HOW WE BROUGHT THE FUTURE OF EV CHARGING TO YOU



BY
THE EVAM INTERIOR TEAM

SPECIAL THANKS TO PROF MIKE REEVES, HUNN WAI & WEI LEK FOR MAKING THIS POSSIBLE

CHECK OUT OUR OTHER PRODUCTS OUT TOO!





About Us

Meet the AY2025 EVAM Interior Team



We (Luyuan, Hans, Hui Yi, Fion, Chun Yong) were tasked to design the interior of a car for one of our Term 4 core modules, Product Design Studio. We worked closely with the EVAM exterior team and completed Project PIP with the help of our professors.

PIP stands for Portable Integrated Pod and means pup (child of a manta ray) in Latin. It works with its mothership, RAIA, to bring the future of EV charging

Thanks Profs :)

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The Future

Singapore's push toward sustainable mobility solutions is underscored by the government's ambitious timeline to phase out fossil fuel vehicles and embrace electric alternatives. By 2040, the country is projected to have half a million EVs on the road—an exponential leap that demands reliable, scalable charging infrastructure.

Traditional chargers are limited by: land constraints, cost of implementation and hoarding the charger by a user

This report documents the ideation of the EVAM team and the design process behind PIP, our mobile EV charger, and its symbiotic relationship with RAIA.





How might we

address user frustrations around charger availability and "charger hogging" penalties, with a focus on user convenience and ease of retrofitting all carparks?

Approach

Our approach utilised the double diamond design process centered on user research, iterative design and prototyping to explore how autonomy could reshape the charging experience.

Double Diamond Design Process



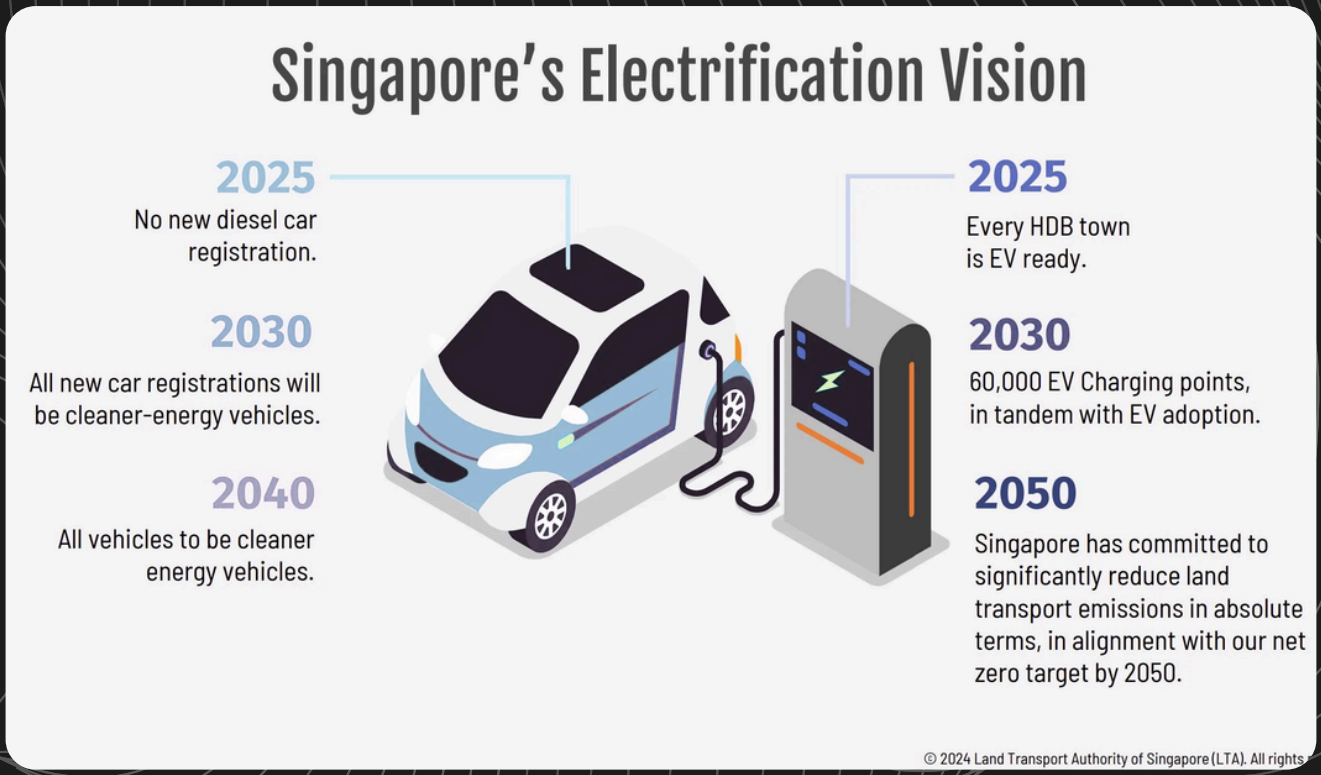
Research

We, the interior team, initially conceptualised the idea to address emergency car breakdowns on highways, aiming to streamline assistance for drivers facing mechanical failures. However, this idea faced many challenges mainly due to the user demand for an autonomous road side assistance solution and the feasibility of implementing it in Singapore's context.

We then pivoted our idea to instead provide means for road side refilling, then with the idea of 2040 Singapore in mind, complied with EV adopter fears on "range anxiety" we thought about the idea of having a battery and can of petrol being carried by RAIA which would provide a quick charge for stranded EV or ICE vehicles. This idea then came with its own slew of challenges mainly due to the lack of statistical information supporting the average number of stranded vehicles due to lack of fuel or charge.

While considering the challenges that our initial idea faced of road side assistance, and as Singapore is accelerating its transition to electric vehicles (EVs), driven by national sustainability goals.
As a result, we decided to step away from the emergency response approach and zoomed in on the EV charging aspect. By aligning with Singapore's net-zero agenda, RAIA and PIP was pivoted to address the emerging needs of charging infrastructure.





Our Final Concept

Our final concept centers around an autonomous mobile EV charger designed to meet users where they are—literally.

Meet PIP, the power bank on wheels. Developed as part of the RAIA ecosystem, PIP reimagines Singapore's charging infrastructure by replacing fixed stations with a fleet of mobile chargers. In our vision, every carpark in Singapore is home to a RAIA, which autonomously deploys its PIPs across the lot to locate and charge EVs. No more stressing over unavailable charging lots or paying steep overstay fees—PIP handles it all.

Once deployed, PIP navigates to the assigned vehicle and extends a robotic arm equipped with a DC charging head. When charging is complete, it signals RAIA to return, picks PIP up, and brings it back to its charging bay—ready for the next task.

Anticipating future innovations, we designed PIP to work seamlessly with cars that feature automatic charging flap mechanisms. But for today's EVs, the charging head is also detachable, giving users the option to manually plug in if needed. After charging, PIP neatly closes the flap before returning home.

Beyond PIP, our team also focused on the interior elements of RAIA: a collapsible steering wheel and a removable foldable seat, both designed with flexibility in mind.

We envision a future where the driver only takes control in rare cases—such as when RAIA requires maintenance or is dispatched to areas with unusually high EV demand. In everyday use, however, RAIA operates autonomously.

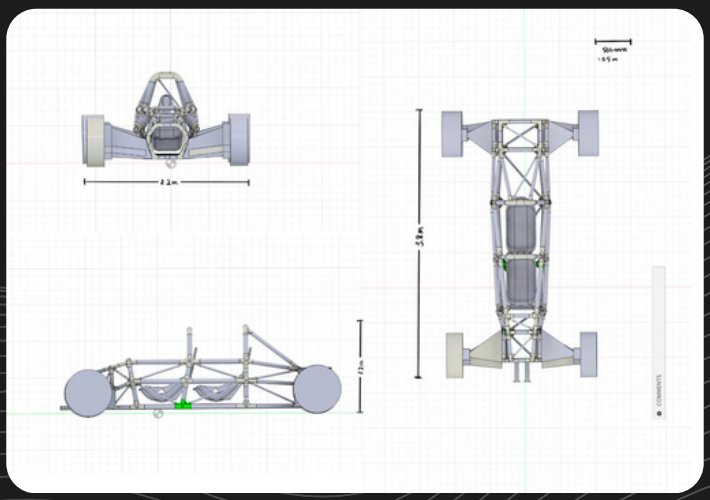
The steering wheel folds seamlessly into the dashboard, maintaining a clean, minimal interior when not in use. The seat, designed to be modular, can be folded and detached—serving as a stool or even a rest point for users waiting as their car charges.
Together, PIP, the steering wheel, and the seat form a system that's not just about mobility—but about adapting to people's needs.

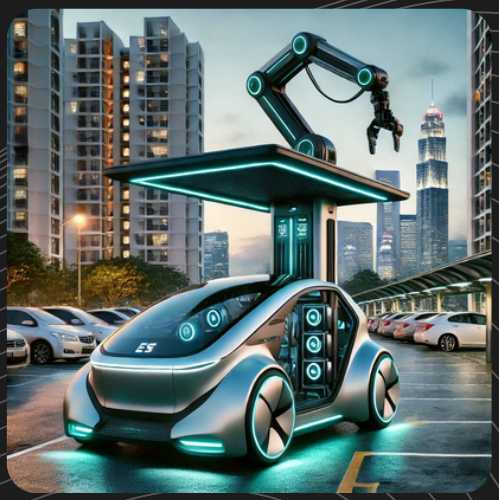
The following pages take you through our journey—from first sketches and systems thinking to the creation of a concept designed for efficiency, autonomy, and user experience.

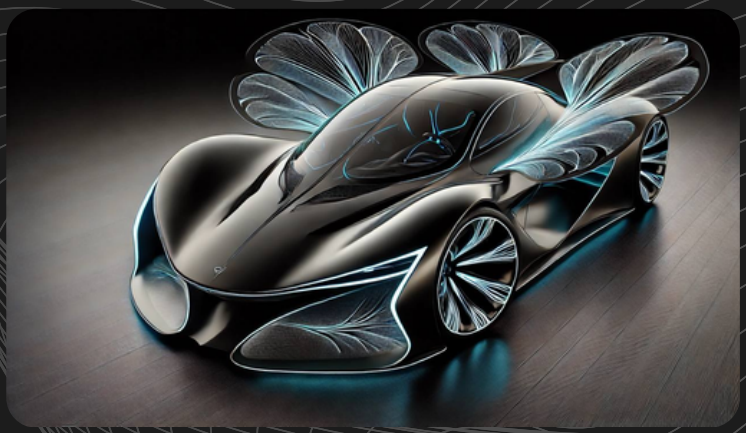
How did PIP come about?

PIP was not something that was conceptualised immediately. In fact, in our first few iterations, the idea of a separate, modular, deployable battery pack did not exist. We, alongside the EVAM exterior team, initially visualised our solution to the EV charging issue as an all-in-one autonomous car with a deployable robotic arm built into the car. This car would deploy behind cars on a demand basis and charge it.

Working with the package drawing we were given, these were the iterations we came up with.



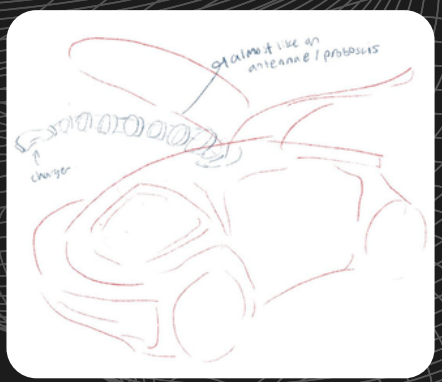












We were heavily inspired by the form of a butterfly, envisioning the antennae as the charging elements. Our goal was to create an organic, approachable design that would evoke a friendly and inviting presence.

However, this concept posed several challenges. Most notably, the vehicle's size became impractical, obstructing other cars in a compact parking environment. Additionally, our interpretation of the "butterfly" motif was too literal, resulting in a design that appeared overly striking and unintentionally intimidating.

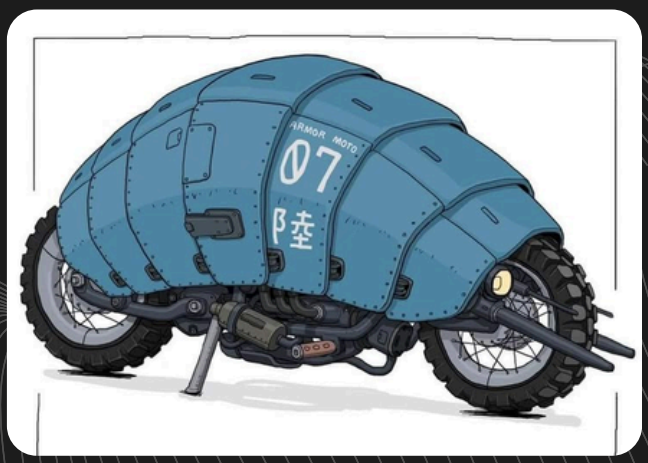
Re-evaluation of our concept

We re-evaluated our entire vehicle concept and conducted further research into the carpark environment to better ground our design. Two key considerations guided our next phase:

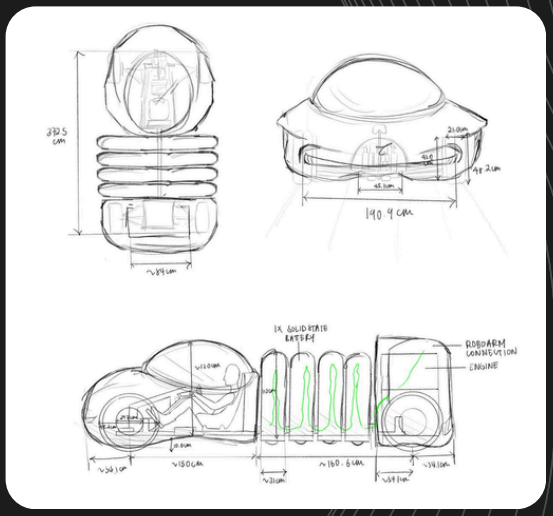
- Ensuring the vehicle would not obstruct the movement of other cars in a compact parking space
- Creating a form that appeared friendly and non-intimidating to users and passersby

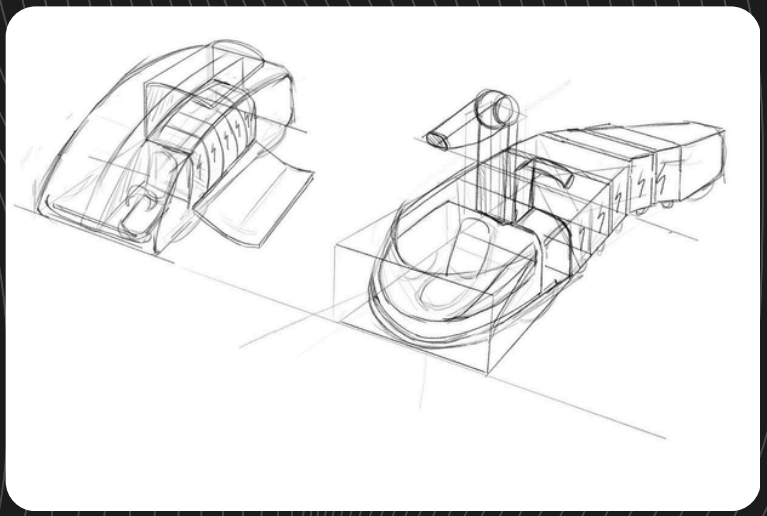
We were inspired by the ideas of modularity and compartmentation in these 2 designs.



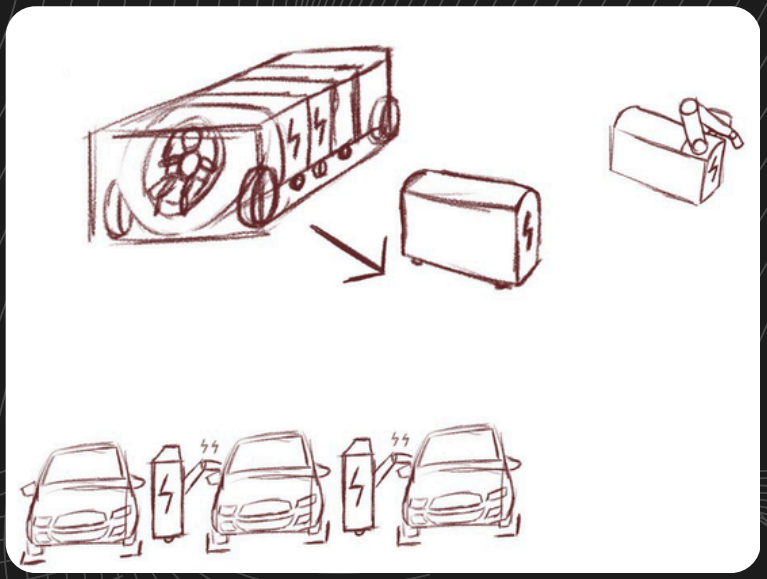


Alongside the exterior team, here were the designs we conceptualised





Our idea was a caterpillar-like mothership, where its segments were portable battery packs that could be deployed at each electric vehicle. Each battery pack would have its own robotic arm to automatically charge the user's car.

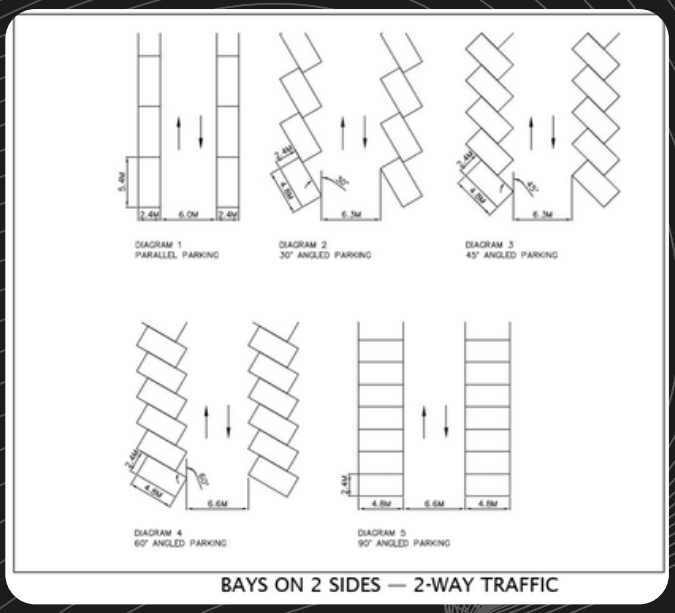


Research into dimensions

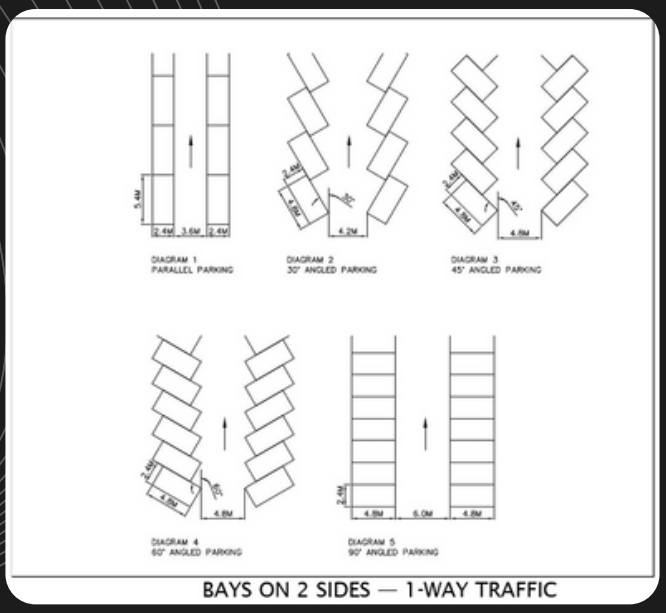
With these modular battery packs, we had to think about the size of these battery packs and where to deploy this:

- In between EV
- Behind EV

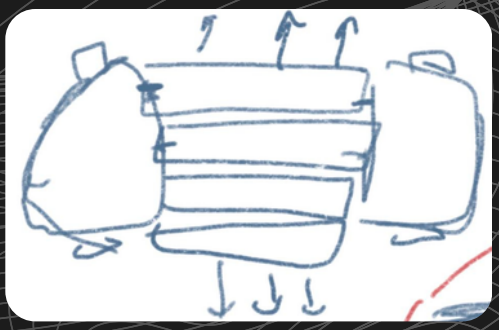
To decide that, we researched into common EV car models and dimensions of a parking lots, where there was an LTA documentation on carpark sizing regulations.

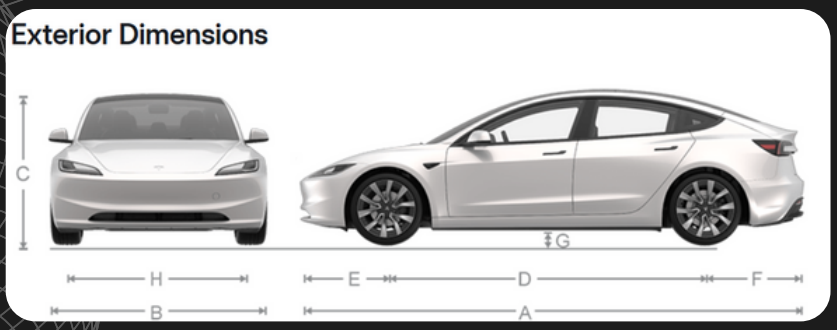


BAYS ON 2 SIDES — 2-WAY TRAFFIC



BAYS ON 2 SIDES — 1-WAY TRAFFIC





We ultimately went with a modular battery pack that was long and skinny as that would give us adequate space for the robotic arm and battery pack.

We also decided that these battery packs would be deployed to the back of EVs as there was insufficient space in between cars.

Therefore, with it being deployed at the back of cars, we have decided to place the battery packs with the longer edge facing outwards for faster deployment and to minimise the need for turning around.

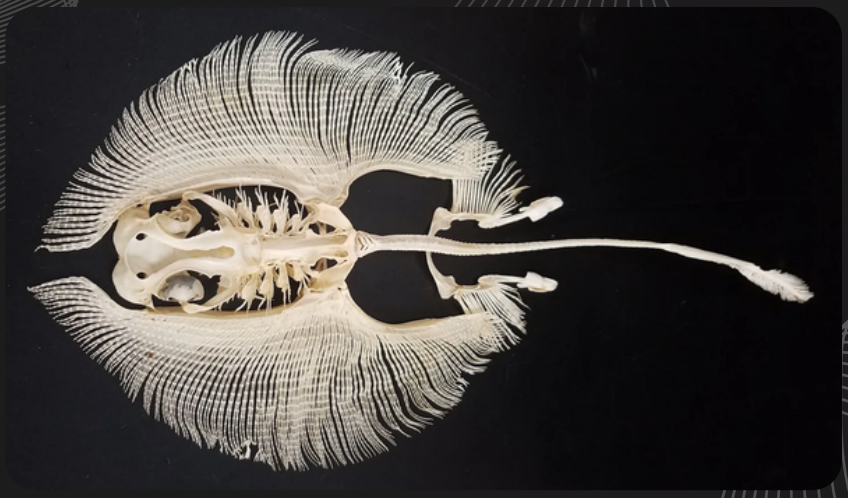
Rear-Wheel Drive/Long Range		Measurement (inches)	Measurement (mm)
A	Overall Length	185.8	4,720
B	Overall Width (including mirrors) Overall Width (including folded mirrors) Overall Width (excluding mirrors)	82.2 76.1 72.8	2,089 1,933 1,850
C	Overall Height	56.7	1,440
D	Wheel Base	113.2	2,875
E	Overhang - Front	34.2	868
F	Overhang - Rear	38.5	977
G	Ground Clearance	5.4	138
H	Track - Front Track - Rear	62.4 62.4	1,584 1,584

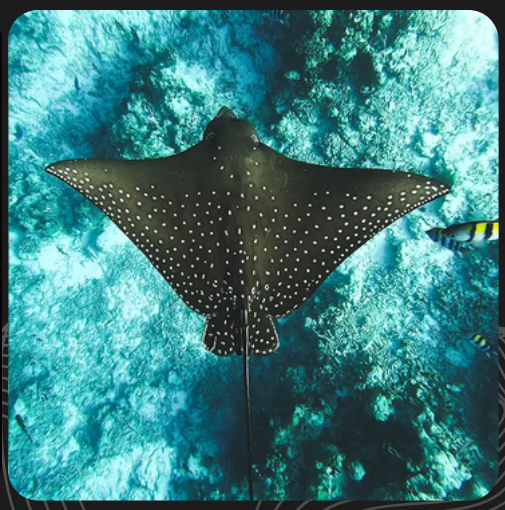
*Values are approximate. Dimensions can vary depending on a vehicle's options and various other factors.
**The track of the vehicle is based on measurements at the wheel center.

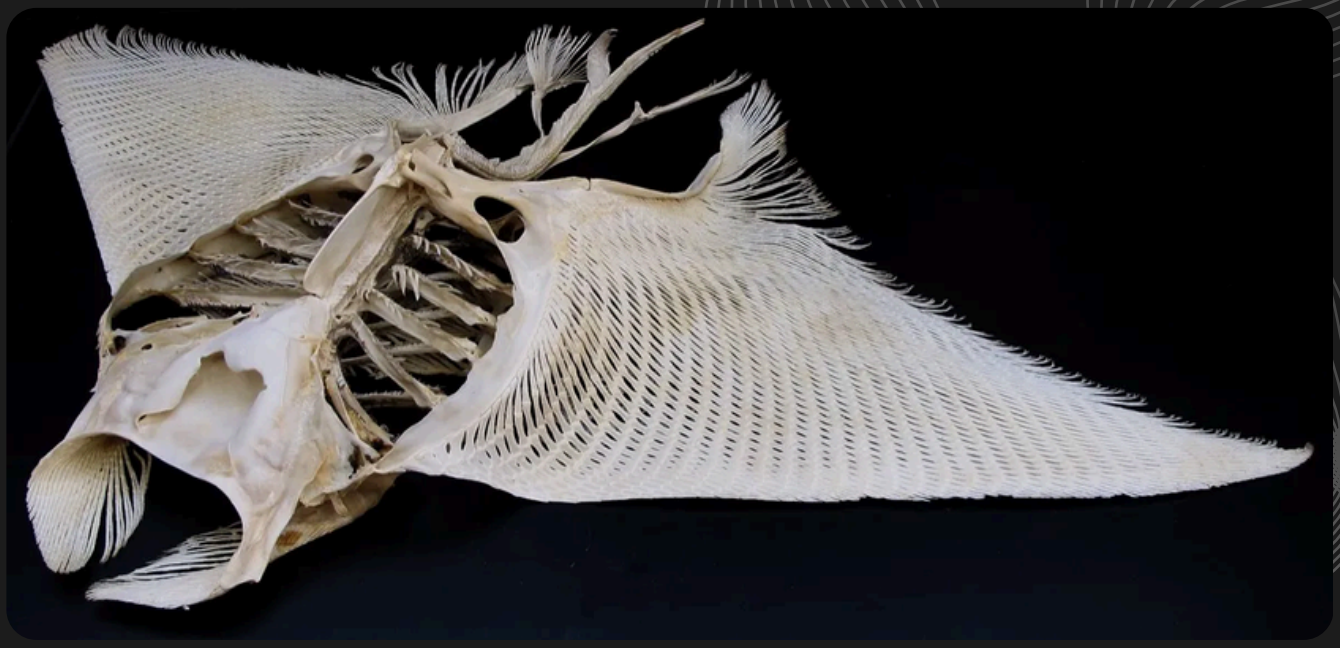
PIP's Iterations

With the main concept finalised, we underwent two distinct design phases for PIP. The first was heavily inspired by animal forms — particularly a mantaray (conceptualised alongside the exterior team), resulting in a visually striking concept. However, we found this design to be intrusive in a carpark setting and struggled to integrate PIP's core functions effectively. This prompted a shift to a second, function-led design phase. In this stage, we identified and prioritized PIP's essential functions, considered the kind of presence or character it should convey, and developed the design around these functional and experiential goals.

Phase 1 - Mantaray

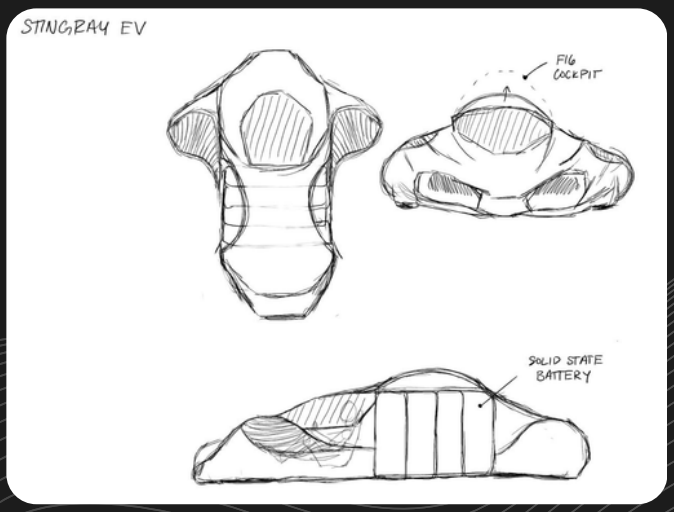


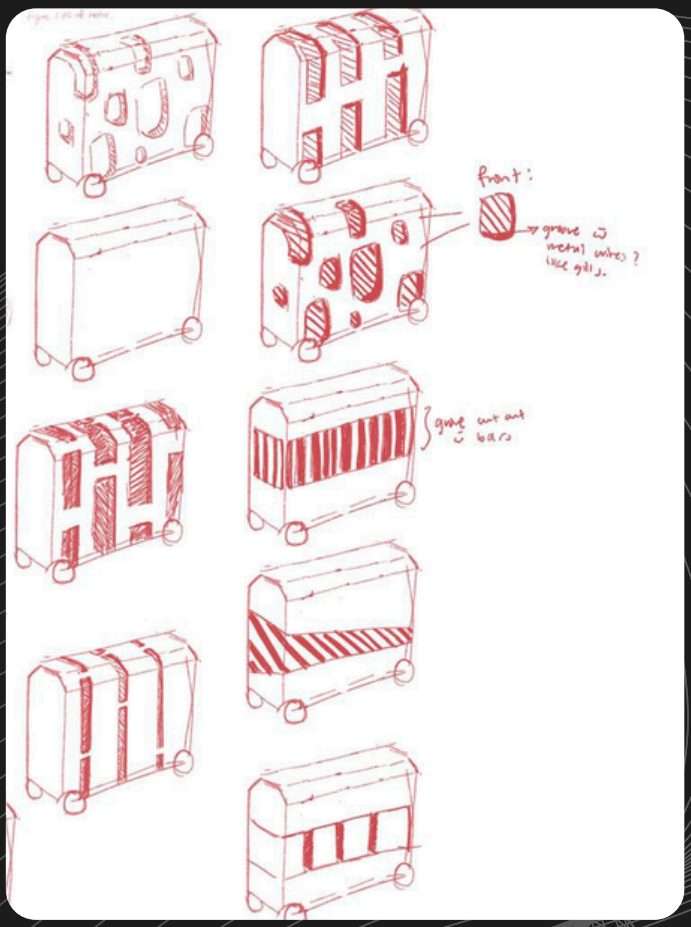


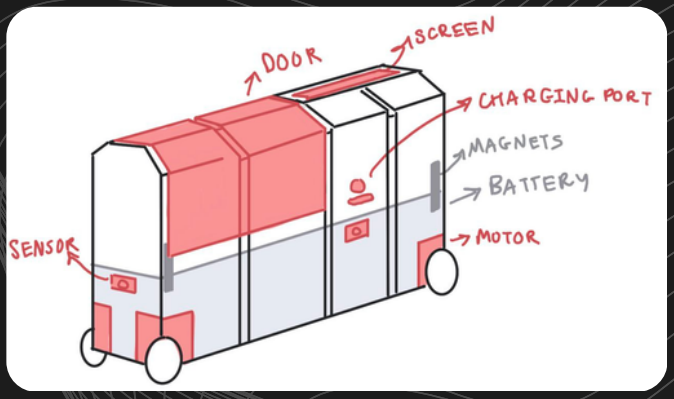


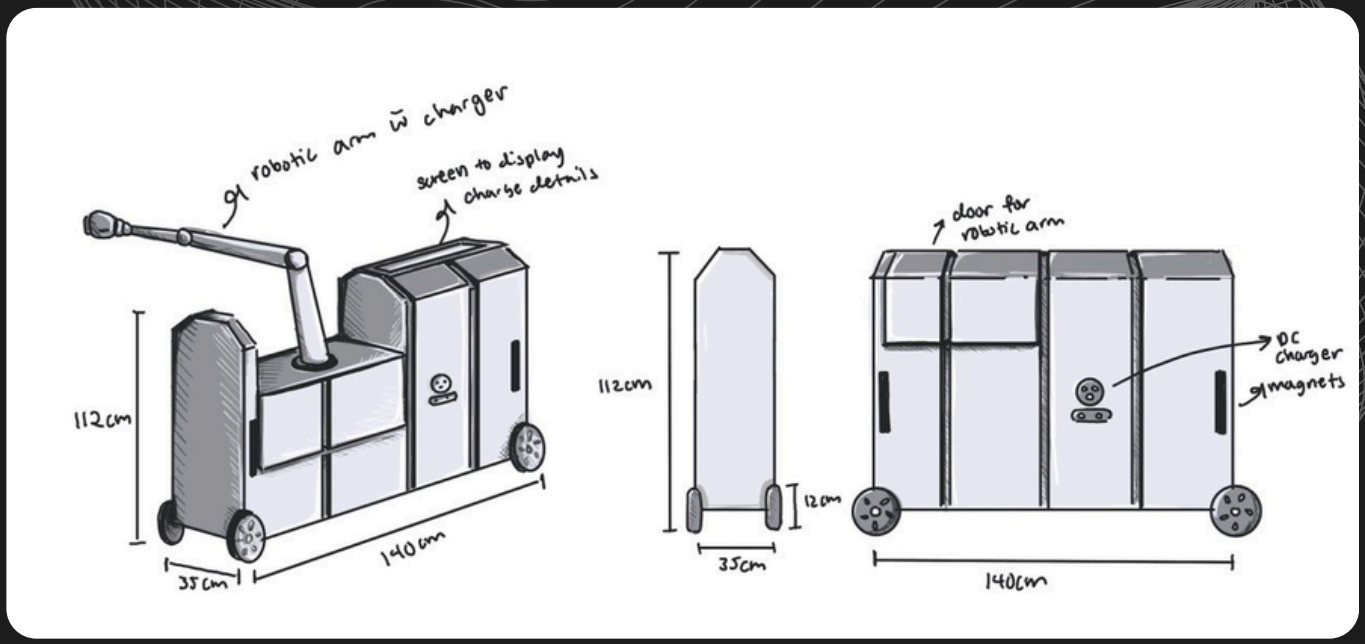
Phase 1 - Design Iterations

Since PIP would be displayed side-on, with its longer edge visible, we initially conceptualised it to resemble the skeleton of a mantaray. During the iteration process, we also found the distinctive spots on the mantaray to be a compelling visual motif. As a result, our early design iterations incorporated both the skeletal structure and the spotted pattern of the manta ray as key visual elements.



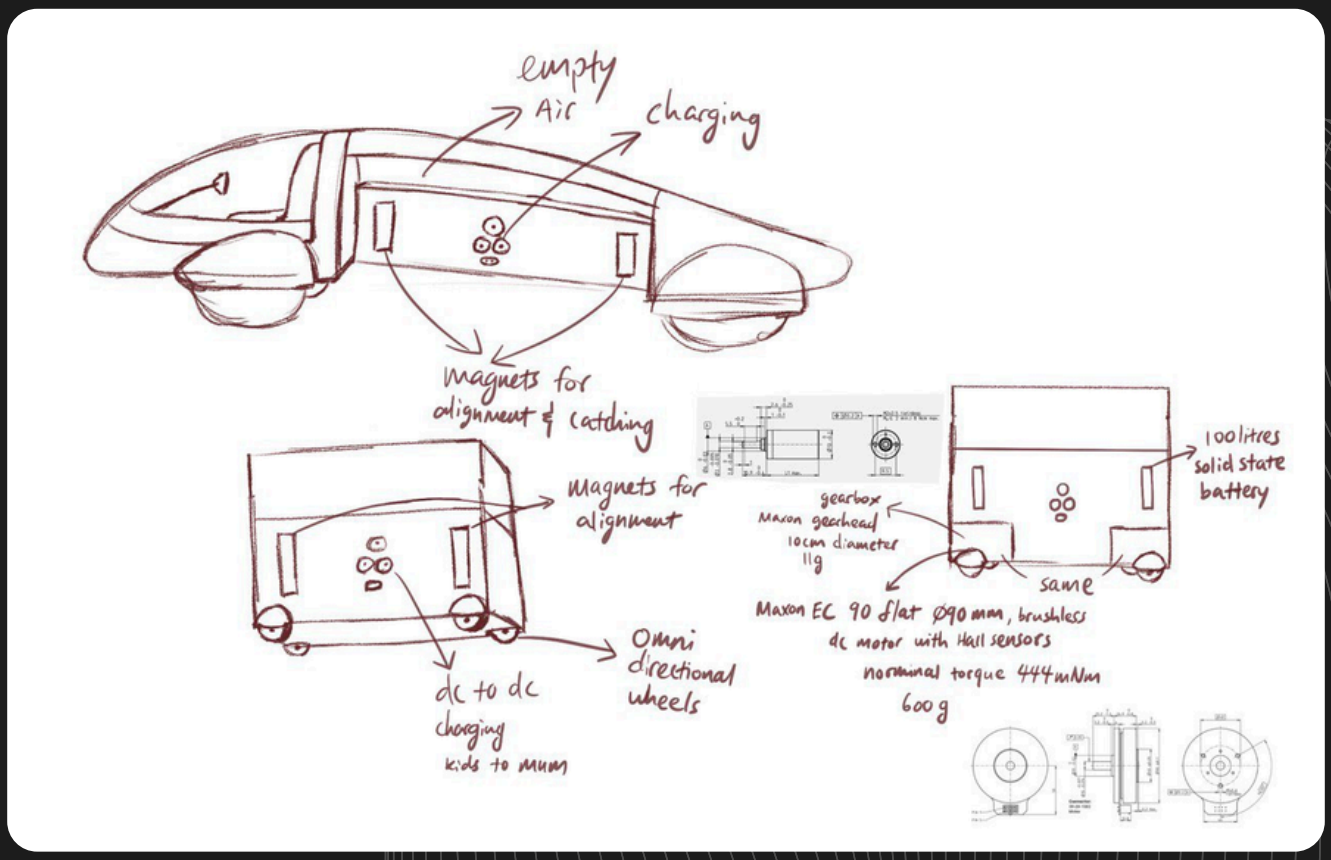






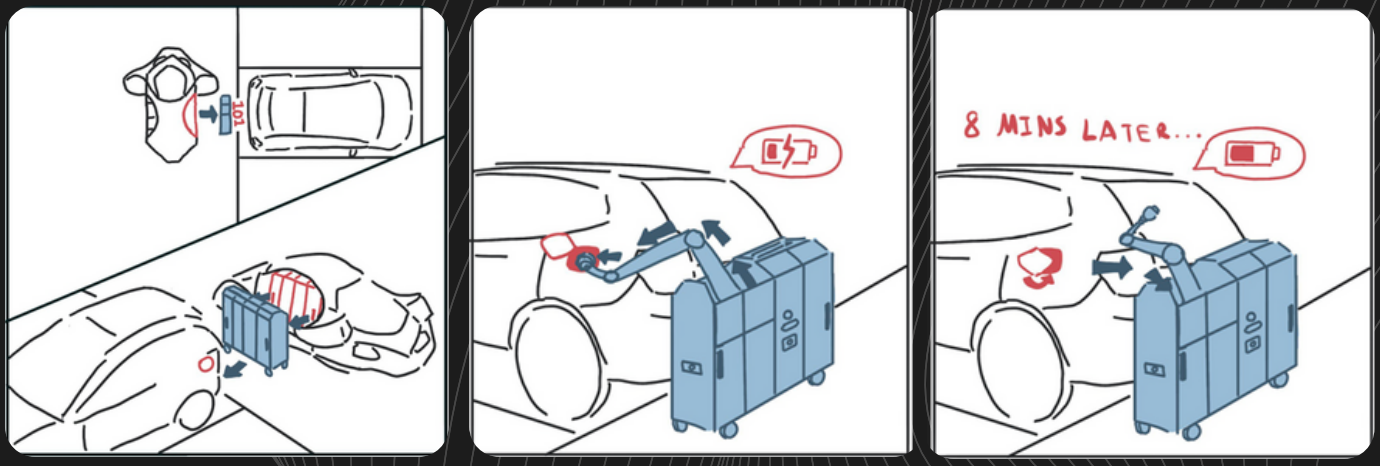
Phase 1 - Deployment

As the interior team, we had to think beyond form—considering how PIP would latch onto RAIA. We explored options like magnets, lift systems, and docking rails to ensure a secure and seamless deployment and return process.
We also wanted PIP to charge RAIA, creating symbiotic relationship between the two. This meant equipping both with charging ports—PIP with a charger, RAIA with a receiving interface.



For the latching mechanism, we opted for magnets, allowing PIP to securely attach to RAIA with ease.
For the PIP-RAIA charging mechanism, we ensured the chargers were centrally positioned on both sides of PIP and RAIA, enabling locking from any direction.

This was how we first envisioned the deployment:



However, this design revealed several key flaws. The magnetic latching mechanism lacked clarity and strength—we hadn't yet defined how PIP's magnets would secure to RAIA. Questions also emerged around scale and proportion: *How tall should PIP and RAIA be for effective locking?* Visually, the design felt too utilitarian, with sharp edges and rigid forms that felt unfriendly—not like the approachable, user-friendly experience we were aiming for.

Phase 2 - Inspirations

As commented by our professor, Hunn Wai, there were many gaps in PIP's design. Hence, we decided to take a step back to relook at the core features that we needed PIP to fulfill and work around that instead.

We tried to gain inspiration from existing products.

These products are are simple yet intuitive. They maintain a friendly presence without appearing out of place in their environment. We also noticed they feature simple shapes like the slot and circle.

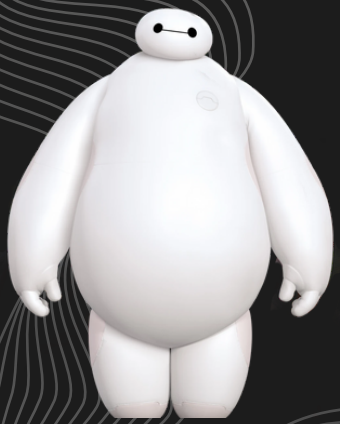






To gain inspiration on more friendly products, we looked at conceptual products and fictional characters. We noticed that the materials used are normally white, black and an accent color. We also noticed a translucent/ reflective black material is often to contrast the matte white. This all together presented a clean and minimalist design.

Additionally, we noticed that friendly robots often feature bigger bottoms and chamfered/fillet tops. The bottom heavy shapes gives viewers a sense of security and safety.









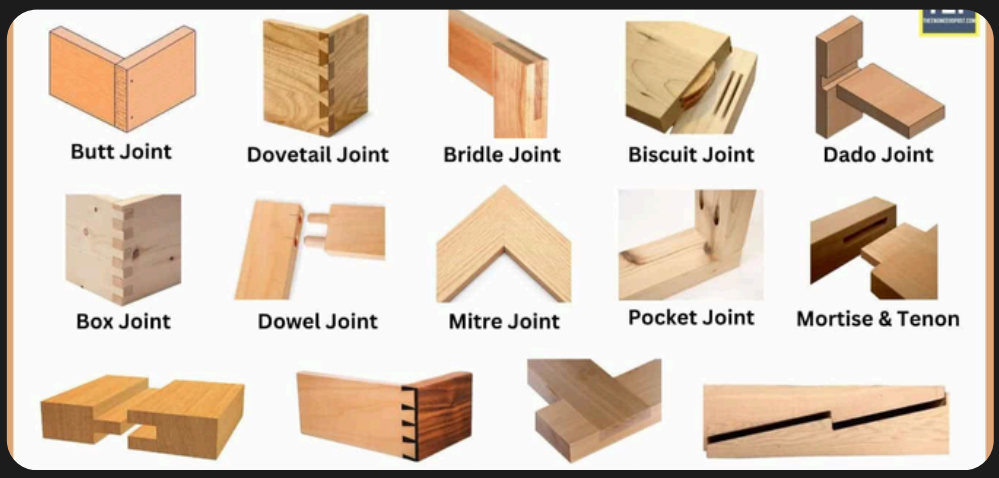


Phase 2 - Function-Led Design

The core design features of PIP were the locking mechanism to latch PIP onto RAIA, the charging port (to charge RAIA) and charging indicator lights.

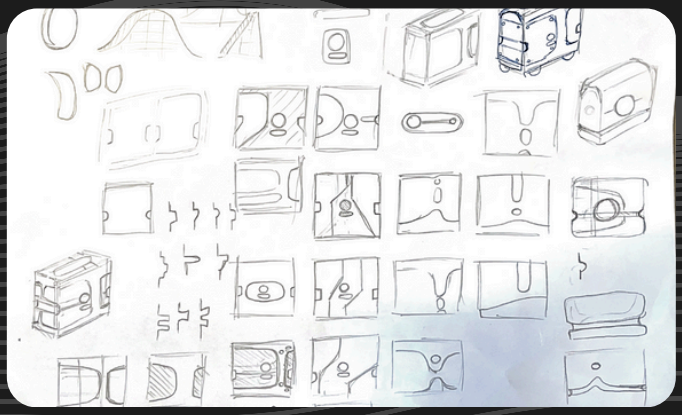
The interior team conceptualised a 2 stage locking mechanism: precision-fitted grooves and electromagnets When deploying, we also needed a way to bring PIP to the ground. We found that the best idea was to either make PIP's wheel retractable/extendable, or to lower RAIA onto the ground, to which the interior team proposed the latter. This was due to PIP's space constraint for the arm and battery.

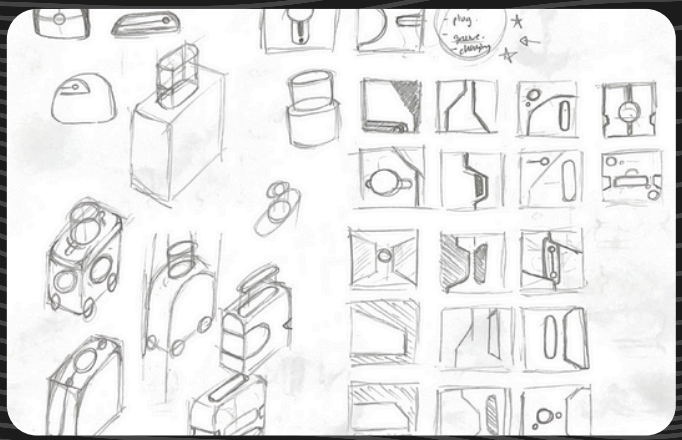
For the grooves, we took inspiration from Japanese wooden joints. Where there is often an extrusion and groove to hook 2 bodies together. Instead of the complex shapes normally used in Japanese craftsmanship, we opted for simple shapes like rectangles and circles.

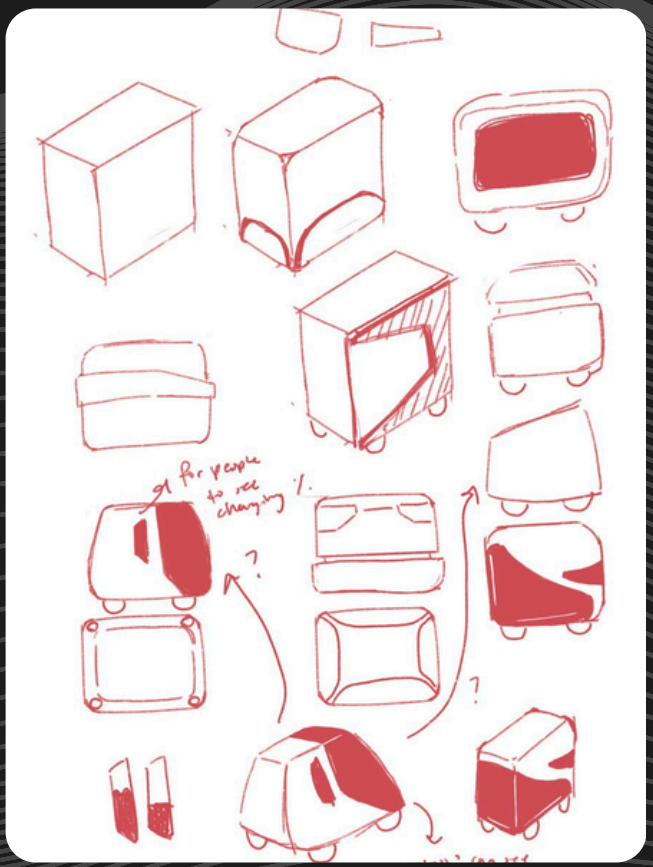




Here were some iterations we went through:

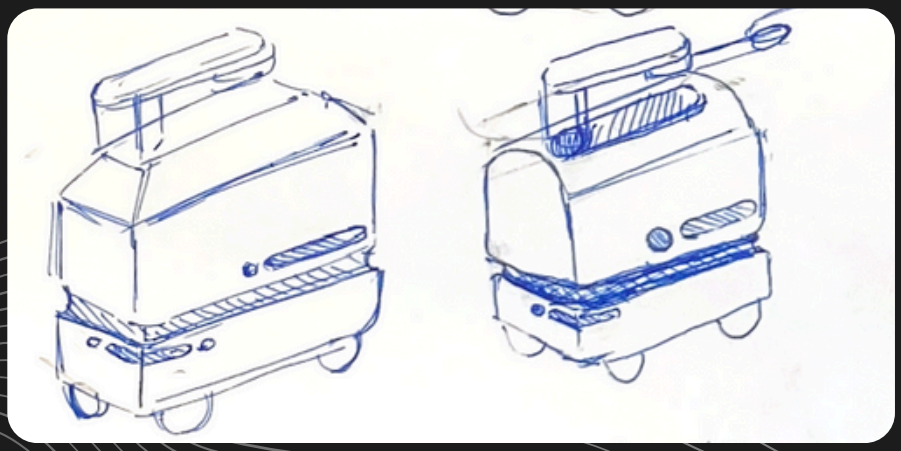






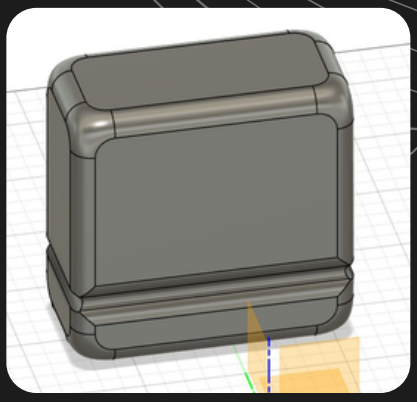
Phase 2 - Function-Led Design

These were the iterations that stood out. Instead of the grooves being on the short ends of PIP, it became a feature in a design, where it stretched across the lower half. The slots and circle cut outs also acted as a place to put our sensors. However, we noticed 2 problems with this design: the curved top surface posed a challenge when attaching magnets, as it lacked the flatness needed for them to achieve a secure and seamless fit with RAIA. The rounded top also resulted in less space for the arms.

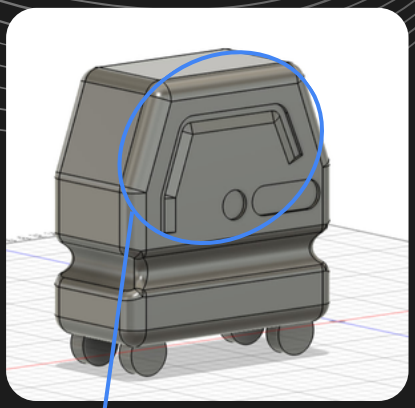




With that in mind, we kept the long side as flat as possible, only rounding the short edges. With all those in mind, it led to this iteration.







We wanted the part circled in blue to be an LED indicator and a place to put our magnets.
We opted for LED lights instead of a screen, as using a full display solely for charging feedback felt excessive and unnecessary.

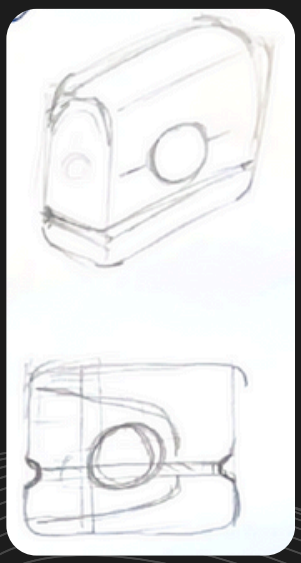
However, our professor, Mike Reeves, brought up that using that as an LED indicator might not be intuitive for users. Normally, charging indicators are circular (to represent a charging cycle) or linear (to represent start to end).

Our professor, Hunn Wai, also brought up that the sensors should be placed strategically. We thus also reconsidered the placement of our sensors.

Lastly, we noticed that the shape could be rounded more to appear more friendly while still giving sufficient space for the arms.

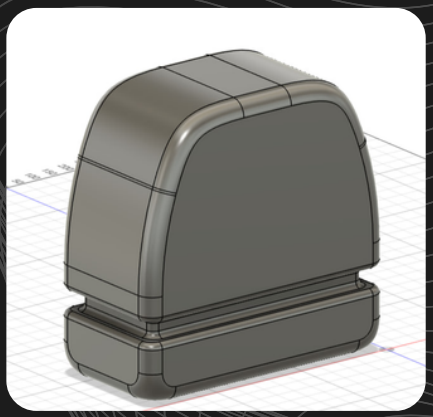
Phase 2 - Function-Led Design

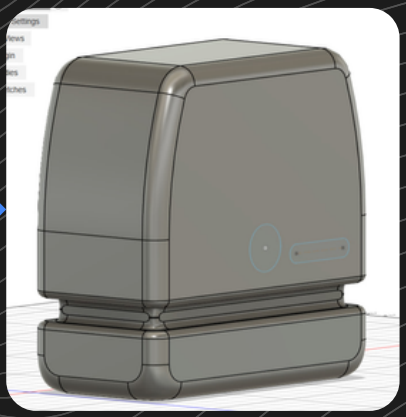
We felt that the charging indicator was the most difficult to work around. Hence, we rethought the updated design based off that feature. We looked back at our previous iterations, and these stood out to us, where the indicators was circular.

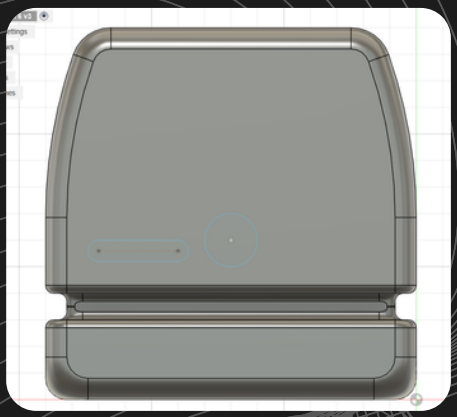




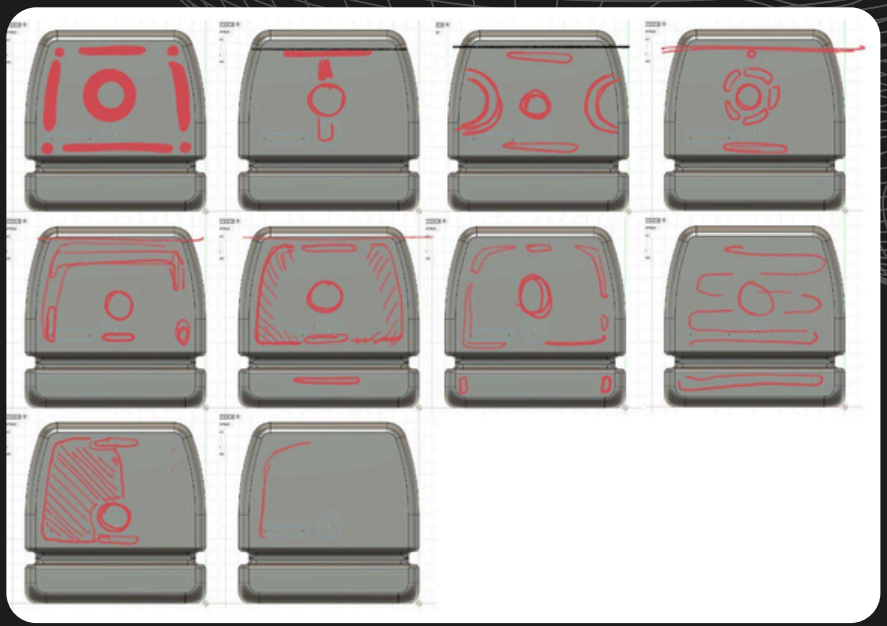
We also modified the shape slightly to allow for more space at the top, where the arm will be stored.





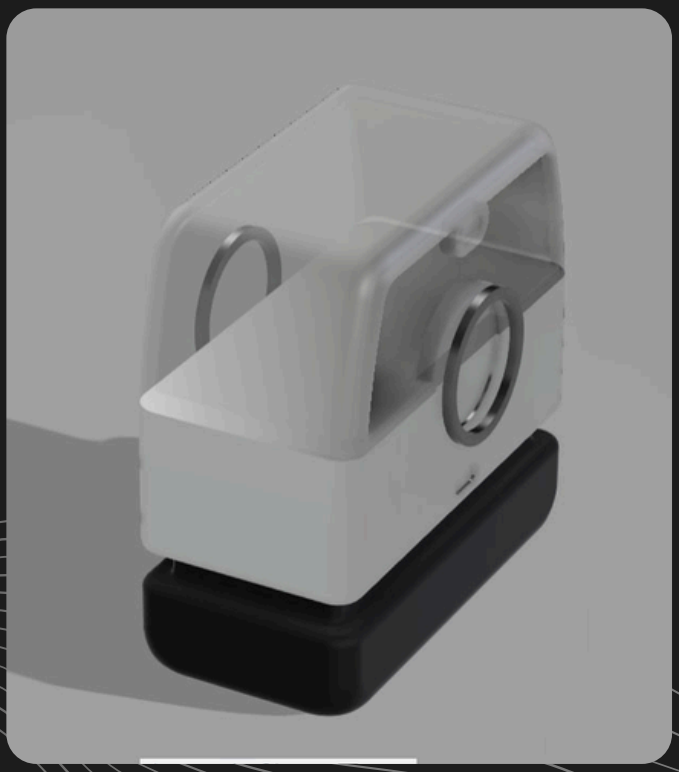


With the new shape and the Circular motif, we iterated a little more. However, we went with something simpler. With just the circle in the center as the core feature. We felt that this gave the most sleek, modern, friendly and intuitive look.



Phase 2 - Materials

For the materials, as mentioned previously (in our inspirations page), we noticed that matte white and black tinted glass contrast gave a sleek and minimalistic look. We hence did the same on ours, and added an accent color.







We initially went with an accent color of Yellow to display when PIP was idling. But it eventually changed to blue as we felt it gave a more futuristic look.

We went with a slightly tinted glass top to give users a glimpse of the workings of the arm. It also made the top feel lighter. The tint was slightly blue to give a more cohesive look.

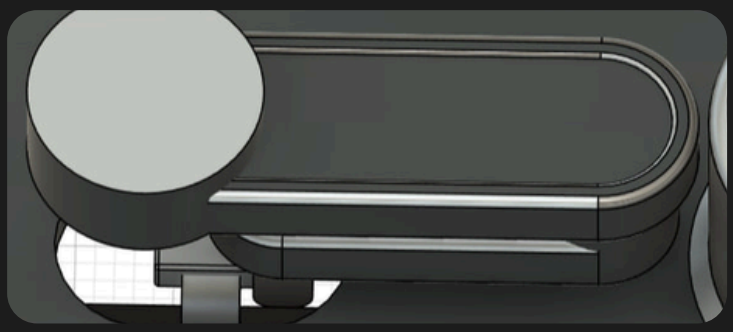
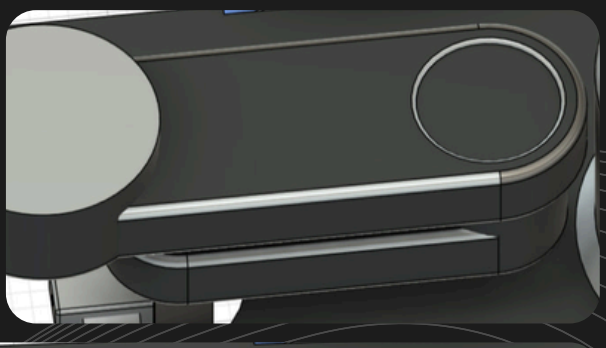
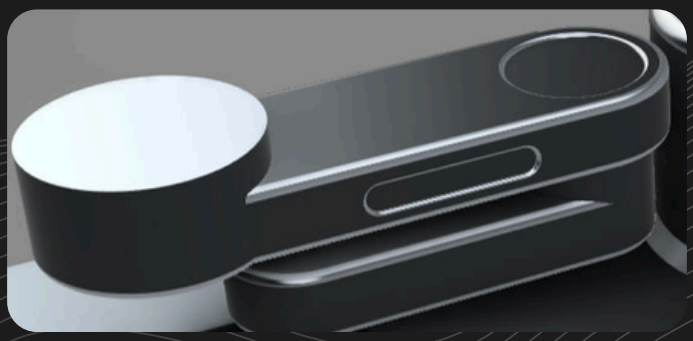
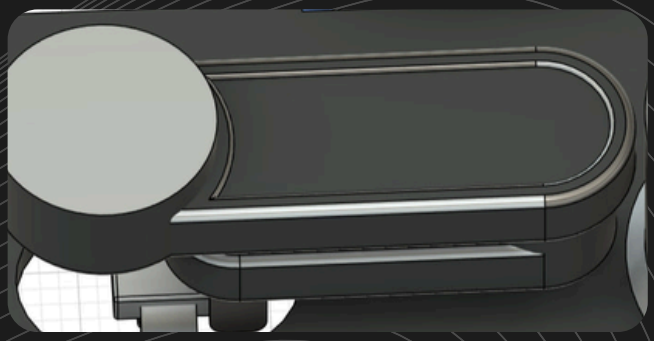
The aluminum was chosen for its durability and light weight. The main body is the same color as the tinted glass.

A dark grey base of Aluminum and rubber was chosen to act as a contrast to the lighter color. As well as give an solidify the impression of a bottom heavy object. Moreover, darker colors tend to hide scratches and dents better.

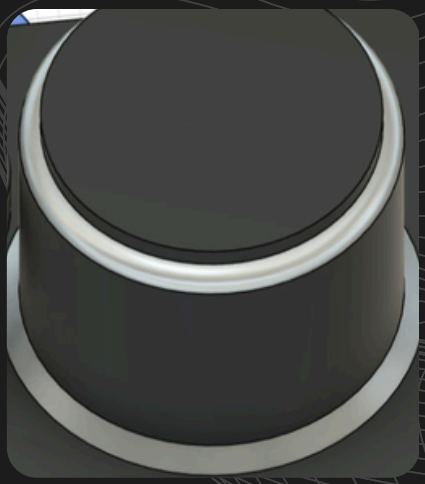
This material, color, and circular motif choice eventually influenced the exterior team's designs.

Phase 2 - Arm design

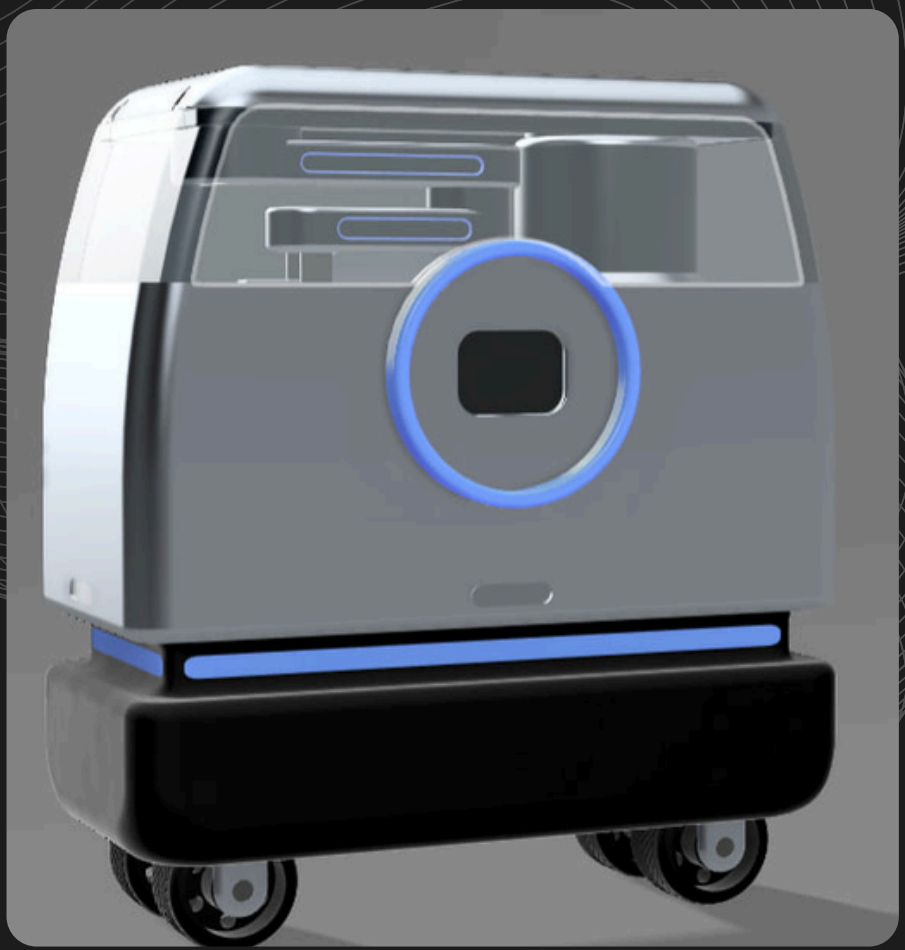
We wanted to add more dimension to the arm and experimented with the arm designs

Using the same light and dark bluish grey, we added accents to the arm as well.



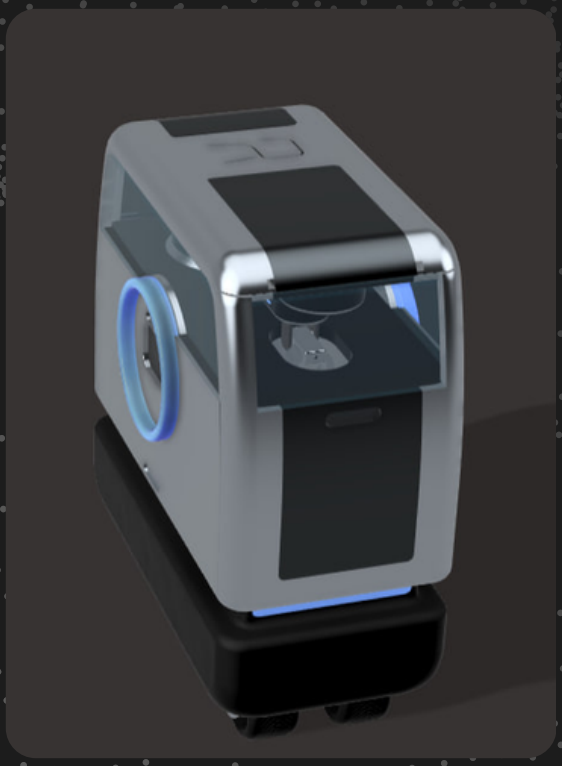

We integrated LED lights into the side slots of the arm to signal different states, serving as a warning indicator during arm movement and displaying charging status when active.

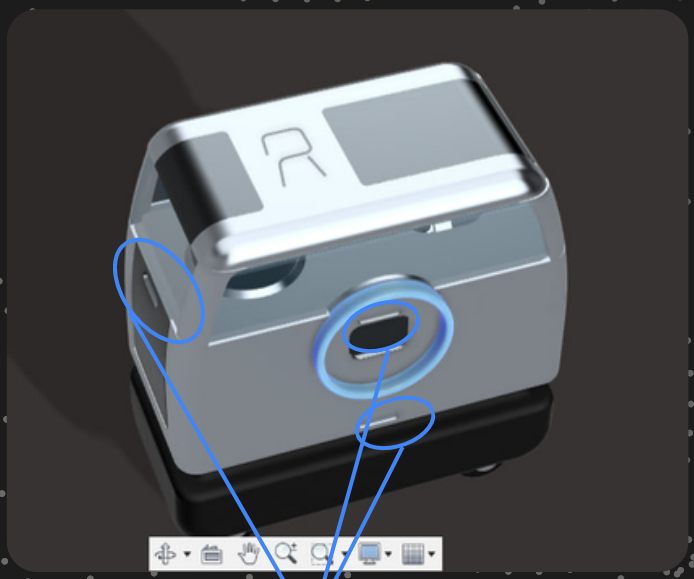


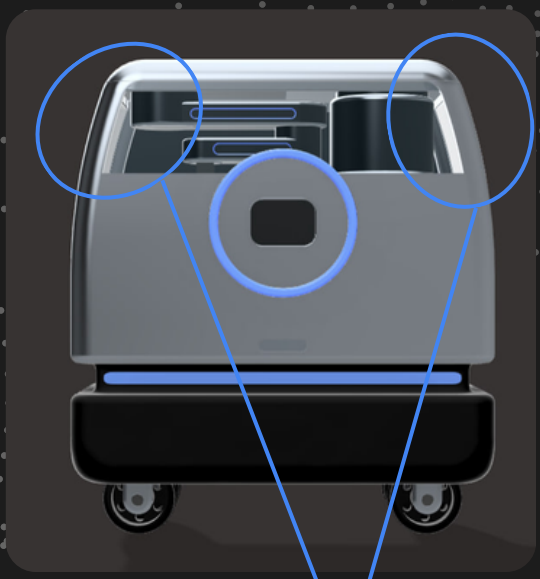
Refinement

To finalise the design as a whole, we added the slots where the sensors would go, added a logo, and some strips to give PIP some character. We also started to think about how PIP would be assembled in a real world scenario. Hence, adding some aluminum supports all around the glass area at the top









4 sensors at the top and 2 sensors at the bottom as we found that this was the most optimal solution for PIP to detect its surroundings, car plates, and obstacles on the floor. There was an indentation for the sensors, along with a glass piece that would protect the sensors from dust and debris. The glass sits flush with the main body.

RAIA logo and serial numbers at the top

Aluminum frames

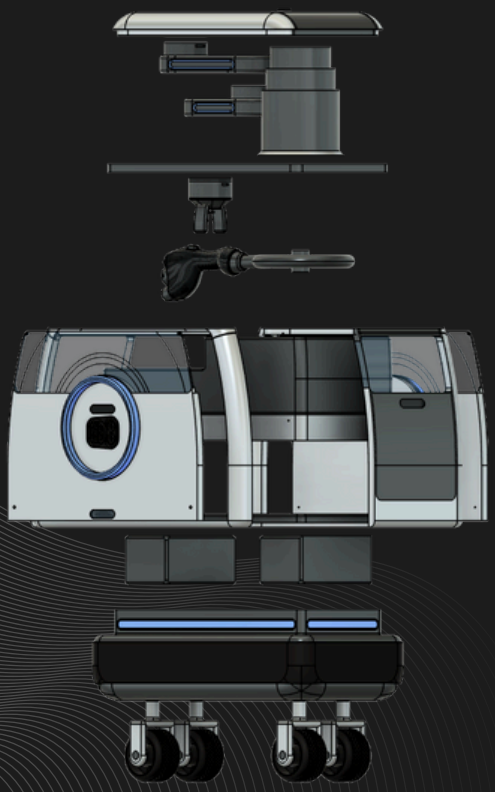


Assembly

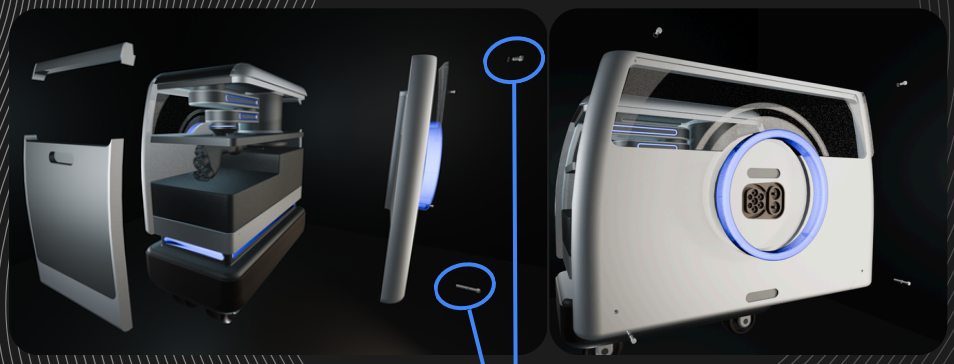
As part of refining PIP's design, we focused on ensuring that each component was easy to assemble and maintain.

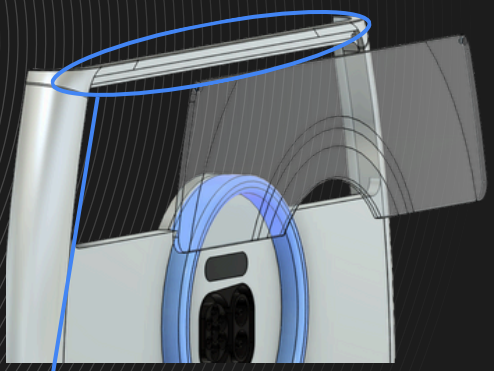


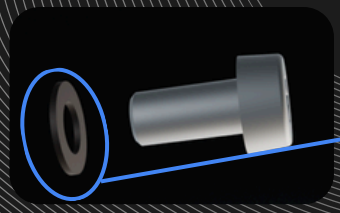
We utilized hexalobular socket cheese head screw through out the build. For the improved torque transfer, reduce wear and tear when using a driver, and added security against light tempering.



For the main body, we made the longer side of the body detachable via screws. We were inspired by PC cases where the acrylic/glass were screwed onto the main case.





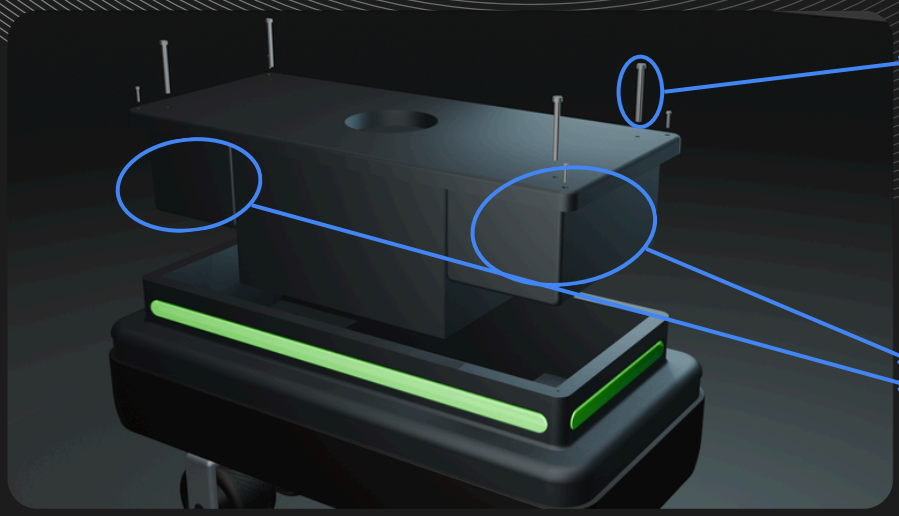


Rubber rings to minimise damages to glass from the screws

Latch for glass to be screwed on



Attachment of base to main body:

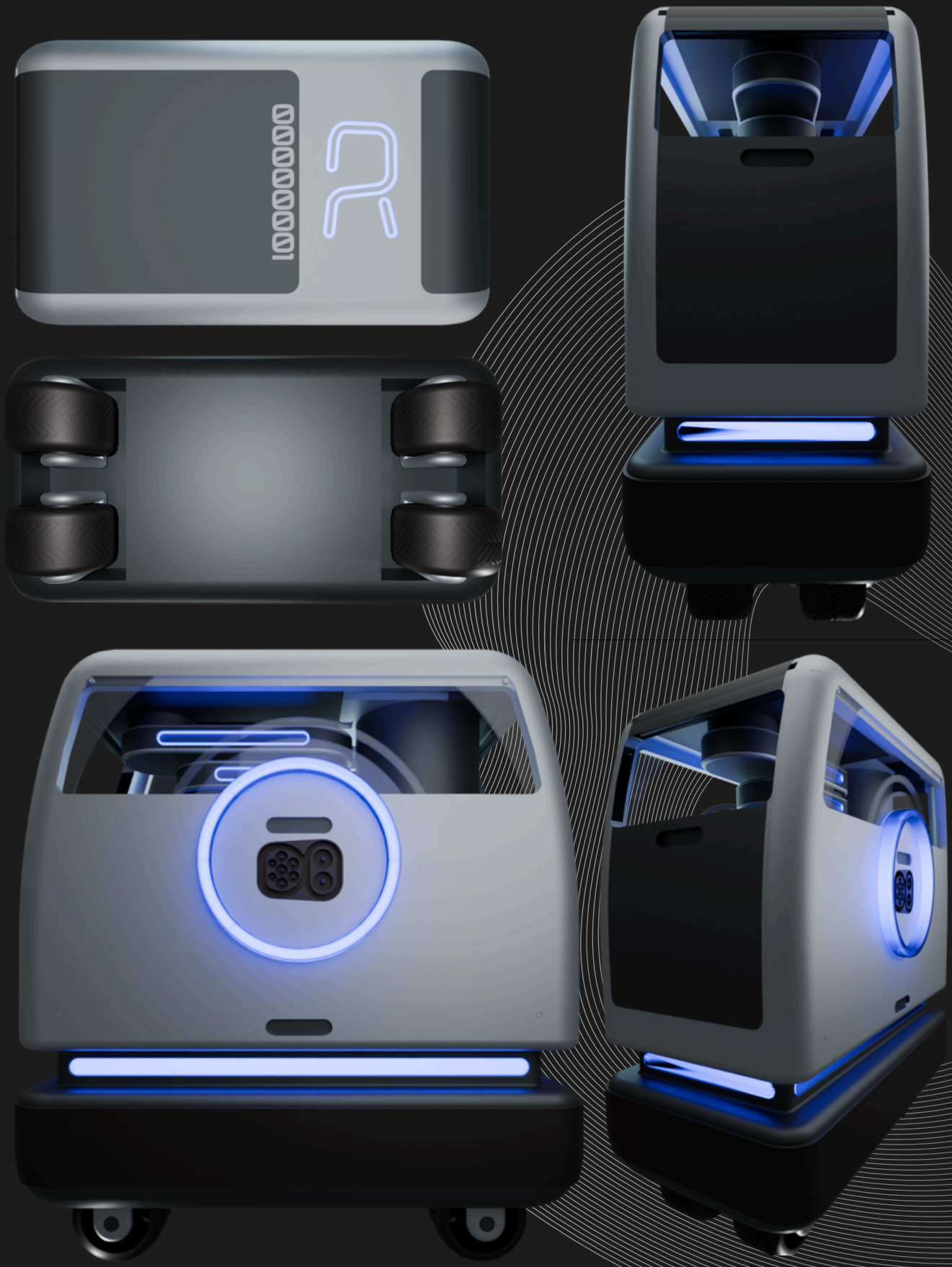


Screws mounting upper body to lower body

Gear boxes screwed to the bottom lid

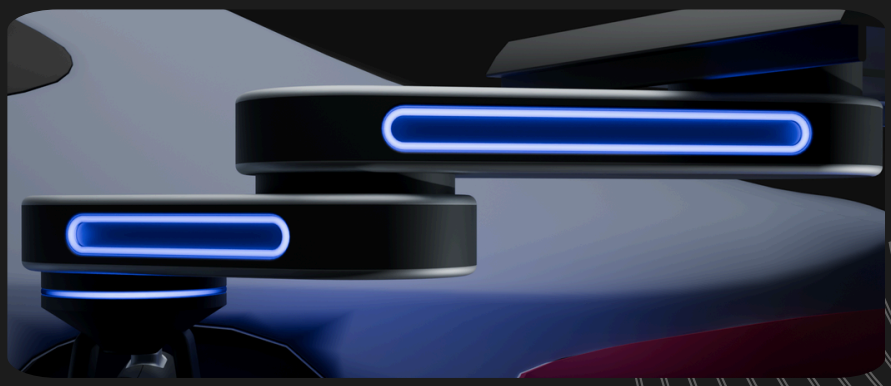
Final design

Top, Bot, Side view of PIP



Charging Indicators

Arm Gradient

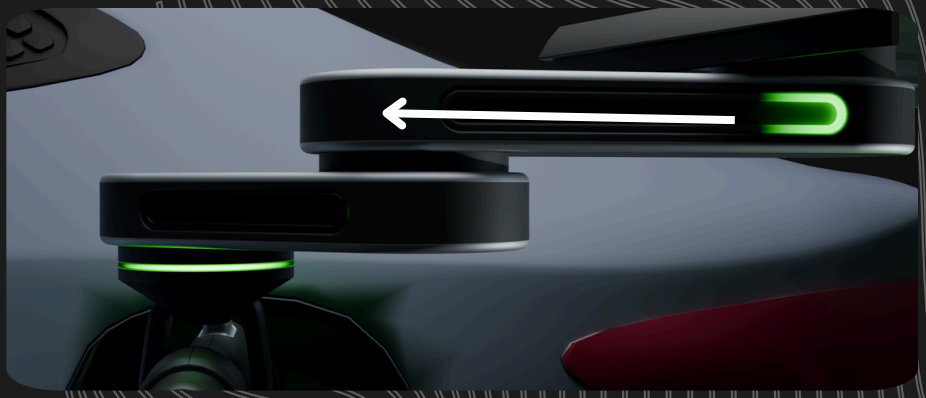


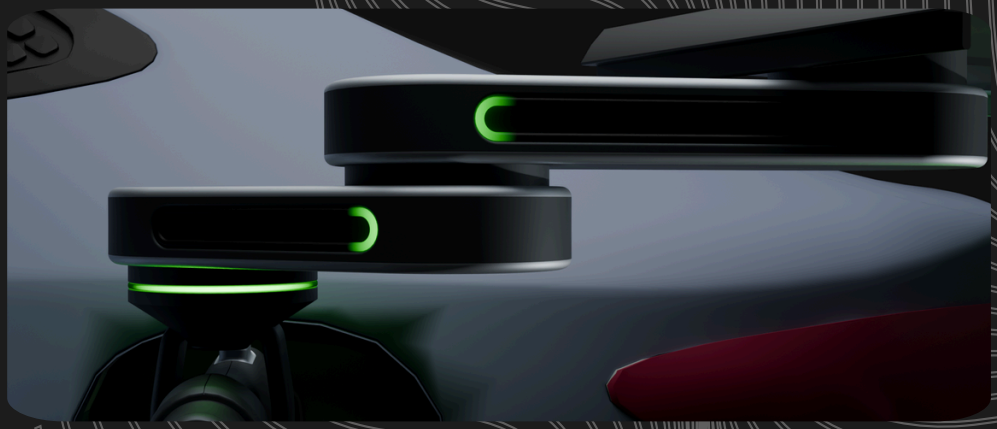
To intuitively show pip's charging process, we decided to design our charging arm to house LEDs that will "pulse" towards the car when charging occurs.

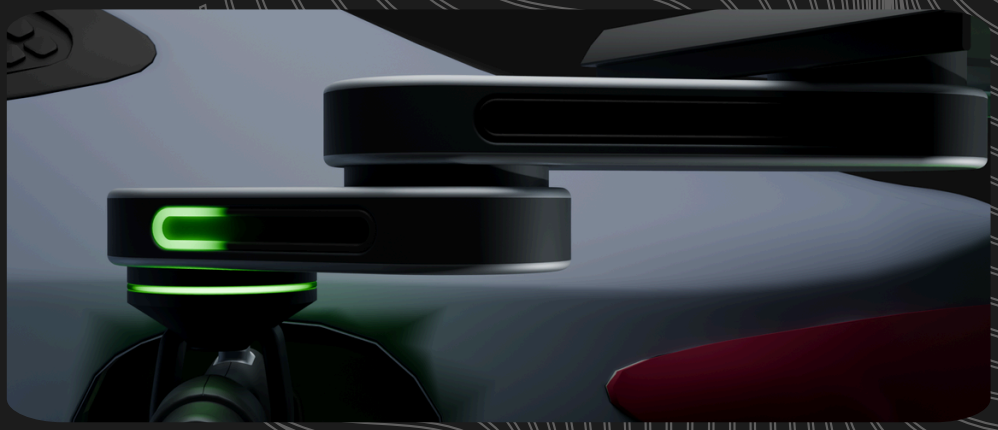
The change of light to green and movement of light towards the EV is meant to simulate power entering the car and also to effectively show the user that charging is happening.

The blue and stationary state of LED signifies the dormant state of PIP. This is when charging has not yet begun.

When charging begins, the light will change to green and rythemically pulse from PIP towards the EV socket, symbolising the transfer of energy







Charging Indicators



Other than the arm, we also designed a charging indicator for PIP at on its side in the form of a circle.

When charging beings, the charging line starts from 12 O'clock and gradually moves clockwise as the EV gains more charge

This is at the beginning of the charge



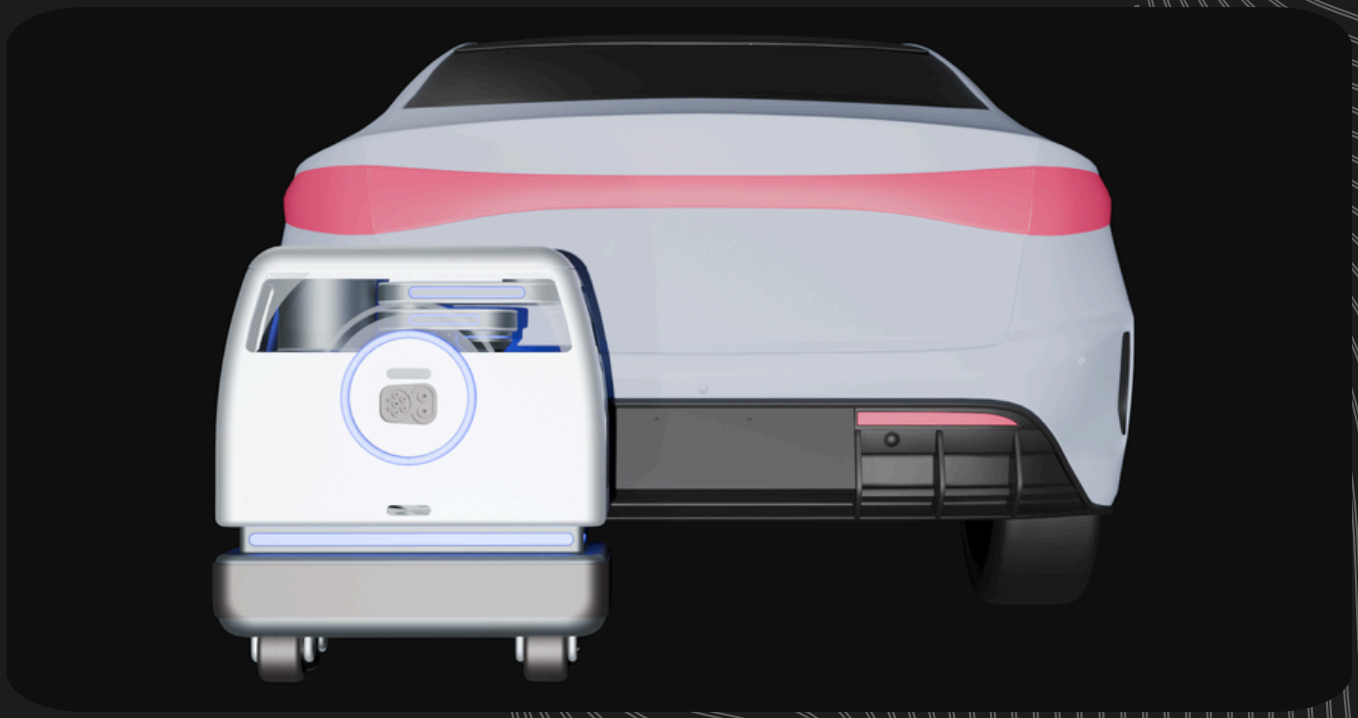
This is during the charge



This is when charging is complete!

PIP in real-world context

We also designed PIP to be compact such that it will not be too bulky and block the paths in carparks



Back view

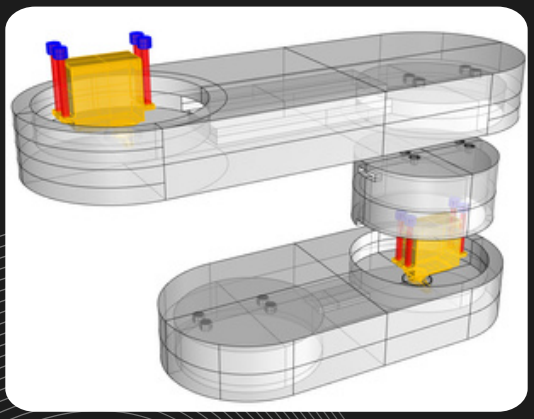


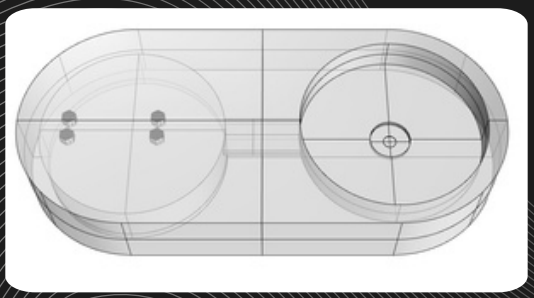
Side view

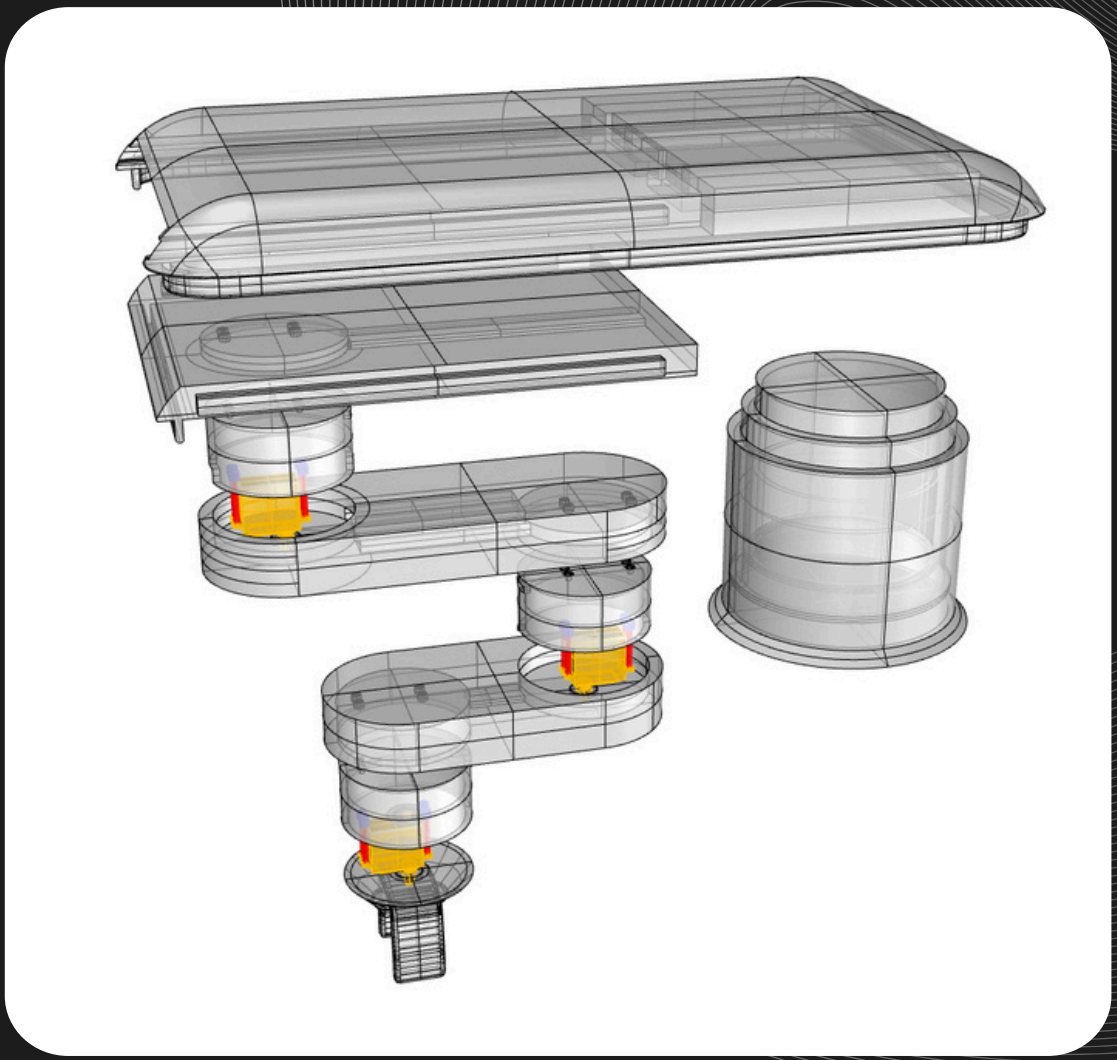
Iteration - Arm Design V1

PIP's main feature is a robotic arm that automates EV charging. We chose a SCARA (Selective Compliance Articulated Robot Arm) over other types like Cartesian arms because it's more compact and flexible. Its two-link, jointed design moves like a human arm, making it easier to reach into tight spaces. Unlike Cartesian arms, which move in straight lines and need more space, the SCARA arm can fold up neatly—perfect for fitting inside PIP's small chassis.

However, after building and assembling the first iteration of our robotic arm, we encountered an unexpected issue—sag. Since the arm extends up to 50 cm, it generates significant torque and downward force, which led to our motors failing after a few uses. The problem stemmed from the torque being fully supported by the motor shaft, causing excessive wear and eventual failure. We tried reinforcing the setup by locking the arm to the motor with screws and adding screws to the edges of the motor horn to distribute the load more evenly. Despite these efforts, the sag persisted, prompting us to reconsider our design.







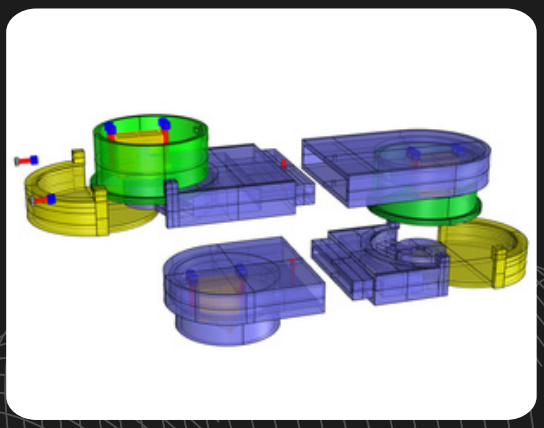
Iteration - Arm Design V2

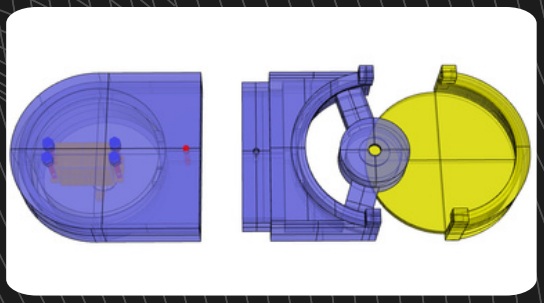
In the second iteration of our robotic arm, we focused on resolving the sagging issue by addressing three key areas:

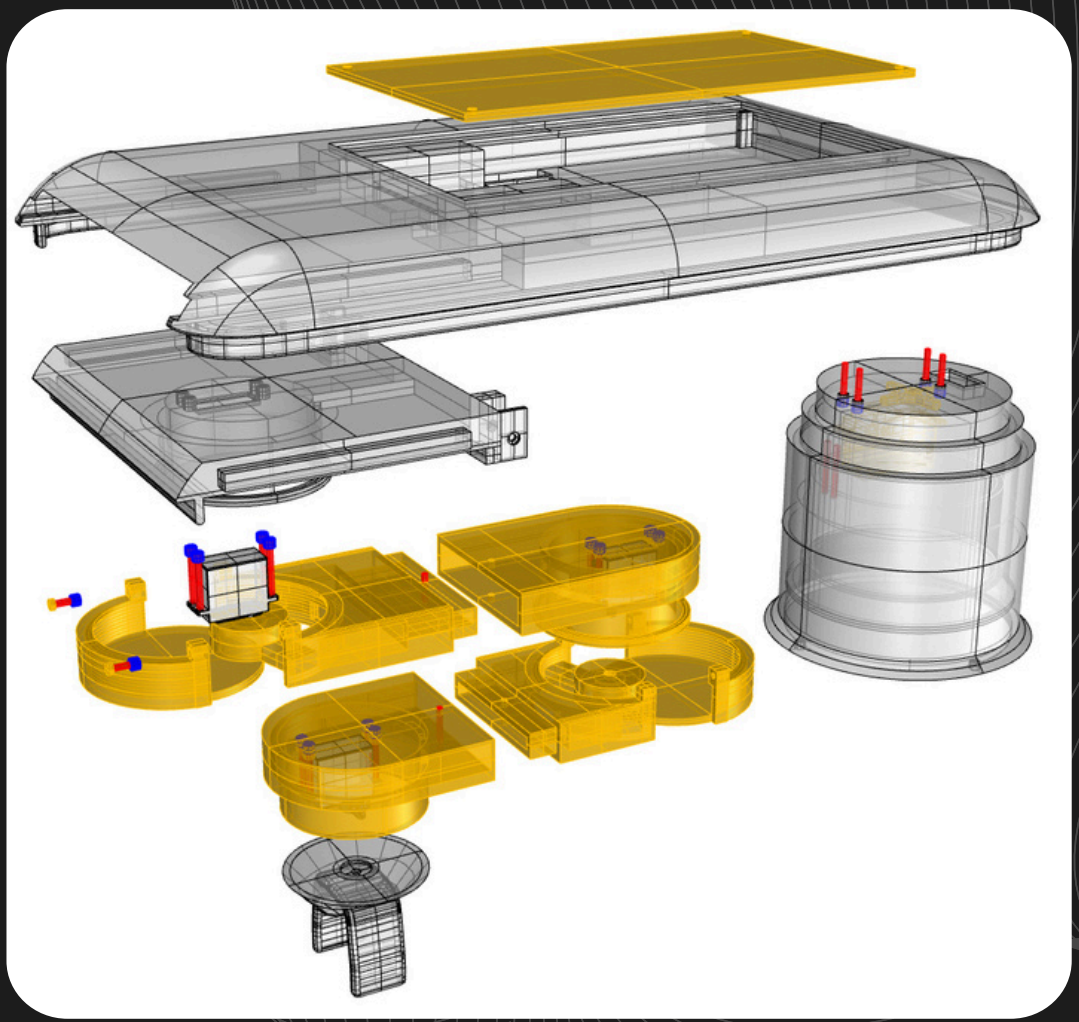
Improved Load Distribution (Green):
We redesigned the load-bearing structure so that the weight is supported by the arm's body rather than the motor shaft. Extrusions were added to redirect the downward force onto the chassis, significantly reducing stress on the motor and extending its lifespan.

Weight Reduction (Blue):
The original arm was a solid piece, with each joint weighing around 300 grams, resulting in nearly 10 kg of torque. In the new design, we hollowed out the arm structure, reducing its weight by up to 40% and minimizing the torque generated during extension.

Easy Maintenance (Yellow):
We introduced removable panels for quick access to internal components. These allow motors and other parts to be easily replaced, improving serviceability and reducing downtime.

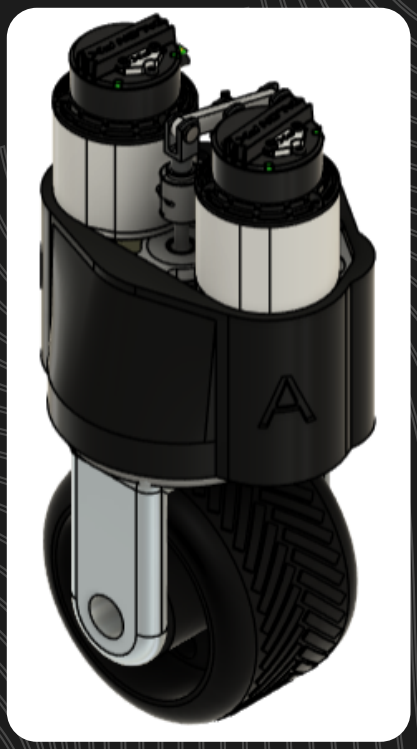






PIP's Maneuverability

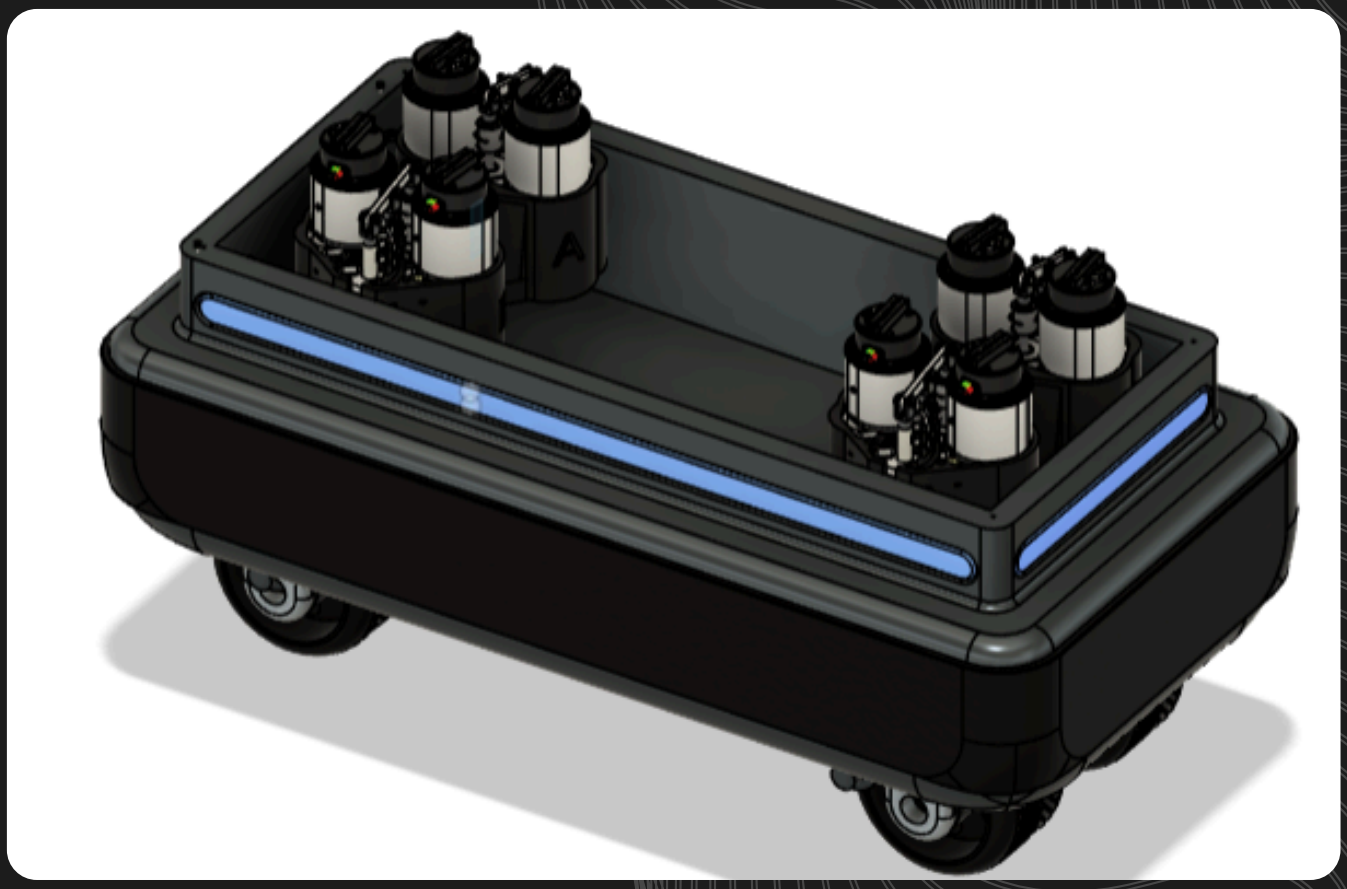
The integration of a swerve drive system in PIP offers significant functional and ergonomic benefits, particularly in dense, space-constrained urban environments like Singapore. PIP depends on precise, flexible movement to navigate complex spaces autonomously.



Traditional wheeled robots often require complex, multi-point maneuvers to handle parking aisles, tight turns, and compact stalls. In contrast, PIP's swerve drive allows it to glide into position beside parked vehicles, shift sideways to align with charging ports, or rotate in place—eliminating the need for extra clearance or manual correction.

The swerve drive system enables each wheel module to rotate independently on a vertical axis, providing omnidirectional movement and 360-degree rotation. This allows PIP to perform smooth lateral shifts, tight turns, and fine positional adjustments—essential for autonomous operation in narrow spaces.

This maneuverability enables PIP to function effectively even during peak hours or in high-density areas, minimizing disruption and maximizing uptime for EV servicing.



How Pip Navigates

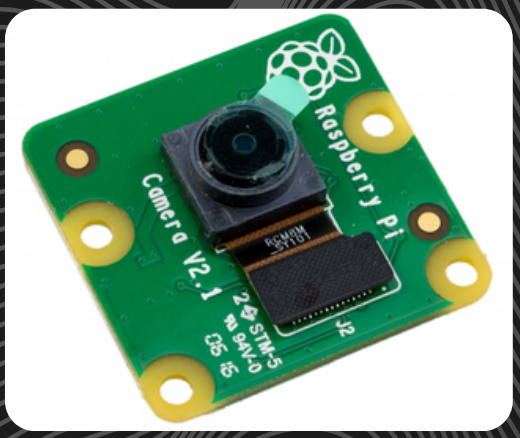
To support its autonomous navigation capabilities, PIP is equipped with a visual odometry system, enabling it to estimate its position and orientation in real time based solely on visual input. This allows PIP to operate without dependence on external infrastructure like GPS or magnetic strips. To achieve comprehensive environmental awareness and precise motion tracking, camera sensors are strategically mounted on all four sides of PIP. This 360-degree visual coverage ensures that the platform can detect passersby, navigate around vehicles, and maintain accurate localization even in visually complex or low-light environments.



Two camera sensors, Luxonis OAK-D and the Sony IMX219, were considered for PIP. The OAK-D offered many advanced features, including built-in depth sensing and its own processing power for visual data. However, it was physically larger and bulkier, which made it difficult to fit within PIP's compact frame. Since one of the top design priorities for PIP was keeping it small and lightweight, the OAK-D simply wasn't a practical option. Its size would have made the internal layout of PIP more complicated, leaving less room for other essential components like the robotic arm.

The IMX219 delivers clear, reliable visuals that support PIP's autonomous functions. Its low power use and compact size make it well-suited for mobile applications, helping PIP operate longer. With one camera on each side feeding real-time data into its navigation system, PIP can confidently move through dense environments like HDB car parks, avoiding obstacles and repositioning precisely while maintaining a streamlined and cost-effective design.







One of PIP's most intuitive features lies in its use of color to communicate presence and awareness. When any of its onboard cameras detect an object within close proximity, PIP's ambient lighting shifts from a calming green to a vivid red—signaling not just a change in state, but a heightened sense of spatial alertness. This visual cue is designed to be instantly recognizable, blending functional safety with a sleek, modern aesthetic. It's a small detail with big impact, ensuring both bystanders and users can understand PIP's behavior at a glance.

Our system

As the interior team, we didn't just design a product. We developed a system that reimagines the future of EV charging.

Through the design of PIP, we discovered its potential to serve multiple functions. Beyond its role as a daily EV charger, PIP can also operate as a portable power source for temporary events, such as those held at community clubs. In larger venues like expos, higher demand may require multiple PIP units to be deployed. While our mothership, RAIA, is fully autonomous, certain scenarios such as external deployment, maintenance, or surges in demand, may still require occasional manual transportation support. And with that need in mind, it made sense for us to also dive into the design of a suitable **seat** and **steering wheel** for RAIA.



Hence, our system is not only about PIP, but also about the seat and steering wheel that would accompany the user throughout their interaction with RAIA. The following part of this report will dive into the design process of the seat and steering wheel. Where our team made design decisions with the needs of our users in mind.





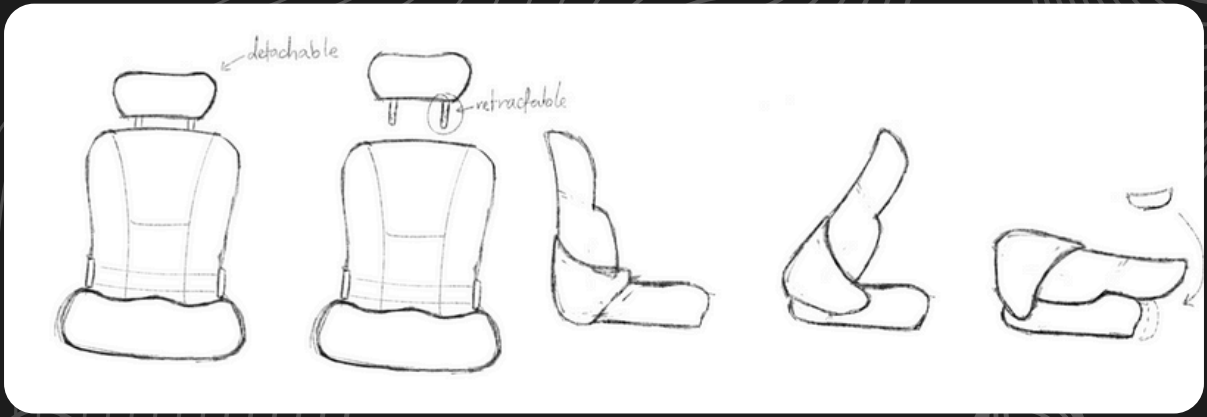
Car Seat - Iterating

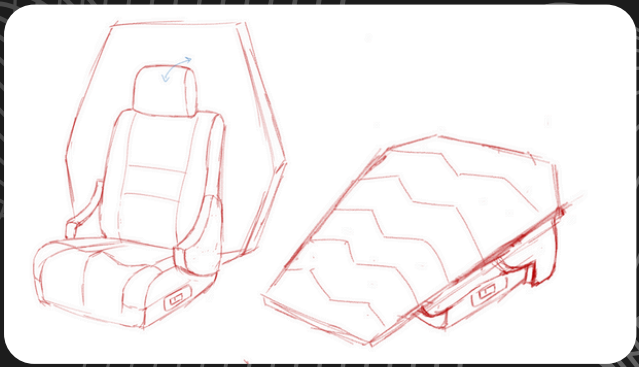
Our foldable seat began with a familiar silhouette—a standard car chair, complete with a detachable headrest that neatly stowed into the seat base. While functional, this early version felt bulky and lacked the visual clarity we were aiming for in a modular, minimal interior.

In our next iteration, we took inspiration from racing car seats—introducing sleeker lines, a slimmer profile, and a cockpit-like chassis. The backrest flipped up with a dramatic curve, giving the form a more dynamic and tech-forward look. While exciting, it began to feel overdesigned for its intended use.

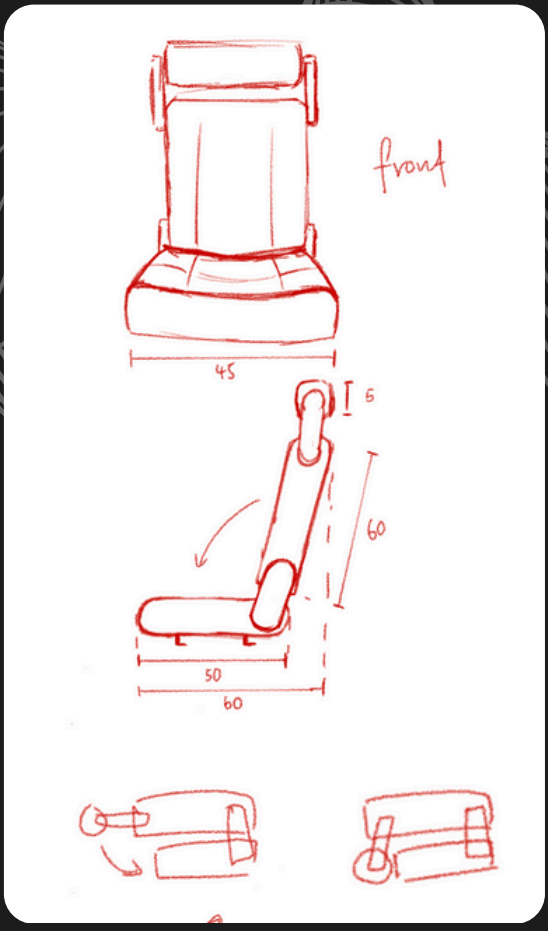
So, we dialed things back.

The next form, heavily inspired by Citroen's INSIDEOUT's foldable chair, embraced clean geometry and restraint. We straightened the exaggerated curves, simplified the overall structure, and shifted toward flat cushion panels with supportive plastic backings. The result is a seat that's lightweight, minimalist, and intuitive to fold.
Both the headrest and backrest collapse inward, folding into a compact rectangle—streamlining storage and portability without sacrificing comfort.









Car Seat - Final

Our final seat design, iterated from the Citreon inspiration, stays true to the minimalist direction but refines the details for both form and function.

The headrest was removed entirely, giving the seat a cleaner silhouette, while subtle curves were added to the cushion for ergonomic comfort. The plastic backing now wraps around to the cushion's sides, allowing the seat to fold into a sleek, seamless rectangle. It's like a Lego piece :)

For integration into RAIA, we introduced a locking mechanism that prioritizes ease and stability. A turn knob controls a latch at the main hinge, securing the seat firmly to the car floor. Unlike traditional car seats that fold backward, our model is designed to be inserted upright. The seat base flips downward and locks into place with a satisfying click-lock system, blending mechanical clarity with spatial efficiency.

This final version embodies the essence of our design values—modular, intuitive, and quietly sophisticated.

The video linked below showcases how the locking mechanism on our foldable chair works.



Here is the link of this video: https://youtu.be/uIMTpDL-Io4

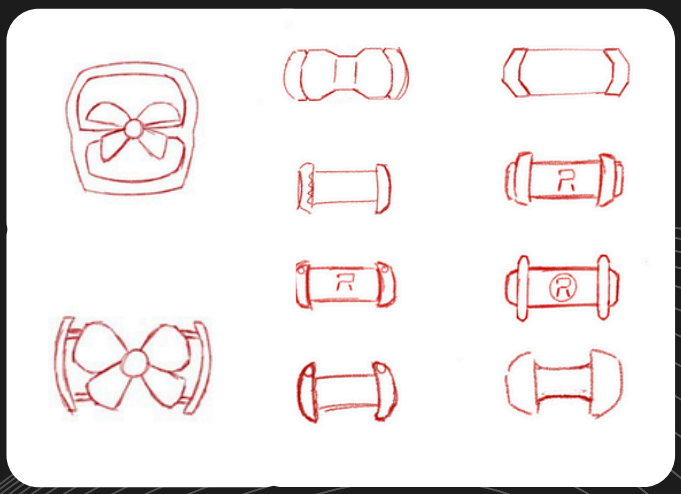
Steering Wheel - Iterating

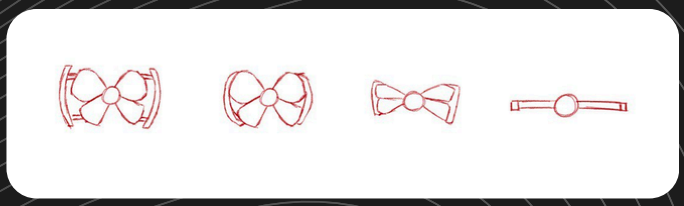
Our steering wheel underwent one of the most open-ended ideation phases in the project, with many design directions sketched and explored.

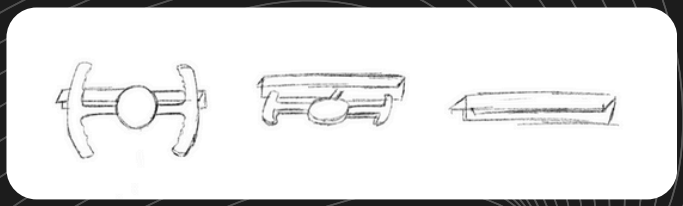
We began with a whimsical yet symbolic concept—a butterfly-shaped wheel, drawn from RAIA's early mothership identity. It captured the softness and symmetry we initially envisioned, but felt too literal, especially as RAIA's overall form language evolved.

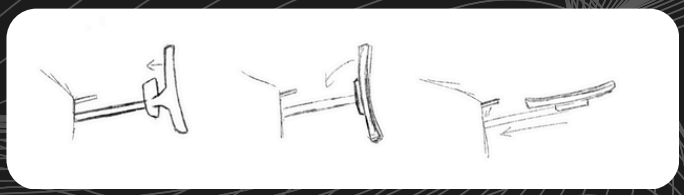
From there, we turned to a cleaner design, inspired by the BMW Vision Next 100. This iteration featured a flat steering interface with pop-out handles, combining futuristic visuals with interaction design. While bold, the bulkiness clashed with our goal of a sleek, modular interior.

We also began prototyping ways the wheel could collapse and disappear when not in use. One early folding concept involved having the steering wheel fold flat and slide into the dashboard, parallel to the car floor. Visually discreet, but functionally flawed—the wheel had to be made too thin, which compromised both grip comfort and structural integrity. It simply didn't feel like a real wheel anymore.

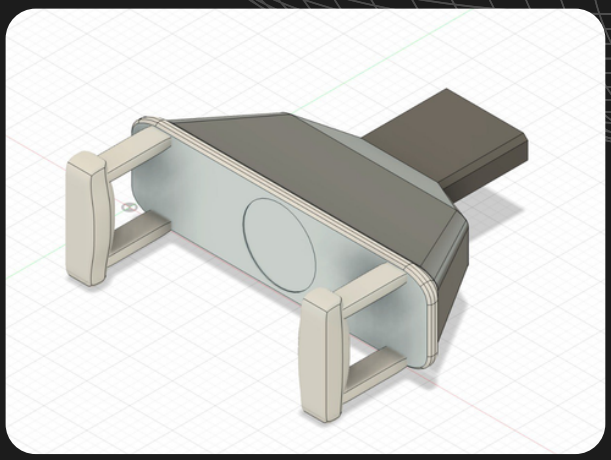


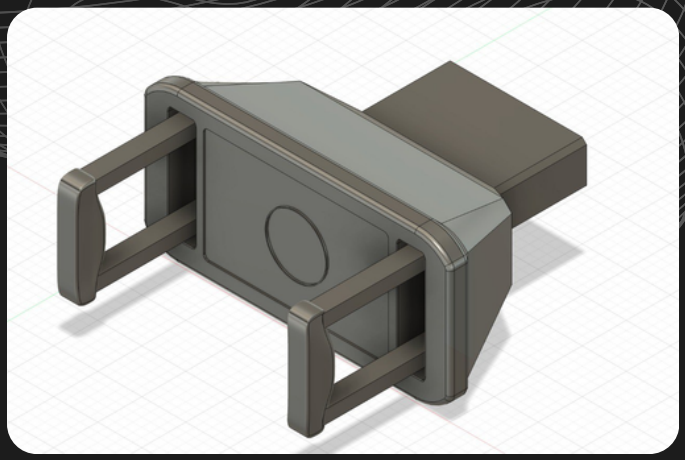












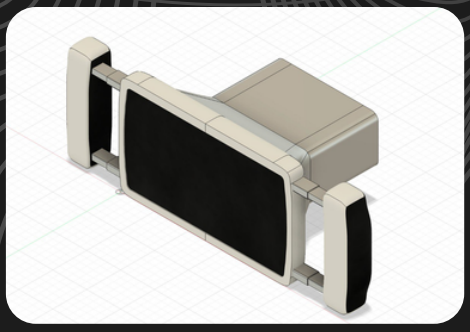
Steering Wheel - Final

Our final steering wheel design brings together futuristic inspiration and intuitive functionality, striking a balance between aesthetics, ergonomics, and modularity.

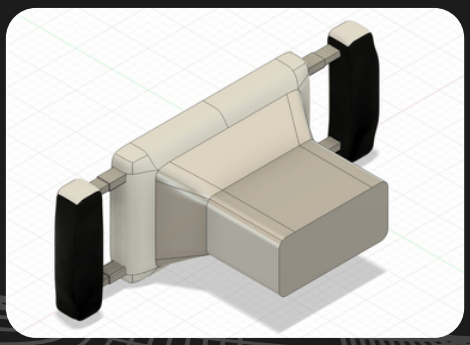
Building on the silhouette inspired by the BMW Vision Next 100, we introduced elements from an unexpected source—the Nintendo Switch.

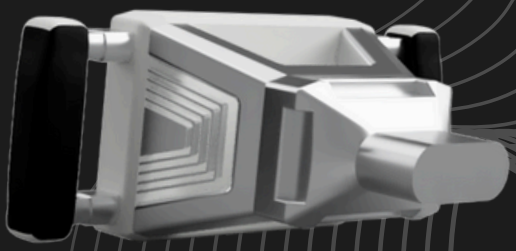
Instead of the front of the wheel, our use of telescopic posts that connect the central wheel body to the handles now allow the handles to collapse inward, making the wheel more compact when not in use, but also provide customizable spacing, letting drivers adjust the grip width to their personal preference.

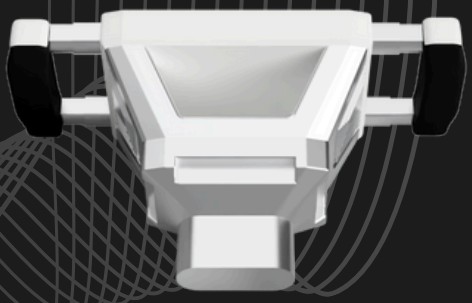












Guided by feedback from Prof Mike, we revisited the back of the wheel, recognizing it as an underused space with design potential. In response, we integrated RAIA's headlight design language into the wheel backing, creating a subtle but cohesive visual link between interior and exterior of RAIA.

Functionally, the dashboard is integrated directly into the wheel, featuring a built-in screen that hosts essential driving controls—GPS, turn signals, ABS, and headlights—giving RAIA full operational capability while keeping the interface clean and centralized.

This final iteration embraces collapsibility, user customization, and design cohesion, embodying our vision for a steering system that is both intelligent and seamlessly integrated into the RAIA experience.

Conclusion

This project aimed to design and develop an autonomous EV charging vehicle equipped with a robotic arm. Over two iterative design phases, we evolved from an aesthetics-driven concept to a function-focused solution emphasizing usability, compactness, and maintainability. We successfully produced full-scale prototypes of both the robotic arm and steering wheel, incorporating key lessons from our initial designs.

For the robotic arm, major improvements included resolving the sagging issue through better load distribution, reducing overall weight to enhance performance, and incorporating features that support easy maintenance.

For the steering wheel, we refined the form by reducing grip thickness, beveling the edges for improved comfort, and enhancing the design to better align with RAIA's visual language.

Despite the technical challenges encountered, this project deepened our understanding of robotic mechanics, hands-on prototyping, user-centered design, and product presentation. Future development could explore the use of advanced materials and improved joint mechanisms to further enhance the arm's performance and reliability

Learning points

Arm

- Plan wiring location early
  - Electrical wiring routes should be planned before CAD modeling to ensure sufficient space and accessibility within the final design.
- Secure mounting for fasteners
  - Screw holes should be designed with proper recesses or constraints to prevent nuts from rotating or being pushed out during assembly or use.
- Adjustability for electrical components
  - Incorporating adjusting mounting methods like removable panels to allow for easier calibration and replacement of electrical parts
- Structural orientation
  - Vertical placement of components can introduce sagging due to gravity and the lack of better load distribution. Joints should include intersecting horizontal elements to better support weight and reduce mechanical stress
- Tight fitting for friction secured mounting
  - Tight-fitting joints in CAD often result in friction fits that don't assemble correctly in real life, likely due to the limited precision of 3D printers. It's important to manually include appropriate tolerances during the design phase to ensure proper fit and ease of assembly.

Steering Wheel

- Handles for the steering wheel
  - The soft TPU material used may have given a wrong impression on how our envisioned steering wheel was actually supposed to be like. A fabric or leather sheet covering the wheel might have been a better choice for the prototype.

Car Seat

- Lack of design on chair
  - Incorporating more slits, structure or material texture to the chair, rather than just the circle and logo, would give more personality to the chair.

Source

Pg 5:

- https://www.nccs.gov.sg/files/docs/default-source/default-document-library/e-mobility-technology-roadmap.pdf
- https://www.lta.gov.sg/content/ltagov/en/who_we_are/statistics_and_publications/Connect/charging-an-ev-is-it-that-ez.html

Pg 9:

- https://www.youtube.com/watch?v=wjKbx0LFwow
- https://cnevpost.com/2025/02/15/byd-demonstration-use-all-solid-state-batteries-2027/
- https://www.nasdaq.com/articles/quantumscapes-qs-stock-jumps-fast-charging-ev-battery-breakthrough

Pg 10:

- https://mantaray-world.com/
- https://www.reddit.com/r/oceanskeletons/comments/ljpp8a/manta_ray_skeleton/?rdt=34988

Pg 13:

- https://www.dyson.com.sg/dyson-am07-tower-fan
- https://www.irobot.com/en_US/roomba-j6plus-self-emptying-robot-vacuum/J655020.html
- https://www.dyson.com.sg/dyson-supersonic-hair-dryer-prussian-blue-rich-copper-605j
- https://bighero6.fandom.com/wiki/Baymax
- https://starwars.fandom.com/wiki/BB-8
- https://www.solarquotes.com.au/blog/mobile-ev-charging-mb1819/
- https://www.greencars.com/news/volkswagens-ev-charging-robots
- https://k-robot.co.kr/k-robot/en/view.php?idx=146951&key=%EC%97%90%EB%B0%94&cidx=56608&page=1

Pg 14:

- https://www.theengineerspost.com/wood-joints/

Pg 18:

- https://robodk.com/blog/what-is-a-scara-robot/
- https://youtu.be/3SjZITgZRt8

Pg27

- https://youtu.be/uMM0lRfX6YI
- https://www.chiefdelphi.com/t/intuitive-swerve-drive-explanation/413736

Pg 28

- https://www.iottechtrends.com/product-review/raspberry-pi-camera-v2-review/
- https://forum.derivative.ca/t/luxonis-oak-d-pro-poe-vs-orbbec-femto-mega/411343
- https://www.arducam.com/imx219-raspberry-pi-camera-module-b039001