CU Vision and Mission for Senior Design

Vision:

Integrity - understanding the big picture.

Mission:

Next step toward a professional career

• Pull together knowledge from various courses
• Learn new techniques
• Model a professional work environment
• Deal with ill-defined problems
Class Objectives

- Two-semester, 8-month long projects
- Integrate knowledge from previous courses
- Topics:
  1. Communications
     - Verbal, technical presentations
     - Writing documentation
  2. Business and legal aspects
  3. Systems engineering
  4. Ethics
  5. Design and development + project
     - Combine techniques and skills learned
     - Framework: approaching problems & solutions

ENGR 491-492
Projects - Selection

- Industry sponsored
  - 39 of 42 at CU, (5 projects sponsor out of 65 at KSU)
  - Example projects follow

- Selection
  1. Begin meeting sponsors preceding spring semester
  2. Discuss projects, explain expectations:
     - Must meet once a week – status and guidance
     - Must buy supplies and parts
     - (CU Still considering course fees)
       - First time sponsor
       - Small company vs. big
  3. Assign projects according to interest and engineering concentrations
1. Survey students
   - Concentrations (ME, EE, ChE)
   - Interests
   - Markets after graduation

2. Assign projects

3. Student-generated projects
   - Special case
   - Form company
   - Course fee, buy project supplies
   - Keep IP (CU still working this issue)
Business Aspects

- Professional (or essential) skills
  - Communications and technical presentations
  - Writing and documentation
  - Business etiquette

- Meetings, structure, conduct

- Negotiation

- Team psychology

- Technical legal issues – e.g., contracts, patents, copyrights, trade secrets
Systems Engineering in Senior Design
Systems Engineering Topics

- Problem Definition
- Organization
- Documentation
- Requirements and Standards
- Design techniques
- Analyses, synthesis, evaluation, decisions
- Review, QA
- Test and integration
Problem Definition

**Sponsor**
- Defines problem, supplies funding
- Statement of work (SOW)
- Meet and interview
- Tour facility (if possible)

**Development**
- Define stakeholders
- Brainstorm, evaluate, iterate
- Competitive analysis
  - Is someone else doing something similar?
  - Compare and contrast to other products
  - Decide
    - Innovate
    - Redesign the wheel in direct competition
    - Drop and move to another problem
- Organize team, tasking, scheduling
- Set vision, mission, goals

Team visits Fire Scout at Patuxent River Naval Air Station with sponsor
First Things First

- What is the need – the product?
- Who is going to use it?
- Why will people use it?
- Where will they use?
- When will they use it?
- And finally, how will they use it?
- Not just for marketing anymore!
Stakeholders defined

• Who will design the product?
• Who will manage the project?
• Who will benefit?
• Who are the customers?
• Who influences or regulates the use of the product?

Specify

➢ Primary
  ✓ Client or sponsor
  ✓ Design team and management (advisors)

➢ Secondary (may overlap with primary)
  ✓ Users
  ✓ Customers
  ✓ Regulators

➢ Tertiary
  ✓ People in proximity (townspeople near factory)
  ✓ Family of users

Stakeholders evaluate

• Status meetings and design reviews
• Prototype tests
• Field tests
• Compliance tests

Team field tests revised equipment carts with stakeholders – band members in actual performances
Project Organization

- Contract by each team to deliver, based on tasking/scheduling in PMP
- Planning – tasking, Gantt Chart
- Project management
- Documentation
- Weekly sponsor meetings
  - Purpose
    - Provide status
    - Receive guidance
  - Sponsor + advisor(s)
  - Team meetings
  - Minutes and action items
  - Design reviews

Team with Grifols sponsor and advisors
First semester
- Team contract
- PMP
- CONOPs
- Requirements (with standards)
- Report of Analyses
- Test Plan
- Global, Societal, Economic Impact Memo

Second semester (update & add)
- Test results
- Design Descriptions
- User Manual
- Action Item Memo
- Debrief or Production Handoff Memo
Requirements and Standards

- Use CONOPs (concept of operations) to develop requirements
- Interview and survey stakeholders
  - Sponsor
  - Potential customers
  - Potential users
- Analyses and synthesis
  - Brainstorm
  - Calculations and bench tests
- Living document – requirements can change
- Standards are researched, identified, and documented
Analyses, Synthesis, Evaluation

- Synthesis and tradeoffs
- Various models reviewed
  - V-model
  - Spiral model
- Evaluation
  - Calculations
  - Simulations
  - Bench tests
  - Field tests
Design and Decisions

- Rapid prototyping
- Iterative
- Decision
  - Decision matrices
  - Discussions with sponsors
  - Discussions with other stakeholders
Analyses is Iterative!

- PERRU model of iteration
  - Model used at all levels of abstraction
    - High-level – general project overview
    - Mid-level – particular module overview
    - Low-level – can be for particular tasks

- Record development effort

- Documents are living, revisable

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### Severity Matrix

<table>
<thead>
<tr>
<th>Consequence or Criticality</th>
<th>C</th>
<th>S</th>
<th>I</th>
<th>N2</th>
<th>N1</th>
<th>N0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Likelihood</strong></td>
<td>r</td>
<td>lo</td>
<td>mod</td>
<td>hi</td>
<td>v</td>
<td></td>
</tr>
</tbody>
</table>

- **Red** shade: fix first, track in the management database
- **Yellow** shade: fix, track in the management database
- **White** shade: track in the management database at the discretion of the program manager
When to Analyze?

- Safety cases
- Basic calculations
- Behavioral simulation
- Monte Carlo simulations
- Analog simulation
- Fault trees
- Event tree analysis
- FTA
- ETA
- STPA
- FMECA
- Petri Net
- Barrier
- Bent pin
- Prototype tests
- Monte Carlo simulations
- Research Development
- Critical Design Phase
- Conceptual Design Phase
Types of Analyses

Various techniques
• System Theoretic Process Analysis (STPA)
• Event Tree Analysis (ETA)
• Fault Tree Analysis (FTA)
• Failure Modes Effects Criticality Ana. (FMECA)
• Safety Case

Proactive
• Inform design and development
• Addressing feasibility and failure:
  ➢ reliability,
  ➢ criticality,
  ➢ robustness, and
  ➢ safety

Reactive – Root Cause Analysis; helps find and fix problems after development begins
• Determine fault path and propagation
• Root Cause Analysis

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Hazard Analysis (HA)

Verify coverage of requirements within design and establish degree of confidence.

Risk Management

Risk and Hazard Analysis (RHA)

- STPA Document
- FMECA Document
- FTA Document
- ETA Document

- System-Theoretic Process Analysis (STPA)
- Failure Modes Effects and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)

- Reliability calculations
- Electronic hardware
- Mechanical hardware and materials
- Software components and modules
- Software correctness processes
- Tools support and certifications

- More formal and analytical methods
- More heuristics

Currently this is almost a completely subjective assessment based on experience.

Project goal: make this a more formal derivation.

Requirements and Descriptions

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Review, QA

PMP defines
- QA
- Development model – V or spiral
- Phases – concept, preliminary, critical, fielding, production, etc.
- Review – types and timing

Review
- Sponsor reviews
- Group reviews of project
- Peer reviews – determine individual contributions
- Formal reviews
  - Sponsor meetings
  - 3 formal design reviews
PMP defines test and integration
Start early with bench tests in fall semester
Formal unit/module tests in January and February
Formal integration tests in March
Field tests in March/April
Design Reviews

- 3 over the year
  - Conceptual Design Review (CoDR) – early December
  - Preliminary Design Review (PDR) – early March
  - Critical Design Review (CDR) – late April

- Format
  - Expected time ≤ 12 min.
  - Q & A ~ 8 minutes
  - Short dry-run, week before
  - Formal business attire
Students procrastinate (surprised?)

- Staged delivery
  - Draft documents (see next slide)
  - Bench tests of modules, concepts, prototypes
  - Hard deadline for prototype (we are moving to early March)
  - Require field testing of prototype (with prototype want at least 5 weeks of solid testing)
  - Completed documents

Peer review to help determine individual contributions

- Contract in spring for teams to assign individual tasks – monitor for completion by assignee
- Grade on contract completion
- Perform peer review last week of classes (see slide following schedule)
A Bit about Campbell Engineering
Awards an Engineering Degree with a stated concentration
- EE
- Electro-Mechanical Systems
- ME
- ChE
  - (coming soon – Computer Engineering)

Project-based and teamwork collaboration curriculum
- Year 1
  - Intro. to Engineering
  - Engineering Design I – get several projects with hands-off guidance
  - Engineering Design II – learn the entire engineering cycle
- Years 2 & 3 – class labs in chosen concentration
- Year 4 – Senior Design for both semesters + class labs in chosen concentration

136 credit hours
- Most classes limited to 24 students or less
Learn hand and machine tools in first year
  • Very large fabrication area
  • Large tools
    ➢ 2 CNC machines
    ➢ Laser cutter
    ➢ 4 x 8 ShopBot
    ➢ 6 x 6 waterjet for up to 8” of steel plate
    ➢ Scanning electron microscope
    ➢ Industrial mill and lathe, 3 welders,
  • Encouraged to work on personal projects!
  • Trained for tool use with levels of proficient labeled on badges

3D Printers for use by all campus students
  • 5 High-quality + a recent donation of printer that handles many materials including carbon fiber
  • Carbon fiber printer

Class labs have top-quality equipment and tools
Additional Slides with Some Details
# Schedule for Staged Deliveries

## Fall semester

<table>
<thead>
<tr>
<th>Document or Demonstration or Presentation</th>
<th>Date due</th>
<th>Grade points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draft contract</td>
<td>Sept. 14, 2022</td>
<td>4</td>
</tr>
<tr>
<td>Project Management Plan (PMP)</td>
<td>Sept. 23, 2022</td>
<td>4</td>
</tr>
<tr>
<td>Concept of Operations (CONOPs)</td>
<td>Oct. 12, 2022</td>
<td>4</td>
</tr>
<tr>
<td>Requirements</td>
<td>Oct. 12, 2022</td>
<td>4</td>
</tr>
<tr>
<td>Amended contract (bench tests specified)</td>
<td>Oct. 21, 2022</td>
<td>4</td>
</tr>
<tr>
<td>Report of Analyses</td>
<td>Oct. 28, 2022</td>
<td>4</td>
</tr>
<tr>
<td>Test Plan</td>
<td>Nov. 11, 2022</td>
<td>4</td>
</tr>
<tr>
<td>Bench tests of subsystems</td>
<td>Dec. 5, 2022</td>
<td>20</td>
</tr>
<tr>
<td>CoDR Presentation</td>
<td>Dec. 6, 2022</td>
<td>100</td>
</tr>
<tr>
<td>Deliver these documents + Global Impact memo</td>
<td>Dec. 9, 2022</td>
<td>130</td>
</tr>
</tbody>
</table>

## Spring

<table>
<thead>
<tr>
<th>Document or Demonstration or Presentation</th>
<th>Date due</th>
<th>Grade points</th>
</tr>
</thead>
<tbody>
<tr>
<td>contract</td>
<td>Feb. 2, 2023</td>
<td>25</td>
</tr>
<tr>
<td>Demonstrate complete and functional prototype</td>
<td>Mar. 23, 2023</td>
<td>45</td>
</tr>
<tr>
<td>PDR Presentation</td>
<td>Mar. 2, 2023</td>
<td>100</td>
</tr>
<tr>
<td>Previous documents updated + draft Design Descriptions + draft User Manual</td>
<td>Mar. 2, 2023</td>
<td>175</td>
</tr>
<tr>
<td>deliver field test results</td>
<td>Apr. 20, 2023</td>
<td>60</td>
</tr>
<tr>
<td>CDR Presentation</td>
<td>Apr. 24, 2023</td>
<td>100</td>
</tr>
<tr>
<td>Deliver all documents + Debrief memo + electronic files + scrapbook</td>
<td>Apr. 28, 2023</td>
<td>195</td>
</tr>
</tbody>
</table>
Team Name or Sponsor: __________________________

Performance Reviews: Reviewer __________________________

Reviewed
team member: __________________________ Date: ____________

Reviewed
team member: __________________________ Date: ____________

Please rate the team member on the following concerns - fill in a circle per line

For questions 1, 2, 3, and 4, complete this sentence: “This team member was - ”

<table>
<thead>
<tr>
<th>Always</th>
<th>Usually</th>
<th>Sometimes</th>
<th>Seldom</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. timeliness to meetings:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. timeliness in communications:</td>
<td></td>
<td></td>
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<tr>
<td>3. timeliness in completing tasks:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. an initiate, left nothing out:</td>
<td></td>
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</tr>
</tbody>
</table>

5. In a future technical business, I would want this team member with me on the same projects:

<table>
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<th>Usually</th>
<th>Sometimes</th>
<th>Seldom</th>
<th>Never</th>
</tr>
</thead>
</table>

Describe the title and responsibilities of this team member:

______________

Describe in your own words how well this person performed:

______________

Describe the title and responsibilities of this team member:

______________

Describe in your own words how well this person performed:

______________
Prototype Grading Rubrics

Fall grade rubric

Prototype Project Grades

<table>
<thead>
<tr>
<th>Individual grades</th>
<th>Team grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Per activity</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Points</td>
<td>7 Speech exercises</td>
</tr>
<tr>
<td>Per activity</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
</tr>
<tr>
<td>grade</td>
<td>7%</td>
</tr>
</tbody>
</table>

Spring grade rubric

Prototype Project Grades

<table>
<thead>
<tr>
<th>Preliminary Design</th>
<th>Critical Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Per activity</td>
</tr>
<tr>
<td>Points</td>
<td>Total</td>
</tr>
<tr>
<td>PMP &amp; Contract update</td>
<td>Prototype built</td>
</tr>
<tr>
<td>Per activity</td>
<td>15</td>
</tr>
<tr>
<td>grade</td>
<td>1.5%</td>
</tr>
</tbody>
</table>
Books

Research
• Vibration profiles to improve placement
• Different recycled wastes as aggregate
• Automated placing of reinforcement

Prototype placement and compare compressive strength
Research

- Large steel culverts, partially submerged, corroding, collapsing
- Instrument and automate inspection to avoid visual inspection:
  - After draining ($25,000)
  - Or sending 2 divers (> $400/hr for 2 days)

Easily used by DOT personnel
ARL-Harnett Co. Illegal Dumping Monitor

- Alert to illegal dumping
- Test and re-develop AI-enabled camera system
  - Camera
  - Solar panel + battery
  - Cell-phone connection
  - All-weather operation
Prototype a tread-clamp for manufacturing skid-steers

Issues
- Cheap
- Easy and fast to use
- Manufacturing

People
- 4 ME
- Test and refine carts and electric tugs

- Issues
  - Ergonomics
  - Battery charging (Li-ion)
  - Cheap
  - Easy and fast to use
  - Manufacturing

- People
  - 3 ME
  - 1EE
Test and prototype a ToF camera
  • Custom & proprietary
  • Cheap
  • Does not need all capabilities

Tough problem
  • 2 ME
  • 2 EE
Test and prototype coatings to protect doors in salt environment

- Custom & proprietary
- Cheap

Estimated team

- 1 ME
- 2 ChE
Small facility (2 clean rooms + equipment) to deactivate potential viruses in plasma donations from COVID survivors. The plasma would then be used to treat COVID patients.

- whitepaper
- 3 ChEs
Canvas and survey CU students to find a need

Prototype a kiosk
- 2 EEs
- 2 Mes
- Business/Entrepreneur students
NAVAIR Tailboom Alignment

• Test helicopter boom shaft alignment
• Needs new instrumentation