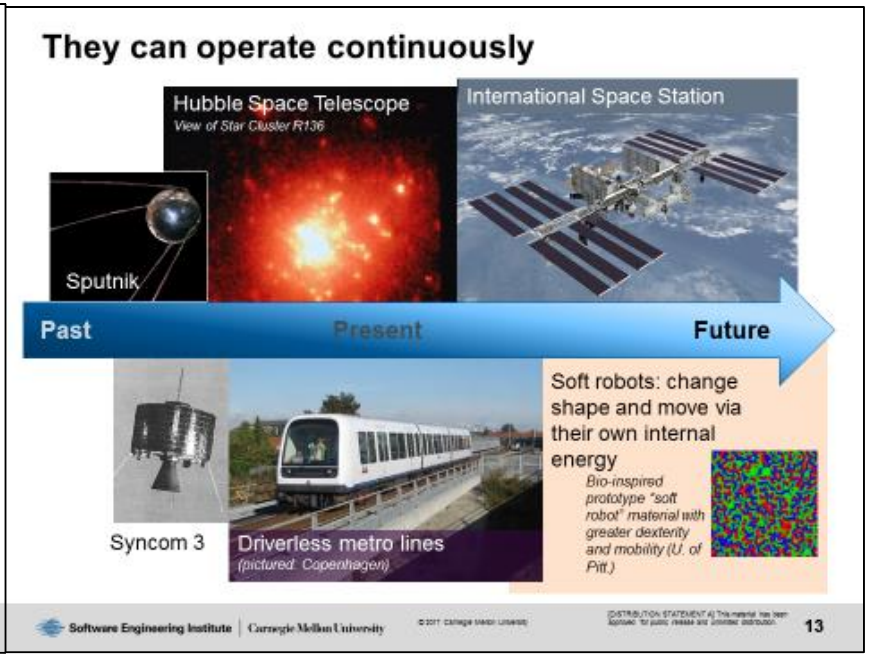
Example: Recent technology adoption with increasing complexity

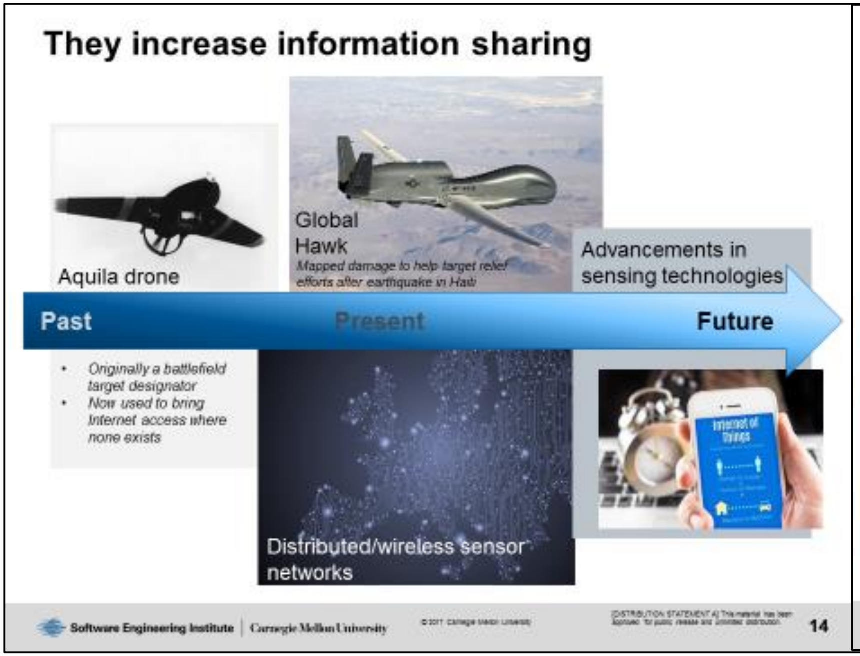
Autonomy / AI

- 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

Credit: Steve Jurvetson, 2012.

Effects of Autonomy





Source: Paul Nielsen, "Systems Engineering and Autonomy: Opportunities and Challenges", Keynote Presentation at INCOSE Symposium, July 2017 – used with permission

Effects of Autonomy - 2

Source: Paul Nielsen, "Systems Engineering and Autonomy: Opportunities and Challenges", Keynote Presentation at INCOSE Symposium, July 2017 – used with permission

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

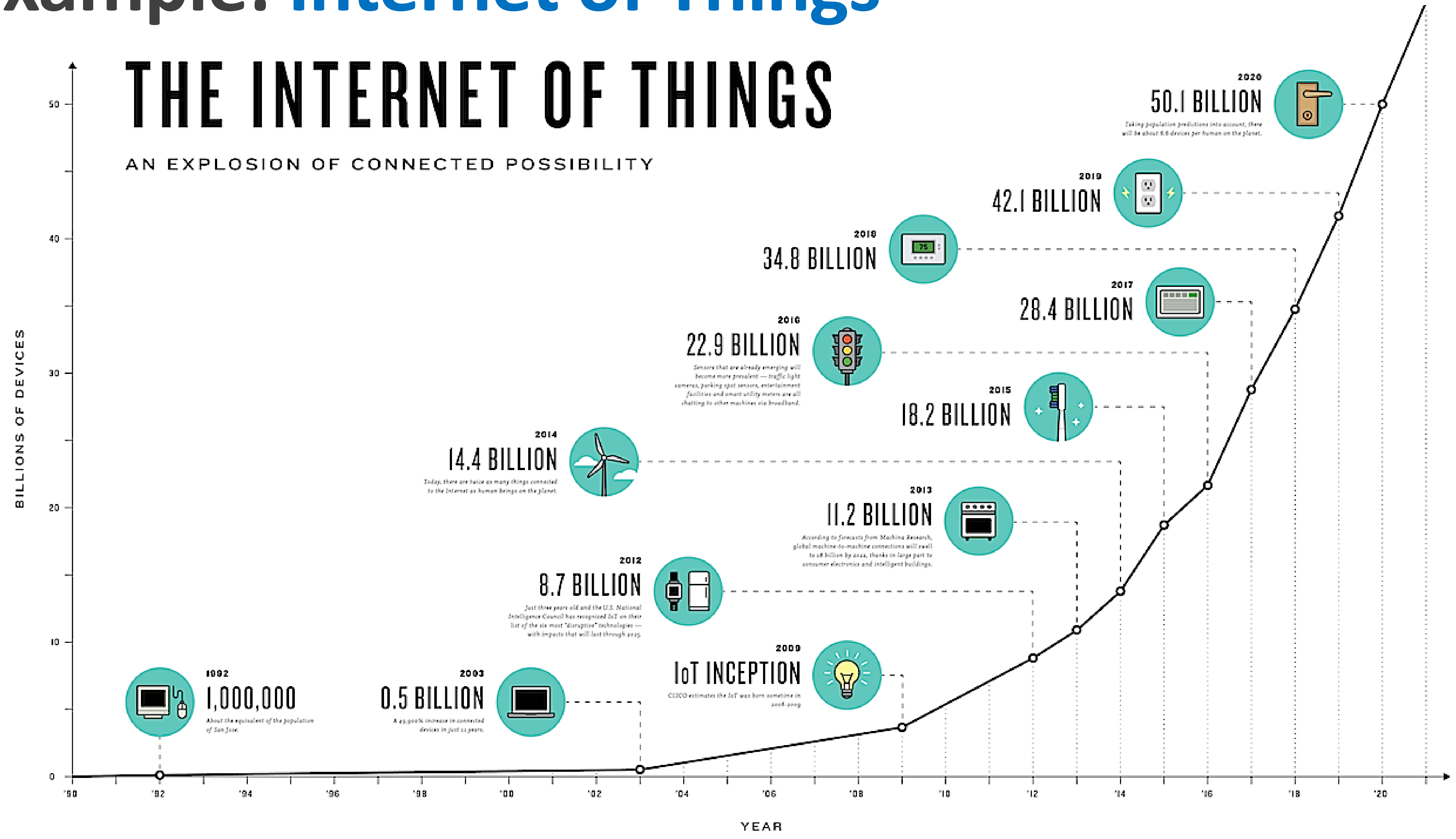
Computers are going to take over from humans, no question. If we build these devices to take care of everything for us, eventually they'll think faster than us and **they'll get rid of the slow humans to run companies more efficiently**." (Steve Wozniak)

…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



Other technology trends in systems

Brain-Machine Interface Systems

Intelligent Systems, Intelligent Sensing, and Intelligen
Learning in Systems

Digital Engineering / Digital Twins

Cognitive Computing

Applied Artificial Intelligence - Cognitive Assistants an
Human Augmentation

Interactive and Wearable Computing and Devices

Cyber physical systems

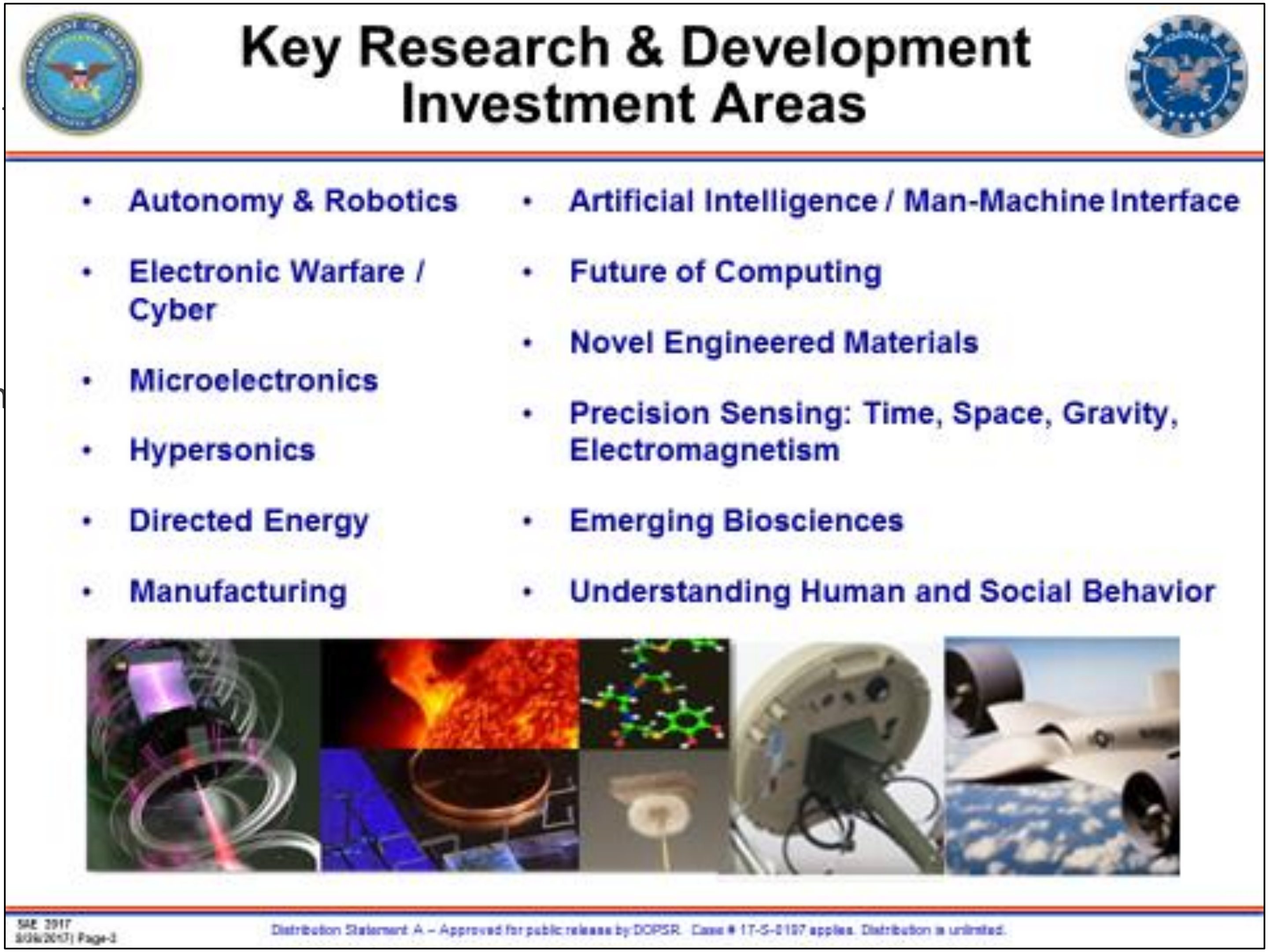
Biometrics, Bio-mechatronics, and Bio-robotics

Augmented Reality / Virtual Reality

Big Data and Data Analytics

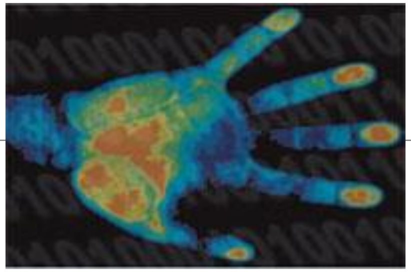
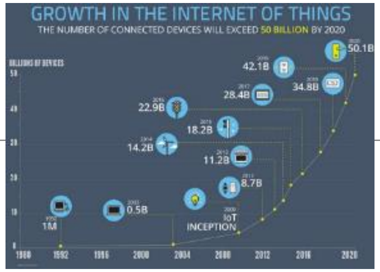
Cyber Resilient Systems

…



Evolution is Needed

- Evolve our systems

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

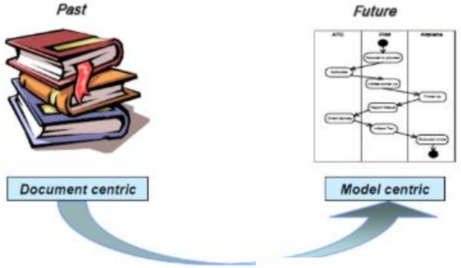
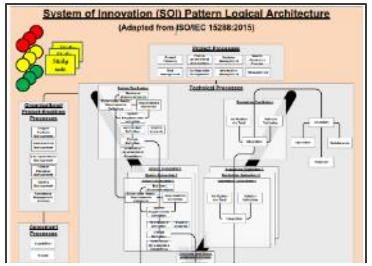
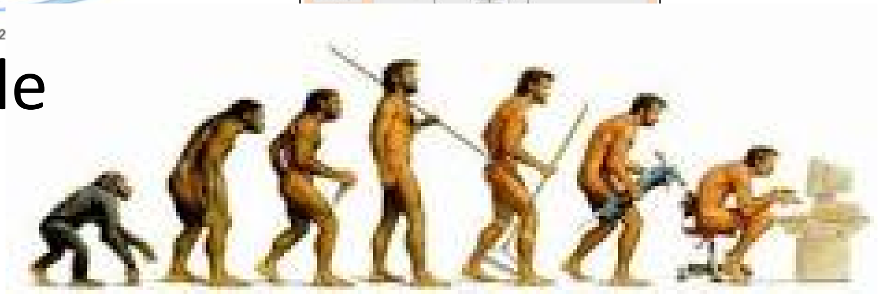


Figure from INCOSE Systems Engineering Vision 202



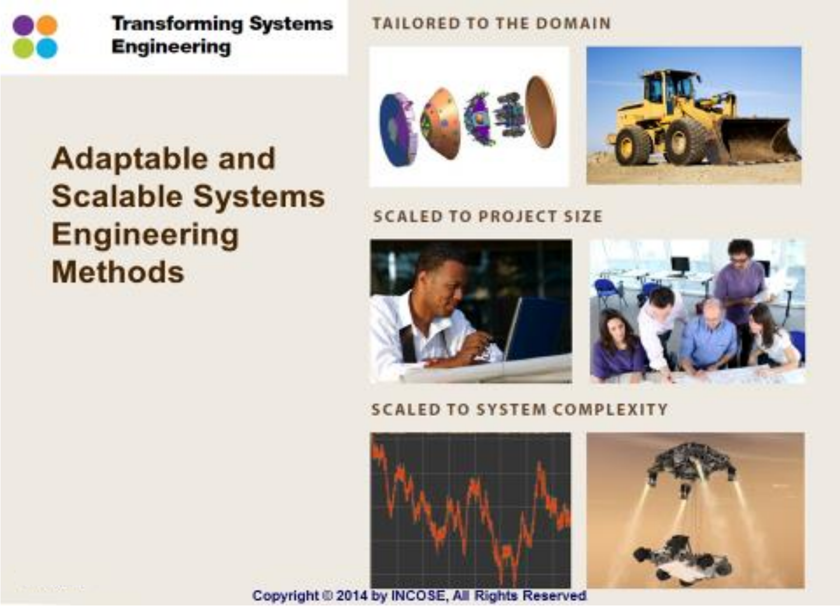
Deterministic Linear Predictable	→	Non-deterministic Evolutionary Stochastic

- Evolve our people


Alphabytesoup.wordpress.com

"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

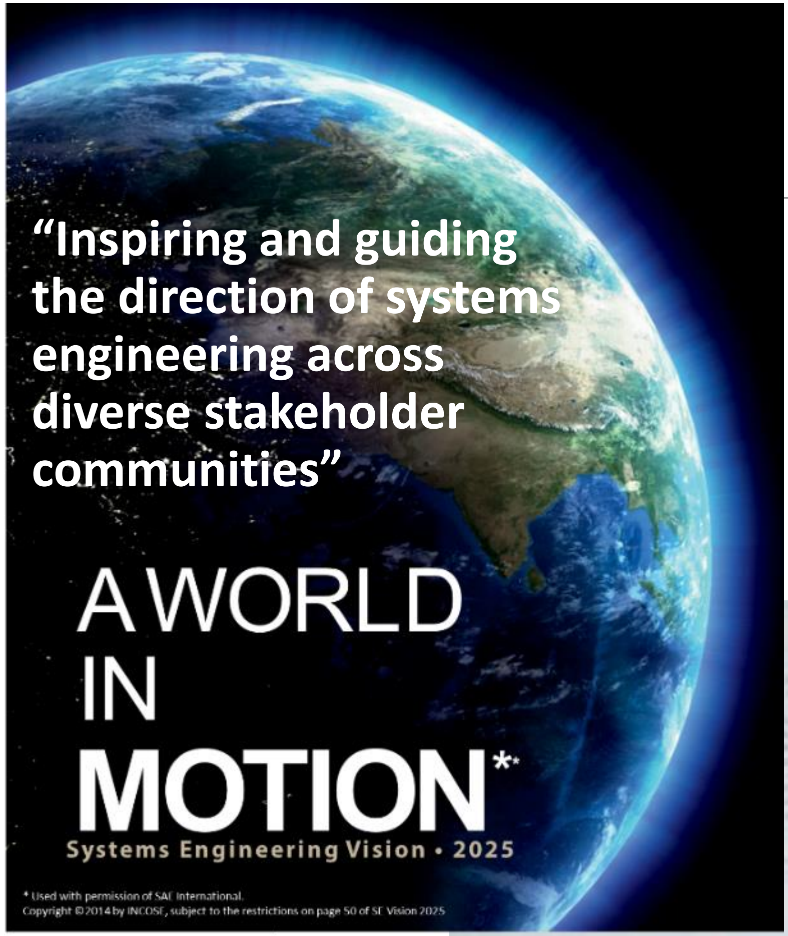
Move SE to a cohesive discipline

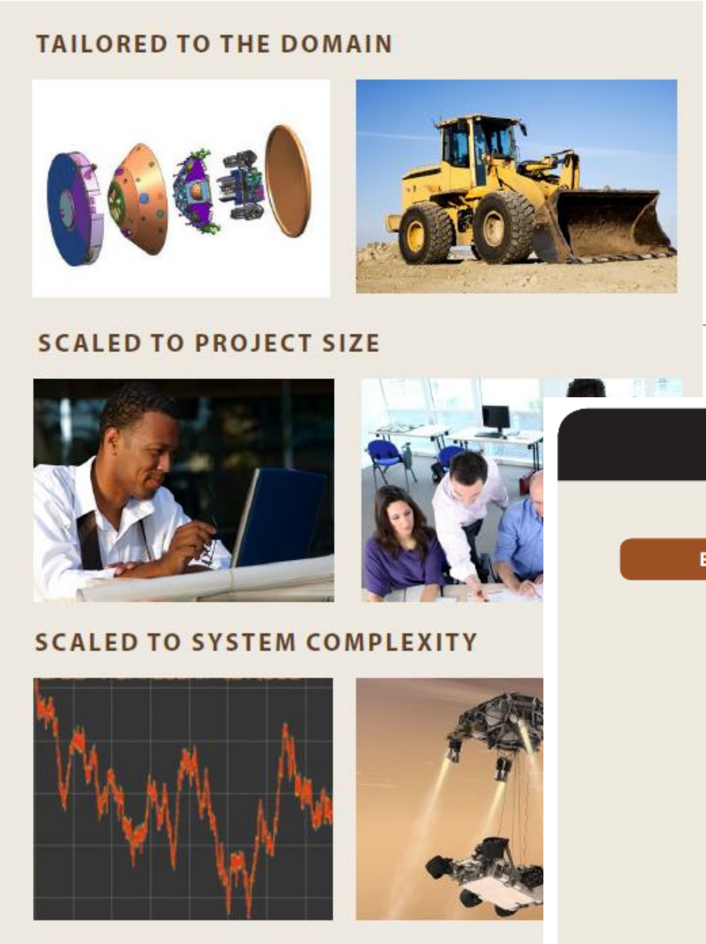
- Need to place emphasis on transforming our SE practices
  - Model Based Systems Engineering / Digital Systems Models
  - System of Systems / Complex Systems
  - Agile Systems Engineering
  - Product Line Engineering
  - Composable Architectures and Designs
  - Resilient and Adaptable Systems
  - …

Overview of SE Vision 2025 and the Need for Change

Are we ready for the Future?

SE Vision 2025





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

Vision Objectives

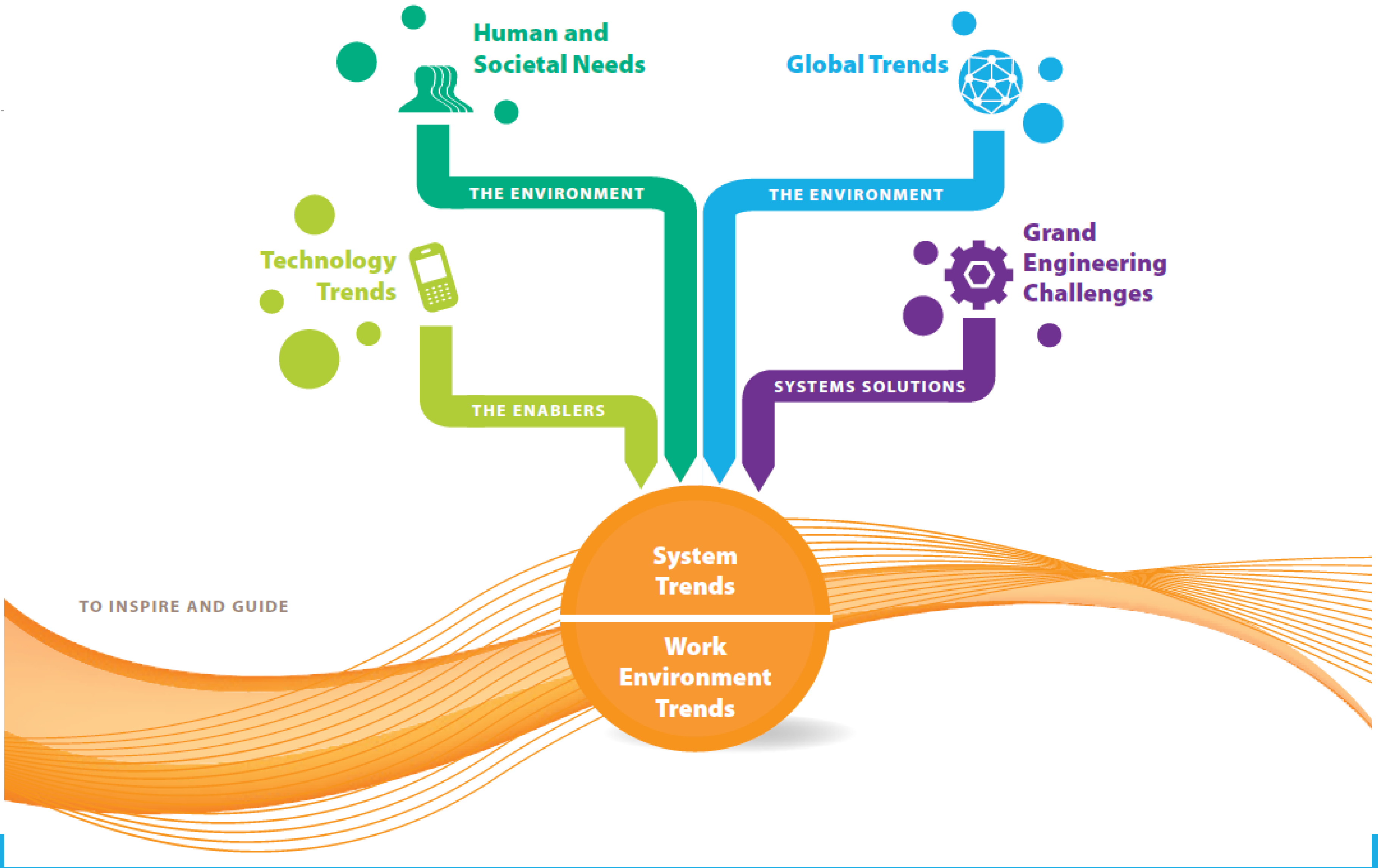
SE Vision Systems Engineering Imperatives

- 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

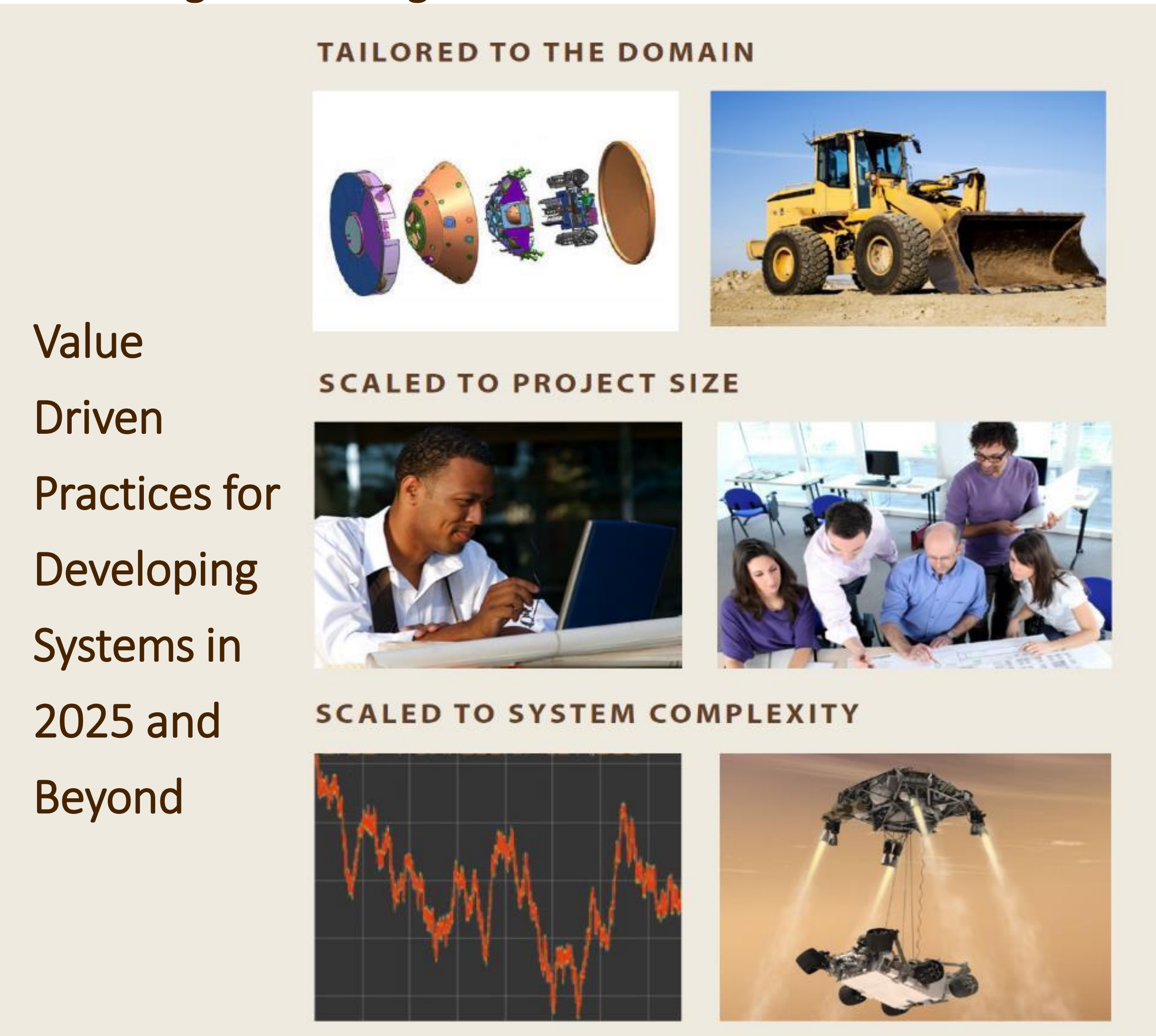
Application of Systems Engineering - Systems Engineering Across Industry Domains

SHARING OF PRACTICES AND KNOWLEDGE ACROSS DOMAINS (AND ADDING VALUE TO EACH DOMAIN)

Transforming Systems Engineering

Leveraging Technology for SE Tools

Tailoring and Scaling Practices for Best Value



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Transforming Practices

Collaborative Engineering

Complex System Understanding

System of Systems Engineering

System Architecting for multiple viewpoints

Composable Design

Design for Resilience

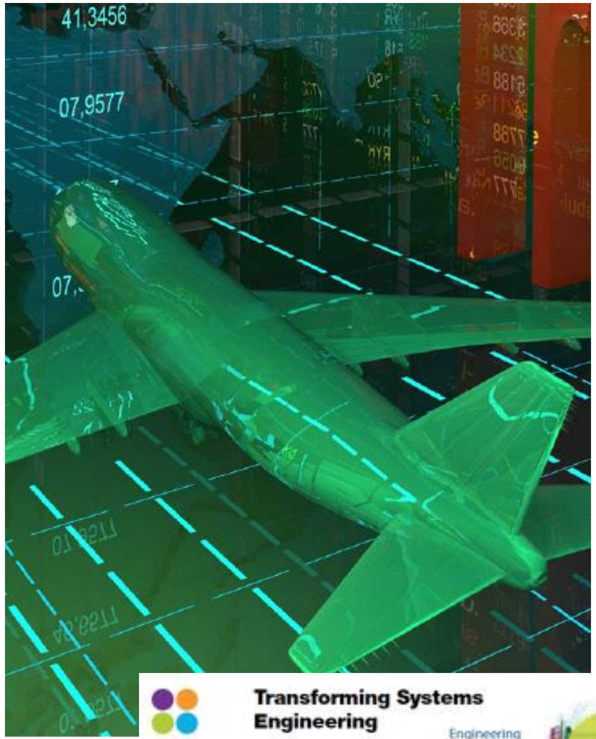
Design for Security – system integrity

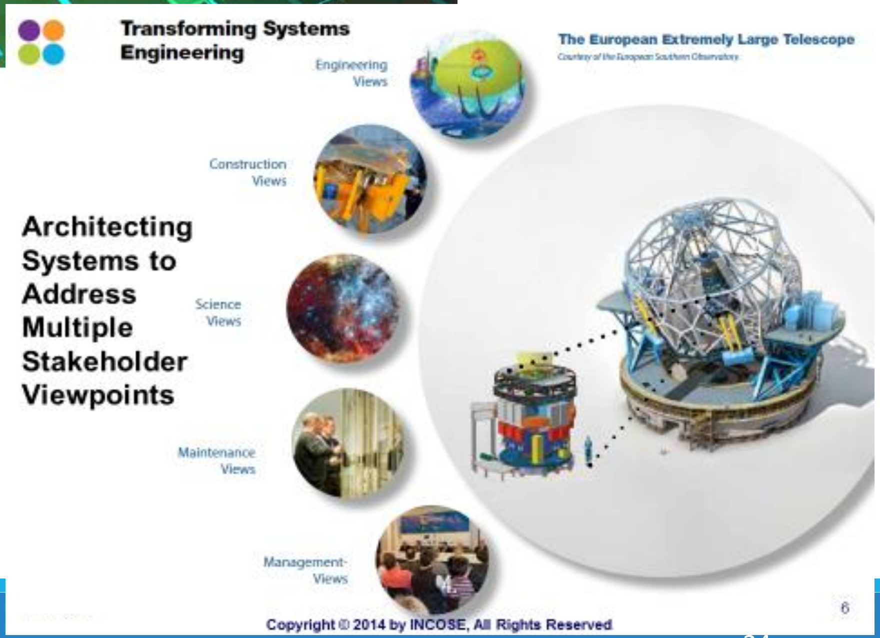
Decision Support

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)

Dynamic, non-deterministic, evolutionary	• Emergent Behavior is common • Capabilities continue to evolve • Learns and adapts to new needs
Cybersecurity and assurance need to be integral, not "bolt-on"	• Integrity, Availability, and Confidentiality (resistance to access)
New approaches to V&V	• Current methods are inadequate for testing systems that learn and adapt • Behavior changes as data and models are changed by system • V&V needed throughout life cycle – especially when state changes

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

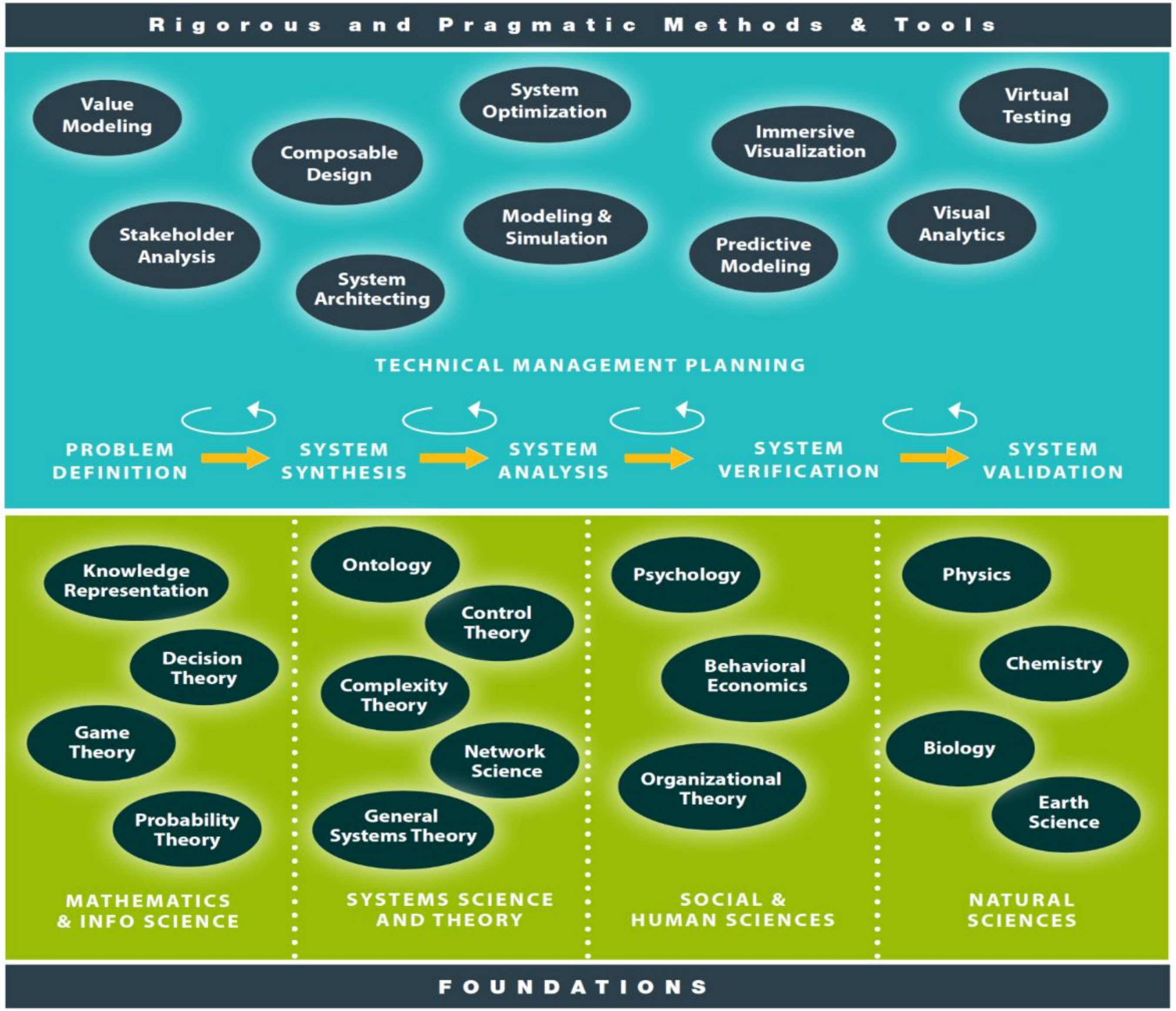
- But at potential faster rates …
- “Tech watch” programs are necessary, but not sufficient

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

Systems Engineering Foundations

SHORING UP THE THEORETICAL FOUNDATION OF SYSTEMS ENGINEERING



Essential Systems Engineering Competencies

Back-up Charts

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