



ISE-599: Research problems in large, complex systems

Units: 3

Term—Day—Time: Spring 2018,

Mondays and Wednesdays, 12:00 pm to 1:50 pm

Location: TBD

Instructor: Neil Siegel, Ph.D.

IBM Professor of Engineering Management,
Daniel Epstein Department of Industrial and
Systems Engineering,
Viterbi School of Engineering

Office: OHE 310D

Office Hours: TBD

(other office hours are available by appointment)

Contact Info: nsiegel@usc.edu

I usually respond the same day.

Teaching Assistant:

Office: TBD

Office Hours: TBD

Contact Info: TBD

IT Help (for the Rhapsody laboratory): John Ng

Hours of Service: Monday-Friday, 9:00 am to 4:00 pm

Contact Info: johnng@usc.edu

Course Description

Systems as complex collaborative ensembles of interconnected components. Theory and practice of requirements, design, implementation, testing, deployment, operation, and disposal. Analysis of currently-unsolved problems affecting the development of large, complex societal systems. Examine of the research opportunities that these unsolved problems might represent. Case studies from real projects.

This course is designed for ISE (or other engineering) Ph.D. students interested in learning about using systems engineering methods to specify, design, and develop large complex systems, and also learning about where these methods (and the underlying theory) are inadequate, and therefore, there are opportunities for new research.

Society today depends on many large systems – complex ensembles of capability, interconnected so as to provide some benefit not achievable by the individual components. Examples include air traffic control and route planning, medical systems that optimize care and cost, the power grid that integrates many sources of energy to provide continuous electric service (even in the presence of disruptions and failures of components), systems that coordinate the supply chain of businesses so as to ensure continuous availability of desired products while also reducing waste, and so forth. It is not an exaggeration to say that society as we know and expect it could not exist without such systems, which provide benefits such as operation at very large scale, safety, reliability, and affordability for many critical products and services.

Such systems are among the most complex artifacts ever created by humans. How does one learn to design and build such systems? This is the role of the field of **systems engineering**. This course provides an introduction for aspiring researchers and practitioners and other interested persons into the art of creating such complex systems for our society.

This course is divided into two portions:

1. In the first half of the course, we teach the system method (hierarchy, decomposition, the “vee” diagram, synthesis, model / analysis / optimization, traceability, obtaining and retaining stakeholder buy-in, design principles, completion criteria, limiting the impact of adverse events, etc.) and the system life-cycle (concept, requirements, design, implementation, integration, verification, production, deployment, utilization, support, retirement).
2. In the second half of the course, we discuss the strengths and weaknesses of current practice, and in the underlying theory. We then go on to identify research needs and opportunities in support of the development of these large, complex systems.

Learning Objectives

By the end of the course, students will:

- Understand the motivation for systems thinking, and for the use of systems engineering
- Understand the systems engineering value-proposition, be familiar with examples of systems that are in use today, and understand the contribution of systems engineering to society
- Have been through an introduction and analysis of the major elements of the *system engineering process*, interspersed with examples (case-studies) drawn from real projects

- Have learned the complete *system life-cycle* (requirements, design, implementation, test, deployment, operations and maintenance, disposal), and also learned about key leverage points, and key lessons-learned from actual large projects
- Have learned about the methodologies, tools, representations, and analysis methods used in systems engineering, and (through the case studies from actual projects that are presented in the class) how systems engineers tackle and solve problems in roles ranging from an entry-level position on a large project, to chief systems engineer on a large project. These case studies cover both the technical and social aspects of being an effective systems engineer, including dealing with our non-technical stake-holders (which might include those who make procurement decisions, those who make funding decisions, those who make applicable laws and regulations, our customers and users, and (increasingly) the general public and the media), as well as our fellow engineers and scientists.
- Have learned about the theory that underlies key steps of the systems engineering life-cycle, and in particular, stages and methods where that theory is weak or inadequate.
- Discussion of the research needs / opportunities that come out of those identified weaknesses.
- Learned and used a computer-based systems engineering tool (IBM Rational Rhapsody) to create automated representations of a use-case provided by the professor
- Have used the systems engineering analysis techniques taught in the lectures to solve example problems provided by the professor

Prerequisite(s): Open to all ISE and Viterbi Ph.D. students

Co-Requisite(s): None

Concurrent Enrollment: None

Recommended Preparation: None

Course Notes

The course may be taken *only* for a conventional letter grade; taking the course on a pass/fail basis is not allowed by the instructor.

Lecture, 80 minutes, twice per week. Some of the class sessions will be facilitated lab sessions.

Outside study and homework includes reading assignments, short written summaries of those readings, individual study to master the lecture materials, and completion of projects started during the weekly facilitated lab sessions.

The professor will hold a minimum of 2 hours of office hours per week for students of this class, and will also be available for consultation via email.

Lecture slides will be posted on Blackboard.

Technological Proficiency and Hardware/Software Required

The IBM Rhapsody software will be used for a 4-week section of the course. That portion of the course will be conducted in a USC computer laboratory that has that software

already installed and available to students. The Rhapsody software will likely not be available for installation onto the student's own computers.

Required Readings and Supplementary Materials

There will be one textbook to be purchased (“Managing Complex Technical Projects”, Faulconbridge and Ryan, Artech House, ISBN 1-58053-378-7; available via the USC bookstore, and also conventional on-line sources, such as Amazon); additional reference materials will be provided via Blackboard by the professor.

Description and Assessment of Assignments

Homework will be assigned during the course, and will figure as a part of your grade (see the section below, “Grading Breakdown”). Most of the homework assignments consist of written summaries of your readings from the textbook. Instructions regarding this portion of the homework will be contained in the weekly lectures.

During the facilitated lab work, there will be work assigned to you, some of which will be accomplished during the lab sessions themselves. Your products from these sessions will also constitute homework, and will be counted towards your grade.

The specific homework assignments, their due-dates, and their point-value towards your grade for this course are summarized in the matrix provided in the section “**Course Schedule: A Weekly Breakdown**”, below. All assignments should be turned in through Blackboard. All homework and examinations will be graded by the professor.

Examinations

There will be two written examinations as a part of the course:

Mid-term examination – during the regular lecture session for week 8 (300 points)

Final examination – during finals week; you will be notified of the specific date, time, and location well in advance of the examination (400 points, *including* the homework assignment that is due on the day of the final examination).

The two written examinations will be cover materials presented in the class lectures.

The date for the final examination is prescribed by the University, and cannot be changed by the professor; the final examination can be offered on another date only under the most extraordinary circumstances (I once had a student who was getting married that day – we did arrange for that student take the test the day before!). The following describes the written examinations:

- Some of the questions will be “closed-form” (true/false, multiple choice), but most of the score will likely be derived from “essay” questions, e.g., the professor will describe a situation, and ask you to discuss it in light of what you have learned from the class. Expect that the questions will draw from material in both the lectures and the textbook, with more emphasis on the lectures.
- ***You may bring 1 letter-sized piece of paper*** (8½” x 11” – with text &/or drawings on both sides – hand-written or typed, at your discretion) ***of notes to use during each examination.***
- You may use a stand-alone calculator (e.g., no memory or internet connectivity) during the examinations.
- Bring pencils, erasers, and a pencil sharpener to the examinations!

- Bring some scratch paper, too.
- No computers, phones, iPads / tablets, Dick-Tracy wrist watches, etc. – nothing with computing, storage, or internet connectivity will be allowed during the examinations.

Grading Breakdown

- Homework assignments – 30%
- Mid-term examination – 30%
- Final examination – 40%

The grading scale for the course is as follows:

A 933-1,000	A- 900-932	B+ 866-899	B 833-865	B- 800-832	C+ 766-799
C 733-765	C- 700-732	D+ 666-699	D 633-665	D- 600-632	F Below 600

The total for all point-scoring opportunities is 1,000; the mid-term examination is 300 points (e.g., 30% of your grade); final examination is 400 points (e.g., 40% of your grade); and the homework assignments are 300 points (e.g., 30% of your grade). Your grade will be based on your total point score, using the table above. During the conduct of the course, all of your examination and homework scores will be posted on Blackboard (usually within a couple of days), to which you can gain access anytime by logging in with your USC login information.

week	lecture (Monday)	Facilitated lab session (Wednesday)	homework assigned	homework due
<i>1st half of the course: methods used for developing large, complex systems</i>				
1 (1-8)	Motivation, overview of the systems method	Where are the research problems in big, complex systems?	Falconbridge chapters 1 & 2	
2 (1-15)	Requirements	Requirements	Falconbridge chapters 3 & 4	Falconbridge chapters 1 & 2
3 (1-22)	Design	Design	Falconbridge chapter 5. Decision-tree.	Falconbridge chapters 3 & 4
4 (1-29)	Implementation and integration	Decision-tree	Falconbridge chapters 6 & 7	Falconbridge chapter 5
5 (2-5)	User experience. Testing.	Decision-tree	Falconbridge chapter 8	Falconbridge chapters 6 & 7
6 (2-12)	Risk management	Decision-tree		Falconbridge chapter 8
7 (2-19)	12 important concepts in systems engineering	Review of the course to-date		
8 (2-26)	Mid-term examination	(no lab this week)		
<i>2nd half of the course: research needs in support of the development of large, complex systems</i>				
9 (3-5)	Dynamic versus static behavior in representations and design.	Rhapsody problem in the computer lab	Rhapsody problem	Decision-tree
<i>(week of 3-12-2017: spring break)</i>				
10 (3-19)	How do we know that we are designing and building the right thing?	Rhapsody problem in the computer lab		
11 (3-26)	The software problem	Rhapsody problem in the computer lab		
12 (4-2)	Cyber-security considerations: Operating with the enemy inside. Cyber-physical integration.	Rhapsody problem in the computer lab	2-pager about a research need of your selection	Rhapsody problem
13 (4-9)	Student 5-minute presentations: your candidate research topic. Discussion by the entire group.	Student 5-minute presentations: your candidate research topic. Discussion by the entire group.		
14 (4-16)	2 unsolved systems engineering problems: (a) health-care (b) reliability of the electric power grid	Reprise: Where are the research problems in big, complex systems?		
15 (4-23)	Review of the course	Q&A		
finals week	Final examination			2-pager about a research need of your selection (graded as a part of the final examination)

Course Schedule: A Weekly Breakdown Additional Policies

Late papers and assignments will usually be marked down for every day late; in general, *no* papers will be accepted more than **3 days after the due date**. The professor will try to make accommodation for legitimate personal crises. The professor, however, has no obligation to do so; such accommodation is at his discretion.

The professor will always endeavor to treat his students with respect and dignity; he expects that you will do the same, both to him, and to the other students in the class. He invites questions and discussion, but reserves the right to structure the course and the class time as he sees fit, including the right to request that a student take a line of discussion “off-line” to office hours if the professor believes that this line of discussion is not of general interest to the class, or not contributing to the established teaching objectives for this course.

The following is the USC Viterbi School honor code:

Engineering enables and empowers our ambitions and is integral to our identities. In the Viterbi community, accountability is reflected in all our endeavors.

*Engineering+ Integrity.
Engineering+ Responsibility.
Engineering+ Community.
Think good. Do better. Be great.*

These are the pillars we stand upon as we address the challenges of society and enrich lives.

This honor code was developed by Viterbi students.

In your written homework, please be sure to cite all referenced sources appropriately. We will not look kindly on plagiarism or cheating; we will hold you to the highest standards in this regard, and you will receive a grade of zero for the assignment if you are caught cheating or plagiarizing, which will result in a lowered or failing grade for the class. You will also be reported to the appropriate University office for plagiarizing, which could result in further sanctions, including suspension or expulsion from school. Don't do it.

The same, of course, applies to the examinations; you are expected to do your own work during the examination. The only legitimate source of information about what to expect on the examinations is the professor and the TA.

To quote from a USC guidebook: "Behavior that persistently or grossly interferes with classroom activities is considered disruptive behavior, and may be subject to disciplinary action. Such behavior inhibits other students' ability to learn and an instructor's ability to teach. A student responsible for disruptive behavior may be required to leave class pending discussion and resolution of the problem, and may be reported to the Office of Student Judicial Affairs for disciplinary action."

Statement on Academic Conduct and Support Systems

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Academic Conduct:

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, “Behavior Violating University Standards” <https://policy.usc.edu/scampus-part-b/>. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, <http://policy.usc.edu/scientific-misconduct>.

Support Systems:

Student Counseling Services (SCS) - [\(213\) 740-7711](tel:(213)740-7711) – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. <https://engemannshc.usc.edu/counseling/>

National Suicide Prevention Lifeline - [1-800-273-8255](tel:1-800-273-8255)

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. <http://www.suicidepreventionlifeline.org>

Relationship & Sexual Violence Prevention Services (RSVP) - [\(213\) 740-4900](tel:(213)740-4900) - 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender-based harm. <https://engemannshc.usc.edu/rsvp/>

Sexual Assault Resource Center

For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: <http://sarc.usc.edu/>

Office of Equity and Diversity (OED)/Title IX compliance – [\(213\) 740-5086](tel:(213)740-5086)

Works with faculty, staff, visitors, applicants, and students around issues of protected class. <https://equity.usc.edu/>

Bias Assessment Response and Support

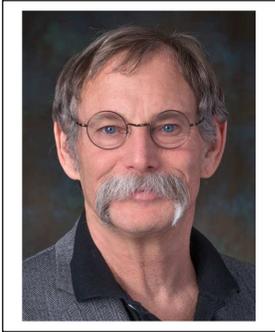
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. <https://studentaffairs.usc.edu/bias-assessment-response-support/>

Student Support & Advocacy – [\(213\) 821-4710](tel:(213)821-4710)

Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. <https://studentaffairs.usc.edu/ssa/>

Diversity at USC – <https://diversity.usc.edu/>

About the professor



Neil Siegel, Ph.D. is the IBM Professor of Engineering Management, in the Daniel Epstein Department of Industrial and Systems Engineering, at the Viterbi School of Engineering at USC. He was for many years the sector vice-president & chief technology officer at Northrop Grumman, at times responsible for as many as 12,000 engineers and scientists. Dr. Siegel has been responsible for a large number of successful military and Government systems, including the Force-XXI Battle Command Brigade-and-Below / Blue-Force Tracking system, the Army's first unmanned aerial vehicle, the Counter-Rocket-Artillery-and-Mortar system, and many others.

These systems have repeatedly been cited as model programs and important National capabilities. He also led work for the steel industry, the movie industry, and other commercial enterprises. He has a large number of inventions that have been implemented into fielded U.S. Government products and systems (and also in commercial products by companies like Garmin and Apple), and holds more than 20 issued patents. Several elements of these patents have been widely adopted, and are used in a billion devices around the world, such as smart-phones, tablet computers, and so forth.

His expertise is recognized by the U.S. Government, as indicated by past membership on the Defense Science Board, the Army Science Board, and other senior government advisory panels.

His many honors include:

- Election to the U.S. National Academy of Engineering
- Election as a Fellow of the IEEE
- The IEEE Simon Ramo Medal for systems engineering and systems science
- Selection to the U.S. National Academy of Inventors
- His company's Chairman's Award for Innovation (three times)
- The Army's Order of Saint Barbara
- The iCMG award for system architecture
- The Northern Virginia Technology Council CTO-of-the-year award

Programs that he has led have also won many honors, including the inaugural Crosstalk award as the best-ran software program in the entire U.S. government, the IDGA award as the "Most Innovative U.S. Government Program", and the Federal 100 Monticello Award.

His personal research contributions have centered around how to implement large, mobile, ad-hoc radio networks over relatively low data-rate carriers, focusing on what he calls "infrastructureless" networks (e.g., wireless radio-frequency networks that have no fixed infrastructure, such as cell-phone towers, repeaters, etc.) and techniques for achieving acceptable dynamics through what he calls "force-structure-aware" networks. He has been a pioneer in large-scale deployments of GPS-enabled applications (like the Blue-Force Tracking system). Much of his recent research has made contributions in the field of improving development methodology for large-scale systems, through the identification of novel root-causes of system-development failures, new methods to correct those root-causes, and application of those new techniques to problem domains such as health, energy, and Government information systems.