

16-650 Systems Engineering and Management for Robotics
Course Syllabus
Fall 2024

Course Overview

This course consists of two parts: In the first part, we study the fundamentals of systems engineering as they apply to the development of robotic systems. Systems Engineering is a formal discipline that guides a product from conception and design all the way to production, marketing, servicing, and disposal. The higher the complexity of the system, the more its creators benefit from applying formal processes such as Systems Engineering to its development. Topics in Systems Engineering covered in this course include needs and objectives analysis, requirements elicitation and formalization, system architecture development, trade studies, verification and validation, structured methodologies, etc. In the second part of this course, we study key concepts of Project Management that must be performed along with Systems Engineering to achieve a successful project and product in a finite time. For the Project Management portion of the course, we cover topics such as work breakdown structures, scheduling, estimation, risk management, and agile methods. The students apply the concepts and methods they learn in this course to the MRSD Project Course, thus giving them the opportunity to put the theory into practice in a requirements-driven robotic system development.

Learning Objectives

The students in this course learn to:

- Conceptualize, design, and develop a robotic system following a formal Systems Engineering process
- Elicit user needs, develop system objectives, and formulate and analyze functional and non-functional requirements
- Architect technical system using systematic engineering design methods
- Conduct trade studies at system, subsystem, and component levels
- Formulate and conduct system validation via analysis, simulation, testing, and demonstration
- Formulate, detail, and carry out a project management plan
- Break-down and manage work that focuses on requirement-drive system development
- Implement, track, control, and rescope technical development in relation to performance objectives, schedule, and money constraints
- Identify, define, manage, and mitigate technical and programmatic risks
- Perform project management using classical and modern agile methods
- Concurrently execute Systems Engineering and Project Management to achieve a successful product and project

Pre-requisites

There are no pre-requisites for this course

Number of Units: 12

Instructor

Dr. Dimitrios (Dimi) Apostolopoulos
Principal Systems Scientist, RI
da1v@cs.cmu.edu
Office: NSH 3217
Phone: (412) 916-8807 (cell)

Teaching Assistants (TA)

Sivvani Muthusamy, smuthusa@andrew.cmu.edu
Jaskaran Singh Sodhi, jsodhi@andrew.cmu.edu

Class Time & Place

Tuesdays and Thursdays, 11:00AM-12:20PM, GHC 4307

Office Hours

Flexible. Available to meet upon request as needed.

Course Materials

No textbook required

Students should take detailed class notes

The syllabus, lectures, instructions, and assignments will be available on Canvas

Useful References

- International Council on Systems Engineering. Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. C. Haskins (ed.), version 3.2.1, January 2011
- NASA Systems Engineering Handbook: <https://www.nasa.gov/connect/ebooks/nasa-systems-engineering-handbook>
- "Systems Engineering and Analysis," Benjamin Blanchard, Wolter Fabrycky, 2011
- "Systems Engineering Management," Benjamin Blanchard, John Blyler, John Wiley & Sons, 2016

Coursework Requirements

This course requires students to report on the formulation of their team and project selection, perform technical assignments, present progress on Systems Engineering and Project Management aspects of their MRSD system, and present the Conceptual Design of their MRSD system, and deliver a relevant report at the end of the semester. Students will take two in-class tests, one on Systems Engineering topics and the other on Project Management Topics.

Assignments & Grading

The following table summarizes the various course assignments, assignment id, method of delivery, due date, and value in relation to the overall grade.

Detailed descriptions of the assignments and associated requirements for each can be found in the Assignments Module of the course on Canvas.

Systems Engineering and Management for Robotics: Due Dates of Assignments, Tests, and Grading 16-650 Fall 2024				
Due Date	Assignment #	What is Due	Method	% of Grade
9/13/24	PRJ01	CAD Familiarization Part 1	Individual submission, on Canvas	2
9/20/24	SYSPM01	Teaming and Project Selection	Teams email Instructors	0
9/24/24	PRJ02	CAD Familiarization Part 2	Individual submission, on Canvas	3
10/1/24	PRJ03	Microcontroller Familiarization	Individual submission, on Canvas	8
10/4/24	PRJ04	Tiny Gadget PCB	Individual submission, on Canvas	7
10/10/24	T01	Test on Systems Engineering Topics	In class, closed notes	10
10/29/24 (*) 10/31/24 (*)	SYSPM02	Project Progress on Systems Engineering	Team presentation, in class (Location TBD)	15
11/14/24	T02	Test on Project Management Topics	In class, closed notes	10
11/25/24	PRJ05	MRSD Website	Teams email Instructors	0
12/3/24 (*) 12/5/24 (*)	SYSPM03	Conceptual Design Review Presentation	Team presentation, in class (Location TBD)	15
12/12/24	SYSPM04	Conceptual Design Report	Document, team submission, on Canvas	20
				90
(*) These presentations will be held during inserted evening meetings. Block-off 6:00-8:30 for the evenings of October 29 and October 31 for assignment SYSPM02, and December 3 and December 5 for assignment SYSPM03. Location TBD.				

Assignments and tests account for 90% of the final grade. The remaining 10% is based on class attendance and participation in meetings and project reviews.

Policy on Late Assignments

Assignments must be submitted on time. For each day after the due date an assignment is submitted, 5% will be deducted from the grade.

Recording of Class Sessions

No recording is allowed without the permission of the instructor.

Tests

Test on Systems Engineering Topics

Objective: Test broad understanding of Systems Engineering concepts and methods presented and discussed in class. The test is structured as follows:

- In-class
- Closed note
- No laptops, no phones
- 4-6 questions, questions designed to be answered in about 60 minutes

How to prepare for the test:

- Study class notes
- Review your personal notes
- Test yourself without looking at any notes
- Discuss with classmates to further build your understanding of the material
- Email me questions; I will answer them ASAP and post answers for all students to see

What you should study and understand:

- Systems, system hierarchy, significance of top-down representation of a system
- The V Model of Systems Engineering
- Lifecycle considerations
- Phases in Systems Engineering: what they are, what they entail
- The Concept Development Phase: what it is, what it entails
- The Objectives Tree method: what it is, significance
- Types of requirements: what they are, significance, attributes of good requirements, examples
- Methods to elicit requirements
- Use Cases: what they are, how to develop them, significance
- Functional architecture: what it is, how to develop it, significance
- Cyberphysical architecture: what it is, how to develop it, significance
- Morphological Charts: what are they, how to synthesize concepts
- Trade studies and the Weighted Objectives Method: what they are, how to perform

Sample Questions:

- What is the difference between a functional and non-functional requirement? Give examples.
- What types of activities should take place during Needs Analysis and why?
- How can Use Cases be used to identify requirements?
- Discuss a system-level trade study that is relevant to your MRSD project.

Test on Project Management Topics

Objective: Test broad understanding of Project Management concepts and methods presented and discussed in class. The test is structured as follows:

In-class

Closed note

No laptops, no phones

4-6 questions, questions designed to be answered in approximately 60 minutes

How to prepare for the test:

- Study class notes
- Review your personal notes
- Test yourself without looking at any notes
- Discuss with classmates to further build your understanding of the material
- Email me questions; I will answer them ASAP and post responses to the whole class

What you should study and understand:

- Life cycle of a project; trends and considerations
- Phases in Project Management
- Elements of a Project Management Plan
- Types of Work Breakdown Structures (WBS)
- How to construct a Work Breakdown Structure
- Create a schedule from the WBS (focus on Gantt)
- How to set up project milestones
- Basic estimation through empirical methods and critical path
- Critical dependencies in Risk Management
- Hierarchical approach to Risk Management
- The Likelihood/Consequence Matrix
- How to apply Project Management concepts and methods to your MRSD project
- Connections between Systems Engineering and Project Management

Sample Questions:

- What is the Work Breakdown Structure? Discuss 2 different types of WBS.
- What types of risks are there? How can someone analyze a risk?
- Discuss major considerations regarding the schedule of your MRSD project.

Schedule of Classes

Systems Engineering and Management for Robotics: Schedule of Classes				
16-650 Fall 2024				
Tuesdays & Thursdays 11:00-12:20, GHC 4307				
Date	Day	Class #	Topic	Presenter
27-Aug	T	1	Course & Project Overview	Apostolopoulos
29-Aug	R	2	Systems (1)	Apostolopoulos
3-Sep	T	3	Systems (2)	Apostolopoulos
5-Sep	R	4	Systems Engineering (1)	Apostolopoulos
10-Sep	T	5	Systems Engineering (2) Focus on Concept Development	Apostolopoulos
12-Sep	R	6	Requirements (1)	Apostolopoulos
17-Sep	T	7	Requirements (2)	Apostolopoulos
19-Sep	R	8	Architectures (1)	Apostolopoulos
24-Sep	T	9	Architectures (2)	Apostolopoulos
26-Sep	R	10	Trade Studies	Apostolopoulos
1-Oct	T	11	Verification & Validation	Apostolopoulos
3-Oct	R	12	<i>Case studies and practice on projects</i>	Apostolopoulos
8-Oct	T	13	<i>Case studies and practice on projects</i>	Apostolopoulos
10-Oct	R	14	Test on Systems Engineering Topics	In Class
22-Oct	T	15	Project Management: Introduction and Plan	Apostolopoulos
24-Oct	R	16	Managing Scope and Work (1)	Apostolopoulos
29-Oct	T	17	Managing Scope and Work (2)	Apostolopoulos
31-Oct	R	18	Managing Time and Schedule (1)	Apostolopoulos
7-Nov	R	19	Managing Time and Schedule (2)	Apostolopoulos
12-Nov	T	20	Managing Risk	Apostolopoulos
14-Nov	R	21	Test on Project Management Topics	In Class
19-Nov	T	22	Agile Management (1)	Lachell
21-Nov	R	23	Agile Management (2)	Lachell
26-Nov	T	24	<i>Case studies and practice on projects</i>	Apostolopoulos
3-Dec	T	25	<i>Case studies and practice on projects</i>	Apostolopoulos
5-Dec	R	26	Course Summary & Preview of Spring Semester	Apostolopoulos

Student Wellness

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at <http://www.cmu.edu/counseling/>. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

CaPS: 412-268-2922

Re:solve Crisis Network: 888-796-8226

If the situation is life-threatening, call the police:

On campus: CMU Police: 412-268-2323

Off campus: 911

If you have questions about this or your coursework, please let the course instructors know.

Student Academic Success Center (SASC)

SASC focuses on creating spaces for students to engage in their coursework and approach learning through a variety of group and individual tutoring options. We offer many opportunities for students to deepen their understanding of who they are as learners, communicators, and scholars. Our [workshops](#) are free to the CMU community and meet the needs of all disciplines and levels of study. SASC programs to support student learning include the following (program titles link to webpages):

- [Academic Coaching](#)--This program provides holistic, one-on-one peer support and group workshops to help undergraduate and graduate students implement habits for success. Academic Coaching assists students with time management, productive learning and study habits, organization, stress management, and other skills. Request an initial consultation [here](#).
- [Peer Tutoring](#)--Peer Tutoring is offered in two formats for students seeking support related to their coursework. Drop-In tutoring targets our highest demand courses through regularly scheduled open tutoring sessions during the fall and spring semesters. Tutoring by appointment consists of ongoing individualized and small group sessions. You can utilize tutoring to discuss course related content, clarify and ask questions, and work through practice problems. Visit the [webpage](#) to see courses currently being supported by Peer Tutoring.
- [Communication Support](#)--Communication Support offers free one-on-one communication consulting as well as group workshops to support strong written, oral, and visual communication in texts including IMRaD and thesis-driven essays, data-driven reports, oral presentations, posters and visual design, advanced research, application materials, grant proposals, business and public policy documents, data visualisation, and team projects. Appointments are available to undergraduate and graduate students from any discipline at CMU. Schedule an [appointment](#) on our website (in-person, zoom synchronous, or recorded video), attend a [workshop](#), or consult [handouts or videos](#) to strengthen communication skills.
- [Language and Cross-Cultural Support](#)--This program supports students seeking help with language and cross-cultural skills for academic and professional success through individual and group sessions.

Students can get assistance with writing academic emails, learning expectations and strategies for clear academic writing, pronunciation, grammar, fluency, and more. [Make an appointment](#) with a Language Development Specialist to get individualized coaching.

- [Supplemental Instruction](#) (SI)--This program offers a non-remedial approach to learning in historically difficult courses at CMU. It utilizes a peer-led collaborative group study approach to help students succeed and is facilitated by an SI leader, a CMU student who has successfully completed the course. SI offers a way to connect with other students studying the same course, a guaranteed weekly study time that reinforces learning and retention of information, as well as a place to learn and integrate study tools and exam techniques specific to a course. Visit the website to see courses with SI available [here](#).

Accommodations for Students with Disabilities

If you have a disability and have an accommodations letter from the Disability Resources office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, I encourage you to contact them at access@andrew.cmu.edu.

Academic Integrity Policies

CMU Academic Integrity Policy (<http://www.cmu.edu/academic-integrity/index.html>):

In the midst of self-exploration, the high demands of a challenging academic environment can create situations where some students have difficulty exercising good judgment. Academic challenges can provide many opportunities for high standards to evolve if students actively reflect on these challenges and if the community supports discussions to aid in this process. It is the responsibility of the entire community to establish and maintain the integrity of our university.

This site is offered as a comprehensive and accessible resource compiling and organizing the multitude of information pertaining to academic integrity that is available from across the university. These pages include practical information concerning policies, protocols and best practices as well as articulations of the institutional values from which the policies and protocols grew. The Carnegie Mellon Code, while not formally an honor code, serves as the foundation of these values and frames the expectations of our community with regard to personal integrity.

The Carnegie Mellon Code

Students at Carnegie Mellon, because they are members of an academic community dedicated to the achievement of excellence, are expected to meet the highest standards of personal, ethical and moral conduct possible.

These standards require personal integrity, a commitment to honesty without compromise, as well as truth without equivocation and a willingness to place the good of the community above the good of the self. Obligations once undertaken must be met, commitments kept.

As members of the Carnegie Mellon community, individuals are expected to uphold the standards of the community in addition to holding others accountable for said standards. It is rare that the life of a student in an academic community can be so private that it will not affect the community as a whole or that the above standards do not apply.

The discovery, advancement and communication of knowledge are not possible without a commitment to these standards. Creativity cannot exist without acknowledgment of the creativity of others. New knowledge cannot be developed without credit for prior knowledge. Without the ability to trust that these principles will be observed, an academic community cannot exist.

The commitment of its faculty, staff and students to these standards contributes to the high respect in which the Carnegie Mellon degree is held. Students must not destroy that respect by their failure to meet these standards. Students who cannot meet them should voluntarily withdraw from the university.

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Cheating

(<http://www.cmu.edu/academic-integrity/cheating/index.html>) states the following:

According to the University Policy on Academic Integrity, cheating "occurs when a student avails her/himself of an unfair or disallowed advantage which includes but is not limited to:

- Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
- Use of an alternate, stand-in or proxy during an examination.
- Copying from the examination or work of another person or source.
- Submission or use of falsified data.
- Using false statements to obtain additional time or other accommodation.
- Falsification of academic credentials."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Plagiarism

(<http://www.cmu.edu/academic-integrity/plagiarism/index.html>) states the following:

According to the University Policy on Academic Integrity, plagiarism "is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

- Text, either written or spoken, quoted directly or paraphrased.
- Graphic elements.
- Passages of music, existing either as sound or as notation.
- Mathematical proofs.
- Scientific data.
- Concepts or material derived from the work, published or unpublished, of another person."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Unauthorized Assistance

(<http://www.cmu.edu/academic-integrity/collaboration/index.html>) states the following:

According to the University Policy on Academic Integrity, unauthorized assistance "refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

- Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
- Submission of work completed or edited in whole or in part by another person.
- Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
- Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
- Use of unauthorized devices.
- Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Research Misconduct

(<http://www.cmu.edu/academic-integrity/research/index.html>) states the following:

According to the University Policy For Handling Alleged Misconduct In Research, "Carnegie Mellon University is responsible for the integrity of research conducted at the university. As a community of scholars, in which truth and integrity are fundamental, the university must establish procedures for the investigation of allegations of misconduct of research with due care to protect the rights of those accused, those making the allegations, and the university. Furthermore, federal regulations require the university to have explicit procedures for addressing incidents in which there are allegations of misconduct in research."

The policy goes on to note that "misconduct means:

- fabrication, falsification, plagiarism, or other serious deviation from accepted practices in proposing, carrying out, or reporting results from research;
- material failure to comply with Federal requirements for the protection of researchers, human subjects, or the public or for ensuring the welfare of laboratory animals; or
- failure to meet other material legal requirements governing research."

“To be deemed misconduct for the purposes of this policy, a ‘material failure to comply with Federal requirements’ or a ‘failure to meet other material legal requirements’ must be intentional or grossly negligent.”

To become familiar with the expectations around the responsible conduct of research, please review the guidelines for Research Ethics published by the Office of Research Integrity and Compliance.

This policy applies, in all respects, to this course.