Summit Themes Recommendations

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An international group of high-level representatives from academia, industry, government agencies, and professional organizations convened 8 and 9 October at Delft University of Technology. They discussed the technical, economic and societal challenges of today's complex systems and articulated the need for multi-disciplinary competencies for systems professionals which are scarce and in high demand worldwide. The Summit's outputs focus upon a Call for Action and Recommendations from each of the five Themes. The Theme Recommendations are listed below.

General Observations

Interactions between economic, scientific, and engineering competencies are needed to cope with today's social and technological developments. Sustainability and circularity are increasingly valued by society, as exemplified by the UN Sustainable Development Goals which give rise to broad and complex system solutions. Such overarching needs must be tackled by government, research establishments and industry with multi-disciplinary, holistic approaches. Academia needs to take action towards increasing the systems workforce. Industry needs to invest into keeping their systems workforce up-to-date. Professional organizations need to support the systems workforce developments. Life-long learning and training is key to maintaining the systems workforce current with the digital transformation and the advancing technologies.

Theme 1 Recommendations and Observations on Context and System Needs

1. Digital transformations are driving system applications in many fields, such as in healthcare, agriculture, cities and public infrastructures. Most systems have become elements of system of systems, or digital ecosystems, with the associated issues of distributed system control and regulatory patchworks. Protection of intellectual property, personal privacy, and associated information credibility are critical.

2. Global interconnectivity and interdependence of infrastructures and product developments are becoming more difficult by a growing desire for regional sovereignty over critical technologies, natural resources, and supply chains.

3. Acquiring an understanding of software defined systems is important for the systems workforce since enterprises will increasingly depend on system architectures and platform adoption strategies, such as third-party cloud services. This calls for knowledge on digital systems, AI, cloud interactions, edge computing, software verification, and more for enterprise leaders and experts. Integration of such topics in university degrees for business administration, management, innovation, industrial engineering, and more is recommended.

4. A step-up in terms of the number of multi-disciplinary system competencies is needed. This requires changes in universities to accommodate dedicated systems engineering and management education. Creating engineering schools fostering interdisciplinary approaches to system solutions linked to societal and economical challenges and industry needs should be pursued.

5. To help develop a suitable regulatory environment for complex systems and technologies system engineers, architects, analysts and managers need to be trained in policy analysis and the conduct of assessments that support regulations. This includes understanding of broad stakeholder needs and expectations along with designs for system safety, data privacy, and user trust.

6. The increasing use of AI and autonomy presents profound issues with respect to system verification and validation, trust, and life-cycle management. Software-defined systems, e. g. in communications, automobiles, defense, or medical facilities, require end-to-end approaches to system architectures and implementation plans to mitigate interdependency and technology risks while assuring uninterrupted functionality. Early collaboration between systems and software engineering experts is required.

7. The shortage of multi-disciplinary systems analysis, engineering, manufacturing and management talent to cope with increasing interdependency issues endangers the efficient realization of future systems. A paradigm change is needed to ensure a growing systems workforce with profound multi-disciplinary skills. Such competencies will become, even more than today, strategic assets for competitive enterprises.

Theme 2 Recommendations on Industry System Workforce Needs & Sustainment

1. A new paradigm for stakeholder collaboration is needed for public and industry funded undertakings. Recent digital advances enable close collaboration between all players already in the concept phase. This may require different tendering and contract frameworks in the future.

2. Selecting the proper development life-cycle for a specific project should help to better meet commitments and enhance collaboration, rather than meeting sometimes arbitrary contractual milestones. To this effect recognition, transparency and a holistic life-cycle approach is required from all stakeholders, when offering or developing a new product, system, or service.

3. Systems workforce need to straddle contractual boundaries to better share data and modelling outputs. Alternatively, or in addition, a shared risk profile adoption between industry and suppliers, and if applicable with agencies, would aid closer collaboration.

4. Systems thinking and system approaches, including some systems engineering practices, should be included in all engineering and related system disciplines' undergraduate programs. Transversal skills taught at universities and advanced through one's career is foundational for the systems workforce.

5. Continued life-long professional development for maintaining and growing system competencies of individuals and of enterprise systems workforce is imperative. Reasons are the increasing number of multiple technology advances, and the growing number and importance of specialty engineering disciplines, including, cybersecurity, system safety, human factors, sustainability, ecodesign, data analytics, and more. Some of these developments can be taught at universities, but much need to be learned on-the-job. Short courses by educational institutions should be offered to augment the on-the-job learning, and life-long career development.

6. Industry must provide inputs to educational and professional organizations developing systems career guidance, related documents, and standards. Industry representatives should be solicited as "guest speakers" to educational institutions providing real system examples. They can also help to review and grade specific system case studies and projects.

7. AI can be embedded in system solutions. Verification and certification of AI embedded solutions will need to be mastered. Building the evidence for assurance and trust will be key. The systems workforce must be deeply involved in providing and or verifying the source of truth, and the necessary training data

for the AI to learn from. The drive for ever increasing industrial productivity will involve various levels of systems autonomy and AI, and require new approaches to how system engineers accomplish component integration and system validation.

Likewise, AI can enable systems workforce effectiveness and efficiency, including enhancing the system workforce skills, e.g. for navigating regulations and standards, knowledge management repositories, or in generating options to support trade studies, decision and risk analyses. Consequently, the systems workforce will need to be adept in using AI, understanding the risks, and know how to prompt, interrogate and adapt the outputs.

8. The role of system architects and software architects will become more and more blended in time, with just one architecting role taking on all architecting aspects for software intensive systems. However, the detailed design and development activities will remain within each respective discipline, and be carried out in parallel in most enterprises. Industry should regularly visit the foundational competencies of each discipline while enhancing cross-cutting and transversal skills.

9. Toolsets are key to migrate architecting and design details between different disciplines. Modelling, simulations and the creation of digital twins as appropriate, prior to product development will yield better chances of a successful outcome and facilitate adoption of agility practices. Industry needs tools that can be readily integrated with each other, can easily share data, and be independent of the supplier. As such, the systems workforce need to have an integrated toolset/workbench.
   Systems workforces must become proficient embracing digital tools involved in systems analysis, design, implementation, validation/test, and sustainment as well as to work in agile cross-disciplinary teams. Appropriate standards should be developed with urgency.

10. Systems engineers with educational roots in physical engineering (mechanical, electrical, aeronautical) disciplines need to develop an enhanced understanding of software architectures and software verification methods. As a corollary, software engineers should learn the fundamentals of traditional engineering disciplines and aspire to broad systems engineering roles in which they can bring to bear an in-depth understanding of system behaviors. Early cooperation of the two disciplines is essential to generate balanced system architectures.

Theme 3 Recommendations on Education of System Engineers, a life-long Trajectory

1. Engineering education needs to embrace systems engineering in an integrated yet visible way. Disseminating and cultivating systems thinking, comparative analysis and trade-offs, design, verification and validation are critical elements for complex and successful solutions of the future.

2. Designing and delivering relevant engineering education requires overcoming traditional boundaries and to integrate and combine:
    - Hardware and software elements to appreciate and foster the understanding of complex interfaces
    - Latest technologies of relevance to systems planning and execution
    - Analysis, modelling and simulation to understand and deliver workable and resilient concepts, designs and products.

3. Specific domain competencies are essential for effective Systems Engineering activities. Academia and industry shall make sure that both elements are present in a balanced way in their curricula and development programs. Systems workforce development organizations need to address the growing need for coherent and broad systemic thinking, design thinking, systems of systems architecting and engineering, and digital platforms with a focus on multi-stakeholder value.

4. Capstone system projects shall be consistently applied and strengthened through curricula in academia and workforce development programs in industry and agencies. These support systems understanding, application and support the training for state-of-the-art systems engineering and management approaches and also to discover and experiment with innovative approaches. Project reviews shall be an integral part of capstone projects to provide focus and facilitate compliant delivery with expected learning objectives as well as to prepare participants to their future career steps. Capstone projects shall integrate:
    - responsible use of Artificial Intelligence (AI) in relevant fields, such as requirements engineering, design, verification and validation, as well as project management to benefit from existing knowledge, facilitate the transition between project phases, and enable new approaches
    - Stakeholders from other fields of expertise should become involved. Projects or courses in academia should incorporate current and future needs from industry and/or agencies. They in turn should cooperate with academia for the development of their own systems workforce. Mechanisms for stronger collaboration between academia and industry

need to be specified, such as co-sponsoring of capstone projects by both sectors.

- Soft skills development and inter-disciplinary knowledge which can be demonstrated through practical use cases. They can assure a sufficiently broad approach to solve societal problems or complex product developments of the future.

5. Designing and conducting relevant engineering education in schools, academia and industry requires the educators themselves to learn and master systems thinking, systems engineering principles and practices with associated tools (Teaching the Teachers). Educators should also follow up to date training programs. Life-long learning of educators will be realized through enabling educators to exchange and cooperate with other educators beyond their departments, their organization and their countries. This can be achieved, for instance, through participation in dedicated symposia, publications in relevant journals, or through facilitating exchanges of visiting staff between organizations.

6. The recognition of Systems Engineering academic pathways and impact needs to be promoted by recognizing the varied trajectories that may span academia and industry.

Theme 4 Recommendations on Agencies System Workforce Needs, Roles & Contributions

1. End-to-end system analyses and development for systems and their supply chain is essential. The complexity of many systems in high-tech fields, such as energy or public infrastructures keeps growing. Governments are frequently taking more responsibility and initiatives in defining parameters for complex systems and setting initial architectures. Leaving it to the markets and preventing unwanted developments is an enormous challenge for policymakers. They have more control and risk understanding when they become aware of the consequences of their choices/policies. This however requires combined end-to-end system architecting, engineering and management competencies which are also scarce in government organizations.

2. Policymakers should have improved access to fact-based information, technology applicability, risk factors and underlying causes. A formalized system analysis approach helps to create a broad system-level understanding and informs policy and decision makers at all levels to better ensure project success. Close cooperation between agencies, research establishments, and industry along with a life-cycle approach at the initiation of common undertakings can mitigate misunderstandings and failing implementation.

3. Closer collaborations with all stakeholders to enhance systems understanding and competencies are necessary for complex systems realization. Government agencies can influence the development of systems via policies, advice, reports, regulations, subsidies, taxes, etc. To do this effectively, they should have a broad system understanding which includes political, economic, social, technological, environmental and legal (PESTEL) dimensions. Advice from independent consultants, educators, researchers with sound systems experience could help.

4. Stimulate the independent role of government-related systems analysis entities even more than is done today. Formalize systems analyses and trade-offs of policy alternatives analyses. This could e.g. be realized by independent research/knowledge institutes with sound systems competencies. Close cooperation between systems and software engineers, domain experts, and project managers is required to ensure sound independent advices. Use of digital tools such as systems modelling, simulation, virtual reality and AI must be mastered.

Theme 5 Recommendations by Professional Organizations on System Needs and Opportunities

1. Recognize the value of systems competencies, especially in the engineering, business and management fields for tackling broad social and technological challenges. Work towards closer cooperation with other professional societies which value system competencies and multi-disciplinary cooperation capabilities for solving complex undertakings. Such initiatives should involve professional societies from many different engineering, policy, economic/business, management and application fields.

2. Promote the value of systems competencies across all application domains. Stress the value of multi-disciplinary cooperation by soliciting and developing publications which document past achievements and future challenges in related competency fields. Address information updates to executives, senior leaders, experts, educators, learners, regulators, and policy makers. Utilize real examples showing hard return on investment (ROI) for successful and failed system projects.

3. Facilitate both the growth in and the diversity of the systems workforce and expand their global footprint. This should include e.g. promoting the introduction of systems engineering and systems management into existing traditional engineering education, by introducing programs for young engineers, or by curating content and best practices. Partnering with developing countries to introduce systems engineering and related competencies into their education systems should be part of this initiative, thus supporting their development of well-trained systems workforces.

4. Professional organizations should support systems workforces in a number of additional ways, for example as:
    - Custodians for the needs and future of global systems application practices
    - Organizers of forums for the advancement of associated disciplines
    - Independent voices for advocating high professional standards
    - Advisers to governments and agencies
    - Providers of trainings, certifications, professional guidance documents and standards which can help to grow and focus the systems workforce
    - Thought leaders in determining the cutting edge of the practice, challenging the status quo
    - Developers of visions and strategic roadmaps for the evolution of their disciplines

- Catalysts for promoting and incorporating new technologies, data repositories, standards and tools into practice, while advising their communities upon the maturity of such tools and related technologies

5. Align systems engineering and project management processes/guidance for tackling small and large system projects. Pragmatism and tailoring options along with a focus upon product realization and value creation should become the guiding principles.