ECE180DA (Winter 2025)

Systems Design I

Lecture 1: Getting started

January 7, 2025

Today's agenda

My history

- PhD research in:
  - MEMS process development, devices, and systems
  - Micro autonomous air vehicles localization and control
  - Wireless communications protocols and hardware
- Postdoctoral research in:
  - Integrated robotic design and design automation
  - Functional specification of robotics
  - Robotics for education
- Other interests:
  - Ultimate frisbee, roller skating
  - Puzzle hunts, board games, elementary school art

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The Laboratory for Embedded Machines and Ubiquitous Robotics

LEMUR

https://uclalemur.com

- Overarching research interests:
  - How do we enable robots everywhere?
  - What can we do once we have that?
- Projects:
  - Democratization of engineering
  - Accessible printable robots
  - Mechanical intelligence
  - Distributed state estimation, localization, mapping
  - Robotics for education and art

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About your TA

Anwesha Chattoraj

4th-year PhD student (ECE department)

Research interests: Modelling the nonlinear dynamics of soft robots, in particular membrane based actuators

Things I like to do in my free time: read, swim/run, salsa, and collect random hobbies

About you

Tell us who you are! Due **this Thursday** (two days from now!) at **11am**:

- Public introduction slides
  - One slide about you personally
  - Two possible final project ideas driven by your personal interests
  - Upload PDF slides to Bruinlearn
  - Will be presented live during Thursday's class

Today's agenda

1. About us
2. About this course
3. Design as a core principle
4. Course organization

ECE180: Systems Design

- This class is about **design**:
  - Planning
  - Analysis
  - Validation
  - Communication

- This class is (mostly) **not**:
  - Hacking
  - Book problems
  - Product development

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Goals of this class

In decreasing order of impact:

- Learn the **design process**, i.e. how to successfully plan, execute, and present a meaningful engineering project
- Learn tools and skills relevant to project management
- Reinforce engineering skills learned from your past classes
- Learn tools and skills relevant to integrated systems

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ABET goals

- An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- An ability to communicate effectively with a range of audiences
- An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Schedule and structure

- 4 unit class = 12 hrs commitment per week
- Winter term
  - In-class lectures, lab activities, project presentations: 6 hrs
  - Additional commitments: ~6 hrs
    - Lab and project work & planning
    - Self directed study
    - Communication
- Spring term
  - Final project execution: ~10 hr
  - Meeting with staff: ~0.5 hr
    - Both scheduled and ad-hoc "board meetings"
    - Weekly progress reports presented to the class
  - Peer assessment: ~1.5 hr

Schedule and structure

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Lectures

- In-class lectures
  - Deliverables (design reviews)
  - Design process and mindset
  - Guest lectures?
- Auxilliary lecture videos
  - Engineering and society ("guest lecture")
  - How to present
  - Formal design / design for debugging
- Supplementary reference videos
  - Detailed design lectures

Videos are available on our course website:

- https://capstone.uclalemur.com

All project assignments are available right now on our course git server:

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Suggested pacing given there, feel free to peek ahead

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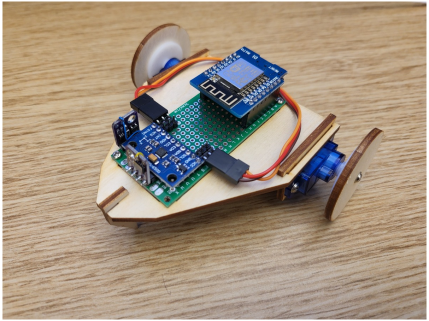
Mini-project lab

- Minimal subproblem selected from project plan
  - Make a simple design decision, with known/easily discoverable dependencies
  - Develop experiments to support design process
  - Explore variety of modeling / prototyping tools
    - Analytical computation
    - Simulation
    - Physical experiments
- Lab objectives:
  - Optimize design process steps
  - Establish good project management habits
  - Accurately schedule upcoming project plan



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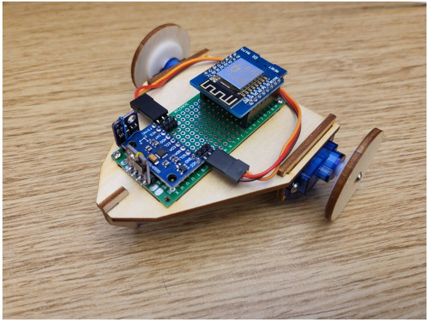

Final project

- Formulate, design, justify, evaluate, and present an engineered system solution for a real-world problem
- Open-ended definition but must include:
  - Computation for processing / intelligence
  - Physical embodiment
  - System integration to address application needs
  - Quantitative evaluations and comparative analysis
  - Impact assessment
- **Problem selection and definition is the core objective of 180DA**

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Course communication

Three main sites to keep in mind:

- Class website: https://capstone.uclalemur.com
- Bruinlearn: https://bruinlearn.ucla.edu/courses/199210
- Gitlab repository: https://git.capstone.uclalemur.edu

Everything official from us will be handled via these websites:

- Announcements
- Handouts
- Assignments

Make sure your email address is correct, and check email regularly.

High level notes

- This class is a bridge between student life and an engineering career
- We want your experience to be valuable and enjoyable
- Feedback is encouraged and always welcome
- This class is likely to evolve over the course of the year

Questions?

Any questions on the administrivia?

Today's agenda

Not design: Coursework

- Problem set
  - **Given**: tool, problem
  - **Do**: apply tool to problem
  - **Goal**: answer to problem
- Exam
  - **Given**: collection of tools, problem
  - **Do**: choose appropriate tool, apply to problem
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- Fundamental question:
  - Here's a problem, **how** do you solve it?

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Design

- Fundamental questions:
  - **What** is a problem worth solving?
  - **Why** would a solution be meaningful?
- Design
  - **Given**: real world (universe of tools, universe of problems)
  - **Do**: identify requirements, capabilities, and dependencies of problems and tools
  - **Goal**: validate optimality of problem + tool combination

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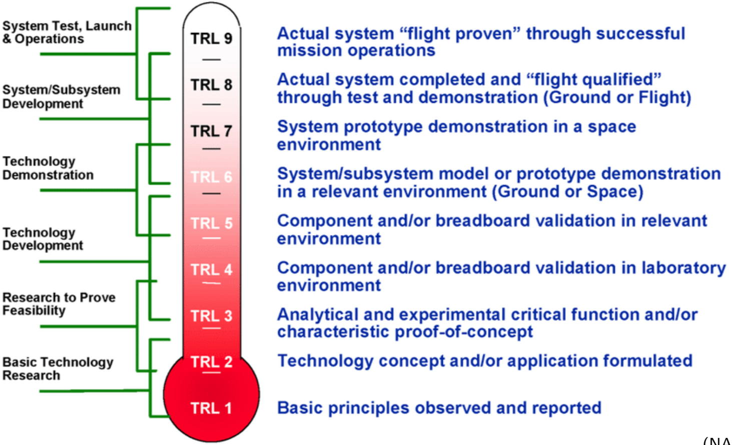
Design process metric: Technology Readiness Level (TRL)



(NASA / source unknown)

Also not design (*)

- Product development (TRL 7+)
    - **Given**: validated design (plan)
    - **Do**: implement the solution according to the plan
    - **Goal**: complete functional product
- Hacking
    - **Given**: tools
    - **Do**: implement and apply tools
    - **Goal**: answer to a problem? experience, intuition, new ideas

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Solving real-world problems

technologies $\rightarrow$ **solution** $\rightarrow$ **application** := project

The design process ensures that the **best** technologies are engineered in the **best** way to address the **best** problem.

... and optimizes resource usage along the way

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Validation

- What constitutes support that a problem is “best”?
  - Market research
  - User interviews
  - Experimentation / analysis
  - ...
- What constitutes support that technologies and assemblies are “best”?
  - Industrial / academic research
  - Modeling / simulation
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Comparative analysis

Isolated evaluations are not enough

- Identify candidates and alternatives
- Determine the metric / figure of merit (FOM)
- Select evaluation methods
  - Literature search
  - Analysis
  - Prototyping
- Execute the method to **validate** a choice based on FOM

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Potential pitfalls

- Don't assume the answer going in
  - Evaluate to **eliminate**, not justify—Don't stop when you've found supporting evidence, only stop once you've exhausted all possible counterpoints.
- **Process** is more important than product
  - Minimum effort for maximum value (as defined by validity of FOM justification)
  - In particular, don't build what you don't have to
- Leave any preconceived expectations at the door
- If you don't **analyze and validate** your choice of technologies, solution, and application, you're going to have a bad time.

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Why design?

Potential **failure**

- Inappropriate application
  - Google glass: Pervasive (wearable) vision-based computing
- Inappropriate technology
  - Nintendo Virtual Boy: Monochrome stereo-vision display
- Inappropriate matching of technology to application
  - Kodak (eventually): Light sensitive film for personal photography
- Inappropriate solution integration
  - Blackberry: pocket computer for personal computing via keypad

https://www.pbs.org

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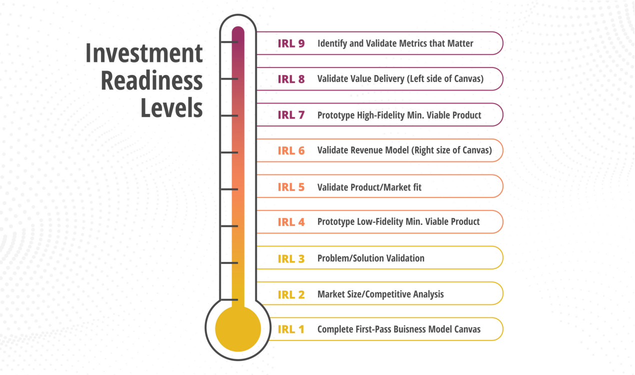
Tech startup

- Acquire funding to move up the TRL ladder
- Justify investment via extensive planning
- Results are generated to validate **process**
- Prove value of engineering team



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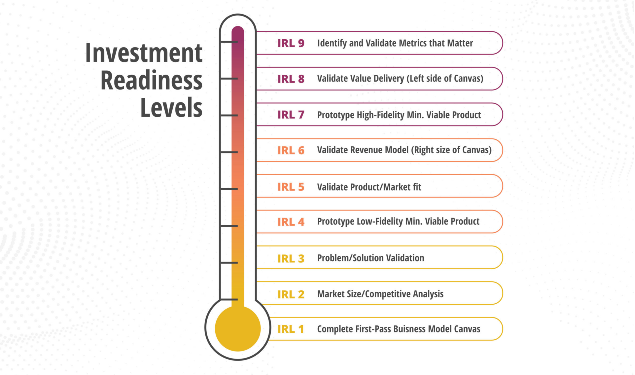

(https://gongos.com)

Funding roadmap

(https://licens.io)

Today's agenda

1. About us
2. About this course
3. Design as a core principle
4. Course organization

Progress milestones

- Align course objectives with design process / TRL metrics
- Periodic deliverables
  - Scoping, design reviews, plans, milestones
- Endpoint deliverables
  - Artifacts, demonstrations, presentations, writeups
- Mimic tech startup

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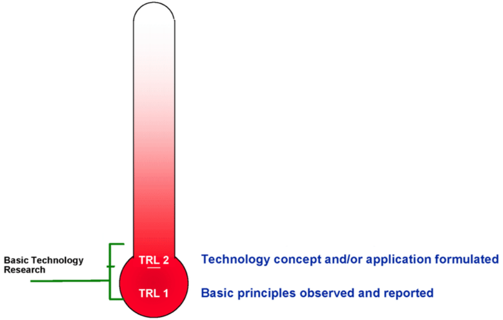
Project deliverables: Brainstorming

Goal: Explore, formulate, and **justify** project ideas

- **P0**: Individual: build team of like interest, complementary skills
  - Due Thursday in your introduction presentation
- **P1**: Team: get feedback to minimize unexpected challenges and maximize success
  - Starts next week



Brainstorming seeds

- Initial ideas:
  - Top-down application with multiple technology options
    - Traditional design flow
  - Bottom-up technology with multiple application options
    - "Silicon valley" design flow
  - Both directions will end up in the same place
    - **technologies** $\rightarrow$ **solution** $\rightarrow$ **application**

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Top-down brainstorming

- **Application** pull, e.g.:
  - Netflix: Pain point = late fees for movie rentals
    - Technology option 1: DVDs by mail
    - Technology option 2: streaming downloads
  - Early Uber: Pain point = interaction with taxi drivers
    - Technology option 1: app-mediated taxi hailing
    - Technology option 2: ridesharing

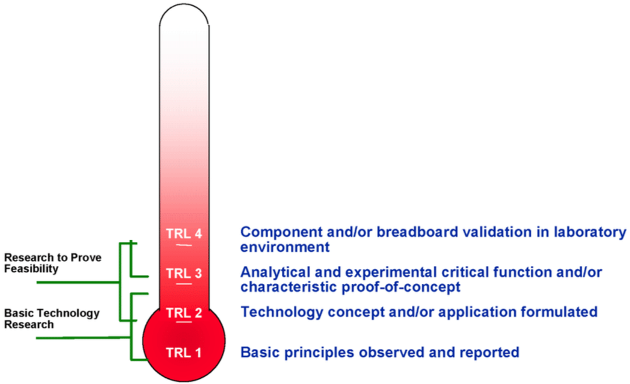
Bottom-up brainstorming

- **Technology** push, e.g.:
    - Amazon: Technology = scaleable computation
        - Application option 1: product recommendations
        - Application option 2: cloud compute services
    - Recent Uber: Technology = gig workers
        - Application option 1: ridesharing
        - Application option 2: food delivery

Project deliverables: Pre-planning

Goal: Define and **justify** a specific project scope

- **P2**: Background research, sources for data
- **P3**: One technology and application, with multiple pathways
- **P4**: Requirements Review (RR) / System Design Review (SDR)



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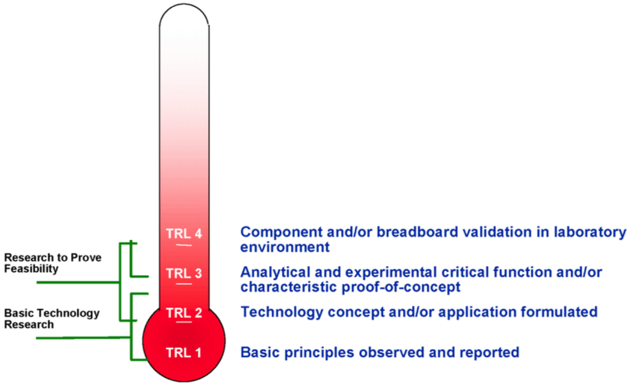

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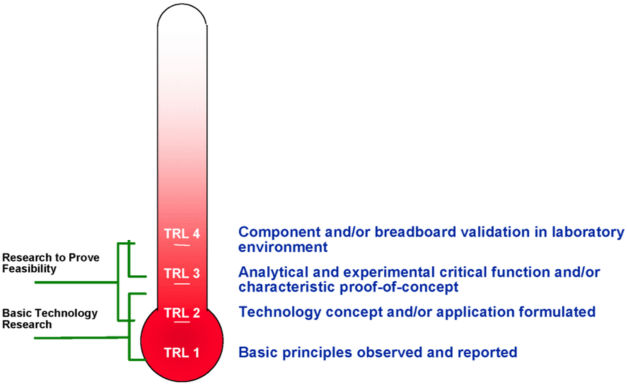

Project pathways

- **technologies** $\rightarrow$ **solution** $\rightarrow$ **application**
- Solution will have multiple subsystem options
- E.g. Uber: gig workers for ridesharing
  - Build app to connect to connect passengers to drivers
  - Learn models of passenger distribution to command driver patrol routes
- By **P4**:
  - Identify all necessary subsystems (**justify** design choices)
  - Understand available design decisions (subsystem parameters)
  - Identify interactions between subsystems
  - Characterize unknowns, action items, and risk

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Project milestone: Shark tank VC pitch

P5 Goal: Externally **validate** your preliminary justifications

- Explain to potential investors:
  - Project scope (technology, application, and pathways)
  - Resource allocation
    - Time
    - Personnel
  - Expected deliverables
  - Risk/reward analysis

- Initial investments reflect:
  - potential value of solution
  - thoroughness of pre-planning process

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  - Expected deliverables
  - Risk/reward analysis

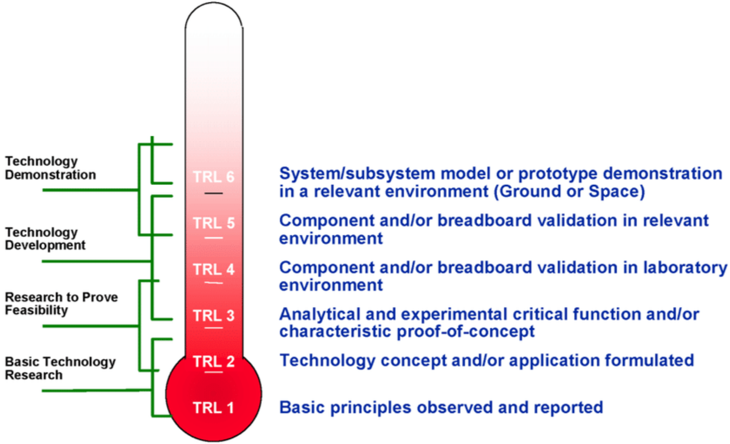
- Initial investments reflect:
  - potential value of solution
  - thoroughness of pre-planning process

Project deliverables: Planning

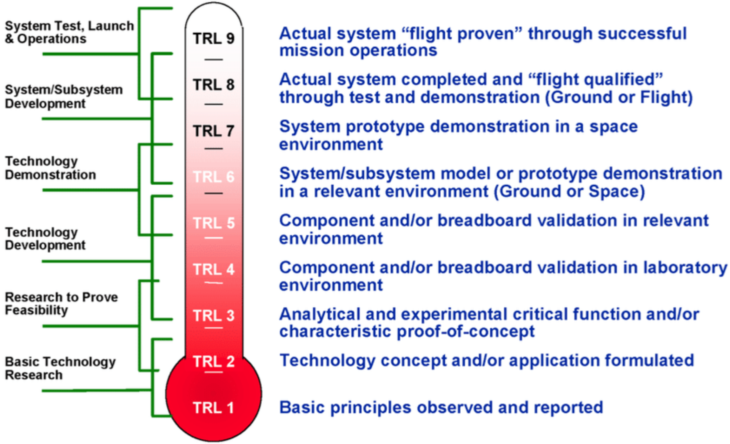
P6 Goal: Ensure successful project completion

- Preliminary Design Review (PDR) / Test Readiness Review (TRR)
  - Resolve most impactful unknowns
  - Mitigate most significant risks
  - Decompose project (hierarchically) into individual atomic tasks
  - Allocate / schedule all tasks and all resources
  - Ensure that dependencies are identified and accomodated
  - Manage internal and external uncertainty
  - Define incremental success criteria

Planning endpoint



Final outcome: TRL 7+ justification



Project planning goals – q1

- Achievable
  - Meet weekly deliverables and final goals
  - Culminate in interactive demo(s)
  - **Justify** final design
- Impactful
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  - Engineer for social / societal good
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Project deliverables: Weekly execution – q2

Goal: Ensure regular progress and allow course correction

- Progress update
  - Comparison of current status to PDR plan
    - Mitigation strategy for shortfalls
  - Refinement of future tasks
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  - Sales pitch for product / results
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- The important contribution is the **process**; generating and analyzing results is necessary to **validate** the process
- Answer the What, How, Why of the results:
  - **What** did you accomplish?
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  - **Why** that way?
- . . . and again for the process:
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Questions

Any questions on course and project expectations?

Next up

- Due before the start of this Thursday's class:
  - Introduction slides
- Thursday class:
  - Introductions, meet-and-greet, project team formation
- Due before the start of next Monday's class:
  - Video lecture A1 (engineering and society)