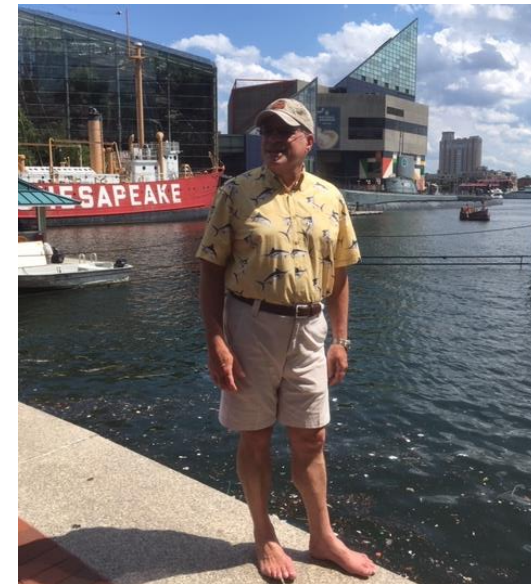# Evolution of Systems Engineering and SE Professional Development in INCOSE

Garry Roedler, ESEP
INCOSE President,
NDIA SE Division Vice-Chair,
INCOSE Fellow and Founder Recipient,
IEEE-CS Golden Core,
Lockheed Martin Senior Fellow,
Engineering Outreach Program Manager
garry.j.roedler@lmco.com

INCOSE Chesapeake Chapter SEP Gala – 9 August 2019

IMAGINE …
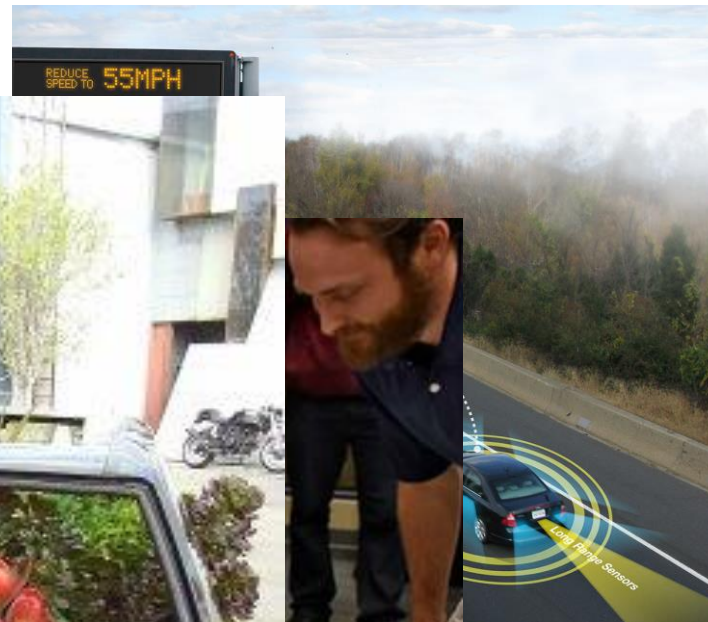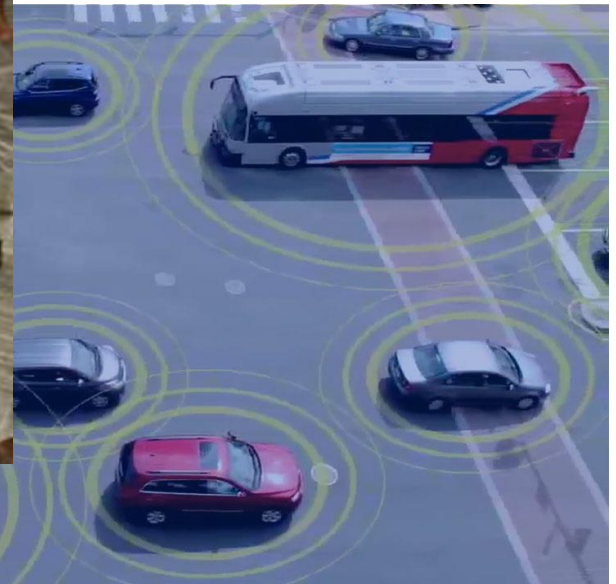
SE Evolution / Future of Systems Engineering

SE Vision 2025

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

A WORLD IN MOTION*

Systems Engineering Vision • 2025

* Used with permission of SAE International.
Copyright ©2014 by INCOSE, subject to the restrictions on page 50 of SE Vision 2025
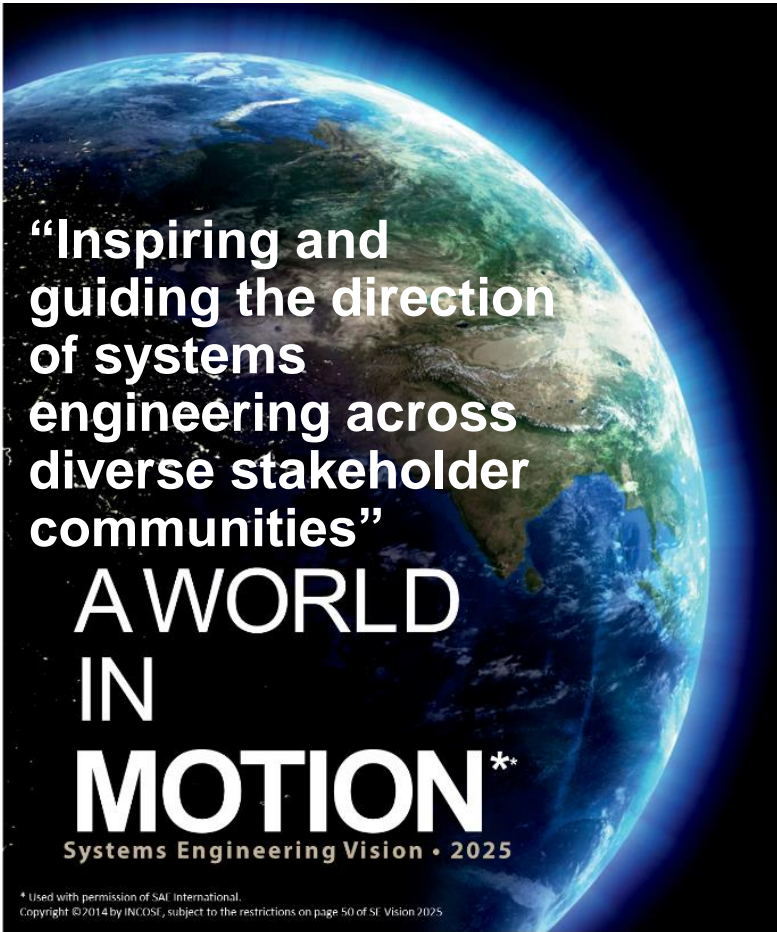
Note: Chapter and Domain versions of the Vision are being developed (e.g., Dutch Chapter and Automotive)
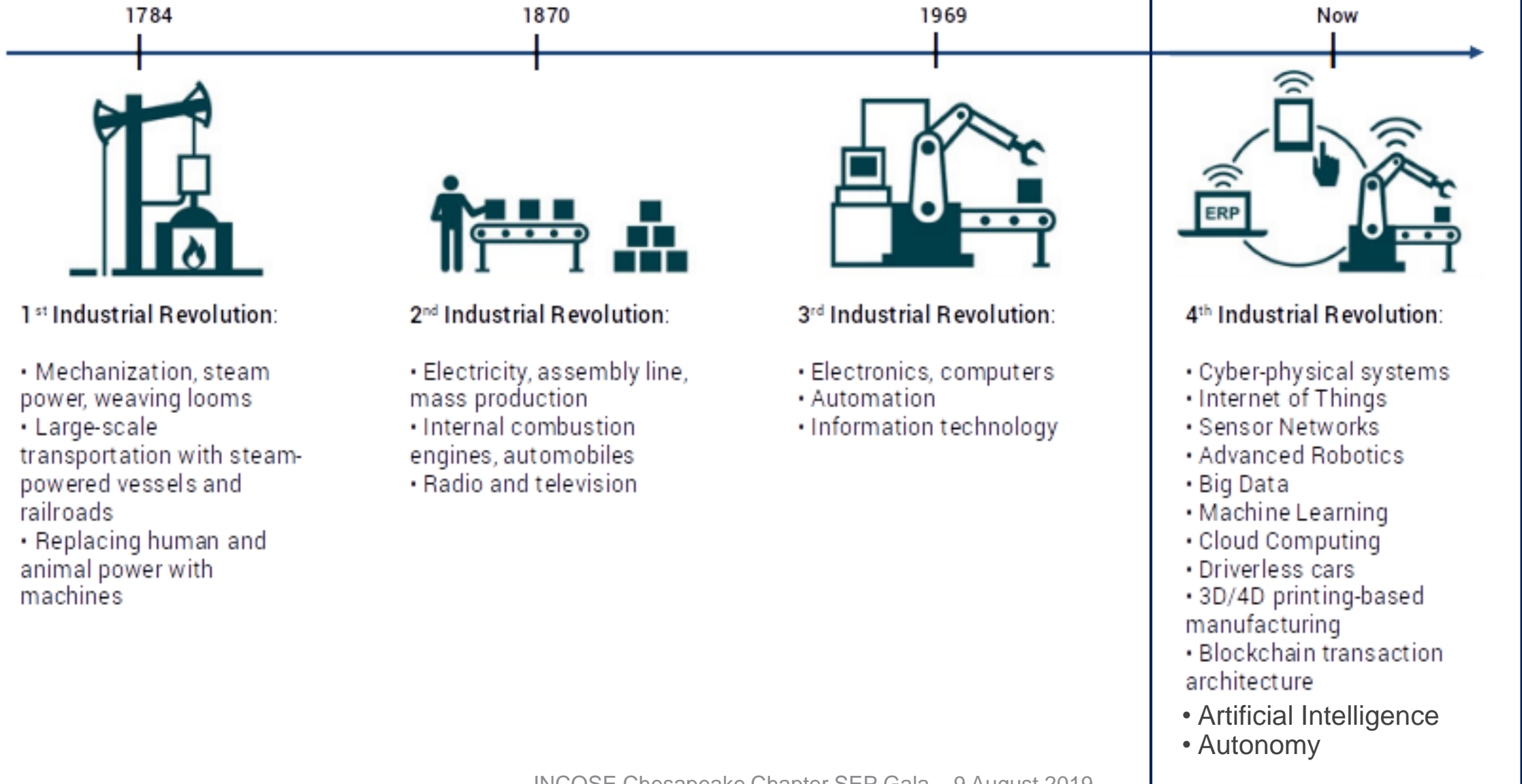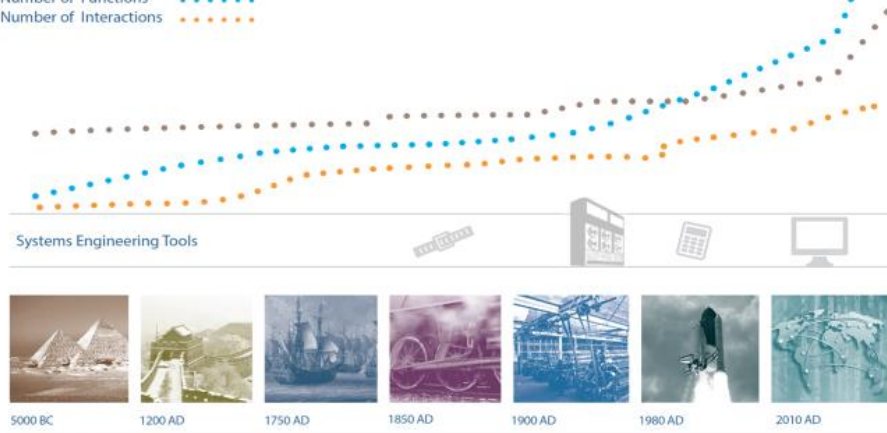
TAILORED TO THE DOMAIN

SCALED TO PROJECT SIZE

SCALED TO SYSTEM COMPLEXITY

THE PATH FORWARD

EVOLVING THE VISION THROUGH COLLABORATION

- Establish Grand Challenges
- Establish Research Roadmap
- Establish Standards Roadmap
- Establish Education and Training Roadmap
- Evolve the SEBoK to encompass new application domains
- Engage industry, government, and academic leaders

ASSESSING THE CURRENT STATE → DEVELOPING DETAILED ROADMAPS → EXECUTING FOR ACHIEVEMENT

Driving Change in Industry

1784   1870   1969   Now

1st Industrial Revolution:

• Mechanization, steam power, weaving looms
• Large-scale transportation with steam-powered vessels and railroads
• Replacing human and animal power with machines

2nd Industrial Revolution:

• Electricity, assembly line, mass production
• Internal combustion engines, automobiles
• Radio and television

3rd Industrial Revolution:

• Electronics, computers
• Automation
• Information technology

4th Industrial Revolution:

• Cyber-physical systems
• Internet of Things
• Sensor Networks
• Advanced Robotics
• Big Data
• Machine Learning
• Cloud Computing
• Driverless cars
• 3D/4D printing-based manufacturing
• Blockchain transaction architecture
• Artificial Intelligence
• Autonomy

Trends Driving Change

Trend: Increasing Complexity of Systems

Trend: Increasing Rate of Technology Adoption
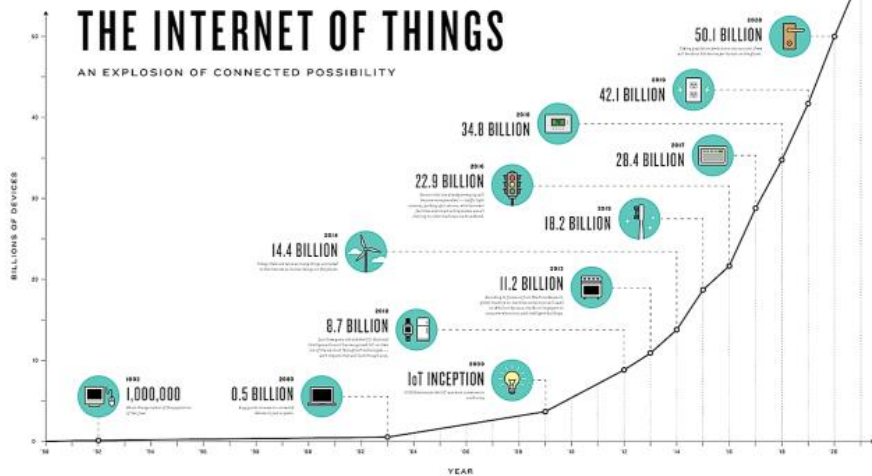
NEW TECHNOLOGIES CHANGE OUR DAILY LIFE AT AN EVER INCREASING RATE
Source: Forbes magazine
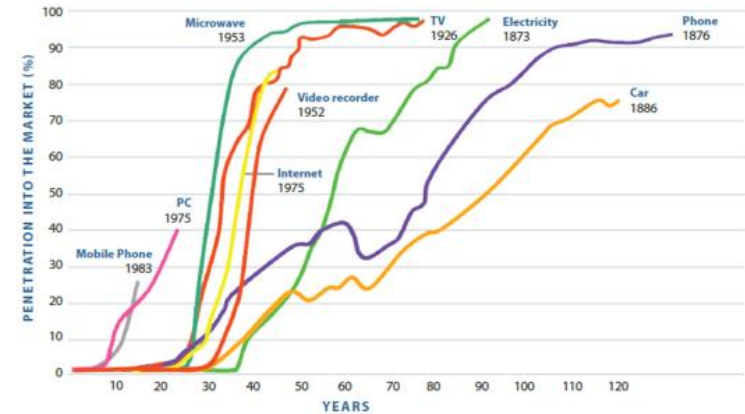
"With technology infusion rates increasing, the pressure of time to market will also increase, yet customers will be expecting improved product functionality, aesthetics, operability, and overall value. "

Trend: From Stand-Alone to Interconnected to IoT

Example: Systems of Systems Connectedness
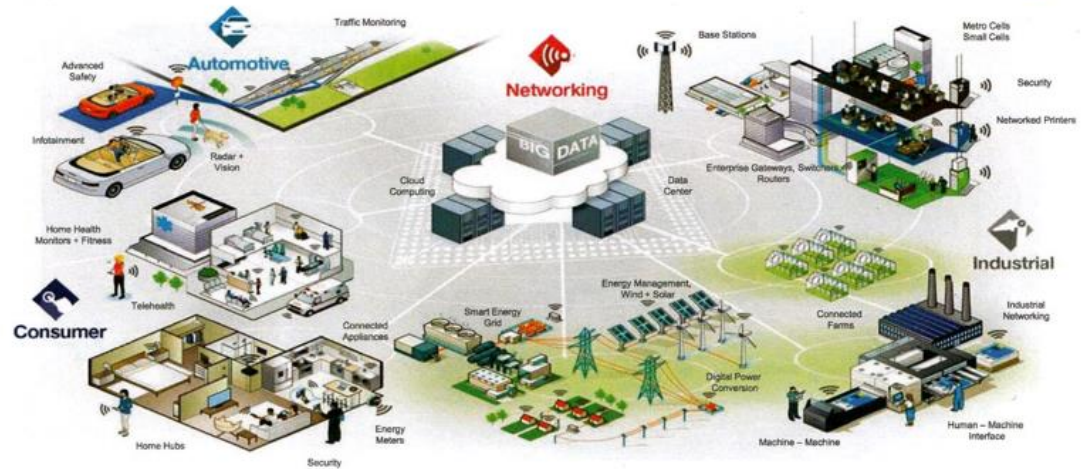
Transforming Systems Engineering

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

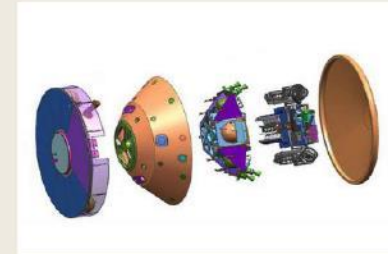Immersive technologies support data visualization
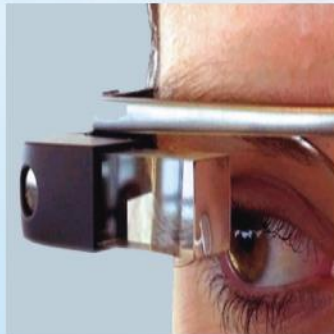
Net-enabled tools support collaboration

MOBILE
LAPTOP
SERVER
NETWORK
DATABASE

Tailoring and Scaling Practices for Best Value

Value Driven Practices for Developing Systems in 2025 and Beyond

TAILORED TO THE DOMAIN

SCALED TO PROJECT SIZE

SCALED TO SYSTEM COMPLEXITY
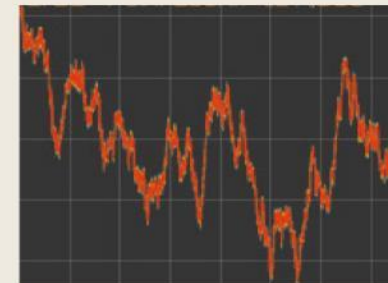
SE Foundations

SE Foundations – System and SE Definitions

Problem (2016) –
* Existing definition considered too limiting given the aspirations of SE Vision 2025

Objective –
* Review INCOSE definitions of Systems and SE and recommend any changes

Approach –
* 2.5 years project led by INCOSE Fellows
* Series of many briefings, working papers, research, 50 team webexes and wider stakeholder engagement
* 2 surveys, 6 published papers

Results –
* IS2018 – panel & 4 papers (incl Best Paper Award)
* Sep-Nov 2018 – review open to all INCOSE members receiving over 300 comments
* Jan 2019 – finalised and approved by BoD
* Jul 2019 – Roll-out, including 90-min President's Invited Content session
* Q2/Q3 2019 – Formal and full publication

Definitions -
* Systems Engineering is a transdisciplinary and integrative approach to enable the successful realization, use and retirement of engineered systems, using systems principles and concepts, and scientific, technological and management methods.
* An engineered system is a system designed or adapted to interact with an anticipated operational environment to achieve one or more intended purposes while complying with applicable constraints.
* A system is an arrangement of parts or elements that together exhibit behaviour or meaning that the individual constituents do not.

www.incose.org/symp2019

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SE Foundations – SE Principles

* INCOSE Systems Engineering Principles Action Team Formed at INCOSE IW 2018
  - Started with Input from the NASA Systems Engineering Research Consortium
    * Systems Engineering Postulates(7), Principles(12), Hypotheses(4) distilled over past 8 years
      - Research conducted by 17 Universities, 5 companies, 4 NASA Centers, and the Air Force Research Laboratory
      - Included surveys of 106 companies in the Aerospace, Agricultural, and Mining industries
      - Presented and reviewed at INCOSE IW 2018 as part of MBSE Initiative
  - Met monthly since March 2018
  - Face to Face in December 2018

* Developed Criteria for INCOSE Systems Engineering Principles

* Defined 15 Systems Engineering Principles, 3 Systems Engineering Hypotheses
  - Developing Articles for Input in Systems Engineering Body of Knowledge (SEBoK)

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Future Focus in INCOSE

And many others projects and initiatives …

Future of Systems Engineering: Charter

Purpose: Evolve the practice, instruction and perception of SE

1) Position SE to leverage new technologies
2) Enhance SE's ability to solve the emerging challenges
3) Promote SE as essential for achieving success and delivering value

Goal: Create a road map that drives the evolution of SE to:

1) be increasingly *adaptable, evolvable and fit for purpose*
2) account for human abilities, needs and their interactions with a system
3) be more responsive in resolving increasingly challenging societal needs
4) realize and enhance INCOSE SE Vision 2025 and other visionary inputs

Scope: Identify the needs, priorities and means for transforming SE including:

1) underlying foundations, systems theory and principles
2) people, methods, tools, processes, education and training
3) the future social and ethical duties, contributions, and responsibilities of future systems engineers

Collaborating Organizations

Initiative Lead and Primary POC
Bill Miller
(wdmiller220@gmail.com)

FuSE Road Map

Horizon Scanning
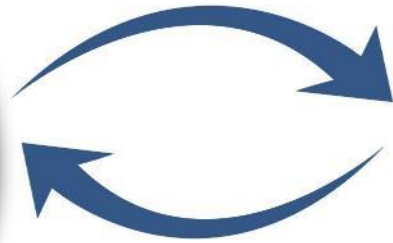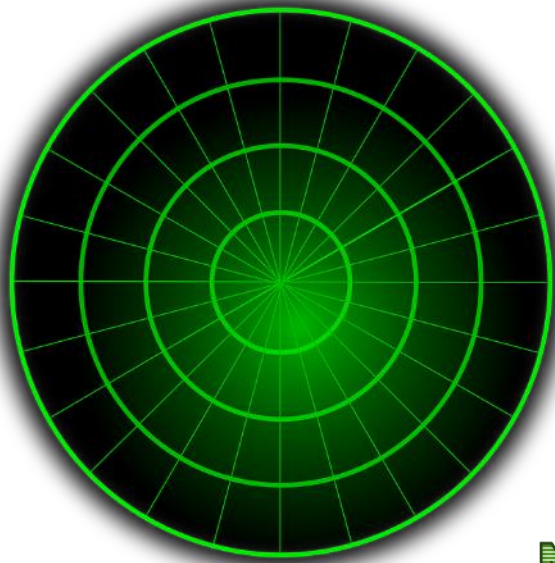
Projects

Theoretical Foundations

AI&SE
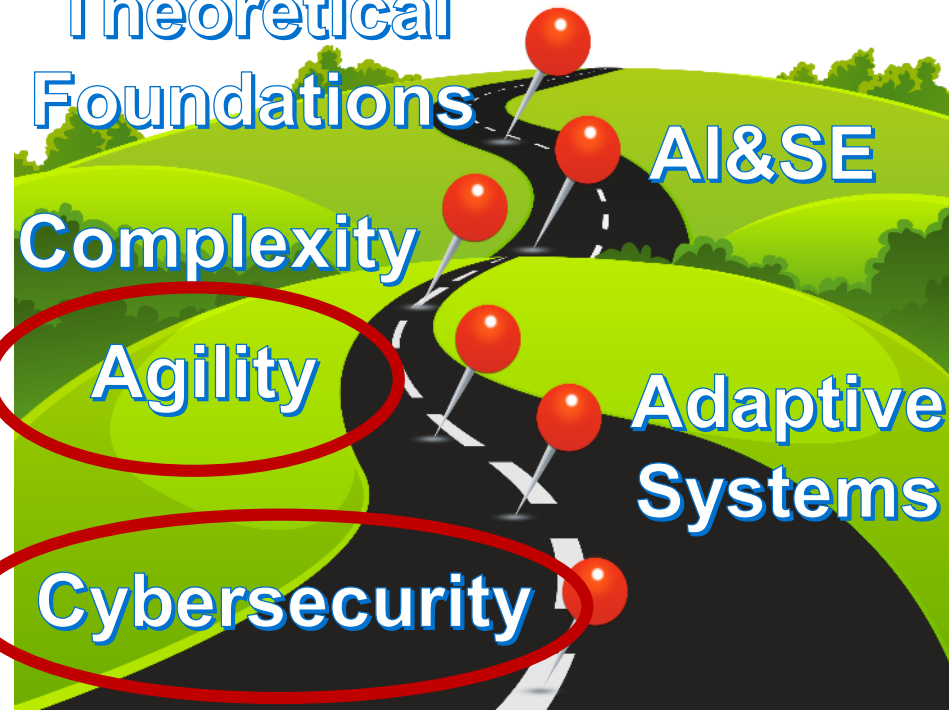
Complexity

Agility

Adaptive Systems

Non-SE

Cybersecurity

Affiliated Orgs

Body(ies) of Knowledge

CAB

Working Groups

FuSE is Accelerating the Future : Contact us at fuse@incose.org

A View to the Future of SE

- Continue to Address SE Vision 2025, begin looking beyond
- Future of SE (FuSE) initiative
  - SE Foundations (Principles/Definitions); AI4SE/SE4AI; Horizon Scanning; …
- Evolving Practices and Standards
  - MBSE / Digital Engineering; Agile Systems/SE; SoSE; …
- Future Directions of SE Research
- Application of SE for Grand Challenges
- SE for Policy and Governance
- Effective Integration with Other Disciplines
- What else?

What is each WG and other INCOSE entity doing to move the needle?

Just Released!
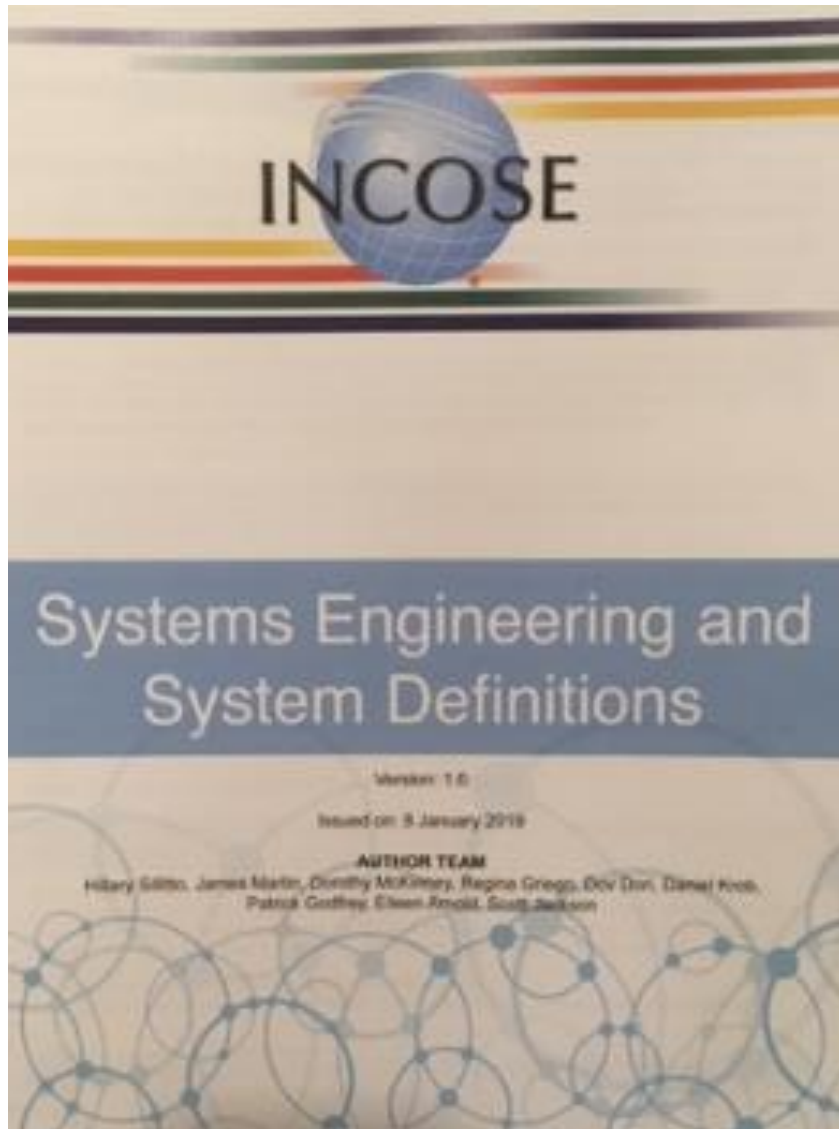
Available from the INCOSE Store
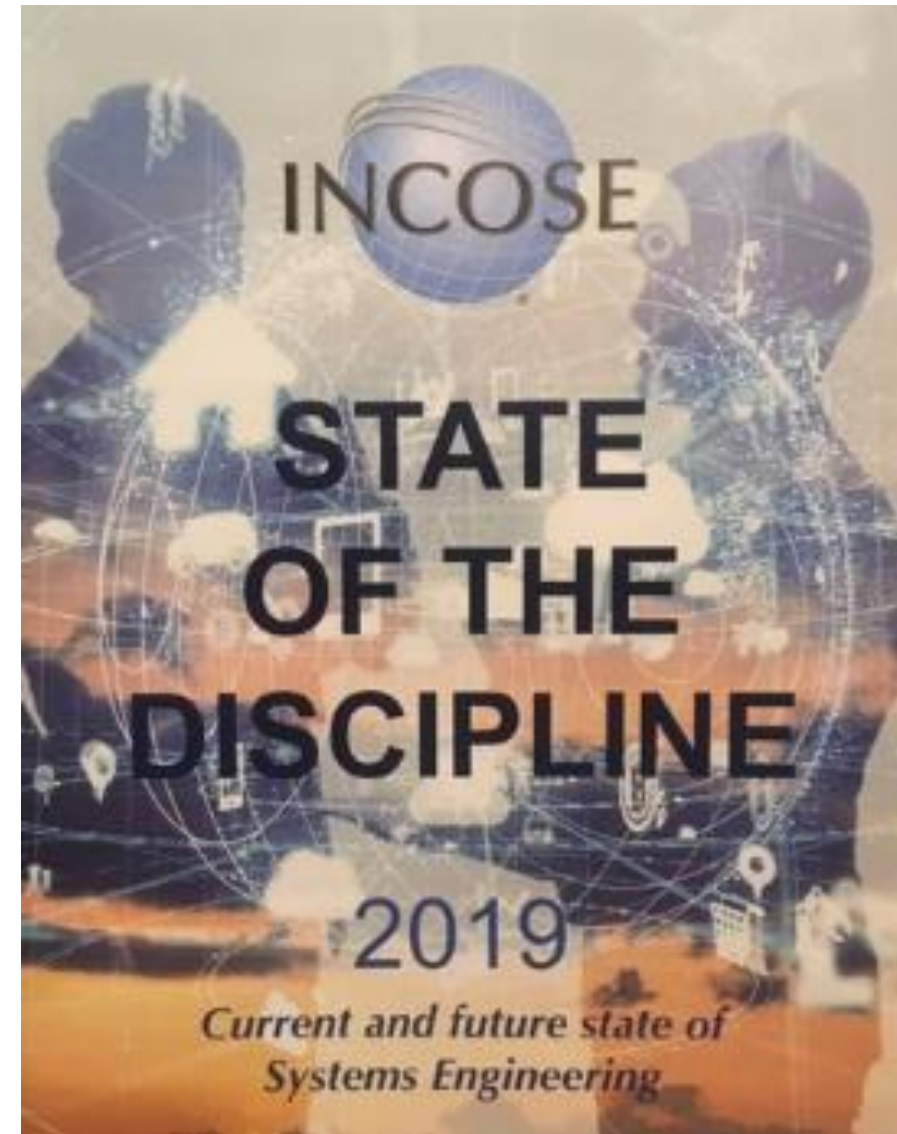
SE Professional Development
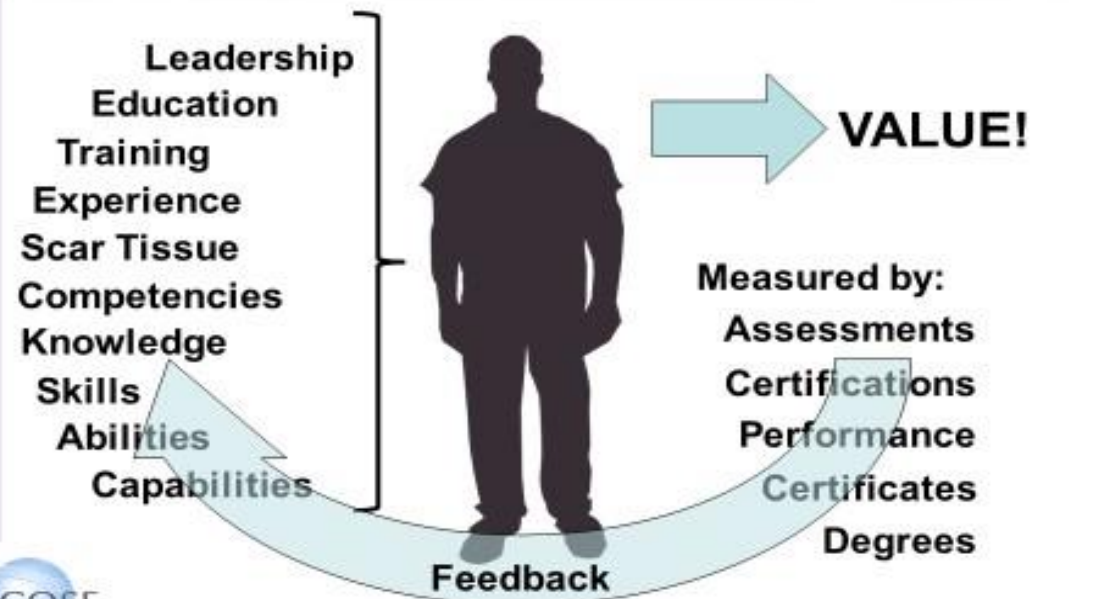
INCOSE Focus on Professional Development and Competency

Professional Development of a Systems Engineer

Leadership
Education
Training
Experience
Scar Tissue
Competencies
Knowledge
Skills
Abilities
Capabilities

VALUE!

Measured by:
Assessments
Certifications
Performance
Certificates
Degrees

Feedback

Graphic Source: INCOSE Competency WG, Don Gelosh, used with permission

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Graphic Source: INCOSE Competency WG, Don Gelosh, used with permission

Graduate Reference Curriculum for Systems Engineering

Includes:

– Understand the characteristics of Systems Engineers

– Evolving existing INCOSE SE Competency Framework

– Ensure the right enablers are in place

– Holistic approach to Professional Development

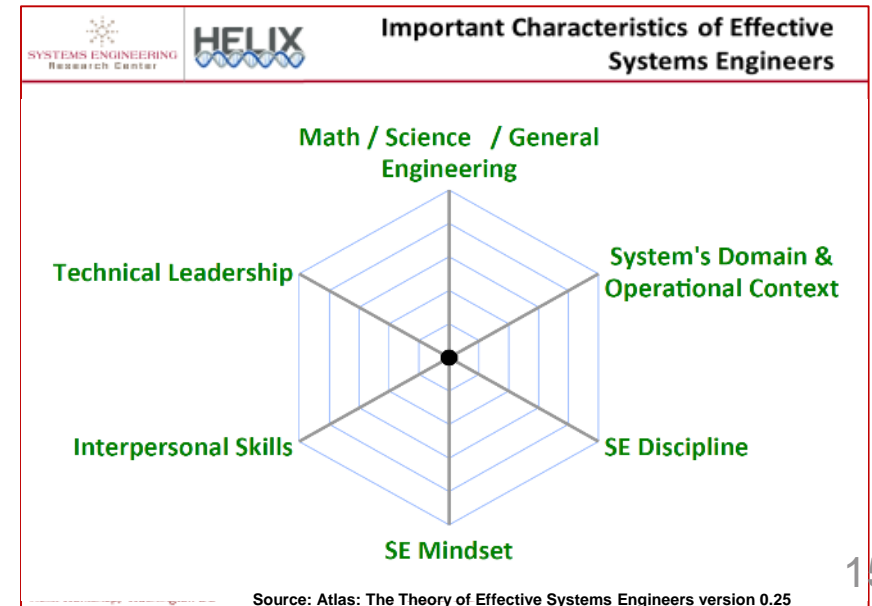– Work collaboratively to get community consensus

HELIX — Important Characteristics of Effective Systems Engineers

Math / Science / General Engineering

System's Domain & Operational Context

Technical Leadership

SE Discipline

Interpersonal Skills

SE Mindset

Source: Atlas: The Theory of Effective Systems Engineers version 0.25
Copyright 2014, Stevens Institute of Technology

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# Systems Engineering Competency Framework

Represents a world view of 5 competency groupings with 36 competencies central to the profession of Systems Engineering, including indicators of knowledge, skills, abilities and behaviors across 5 levels of proficiency.

Aligns with major ongoing INCOSE initiatives.

Supports a wide variety of usage scenarios including individual and organizational capability assessments.

Enables organizations to tailor and derive their own competency models that address their unique challenges.
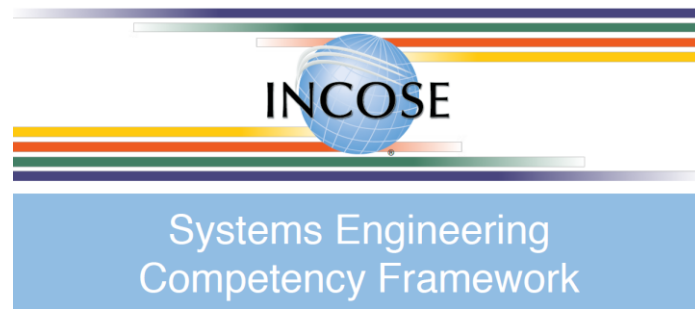
The complete Competency Framework can be accessed at:
https://www.incose.org/CompetencyFramework

Collaboration by many – Free access to all

Notional Vision - Professional Development

The Professional Development Learning System

Education — Learner Centric — Training
Experience — Provide Value! — Metrics — Mentoring & Coaching
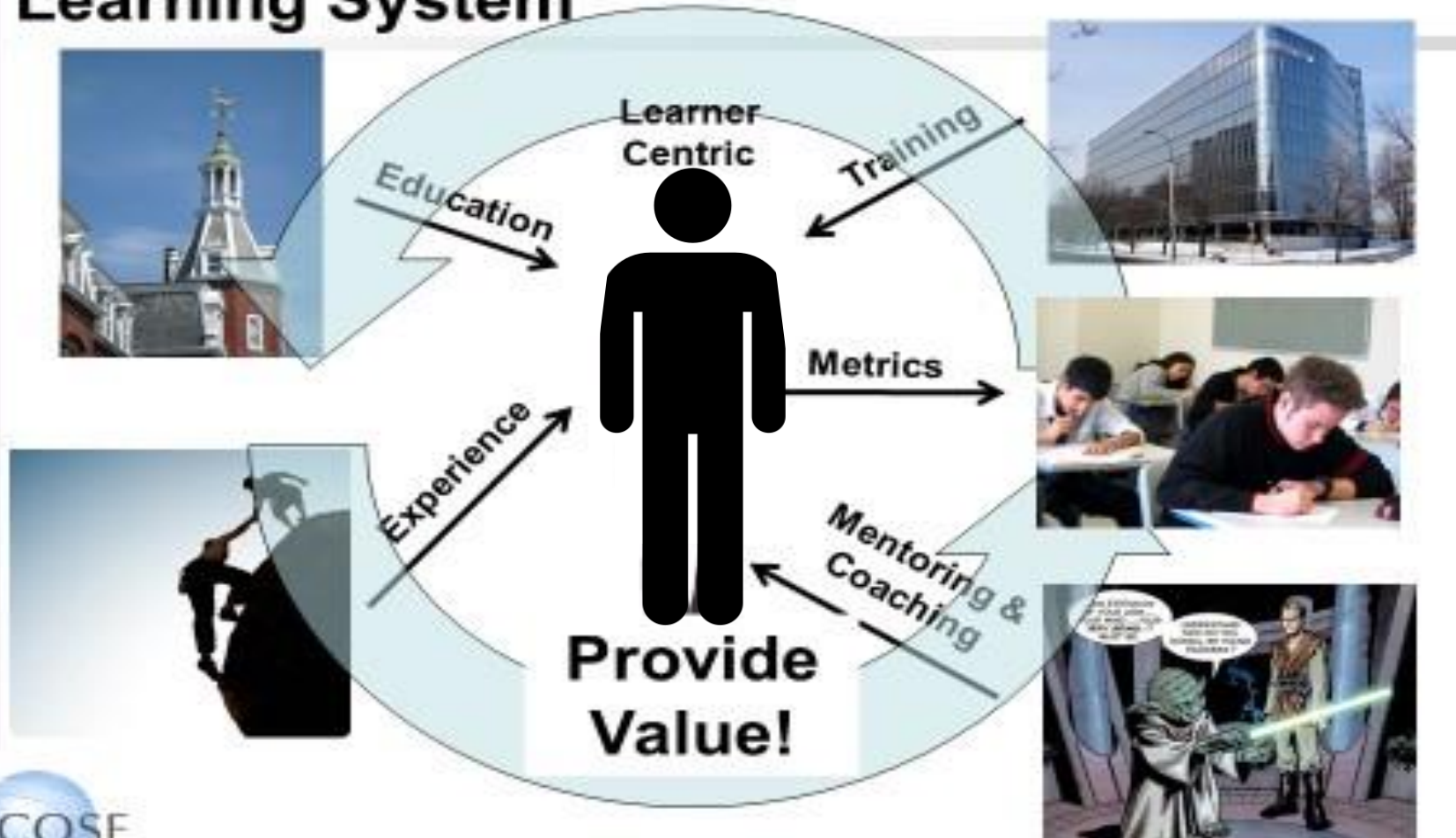
This Photo by Unknown Author is licensed under CC BY-SA

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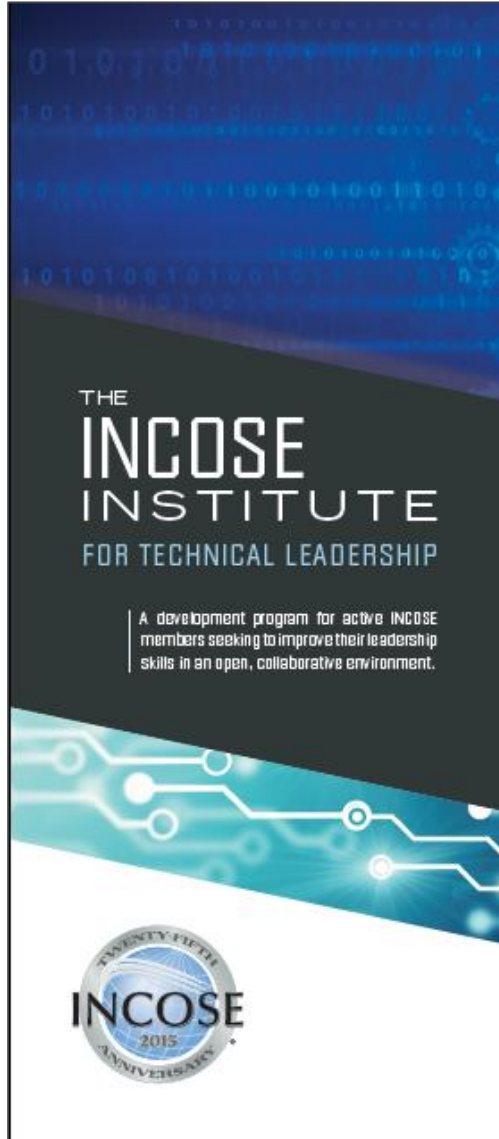# Notional Vision - Professional Development

Professional Development Portal Demo

- 2 kiosks
- 6 Laptops
- 444 Visitor Sessions
- Average Duration > 13 min.

SEs as Leaders: The INCOSE Institute for Technical Leadership

- # Purpose
  - *Accelerate the development of systems engineering leaders who will exemplify the best of our organization and our profession*

- # Benefits
  - *Individual members become more capable leaders*
  - *INCOSE has a growing pool of leaders to draw on*
  - INCOSE's international reputation will be enhanced

- # Program Overview
  - Two-year program; new cohort formed annually
  - Four events per year: two face-to-face, two webcast
  - Individual project work between events
  - Each cohort will mentors the following one
  - Candidates must apply and be recommended by their organization and an INCOSE Leader

THE
INCOSE
INSTITUTE
FOR TECHNICAL LEADERSHIP

A development program for active INCOSE members seeking to improve their leadership skills in an open, collaborative environment.

TWENTY-FIFTH
INCOSE
2015
ANNIVERSARY

Next Evolution of Certification?

Courtney will discuss this …

Thank you!

For More Information or To Share Ideas contact:

Garry Roedler
INCOSE President
garry.j.roedler@lmco.com

Questions?

www.incose.org

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(for extracts from the Vision)