

TRASEE™:
Educational Paradigm of the SAE Program

Professor Azad M. Madni
Executive Director, SAE Program

Transdisciplinary Systems Engineering Education (TRASEE) paradigm is the educational paradigm underlying USC's Systems Architecting and Engineering (SAE) Program. This educational paradigm is based on *Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyperconnected World*, written by Professor Azad Madni, University Professor of Astronautical Engineering and Education, and Executive Director of the SAE Program. It addresses the *needs* of 21st century systems engineering workforce and the *proclivities* of 21st century learners. Its five transdisciplinary pillars are:

- 21st Century Mindset
- System Modeling with Partial Initial Information
- Storytelling as a Pedagogical Strategy
- Hands-On Learning with Digital Twins
- Dynamic and Authentic Assessment

21st Century Mindset: TRASEE exploits concepts from cognitive psychology, biology, social sciences, and economics to expand the frontiers of systems engineering thinking. Based on developing an innovation-oriented mindset for the 21st century workforce, it emphasizes the development of both interdisciplinary and leadership skills that balance *opportunism* and *pragmatism* when making decisions especially in the face of uncertainty and ambiguity. It fosters the development of specific leadership qualities during systems engineering including the ability to envision and evaluate alternate futures before making decisions in the present, engaging in and learning from self-reflection, and resisting the tendency to become enamored with one's own ideas. It offers strategies to counter such cognitive biases by, for example, explicitly addressing worst case scenarios.

System Modeling with Partial Information: TRASEE teaches how to model systems when only partial information is available at the outset. Using a combination of probabilistic modeling and AI/Machine Learning capability, this system modeling approach uses the former to reflect uncertainty in the knowledge of system state and status and uses the latter to employ new evidence to fill in gaps and update the system model with up-to-date information. This "closed loop" modeling capability is realized by exploiting the convergence of systems engineering and AI/ML. Importantly, this capability extends the system modeling approach beyond popular modeling languages such as SysML, currently used in Model Based Systems Engineering.

Storytelling as a Pedagogical Strategy: TRASEE exploits storytelling concepts from the entertainment and cinematic arts as a teaching strategy. Through this approach, it transforms instructor-led lectures into interactive storytelling and role-playing exercises that foster *learner*

engagement, material retention and transfer, and recall. Students are encouraged to *envision* and *evaluate* alternate futures as a means to inform and guide decision-making and action-taking in the present. It views stories as a means to not just educate but inspire and motivate learners. Stories in the form of vignettes (i.e., mini-scenarios) presented in the classroom provide context for discussion and question-answering thereby making the class interaction-rich and enjoyable. Wrapping stories around engineering concepts, facilitates their recall because they are remembered in context. TRASEE combines storytelling with *principles from the learning sciences*: learning should be learner-centric; learning should build on prior knowledge; and learning should allow the learner to extrapolate the material learned to new problem situations. Students quickly learn that stories are an effective means for eliciting and sharing tacit knowledge and building and engaging communities of learners in shared practices, while exploring new practices through changes in assumptions and conditions in the stories. Tacit knowledge typically contains the compiled knowledge of experts which is difficult to elicit from experts but can be drawn out through storytelling and story exploration with different assumptions and conditions. Stories are also an effective enabler of interdisciplinary skills acquisition. They provide ample opportunities to acquire engineering leadership skills (e.g., decision-making with partial information). Stories are an effective means for capturing historical lessons and lessons learned and offer an effective vehicle for continuous improvement in engineering decision making. When “executed,” stories enable discovery of new knowledge as alternate futures are explored with different assumptions and conditions. In this sense, stories become effective “experience accelerators.” TRASEE also employs stories to convey abstract concepts such as “ethics,” “societal norms,” and “culture.” Ultimately, storytelling is an effective pedagogical strategy with self-reflective properties that encourage and enhance both critical thinking and systems thinking.

Hands-on Learning with Digital Twins: TRASEE exploits key concepts such as digital twins from digital engineering (DE) to afford rich hands-on learning opportunities to students in SAE’s Distributed Autonomy and Intelligent Systems Laboratory (DAIS). The creation and application of digital twins using a Model Based Systems Engineering (MBSE) innovation testbed allows students to innovate while increasing their knowledge of system verification and validation testing. This TRASEE strategy exploits the growing convergence of MBSE and DE.

Dynamic and Authentic Assessment: TRASEE employs dynamic and authentic assessment techniques to foster real-world problem solving on the part of students. The implementation of digital twins in the Innovation Testbed supports the curriculum by providing the requisite platform for cognitive skills acquisition. These skills include troubleshooting, critical and creative thinking, lateral thinking, and systems thinking. These skills, which are foundational to learning leadership and interdisciplinary skills, are exercised in the digital twin-enabled testbed environment, and reinforced by storytelling pedagogy which enables dynamic and authentic assessment of students during real-world *problem framing* and problem solving. Currently, the instructor provides diagnostic and formative feedback. Eventually, parts of that feedback will be handled by the system.

Educational Impact of TRASEE: TRASEE is producing several educational benefits including new ways of thinking, new content based on new concepts resulting from the integration of SE with other disciplines, a new form of teaching that is learner-centric, employs storytelling to communicate new concepts, and exploits synergy of SE with other disciplines when framing complex problems. TRASEE replaces siloed courses with courses that cover synergistic disciplines in suitable detail to help students in framing system problems at the right levels and from the relevant perspectives. These qualities enable the development of engineers with both leadership and interdisciplinary skills. The leadership skills result from being encouraged in the courses to make decisions in the face of uncertainty while working in teams composed of students from different backgrounds. The interdisciplinary skills result from acquiring an in-depth understanding of the synergy of SE with complementary disciplines such as digital engineering, decision analysis, cognitive psychology, AI and machine learning, and the entertainment arts.

Current Status: SAE courses, based on TRASEE, have been disseminated within the program and the systems engineering communities at large through various means including INCOSE and IISE webinars, keynotes and invited presentations, international conferences, aerospace companies, and IEEE SMC Technical Committee on MBSE. The approach is well-received and embraced not only by students but also their employers. As important, professional engineering and professional engineering education societies have enthusiastically received this approach. Graduate courses in countries in Europe and Asia are also embracing this approach. We have already begun disseminating TRASEE beyond systems engineering to all engineering programs within USC and other engineering schools within the international engineering communities. With respect to the latter, professional engineering societies such as INCOSE, IEEE SMC, and IISE networks are being exploited.