Individual Innovation Challenge 2

INNOVATE 100G

Jasper Miller-Waugh | 664756945 | jmil710

Problem Space (OPTION B)

I choose to build off my Week 6 assignment, and explore first-year students' experiences with their accommodation room locks.

Problem Space Exploration

EMPHASISE

My Problems

- Getting locked out Uni Hall rooms, by leaving the card inside
- Long wait and a fine of $25 to get the master key to unlock the door
- Not able to share access to my room with trusted other's to pickup items

How does that make the students feel?

- Frustrated
- Angry that the hall is profiting off the lockout problem
- Super annoyed at self and at hall

Observed Problems

- Complaints about having no form of "spare key"
- Door locks running out of battery, meaning the room isn't accessible all day
- Having the campus card expire every 24 hours, means a long trip downstairs to refresh

How are they solving their problems now?

- By never closing the door when leaving
- Homemade string contraption to pull the door-handle up on he inside
- By repeatedly paying the "lockout" fine to open their door

DEFINE

Problem Trends

- Students experiencing security fatigue
- Low frequency, but high pain associated

How are people locking themselves out?

- Card is super easy to lose, and is highly multi-functional
- Distracted, leaving the entire wallet inside the room when leaving
- The door auto-locking on close

Distracted, leaving the entire wallet inside the room when leaving / The door auto-locking on close → People usually realize immediately after closing the door

Problem Statement

Students living in UoA halls have rooms controlled by their Campus Card, that automatically lock behind them. When their card is left behind in the room when the door locks behind them, they have to pay a hefty fine. When their card is lost, expires, or lock broken, they lose complete access to their room until the issue is resolved

HME Statment

How might we empower students living in UoA accommodation to take control of their room locks, so they can reduce the amount of lockouts as a whole

Solution Criteria

- Reduce chance of lockouts
- Students can install the solution themselves
- Hidden from outside of the room
- Able to temporarily "share" access to the room
- Improved security over leaving the door open

IDEATE

Morphological Analysis

Power Source	Lock Bypass Mechanism	Activation Mechanism
User replaceable batteries (9V or AA)	Insert to go in the door frame to stop the locking lug	Garage door remote
Internal lithium battery, charged via USB	Wire into the back of the door lock	IoT Wifi device + corresponding App
No electrical power	Remove the hall's lock system, and replace it with a key	Offline Bluetooth, unlocked by App
Long cable to wall plug	Remove the door entirely	Secret knocking code
Gravity based system with pendulum weights	Open door handle from the inside	Bluetooth range authentication
		Always unlocked

Door Frame Insert

Little insert into the door frame locking area to stop the door from ever locking

PROS
- Very Cheap
- No recharging batteries/running wires
- Hidden from outside

NEG
- Can't lock without removing it
- Doesn't meet security criteria

Wire into back of door lock

Control box that has a radio receiver, that wires into the back of the existing electronic lock

PROS
- Works alongside of campus card unlocks
- Second remote can be passed around
- Very Secure

NEG
- Installation would trigger the tamper-switch in the back of the lock
- Risk of screwing up the lock itself
- Risk of running out of battery

SELECTED

Open Door Handle From Inside

The control box uses a Bluetooth enabled MCU, which uses a stepper motor to pull the door handle up, unlocking the room from the inside.

PROS
- Works alongside of campus card unlocks
- Easy to extend functionality after installation with the app unlock.
- Leaves locking mechanism unchanged
- Potential to be agnostic across halls

NEG
- Cybersecurity risk of connecting door to bluetooth
- Risk of running out of battery, especially with high draw from motor

Selection Justificaiton

I selected this idea as it aligned closely with the solution criteria. It would reduce the chance of lockouts by being the backup mechanism; access sharing could be as simple as sharing a pin-code. It would be installed on the inside of the door and could be designed not to damage the door to install. Lastly, having authentication to unlock the door would provide much better security than the security solution criteria requires.

Wallet Tracker

Gives an immediate warning when the user's wallet is left behind in the rooom.

PROS
- No room modifications necessary
- Usefull for the user in all scenarios leaving their wallet behind

NEG
- Accuracy concerns, hard to tell if the wallet is just inside the door.
- Would be bulky given the size of existing bluetooth trackers
- Potential for many false alarms

Secret Knock Pattern Lock

Like the device that opens the door handle from the inside, but activated by a secret sequence of knocks on the door.

PROS
- Leaves locking mechanism unchanged
- Works alongside of campus card unlocks
- Potential to be agnostic across halls
- No need to use a phone/device

NEG
- Neighbors will be able to overhear the code, and recreate it
- In a panic'ed state, it might be hard to precisely recreate the code
- Risk of running out of battery, especially with high draw from motor

Concept Sheet

NAME OF IDEA

DoorSaver

SIMPLE DESCRIPTION

A third-party device for students to install on the inside of their doors, which can mechanically lift the door handle from the inside.

FOR...

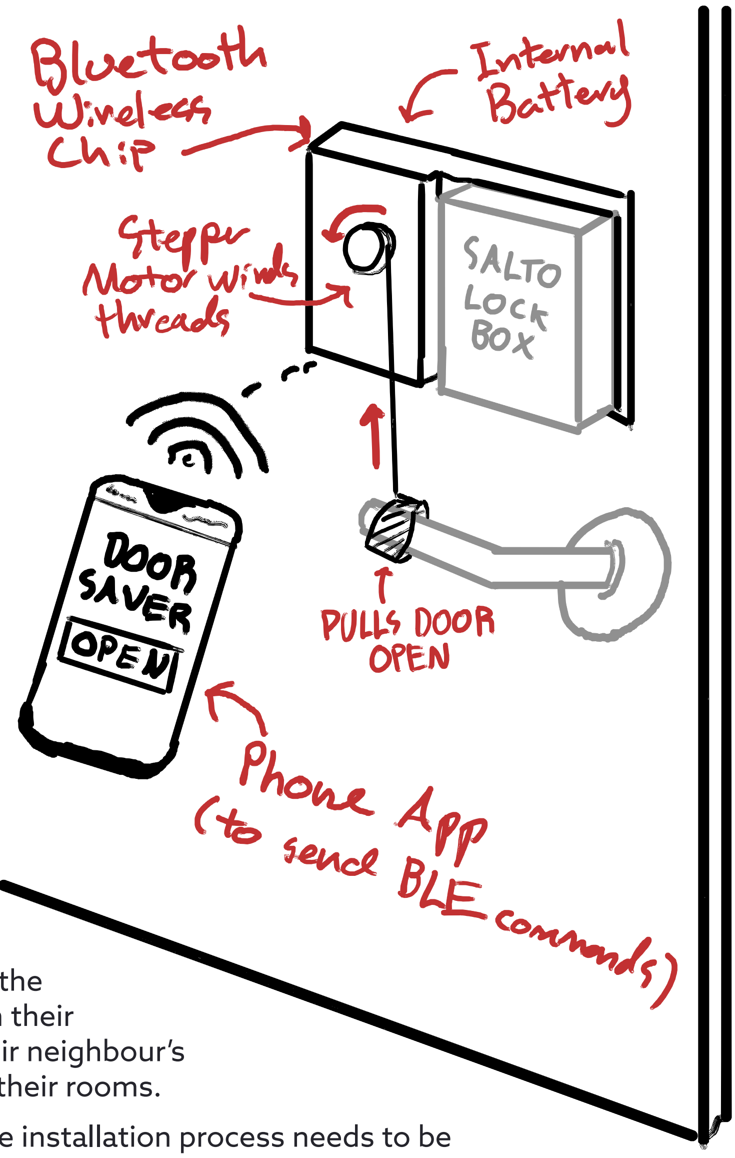
Forgetful university students living in halls with Salto Locks installed

SIMILAR TO...

Having a spare key

USER NEEDS

Students leave access cards inside their rooms and get locked out due to the auto-locking doors. They need some way to get back inside their rooms, without paying $25 and waiting up to an hour.



WE PROVIDE...

The hardware and software solution to resolve lockouts, by opening the door handle from the inside robotically.

CONCEPT BENFITS

- Prevents students from locking themselves out of their room
- Allows sharing access to rooms with friends/partners.
- Ability to bypass accommodation locks in the case of a failure.

CONCEPT FEEDBACK

- Questions were raised about the case where the user's phone was locked inside the room with their keycard. They would like to be able to use their neighbour's phone, or even their laptops to get back into their rooms.
- Worries about damaging the door/lock, so the installation process needs to be simple and non-destructive.

Prototype 1

INNOVATE 100G

Using a WiFi hotspot captive portal to control the door

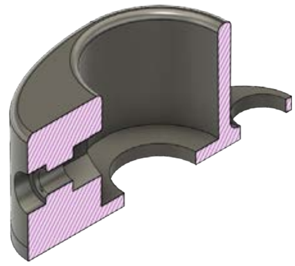
Mechanism Development

Before designing the first main prototype, I rapidly iterated on a manual device version to test the core mechanism of pulling the door handle open from the inside.

V1 - Simple fabric loop

I first tested the most apparent design, a loop of fabric sewn onto some string. Unfortunately, the loop slides right off the door handle when pulled directly upwards.

V2 - 3D Printed Mount



To lock the string, I designed a tiny mount that used a screw to latch onto the door handle. This worked much better than the previous design, and won't slide off unless unscrewed.

Key changes from the concept

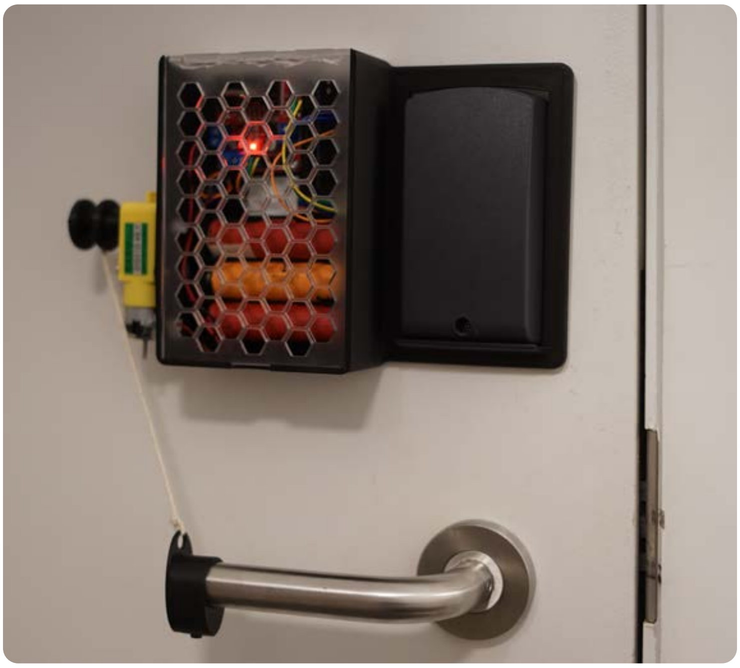
- Instead of having a native app, to control the DoorSaver over Bluetooth, I pivoted to a more platform agnostic approch: A password-protected WiFi hotspot, with the captive portal as the control interface. This way, any phone/laptop/tablet can unlock the door, given the user remembers the door code.
- I switched from a stepper motor to a geared-down DC motor. This saves component cost and power budget, as we don't need precise control over the amount of string pulled.

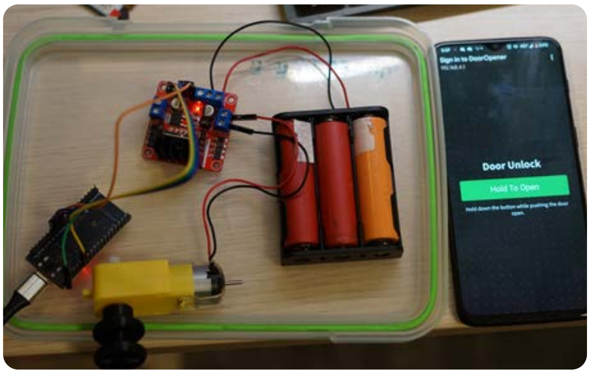
Prototyping Learning Plan

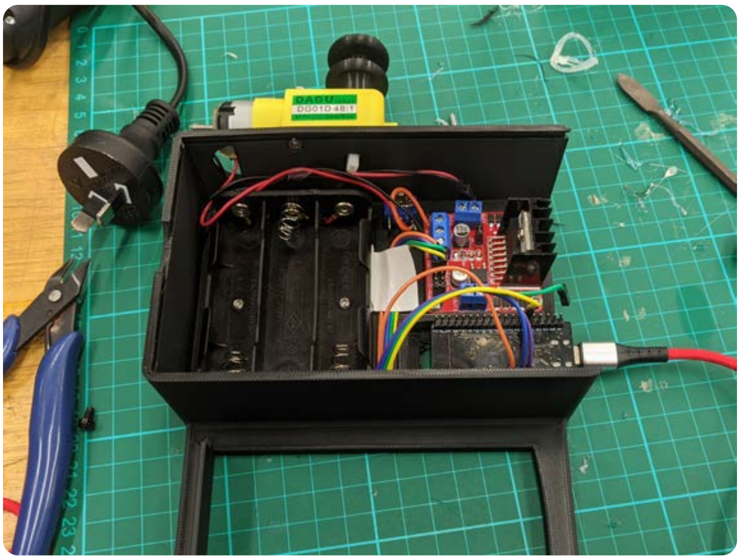
LEARNING QUESTIONS	Is friction mounting the device to the existing lock body suitable for a long-term deployment?	How large of a battery would be needed to last a month without charging?	How is the user experience with using the hotspot/captive portal system?
KEY METRICS	No marks are left on the door or lock body and a strong hold on the door	Miliamps used by the device on standby vs the additional current used when activated with the motor running.	After a quick verbal explanation of the device and its usage, can all new users connect and run the motor with their own phone without additional help?
TESTING METHOD	Handoff the prototype to potential users so they can see if it fits their door and comes off cleanly.	Use a multimeter to probe isolated parts of the circuit, to find where exactly the power is going.	Asking both friends and strangers at the Makerspace to connect and give the controls a go themselves while I build the device.
ASSUMPTIONS	In the design, I'm assuming all Uni hall doors are similar to my own.	The electronics of the prototype should be fully functional before testing, with complete firmware running, to test the power draw.	Assuming I get the core interface ready before I build the final design for this prototype.

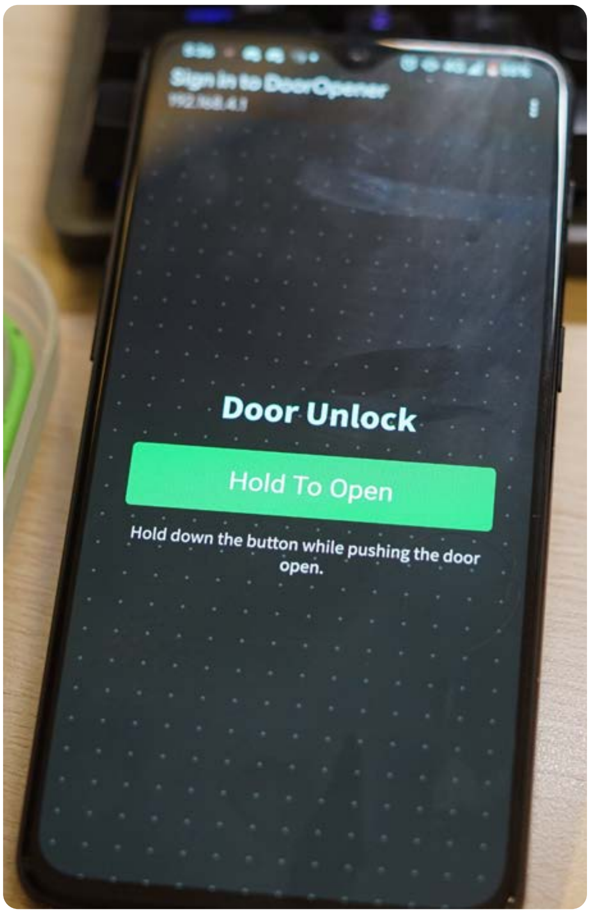
Jasper Miller-Waugh | 664756945 | jmil710

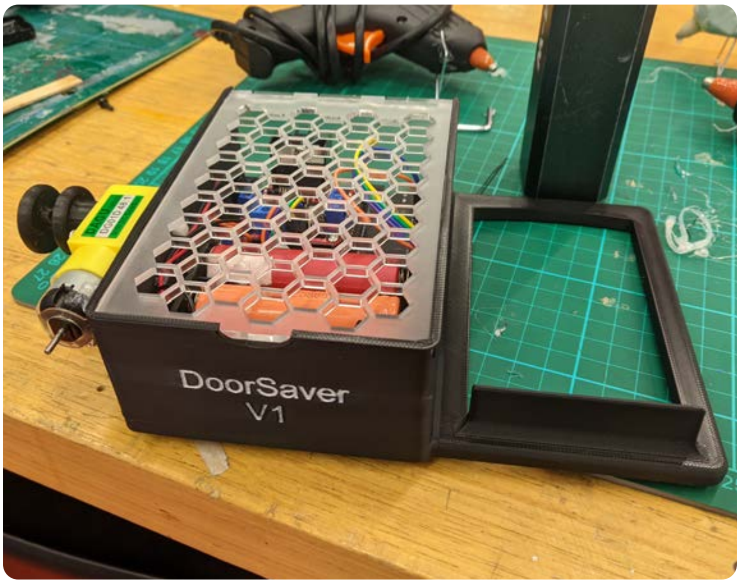
Prototype Gallery

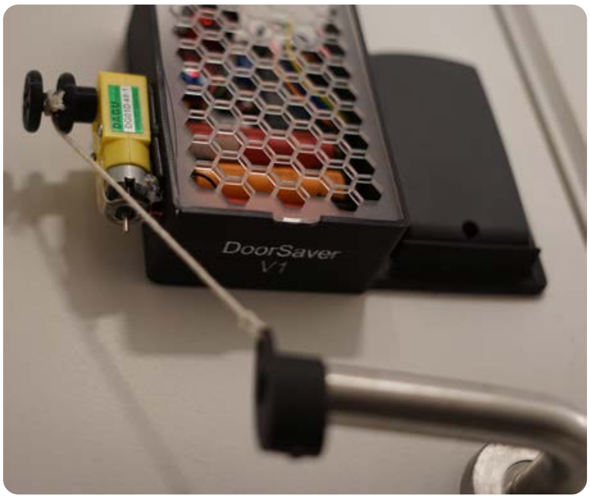










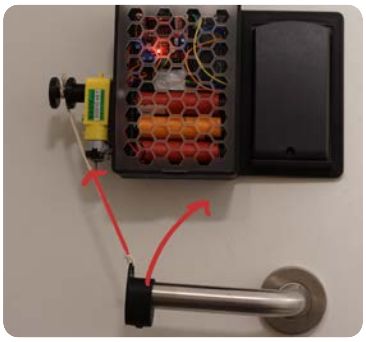


Prototype Review

DOOR MOUNT

The mount to the door's lock body worked perfectly and met all key metrics. Unfortunately, there were two massive oversights in this design.

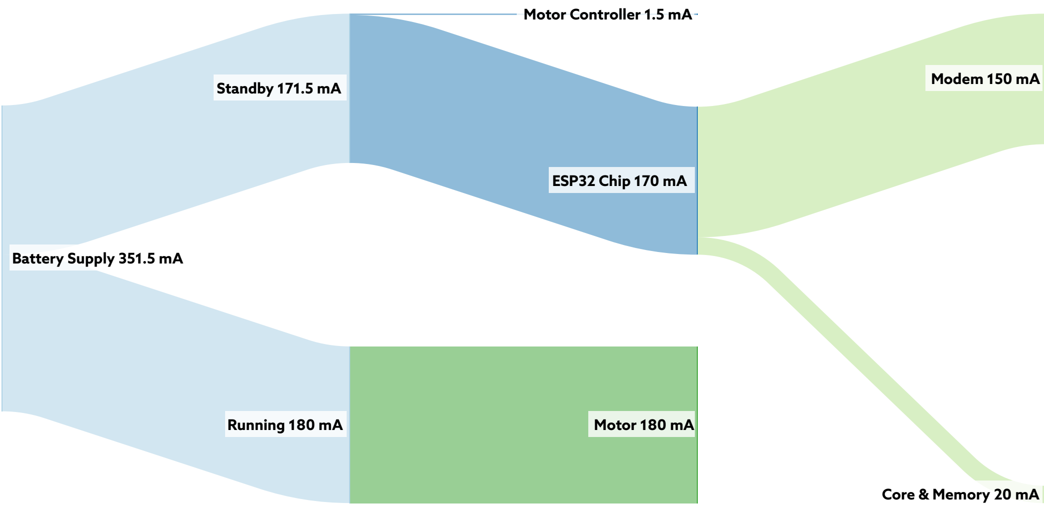
- The assumption that all Uni hall doors are similar to mine was incorrect. When testing the prototype with a few others in my hall, I realised some rooms are entirely mirrored, so in the current form, the device only works for half of Waiparuru Hall, which has "left" doors.
- The mount places the motor far too right for it to pull the door handle up, it pulls the handle to the left more than it pulls it up as per the photo.



BATTERY LIFE

The prototype used three recycled 18650 Li-ion batteries with a total capacity of 6000 mAh. When the motor was running, the total draw peaked at 350 mA, which means it could handle a theoretical 5,000 activations on a single charge.

There is a critical flaw with that calculation: it neglects the time the prototype waits around to be used. It draws a whopping 170 mA while sitting on standby, draining the battery entirely in less than two days. This isn't a quirk of the parts used for prototyping, and it's mostly going towards constantly hosting the WiFi hotspot. It drains its batteries, and for the same reason, your phone drains its battery faster when hosting a hotspot - there's no way to save power when hosting the hotspot.



The next iteration will need to find some mechanism to reduce the standby power draw to at least 20x, just 8 mA, to hit the target of a one-month battery life.

USER EXPERIENCE

Users loved the lack of setup, and all six testers could use the interface without further instructions. They quickly got that motor to run only when they pushed the button, and everyone played with how responsive it was.

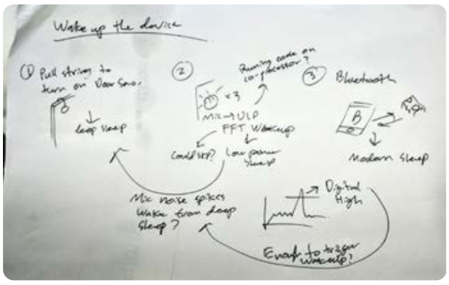
Most ran into a little hiccup in the process; they tried to use the "open" button before the page had finished loading and got confused when nothing happened. The next iteration should include a loading indicator of some form to show when the page is connected.

GENERAL FEEDBACK

- Many found the current design somewhat bulky/boxy and suggested flattening out the design to reduce the visual size.
- Some wanted to ditch the web portal and use a secret knocking code to unlock their door instead.
- The power switch is hard to reach with the motor in the way.
- On very close inspection, the hexagon pattern on the top is uneven. This was noticed by far more people than I expected.

The Battery Life

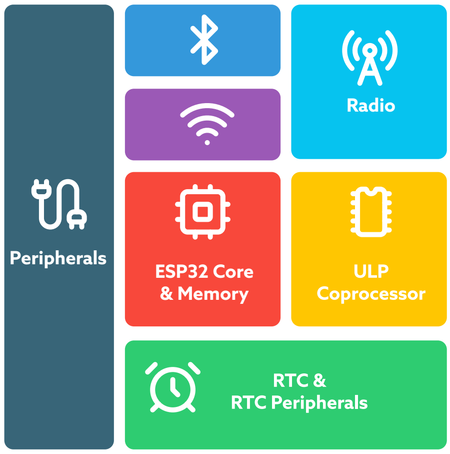
The high power-draw of running a hotspot is quite a sticky issue for the web interface. It requires a bit of a rework of the concept, and it took some late-night pondering to find potential solutions. I'll re-express those thoughts in a neater form below.



INTRODUCING: The ESP32 Chip

It's at the heart of my design; it's a common choice for low-cost smart/IoT devices. The production version of the DoorSaver might not use this particular chip, but **its power-saving features represent most devices out there**.

The processor is broken into chunks, which can be put to "sleep" when not needed to save on power massively. Right now, everything is enabled, all the time, as shown on the right.



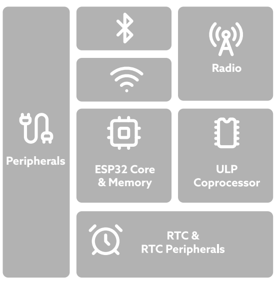
Diagrams adapted from Last Minute Engineers

POWER SAVING IDEATION

1

Run a pull cord over the top of the door as a power switch.

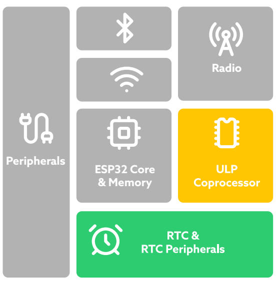
This would allow the DoorSaver to turn off when irrelevant and only enable itself when needed. This could allow a multi-year battery life, but it requires the device to be externally visible and relies on the pull-string staying in place over the top of the door.



2

Use a microphone to listen to knocking sounds and wake the whole device from deep sleep.

Users could knock on their door to trigger the current wifi hotspot interface. It would work similarly to "wake words" used in voice assistant devices; the central processor goes to sleep while a smaller, low-power processor keeps working and looks for prominent peaks in the audio waveform to wake the central processor back up.

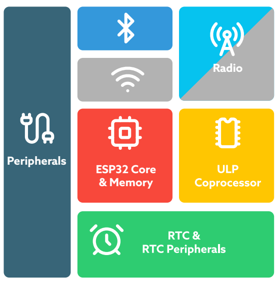


Selected for the next iteration

3

Return to the original concept and make a companion app with BLE communication.

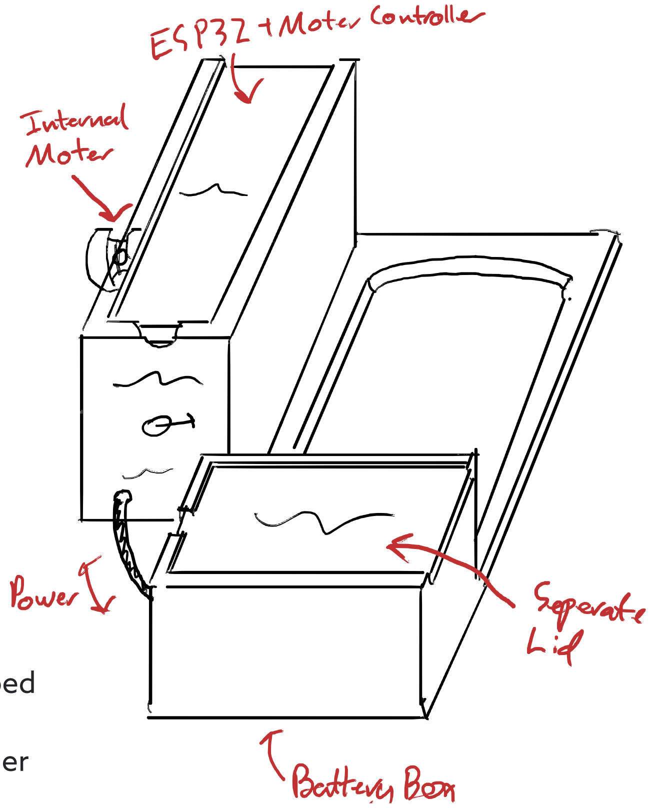
This is still a valid option, as DoorSaver doesn't need to host the network this way, it could get halfway to the target battery life. This solution comprises the zero-device setup, and with the positive feedback of the web interface, this isn't the way.



Prototype 2

Finding the balance between user experience and battery life

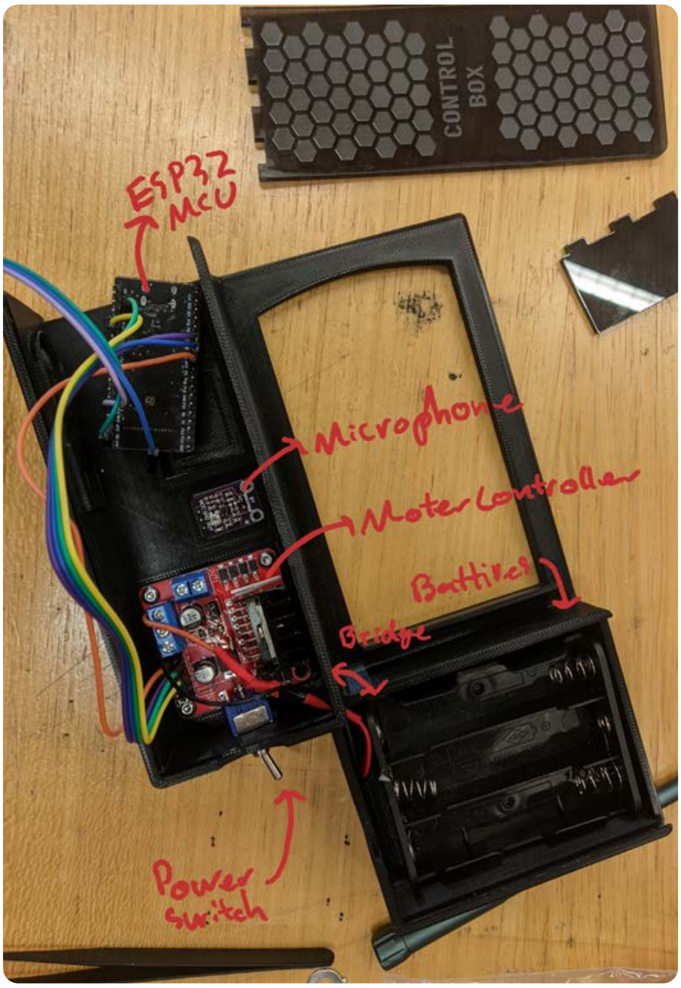
For the next iteration, I went back to the drawing board in terms of case design. I took feedback about the current design's "boxiness, " so I split the central electronics from the batteries to tie everything closer to the existing lock body. The motor is moved into the case in the sketch and now lines up much closer to the door handle.

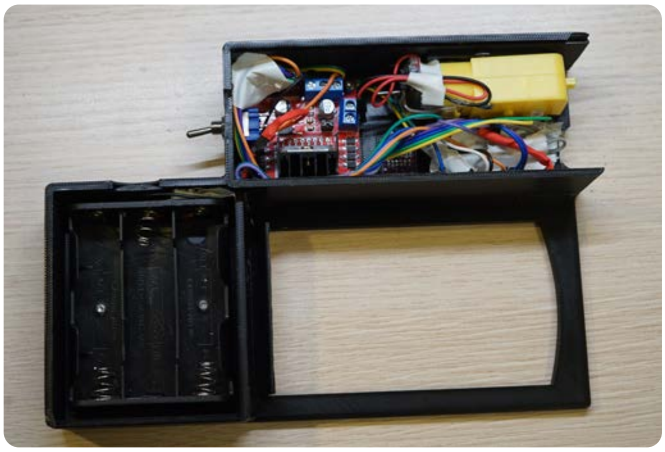


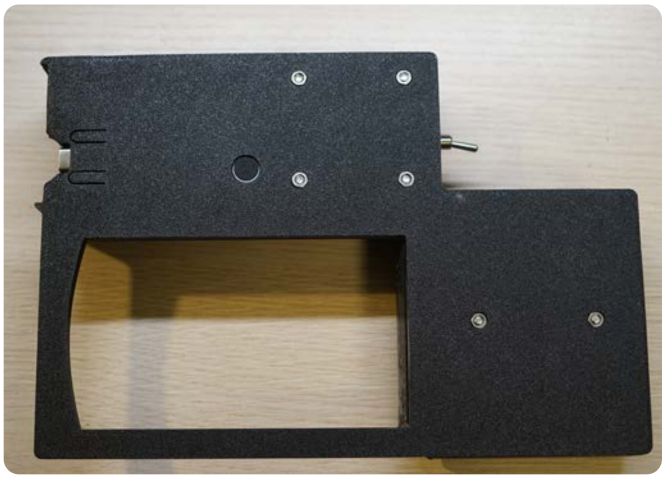
Primary Changes

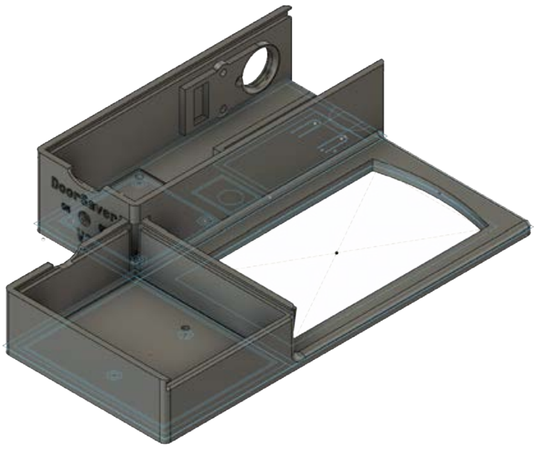
- Redesigned compact case
  - The motor is now moved inside the case
  - Power switch labelled
  - Batteries get their own compartment for easy swapping
- RGB Indicator lights built-in
- Door knock microphone integrated
- Compliant mechanism buttons for easy debugging/flashing on the bottom of the case
- The string connected to the door handle was swapped for fishing line for better durability
- Low standby power usage due to the knocking trigger

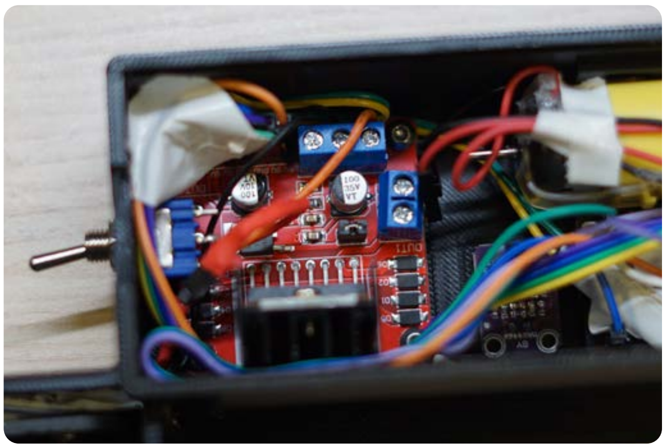
Prototype Gallery



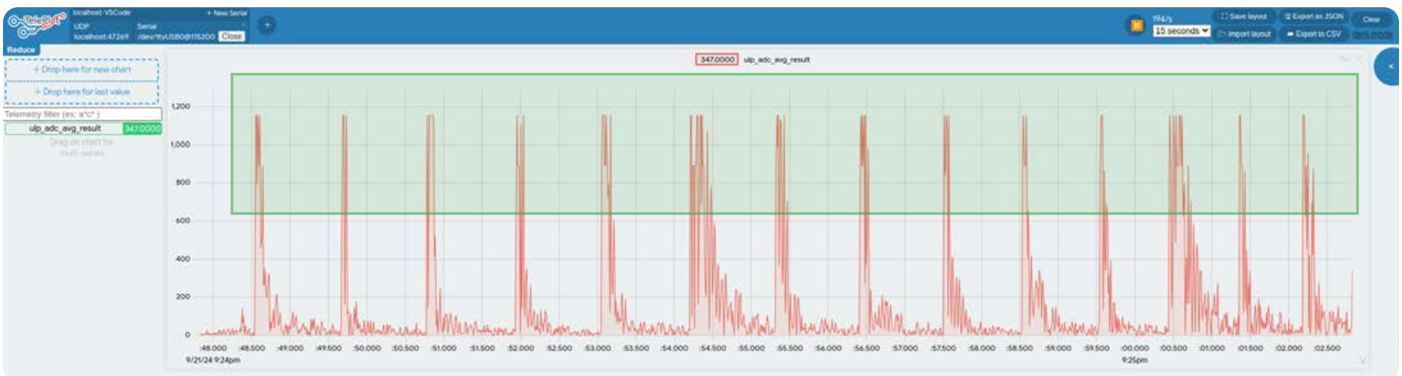




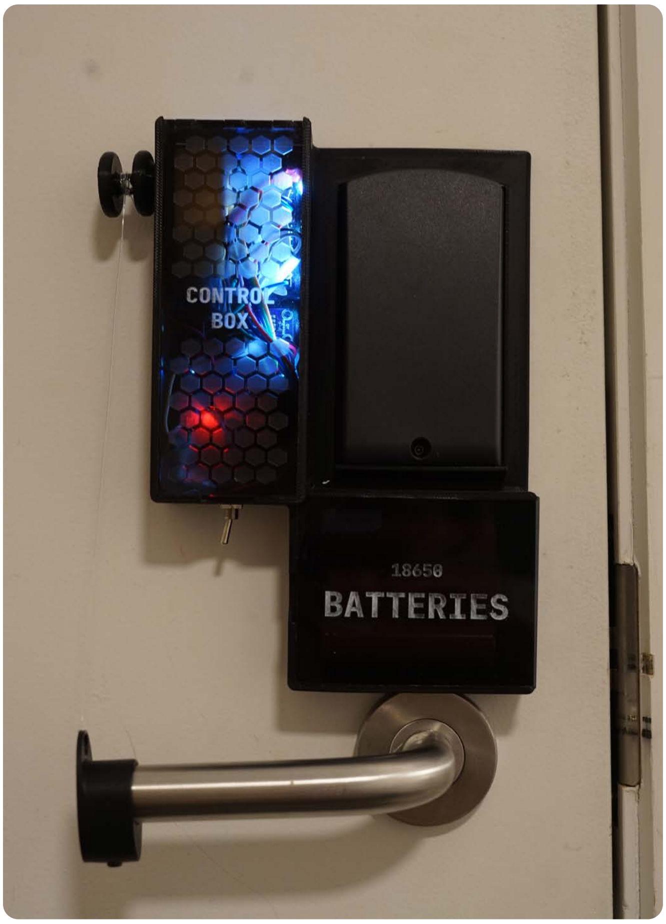


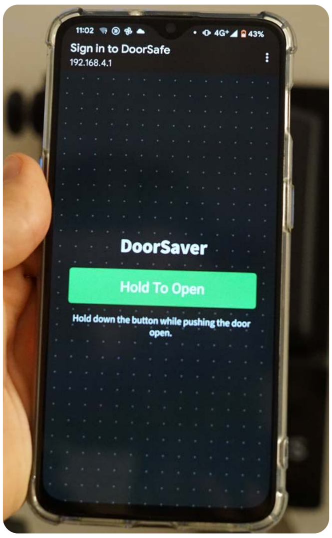


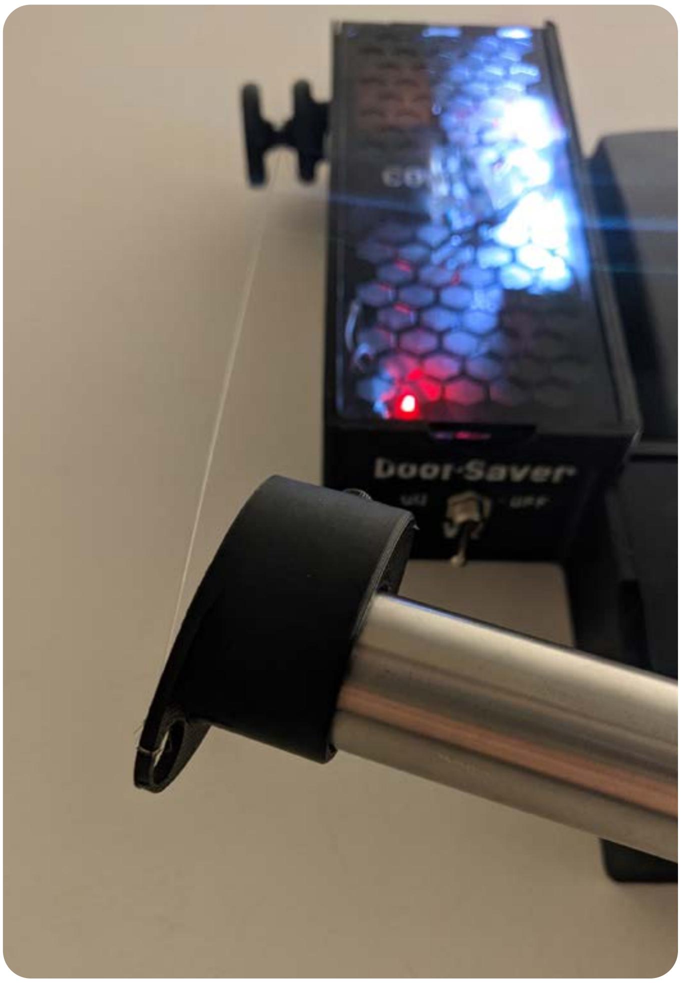
The onboard microphone detecting regular knocks on the door, as read by the ULP coprocessor.



Prototype Gallery







Prototype Review Follow Up

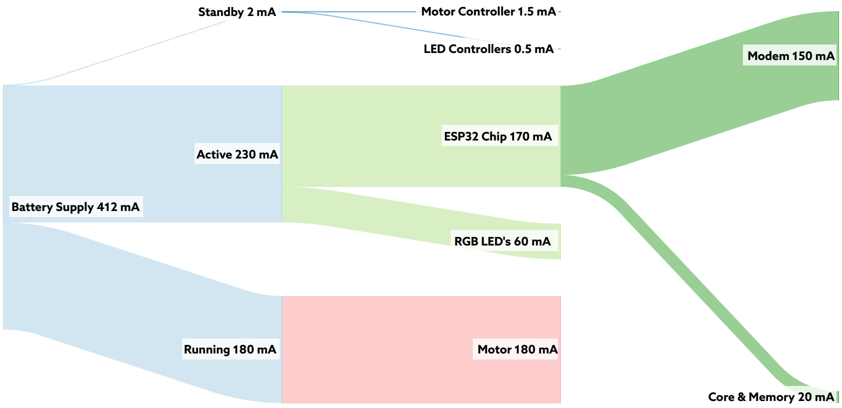
DOOR MOUNT

The second iteration of the door mount now lines up correctly with the handle! I decided to leave the mirrored doors out of the scope of this prototype, but the design can easily be flipped and produced as two variants.

A new problem has been introduced with the design. **It's prone to pull itself off the door entirely when trying to open.** A future version of this design should have a way to screw mount onto the door, like how the design screws onto the door handle.

BATTERY LIFE

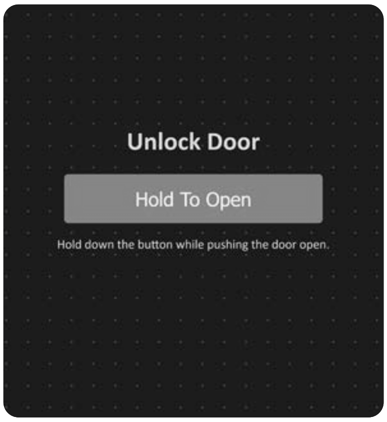
With the knock wake system implemented, the prototype's standby power draw has been reduced from 170 mA to just 2 mA, well under the target. Assuming one use and five accidental wakeups daily, the battery pack will last over three months on a single charge.



USER EXPERIENCE

The loading page has now been implemented; it just disables the button until everything is loaded.

The experience has been significantly slowed by the power-saving measures. Users must knock on the door, wait for the wifi network to connect, join it on their phone, and wait for the page to load. Only then can they get back into their room. This hasn't been helped by the occasional knocks falling between the ULP coprocessor, meaning they wait for a wifi network that won't show up. That last one has been remedied by only looking for one knock to turn on but telling users to knock on the door three times.



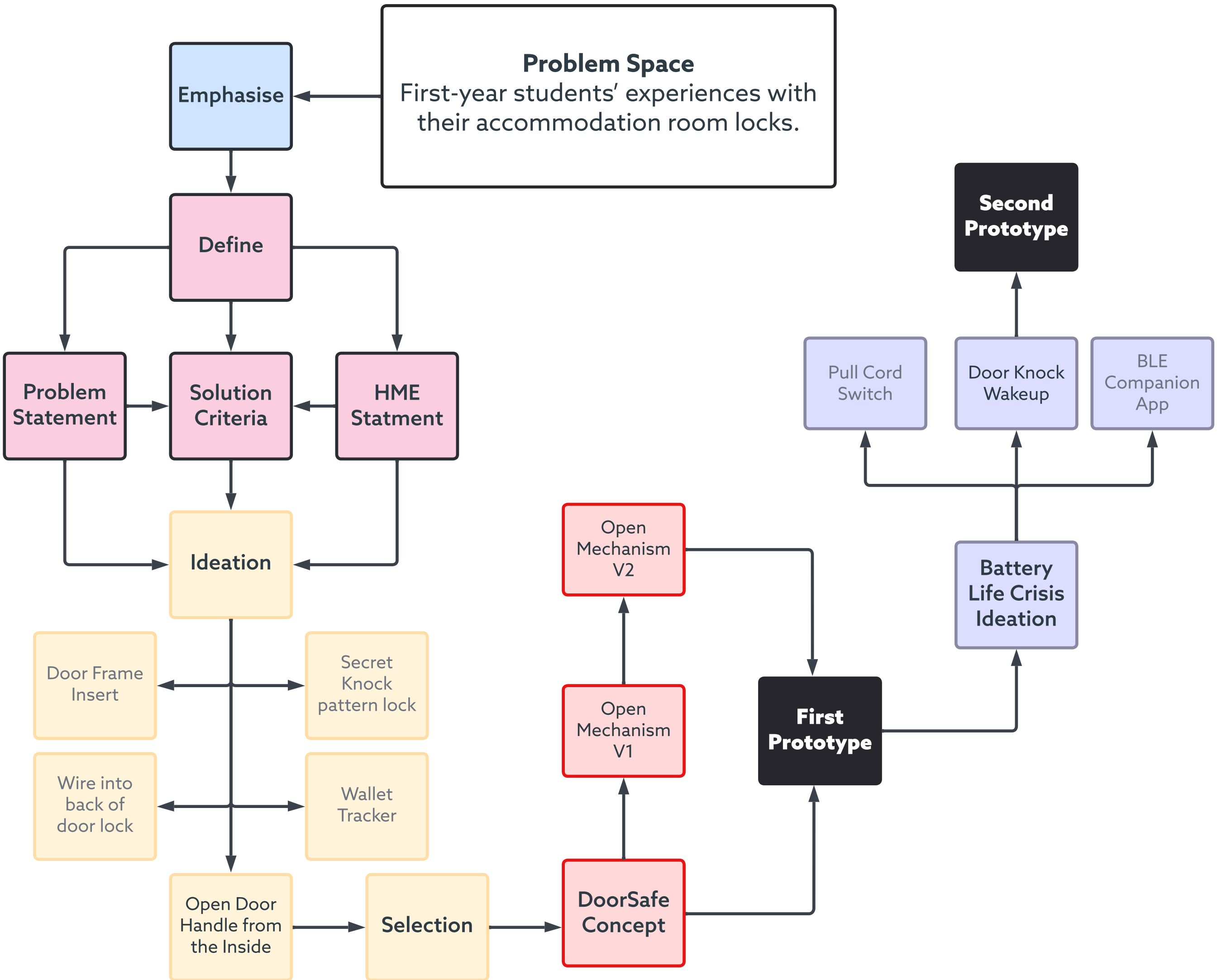
GENERAL FEEDBACK

- The people who found the old design boxy like the new compartmentalised version.
- Using the microphone for secret-knock authentication is now entirely possible with a firmware update.
- The power switch has been moved to the bottom of the device, out of the way of the motor.
- The hexagon pattern on the top is now even.

MORSE KNOCKING PATTERN

-. . ...- . .-. / --. ---
-. -. .- / --. .. ...- . /
-.-- --- ..- / ..- .--.

Process Overview



Next Steps

Getting a few prototypes into real users at multiple halls for a long-term test is critical to validating this concept's market. It's a small, tough market of budget-conscious students, so the device must work extra hard to justify its cost. Market validation would come after a couple more rapid iterations of the current design to simplify and polish the user experience, as it's missing some features an end-user would need:

- Device configuration in the interface, like password changes and knock detection sensitivity.
- A second flipped design for all of the mirrored doors
- An end user would need to be able to charge the batteries onboard, so a balancing and charging circuit would be required.
- The design needs to stop falling off the wall! I want to use the device, so I've already fixed this in the design outside this assignment. I simply added screw/nut holes to the lock mount, like the door-handle mount, as shown on the right.