

SYLLABUS

SAE 549: Systems Architecting

Fall 2023

Class Session: Monday, 4:00 pm – 6:40 pm, ONLINE

Class Section: 32319D (DEN/Off-campus)

Contact Information:

Instructor: Prof. Azad M. Madni
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Kindly use online discussion boards (available on D2L) if you have any questions on course materials, mid-term, or final paper. The turnaround time for TA to answer questions is 24 hours. The use of email should be limited to emergency situations. The TA will consult with instructor before responding.

Course Learning Objectives:

- To improve students' ability to think critically, ask the right questions, and apply the right methods when architecting various types of systems.
- To improve students' understanding of the role of system architects and their relationship to systems engineers and transdisciplinary systems engineering.
- To introduce the students to new, advanced multidisciplinary topics (e.g., systems thinking, systems modeling, psychological principles in systems architecting, biologically-inspired architectures, agent-based modeling, human capabilities and limitations, human behavior modeling) relevant to complex systems architecting.
- To introduce the students to key concepts associated with trade-off analysis which are important to both systems architecting and engineering.

Readings and Notes:

- Weekly lecture notes will be posted on the Desire to Learn (<http://www.courses.uscdcn.net>)
- Required Text:
 - Bahill, T. A., Madni, A.M., “*Trade-off Decisions in Systems Design*” Springer, 2017. *Note: you can download this book through USC Libraries for free.*
 - Madni, A.M. *Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyper-connected World*, Springer, 2018
 - Maier, M., & Rechtin, E. (2009). *The art of systems architecting* (3rd ed.). Boca Raton, FL: CRC Press ISBN: 978-1-4200-7913-5
- Recommended Reading:
 - Madni, A.M. and Augustine, N(Eds.) *Handbook of Model Based Systems Engineering*, Springer, 2023

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Grade

Your grade will be based on one exam (will account for 40% of your final grade) *and* a final term paper (which will account for the remaining 60% of your final grade). The exam will be administered online through Desire 2 learn.

Exam

- The exam will consist of multiple questions that will test students' knowledge about the fundamentals of systems architecting, complex systems, and systems thinking. The exam will be on all the subjects covered in previous lectures and assigned readings. This will be timed exam (2 hours and 40 minutes). The exam will be administered on **Monday October 19 2023**.
- **Collaboration on the exam is forbidden.** Violators will receive an automatic F for the course.

Term Paper:

The term paper should address the following problem:

Describe and analyze the architecture of a selected system as a case study. Your analysis should discuss how the architecting process led to the architecture. The architecting process should address the heuristics used, key tradeoffs, questions posed, people involved, options generated, and decisions made, the outcomes and implications for the future.

Submit a maximum 1-page abstract by September 28, 2023 3:30 PM on your chosen topic.

Student must write on a specific system from one of the following categories.

- Autonomous Systems
- Smart phones or smart tablet computers
- Passenger Aircraft
- Space Telescopes
- Robotic Systems
- Manned Space Transport
- Airborne Platforms (e.g., Unmanned Aerial Vehicles)

LENGTH: The term paper should be between 6-8 pages (excluding references and appendices, and cover page), single-spaced, in 12-point type. The term paper is due on or before **December 7, 2023 3:30 PM**.

DELIVERY: The term paper must be submitted through the Desire to Learn (D2L) system. Links for submitting final paper will be available on D2L (<http://courses.uscdcn.net>).

LATENESS: Term papers are due on **December 7, 2023 3:30 PM**. *No late papers will be accepted after the due date and time, and the student will receive an automatic F grade for final paper.*

UNIVERSITY LEVEL ISSUES

- **Statement for Students with Disabilities:**
Any student requesting academic accommodations based on a disability is required to

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register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in GFS 120 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

■ **Statement on Academic Integrity:**

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus*, the Student Guidebook, contains the Student Conduct Code in Section 13.00, while the recommended sanctions are located in Appendix A:

<https://scampus.usc.edu/university-student-conduct-code/>. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: <http://www.usc.edu/student-affairs/SJACS/>.

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Schedule of Class Sessions: The exact schedule is likely to change, based on availability of guest lecturers. Dates of readings may change to align with other schedule adjustments. Changes will be announced.

2023	Lecture Topics	Readings
Aug 21	SAE Program, Course Overview, Systems Architecting Introduction	First 4 chapters of Maier and Rechtin, 2009 Madni, A.M. Generating Novel Options During Systems Architecting: Psychological Principles, Systems Thinking, and Computer-Based Aiding,” <i>Systems Engineering</i> , Volume 17, Number 1, pp. 1-9, 2014.
Aug 28	Transdisciplinary Systems Engineering	Madni, A.M. Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyperconnected World, Springer 2018 <i>Submit student bio by 3:30 PM Monday Aug 31 2023</i>
Sep 4	University Holiday – No Class	
Sep 11	Guest Lecture – Model-Based Systems Architecting using Dependency Structure Matrix	Purohit, S. and Madni, A.M. A Model-Based Systems Architecting and Integration Approach Using Interlevel and Intralevel Dependency Matrix, in <i>IEEE Systems Journal</i> , 2021, doi: 10.1109/JSYST.2021.3077351. Madni, A.M. and Sievers, M. Model-Based Systems Engineering: Motivation, Current Status, and Research Opportunities, <i>Systems Engineering</i> , Vol. 21, Issue 3, p. 172-190, 2018.
Sep 18	AI and ML and Ontology-Enabled Systems Architecting	Madni, A.M. Minimum Viable Model to Demonstrate the Value Proposition of Ontologies for Model Based Systems Engineering, 2020 Conference on Systems Engineering Research, Redondo Beach, CA, Oct 8-10, 2020.
Sep 25	Role of Heuristics in Systems Architecting	Appendix A of Rechtin 1991 Section 2.4 of Bahill & Madni 2017 <i>Submit abstract by 3:30 PM Monday Sep 28 2023</i>
Oct 2	Guest Lecture – Ontology-Enabled Hardware-Software Testbed for Engineering Adaptive Systems	Ordoukhanian, E. and Madni, A.M. Ontology-Enabled Hardware-Software Testbed for Engineering Adaptive Systems, In Madni, A.M. et al., (Eds.) Recent Trends and Advances in Model Based Systems Engineering, Springer, 2022
Oct 9	Human-System Integration: Implications for Systems Architecting	Madni, A.M. “Integrating Humans with and Within Software and Systems: Challenges and Opportunities,” (Invited Paper) <i>CrossTalk, Journal of Defense Software Engineering</i> , May/June 2011, “People Solutions.” Madni, A.M. “Integrating Humans with Software and Systems: Technical Challenges and a Research Agenda,” <i>Systems Engineering</i> , Vol. 13, No. 3, pp. 232-245, Autumn (Fall) 2010.
Oct 16	Midterm	
Oct 23	Guest Lecture – Role of Digital Twin Technology in SA/SE	Madni, A.M., Madni, C.C., and Lucero, D.S. Leveraging Digital Twin Technology in Model-Based Systems Engineering, MDPI <i>Systems</i> , special issue on “Model-Based Systems Engineering,” 7(1), 7, 2019.

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Oct 30	Augmented Intelligence and Human-Machine Teaming Architectural Framework	Madni, A.M. Exploiting Augmented Intelligence in Systems Engineering and Engineered Systems, <i>INSIGHT Special Issue</i> , Systems Engineering and AI, April 2020, https://doi.org/10.1002/inst.12282 .
Nov 6	Guest Lecture – Model-Driven Dynamic Case Simulation for Exploration of Outcome Space	Wheaton, M. and Madni, A.M. Modeling of Case Studies for Dynamic Exploration of Alternate Outcomes, 2021 AIAA SciTech, Nashville, Tennessee, Jan 11-15, 2021.
Nov 13	Guest Lecture – Model-Based Systems Architecting Methods for Inheritance and Design Reuse	Trujillo, A. and Madni, A.M. MBSE Methods for Inheritance and Design Reuse, in <i>Handbook of Model Based Systems Engineering</i> Madni, A.M. and Augustine, N. (Eds.), Springer 2023
Nov 20	Architecting Resilient Systems and System-of-Systems	Chapter 9 from Madni 2018 Madni, A.M., Erwin, D., and Sievers, M. Constructing Models for Systems Resilience: Challenges, Concepts, Formal Methods, and Illustrative Examples, <i>Systems</i> , 2020, 8,3; doi:10.3390/systems8010003.
Nov 27	Architecting Adaptive Cyber-Physical-Human Systems	Madni, A.M., Sievers, M. and Madni, C.C. Adaptive Cyber-Physical-Human Systems: Exploiting Cognitive Modeling and Machine Learning in the Control Loop, <i>INSIGHT</i> , Vol. 21, Issue 3, pp. 87-93, 2018.
Dec 4	Course Review	Review of chapters in 3 textbooks
Dec 11	Final Term Paper Due	

Assigned Readings List

You can download these papers from Google Scholar or USC Libraries for free.

- Madni, A.M. "Generating Novel Options During Systems Architecting: Psychological Principles, Systems Thinking, and Computer-Based Aiding," *Systems Engineering*, Volume 17, Number 1, pp. 1-9, 2014.
- Madni, A.M., Madni, C.C. and Sievers, M. "Adaptive Cyber-Physical-Human Systems," 2018 INCOSE International Symposium, July 7-12, 2018.
- Madni, Azad M., and Michael Sievers. "Chapter 1 System of Systems Integration: Fundamental Concepts, Challenges and Opportunities." 1-34.
- Madni, A.M., Sievers, M. "Model-based systems engineering: Motivation, current status, and research opportunities", INCOSE 20th Anniversary Special Issue, 2018
- Madni, A.M., Erwin, D., and Sievers, M. Constructing Models for Systems Resilience: Challenges, Concepts, Formal Methods, and Illustrative Examples, *Systems*, 2020, 8,3; doi:10.3390/systems8010003
- Trujillo, A. and Madni, A.M. MBSE Methods for Inheritance and Design Reuse, in *Handbook of Model Based Systems Engineering* Madni, A.M. and Augustine, N. (Eds.), Springer 2023
- Wheaton, M. and Madni, A.M. Modeling of Case Studies for Dynamic Exploration of Alternate Outcomes, 2021 AIAA SciTech, Nashville, Tennessee, Jan 11-15, 2021.
- Madni, A.M. Exploiting Augmented Intelligence in Systems Engineering and Engineered Systems, *INSIGHT Special Issue*, Systems Engineering and AI, April 2020, <https://doi.org/10.1002/inst.12282>.
- Madni, A.M., Madni, C.C., and Lucero, D.S. Leveraging Digital Twin Technology in Model-Based Systems Engineering, MDPI *Systems*, special issue on "Model-Based Systems Engineering," 7(1), 7, 2019.
- Madni, A.M. "Integrating Humans with and Within Software and Systems: Challenges and Opportunities," (Invited Paper) *CrossTalk, Journal of Defense Software Engineering*, May/June 2011, "People Solutions."
- Madni, A.M. "Integrating Humans with Software and Systems: Technical Challenges and a Research Agenda," *Systems Engineering*, Vol. 13, No. 3, pp. 232-245, Autumn (Fall) 2010.
- Ordoukhanian, E. and Madni, A.M. Ontology-Enabled Hardware-Software Testbed for Engineering Adaptive Systems, In Madni, A.M. et al., (Eds.) Recent Trends and Advances in Model Based Systems Engineering, Springer, 2022
- Madni, A.M. Minimum Viable Model to Demonstrate the Value Proposition of Ontologies for Model Based Systems Engineering, 2020 Conference on Systems Engineering Research, Redondo Beach, CA, Oct 8-10, 2020.
- Purohit, S. and Madni, A.M. A Model-Based Systems Architecting and Integration Approach Using Interlevel and Intralevel Dependency Matrix, in *IEEE Systems Journal*, 2021, doi: 10.1109/JSYST.2021.3077351.
- Madni, A.M. and Sievers, M. Model-Based Systems Engineering: Motivation, Current Status, and Research Opportunities, *Systems Engineering*, Vol. 21, Issue 3, p. 172-190, 2018.
- Madni, A.M. Generating Novel Options During Systems Architecting: Psychological Principles, Systems Thinking, and Computer-Based Aiding," *Systems Engineering*, Volume 17, Number 1, pp. 1-9, 2014.
- Madni, A.M., Sievers, M. and Madni, C.C. Adaptive Cyber-Physical-Human Systems: Exploiting Cognitive Modeling and Machine Learning in the Control Loop, *INSIGHT*, Vol. 21, Issue 3, pp. 87-93, 2018.