ME 370 Fall 2025: Project 2

Project Overview

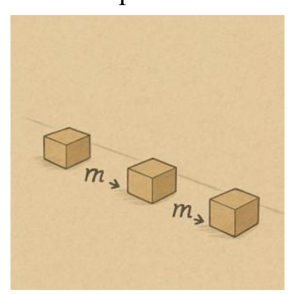
As campus life grows more dynamic, the need for efficient delivery systems is becoming increasingly important. From package **drop-off in dorms**, to **delivering lab supplies across departments**, to dispensing **medication at McKinley Health** Center, the University of Illinois faces challenges like those being solved worldwide by delivery, medical, military and service robotics.

To address this, campus management has approached the ME 370 class with a design challenge: create a scaled prototype (about 1/10 scale) of a legged dispensing robot that can travel down hallways and deliver items on demand. This design must demonstrate decoupled operation—dispensing and movement must be able to occur independently.

The task is to design and build a dispensing robot that will **travel down a building hallway**, **store multiple payloads**, and **release them in sequence at controlled times**. Teams have the freedom to decide what their robot dispenses, within the specified payload constraints (size, weight, and number of items).

In addition to meeting these technical requirements, the **objective is also to discover, define, and meet the requirements of an identified user case**. This means teams must select a realistic context—such as dormitory package delivery, lab supply distribution, or medication dispensing at a health center—and demonstrate that their robot design addresses the needs, constraints, and expectations of that chosen scenario.

To accommodate most campus requirements, the design should be efficient, use as few components as possible, and be optimized for rapid movement and stability.



To help guide the process, the project will be divided into two stages:

- Project 1 – Stationary Manual Dispensing & Timing Mechanism
- Project 2 – Dispensing Legged Robot

Project 2 - Dispensing Legged Robot

Functional Requirements

- The robot must travel in a straight line down a hallway for 10 m with a speed of at least 4m/min on average.
- The robot must complete a cycle every 2 m of walking and while simultaneously dispensing exactly one object from its storage bin.
- The dispenser should hold at least 5 objects to be dispensed, each weighing 25 g or less.
- The design should be fully mechanical, with all mechanism actions (walking, dispensing) driven by a single motor. The motor will be continuously running throughout the journey down the hallway. Thus, it must be fully autonomous, with no external control (i.e., open loop control, so turn it on and let it go). No human input other than loading objects at the beginning of the sequence.

- Teams should remember that stability is strongly correlated with the height of the center of mass, i.e., taller means less stable, unless your vehicle is weighed down by a ballast.
- The robot should be stable, without spilling or dropping its payload, or tipping over through the entire cycle.
- To allow us to see the inner workings of your mechanisms, at least one side of the mechanism cannot be fully enclosed by an opaque material (e.g., no fully 3D printed or wood enclosure, make one side open, capable of being opened, or from acrylic).
- Nothing can be added to the hallway (e.g., no rails, tracks or poles).
- Teams must carefully design and plan for their payload in accordance with the identified user group. The payload and dispensing robot should have a theme to align with the user group.
- Creativity, aesthetics, and human-centered design must be incorporated into the project. Teams will be evaluated on how well functional requirements are met, the simplicity of the design, the creativity of the theme, and how specific design choices enhance or detract from the intended user experience.

Physical Requirements

Overall Robot:

- When integrated with the walker, the **entire** robot (frame, legs, dispensing mechanism, and storage) must fit inside a standard shoebox ($18 \times 18 \times 30$ cm^3), in its most compact configuration.
- You will find that mass minimization enhances performance while ensuring that links do not break.
- The walker should be optimized for rapid movement, balance and stability, while considering the chosen theme walker. Teams should think carefully about how to achieve this walking gait and present options during the Concept Design Review. Particularly consider how weight affects speed, center of mass affects balance and stability, foot shape & position affect grip, and motion interacts with theme.
- The robot should be built using rapid prototyping materials and show good craftsmanship. Components bearing loads or transmitting forces must use good engineering practices (using fasteners) and cannot be glued or taped. Recycled or scrap materials (wire, wood, acrylic, etc.) are acceptable, but all items found must be documented in the expense report.

Dispensing Mechanism:

- Gravity-assisted dispensing is allowed, but a mechanism (linkage, gears, cams, belts, etc.) must be used to release the payload.

Walker:

- The robot must use at least two motorized mechanism-based legs or feet.
- Passive (unpowered) wheels or rotating spokes are allowed for stability, but not for locomotion. They cannot be attached to the motor directly or indirectly.
- The leg design can NOT be based on the Theo Jansen Strandbeest leg – we will use the Jansen mechanism as a worked example for analysis later in the semester.
- The walker should be optimized for rapid movement and stability, whilst considering the chosen theme and budget. It is recommended to make the mechanism light and use as few components as possible.

Total Budget:

All projects must be made in a cost-effective manner. For Project 2, teams will be allowed an additional \$50 to spend on materials to purchase in the Innovation Studio. **Please note that you are allowed to use any leftover budget from project 1 on project 2. Furthermore, you may reuse materials from**

project 1 on project 2. The Innovation Studio website has pricing for provided materials in the stockroom (here).

For the final submitted expense report, teams should include:

- Items purchased at the Jackson Innovation Studio stockroom, e.g., acrylic, wood, shafts, collars, filament.
- Manufacturing costs for 3D printing and laser cutting (printing based on volume of the part: \$0.025 per cm^3, cutting based on total cutting length: \$0.001/cm).
- You are welcome to use your personal 3D printer for prototyping; however, please note that teams are only allowed to produce up to 50% of their total budget in parts fabricated outside the Innovation Studio.
- If you choose to print parts on your own equipment, you must still account for the equivalent cost as if those parts had been printed at the Innovation Studio when reporting expenses.
- Anything purchased by the students themselves. No reimbursements are allowed. Student independent purchases should be minimized. If an instructor determines that the use of student's own funds have unfairly advantaged them, they reserve the right to assess a point penalty.
- An estimated cost of any items included that have been "found". These items also include materials available in the "ME 370 cabinet inventory" that can be obtained by consulting your TA. There are many items, including gears, shaft collars, timing belts, D-shafts, barrel nuts, washers, super glue.
- A kit will be provided, including 12 V 34:1 brushed DC motor (Pololu, # 3240), 1.2V NiMH rechargeable batteries (qty = 8) (Pololu, #1003), 8-battery holder (Pololu, #1161), motor mounting hub (Pololu #1081), battery charger with USB-C charging cable (XTAR MC4S), and toggle switch (E-Switch, 100SP1T2B3M1QEH). These are not to be included in your expense report, but should be a part of any bill of materials used. CAD STEP files for these components are available on Pololu.
- You may use freely available materials such as recycled scraps offered for this purpose in maker spaces, but their total value should not exceed 1/2 of the design budget and the team must inform their section's TA of the material use on or before the demo day.

Table 1. Timeline of Deliverables and Grading

Deliverable	Task	Due Date	Points
D1	Conceptual design review	Lab 9 (Oct 22-24)*	10%
D2	Critical design & prototype review	Lab 12 (Nov 12-14)*	20%
D3	Video	Dec 7	10%
	Video presentations (best of sections)	Dec 10 during lecture *	
D4	Final performance	Dec 12 7-10 pm*	25%
D5	Final report	Dec 17	25%
D6	Post-project cleanup & material recycling	By Dec 17 5 pm	10%
D7a,b	Peer Evaluation Multiplier – Individual final project grade will be modified per CATME peer evaluations**	After D2, D5	

* Mandatory attendance

** Reminder that 2% of final course grade is based on Evaluative Assessments (# completed CATME peer evaluations)

Grading: In each review, the instructional team will be looking for the specific items listed in the project descriptions. More detailed rubrics will be given prior to each review and report. These rubrics are designed to ensure that teams consider all the potential pitfalls and requirements in a long-term design project. Extra credit may be available for going above and beyond the minimum requirements. These extra credit points will be indicated in the rubric posted at the start of the design stage. In addition, there will be significant bonuses for the fastest walker, best designed robot, and best video.

Informed Team Members: It is very important that all members of the team be fully briefed on all aspects of the project prior to any review. The instructors should be able to ask any question from any team member and receive fully-informed answers.

5. Project Stages and Deliverables

All aspects of the project listed here, including all reports, are submitted as a team. The specific requirements for the design stages are tentative guides, and are subject to (minor) changes as the project progresses. For each design stage, a more detailed rubric will be provided with requirements.

5.1 Concept Stage

The goal of the first concept stage is to translate the scenario into a set of design requirements and think through a couple of designs that meet those requirements.

(D1) Conceptual Design Review:

- The concept design review will be a presentation during lab with the instructors to go over the proposed designs for your dispensing walker. Attendance is mandatory.
- Present a slide report of your design progress and project concept. Upload to Gradescope.
- Lab will be held in 1001 MEL for this presentation

<u>The slideshow report:</u>

- A presentation template will be provided. Below are general topics to consider for this review.
- Your user group and walker theme.
- Explanation of your ideation process and how it led you to this theme, dispenser, walker, and its gait.
- A list of design specifications considering potential challenges for how to translate the real-life scenario to a working design. Do not repeat the specifications above, instead consider potential pitfalls not listed and how to address them in your design.
- Design should consider:
  - How coordination between moving mechanisms (multiple legs, dispensing) will be achieved.
  - How many legs and passive supports are needed given the need to power the dispensing mechanism and legs from a single motor. How the chosen design and number of legs affect balance and gait.
  - The shape of the chassis, considering how to contain all components, connectors, and maintain balance. Minimize weight.
  - The drive train from the motor to all of the legs and dispensing mechanism, including supports and connectors.
  - The location and mounting of the motor and battery. The largest forces are on the motor mounting, so careful thought should go into a reinforced design.
  - Where the wiring will run (does not need to be visually represented), and room for electrical connections.
  - Leg mechanism(s), including the holes for the pin or slider joints. Proposed joints to fit those connections.
  - Foot shape for traction in a way that will maintain balance.
- Neat, annotated hand sketches showing **two** design ideas/concepts. For each design:

    - Brief description of the overarching concept and inspiration.
    - The proposed design for a single leg mechanism.
    - The full chassis showing placement of different mechanisms, and theme.
    - The power transmission elements (e.g., gears and belts from a rotating motor all the way to the legs and dispensing mechanisms -- no calculations required at this stage).
    - Use multiple views, sectional and detailed views as needed.
- A list of pros and cons for the two proposed designs, with regards to how well they address your design specifications and the listed functional and physical specifications.
- A team consensus for what design will be pursued and why.
- A timeline including milestones and division of labor for the design and prototype stages.
- Who will work on what?
- Consider showing a functional prototype of the leg mechanism for each design.

Scoring will be based on the **creativity of the ideas**, the **depth of consideration of the design**, and the **quality of the report**, including **sketches**, and **presentation of ideas**. The instructor should be able to ask any team member any question, so make sure all team members are fully briefed.

5.2 Design Stage

The goal of the design stage is to produce a design with enough detail that you could immediately purchase and manufacture components. This stage is very busy, so plan ahead and start early. The Innovation Studio fills up in the last few days before the deadline, causing lines to wait for tools. Moreover, supplies run out in the stockroom, so don't wait until the last minute to make your purchases.

(D2) Critical Design and Prototype Review:

- The critical design and prototype review will be a presentation during lab with the instructors to go over the detailed design of your robot.
- Version 1 of the entire robot (walker + dispensing mechanism together) should be demonstrated. This 1st version of the machine should have "final" components, made using materials in your kit or purchased from the studio.
- Lab will be held in 1001 MEL for this presentation.

A presentation template will be provided with greater details. Below are general topics to consider for this review.

- Full 3D CAD of your robot including all components (assembly, drawings, animation).
- PVA analysis of the leg mechanism: Specific details will be provided.
    - Output at the foot's center point to the input at the drive shaft.
    - Leg motion, gait, and robot velocity
    - Lift and contact phases of the foot
- Bill of Materials including all parts (including ones in the kit and estimates for 3D printed parts), expenditures from Project 1, and estimated budget for Project 2.
    - Remember to leave some $$ to allow for mistakes & design iteration.
- Images or videos of the functional prototype.
- A timeline including past and remaining milestones and division of labor for this stage.

During the prototype review, the mechanism will be assessed on:

- Compliance with physical requirements.
- The completeness of the prototype.
- The degree of functionality of the robot. If the prototype breaks before/during the review, a video will be accepted for most points in lieu of direct observation. *Take videos when testing.*
- Whether the legs and dispenser operate with correct phase when the motor is connected (without walking).
- Whether robot can walk some distance and/or dispense one or more payloads.

- Aesthetics will not be considered at this stage, but teams should be planning ahead so that decoration is not an afterthought.
- Teams should aim to get their prototype as close to the final product as possible at this stage, to reduce the need for iteration later.

5.3 Final activities

After the critical design and prototype review, teams will have time to iterate on their design, analyze the final mechanism, and optimize their robot for the competition, and add any aesthetic elements. You will do a final report where you describe the final mechanism and reflect on the design process.

(D3) Video

Each team will upload a 2-minute informative and entertaining video. Due Sunday Dec 7. Students from each lab section will rate the videos from the 5 teams in their lab section – due Tuesday Dec 9. The top video from each of the 12 lab sections will receive a bonus. Additionally, these 12 videos will be played during the last lecture classes on Wednesday December 10. The top video will receive an additional bonus. Attendance is mandatory at the last lecture.

The video should include the following information.

- Team # and member names, project name
- CAD and Assembly drawings, labeling key elements of the design
- Photos, and videos of your final robot in action.
- (Optional) Photos/videos of your team working on the machine and evolution in design process.
- (Optional) Music – must be open source and free. **Do not use copyrighted material.**

Here are examples (some of the example videos are longer than 2 minutes because these sections were tasked with creating a 3-minute video):

https://www.dropbox.com/s/xkg7ennkfp36j97/
https://www.dropbox.com/s/qs7d4zjub8ho1ce/
https://uofi.box.com/s/nts9clc8w03zj70lhbb89nnzyidho6xz
https://uofi.box.com/s/ch41fk9jfuticlwt0n9x2w2pbyq7bk5c

(D4) Final Performance

The competition will be held on the first and second floors of MEL (Bardeen Quad side) on Friday December 12, 7-10 pm. Attendance is mandatory. We will race several robots at a time.

During the performance evaluation, the mechanism will be assessed on:

- Dispenses payload every 2 m. (Excellent: within ± 2.5% of 2 , Good: ± 5%, Fair: ± 10%, Poor: ± 20%)
- Number of payloads dispensed.
- Distance traveled.
- Ability to get to the finish line.
- Average speed (total distance/traverse time)
- Design meets physical requirements.
- Design is creative.
- Manufacturing and assembly are of high quality.
- Robot (walker/dispenser) is robust and does not break apart during the race.
- Whether human intervention or multiple attempts are needed to complete the task.

Peer evaluation: the robots will be ranked based on aesthetics, complexity, and creativity by your peers. Top teams will receive extra credit.

(D5) Final report & expense report
Teams will prepare a final report (up to 11 pages, single spaced, 1" margin, 11 pt font or larger) reflecting on the performance of their robot. The report should be formatted according to the provided template. Make sure that the report is significantly more than a "Figure dump" (i.e., it must have an executive summary, an introduction, a conclusion, and a well-presented body).

A template will be provided with greater details. Below are general topics to consider for this final report:

- A CAD of your final mechanism from the competition. This should be updated from the critical design review.
- A discussion of design features.
- Final expense report.
- Reflection on your machine's performance, challenges it faced, and suggest ways to overcome them.

5.4 Wrap-up and Reflection

In this stage, you will do a cleanup of your studio space, recycling of your project supplies, and peer evaluation for individual project multiplier.

(D6) Project cleanup
Teams will clear their workstations, rented storage locker, and disassemble their walkers, sorting the parts into the assigned recycling boxes in the Innovation Studio. Teams will upload to Gradescope pictures of (1) Their cleared lockers and (2) The disassembled robot.

(D7 a,b) CATME Peer evaluation
Peer Evaluation Multiplier – Individual final project grade will be modified based on team member peer evaluations. Complete after D2 and D5.

6. Extra Resources & Design Tips

Prototyping Advice

See the many advice slides posted in Canvas.
The tips below are merely to help kickstart your activities. For more prototyping and construction suggestions, a great resource is the Stanford biomimetics course website:
http://bdml.stanford.edu/Main/FinalProjectMaterials

- Aim for flexibility of your design. For instance, consider whether you want to use gears, pulleys or chained gears. Similarly, consider variable speed and/or multi-stage speed reduction.
- Think about design for assembly and disassembly. During testing, you may want to re-design parts and assemble them, so avoid permanent constructions.
- When brainstorming design ideas, check out the inventory available in the Innovation Studio stockroom. They have components and potential solutions to common design problems.
- Think about dimensional accuracy, alignment, clearances, and how they affect the precision of assembly and the operation. Avoid "wobbling" motion and "sloppy" assembly.
- Screwing flat panels together is imprecise and will lead to alignment problems. Use concepts from woodworking, joinery, and construction to ensure secure attachment and self-alignment of critical components during construction. For example, laser cutting is highly conducive to box joints, mortise and tenon, and cross laps.
  https://en.wikipedia.org/wiki/Woodworking_joints
- Talk to other teams and students from previous years.

Robot Locomotion

To get inspiration for biomechanical design, take time to search the web, go to a toy store, and read some articles.

There are many examples of small legged robots with 2, 4 and 6 legs.
Bob Full's Ted talk on bioinspired robots from cockroaches
RHex This robot has wheel/legs that rotate, but the legs are compliant so that it bounces with a Spring Loaded Inverted Pendulum (SLIP)-like gait.
The OctoRoach family of robots from U.C. Berkeley.
Theo Jansen has examples of unpowered walkers based entirely on linkages.
and entire books on animal locomotion