USC Viterbi School of Engineering

Systems Architecting & Engineering Program

SAE 546: Engineered Resilient Systems and System-of-Systems
Fall 2018—Thursday—3:30-6:10 PM
Location: OHE 100B (DEN Webcasted Class).

Instructor: Mr. Kenneth L. Cureton
Office: Research Annex (RAN) 215 & Virtual
Office Hours: 2:00-3:00 PM Thursday
Contact Info: cureton@usc.edu
         Office Phone: (213) 740-1713

Teaching Assistant: None

Course Description
Resilience Engineering has become an important subject in systems engineering, as systems continue to grow in size, scale, and complexity. This course provides Systems Architects and Engineers with key definitions, concepts and methods for the design and analysis of resilient systems and system-of-systems (SoS).

Learning Objectives
- Introduce students to the different definitions of resilience in various domains
- Introduce students to key resilience concepts associated with systems and system-of-systems (SoS)
- Introduce students to complexities posed by adaptable systems and impact on human-systems integration
- Introduce students to key approaches for engineering resilient systems and system-of-systems
- Improve students' ability to write a scholarly research paper suitable for peer-reviewed conferences

Prerequisite(s): None; however, SAE 549 *Systems Architecting* is recommended
Co-Requisite (s): None
Concurrent Enrollment: None
Recommended Preparation: 2 or more years of Systems Engineering experience desirable, but not required

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

Course Notes
This is a webcasted class in Distance Learning format via the USC Distance Education Network (DEN). All course materials (webcasted lectures, lecture notes, references, and reading material) are available on-line via the DEN.

Technological Proficiency and Hardware/Software Required
Must have access to (and be proficient in the use of) a web browser in order to access course materials, view lectures, submit assignments, and interact with the Instructor.

THIS IS AN EXPERIENTIAL COURSE!

This class is not a "one-way" lecture: student participation is strongly encouraged and is a factor in your class grade. You can choose to work as individuals or in groups or teams for discussions. Just as in the real world, interaction with the instructor and each other can be (but does not have to be) face-to-face. Interaction can be in class or real-time via the DEN tools (e.g. Webex) or even asynchronously (i.e. at any time on any day). You can use e-mail, social media tools, collaboration tools and DEN discussion areas and thus interact asynchronously regardless of Time Zone differences and regardless of time-of-day.

There will be checkpoints in each lecture to allow student questions in real-time. You can also document your questions and observations on the DEN discussion areas so that others may respond either in real-time or at a later date. This way, there is a record of all discussions, questions-and-answers, etc.

Remember, student participation IS a factor in class grading!

Required Readings and Supplementary Materials
All required materials are available on-line via the DEN or USC Libraries—no textbooks are required for purchase. However, the following materials are suggested for reference:
- Madni, A.M., "Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyper-Connected World," Springer 2018
  Note: you can download this book through USC Libraries for free.
- Kate L. Turabian (April 2018). A Manual for Writers of Research Papers, Theses, and Dissertations, Ninth Edition by The University of Chicago Press, Hardback ISBN: 9780226494425, Paperback ISBN: 9780226430577

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

Description and Assessment of Assignments
One Midterm Exam is required of each student. One Research Paper is required of each student in place of a Final Exam. Students choose their research topic, and submit an abstract for approval by Instructor.

Grading Breakdown

Assignment	Points	% of Grade
Midterm Exam	40	40%
Research Paper	50	50%
Participation	10	10%
TOTAL	**100**	**100%**

Assignment Submission Policy
Submit assignments on-line to the DEN system, according to the published course schedule (see below). All assignments (including late submissions) are due no later than the scheduled Final Exam date—no submissions will be accepted beyond that date.

MIDTERM EXAM
The exam will consist of multiple questions that that require short essay answers. It will test students' knowledge about the fundamentals of resilience engineering. The exam will be on all the subjects covered in lectures #1 through #7 and assigned readings.

- This will be timed exam (2 hours and 40 minutes). The exam will be available on D2L at any time between Saturday October 13, 2018 at 6:00 AM Pacific Time and Tuesday October 16, 2018 at Midnight Pacific Time. Answers to the exam will be reviewed in Lecture #14.

- Collaboration on the exam is forbidden. Violators will receive an automatic F for the course.

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

RESEARCH PAPER

GOAL: Your paper must be purposeful—it should have an academically acceptable goal, something more than just demonstrating that you can accomplish research and write a cogent Research Paper that summarizes that research, as those are necessary but not sufficient goals for academic purposes.

For this class, your purpose should include two additional goals that are above and beyond conducting research and writing Masters-level Research Papers:

- Your first goal is to demonstrate that you understand and can properly apply the concepts presented in the class through the accomplishment of resilience analyses of a technical topic.

- Your second goal is to inform the reader and "teach" your Instructor regarding the resilient characteristics and technical details of your chosen topic.

Failure to achieve any of the above will impact your paper's grade!

TOPIC: Select a complex system or system-of-systems from following domains and discuss how you would introduce resilience into the selected system or system-of-system. Your research paper should build on the resilience concepts presented in the class and the reference papers.
   1) Aerospace/Space
   2) Energy
   3) Healthcare
   4) Transportation

Subject to my approval, you get to choose the topic within one of the above domains:
- It can be something that interests you, or something with which you have been personally involved. But be careful if using a program from a current employer— make sure that you have authorization to write on that topic!
- It should address a system where the need for resilience is well-recognized, and the measures of effectiveness are available.
- It can be ongoing or it can be past history. New or future programs are allowable if they have substantial progress to-date or if comparable experience is available with past systems.

APPROVAL: You must submit a one-page abstract regarding your proposed topic for approval. Please submit on-line via DEN Assignments no later than September 20, 2018.

FORMAT: Microsoft WORD (.DOC) or Adobe Acrobat (.PDF) format for abstracts and research papers.

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

LENGTH**:** Experience to date shows that the average is somewhere around 20 pages, single-spaced, in 10 or 12-point type. Papers are NOT graded by their weight! Take as long as it takes to tell the story clearly and to present a well-organized analysis in terms of the concepts presented in this course. N.B. very few papers of size less than 15 pages have been worthy of a good grade in this class.

SOURCES: You must properly reference all sources. We use the turnitin.com service to look for matches with existing books, magazine and newspaper articles, journals, prior student papers, and all Internet sources. Published works (such as books, scholarly articles, and journal publications) are preferred. If you obtain information via interviews, then a list of sources and contacts is essential, listing what sources you used and anyone you interviewed. Be sure to provide the URLs of any Internet sources used in your research. If you directly quote text from a source, you must properly designate quoted material "in quotation marks" or in italics, and give a citation for each quotation via a footnote or a numbered reference or in-text (author-date) notation. The amount of quoted text relative to the total text in your paper should be kept to a minimum—if excessive; this will detract from your paper's grade.

WARNING: Failure to properly designate copy-and-pasted text will be considered as a violation of academic integrity (see University Policy Statements at the end of this syllabus). This includes quotations from your prior papers (e.g. from SAE 549 or other classes)! You can build on your own work from other classes, and from other author's works, as long as you properly cite those references. You must not directly copy text from those sources— *even your own*—unless properly marked and cited as a quotation. Instead, you must add value by citing then restating such work in your own words plus your own enhancements, such that the combination has enhanced relevance to this class. You can directly copy graphics, tables, or figures if you give a citation for each copied item. Although there is no limitation on the relative amount of copied items, your own artwork—however crude yet clearly legible and illustrative—is always acceptable.

LIMITS: I cannot accept a request to limit access to your abstract or research papers. Although I do not plan to disseminate your work without your permission, I cannot guarantee that other people (including non-US citizens) will not view or handle your submitted materials. Thus you must not use classified, proprietary or company limited-distribution materials in your coursework. If your employer requires review and approval for your submitted materials (e.g. Public Affairs Office or Export Compliance Review) then you must obtain such approval within the deadlines listed in this syllabus. As the approval practices in many companies may be time consuming, the best practice is not to use company material at all.

DELIVERY: Please submit on-line via DEN Assignments no later than the scheduled final exam date (December 6, 2018).

GRADING: Your research paper will be graded on the letter scale: A, A-, B+, B, B-, etc.

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

I have to turn in the class grades shortly after the end of the Semester (after Final Exams Week), so I'll inform you via e-mail regarding your research paper grade (as well as your overall grade) no later than two weeks after the paper is due.

Note: if your employer requires a written statement (or a signed postcard) for re-imbursement for this class, then please provide me with the appropriate paperwork and a self-addressed, stamped-envelope (or postcard) before the end of the semester.

 ADDITIONAL INFORMATION:

- Please feel free to e-mail me for help in structuring your research plan. I will gladly work with you to review your outline, draft paper, potential references, etc.

- If English grammar, spelling and syntax are not your strong points, I strongly suggest that you obtain help in editing your text. Your grade depends on the clarity of presentation.

CLASS PARTICIPATION

GOAL: Each week the Instructor will pose a question for class discussion. You will have a chance to comment on that question as well as the material presented in that lecture. If you cannot attend a lecture in person or on-line during the class, then you can post your comments on that week's discussion area on the DEN.

GRADING: Your participation is scored on a scale of 0-to-10. Note that 'participation' must be in person or online during class or else posted on the appropriate DEN discussion area— e-mail correspondence and telephone calls, although encouraged to answer questions, do NOT count toward your class participation score. You'll receive all 10 points if you have a significant level of interaction with me and other students (on a weekly basis), either in-class or on-line or in a DEN discussion area for that lecture. Less frequent participation (less than an average of once each week) will receive 5 points. Occasional participation (more than once or twice) will receive 2 points, and if you choose to not significantly participate in the lectures (other than submitting required assignments), then you'll receive zero points for class participation.

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

FINAL GRADE

GRADING: Your class grade is computed as follows:

First, your research paper letter grade is converted into a numerical score according to USC Grading Standards: 4.0 for A, 3.7 for A-, 3.3 for B+, 3.0 for B, 2.7 for B-, 2.3 for C+, 2.0 for C, 1.7 for C-, 1.5 for D+, 1.0 for D, 0.7 for D-, 0.0 for F. This score is then multiplied by 12.5 to achieve a point range of 50-to-0.

Your Midterm Exam score is added to the above (0 to 40 points total).
Your level of participation in the class is added to the above (0 to 10 points total).

The grand total of points is divided by 25 (to scale your total to a range of four-to-zero):
CLASS SCORE = (PAPER + HOMEWORK + PARTICIPATION) / 25

(i.e. 50% for your research paper, 40% for your midterm exam, 10% for class participation.)

This class score is converted into a letter grade for the class:

A   4.0 to above 3.7
A-   3.7 to above 3.3
B+   3.3 to above 3.0
B   3.0 to above 2.7
B-   2.7 to above 2.3
C+   2.3 to above 2.0
C   2.0 to above 1.7
C-   1.7 to above 1.5
D+   1.5 to above 1.0
D   1.0 to above 0.7
D-   0.7 to above 0.5
F   0.5 or below.

This letter grade is reported to USC as your class letter grade.

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	Readings	Deliverable
Lecture 1 **Aug 23**	**Syllabus, Introduction to the Course & Resilience Concepts in Various Domains**	• **Chapter 9 Madni (2018)**	**None**
Lecture 2 **Aug 30**	**Resilient System Concepts & General Approaches for Hardware, Software, and Networks**	• **Madni & Jackson "Towards a conceptual framework for resilience engineering"** • **Madni & Boehm "Engineered Resilient Systems: Challenges and Opportunities in the 21st Century"** • **Goerger & Madni & Eslinger "Engineered Resilient Systems: A DOD Perspective"** • **Madni A. "Adaptable Platform-Based Engineering: Key Enablers and Outlook for the Future"**	*Personal Introduction*
Lecture 3 **Sep 6**	**Resilient System-of-Systems Concepts and General Approaches**	• **Klingensmith & Madni "Architecting Cyber-Secure, Resilient System-of-Systems"** • **Klingensmith & Madni "Resilience Concepts for Architecting an Autonomous Military Vehicle System-of-Systems"**	**None**
Lecture 4 **Sep 13**	**Affordably Adaptable and Effective Systems**	• **Neches & Madni "Towards Affordably Adaptable and Effective Systems"**	**None**
Lecture 5 **Sep 20**	**Complexities Posed by Adaptable Systems**	• **Chapter 7 Madni (2018)**	*Abstract for Research Paper*
Lecture 6 **Sep 27**	**Model-based Approach for Engineering Resilient System-of-Systems**	• **Madni & D'Ambrosio & Sievers & Humann & Ordoukhanian & Sundaram "Model-Based Approach for Engineering Resilient System-of-Systems: Applications to Autonomous Vehicle Network"**	**None**
Lecture 7 **Oct 4**	**Flexible Contracts Approach to System Resiliency**	• **Sievers & Madni "A Flexible Contracts Approach to System Resiliency"**	**None**
Lecture 8 **Oct 11**	**Domain Case Study: Multi-UAV Swarms**	• **Madni & Sievers & Humann & Ordoukhanian "Model-Based Approach for Engineering Resilient System-of-Systems: Application to Multi-UAV Swarms"**	**None**
Midterm **Oct 13-16**	**Midterm Exam**	• **2 hour 40 minute timed exam at any time of your choice between October 13 at 6 AM and October 16 Midnight (Pacific Times)**	*Midterm Exam*

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

	Topics/Daily Activities	Readings	Deliverable
Lecture 9 Oct 18	**Domain Case Study: Planetary Exploration**	**TBD**	**None**
Lecture 10 Oct 25	**Domain Case Study: Spacecraft Swarms**	• **Sievers & Madni "Contract-Based Byzantine Resilience for Spacecraft Swarm"** • **Sievers & Madni "Agent-Based Flexible Design Contracts for Resilient Spacecraft Swarms"**	**None**
Lecture 11 Nov 1	**Domain Case Study: Manned Space Systems**	**TBD**	**None**
Lecture 12 Nov 8	**Guest Lecture (TBD)**	**None**	**None**
Lecture 13 Nov 15	**Guest Lecture (TBD)**	**None**	**None**
Nov 22	**Thanksgiving Holiday (no class meeting)**	**None**	**None**
Lecture 14 Nov 29	**Class Review and Summary**	**None**	**None**
FINAL Dec 6	**None—no lecture**	**None**	***Research Paper***

SAE 546: Engineered Resilient Systems and System-of-Systems (Fall 2018)

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 STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. Website and contact information for DSP: http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html, (213) 740-0776 (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX) ability@usc.edu.

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, (www.usc.edu/scampus or http://scampus.usc.edu) contains the University Student Conduct Code (see University Governance, Section 11.00), while the recommended sanctions are located in Appendix A.

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of on-line message systems, teleconferencing, and other technologies.