

# SYLLABUS

SAE 549: Systems Architecting

Spring 2025

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

**Class Section:** 32319D (DEN/Off-campus) and 32349D (On Campus OHE100D)

## **Contact Information:**

Instructor: Dr. Robert J Minnichelli

Office hours: Virtual, By Appointment Only

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Course Producer: Fabio Silva

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Please use online discussion boards (available on D2L) for questions on course materials, homework, mid-term, or final paper. E-mail the course producer and instructor with questions on grades or individual issues or concerns.

## **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 using TRASEE™ education paradigm
- 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 online platform, Desire to Learn (<http://www.courses.uscdcn.net>)
- Required Text (available for free download from the USC Library):
  - 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 (Available for free download from the USC Library):
  - Madni, A.M. and Augustine, N. (Eds.) *Handbook of Model Based Systems Engineering*, Springer, 2023
- Assigned papers and references for individual lectures (Available for free download from the USC Library):
  - 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.

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- 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.
- Maier, M. "Is There a Case for Radical Change to Weather Satellite Constellations", IEEE Aerospace Conference, March 2018.

### Grade

Your grade will be based on one midterm exam (will account for 35% of your final grade), a final term paper (which will account for 40% of your final grade), and homework assignments. The exam will be administered online through Desire 2 Learn.

### Homework:

There is not a lot of homework assigned in this class. Instead, this is a very concept-oriented class, and you are expected to spend most of your preparation time reading an expansive amount of material that complements the lecture material and thinking through these connections. As a result, most of the weekly homework assignments will simply be acknowledgements at the end of the week following the assigned reading, indicating that you have read the assigned material and

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trusting the integrity of your responses. In addition, two homework assignments (HW#3 and HW#6) will include one problem each, based on the lectures, that are not expected to require much time to complete either, but do exercise a particular method. The intent is to help you focus most of your time on studying different perspectives of these architecting concepts for this class. (There are other classes in the SAE Program that focus more on practice of methods with extensive homework assignments rather than this focus on concepts...)

### 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 a timed exam (2 hours and 40 minutes). The exam will be administered on **Monday April 01, 2024**.
- **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, as well as the outcomes, implications, lessons-learned, and potential future heuristics.*

**Submit a maximum 1-page draft abstract by Sunday March 9, 2025 on your chosen topic. An annotated outline is required by Monday March 31, 2025, 4:00 PM before class. The format of the abstract and outline will be discussed in class at least 2 weeks prior to their due dates.**

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 (Fighter /Bomber aircraft/helicopter/Unmanned Aerial Vehicles)

Any other categories must be approved in advance by the instructor. It is highly encouraged that you avoid programs and projects that you have been personally involved with, and that you consider systems that have ample published insights into the inner workings and assessments of outcomes.

**LENGTH:** The term paper should be between 6-10 pages (excluding references and appendices, and cover page), single-spaced, in 12-point type. The term paper is due on or before **May 2, 2025, 5:00 PM (PT)**.

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**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.uscden.net>).

**LATENESS:** Term papers are due on **May 2, 2025, 5:00 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 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.

2025	Lecture Topics	Readings
Jan 13 Week 1	SAE Program, Course Overview, and Intro to Systems Architecting Part 1	<i>Submit student bio by Sunday Jan 19, 2024 11:59 PM</i> - Maier and Rechtin (2009): Preface, Introduction, Chapters 1-4, and Case Study 1: DC-3
Jan 20 Week 2	University Holiday – No Class	<i>HW#1 Due Sunday Jan 26 – Reading acknowledgement only</i>
Jan 27 Week 3	Intro to Systems Architecting Part 2: Processes and Frameworks	- Madni (2018): Chapter 1 - Maier and Rechtin (2009): Part III Intro, Chapters 8 and 9 - <i>Example Application Paper:</i> Mark Maier, “Is There a Case for Radical Change to Weather Satellite Constellations”, IEEE Aerospace Conference, March 2018. <i>HW#2 Due Sunday Feb 2 – Reading acknowledgement only</i>
Feb 3 Week 4	Architecture Tradeoff Analysis	- Bahill and Madni (2017): Chapter 5 - Madni, A.M., and Ross, A. “Exploring Concept Trade-offs,” Chapter 10 in “Trade-off Analytics,” Eds Parnell G., Wiley 2016 - 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. <i>HW#3 Due Sunday Feb 9 – Reading acknowledgement &amp; one problem</i>
Feb 10 Week 5	Role of Heuristics in Systems Architecting	- Maier and Rechtin (2009): Chapter 2 (review) and Appendix A - Bahill and Madni (2017): Section 2.4 - Madni (2018): Section 8.6 <i>HW#4 Due Sunday Feb 16 – Reading acknowledgement only</i>
Feb 17 Week 6	University Holiday – No Class	- Maier and Rechtin (2009): Chapters 5, 6, and 7 <i>HW#5 Due Sunday Feb 23 – Reading acknowledgement only</i>
Feb 24 Week 7	Human-System Integration: Implications for Systems Architecting  Plus a brief overview of case study methods	- Chapter 7 from Madni 2018 - A. M. Madni, M. Sievers, and C. C. Madni, “Adaptive Cyber-Physical-Human Systems: Exploiting Cognitive Modeling and Machine Learning in the Control Loop,” Insight (International Council on Systems Engineering), vol. 21, no. 3, pp. 87–93, 2018, doi: 10.1002/inst.12216. - Friedman and Sage, “Case Studies of Systems Engineering and Management in Systems Acquisition”, Systems Engineering, Vol. 7, No. 1, 2004 <i>HW#6 Due Sunday Mar 2 – Reading acknowledgement &amp; one problem</i>
Mar 3 Week 8	Case Study Guest Lecture: Ballistic Missile Defense Marilee Wheaton <i>(Lecture notes by Prof. Ellen Pawlikowski)</i>	- Maier and Rechtin (2009): Chapter 12, and Case Study 3: Intelligent Transportation Systems <i>HW#7 Due Sunday Mar 9 – Reading acknowledgement only</i> <i>Submit draft abstract by Sunday March 9</i>
March 10 Week 9	Architecting Resilient Systems and System-of-Systems	- Madni (2018): Chapter 9 <i>HW#8 Due Sunday Mar 16 – Reading acknowledgement only</i>

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March 17	University Holiday – No Class	Spring Recess
March 24 Week 10	Case Study “Guest Lecture”: GPS (Part 1 – Legacy GPS) <i>(Lecture notes by Prof. Ellen Pawlikowski)</i>	- Maier and Rechtin (2009): Chapter 3 (review) and Case Study 5: The Global Positioning System <i>HW#9 Due Sunday Mar 30 – Reading acknowledgement only</i>
March 31 Week 11	Guest Lecture: Model-Based Systems Architecture using Dependency Structure Matrix (TBR) <i>Shatad Purohit</i>	<i>Submit annotated outline of paper by 4:00 PM Monday March 31</i> - Maier and Rechtin (2009): Chapters 8 and 9 (review) - A. M. Madni and M. Sievers, “Model-based systems engineering: Motivation, current status, and research opportunities,” Systems engineering, vol. 21, no. 3, pp. 172–190, 2018, doi: 10.1002/sys.21438. - S. Purohit and A. M. Madni, “A Model-Based Systems Architecting and Integration Approach Using Interlevel and Intralevel Dependency Matrix,” IEEE systems journal, vol. 16, no. 1, pp. 747–754, 2022, doi: 10.1109/JSYST.2021.3077351. <i>HW#10 Due Sunday Apr 6 – Reading acknowledgement only</i>
April 7 Week 12	<b>Midterm</b>	
April 14 Week 13	Guest Lecture – Ontology-Enabled Hardware-Software Testbed for Engineering Adaptive Systems <i>Dr. Edwin Ordoukhanian</i> Architecting Resilient Systems and System-of-Systems	- E. Ordoukhanian,, A.M. Madni; (2022). Ontology-Enabled Hardware-Software Testbed for Engineering Adaptive Systems. In: Madni, A.M., Boehm, B., Erwin, D., Moghaddam, M., Sievers, M., Wheaton, M. (eds) Recent Trends and Advances in Model Based Systems Engineering. Springer, Cham. <a href="https://doi.org/10.1007/978-3-030-82083-1_16">https://doi.org/10.1007/978-3-030-82083-1_16</a> <i>HW#11 Due Sunday Apr 20 – Reading acknowledgement only</i>
April 21 Week 14	Transdisciplinary Systems Engineering	- A. M. Madni, "Transdisciplinary Systems Engineering: Exploiting Disciplinary Convergence to Address Grand Challenges," in IEEE Systems, Man, and Cybernetics Magazine, vol. 5, no. 2, pp. 6-11, April 2019, doi: 10.1109/MSMC.2019.2899957. - Madni (2018): Chapter 1 (review), Chapter 5 <i>HW#12 Due Sunday Apr 7 – Reading acknowledgement only</i>
April 28 Week 15	Final Thoughts and Review of Key Concepts	
<b>May 2</b>	<b>Final Papers Due at 5:00 PM</b>	