ENGR 689 Theory of Socio-Technical Systems

This course introduces the student to the philosophy, origins, theory, principles, and methodologies of complex socio-technical systems. The purpose of the course is to develop and foster the type of holistic thinking needed to be an effective systems engineer.

COURSE INFORMATION

ENGR 689 Theory of Socio-Technical Systems
Fall 2014, Section 600, Wednesdays 4:10 - 7:00 pm
Class Location: Emerging Technologies Building (ETB) Room 3027

TEXTBOOKS

This course is built on weekly assigned readings, but there is no single required textbook. For each week, a few articles and/or book excerpts are designated as assigned reading. Each week's assigned readings have been chosen based on three criteria: (1) their relevance to the week's theme, (2) their importance to the development of the field of socio-technical systems, and (3) their combination of intellectual depth and accessibility to readers from a variety of backgrounds. Many of the optional readings (when listed) also follow these criteria, but some provide more depth and rigor on certain concepts discussed in class. Students are encouraged to explore these additional readings according to their own schedules and interest.

TEACHING STAFF

Dr. Mark S. Avnet – Course Organizer and Primary Instructor
Office: ETB 4075 Office Hours: Th 1:00 - 3:00 pm or by appointment
E-mail: avnet@tamu.edu (Please include "ENGR 689" in the subject line)

PREREQUISITES

- Demonstrated interest in complex socio-technical systems and permission of instructor.
- Relevant professional and/or research experience helpful but not required.

Students must abide by the policies and regulations of the Dwight Look College of Engineering and Computer and Information Services of Texas A&M University.

SYSTEMS ENGINEERING SEMINAR SERIES

This course will be run concurrently with a Systems Engineering Seminar Series sponsored by the Department of Industrial and Systems Engineering and the Dwight Look College of Engineering. The seminar will take place on Wednesdays, 1:50-2:40 pm in ETB 4002. During most weeks, one of the guest speakers in the course will deliver the seminar for that week. Students are strongly encouraged (but not required) to attend the seminar each week.

COURSE OBJECTIVES

The primary objective of this course is to introduce students to the key principles behind the theory of complex socio-technical systems. To achieve this objective, it is essential that students learn about the foundations of complex systems from an interdisciplinary perspective. As such, the course draws on literature from a wide array of fields, including engineering, physics, biology, complexity science, economics, sociology, psychology, political science, and management. Course topics range from the general and abstract to the applied and immediately relevant. Topics covered include foundations of

the "systems approach," human/machine interaction, complexity science, emergence and hierarchy, dynamics and control, human decision-making, uncertainty, and system architecture. The course also includes discussions of several particular types of systems, including space systems, healthcare systems, energy systems, and manufacturing systems. During the semester, the student will develop a holistic view of systems (broadly defined) and an appreciation for the inherent complexity of the modern world.

COURSE SCHEDULE

This course will survey the diverse set of topics related to the general theory of complex socio-technical systems. In the first unit (Weeks 1-4), the theoretical basis and origins of the study of complex systems and the "systems approach" are introduced, and methods for defining and modeling systems problems are discussed. The second unit (Weeks 5-8) focuses on uncertainty and the design and development of complex engineered systems from a full life cycle perspective that incorporates social, economic, and political factors. In the third and final unit (Weeks 9-14), the discussion will turn to case studies of particular classes of socio-technical systems, and students will focus on team project preparation. The course will involve extensive reading covering both depth and breadth. The instruction will be highly participative and discussion-oriented with lecture being limited to brief introductions to unfamiliar topics. Guest speakers will be involved in each class session to provide an array of perspectives on course topics and to engage students in thoughtful discussion about course material.

The weekly topics to be covered during the course are:

- Week 1: Structure and Dynamics of Socio-Technical Systems
- Week 2: Human/Machine Interaction in Complex Engineered Systems
- Week 3: Understanding and Formulating Systems Problems
- Week 4: Bottom-Up Systems Modeling: Agents, Emergence, and Networks
- Week 5: Uncertainty, Risk, and Safety in Socio-Technical Systems
- Week 6: Dealing with Uncertainty: Flexibility and Real Options
- Week 7: System Architecture and Modularity in Engineering Design
- Week 8: Complexity and Human Decision Making
- Week 9: Lean Engineering
- Week 10: Healthcare Systems
- Week 11: Final Team Project Meetings with Instructor (No Class Session)
- Week 12: Energy Systems
- Week 13: Final Report Preparation (No Class – Thanksgiving Holiday)
- Week 14: Social and Organizational Systems

WEEKLY TOPIC DETAILS

- **Week 1: Structure and Dynamics of Socio-Technical Systems**
  Wednesday, September 3
  Guest Speakers: **David Broniatowski** (The George Washington University, Engineering Management and Systems Engineering); **Rogelio Oliva** (Texas A&M University, Mays Business School)

Required Reading

- de Weck, O.L., Roos, D., and Magee, C.L. (2011). *Engineering Systems: Meeting Human Needs in a Complex Technological World*. Cambridge, MA: MIT Press. (Chapters 1-3)
- Simon, H.A. (1999). *The Sciences of the Artificial*, 3rd ed. Cambridge, MA: MIT Press. (Chapters 7-8)
- Moses, J. (2007). "Architecting Engineering Systems." *First Workshop on Philosophy and Engineering*. Delft, The Netherlands.
- Douglas, M. (1999). "Four Cultures: The Evolution of a Parsimonious Model." *GeoJournal* 47: 411-415.
- Meadows, D.H. (2008). *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green. (Chapter 1)
- Sterman, J.D. (1994). "Learning in and About Complex Systems." *System Dynamics Review* 10 (2-3): 291-330.
- Richmond, B. (1993). "Systems Thinking: Critical Thinking Skills for the 1990s and Beyond." *System Dynamics Review* 9(2): 113-133.

Optional Reading

- Hughes, T.P. (2000). *Rescuing Prometheus: Four Monumental Projects That Changed the Modern World*. New York, NY: Vintage.
- von Bertalanffy, L. (1966). *General System Theory*. Cambridge, MA: MIT Press.
- Meadows, D.H. (2008). *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green.
- Sterman, J.D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. New York, NY: McGraw-Hill/Irwin.

- **Week 2: Human/Machine Interaction in Complex Engineered Systems**
  Wednesday, September 10
  Guest Speakers: **Rodger Koppa** (Texas A&M University, Industrial and Systems Engineering); **Thomas Ferris** (Texas A&M University, Industrial and Systems Engineering)

  Required Reading

  - Simon, H.A. (1999). *The Sciences of the Artificial*, 3rd ed. Cambridge, MA: MIT Press. (Chapters 3-4)
  - Mindell, D.A. (2008). *Digital Apollo: Human and Machine in Spaceflight*. Cambridge, MA: MIT Press. (Selected Chapters TBD)
  - Grazer, B. (Producer) and Howard, R. (Director). (1995). *Apollo 13* [Motion picture]. United States: Universal Pictures.
  - Others TBD

  Optional Reading

  - Wiener, N. (1965). *Cybernetics: or Control and Communication in the Animal and the Machine*, 2nd ed. Cambridge, MA: MIT Press.

- **Week 3: Understanding and Formulating Systems Problems**
  Wednesday, September 17
  Guest Speakers: **Patrick Hester** (Old Dominion University, Engineering Management and Systems Engineering); **Chintan Vaishnav** (Massachusetts Institute of Technology, Sloan School of Management)

  Required Reading
  - Simon, H.A. (1999). *The Sciences of the Artificial*, 3rd ed. Cambridge, MA: MIT Press. (Chapters 1, 5-6)
  - de Weck, O.L., Roos, D., and Magee, C.L. (2011). *Engineering Systems: Meeting Human Needs in a Complex Technological World*. Cambridge, MA: MIT Press. (Chapters 6-8)
  - Others TBD

  Optional Reading
  - Gell-Mann, M. (1994). *The Quark and the Jaguar: Adventures in the Simple and the Complex*. New York, NY: Holt.
  - Mitchell, M. (2009). *Complexity: A Guided Tour*. Oxford, UK: Oxford.
  - Meadows, D.H., Randers, J., and Meadows, D.L. (2004). *Limits to Growth: The 30-Year Update*. White River Junction, VT: Chelsea Green.
  - Carson, R. (2002). *Silent Spring, Fortieth Anniversary Edition*. New York, NY: Mariner.

- **Week 4: Bottom-Up Systems Modeling: Agents, Emergence, and Networks**
  Wednesday, September 24
  Guest Speakers: **Babak Heydari** (Stevens Institute of Technology, School of Systems and Enterprises); **Mark Avnet** (Texas A&M University, Industrial and Systems Engineering)

  Required Reading
  - de Weck, O.L., Roos, D., and Magee, C.L. (2011). *Engineering Systems: Meeting Human Needs in a Complex Technological World*. Cambridge, MA: MIT Press. (Chapter 5)
  - Watts, D.J. (2004). *Six Degrees: The Science of a Connected Age*. New York, NY: Norton. (Selected Chapters TBD)
  - Avnet, M.S. and Weigel, A.L. (2010). "An Application of the Design Structure Matrix to Integrated Concurrent Engineering." *Acta Astronautica* 66: 937-949
  - Others TBD

  Optional Reading
  - Holland, J.H. (2012). *Signals and Boundaries: Building Blocks for Complex Adaptive Systems*. Cambridge, MA: MIT Press.
  - Watts, D.J. (2004). *Six Degrees: The Science of a Connected Age*. New York, NY: Norton.
  - Newman, M.E.J. (2010). *Networks: An Introduction*. Oxford, UK: Oxford.
  - Newman, M.E.J. (2003). "The Structure and Function of Complex Networks." *SIAM Review* 45: 167-256.
  - Eppinger, S. D. and Browning, T. R. (2012). *Design Structure Matrix Methods and Applications*. Cambridge, MA: MIT Press.

— Taleb, N.N. (2010). *The Black Swan: The Impact of the Highly Improbable*, 2nd ed. New York, NY: Random House.
— Surowiecki, J. (2005). *The Wisdom of Crowds*. New York, NY: Anchor.

- **Week 5: Uncertainty, Risk, and Safety in Socio-Technical Systems**
  Wednesday, October 1
  Guest Speakers: **Raktim Bhattacharya** (Texas A&M University, Aerospace Engineering); **Georgia-Ann Klutke** (Texas A&M University, Industrial and Systems Engineering)

  Required Reading
  — Bhattacharya, R. (2006). "Model & Platform Based Design of Embedded Systems." Texas A&M University, College Station, TX. Unpublished manuscript.
  — Leveson, N.G. (2011). *Engineering a Safer World: Systems Thinking Applied to Safety*. Cambridge, MA: MIT Press. (Chapters 2-3)

  Optional Reading
  — Taleb, N.N. (2014). *Antifragile: Things That Gain from Disorder*. New York, NY: Random House.
  — Sheffi, Y. (2005). *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*. Cambridge, MA: MIT Press.
  — Leveson, N.G. (2011). *Engineering a Safer World: Systems Thinking Applied to Safety*. Cambridge, MA: MIT Press.

- **Week 6: Dealing with Uncertainty: Flexibility and Real Options**
  Wednesday, October 8
  Guest Speakers: **Michel-Alexandre Cardin** (National University of Singapore, Industrial and Systems Engineering); **David Ford** (Texas A&M University, Civil Engineering)

  Required Reading
  — de Weck, O.L., Roos, D., and Magee, C.L. (2011). *Engineering Systems: Meeting Human Needs in a Complex Technological World*. Cambridge, MA: MIT Press. (Chapter 4)
  — Cardin, M.-A. (2014). "Enabling Flexibility in Engineering Systems: A Taxonomy of Procedures and a Design Framework." *Journal of Mechanical Design* 136: 011005(14).
  — de Neufville, R. and Scholtes, S. (2011). *Flexibility in Engineering Design*. Cambridge, MA: MIT Press. (Selected Chapters TBD)

  Optional Reading
  — de Neufville, R. and Scholtes, S. (2011). *Flexibility in Engineering Design*. Cambridge, MA: MIT Press.

- **Week 7: System Architecture and Modularity in Engineering Design**
  Wednesday, October 15
  Guest Speakers: **Zoe Szajnfarber** (The George Washington University, Engineering Management and Systems Engineering); **Christine Ehlig-Economides** (University of Houston, Petroleum Engineering)

Required Reading

— Schilling, M.A. (2000). "Toward a General Modular Systems Theory and Its Application to Interfirm Product Modularity." *Academy of Management Review* 25(2): 312-334.
— Ulrich, K. (1995). "The Role of Product Architecture in the Manufacturing Firm." *Research Policy* 24: 419-440.
— Fixson, S.K. and Park, J.-K. (2008). "The Power of Integrality: Linkages Between Product Architecture, Innovation, and Industry Structure." *Research Policy* 37: 1296-1316.

Optional Reading

— Baldwin, C.Y. and K.B. Clark (2000). *Design Rules: The Power of Modularity, Vol. 1*. Cambridge, MA: MIT Press.
— Maier, M.W. and Rechtin, E. (2009). *The Art of Systems Architecting*, 3rd ed. Boca Raton, FL: CRC Press.

- **Week 8: Complexity and Human Decision-Making**
  Wednesday, October 22
  Guest Speakers: **Erica Gralla** (The George Washington University, Engineering Management and Systems Engineering); **Richard Malak** (Texas A&M University, Mechanical Engineering)

  Required Reading

  — TBD

  Optional Reading

  — Kahneman, D. (2013). *Thinking, Fast and Slow*. New York, NY: Farrar, Straus and Giroux.
  — Klein, G.A. (1999). *Sources of Power: How People Make Decisions*. Cambridge, MA: MIT Press.
  — *Gigerenzer, G., Todd, P.M., and the ABC Research Group (1999). Simple Heuristics That Make Us Smart. New York, NY: Oxford University Press.*

- **Week 9: Lean Engineering**
  Wednesday, October 29
  Guest Speakers: **Daniel Roos** (Massachusetts Institute of Technology, Engineering Systems); **Priscilla McLeroy** (Texas A&M University, Petroleum Engineering)

  Required Reading

  — TBD

  Optional Reading

  — Womack, J.P., Jones, D.T., and Roos, D. (1990). *The Machine That Changed the World: The Story of Lean Production-- Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry*. New York, NY: Free Press.
  — Murman, E., Allen, T., Bozdogan, K., Cutcher-Gershenfeld, J., McManus, H., Nightingale, D., Rebentisch, E., Shields, T., Stahl, F., Walton, M., Warmkessel, J., Weiss, S., and Widnall, S. (2002). *Lean Enterprise Value: Insights from MIT's Lean Aerospace Inititative*. New York, NY: Palgrave.
  — Phillips, D.T. and Black, J.T. (2013). *Lean Engineering: The Future Has Arrived*. College Station, TX: Virtualbookworm.com.

- **Week 10: Healthcare Systems**
  Wednesday, November 5
  Guest Speakers: **Sarah Bonzo** (State University of New York at Oswego, School of Business); **Mark Lawley** (Texas A&M University, Industrial and Systems Engineering)

  Required Reading
  — TBD

  Optional Reading
  — TBD

- **Week 11: Final Team Project Meetings with Instructor (No Class Session)**
  Wednesday, November 12
  Guest Speakers: N/A

  Each student team should schedule a 30-minute meeting with the instructor to discuss their final project topic. A one-page project proposal will be due one week prior to each team's meeting.

- **Week 12: Energy Systems**
  Wednesday, November 19
  Guest Speakers: **Darryl Farber** (Pennsylvania State University, Science, Technology, and Society); **Pavel Tsvetkov** (Texas A&M University, Nuclear Engineering)

  Required Reading
  — TBD

  Optional Reading
  — TBD

- **Week 13: Final Report Preparation (No Class – Thanksgiving Holiday)**
  Wednesday, November 26
  Guest Speakers: N/A

  There will be no class meeting this week. Student teams should use the available time to prepare their final project report.

- **Week 14: Social and Organizational Systems**
  Wednesday, December 3
  Guest Speakers: **Bruce Keith** (United States Military Academy at West Point, Systems Engineering); **Jonathan Meer** (Texas A&M University, Economics)

  Required Reading
  — Simon, H.A. (1999). *The Sciences of the Artificial*, 3rd ed. Cambridge, MA: MIT Press. (Chapter 2)
  — Bastiat, M.F. (2006). *That Which Is Seen & That Which Is Not Seen: The Unintended Consequences of Government Spending*. West Valley City, UT: Waking Lion Press.

Optional Reading

- Levitt, S.D. and Dubner, S.J. (2006). *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything*. New York, NY: HarperCollins.
- Gneezy, U. and List, J.A. (2013). *The Why Axis: Hidden Motives and the Undiscovered Economics of Everyday Life*. New York, NY: PublicAffairs.
- Gladwell, M. (2002). *The Tipping Point: How Little Things Can Make a Big Difference*. New York, NY: Little, Brown and Company.
- Senge, P.M. (2006).*The Fifth Discipline: The Art & Practice of The Learning Organization*. New York, NY: Doubleday.
- Keller, S. and Price, C. (2011). *Beyond Performance: How Great Organizations Build Ultimate Competitive Advantage*. Hoboken, NJ: Wiley.

REFLECTION PAPERS

Students will be asked to submit a one- to two-page reflection paper about the assigned reading for each week by noon on the day of the corresponding class session. The format for the paper is open-ended, but it should focus on insights and key learnings from a synthesis of all of the week's readings taken together. Students might find it helpful to draw on prior research and work experience, other courses taken, and readings from earlier in the semester in developing their reflections. These papers will form the basis for discussion at the beginning of each class session. Every week, a different student will be asked to initiate discussion by presenting a brief summary of his/her reflection paper to the class.

PROJECT

Early in the semester, students will form teams of 3-4 based on common interests, research areas, and/or career fields. Each team will formulate a problem that applies the principles of complexity and socio-technical systems to a particular area of interest. The project should focus on some aspect of analyzing, modeling, and/or designing complex socio-technical systems. Each team will submit a paper of approximately 25 pages. Although there will not be a formal in-class presentation for the final project, students will be encouraged to draw on their project topics during in-class discussions throughout the semester.

GRADING

Weekly One-Page Reflection Papers and In-Class Discussion: 60%

Final Team Project on Analyzing/Modeling a Complex Socio-Technical System: 40%

Grading Scale:

90% - 100% A

80% - 89% B

70% - 79% C

60% - 69% D

<60% F

Important Note on Attendance: Although attendance will not be directly included in grading for the course, students' participation during in-class discussions will make up a significant portion of the grade. This does not mean that attendance will be formally taken or that merely "showing up" will improve a

student's grade. Each student will be evaluated based on depth of insight during discussion, willingness to participate, and the extent to which that student contributes to a valuable learning environment for the other students in the class. If you foresee an unavoidable absence, you are strongly encouraged to discuss it with the instructor in advance. Under certain circumstances, it may be possible for a student with a major conflict to find another way to contribute to the topic for the week. This is intended only when absolutely necessary, so all students should plan on attending every class session in its entirety.

STUDENTS WITH DISABILITIES

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact Disability Services (visit http://disability.tamu.edu, call 845-1637, or go to Cain Hall Room B118). If a student has the need for the special services provided by the University, please discuss this privately with the professor the first week of the course.

ACADEMIC INTEGRITY

The Aggie Honor Code states that "An Aggie does not lie, cheat, or steal or tolerate those who do." Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning and to follow the philosophy and rules of the Honor System. Ignorance of the rules does not exclude any member of the Texas A&M University community from the requirements or the processes of the Honor System. For additional information, please visit: www.tamu.edu/aggiehonor.

STUDENT RULES

The following web site contains specific information pertaining to student conduct and other important issues: http://student-rules.tamu.edu/.