

ENG-421

Fundamentals in systems engineering

Cursus	Sem.	Type
Electrical Engineering		Obl.
Systems Engineering minor	H	Opt.

Language of teaching	English
Credits	5
Session	Winter
Semester	Fall
Exam	During the semester
Workload	150h
Weeks	14
Hours	2 weekly
Courses	2 weekly
Number of positions	30

Remark

Not given in 2017-18

Summary

Introduction to systems engineering using the classical V-model. Topics include stakeholder analysis, requirements definition, concept selection, design definition and optimization, system integration and verification and validation. This class is part of the EPFL minor in Systems Engineering.

Content

General introduction to **systems engineering** using both the classical V-model and the new META approach. Topics include stakeholder analysis, requirements definition, system architecture and concept generation, trade-space exploration and concept selection, design definition and optimization, system integration and interface management, system safety, verification and validation, and commissioning and operations. Discusses the trade-offs between performance, lifecycle cost and system operability. Readings based on systems engineering standards and papers. Students apply the concepts of systems engineering to a cyber-electro-mechanical system, which is subsequently entered into a design competition.

Keywords

Systems Engineering, Stakeholder Analysis, Requirements, Concept Generation, Concept Selection, Design, Optimization, Verification, Validation, Operations, Lifecycle Properties

Learning Prerequisites**Required courses**

None.

Recommended courses

COM-502 Dynamical System Theory for Engineers

MICRO-550 Applied Machine Learning

MICRO-570 Advanced Machine Learning

CS-454 Convex Optimization and Applications

MATH-265 Introduction to Optimization and Operations Research

MGT-484 Applied Probability and Stochastic Processes

MATH-600 Optimization and Simulation

Domain-Specific Courses listed in the Minor in Systems Engineering at EPFL Guide depending on the student's particular interests.

Important concepts to start the course

Experience in real world engineering projects either in industry (e.g. through internships, prior positions etc...) or academic research involving engineered systems or artifacts.
Matlab and Simulink proficiency.

Learning Outcomes

By the end of the course, the student must be able to:

- Describe the most important Systems Engineering standards and best practices as well as newly emerging approaches
- Structure the key steps in the systems engineering process starting with stakeholder analysis and ending with transitioning systems to operations
- Analyze the important role of humans as beneficiaries, designers, operators and maintainers of aerospace and other systems
- Characterize the limitations of the way that current systems engineering is practiced in terms of dealing with complexity, lifecycle uncertainty and other factors
- Apply the fundamental methods and tools of systems engineering to a simple cyber-electro-mechanical system as a stepping stone to more complex and real world projects

Transversal skills

- Communicate effectively with professionals from other disciplines.
- Use both general and domain specific IT resources and tools
- Use a work methodology appropriate to the task.

Teaching methods

The class consists of four pedagogical elements that are interwoven to maximize the use of individual, group and class time. These elements are lectures, assignments, readings and the design competition.

- a) **Lectures:** the lectures will last 120 minutes and will present some of the key ideas and concepts for particular steps of the systems engineering process. The lectures will generally be held on Fridays and will roughly follow the “V” model of systems engineering. Lecture notes will be posted on stellar/moodle before the day of the lecture. During the lecture we will ask concept questions online which are used to both check conceptual understanding as well as for taking attendance.
- b) **Assignments:** Small teams of students will do the assignments. Each team will turn in one deliverable per assignment with all team members that contributed clearly identified. The assignments will be scheduled such that they are more or less synchronized with the class materials. The assignment teams will mix MIT and EPFL students.
- c) **Readings:** The readings in this class are of two types. First we will assign weekly readings from the NASA Systems Engineering Handbook and other standard SE texts to supplement the class materials. You can expect to read about 20-30 pages per week in this fashion. Second, we will have one or two journal or conference papers per week as assigned reading. These readings will be discussed during lecture.
- d) **Design Competition:** A design competition will be held at the end of the semester using VEX robotics kits. The design and operations of this system will be used as a context for the team assignments. Prizes will be awarded to the top three teams.

Expected student activities

This class will be taught jointly as ENG-421 at EPFL and 16.842 at MIT. All lectures will be streamed and recorded online using the webex system. Students are expected to log-in to webex individually and/or attend the class physically during lecture time.

Besides class time students will work jointly in mixed teams on their assignments.

Assessment methods

There will be the following four methods for assessing student learning:

1. Concept questions during lecture (with expected electronic submission of answers)

2. Team-based assignments (bi-weekly)
3. Peer Review 360 Feedback at the end of the semester
4. Final Exam

Supervision

Office hours	Yes
Assistants	Yes
Forum	No
Others	Office hours will be held online for 60 minutes each week. The instructor and TA will be available to answer any questions students may have about the theory and methods presented in class or the assignments. The timing of office hours is as follows: Fridays from 17h00-18h00 right after lecture.

Resources

Bibliography

- [1a] NASA Systems Engineering Handbook, NASA/SP-2007-6105, Rev 1, Dec 2007
- [1b] INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities, 4th Edition, ISBN: 978-1-118-99940-0, 304 pages, July 2015
- [1c] ISO/IEC/IEEE 15288:2015, Systems and software engineering -- System life cycle processes
- [2] Rebentisch E., Crawley E., Loureiro G., Dickmann J., Catanzaro S., "Using Stakeholder Value Analysis to Build Exploration Sustainability", AIAA-2005-2553, *1st Space Exploration Conference: Continuing the Voyage of Discovery*, Orlando, Florida, Jan. 30-1, 2005
- [3a] Hauser J.R., Clausing D., "The House of Quality", *Harvard Business Review*, 63-73, May-June 1988
- [3b] de Weck, O.L. and Jones M. B., "Isoperformance: Analysis and Design of Complex Systems with Desired Outcomes", *Systems Engineering*, 9 (1), 45-61, January 2006
- [4] Edward Crawley, Olivier de Weck, Steven Eppinger, Christopher Magee, Joel Moses, Warren Seering, Joel Schindall, David Wallace, Daniel Whitney, "The Influence of Architecture in Engineering Systems", Monograph, *1st Engineering Systems Symposium*, Cambridge, Massachusetts, March 29-31, 2004
- [5] Ross A.M., Hastings D., Warmkessel J., Diller N., "Multi-Attribute Tradespace Exploration as Front End for Effective Space System", *Journal of Spacecraft and Rockets*, 41 (1), 20-28, January–February 2004
- [6] Sobieszczanski-Sobieski J.,; Agte J.S., ; Sandusky R.R., "Bi-level Integrated System Synthesis", *AIAA Journal*, vol.38 no.1 (164-172), 2000
- [7] Tahan M., Ben-Asher J.Z., "Modeling and analysis of integration processes for engineering systems", *Systems Engineering*, Volume 8, Issue 1, Date: 2005, Pages: 62-77
- [8] Cummings, M.L., & Mitchell P.J., Predicting Controller Capacity in Remote Supervision of Multiple Unmanned Vehicles, *IEEE Systems, Man, and Cybernetics*, Part A Systems and Humans, (2008) 38(2), p. 451-460.
- [9] Leveson, N., "A New Accident Model for Engineering Safer Systems", *Safety Science*, Vol. 42, No. 4, April 2004
- [10] HBS Case: 9-603-083
Mission to Mars (A)
This case is set in spring 2000, several months after two successive, failed missions to the planet Mars. Students are asked to evaluate the reasons for these failures in the context of NASA's "Faster, Better, Cheaper" program, which was initiated in 1992. They are also faced with the task of reconstructing a program for the exploration of Mars that considers the many uncertainties--political, financial, outcome related, and scientific--that can impact the program. Includes color exhibits. Setting: California; Government & regulatory; 2000
- [11] Shishko, R., "Developing Analogy Cost Estimates for Space Missions", AIAA-2004-6012, *Space 2004 Conference and Exhibit*, San Diego, California, Sep. 28-30, 2004
- [12] de Weck, O.L., de Neufville R. and Chaize M., "Staged Deployment of Communications Satellite Constellations in Low Earth Orbit", *Journal of Aerospace Computing, Information, and Communication*, 1 (3), 119-136, March 2004

Ressources en bibliothèque

- [INCOSE Systems Engineering Handbook](#)
- [ISO/IEC/IEEE 15288:2015, Systems and software engineering -- System life cycle processes](#)
- [NASA Systems Engineering Handbook](#)

Notes/Handbook

The three major handbooks / standards used are listed above in the bibliography as [1a], [1b], and [1c] and need to be accessible to the students.

Prerequisite for

Minor in Systems Engineering