CAMPBELL UNIVERSITY
SCHOOL OF ENGINEERING

Campbell University: Senior Design and Systems Engineering

March 2, 2024

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

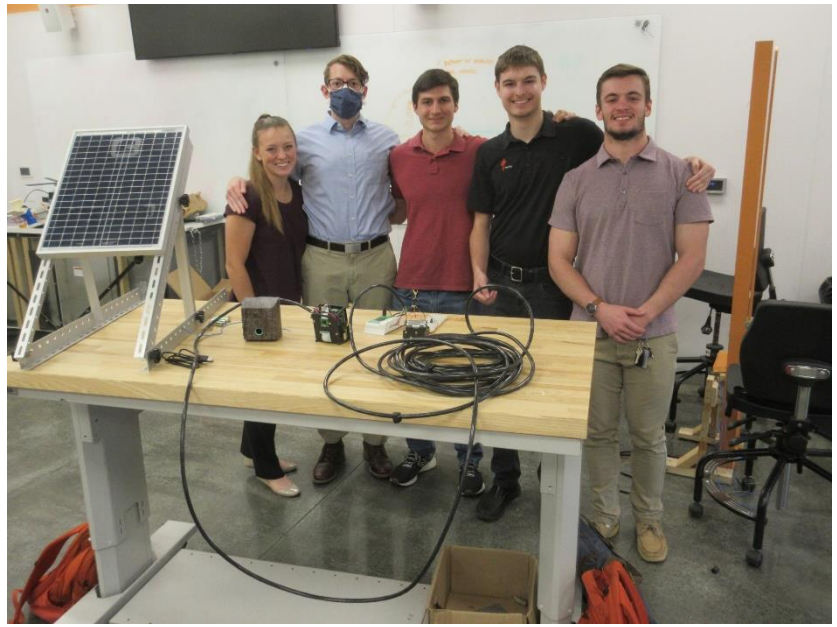
- Two-semester, 8-month long projects
- Integrate knowledge from previous courses
- Topics:
  1. Communications
     - Verbal, technical presentations
     - Writing documentation
  2. Business and legal aspects
  3. Systems engineering
  4. Ethics
  5. Design and development + project
     - Combine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

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

Projects - Assignment

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

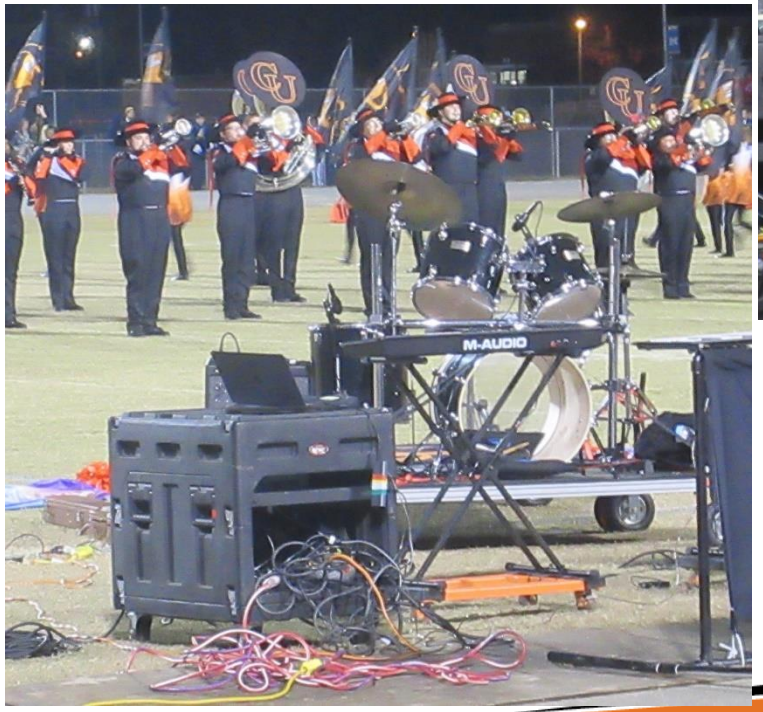
Team visits Fire Scout at Patuxent River Naval Air Station with sponsor

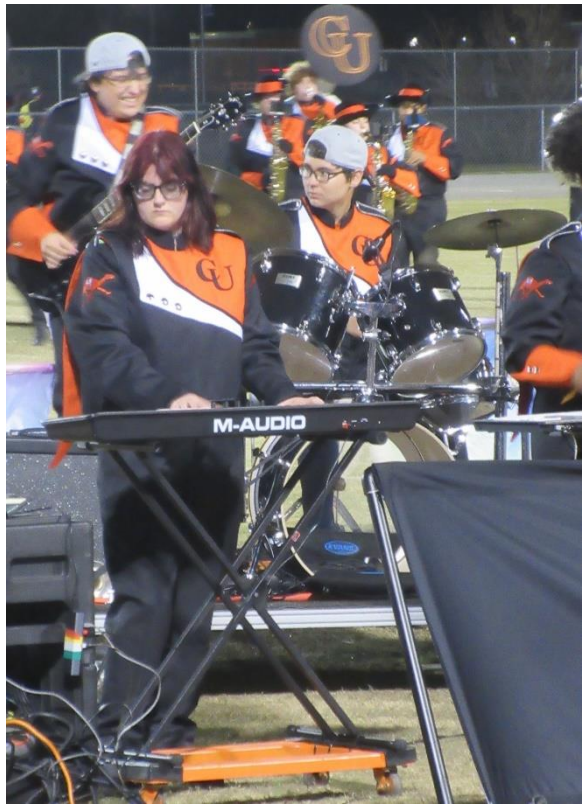
First Things First

- 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

- 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

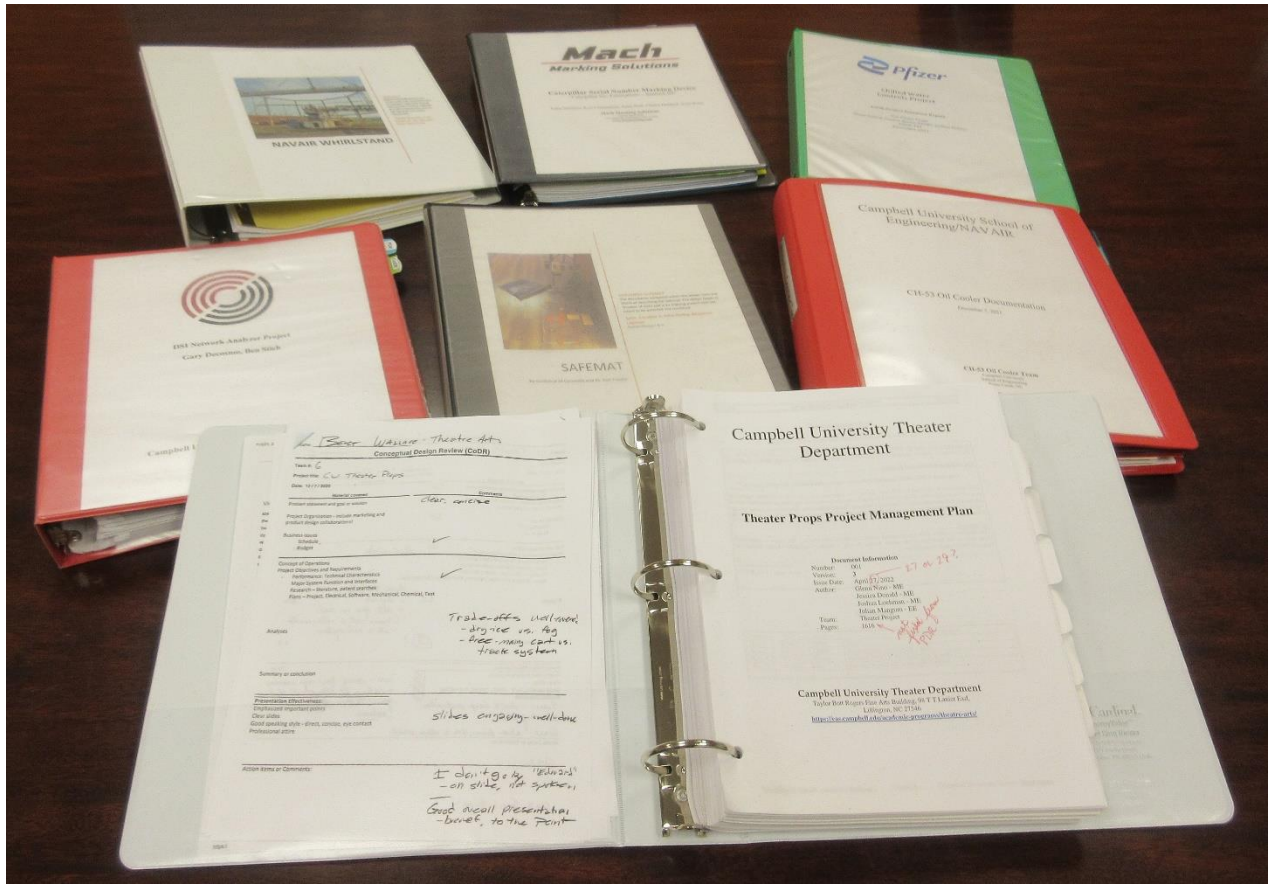
Project Organization

- 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

Documentation

- 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



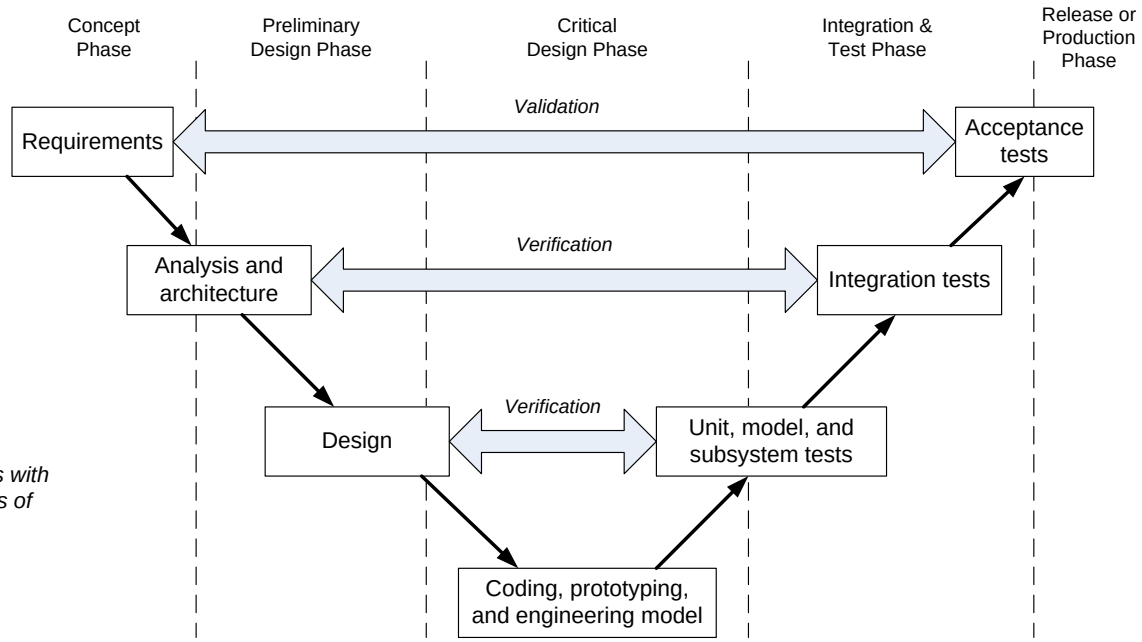
Sampling of 7 different team document binders

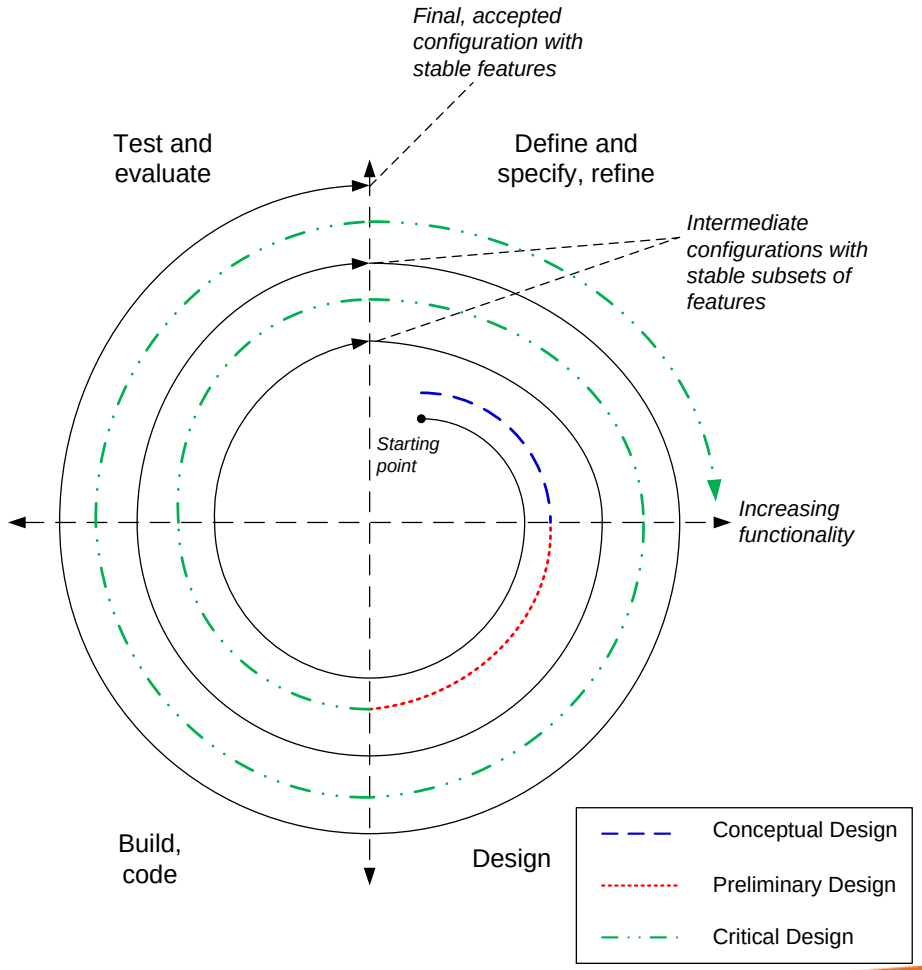
Requirements and Standards

- 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



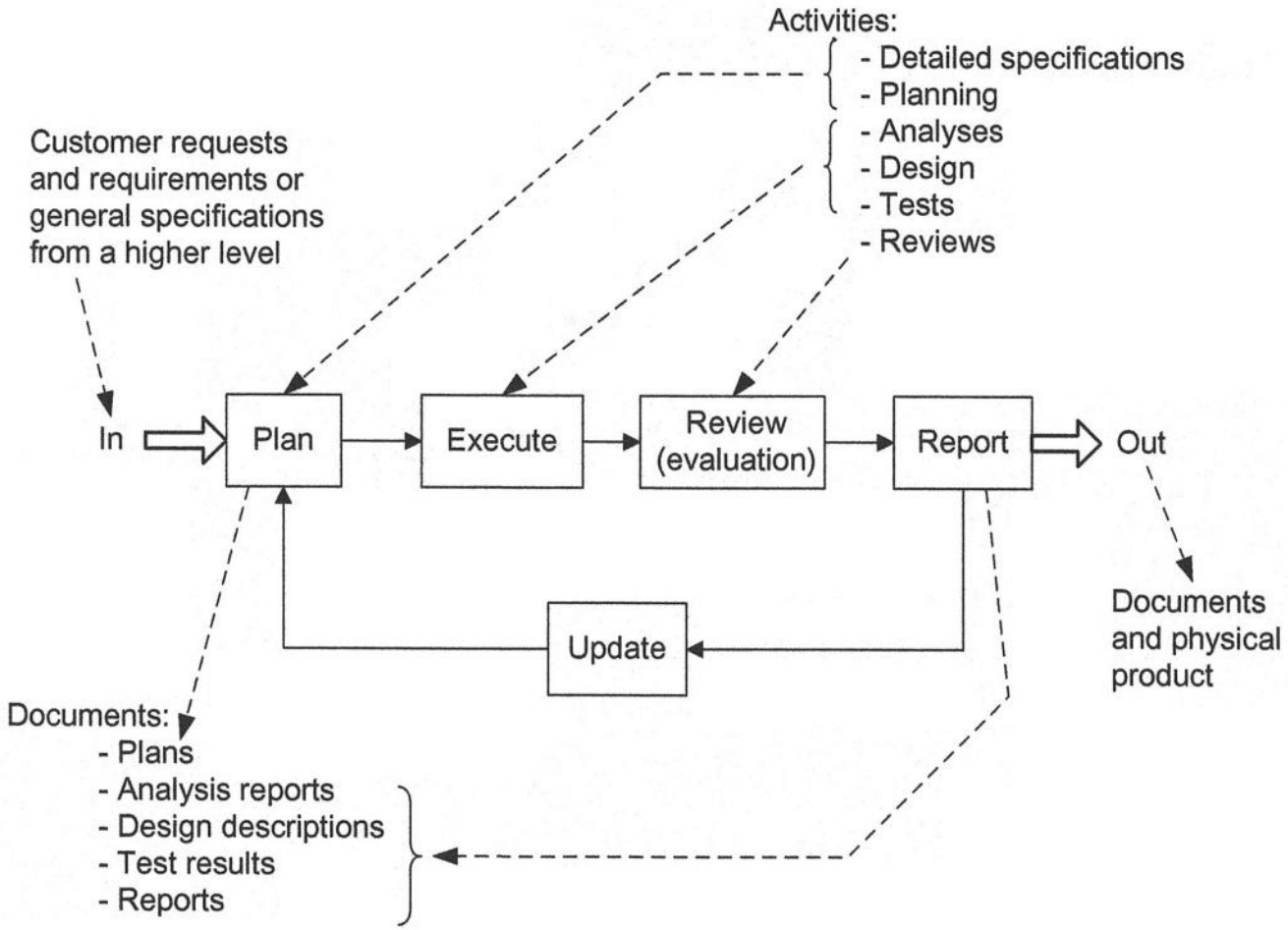


Design and Decisions

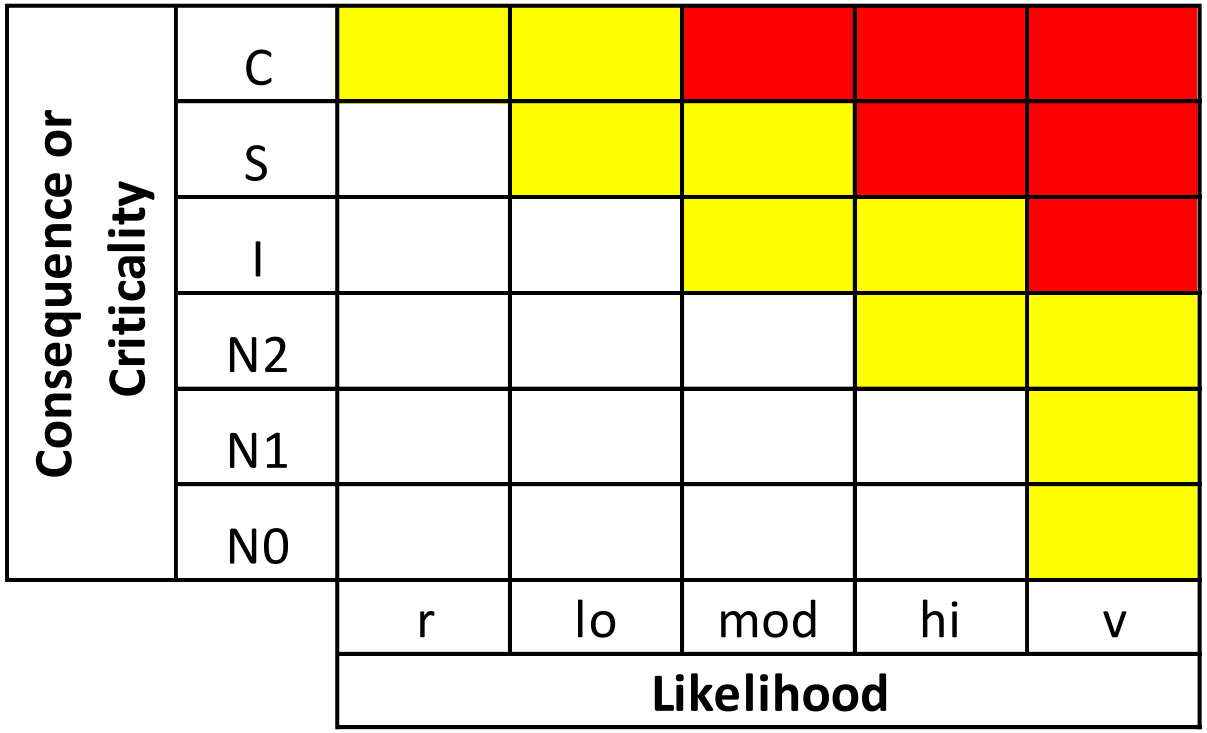
- Rapid prototyping
- Iterative
- Decision
  - Decision matrices
  - Discussions with sponsors
  - Discussions with other stakeholders

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



Severity Matrix

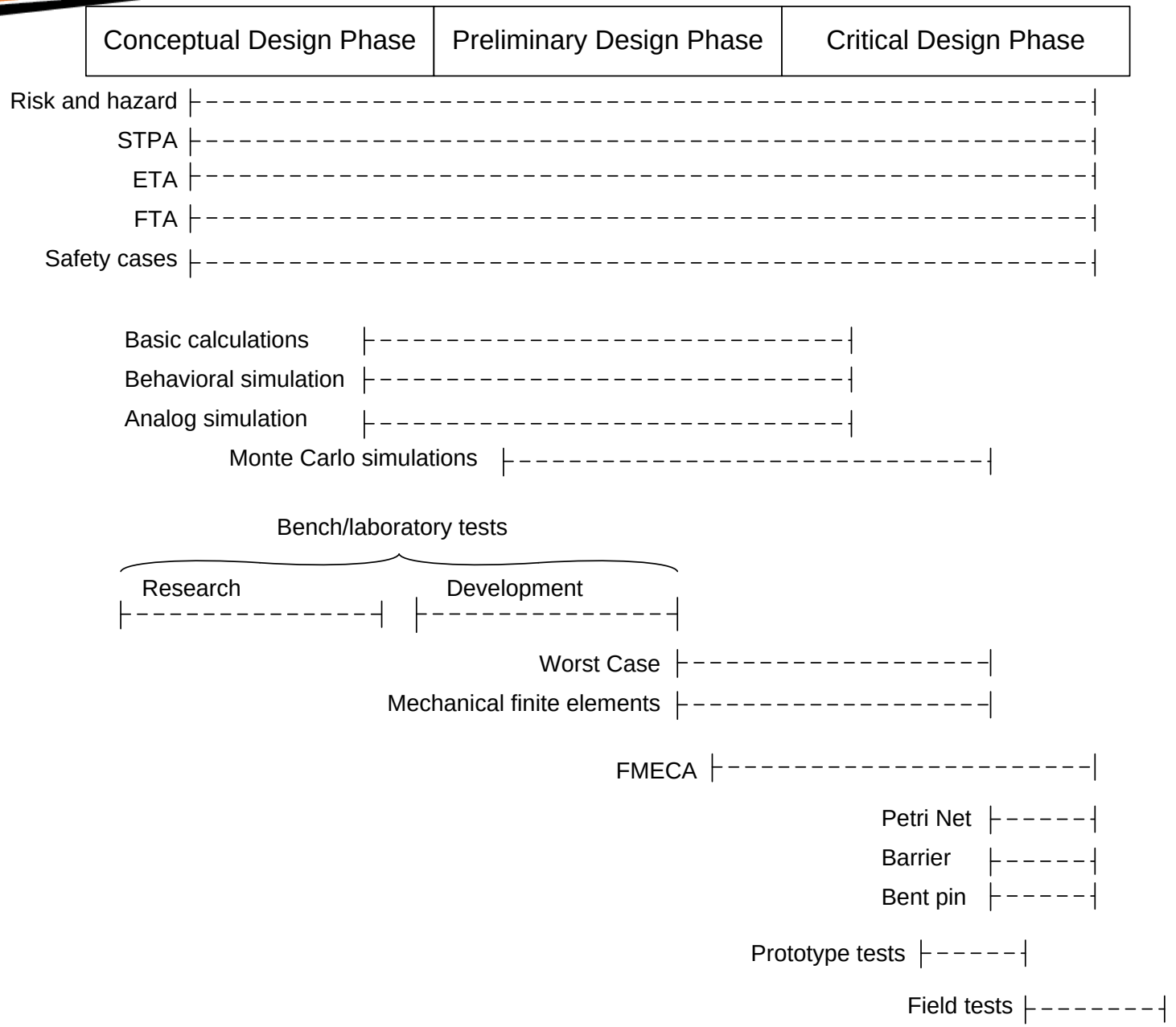


fix first, track in the management database

fix, track in the management database

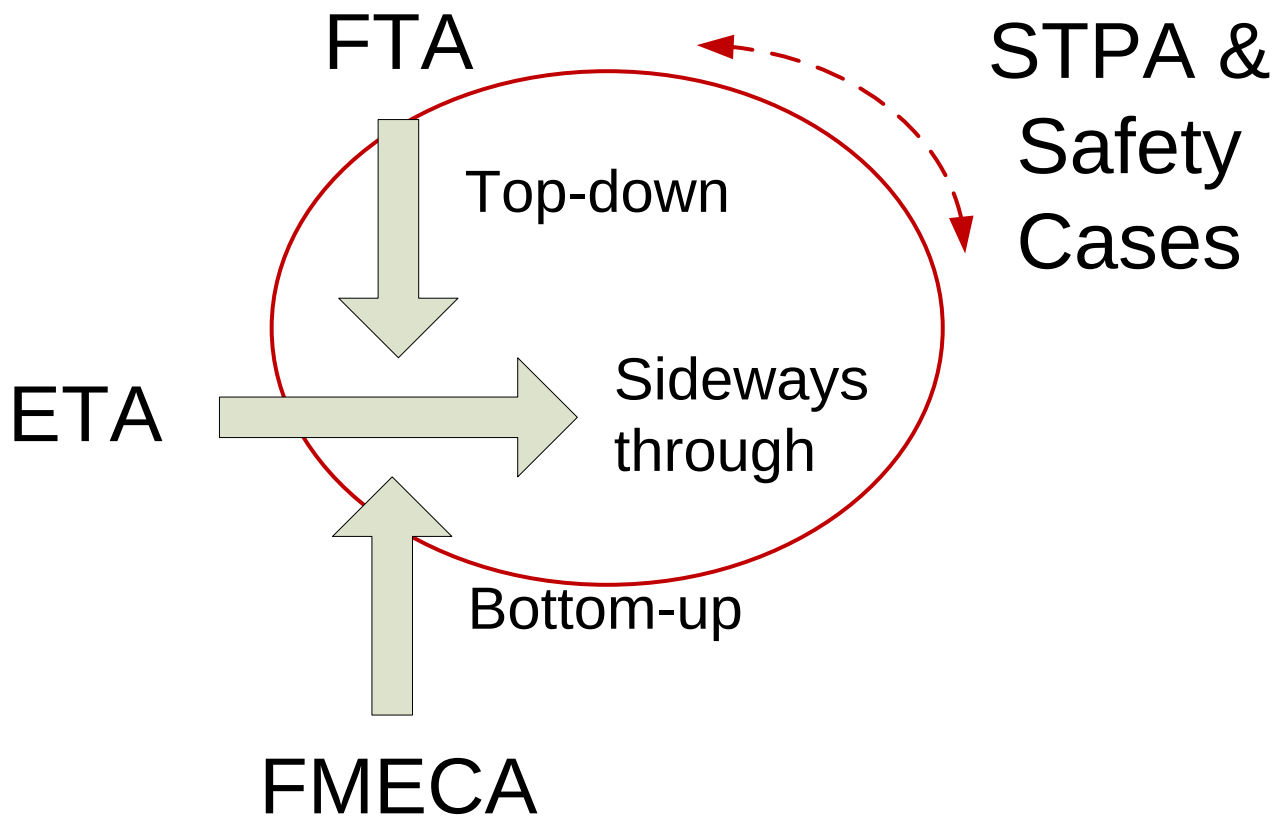
track in the management database at the discretion of the program manager

When to Analyze?

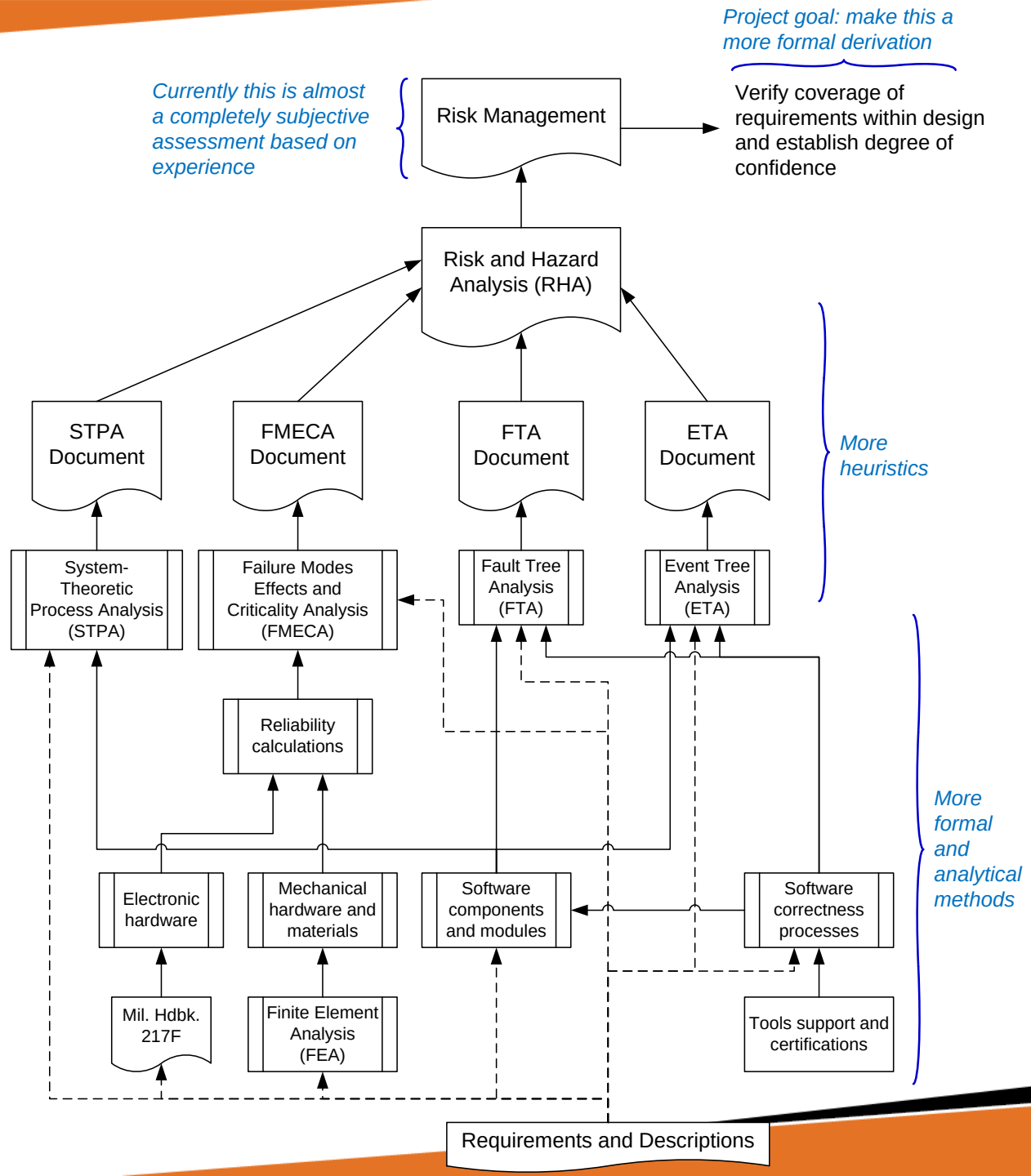


Types of Analyses

- 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



Hazard Analysis (HA)

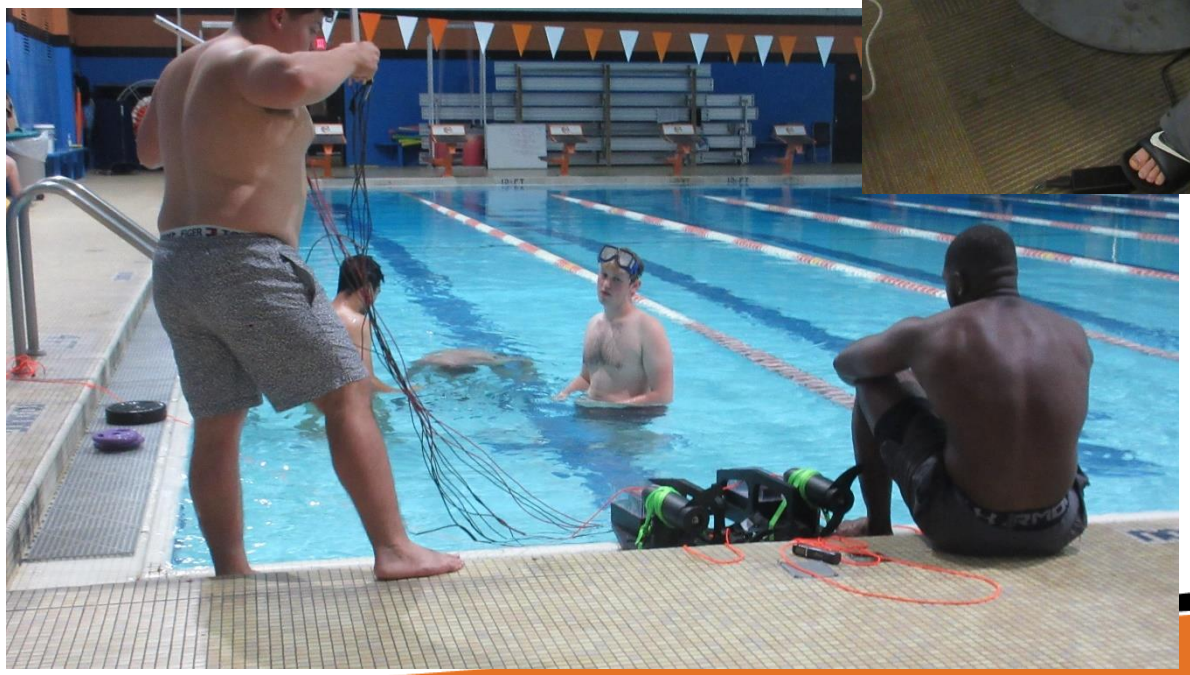


Review, QA

- 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

Test and Integration

- 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

Some Issues

- 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

Curriculum

- 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

Distinctives

- 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

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

- Spring

	Document or Demonstration or Presentation	Date due	Grade points
Spring Semester 2023	contract	Feb. 2, 2023	25
	Demonstrate complete and functional prototype	Mar. 23, 2023	45
	PDR Presentation	Mar. 2, 2023	100
	Previous documents updated + draft Design Descriptions + draft User Manual	Mar. 2, 2023	175
	deliver field test results	Apr. 20, 2023	60
	CDR Presentation	Apr. 24, 2023	100
	Deliver all documents + Debrief memo + electronic files + scrapbook	Apr. 28, 2023	195

Peer Review form

Team Name or Sponsor: _____

Performance Reviews: Reviewer _____

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 - "

	Always	Usually	Sometimes	Seldom	Never
1. timely to meetings:	◯	◯	◯	◯	◯
2. timely in communications:	◯	◯	◯	◯	◯
3. timely in completing tasks:	◯	◯	◯	◯	◯
4. an initiator, left nothing out:	◯	◯	◯	◯	◯

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

Always	Usually	Sometimes	Seldom	Never
◯	◯	◯	◯	◯

Describe the title and responsibilities of this team member:

Describe in your own words how well this person performed:

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 - "

	Always	Usually	Sometimes	Seldom	Never
1. timely to meetings:	◯	◯	◯	◯	◯
2. timely in communications:	◯	◯	◯	◯	◯
3. timely in completing tasks:	◯	◯	◯	◯	◯
4. an initiator, left nothing out:	◯	◯	◯	◯	◯

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

Always	Usually	Sometimes	Seldom	Never
◯	◯	◯	◯	◯

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

	Individual grades					Team grades									
						Contract, draft documents, and bench test demonstrations are all or none grades									
Points	7 Speech exercises	Thank you note	10 quizzes	Final Exam	Team Peer Review	Draft PMP & contract	Amended PMP & contract	CONOPs draft	Require-ments draft	of Analyses draft	Test Plan draft	Demo bench tests	CoDR pres.	CoDR doc.	Total
Per activity	10	30	10	100	250	25	25	25	25	25	25	70	100	130	
Total	70	30	100	100	250	25	25	25	25	25	25	70	100	130	1000
grade	7%	3%	10%	10%	25%	2.5%	2.5%	3%	2.5%	2.5%	2.5%	7%	10%	13%	100%

- Spring grade rubric

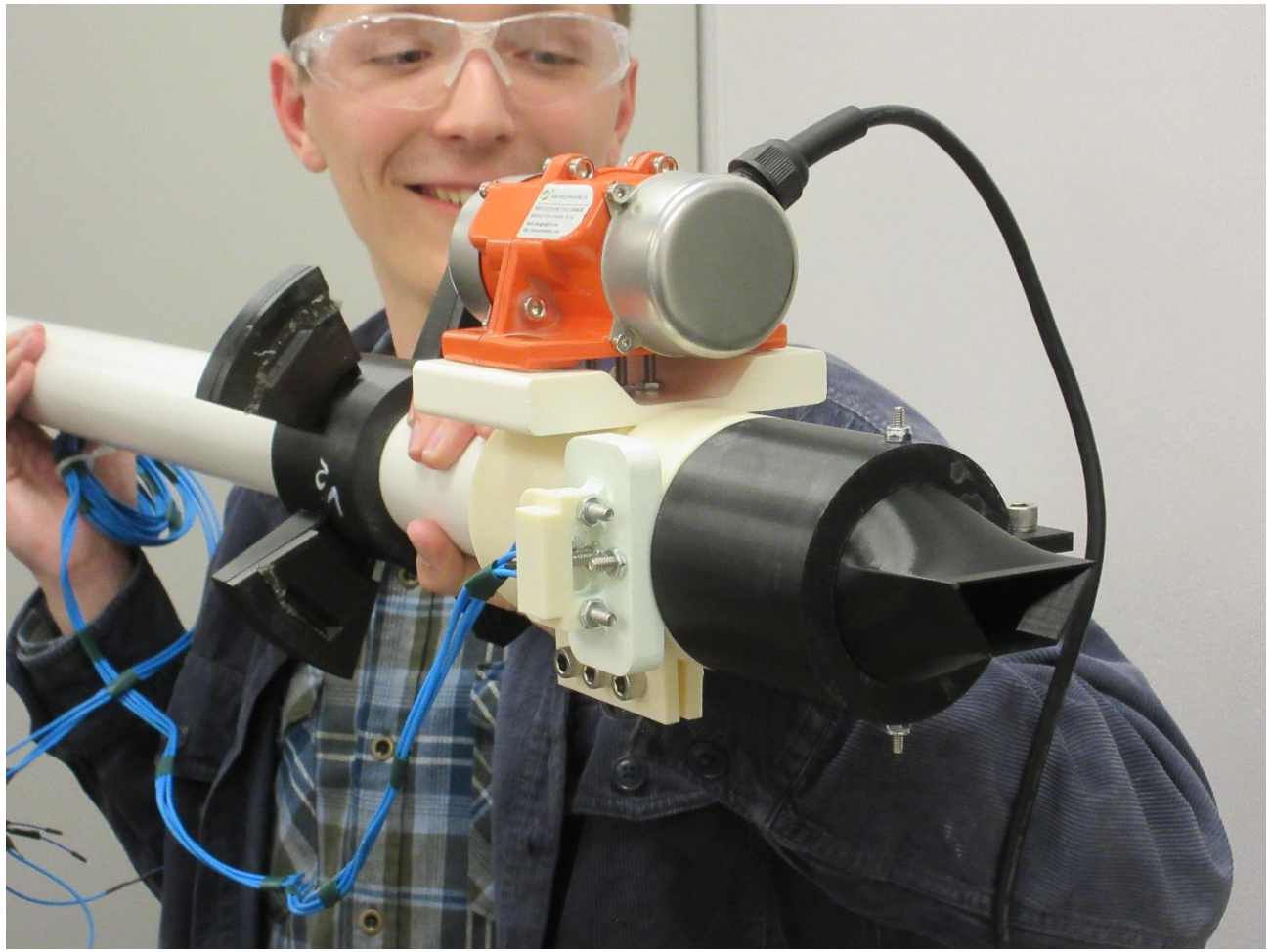
		Preliminary Design			Critical Design					
Points	**PMP & Contract update**	**Proto-type built**	**Present-ation**	**Doc.**	**Test Demo**	**Present-ation**	**Doc.**	**Photo Scrap-book**	**Team Review**	**Total**
Per activity	**15**	**35**	**100**	**175**	**60**	**100**	**195**	**20**	**300**	**1000**
grade	1.5%	3.5%	10.0%	17.5%	6.0%	10.0%	19.5%	2.0%	30%	100%

Books

- **"Giving Presentations**," Harvard Business School Press, 2007.
- **"Negotiating Outcomes**," Harvard Business School Press, 2007.
- **"Running Meetings**," Harvard Business School Press, 2006.
- **"Integrity: The Courage to Meet the Demands of Reality,"** by Dr. Henry Cloud, Collins and imprint of HarperCollinsPublishers, 2006.
- **"Developing and Managing Embedded Systems and Products,"** by Fowler and Silver, Elsevier, 2015.

3D Concrete Printing

- Research
  - Vibration profiles to improve placement
  - Different recycled wastes as aggregate
  - Automated placing of reinforcement
- Prototype placement and compare compressive strength

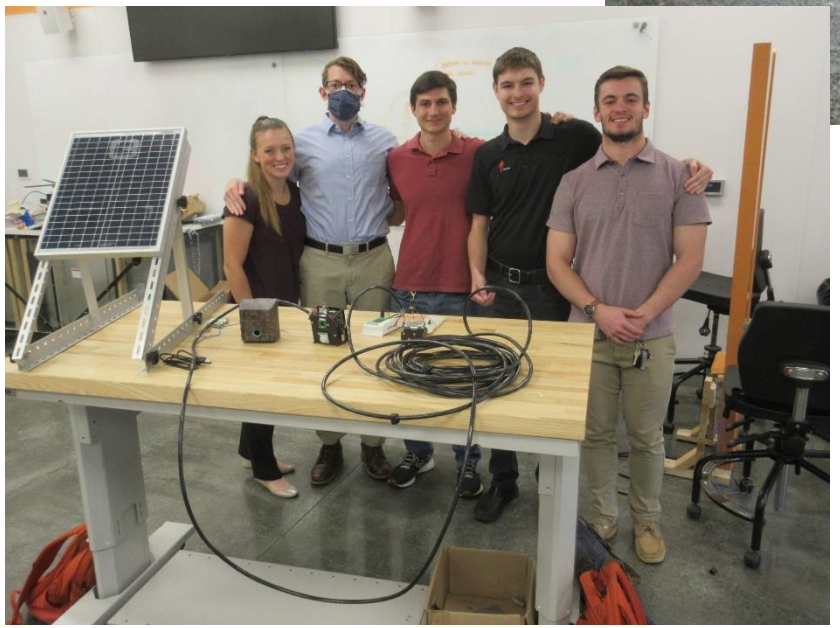


Steel Culvert Inspection

- 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

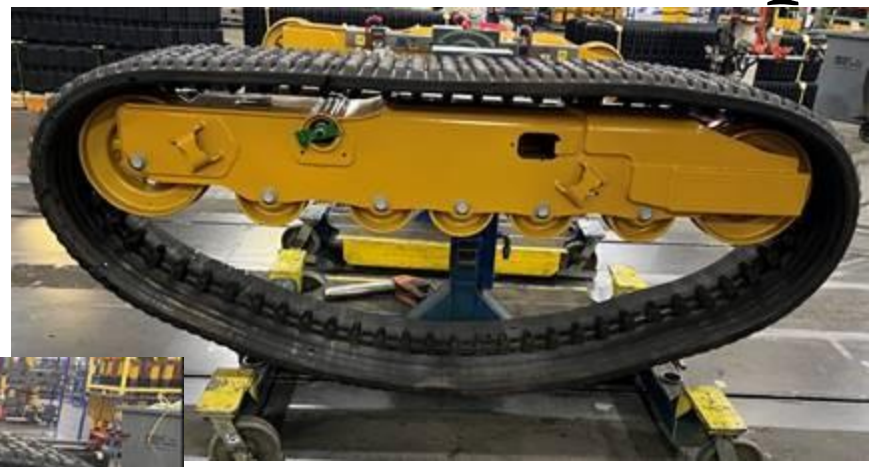
ARL-Harnett Co. Illegal Dumping Monitor

- Alert to illegal dumping
- Test and re-develop AI-enabled camera system
  - Camera
  - Solar panel + battery
  - Cell-phone connection
  - All-weather operation



Caterpillar: Tread Clamp

- Prototype a tread-clamp for manufacturing skid-steers
- Issues
  - Cheap
  - Easy and fast to use
  - Manufacturing
- People
  - 4 ME



CU Bandwagon

- Test and refine carts and electric tugs
- Issues
  - Ergonomics
  - Battery charging (Li-ion)
  - Cheap
  - Easy and fast to use
  - Manufacturing
- People
  - 3 ME
  - 1EE

Boon Edam: Project Erebus

- Test and prototype a ToF camera
  - Custom & proprietary
  - Cheap
  - Does not need all capabilities
- Tough problem
  - 2 ME
  - 2 EE

Boon Edam: Corrosion Coating

- Test and prototype coatings to protect doors in salt environment
  - Custom & proprietary
  - Cheap
- Estimated team
  - 1 ME
  - 2 ChE

Grifols: Facility

- 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

Meridian: CU Kiosk Prototype

- Canvas and survey CU students to find a need
- Prototype a kiosk
  - 2 EEs
  - 2 Mes
  - Business/Entrepreneur students

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NAVAIR Tailboom Alignment

- Test helicopter boom shaft alignment
- Needs new instrumentation