ENG-421

Fundamentals in systems engineering

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Cursus	Sem.	Type
Electrical Engineering		Opt.
Space technologies minor	H	Opt.
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	

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 Engineeri

Content

General introduction to **systems engineering** using both the classical V-model and the new Agile 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, Model Based System Engineering

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 Reserach
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 is desireable, but not required.

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 105 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 online 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.
c) **Readings**: The readings in this class or 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 or other means. 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

Most lectures will be given by video conference. All lectures will be streamed and recorded online using the zoom system. Teaching assistants will be present during the lectures.
This class can be used as preparation for the INCOSE ASEP (Associate Systems Engineering Professional) exam.

Assessment methods

There will be the following 5 methods for assessing student learning:
1. Group Assignments A1-A4 (total of 4): 50%
2. Group Assignment A5 (PDR presentation): 20%
3. Written Quiz: 10%
4. Personal Essay (about 5 pages in length): 10%
5. Active Class Participation: 10%

Supervision

Office hours	Yes
Assistants	Yes
Forum	No
Others	TA will be available to answer any questions students may have about the theory and methods presented in class or the assignments on an online forum.

Resources

Virtual desktop infrastructure (VDI)

No

Bibliography

[1a] NASA Systems Engineering Handbook, NASA/SP-2007-6105, Rev 2, 2016
[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

- Using Stakeholder Value Analysis to Build Exploration Sustainability
- ISO/IEC/IEEE 15288:2015, Systems and software engineering -- System life cycle processes
- NASA Systems Engineering Handbook

- INCOSE Systems Engineering Handbook

Notes/Handbook

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

Prerequisite for

Minor in Systems Engineering