Engineering Faculty Document No. 2-17
April 5, 2016

To: The Faculty of the College of Engineering
From: School of Industrial Engineering, School of Aeronautics and Astronautics
Subject: New Graduate Course: IE 52100/AAE 58100

The faculty of the School of Industrial Engineering and School of Aeronautics and Astronautics have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Course No: **IE 52100/AAE 58100 Tools and Methodologies for Designing System**
Sem. 1. Class 3, Cr. 3.
Prerequisites: Graduate Standing in Engineering or consent of instructor.

Description: Introduction to modeling tools and methods for designing engineered systems. Topics include: defining the design problem; defining and validating stakeholders' and system requirements; discrete mathematics for system modeling; defining and modeling system operational scenarios; the system development life cycle; defining and modeling functional, physical, and allocated architectures; evaluating and modeling the tradeoffs between alternative architectures; and defining the system qualification process.

Reasons: This class has been offered three times as IE/AAE 59000, with enrollments of 19, 79 (including 56 distance) and 10 students. Planned IE and EPE Concentrations in Systems Engineering have this class as a primary required course. Generally, the fundamentals of systems thinking are not taught alongside the processes used in the practice of systems engineering. There is a need to equip upper-level undergraduate and master's students with skills to become practitioners and to have an understanding of the scientific basis for systems practice. Also, there is a need to equip doctoral students with an understanding of the practice of systems that motivates research in the science of systems and systems thinking. No other course of this type exists at Purdue.

Abhijit J. Deshmukh, Professor and Head
School of Industrial Engineering

Tom Shih, Professor and Head
School of Aeronautics and Astronautics

Approved for the faculty of the Schools of Engineering by the Engineering Curriculum Committee

ECC Minutes #3 Date 10-18-16
Chairman ECC

Office of the Registrar
FORM 40G REV. 4/13

PURDUE UNIVERSITY
REQUEST FOR ADDITION, EXPIRATION, OR REVISION OF A GRADUATE COURSE (50000-60000 LEVEL)

PRINT

DEPARTMENT: Industrial Engineering
EFFECTIVE SESSION: Fall 2016

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- ☑ 1. New course with supporting documents (complete proposal form)
- ☐ 2. Add existing course offered at another campus
- ☐ 3. Expiration of a course
- ☐ 4. Change in course number
- ☐ 5. Change in course title
- ☐ 6. Change in course credit/type
- ☐ 7. Change in course attributes
- ☐ 8. Change in instructional hours
- ☐ 9. Change in course description
- ☐ 10. Change in course requisites
- ☐ 11. Change in semesters offered
- ☐ 12. Transfer from one department to another

PROPOSED:
Subject Abbreviation: IE
Course Number: 52100
Long Title: Tools and Methodologies for Designing Systems
Short Title: Tools Method for System Design
Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

EXISTING:
Subject Abbreviation:
Course Number:

TERMS OFFERED
Check All That Apply:
☑ Fall ☑ Spring ☑ Summer

CAMPUS(ES) INVOLVED
- ☐ Calumet
- ☑ Cont Ed
- ☐ Ft. Wayne
- ☐ Indianapolis
- ☐ N. Central
- ☐ Tech Statewide
- ☑ W. Lafayette

CREDIT TYPE
1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range:
   Minimum Cr. Hrs
   (Check One) To ☐ Or ☐
   Maximum Cr. Hrs
3. Equivalent Credit: Yes ☐ No ☐
4. Thesis Credit: Yes ☐ No ☑

COURSE ATTRIBUTES: Check All That Apply
1. Pass/Not Pass Only ☐
2. Satisfactory/Unsatisfactory Only ☐
3. Repeatable ☐
   Maximum Repeatable Credit: ☐
4. Credit by Examination ☐
5. Fees ☐ Coop ☐ Lab ☐ Rate Request ☐
Include comment to explain fee
6. Registration Approval Type
   Department ☑ Instructor ☐
7. Variable Title ☐
8. Honors ☐
9. Full Time Privilege ☐
10. Off Campus Experience ☐

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	50	3	16	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses
AAE 58100

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):

See supporting documents

*COURSE LEARNING OUTCOMES:

See supporting documents

Calumet Department Head — Date	Calumet School Dean — Date	Calumet Director of Graduate Studies — Date
Fort Wayne Department Head — Date	Fort Wayne School Dean — Date	Fort Wayne Director of Graduate Studies — Date
Indianapolis Department Head — Date	Indianapolis School Dean — Date	IUPUI Associate Dean for Graduate Education — Date
North Central Department Head — Date	North Central School Dean — Date	North Central Director of Graduate Studies — Date
[signature] 4/29/16 West Lafayette Department Head — Date	[signature] 10/21/16 West Lafayette College/School Dean — Date	Date Approved by Graduate Council — Date
Graduate Area Committee Convener — Date	Graduate Dean — Date	Graduate Council Secretary — Date
		West Lafayette Registrar — Date

OFFICE OF THE REGISTRAR

(Grad Form 40G [Excel format] - Does not include the Graduate Council's required supporting document. See pdf version of Form 40G)

Office of the Registrar
FORM 40G REV. 4/13

PURDUE UNIVERSITY
REQUEST FOR ADDITION, EXPIRATION,
OR REVISION OF A GRADUATE COURSE
(50000-60000 LEVEL)

PRINT

DEPARTMENT: Aeronautics and Astronautics   EFFECTIVE SESSION: Fall 2016

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- [x] 1. New course with supporting documents (complete proposal form)
- [ ] 2. Add existing course offered at another campus
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- [ ] 4. Change in course number
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- [ ] 6. Change in course credit/type
- [ ] 7. Change in course attributes
- [ ] 8. Change in instructional hours
- [ ] 9. Change in course description
- [ ] 10. Change in course requisites
- [ ] 11. Change in semesters offered
- [ ] 12. Transfer from one department to another

PROPOSED:
Subject Abbreviation: AAE
Course Number: 58100
Long Title: Tools and Methodologies for Designing Systems
Short Title: Tools Method for System Design
Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

EXISTING:
Subject Abbreviation:
Course Number:

TERMS OFFERED
Check All That Apply:
[x] Fall [x] Spring [x] Summer

CAMPUS(ES) INVOLVED
[ ] Calumet [ ] N. Central
[x] Cont Ed [ ] Tech Statewide
[ ] Ft. Wayne [x] W. Lafayette
[ ] Indianapolis

CREDIT TYPE
1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range:
Minimum Cr. Hrs
(Check One) To [ ] Or [ ]
Maximum Cr. Hrs
3. Equivalent Credit: Yes [ ] No [ ]
4. Thesis Credit: Yes [ ] No [x]

COURSE ATTRIBUTES: Check All That Apply
1. Pass/Not Pass Only [ ]
2. Satisfactory/Unsatisfactory Only [ ]
3. Repeatable [ ]
Maximum Repeatable Credit: [ ]
4. Credit by Examination [ ]
5. Fees [ ] Coop [ ] Lab [ ] Rate Request [ ]
Include comment to explain fee
6. Registration Approval Type
Department [x] Instructor [ ]
7. Variable Title [ ]
8. Honors [ ]
9. Full Time Privilege [ ]
10. Off Campus Experience [ ]

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	50	3	16	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses
IE 52100

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):

See supporting documents

*COURSE LEARNING OUTCOMES:

See supporting documents

Calumet Department Head — Date	Calumet School Dean — Date	Calumet Director of Graduate Studies — Date
Fort Wayne Department Head — Date	Fort Wayne School Dean — Date	Fort Wayne Director of Graduate Studies — Date
Indianapolis Department Head — Date	Indianapolis School Dean — Date	IUPUI Associate Dean for Graduate Education — Date
North Central Department Head — Date	North Central School Dean — Date	North Central Director of Graduate Studies — Date
[signature] 4/5/16 West Lafayette Department Head — Date	[signature] 10/2/16 West Lafayette College/School Dean — Date	Date Approved by Graduate Council — Date
Graduate Area Committee Convener — Date	Graduate Dean — Date	Graduate Council Secretary — Date
		West Lafayette Registrar — Date

OFFICE OF THE REGISTRAR
(Grad Form 40G [Excel format] - Does not include the Graduate Council's required supporting document. See pdf version of Form 40G)

(Supporting Materials from Form 40-G)

A. Justification for the Course:

- Justification of Need

Generally, the fundamentals of systems thinking are not taught alongside the processes used in the practice of systems engineering. There is a need to equip upper-level undergraduate and master's students with skills to become practitioners and to have an understanding of the scientific basis for systems practice. Also, there is a need to equip doctoral students with an understanding of the practice of systems that motivates research in the science of systems and systems thinking.

- Justification of Level

A number of major corporations (for example, Boeing, General Electric, and General Motors) and government agencies (for example, NASA) are developing systems programs for executive trainees and senior technical leaders; nearly all of those programs expect that the systems engineering expertise is built on top of a fundamental engineering emphasis within a more traditional engineering discipline. Thus, it is expected that the overwhelming majority of students in the class will be at the graduate level. This expectation is played out in the three experimental offerings of the course. Undergraduates in the course had exactly the same expectations and requirements as their graduate student colleagues.

	Spring 2015 System Tools & Methodologies					
	Academic Unit	Bachelors	Masters	Masters (EPE)	Doctoral	Totals
COE	AAE	6	5	0	2	13
	IE	1	1	0	1	3
	IDE	0	0	0	0	0
Other	POLYTECH	0	1	0	0	1
	MGMT	2	0	0	0	2
	Totals	9	7	0	3	19

	Fall 2015 System Tools & Methodologies					
	Academic Unit	Bachelors	Masters	Masters (EPE)	Doctoral	Totals
COE	AAE	0	4	4	1	9
	IE	5	12	6	0	23
	IDE	0	0	46	0	46
Other	POLYTECH	0	0	0	0	0
	MGMT	1	0	0	0	1
	Totals	6	16	56	1	79

	Spring 2016 System Tools & Methodologies					
	Academic Unit	Bachelors	Masters	Masters (EPE)	Doctoral	Totals
COE	AAE	2	2	0	0	4
	IE	2	0	0	2	4
	IDE	0	0	0	0	0
Other	POLYTECH	0	1	0	1	2
	MGMT	0	0	0	0	0
	Totals	4	3	0	3	10

- Anticipated enrollment
  - Undergraduate 5-10
  - Graduate 30-100

B. Learning Outcomes and Method of Evaluation or Assessment:

- Objectives and Student Learning Outcomes

The purpose of the course is to achieve the following objectives:

1. establish patterns of systems thinking,
2. introduce systems engineering processes and methods,
3. introduce theory for model-based systems engineering, and
4. provide practice in using model-based systems engineering tools.

There are 15 learning outcomes that are mapped to the course objectives in parentheses as follows:

1. apply the discrete mathematics concepts of set theory, relations and functions, and graph theory to characterize and analyze the functional and structural aspects of models for designing engineered systems (1, 3)
2. critique different approaches for system development life cycles and for systems engineering processes (1, 2)
3. define an engineered system's context (1, 4)
4. define and critique a functional model of a system development life cycle using a model-based systems engineering tool (1, 2, 4)
5. define and critique models of the functional architectures of an engineered system using a model-based systems engineering tool (1, 2, 4)
6. define a system's stakeholders and define formal system I/O requirements (1, 2, 3)
7. audit a set of formal system I/O requirements for completeness (1, 2, 4)
8. define models of the physical architecture of an engineered system using a model-based systems engineering tool (1, 2, 4)
9. apply an option creation technique to generate alternative physical architectures (1, 2)

10. define an allocated architecture of an engineered system using a model-based systems engineering tool (2, 4)
11. define the relationship of stakeholders' requirements to design trade-off objectives (1, 2)
12. define models of the interfaces of an engineered system using a model-based systems engineering tool (1, 2, 4)
13. critique a functional model of early validation using a model-based systems engineering tool (1, 2, 4)
14. understand alternative graphical modeling approaches for data modeling, process modeling, and behavior modeling (1, 2)
15. define and model uncertainty, value, and risk preference for evaluating design tradeoffs between alternative system architectures (1, 2, 3, 4)

- Methods of Evaluation

The learning outcomes are assessed using a sequence of homework assignments that are assigned as covered during the lecture. Homework is due prior to each class session beginning with the class session at the end of the second week of class and concluding with the final class session. A detailed example that lists homework assignments and their mapping to learning outcomes for the Spring 2016 offering is as follows:

Assignment	Exercise	Topic	Learning Outcomes
0	0.1	Installing CORE and GeNIe	4, 5, 8, 10, 12, 13, 15
1	1.1	What is a System?	2
2	1.2	Life Cycle Processes and Systems Engineering Processes	2
3	1.3	Comparing Activities to Phases	2
4	2.1	External Systems and Context	3
5	2.2	Entity-Relationship Diagram	1, 2
6	2.3	CORE: Systems Engineering Tool (Part 1)	4, 5, 8, 10, 12, 13
7	2.4	CORE: Systems Engineering Tool (Part 2)	4, 5, 8, 10, 12, 13
8	3.1	CORE: Use Case Diagram	6
8	3.2	Sequence Diagram Messages	6
9	3.3	CORE: IDEF0 Modeling (Part 1)	4
10	3.4	CORE: IDEF0 Modeling (Part 2)	4
11	3.5	CORE: Behavioral Modeling	4, 14
11	4.1	Describing Members of a Set	1
12	4.2	Set Operations	1
12	4.3	Partitions of a Set	1
12	4.4	Power Sets	1
13	4.5	Unary Relations	1
14	4.6	Binary Relations	1
15	4.7	Composition of Functions	1
15	5.1	Graphs and Digraphs	1
16	5.2	Functional Hierarchy Digraph	1
16	5.3	Digraphs	1
17	6.1	IDEF0 for Perform Design Activities	4

Assignment	Exercise	Topic	Learning Outcomes
18	6.2	Stakeholders	6
18	6.3	Requirements Hierarchy	6
19	6.4	IDEF0 for Define System-level Design Problem	4
20	6.5	Sequence Diagrams (Part 1)	5
21	6.6	Sequence Diagrams (Part 2)	5
22	6.7	Sequence Diagrams Using EFFBD	5, 14
23	6.8	Elevator External Systems Diagram	3, 14
24	6.9	Formal Input / Output Requirements	6
26	7.2	Hatley-Pirbhai Template Applied to Elevator Functions	5
27	7.3	Scenario Tracing	7
28	7.4	Tracing Requirements and External Interfaces	7
29	8.1	Generic Physical Architecture for Elevator	8
29	8.2	Option Creation Techniques	9
29	8.3	Block Diagrams of Physical Architecture	8
30	8.4	Levels of Communication Network Centralization	1
31	8.5	Levels of Communication Network Distribution	1
31	9.1	Tracing Requirements to Value Trade-off Objectives	11
32	9.2	Allocating Functions to Components	10
32	9.3	Functional Decomposition for Bicycle Suspension System	5, 14
33	9.4	Morphological Box for Bicycle Suspension System	9
34	13.1	Relevance Diagrams Using GeNIe	15
34	13.2	Problem 13.2 Using GeNIe	15
34	13.3	Disk Forging Decision Problem Using GeNIe	15
35	13.4	Problem 13.6 Using GeNIe	15
35	13.5	Perfect Information Using GeNIe	15
35	13.6	Perfect Information for Problem 13.6	15
36	13.7	Imperfect Information Using GeNIe	15
36	13.8	Risk Averse Decision Maker	15
36	13.9	Perfect Information for Risk Averse Decision Maker	15
37	10.1	Defining Interfaces Using CORE	12
38	11.1	Early Validation	13
38	11.2	Qualification and Detecting Failures	15

- Grading Criteria

The final grades are determined using an average of the homework scores.

Grading Criteria	**Weight Toward Final Grade**
Homework	100%

- Methods of Instruction

Lectures are organized to present the salient information on the tools and methodologies from the textbook and from the literature outside of the textbook. They also provide live examples of solving problems using analytic approaches and using model-based systems engineering tools.

Hours per Week	Method of Instruction	Contribution to Outcomes
3	Lecture	16 of 16 weeks

C. Prerequisite(s):

- Graduate Standing or Permission of Instructor
- Students are assumed to have completed some college-level mathematics, as they will be asked to solve problems related to sets, graphs, and probability and decision trees.
- Ability to install and operate software on a Windows operating system is necessary to use the modeling tools

D. Course Instructor(s):

Name	Rank	Dept.	Graduate Faculty or expected date
C. Robert Kenley	Associate Professor of Engineering Practice	IE	Yes
Staff	Professor	IE / AAE	Yes

E. Course Outline:

This topics and relative amount of time devoted to each topic is as follows:

Topic	Relative Amount of Time
Introduction to Systems Engineering	5%
Overview of the Systems Engineering Design Process	6%
Modeling and SysML Modeling	12%
Discrete Mathematics: Sets, Relations, and Functions	12%

Graphs and Directed Graphs (Digraphs)	6%
Requirements and Defining the Design Problem	21%
Functional Architecture Development	9%
Physical Architecture Development	3%
Allocated Architecture Development	6%
Decision Analysis for Design Trades	9%
Interface Design	3%
Integration and Qualification	3%
Graphical Modeling Techniques	5%
	100%

F. Reading List (including course text):

- Primary Reading List
    - Buede, Dennis M. 2009. *The Engineering Design of Systems: Models and Methods, Second Edition.* Hoboken, NJ: Wiley.

A detailed example that lists homework assignments and their mapping to assigned reading for the Spring 2016 offering is as follows:

Assignment	Exercise	Topic	Supporting Readings
0	0.1	Installing CORE and GeNIe	
1	1.1	What is a System?	Buede: Preface, Sections 1.1 and 1.9
2	1.2	Life Cycle Processes and Systems Engineering Processes	Buede: Sections 1.2 to 1.6
3	1.3	Comparing Activities to Phases	Buede: Sections 1.7, 1.8, 1.10, and 1.11
4	2.1	External Systems and Context	Buede: Sections 2.1 and 2.2
5	2.2	Entity-Relationship Diagram	Buede: Section 2.3
6	2.3	CORE: Systems Engineering Tool (Part 1)	Buede: Sections 2.4 to 2.6, 3.7 to 3.9
7	2.4	CORE: Systems Engineering Tool (Part 2)	Buede: Sections 2.4 to 2.6, 3.7 to 3.9
8	3.1	CORE: Use Case Diagram	Buede: Sections 3.1 to 3.4
8	3.2	Sequence Diagram Messages	Buede: Sections 3.1 to 3.4
9	3.3	CORE: IDEF0 Modeling (Part 1)	Buede: Section 3.5
10	3.4	CORE: IDEF0 Modeling (Part 2)	Buede: Section 3.5
11	3.5	CORE: Behavioral Modeling	Buede: Sections 3.6 and 3.10
11	4.1	Describing Members of a Set	Buede: Sections 4.1 to 4.2.3

Assignment	Exercise	Topic	Supporting Readings
12	4.2	Set Operations	Buede: Sections 4.2.4
12	4.3	Partitions of a Set	Buede: Sections 4.2.5
12	4.4	Power Sets	Buede: Sections 4.2.6
13	4.5	Unary Relations	Buede: Section 4.3
14	4.6	Binary Relations	Buede: Section 4.3
15	4.7	Composition of Functions	Buede: Sections 4.4 to 4.5
15	5.1	Graphs and Digraphs	Buede: Sections 5.1 to 5.6
16	5.2	Functional Hierarchy Digraph	Buede: Sections 5.1 to 5.6
16	5.3	Digraphs	Buede: Sections 5.9 to 5.12
17	6.1	IDEF0 for Perform Design Activities	Buede: Section 6.1
18	6.2	Stakeholders	
18	6.3	Requirements Hierarchy	Buede: Section 6.2
19	6.4	IDEF0 for Define System-level Design Problem	Buede: Sections 6.3 to 6.4
20	6.5	Sequence Diagrams (Part 1)	Buede: Section 6.10
21	6.6	Sequence Diagrams (Part 2)	Buede: Section 6.10
22	6.7	Sequence Diagrams Using EFFBD	Buede: Section 6.10
23	6.8	Elevator External Systems Diagram	Buede: Section 6.11, 12.3.2
24	6.9	Formal Input / Output Requirements	Buede: Sections 6.8, 6.9, 6.14.1; Wymore: Excerpt posted to Blackboard
26	7.2	Hatley-Pirbhai Template Applied to Elevator Functions	Buede: Section 7.4.1
27	7.3	Scenario Tracing	Buede: Section 7.4.4
28	7.4	Tracing Requirements and External Interfaces	Buede: Section 7.7
29	8.1	Generic Physical Architecture for Elevator	Buede: Sections 8.1 to 8.3
29	8.2	Option Creation Techniques	Buede: Sections 8.4
29	8.3	Block Diagrams of Physical Architecture	Buede: Section 8.5
30	8.4	Levels of Communication Network Centralization	Buede: Section 8.6.1
31	8.5	Levels of Communication Network Distribution	Buede: Section 8.6.1
31	9.1	Tracing Requirements to Value Trade-off Objectives	Buede: Sections 9.1 to 9.3.1
32	9.2	Allocating Functions to Components	Buede: Section 9.3.3

Assignment	Exercise	Topic	Supporting Readings
32	9.3	Functional Decomposition for Bicycle Suspension System	Ullman: Excerpt posted to Blackboard
33	9.4	Morphological Box for Bicycle Suspension System	Ullman: Excerpt posted to Blackboard
34	13.1	Relevance Diagrams Using GeNIe	Buede: Sections 13.5.1 to 13.5.2
34	13.2	Problem 13.2 Using GeNIe	Buede: Sections 13.5.1 to 13.5.2
34	13.3	Disk Forging Decision Problem Using GeNIe	Buede: Section 13.5.3
35	13.4	Problem 13.6 Using GeNIe	Buede: Section 13.5.3
35	13.5	Perfect Information Using GeNIe	Buede: Section 13.5.3
35	13.6	Perfect Information for Problem 13.6	Buede: Section 13.5.3
36	13.7	Imperfect Information Using GeNIe	Buede: Section 13.5.3
36	13.8	Risk Averse Decision Maker	Buede: Section 13.5.4
36	13.9	Perfect Information for Risk Averse Decision Maker	Buede: Section 13.5.4
37	10.1	Defining Interfaces Using CORE	Buede: Section 8.5, 10.1 to 10.8
38	11.1	Early Validation	Buede: Sections 11.1 to 11.5
38	11.2	Qualification and Detecting Failures	Buede: Sections 7.6, 11.7 to 11.9

G. Library Resources

- A digital edition of the textbook is available for download via the library.

H. Course Syllabus

An example Syllabus from Spring 2016 is as follows:

IE/AAE 590: Systems Tools and Methodologies

Course Information
Term: Spring 2016
MWF 11:30 – 12:20

GRIS 134
We will use Blackboard

Instructor Information

C. Robert Kenley, PhD, ESEP
Associate Professor of Engineering Practice
School of Industrial Engineering
Office: GRIS 370
Phone: +1 765 494 5160
Web: http://web.ics.purdue.edu/~ckenley/
Office Hours: MF 12:30 – 1:20.

Course Description

Introduction to modeling tools and methods for designing engineered systems. Topics include: defining the design problem; defining and validating stakeholders' and system requirements; discrete mathematics for system modeling; defining and modeling system operational scenarios; the system development life cycle; defining and modeling functional, physical, and allocated architectures; evaluating and modeling the tradeoffs between alternative architectures; and defining the system qualification process.

Prerequisites

Students are assumed to have completed some college-level mathematics. They will be asked to solve problems related to sets, graphs, and probability and decision trees. A Windows operating system is necessary to use the modeling tools.

Course Goals

The purpose of the course is to:

5. emphasize patterns of systems thinking,
6. introduce systems engineering processes and methods,
7. introduce theory for model-based systems engineering, and
8. provide practice in using model-based systems engineering tools.

Learning Objectives

Upon completion of the course, students will be able to

16. apply the discrete mathematics concepts of set theory, relations and functions, and graph theory to characterize and analyze the functional and structural aspects of models for designing engineered systems,
17. critique different approaches for system development life cycles and for systems engineering processes,
18. define an engineered system's context
19. define and critique a functional model of a system development life cycle using a model-based systems engineering tool,
20. define and critique models of the functional architectures of an engineered system using a model-based systems engineering tool,
21. define a system's stakeholders and define formal system I/O requirements,
22. audit a set of formal system I/O requirements for completeness

23. define models of the physical architecture of an engineered system using a model-based systems engineering tool,
24. apply an option creation technique to generate alternative physical architectures
25. define an allocated architecture of an engineered system using a model-based systems engineering tool,
26. define the relationship of stakeholders' requirements to design trade-off objectives
27. define models of the interfaces of an engineered system using a model-based systems engineering tool,
28. critique a functional model of early validation using a model-based systems engineering tool,
29. understand alternative graphical modeling approaches for data modeling, process modeling, and behavior modeling
30. define and model uncertainty, value, and risk preference for evaluating design tradeoffs between alternative system architectures

Course Requirements

Homework assignments will be exercises that are presented as part of the class lectures. **Do not wait until near the due date to begin completing homework assignments. Instead, begin working on them immediately after the material is covered in the lecture.**

Homework assignments are to be completed as individuals and must be submitted via the class Blackboard site at 11:20 a.m. prior to class on the day that they are due.

Required Texts

Buede, Dennis M. 2009. *The Engineering Design of Systems: Models and Methods, Second Edition.* Hoboken, NJ: Wiley.

Class Schedule

This is the order that material from the textbook will be covered:

Chapter 1 Introduction to Systems Engineering
Chapter 2 Overview of the Systems Engineering Design Process
Chapter 3 Modeling and SysML Modeling
Chapter 4 Discrete Mathematics: Sets, Relations, and Functions
Chapter 5 Graphs and Directed Graphs (Digraphs)
Chapter 6 Requirements and Defining the Design Problem
Chapter 7 Functional Architecture Development
Chapter 8 Physical Architecture Development
Chapter 9 Allocated Architecture Development
Chapter 13 Decision Analysis for Design Trades
Chapter 10 Interface Design
Chapter 11 Integration and Qualification
Chapter 12 Graphical Modeling Techniques

Assignments and Readings

Assignment	Due	Exercise	Topic	Supporting Readings
0	22-Jan	0.1	Installing CORE and GeNIe	
1	27-Jan	1.1	What is a System?	Buede: Preface, Sections 1.1 and 1.9
2	29-Jan	1.2	Life Cycle Processes and Systems Engineering Processes	Buede: Sections 1.2 to 1.6
3	1-Feb	1.3	Comparing Activities to Phases	Buede: Sections 1.7, 1.8, 1.10, and 1.11
4	3-Feb	2.1	External Systems and Context	Buede: Sections 2.1 and 2.2
5	5-Feb	2.2	Entity-Relationship Diagram	Buede: Section 2.3
6	8-Feb	2.3	CORE: Systems Engineering Tool (Part 1)	Buede: Sections 2.4 to 2.6, 3.7 to 3.9
7	10-Feb	2.4	CORE: Systems Engineering Tool (Part 2)	Buede: Sections 2.4 to 2.6, 3.7 to 3.9
8	12-Feb	3.1	CORE: Use Case Diagram	Buede: Sections 3.1 to 3.4
8	12-Feb	3.2	Sequence Diagram Messages	Buede: Sections 3.1 to 3.4
9	15-Feb	3.3	CORE: IDEF0 Modeling (Part 1)	Buede: Section 3.5
10	17-Feb	3.4	CORE: IDEF0 Modeling (Part 2)	Buede: Section 3.5
11	19-Feb	3.5	CORE: Behavioral Modeling	Buede: Sections 3.6 and 3.10
11	19-Feb	4.1	Describing Members of a Set	Buede: Sections 4.1 to 4.2.3
12	22-Feb	4.2	Set Operations	Buede: Sections 4.2.4
12	22-Feb	4.3	Partitions of a Set	Buede: Sections 4.2.5
12	22-Feb	4.4	Power Sets	Buede: Sections 4.2.6
Survey 1	22-Feb	S.1	Assignment 0-12 Survey	
13	26-Feb	4.5	Unary Relations	Buede: Section 4.3
14	26-Feb	4.6	Binary Relations	Buede: Section 4.3
15	29-Feb	4.7	Composition of Functions	Buede: Sections 4.4 to 4.5
15	29-Feb	5.1	Graphs and Digraphs	Buede: Sections 5.1 to 5.6
16	2-Mar	5.2	Functional Hierarchy Digraph	Buede: Sections 5.1 to 5.6
16	2-Mar	5.3	Digraphs	Buede: Sections 5.9 to 5.12
17	4-Mar	6.1	IDEF0 for Perform Design Activities	Buede: Section 6.1
18	7-Mar	6.2	Stakeholders	
18	7-Mar	6.3	Requirements Hierarchy	Buede: Section 6.2
19	9-Mar	6.4	IDEF0 for Define System-level Design Problem	Buede: Sections 6.3 to 6.4
20	11-Mar	6.5	Sequence Diagrams (Part 1)	Buede: Section 6.10
21	23-Mar	6.6	Sequence Diagrams (Part 2)	Buede: Section 6.10
22	25-Mar	6.7	Sequence Diagrams Using EFFBD	Buede: Section 6.10
23	28-Mar	6.8	Elevator External Systems Diagram	Buede: Section 6.11, 12.3.2
24	30-Mar	6.9	Formal Input / Output Requirements	Buede: Sections 6.8, 6.9, 6.14.1; Wymore: Excerpt posted to Blackboard
Survey 2	30-Mar	S.2	Assignment 13-25 Survey	

Assignment	Due	Exercise	Topic	Supporting Readings
26	1-Apr	7.2	Hatley-Pirbhai Template Applied to Elevator Functions	Buede: Section 7.4.1
27	4-Apr	7.3	Scenario Tracing	Buede: Section 7.4.4
28	6-Apr	7.4	Tracing Requirements and External Interfaces	Buede: Section 7.7
29	8-Apr	8.1	Generic Physical Architecture for Elevator	Buede: Sections 8.1 to 8.3
29	8-Apr	8.2	Option Creation Techniques	Buede: Sections 8.4
29	8-Apr	8.3	Block Diagrams of Physical Architecture	Buede: Section 8.5
30	11-Apr	8.4	Levels of Communication Network Centralization	Buede: Section 8.6.1
31	13-Apr	8.5	Levels of Communication Network Distribution	Buede: Section 8.6.1
31	13-Apr	9.1	Tracing Requirements to Value Trade-off Objectives	Buede: Sections 9.1 to 9.3.1
32	15-Apr	9.2	Allocating Functions to Components	Buede: Section 9.3.3
32	15-Apr	9.3	Functional Decomposition for Bicycle Suspension System	Ullman: Excerpt posted to Blackboard
33	18-Apr	9.4	Morphological Box for Bicycle Suspension System	Ullman: Excerpt posted to Blackboard
34	20-Apr	13.1	Relevance Diagrams Using GeNIe	Buede: Sections 13.5.1 to 13.5.2
34	20-Apr	13.2	Problem 13.2 Using GeNIe	Buede: Sections 13.5.1 to 13.5.2
34	20-Apr	13.3	Disk Forging Decision Problem Using GeNIe	Buede: Section 13.5.3
35	22-Apr	13.4	Problem 13.6 Using GeNIe	Buede: Section 13.5.3
35	22-Apr	13.5	Perfect Information Using GeNIe	Buede: Section 13.5.3
35	22-Apr	13.6	Perfect Information for Problem 13.6	Buede: Section 13.5.3
36	25-Apr	13.7	Imperfect Information Using GeNIe	Buede: Section 13.5.3
36	25-Apr	13.8	Risk Averse Decision Maker	Buede: Section 13.5.4
36	25-Apr	13.9	Perfect Information for Risk Averse Decision Maker	Buede: Section 13.5.4
37	27-Apr	10.1	Defining Interfaces Using CORE	Buede: Section 8.5, 10.1 to 10.8
38	29-Apr	11.1	Early Validation	Buede: Sections 11.1 to 11.5
38	29-Apr	11.2	Qualification and Detecting Failures	Buede: Sections 7.6, 11.7 to 11.9
Survey 3	29-Apr	S.3	Assignment 26-38 Survey	
-	2-May	CE	Course Evaluations	