

SE of the Future: Shaping the Future of Systems Engineering

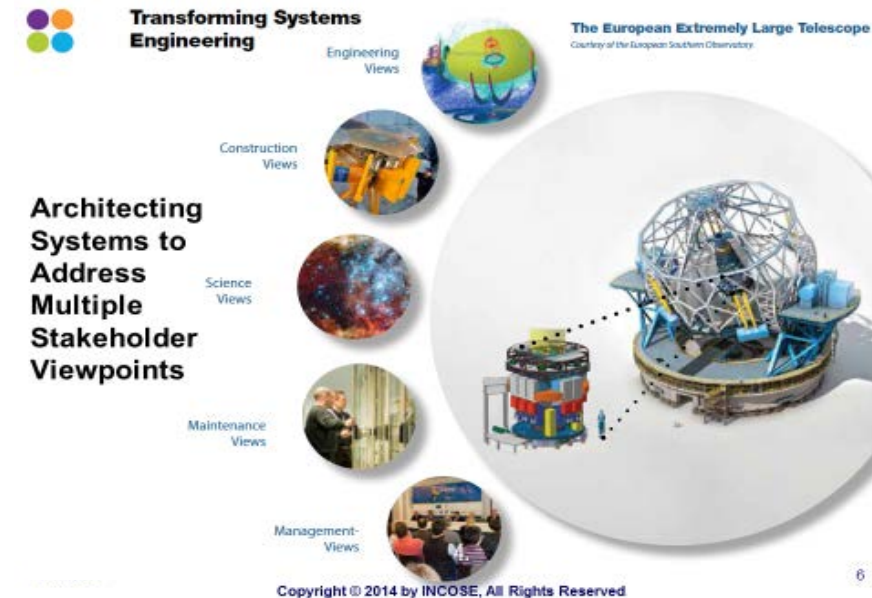
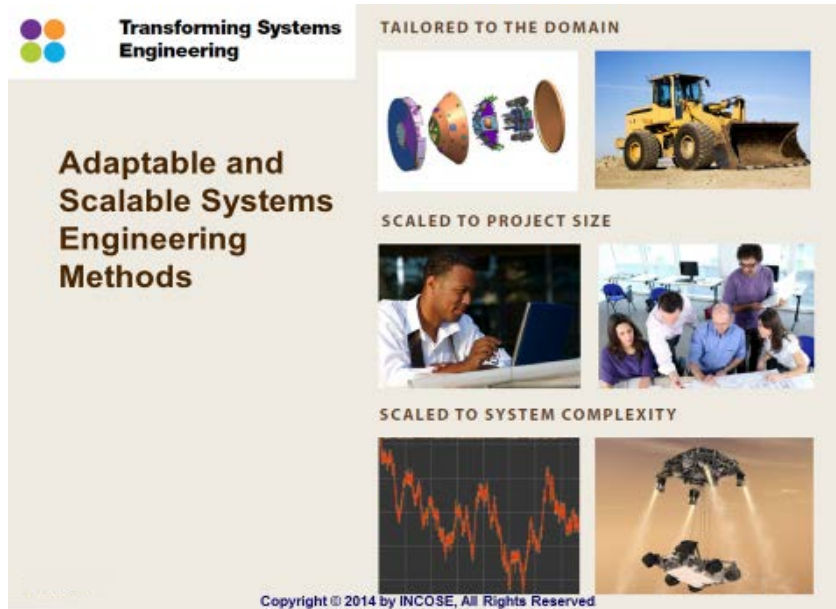
Garry Roedler, ESEP



INCOSE President,
INCOSE Fellow and Founder Recipient,
IEEE-CS Golden Core,
Lockheed Martin Senior Fellow,
Engineering Outreach Program Manager

**NDIA SE Division Meeting
28 February 2018**

INCOSE Focus on Evolving the Discipline



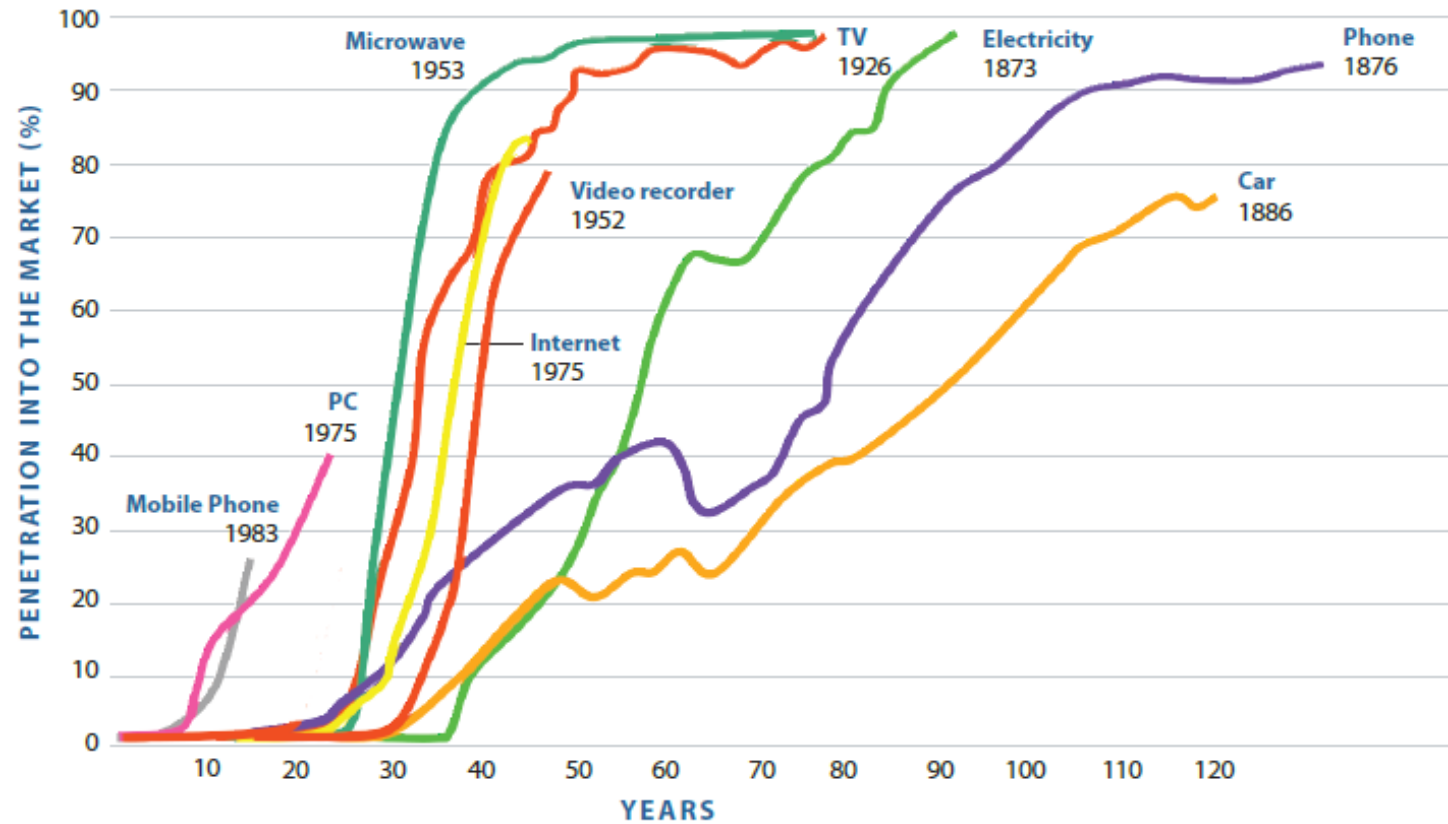
- Systems Engineering needs to evolve practices to address:
 - Faster pace of change
 - Increasing complexity
 - Affordable solutions
 - Agile, adaptable, and resilient solutions
 - Challenges of tomorrow
- Move SE to a cohesive discipline

- 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
 - ...

Trend: Increasing Rate of Technology Adoption



NEW TECHNOLOGIES
CHANGE OUR DAILY
LIFE AT AN EVER
INCREASING RATE
Source: Forbes magazine

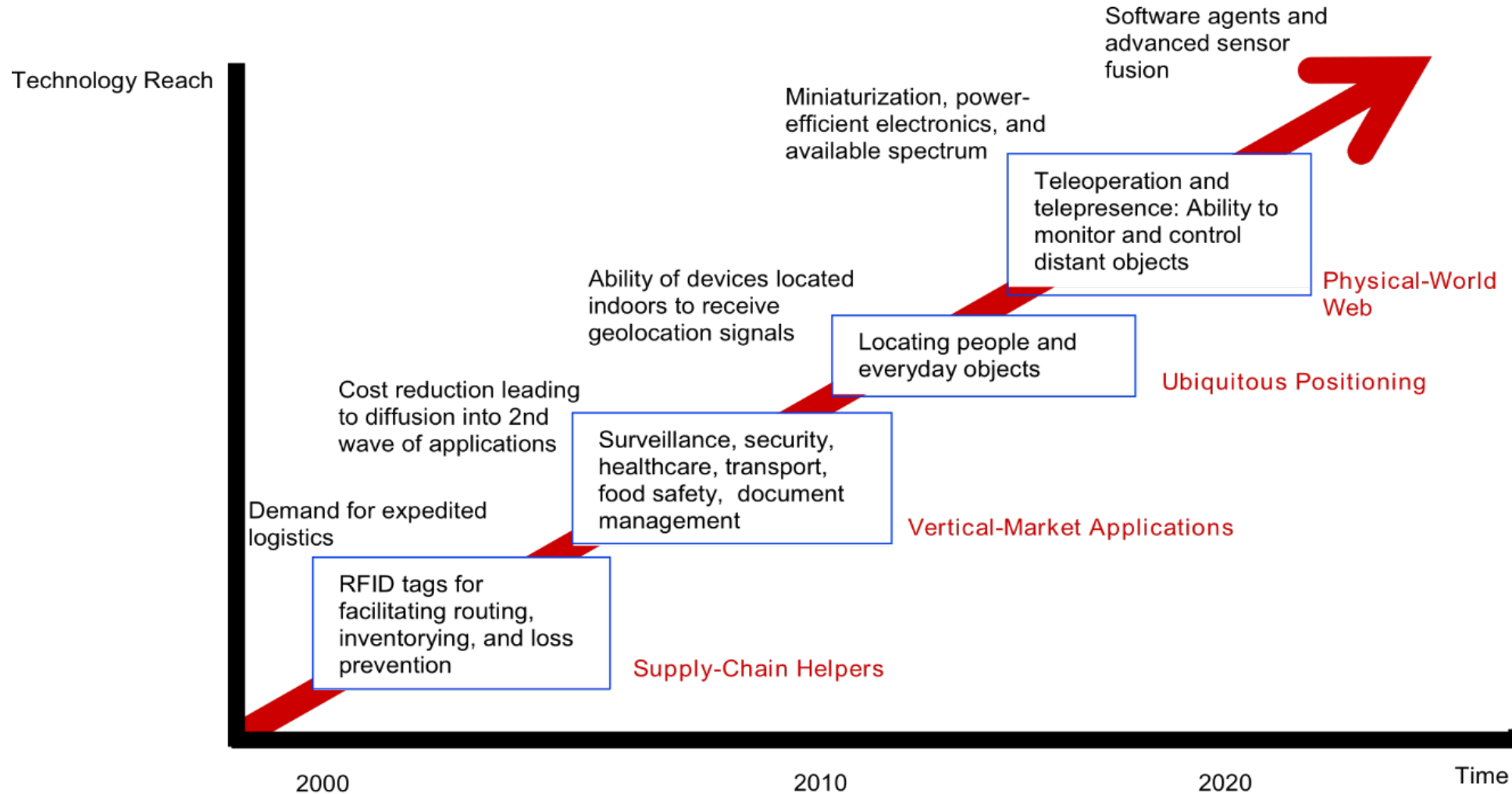


“With technology infusion rates increasing, the pressure of time to market will also increase, yet customers will be expecting improved product functionality, aesthetics, operability, and overall value. “

Trend: From Stand-Alone to Interconnected to IoT



TECHNOLOGY ROADMAP: THE INTERNET OF THINGS



Source: SRI Consulting Business Intelligence

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

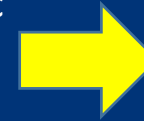
Impacts from Technology Advances

- V&V methods/techniques – Building trust
- Managing models as technologies improve the system? E.g., Self-Adaptive changes
- **Managing an evolving architecture – both from rapidly changing SW and self-adaptation**
- **Need for fast, robust data analysis**
- Increased cyber threat – need for greater emphasis

Systems Engineering of the Future

Systems of Systems Challenges

Deterministic
Linear
Predictable



Non-deterministic
Evolutionary
Stochastic



Context: The scale of complicated and complex systems & services continues to increase exponentially with intricate and often hidden interfaces & interrelationships, and operating in a dynamic and non-deterministic world.

Cyber-physical, complex adaptive, socio-technical systems:

Flows & conversions of energy, materials, signals/information

Transforming materials → objects → goods & services

Mo “When the rate of external change exceeds the rate of internal change, the end of your business is in sight.”

App [Jack Welch]

Systems Engineering of the Future

A New Collaborative Initiative



- Imperative to address current and future systems challenges – “Adapt or be irrelevant”
- Intended Outcome – Evolving systems engineering that enables us to leverage the new technologies that drive us fully into a dynamic, nondeterministic, and evolutionary environment
- Draft Framework:
 - Define problem statement
 - Define the challenges that are driving change
 - Identify impacts to systems engineering
 - Establish roadmaps matching systems engineering capabilities to match the challenges
 - Initiate actions, projects, research, benchmarking, training/education, and communications – short term, mid-term, and long-term



Systems Engineering of the Future

A Systems World Perspective of Context



System Science & SE Foundations

- Processes, Methods & Guidelines
- Models & Tools
- Standards
- Tailoring Guidance
- System Research & Theories

Environments

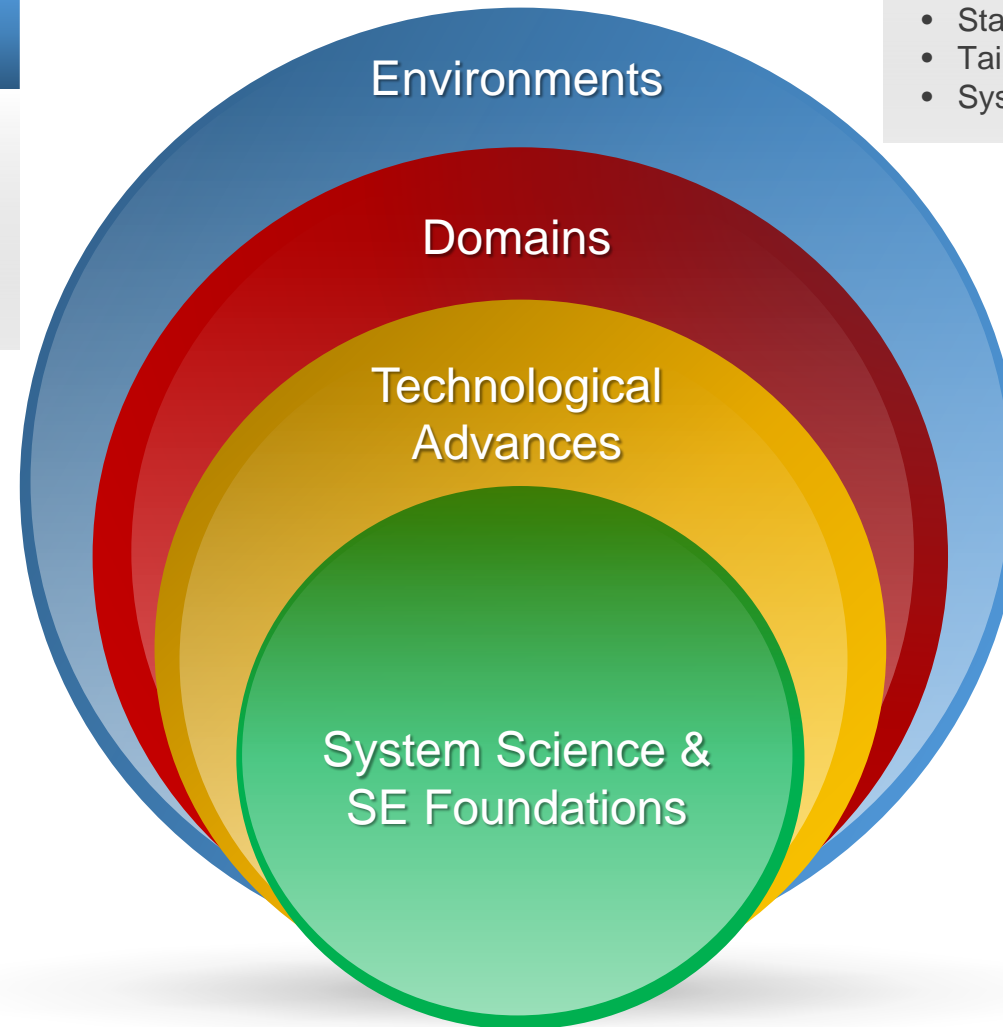
- Ecosystems– Natural & Artificial/Manmade
- Economical Environment
- Political Environment
- Health Environment

Domains

- Defense
- Space
- Healthcare
- Games – serious games
- Transportation
- Communications
- Information
- Consumer Electronics
- Public Policy
- Biomedical
- Housing

Technological Advances

- Artificial Intelligence (AI)
- Autonomy
- Big Data
- Internet of Things (IoT) / Smart Things
- Smart X (eg Smart Cities)
- Cloud Computing
- Ubiquitous Access to Information
- Power/Energy
- Augmented Virtual Reality
- Simulation/Stimulation
- Sustainment/Elegant Systems
- 3D Printing
- Cyber-Physical Systems
- Ability to find Unique (Old) via eBay, Amazon, etc



How You Can Get Involved

- Core Team
 - Meets weekly
 - Requires representation of an major group
 - Requires significant level of commitment
- Broader SE Team
 - Meets Monthly
 - Expected to be more than an interested party
 - Review and input
 - May be requested to lead actions
- Need an NDIA SED Liaison/Representative
- Initiative Lead and Primary POC
 - Bill Miller (wdmiller220@gmail.com)

Plan to be with us in Washington DC for IS2018!



July 7 – 12, 2018

Grand Hyatt Washington

1000 H Street NW, Washington, DC 20001



Back-up Charts

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



Autonomous systems improve productivity

Articulated robotic arm development

Past: First robotic arm
Present: [Image of industrial robot]
Future: [Image of futuristic robot]

Baxter deep-machine-learning robot
Motion planning algorithms

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They can operate continuously

Hubble Space Telescope
View of Star Cluster R136

Sputnik
International Space Station

Past: [Image of Sputnik]
Present: [Image of Hubble Telescope]
Future: [Image of International Space Station]

Syncom 3
Driverless metro lines (pictured: Copenhagen)

Soft robots: change shape and move via their own internal energy
Bio-inspired prototype "soft robot" material with greater dexterity and mobility (U. of Pitt.)

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They increase information sharing

Aquila drone
Global Hawk
Mapped damage to help target relief efforts after earthquake in Haiti

Advancements in sensing technologies

Past: [Image of Aquila drone]
Present: [Image of Global Hawk]
Future: [Image of futuristic drone]

Originally a battlefield target designator
Now used to bring Internet access where none exists

Distributed/wireless sensor networks

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They can process tremendous volumes of data

Stanley
Winner of 2005 DARPA grand challenge

Watson
2,800 microprocessors, with capacity to handle 80 trillion operations per second

Past: [Image of Stanley car]
Present: [Image of Watson game show]
Future: [Image of futuristic car]

Diagnostic expert systems
Deep Blue
Memorial Sloan Kettering Cancer Center trains Watson to help oncologists make more nuanced treatment decisions more quickly

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They will work where we cannot safely go

Dante II
Robotic exploration of extreme terrains

Fukushima
Atlas
Search and rescue

SeaPerch Challenge

Past: [Image of Dante II]
Present: [Image of Fukushima]
Future: [Image of Atlas robot]

Explosive Ordnance Disposal
World Trade Center, Iraq, Afghanistan

U.S. Office of Naval Research program to equip students to build underwater robots and encourage innovation

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Effects of Autonomy - 2

Effects of Autonomy

Autonomous systems improve productivity

Articulated robotic arm development
Baxter deep-machine-learning robot
Motion planning algorithms

They can operate continuously

Hubble Space Telescope
International Space Station
Soft robots: change shape and move via their own internal energy



- 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

They increase information sharing

Aquila drone
Global Hawk
Advancements in sensing technologies
Distributed wireless sensor networks

They can process tremendous volumes of data

Stackley
Watson
Diagnostic expert systems
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They will work where we cannot safely go

Dante II
Fukushima
Atlas
SeaPerch Challenge
Explosive Ordnance Disposal

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

Are we ready to deal with these new issues?

Example Issue: V&V - Trust

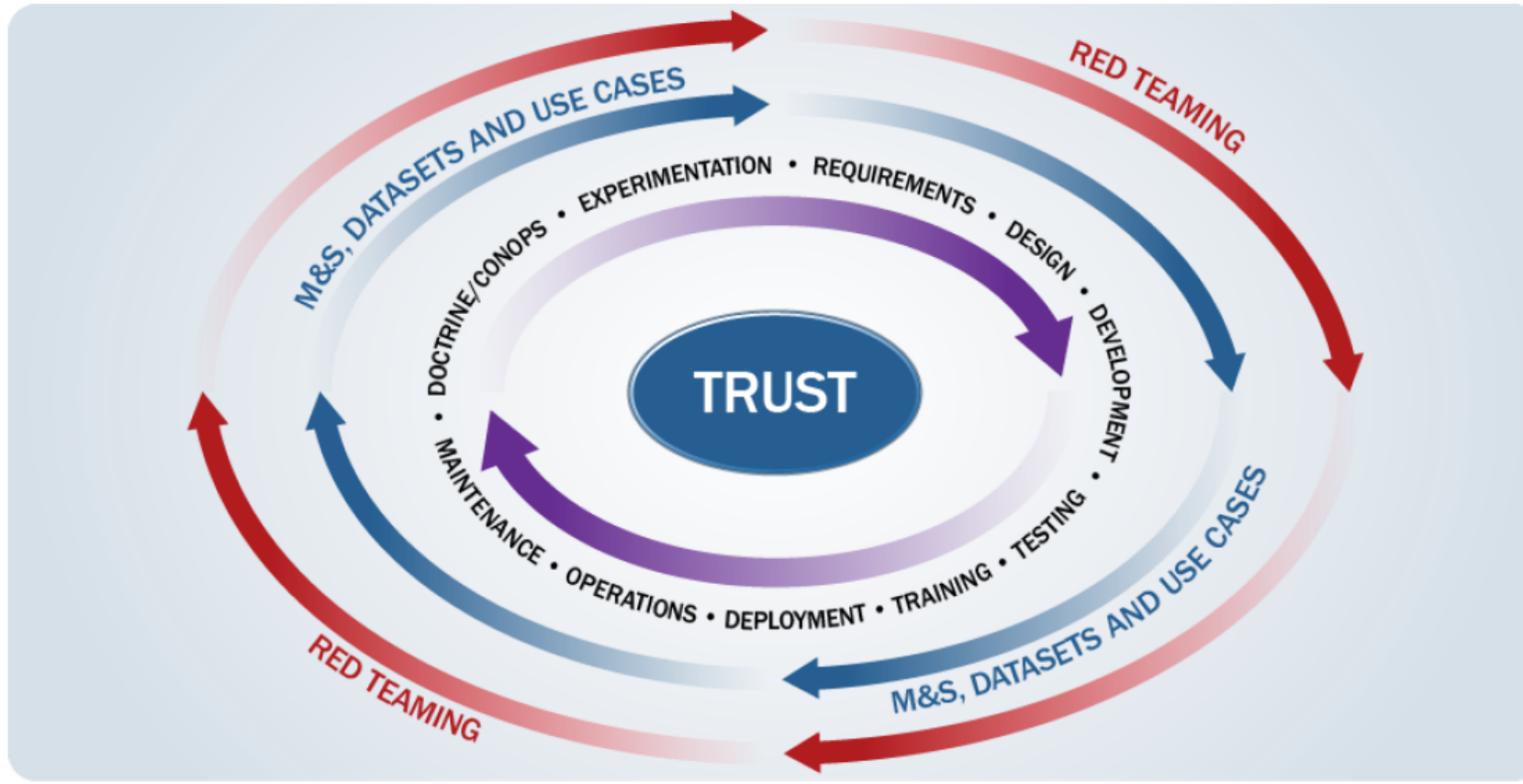
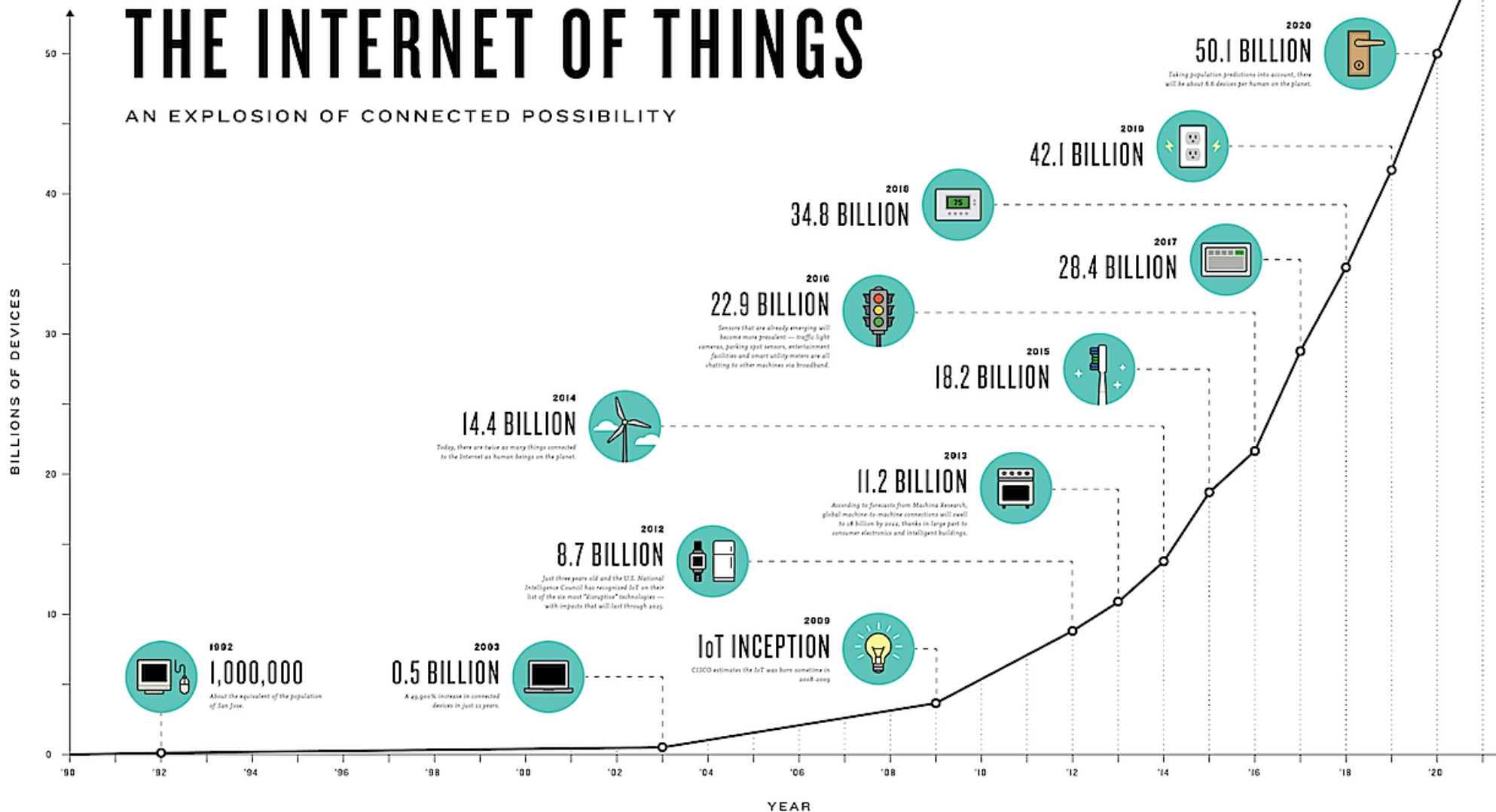


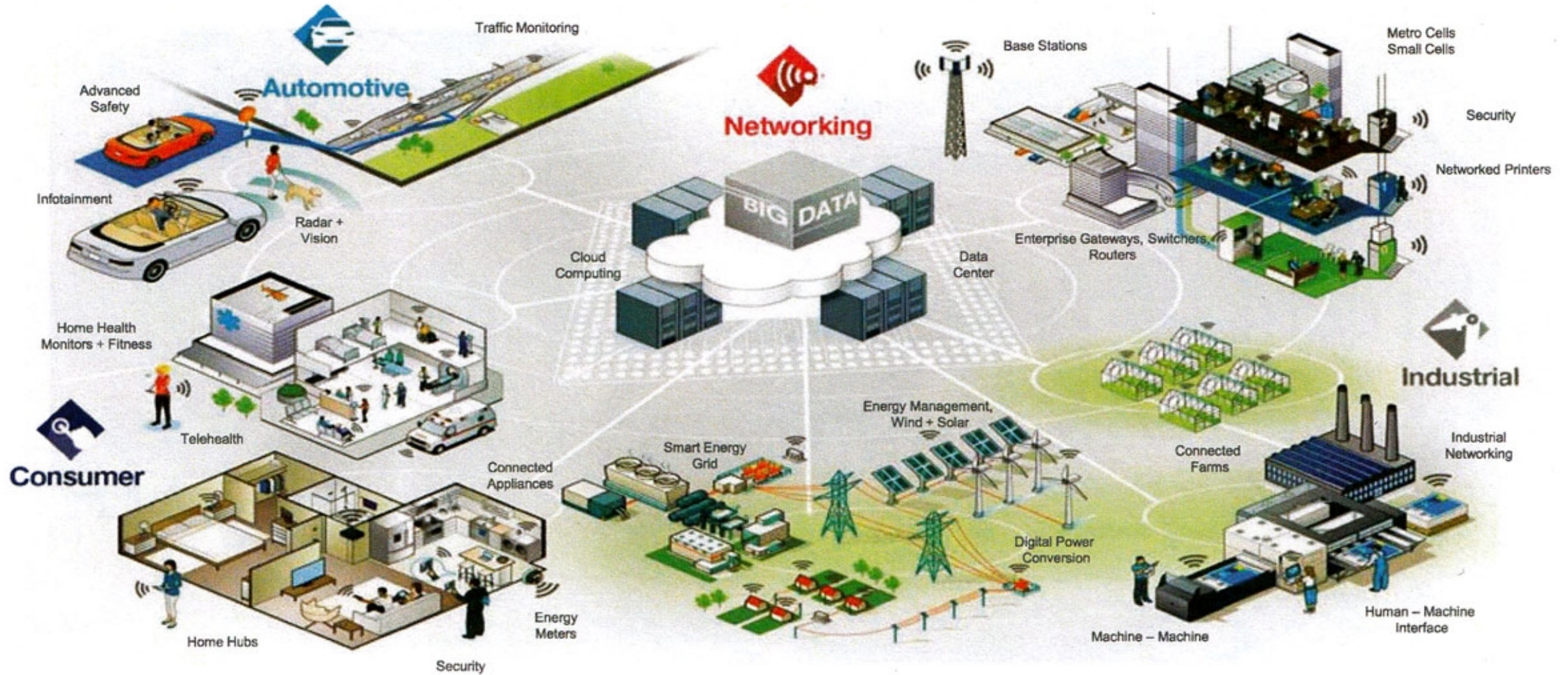
Figure 7 The lifecycle of the systems needs to establish an appropriate calibration of trust in autonomous systems.

- Current problem: Impossible to test all scenarios; what is good enough?
- Future problem: Human acceptance and adoption
- Requires changing how we verify and validate to build the trust in the system

Example: Internet of Things





Example: Systems of Systems Connectedness



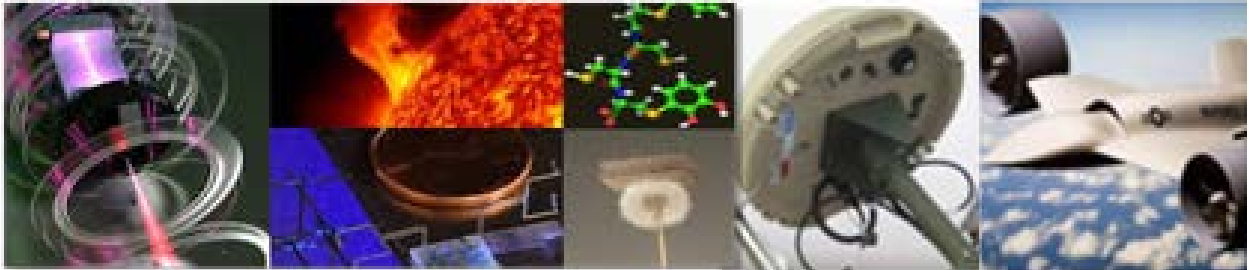
Other technology trends in systems

- Brain-Machine Interface Systems
- Intelligent Systems, Intelligent Sensing, and Intelligent Learning in Systems
- Digital Engineering / Digital Twins
- Cognitive Computing
- Applied Artificial Intelligence - Cognitive and Human Augmentation
- Interactive and Wearable Computing
- Cyber physical systems
- Biometrics, Bio-mechatronics, and
- Augmented Reality / Virtual Reality
- Big Data and Data Analytics
- Cyber Resilient Systems



Key Research & Development Investment Areas

- **Autonomy & Robotics**
- **Artificial Intelligence / Man-Machine Interface**
- **Electronic Warfare / Cyber**
- **Future of Computing**
- **Microelectronics**
- **Novel Engineered Materials**
- **Hypersonics**
- **Precision Sensing: Time, Space, Gravity, Electromagnetism**
- **Directed Energy**
- **Emerging Biosciences**
- **Manufacturing**
- **Understanding Human and Social Behavior**



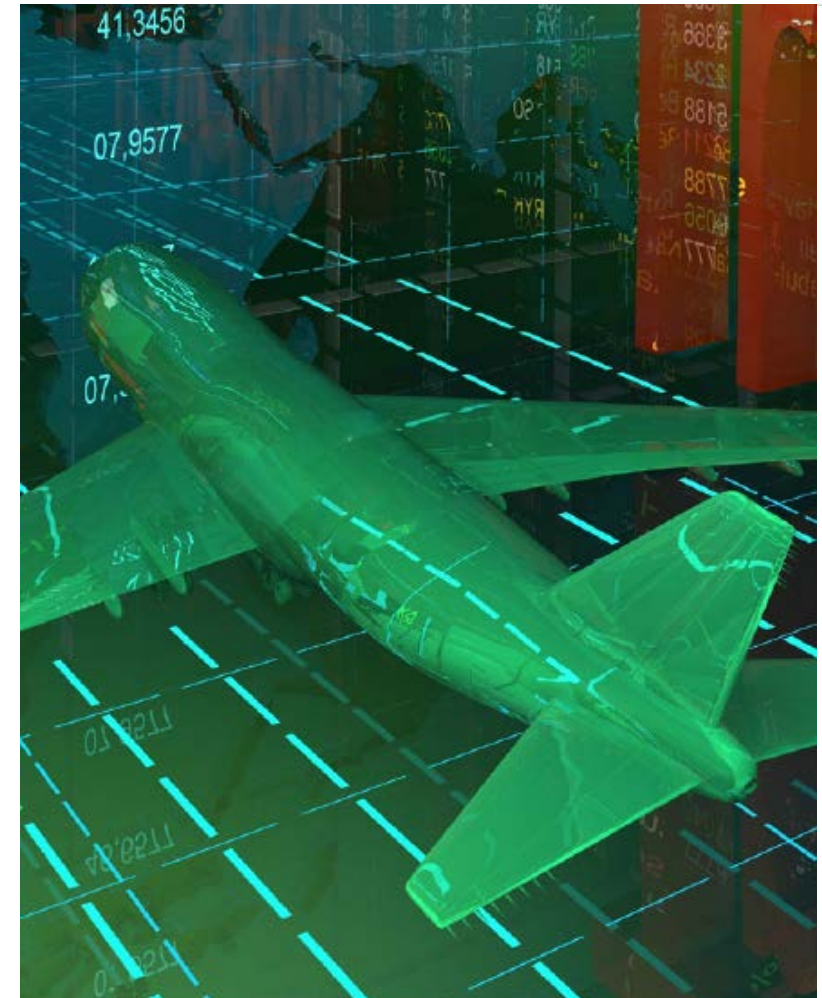
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Transforming Practices

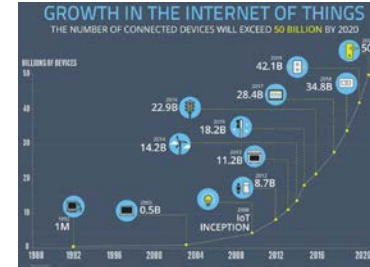
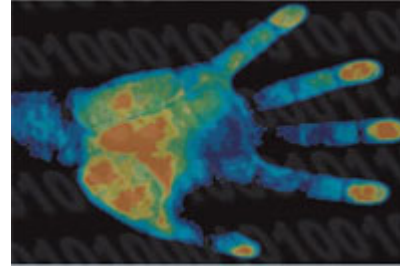
- Collaborative Engineering
- Complex System Understanding
- System of Systems Engineering
- System Architecting for multiple viewpoints
- Composable Design
- Design for Resilience
- Design for Security – system integrity
- Decision Support
- Virtual Engineering and MBSE – part of the digital revolution
- Change of process implementation to address technology & application
- Tailoring and scaling practices for value



Source: SE Vision 2025.
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Evolution is Needed

- Evolve our systems



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

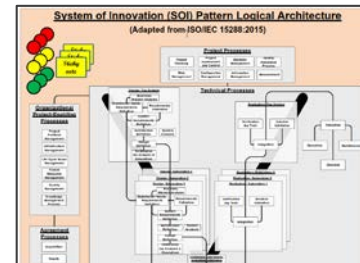
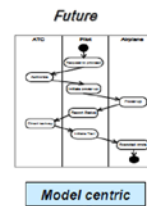
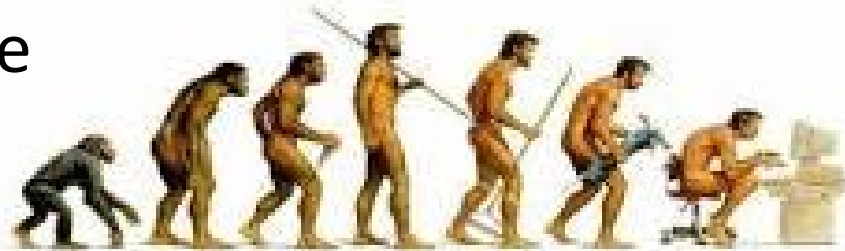


Figure from INCOSE Systems Engineering Vision 202

- Evolve our people



Alphababtesoup.wordpress.com

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

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