00. Course Introduction

NASA ESMD Capstone Design

developed by

thebenshimagroup

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Capstone Design Logistics

- Purpose
  - Learning objectives
  - “Design”
  - Audience
- Projects
  - Types
  - Students
  - Advisors
  - Sponsors
- Design process
  - Capstone vs. NASA vs. the book
  - Project milestones
- Class
  - Integration with projects
  - Assignments
  - Notes
- Texts and resources
- Syllabus
- Facilities and resources
  - Meeting
  - Building
- Grading
  - Elements

What is Capstone Design?

- How to develop products to exceed customer requirements and expectations
- This is the real thing
- We're betting on you with our resources and reputation

Course Overview

- The Capstone Design course requires that students work in teams on "open-ended" engineering design projects. Students are given the opportunity to realize original and creative solutions to real engineering problems, not merely design changes of scale or duplication of existing systems. Important topics are presented in the lectures including the design process, design tools, project management, engineering communication, engineering ethics, and intellectual property. Students are encouraged to take on new team roles and to test the limits of their capabilities.

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Learning Objectives

- Students will understand the importance of a structured design process
- Students will understand and be able to implement the five phases of a structured design process
- Students will be able to implement the key tools of a structured design process
- Students will gain practice in working on self -managed teams
- Students will gain confidence in their abilities to deliver an engineering solution from need to parts

ABET Criteria for Engineering Education

- Development of student creativity
- Use of open-ended problems
- Alternate design solutions and decision rationale
- Use of modern design theory and methodologies
- Formulation of design statements and specifications
- Feasibility consideration
- Consideration of production processes
- Concurrent engineering design
- Detailed system description
- Use of teams in problem solving and design
- Realistic constraints (DFX, economics, *etc.*)
- Development of related communication skills
- Success in a globally competitive world

Engineering Design

- … the systematic and creative application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems. www.iteawww.org/TAA/Glossary.htm
- … a function in the product creation process where a good is configured and specific form is decided. www.shapetomorrow.com/resources/e.html
- … the process of devising a system, component, or process to meet desired needs. The primary way that engineers utilize the forces and materials of nature for the benefit of mankind is through new and innovative designs (from ABET). http://civil.engr.siu.edu/intro/design.htm

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Engineering Design

- … the creative, iterative and often open-ended process of conceiving and developing components, systems and processes. Design requires the integration of engineering, basic sciences and mathematics. A designer works under constraints, taking into account economic, health and safety, social and environmental factors, codes of practice and applicable laws. www.ee.wits.ac.za/~ecsa/gen/g-04.html
- … an activity in the product creation process where a good is configured. Specific form is decided. The activity is sometimes seen as a late step in the R&D process and sometimes as an early step in the manufacturing process. www.faculty.catawba.edu/jbgreen/Dr.Green/glossary.htm

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Engineering Design

- Engineering design is the communication of a set of rational decisions obtained with creative problem solving for accomplishing certain stated objectives within prescribed constraints. Lumsdaine *et al*., p. 316
- Design establishes and defines solutions and pertinent structures for problems not solved before, or new solutions to problems which have previously been solved in a different way. … The ability to design is both a science and an art. … Good design requires both analysis and synthesis. Dieter, pp.1-3
- Design incorporates creativity, complexity, making choices between many possible solutions, and compromise in balancing many (sometimes conflicting) requirements. Dieter, pp.1-3

Audience

- Capstone Design is intended for engineering students that have completed all of the core requirements of their education
- The purpose of the course is to teach students how to implement a structured design process on a real project in a team (perhaps multi-functional) environment
- Teams can contain a mix of students in various years as long as they are all exposed to the design process material

Projects

- Teams of 4 or more students work on one sponsored project lasting two semesters
- Projects encompass the entire design process — ideation through functional prototype build and evaluation
- The first semester ends with a formal project review, reflective of a typical stage-gate process, in which each team demonstrates their design progress to date and gain approval for their plan to complete the project during the second semester
- The second semester concludes with a project-ending full presentation before industry representatives, faculty members, and their peers
- Typical projects are design-intensive, where the team may be asked to develop a new product, design and build a portion of a new manufacturing process cell, or fabricate a special machine designed for a specific task

Example Project Description

Project # 14: **Advanced Filtration System Sealing**

PURPOSE: The purpose of this project is to design an advanced sealing mechanism for an Advanced Filtration System. This system will be utilized on engine applications.

TIMEFRAME: This is a project that will be worked on in Senior Design starting XXXX and XXXX.

PROJECT SCOPE: This team will be comprised of five senior Mechanical Engineering students.

The project we have selected focuses on designing an advanced sealing mechanism for our Advanced Filtration System. The system is to be utilized on engine applications. We are still in the development stage on this program. There are development prototypes built and installed on test vehicles now. One of the components of the filter is currently a rubber inflatable seal. The seal's function is to provide a positive seal between the inlet and exit cavities of the filter unit during filtration. When the filter media is plugged, there is a mechanism on board that allows for new media to be advanced into the filtering window. In order to do this, the seal must disengage/retract. In its current state the seal is deflated. Once the seal retracts the filtering media can be advanced. These inflatable seals have been a reliability issue for us. As you can probably guess, it has been a fatigue issue related to the inflating and deflating of the seal. We have solved the fatiguing problem. However, the solution is a more expensive inflatable seal that is fabric reinforced. This solution has allowed us to continue our field testing. It is now time to look at a less expensive solution for a production design.

Why a Sponsored Project?

- This course is developed around having sponsored projects
- Ideally the projects are paid for by an outside group that is truly committed to the project
- This commitment gives the project financial resources as well as a "customer"
- Even if there is no financial commitment, each project should have a customer that is external to the class that "needs" the final product
- It is important to remind sponsors that not all student projects are successful

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Student Role in Projects

- Each student will participate in a team project
- This is the most important element of the class
- The project is designed to be their first project outside of school and should be treated as a job
- The goal is to give them that experience with fewer ramifications for project failure
- Each person will be expected to participate in the team and work on the project professionally
- Each sponsor and advisor will expect a finished, documented project completed to their expectations

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Advisor

- The advisor and sponsor are also responsible for project success
- The role of the advisor is to help guide the team through the design process, offer advice when appropriate, steer when necessary, and help find information when necessary
- This is accomplished through at least one weekly, hour-long meeting
- The advisors should not be expected to be the sole source for technical information nor necessarily the primary source

Sponsor

- The advisor and sponsor are also responsible for project success
- The sponsors represent their own interests
- The team is expected to serve those interests within the guidelines set by the advisor
- Groups should meet frequently with their sponsors – in person and by teleconferencing or videoconferencing

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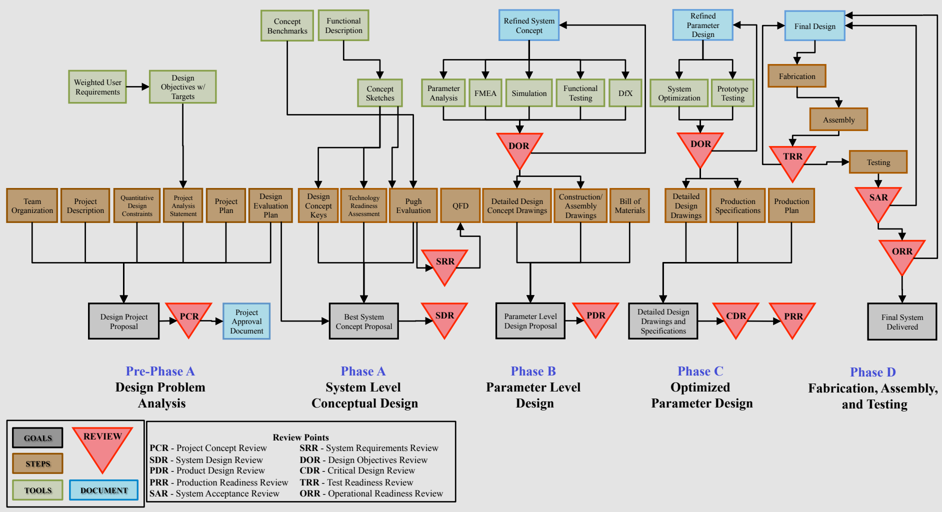
Capstone Design Process



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Abbreviations and Acronyms

CDR	Critical Design Review
DfX	Design-for-X
DOR	Design Objectives Review
FMEA	Failure Modes and Effects Analysis
ORR	Operational Readiness Review
PCR	Project Concept Review
PDR	Product Design Review
PRR	Production Readiness Review
QFD	Quality Function Deployment
SAR	System Acceptance Review
SDR	System Design Review
SRR	System Requirements Review
TRR	Test Readiness Review

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Design Process Comparison - Stages

NASA	Capstone Design	Lumsdaine
	Pre-Phase A	
Concept Studies	Design Problem Analysis	Design Problem Analysis
	Phase A	
Concept and Technology Development	System Level Conceptual Design	Conceptual(System) Level Design
	Phase B	
Preliminary Design and Technology Completion	Parameter Level Design	Parameter Level Design
	Phase C	
Final Design and Fabrication	Optimized Parameter Design	Optimized Parameter Design
	Phase D	
Assembly, Integration, and Test Launch	Fabrication, Assembly, and Testing	-

Design Process Comparison – Reviews and *Documents*

NASA	Capstone Design	Lumsdaine
	Pre-Phase A	
MCR- Mission Concept Review IPR- Informal Proposal Review *Program/Project Proposals* *Preliminary Mission Concept Report*	PCR- Project Concept Review *Project Approval Document*	Review by Instructor, Advisor, and Sponsor *Design Project Proposal*
	Phase A	
SRR- System Requirement Review SDR- System Definition Review	SRR- System Requirement Review SDR- System Design Review	*Design Concept Keys* *Design Decisions*
	Phase B	
PDR- Program Definition Review *Preliminary Design Report* *Interface Control Documents*	DOR- Design Objectives Review PDR- Product Design Review *Refined System Concept*	Review by Instructor, Advisor, Team, and Sponsor *Design Project progress Report*
	Phase C	
CDR- Critical Design Review PRR- Production Readiness Review *Preliminary Operations Handbook*	DOR- Design Objectives Review CDR- Critical Design Review PRR- Production Readiness Review *Refined Parameter Design*	Design review panel and Instructor – Oral Presentation Review *Final progress Report*
	Phase D	
TRR- Test Readiness Review SAR- System Acceptance Review ORR- Operational Readiness Review *Verification and Validation Report* *Operator and Maintenance Manuals*	TRR- Test Readiness Review SAR- System Acceptance Review ORR- Operational Readiness Review *Final Design*	-

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Project Milestones – Reviews (Capstone Design)

REVIEW	CONTENT	TIMING	AUDIENCE
PCR	Design Project Proposal	Pre-Phase A	Sponsor, Advisor
SRR	Pugh Evaluation	Phase A - Mid	Sponsor, Advisor
SDR	Best System Concept Proposal	Phase A - End	Sponsor, Advisor, Faculty, Peers
DOR (Phase B)	Results from Parameter Analysis, FMEA, Simulation, Functional Testing, DfX	Phase B - Mid	Sponsor, Advisor, External technical advisors
PDR	Parameter Level Design Proposal	Phase B - End	Sponsor, Advisor, Faculty, Peers
CDR	Detailed Design Drawings and Specifications	Phase C - Mid	Sponsor, Advisor
DOR (Phase C)	Results from System Optimization and Prototype Testing	Phase C - End	Sponsor, Advisor, External technical advisors
PRR	Detailed Design Drawings and Specifications	Phase C - End	Sponsor, Advisor, Fabrication resource
TRR	Results after Assembly	Phase D - Begin	Sponsor, Advisor
SAR	Testing Results	Phase D - Mid	Sponsor, Advisor, External technical advisors
ORR	Testing results after passing SAR	Phase D - End	Sponsor, Advisor, Faculty, Peers

Project Milestones – Reviews (NASA)

REVIEW	CONTENT	TIMING	AUDIENCE
MCR	Mission goals and objectives Preliminary risk assessment	Pre-Phase A	Internal
SRR	System architecture System requirements document	Phase A - Mid	Technical team, Project Manager & Review Chair
SDR	System architecture Preliminary functional baseline	Phase A - End	Technical team, Project Manager & Review Chair
PDR	Preliminary subsystem design specifications Applicable technical plans	Phase B - End	Technical team, Project Manager & Review Chair
CDR	Product build-to specifications Operational limits and constraint Fabrication, assembly, integration, and test plans and procedures	Phase C - Mid	Technical team, Project Manager & Review Chair
PRR	Design documentation for production	Phase C - Mid	Technical team, Project Manager & Review Chair
TRR	System and subsystem qualification testing results Document with objectives for testing	Phase D - Begin	Technical team, Project Manager & Review Chair
SAR	Results of SAR at all suppliers Manufacturing plans	Phase D - Mid	Technical team, Project Manager & Review Chair
ORR	Operational supporting and enabling products Results of all completed validation tests	Phase D - End	Technical team, Project Manager & Review Chair

Project Milestones – Reviews (Lumsdaine)

REVIEW	CONTENT	TIMING	AUDIENCE
Review by Instructor, Advisor, and Sponsor	Design Project Proposal Oral Team Presentation	Pre-Phase A	Instructor, Advisor and Sponsor
Review by Instructor, Advisor, Team, and Sponsor	Design Project Progress Report	Phase B	Instructor, Advisor, Team, and Sponsor
Design review panel and Instructor – Oral Presentation Review	Final Progress Report Oral Presentation	Phase C	Design Review Panel, Instructor

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Project Milestones – Reports (Capstone Design)

REPORT	CONTENT	TIMING	AUDIENCE
Project Approval Document	Reviewed Design Project Proposal	Pre-Phase A	Sponsor, Advisor
Refined System Concept	Reviewed results from DOR in Phase B	Phase B	Sponsor, Advisor, Technical writer
Refined Parameter Design	Reviewed results from DOR in Phase C	Phase C	Sponsor, Advisor
Final Design	Reviewed results from SAR and ORR	Phase D	Sponsor, Advisor, Technical writer

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Project Milestones – Reports (Lumsdaine)

REPORT	CONTENT	TIMING	AUDIENCE
Design Project Proposal	Project Concept Statement, Design Constraints, Project Analysis Statement	Pre- Phase A	
Design Decisions	Pugh Evaluation Results	Phase A	
Design Project progress Report	Construction/Assembly Drawings and Bill of Materials	Phase B	
Final progress Report	Design Drawings and Specifications, Optimized Designs	Phase C	

Learning Modules

Module	Description
00	Course Introduction
01	The Design Process
02	Team Organization
03	Project Description
04	Project Requirements
05	Project Planning
06	Conceptual Design
07	Pugh Evaluation
08	Quality Function Deployment
09	System Design Review
10	Failure Modes and Effects Analysis
11	Design-for-X
12	Parameter Analysis
13	Parameter Level Design Proposal
14	System Optimization
15	Prototyping and Testing
16	Detailed Design Drawings
17	Fabrication, Assembly, and Testing

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Lecture/Project Integration

- It is important to keep the project as the topic of the lecture
- All lecture topics should be framed in terms of what students need to do on their projects
- Students MUST use a structured design process, even when less formal procedures would suffice
- It is my feeling that additional, non-project assignments and exams do not add to the quality of the learning but can cause “mutinies”

Assignments

- If it is necessary for the course (as opposed to the advisor and the project) to dictate assignments, make sure that the assignments are part of the critical path of ALL projects
- One significant issue with sponsored projects (or even different projects) is that they will have differing milestone timelines and make blanket due dates impractical

Notes

- The notes in this course are designed for you to give to your students BEFORE the lecture
- You can then use your knowledge of the design process and your design experiences to help them "fill in the gaps"

Texts

- *Main text*
  - *Creative Problem Solving and Engineering Design,* Edward Lumsdaine, Monika Lumsdaine, and J. William, Shelnutt, McGraw-Hill College Custom Series, New York, 1999
- Additional suggested texts
  - *Engineering Design,* 3rd Edition, George E. Dieter, McGraw-Hill, Boston, 2000
  - *A Guide to Writing as an Engineer,* David Beer and David McMurrey, John Wiley & Sons Inc., New York, 1997
  - *Patent Fundamentals for Scientists and Engineers,* 2nd Edition, Thomas T. Gordon and Arthur S. Cookfair, Lewis Publishers, CRC Press LLC, Boca Raton, 2000

Additional References

- Bahill,T.A., Gissing,B.,Re-evaluating System Engineering Concepts Using Systems Thinking, IEEE Trans. on Systems,Man and Cybernetics, v.28(4),p.516-527, 1998.
- Ullman,D.G., The Mechanical Design Process,3rd edition, McGraw-Hill, 2003.
- System Engineering Paper Submission Template, http://education.ksc.nasa.gov/ESMDspacegrant /SE_Paper_Submission_Template.doc
- Blanchard,B.S., Fabrycky,W.J., System Engineering and Analysis, 2nd edition, Prentice Hall, 1990.
- ANSI/EIA 632-1998, Processes for Engineering a System, Electronic Industries Alliance, 1999.
- Introduction to Engineering with the Use of Case Studies, Raju,P.K., Sankar,C.S.,Institute for STEM Education and Research, 2007
- Space Mission Analysis and Design, 3rd edition (Space Technology Library) (Space Technology Library) (Paperback) by Wiley J. Larson (Editor), James R. Wertz (Editor)
- Spacecraft Systems Engineering 3rd Edition (Paperback) by Peter Fortescue (Editor), John Stark (Editor), Graham Swinerd (Editor)
- Spacecraft Structures and Mechanisms from Concept to Launch (The Space Technology Library) (Paperback) by Thomas PSarafin and Wiley J. Larson(Editor)
- Space Vehicle Mechanisms: Elements of Successful Design (Hardcover) by Peter L. Conley
- The Space Environment: Implications for Spacecraft Design (Paperback) by Alan C. Tribble (Author)
- Space Vehicle Design (Aiaa Education Series) (Hardcover) by Michael D. Griffin (Author), James R. French
- Fundamentals of Space Systems (The Johns Hopkins University/Applied Physics Laboratory Series in Science and Engineering) (Hardcover) by Vincent L. Pisacane
- Principles of Space Instrument Design (Cambridge Aerospace Series) (Paperback) by A. M. Cruise (Author), J. A. Bowles (Author), T. J. Patrick (Author)
- Elements of Spacecraft Design (Aiaa Education Series) (Hardcover) by Charles D. Brown
- Spacecraft Power Systems (Hardcover) by MukundR. Patel (Author)
- Spacecraft Thermal Control Handbook: Fundamental Technologies (Hardcover) by David G. Gilmore
- Spacecraft Power Technologies (Space Technology) (Hardcover) by Anthony K. Hyder (Author), Ronald L. Wiley (Author), G. Halpert (Author), Donna Jones Flood (Author), S. Sabripour

Additional References

- Aircraft Structures for Engineering Students, Fourth Edition (Elsevier Aerospace Engineering) (Paperback) by T. H. G. Megson (Author)
- Printed circuits in space technology: Design and application (Prentice-Hall space technology series) by Albert E Linden
- Human Spaceflight: Mission Analysis and Design (Space Technology Series) (Space Technology Series) by Wiley J. Larson and Linda K. Pranke
- Solar Power Satellites: The Emerging Energy Option (Ellis Horwood Library of Space Science and Space Technology. Series in Space Technology) by Peter E. Glaser, Frank Paul Davidson, and Katlinka I. Csigi
- Spacecraft structures (Prentice-Hall international series in space technology) by Carl C Osgood (Unknown Binding - 1966)
- Cryogenic engineering (Prentice-Hall international series in space technology) by Joseph H Bell (Unknown Binding - 1963)
- Space mechanics (Prentice-Hall international series in space technology) by Walter C Nelson (Unknown Binding - 1962)
- Navigation and guidance in space (Prentice-Hall international series in space technology) by Edward V. B Stearns
- THE SECOND FIFTEEN YEARS IN SPACE: SCIENCE AND TECHNOLOGY SERIES: VOLUME 31: by Saul (Editor) Ferdman
- The Lunar Base Handbook (Space Technology Series) by Peter Eckart (Paperback - Dec 1, 1999)
- Technologies of manned space systems (Space flight technology series) by Aleck C Bond (Unknown Binding - 1966)
- Metallurgical Assessment of Spacecraft Parts, Materials and Processes (Wiley-Praxis Series in Space Science and Technology) by Barrie D. Dunn and M. Phil (Paperback - Jun 1997)
- Satellite Control: A Comprehensive Approach (Wiley-Praxis Series in Space Science and Technology) by John T. GarnerIntroduction to space communication systems (McGraw-Hill series in missile and space technology) by George NKrassner
- Robots in Space: Technology, Evolution, and Interplanetary Travel (New Series in NASA History) by Roger D. Launius and Howard E. McCurdy (Hardcover - Jan 7, 2008)
- Recent Developments in Space Flight Mechanics (Science and Technology Series Volume 9) by Paul B. (editor) Richards (Hardcover - 1966)
- The Lunar Sourcebook (Heiken et al) is a good reference. Chapter 3 covers lunar environment.
- http://insa.netquire.com/docs/Lessons_Learned_Fina.pdf

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Facilities

- Students need facilities to conduct team meetings without being interrupted, to conduct phone/video conferences with sponsors, to fabricate their prototypes /deliverables, and to do assembly and testing
- Do not underestimate the resources for this
  - Space for projects
  - Personnel for a safe fabrication shop

Fabrication

- This course is not a course in how to use a fabrication shop
- That is an important class for engineers, but it is expected that students have completed such a course beforehand
- It should be possible for them to complete their project (and product) within the university, but it is not required
- Depending upon the project's budget, work can be done "out of house"
- Working with contract fabrication allows students to learn much more about engineering communication

Syllabus

- A sample syllabus will be included here based upon the test implementation this fall

Grading

- Each sponsor and advisor will expect a finished, documented project completed to his or her expectations
- It is important to grade against those expectations as well as the students' use of a structured design process and the tools therein

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