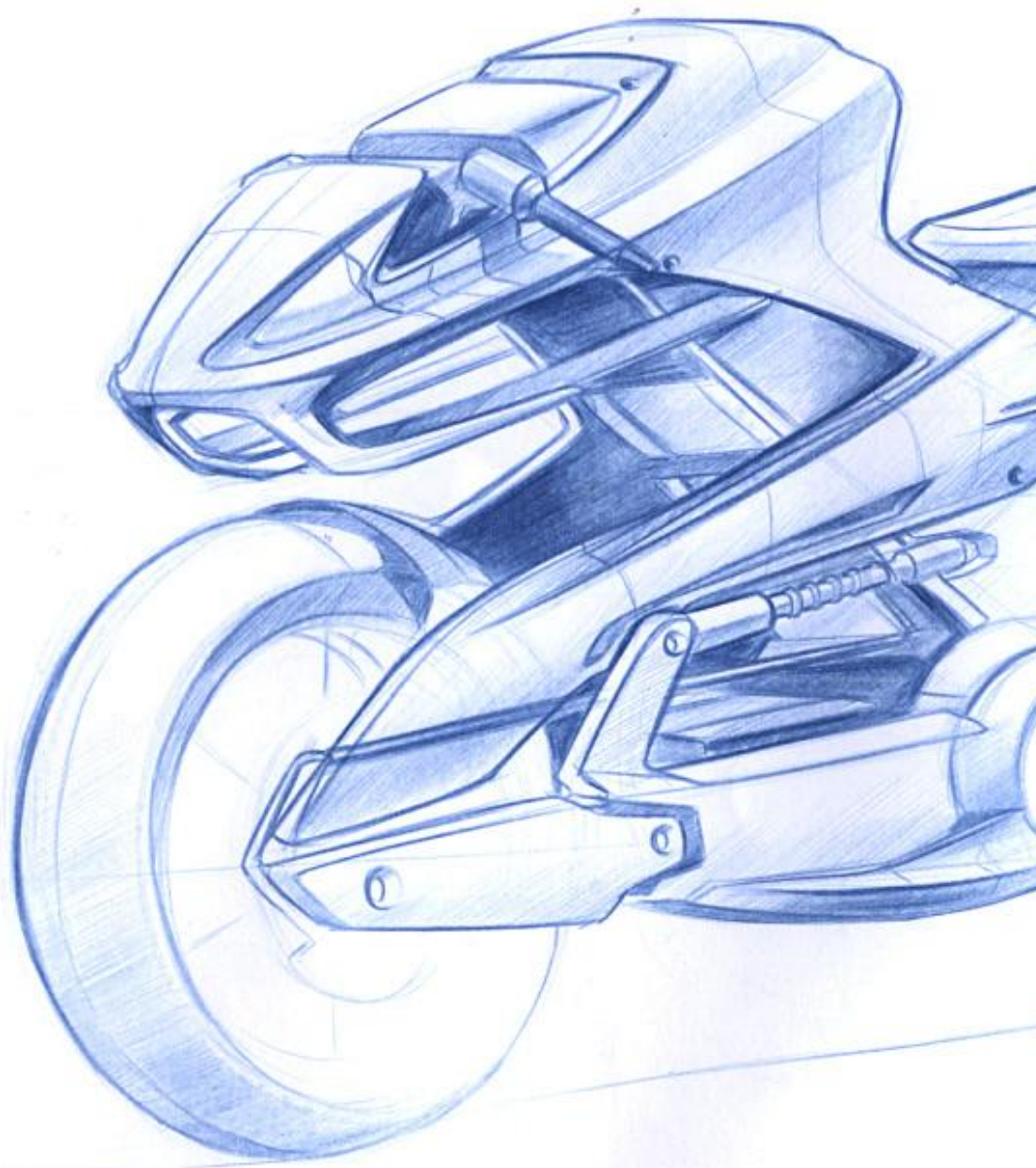
IRAJA

Aesthetic Exploration for a Green Urban Motorcycle



ADVAITH SRIVATHSA
MOBILITY AND VEHICLE DESIGN
IDC, IIT BOMBAY

Mission Statement

- Vehicles are transitioning from IC engines to electric power.
- This change will influence the aesthetics.
- Motorcycles form an important part of the Indian automotive scenario, offering an involved, exciting riding experience at a reasonable cost.
- Bikes are also prime examples of how a vehicle's aesthetic is dependent on its packaging.

How will the aesthetic of a motorcycle evolve given the change from petrol power to alternative sources?

Overview of Design Process

- Research
  - Existing electric motorcycles
  - Emerging electric technology
  - Motorcycle chassis design
  - Motorcycle suspension design
  - User study
  - Product Semantic study
- Design Brief
- Explorations
  - Packaging explorations
  - Metaphor-based form exploration
  - Evolution of design concepts
  - Concept Evaluation
- Scale Model

STAGE 1: RESEARCH AND STUDY

Electric Motorcycle Manufacturers

- **Quantya**: Swiss manufacturers who specialise in producing performance electric motorcycles for recreational purposes
- **Zero Motorcycles**: Zero Motorcycles is a manufacturer of high performance street and dirt electric bikes.
- **Brammo:** Brammo Inc are an electric motorcycle manufacturer headquartered in Ashland, Oregon, USA.
- **Orphiro:** The latest entrant into the electric motorcycle fray, they specialise in cruiser/cafe racer class of motorcycle.

Existing electric bikes

- **Quantya Strada**
  - A dirt bike frame supports the battery pack
  - Designed for the motocross track, where torque and acceleration are more important than top speed

- Specifications:
  - Motor: Axial Gap DC motor
  - Power: 8.5KW (11.39 hp)
  - Torque: 31.5 Nm
  - Battery: Li-ion Polymer (2.08 KwH/ 400 A)
  - Charge time : 2 hours
  - Battery life: est. 80,000 km
  - Range : 80 km
  - Top speed: 70km/h
  - Weight: 95 kg

Existing electric bikes

- **Zero S**
  - The Zero S has been designed to be a streetfighter, with instant torque and pickup.
  - It features a single large battery pack built into the centre.

- Specifications:
  - Motor: Axial Gap DC motor (force air cooled)
  - Battery: Li-ion Polymer (4.4KwH)
  - Charge time : 4 hours/2.5 hrs (Quick charge)
  - Battery life: est. 1,00,000 km.
  - Range : 93 km
  - Top speed: 108km/h
  - Weight: 135 kg

Existing electric bikes

- **Zero XU**
  - The Zero XU is more of an urban crossover
  - The battery pack is removable.

- Specifications:
  - Motor: Axial Gap DC motor (force air cooled)
  - Battery: Li-ion Polymer (2 KwH)
  - Charge time : 2 hours/ 1.2hrs (Quick charge)
  - Battery life: est. 52,000 km.
  - Range : 40 km
  - Top speed: 82 km/h
  - Weight: 99 kg
  - Removable battery pack

Existing electric bikes

- **Brammo Enertia**
  - Built as a lightweight city commuter, to capture the fun of commuting.

- Specifications:
  - Motor: Brushless DC motor
  - Battery: Li-ion Polymer (3.1 KwH)
  - Charge time : 4 hours
  - Battery life: est. 1,00,000 km.
  - Range : 68 km
  - Top speed: 82 km/h
  - Weight: 147 kg
  - Power: 17.5 hp
  - Torque: 40 Nm.

Existing electric bikes

- **Brammo Empulse**
  - An evolution of the enertia, it was built as an electric alternative to sports bikes
  - Available in 3 model ranges, with range from 96km to 160km.

- Specifications:
  - Motor: Permanent AC synchrous motor
  - Battery: 6 KwH – 10KwH
  - Charge time : 6 hours – 10 hours
  - Battery life: est. 1,00,000 km.
  - Top speed: 160+ km/h
  - Range: 100+ km
  - Weight: 163 - 190kg
  - Power: 53.61 hp
  - Torque: 80 Nm.

Emerging Electric Technology

- Aluminium-Celmet Additive
  - High porosity (up to 98%) metal made from nickel or nickel chrome alloy.
  - It features a three-dimensional mesh-like structure that forms interconnected, open and spherical pores.
  - The anode in a battery is made of aluminium foil; if this foil is replaced by Aluminium-Celmet, the area of positive active material is increased, thereby increasing capacity multiple fold.
  - Makers Sumitomo Electric claim that in the case of automotive on-board electric packs, battery capacity has increased 1.5 to 3 times.
  - Commercialisation is expected to happen by 2015.

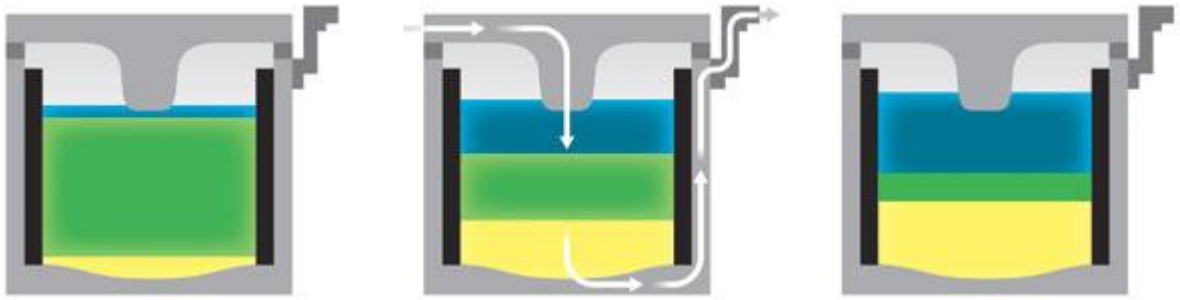
Emerging Electric Technology

- Carbon Nanotube Solar Cell Battery Packs
  - Produce current due to the change of their molecular excitation by sunlight.
  - To store this energy, a material formed by combining azobenzene and the carbon nanotube has been made by researchers at MIT
  - The material is cheap, and has an energy density similar to a lithium-ion battery.
  - The compound stores the energy in a thermochemical fashion, releasing solar energy as heat, which can then be converted to electricity.
  - The cell undergoes almost no degradation over repeated cycles.
  - The technology is expected to be commercialised in another 6 years.

Emerging Electric Technology

- Nanowire Batteries
  - The anode in a Li-ion polymer battery is normally made of stainless steel.
  - In a nanowire battery, the anode is covered in silicon nanowires, which increase the Li-ion storage capacity of the battery.
  - The capacity increase is upto 3-4 orders of magnitude.
  - The silicon does not have to be of high quality, which means the material cost addition would not be very high.
  - The drawback of this is that until commercialisation occurs, the fabrication costs are rather high.
  - The technology is due to be commercialised by 2012

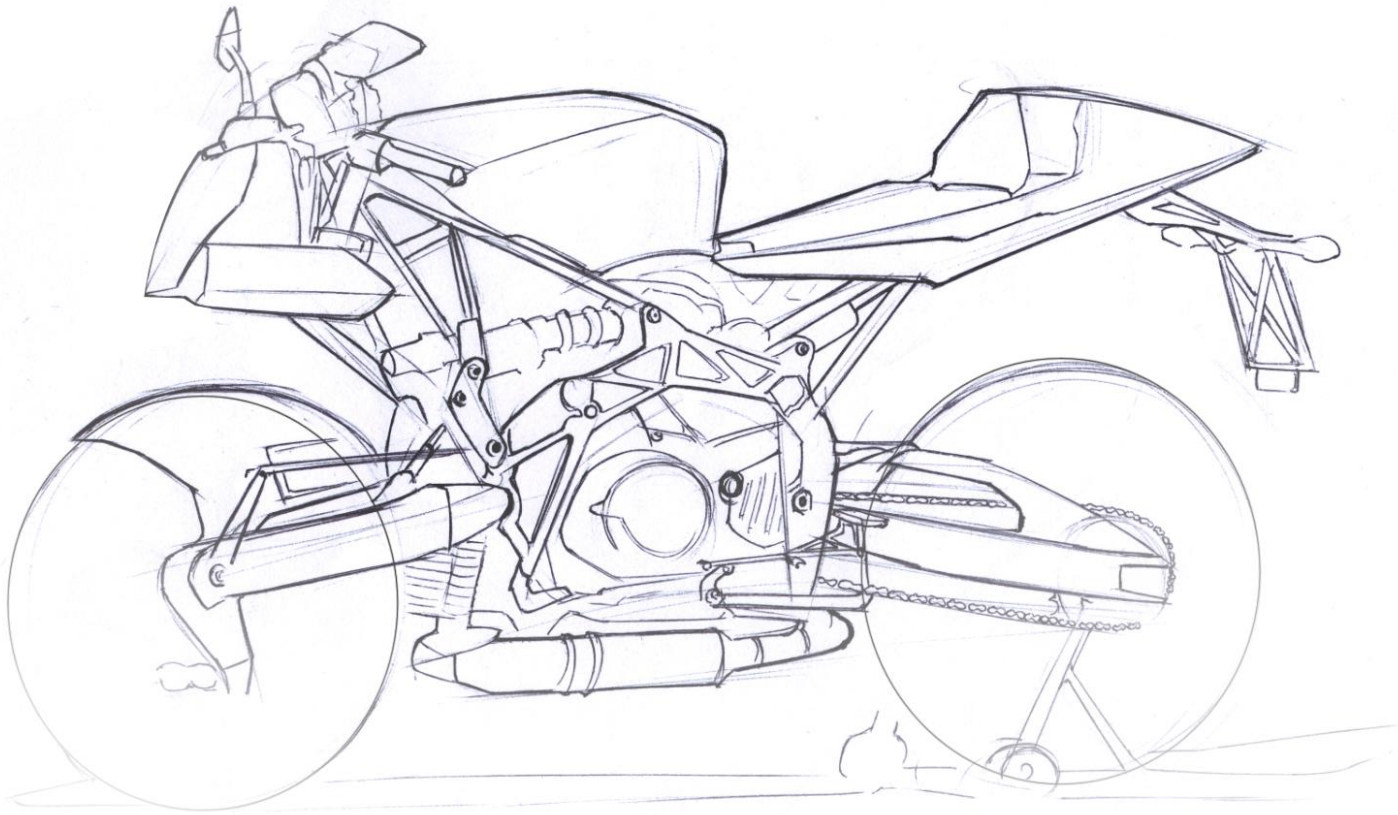
Emerging Electric Technology



- Liquid Batteries
  - The electrodes are a molten metal, and the electrolyte is a molten salt (antimony at the bottom, sodium sulphide electrolyte and magnesium on top)
  - In the discharged state, the electrolyte holds a large amount of magnesium antimonide.
  - While charging, the current causes the magnesium antimonide to disband, reducing the volume of electrolyte.
  - The battery can be put through many charge-discharge cycles with ease and can operate at much higher current levels.

.

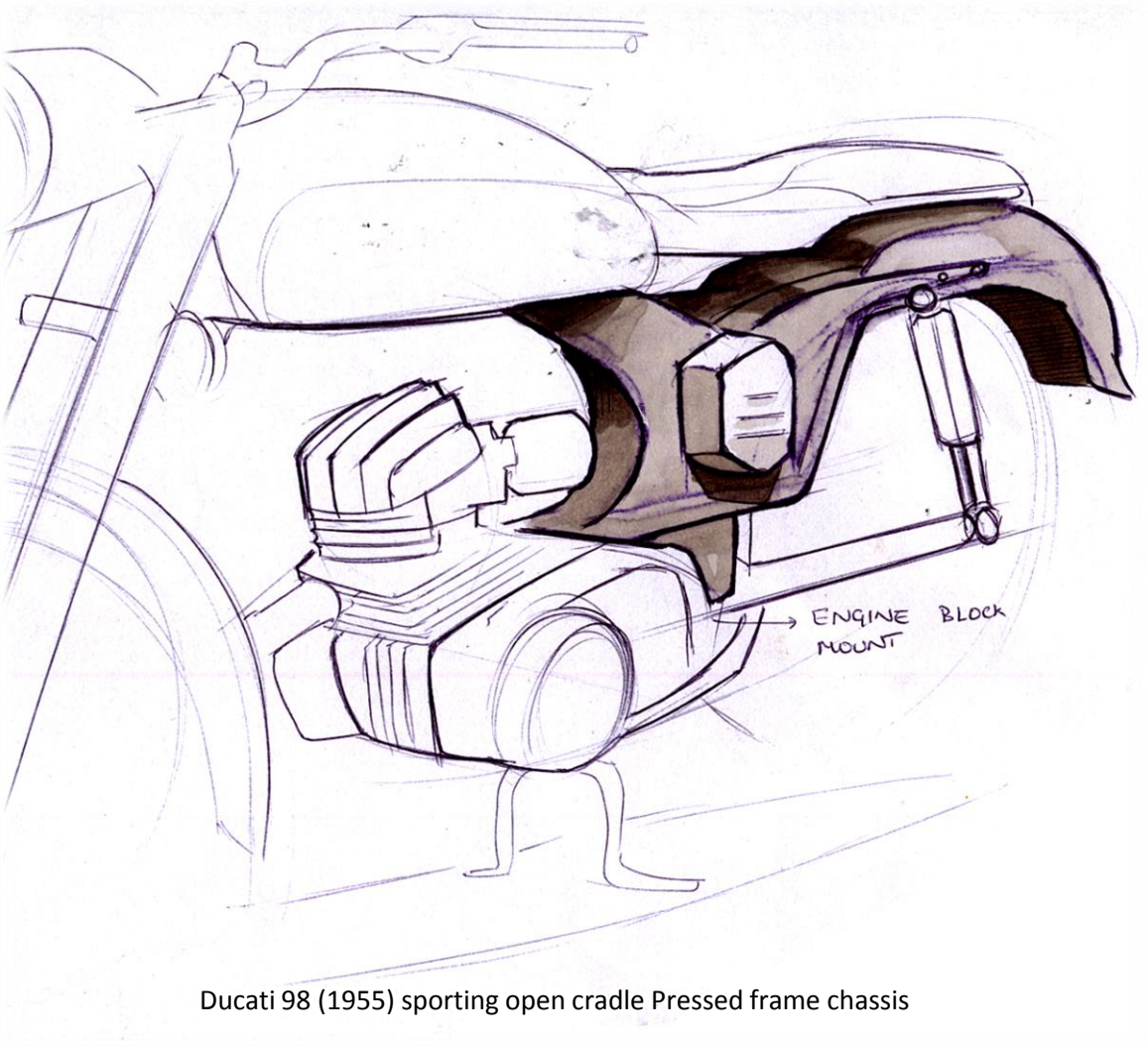
Motorcycle Chassis Types



- In order to understand how motorcycles of today are built, it becomes necessary to deconstruct them.

- The chassis is the skeleton of the bike; designed as a support member for all the components of the bike: engine, crankcase, gearbox, suspension, seats, fuel tank.

Motorcycle Chassis Types



Ducati 98 (1955) sporting open cradle Pressed frame chassis

Pressed Frame Chassis:

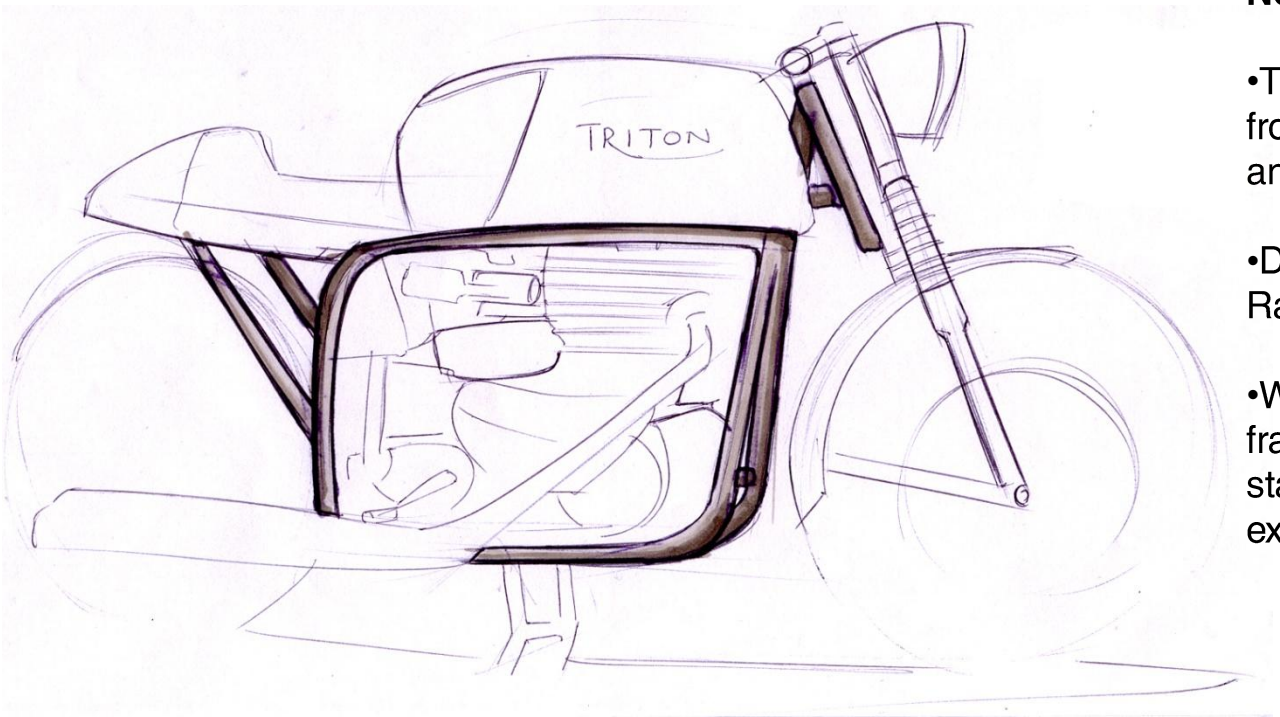
•Mass-produced by sheet metal pressed or stamped into shape.

•Typically a single-cradle open structure is used.

•These frames were usually for low power long wheelbase cruisers.

•They were the earliest type of motorcycle chassis.

Motorcycle Chassis Types



Featherbed frame in a 1960s Triton Café Racer

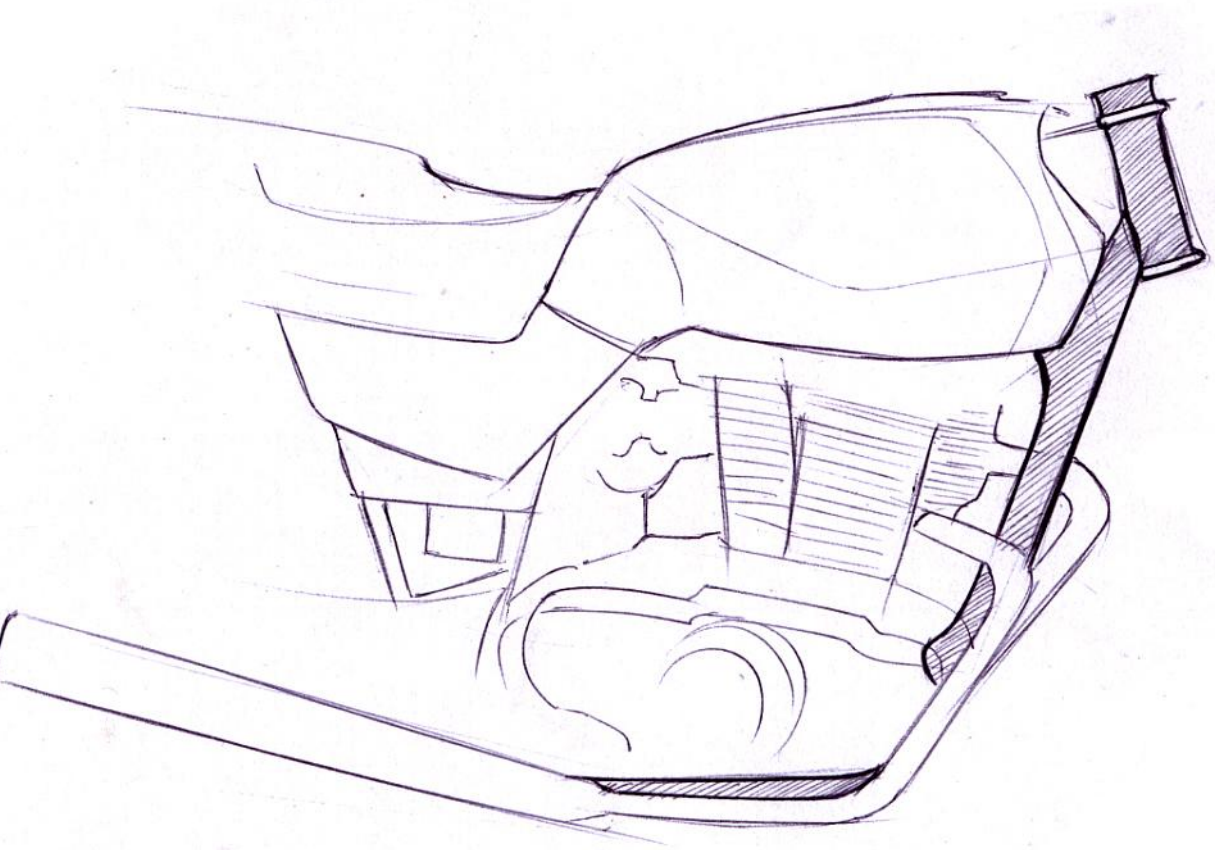
Norton Featherbed Chassis:

•The featherbed frame got its name from the nature of the ride quality and handling prowess that it offered.

•Developed for Isle of Man TT Racing in 1949

•Was a step forward from pressed frames, as it offered much more stability and ride comfort than the existing frames of the time

Motorcycle Chassis Types



Yamaha Boxer 125 sporting a single cradle frame

Single Cradle Chassis:

•The engine is held in a single cradle with a single spine.

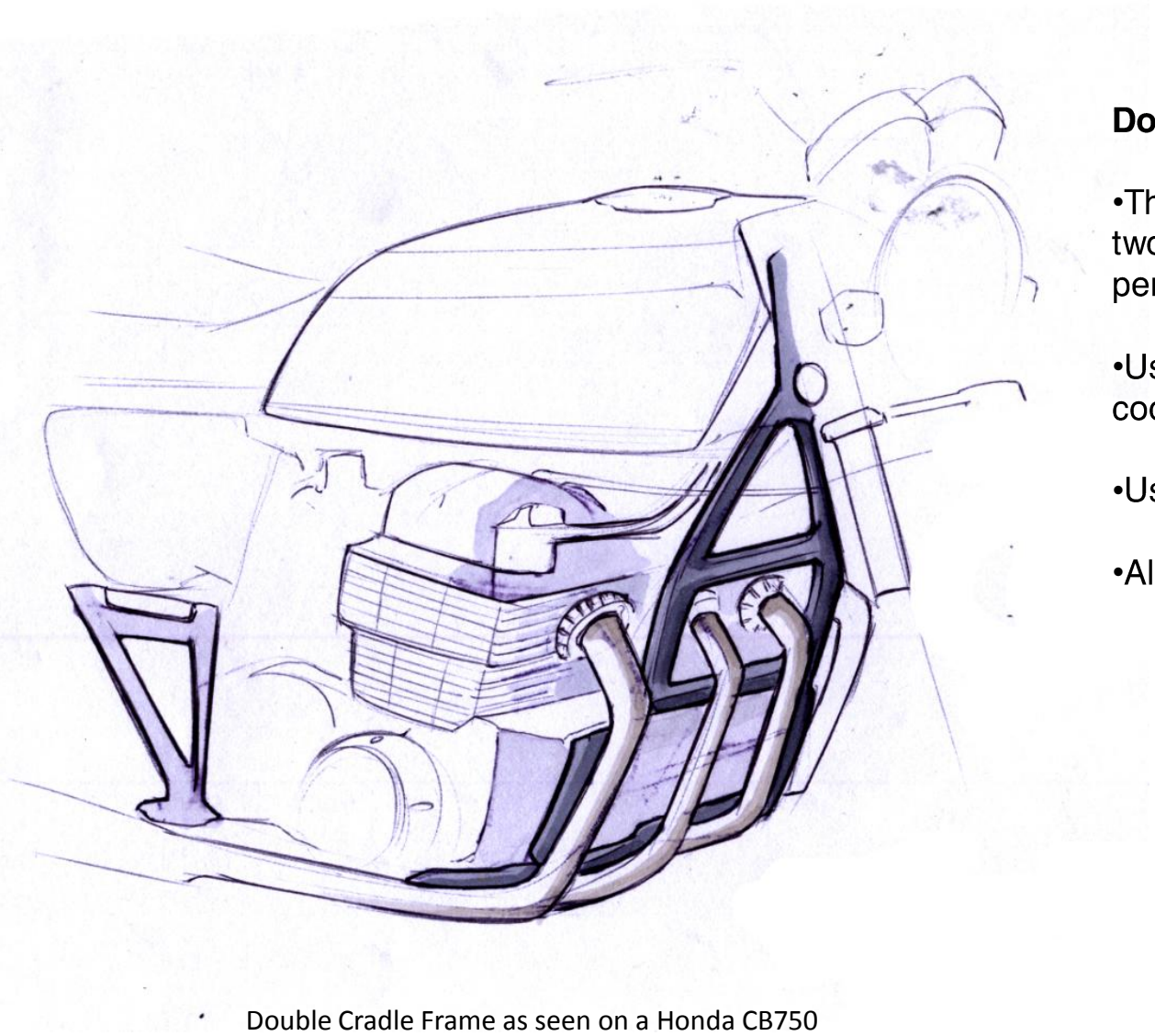
• This configuration is employed on most indian commuter bikes.

•For commuters, weight needs to be kept low.

•A single cradle frame offers the advantage of weight saving without sacrificing strength.

•Not suitable for high capacity bikes.

Motorcycle Chassis Types



Double Cradle Frame as seen on a Honda CB750

Double Cradle Chassis:

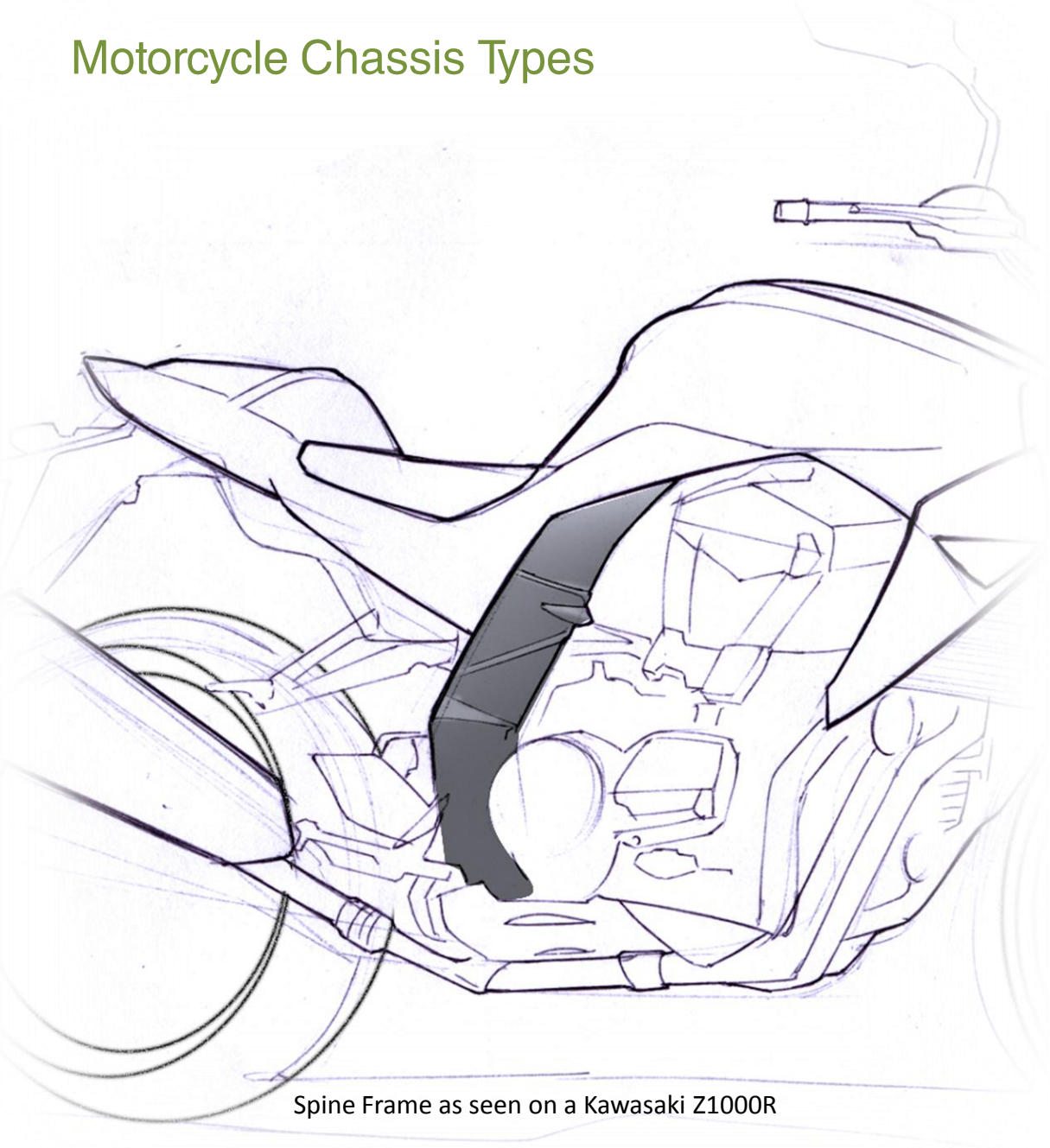
•The double cradle chassis features two cradles running along the perimeter of the body.

•Used to support large block air-cooled engines.

•Usually in-line 4 cylinder engines.

•Also called Perimeter frames.

Motorcycle Chassis Types



Spine Frame as seen on a Kawasaki Z1000R

Spine (Beam) Chassis:

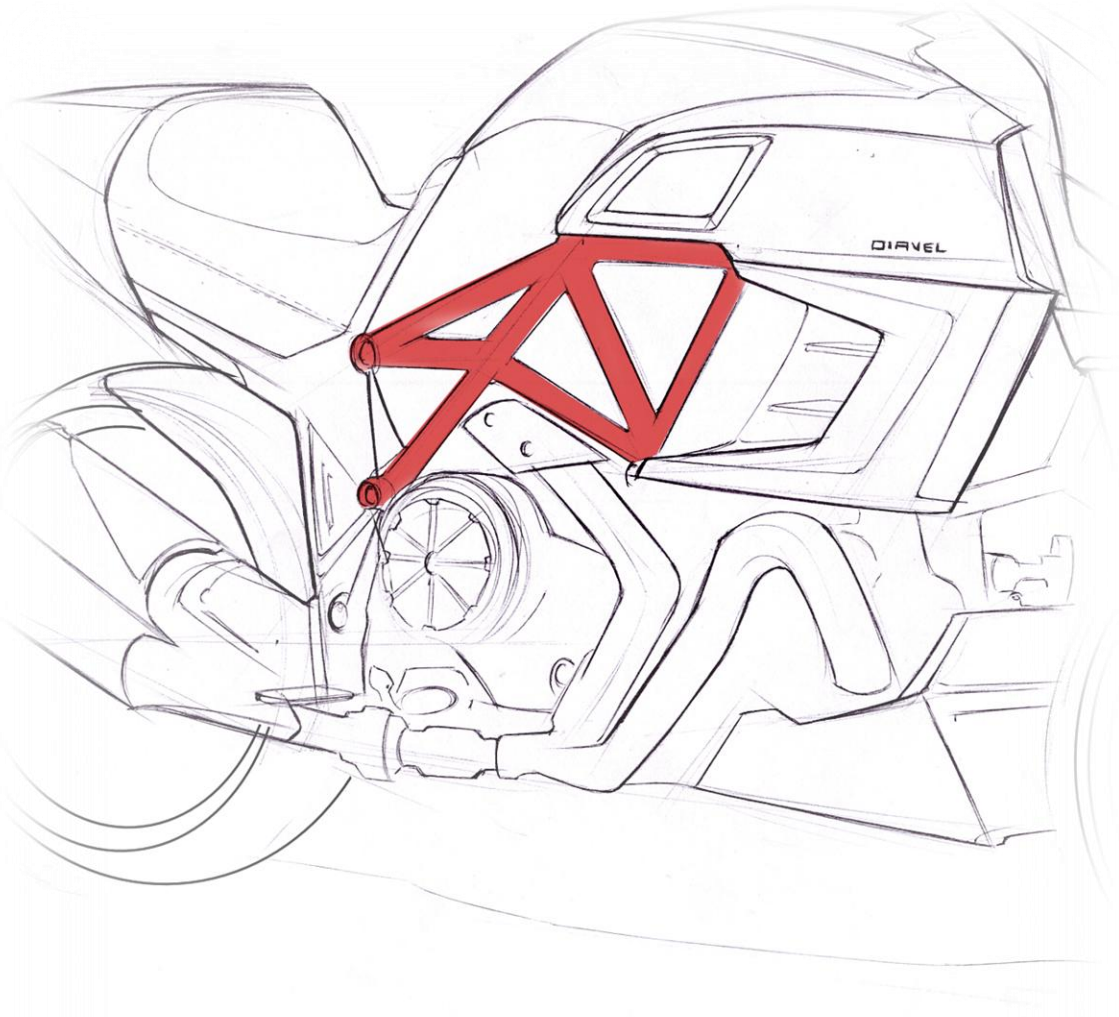
•All the elements are mounted on a strengthened beam frame.

•Preferred for motorcycles which have oil cooling, and hence radiators in the front.

•The frame is usually made of aluminium, and in some cases, titanium.

•Usually seen on high capacity and racing bikes.

Motorcycle Chassis Types



Trellis Frame as seen on a Ducati Diavel

Trellis Frame:

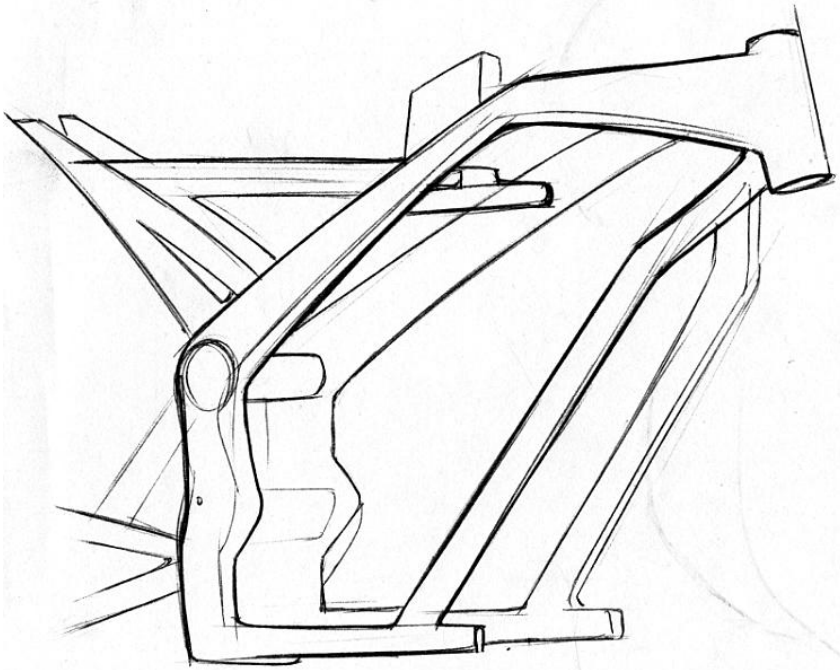
•Instead of a beam, a set of interconnected trellis beams forms the chassis.

•Offers a better strength to weight ratio.

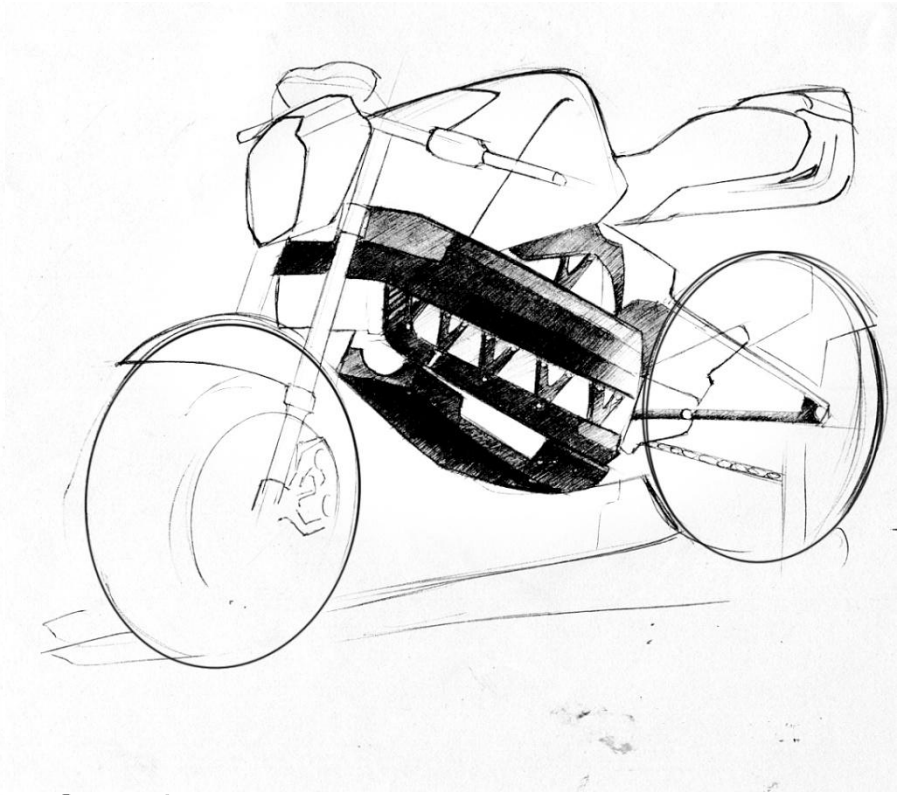
•Often seen on Ducatis, and on early Suzuki racers.

Motorcycle Chassis Types

Frames employed by Electric bikes:



Double Cradle Full Duplex frame as seen on a Zero S. Material: Aerospace Aluminium

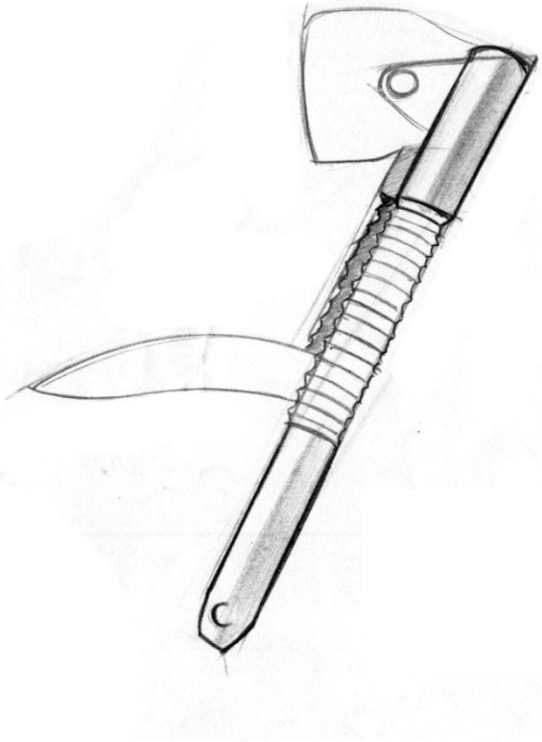


Spine frame with a lower tub as seen on a Brammo Empulse. Material: Aluminium

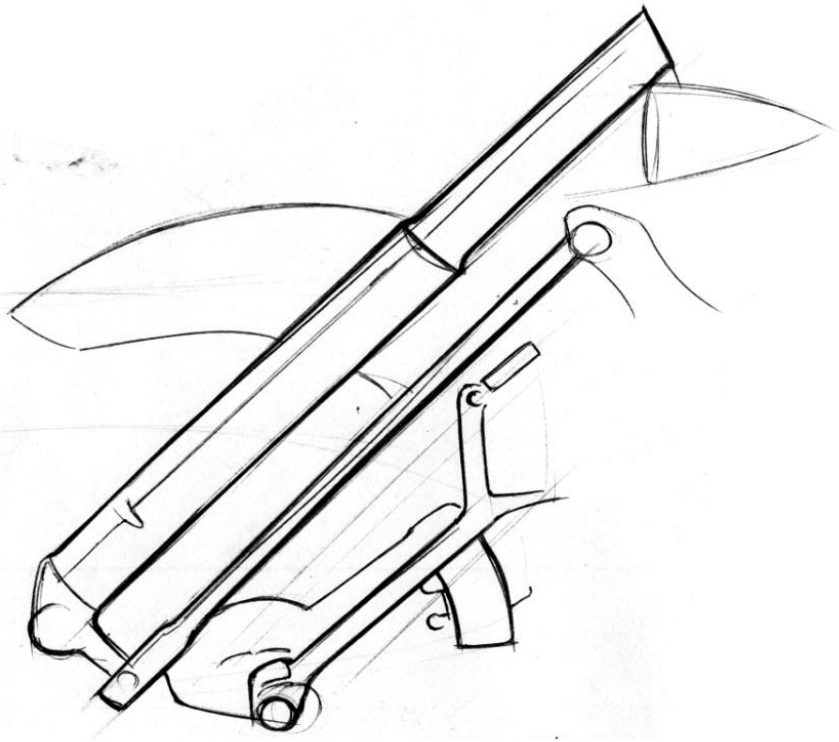
Inferences

- Chassis selection is dependent on the size of the motor, and the consequent vibration levels.
- Material selection is dependent on the motor, as well as the cost of the bike.
- For electric bikes, the frame mainly houses the battery packs and provides a support for the motor and the casing.
- For such bikes, the emphasis is more on reducing weight, as opposed to reducing vibrations in the case of petrol bike.

Motorcycle Suspension Types

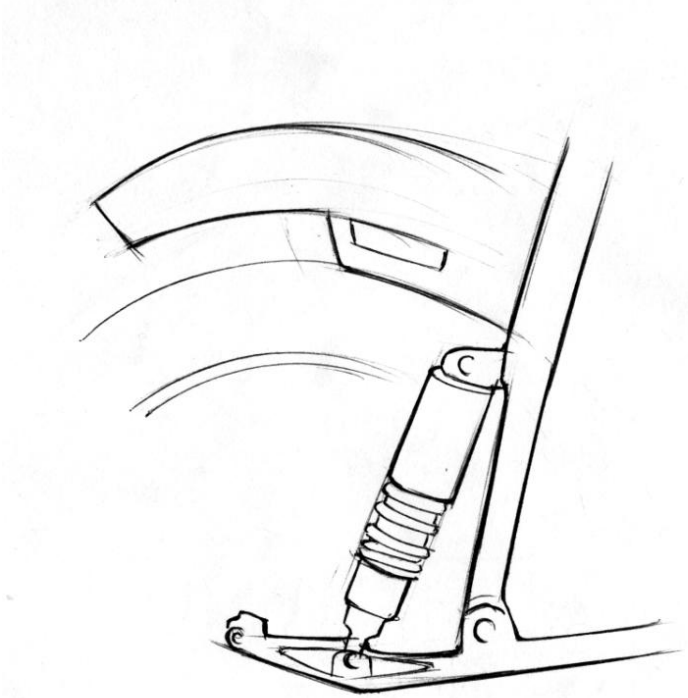


Conventional
Telescopic Forks



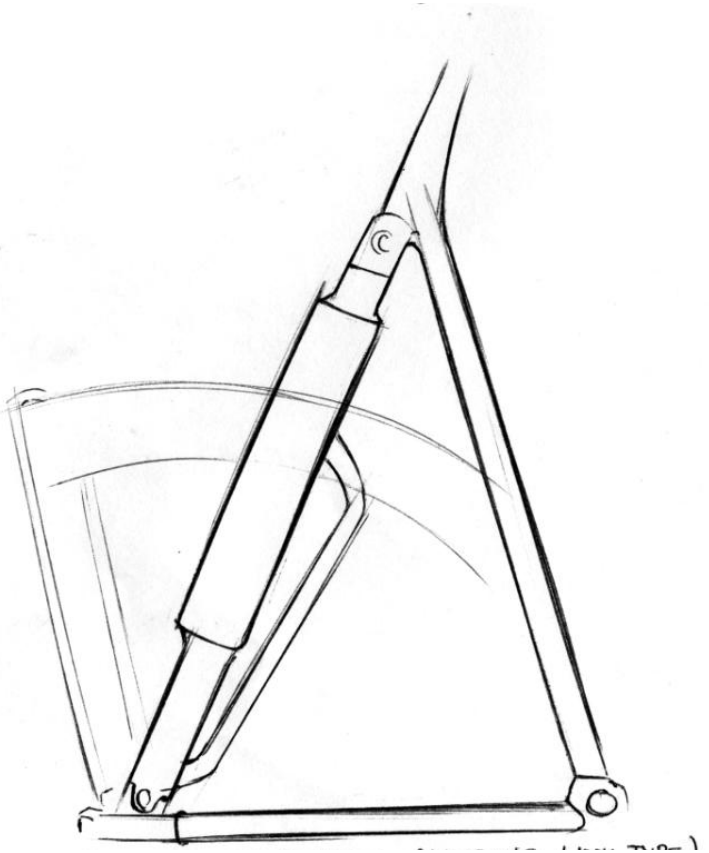
Trailing link forks: Honda Rune
•Shock Absorber and Wheel Centre are offset, improved ride quality

Motorcycle Suspension Types



Leading link suspension as seen on a Ural motorcyle

•Shock absorber separate from suspension linkage



Earles leading link suspension

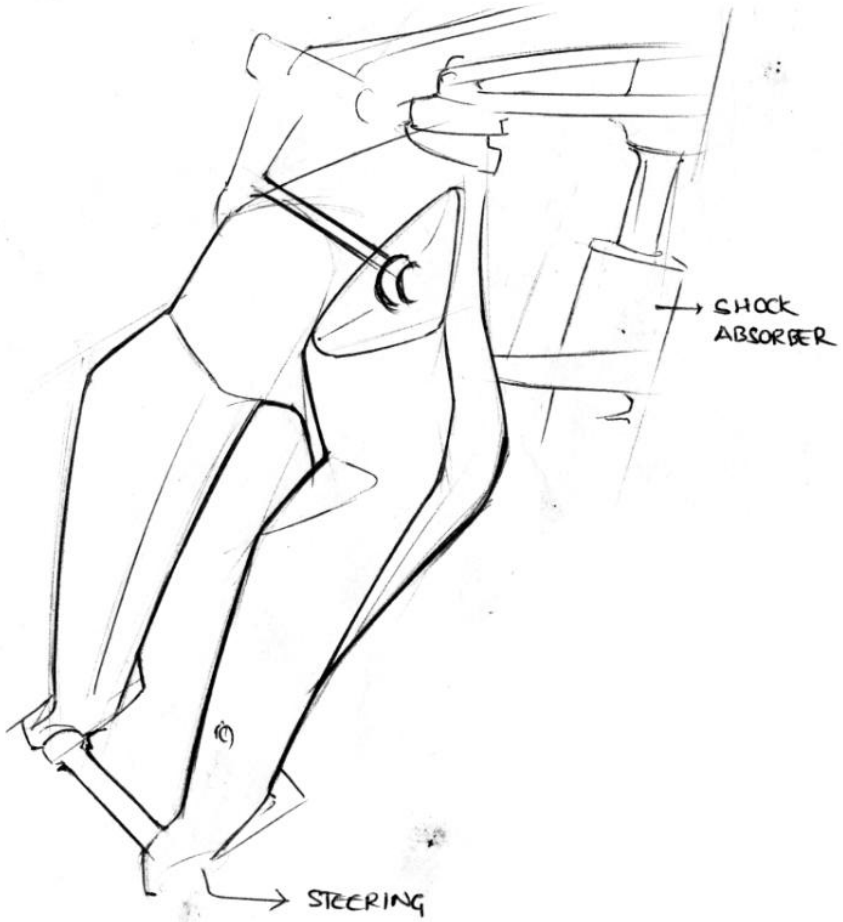
•Would rise under braking as opposed to dipping, due to triangular linkage and inverted forks

Motorcycle Suspension Types

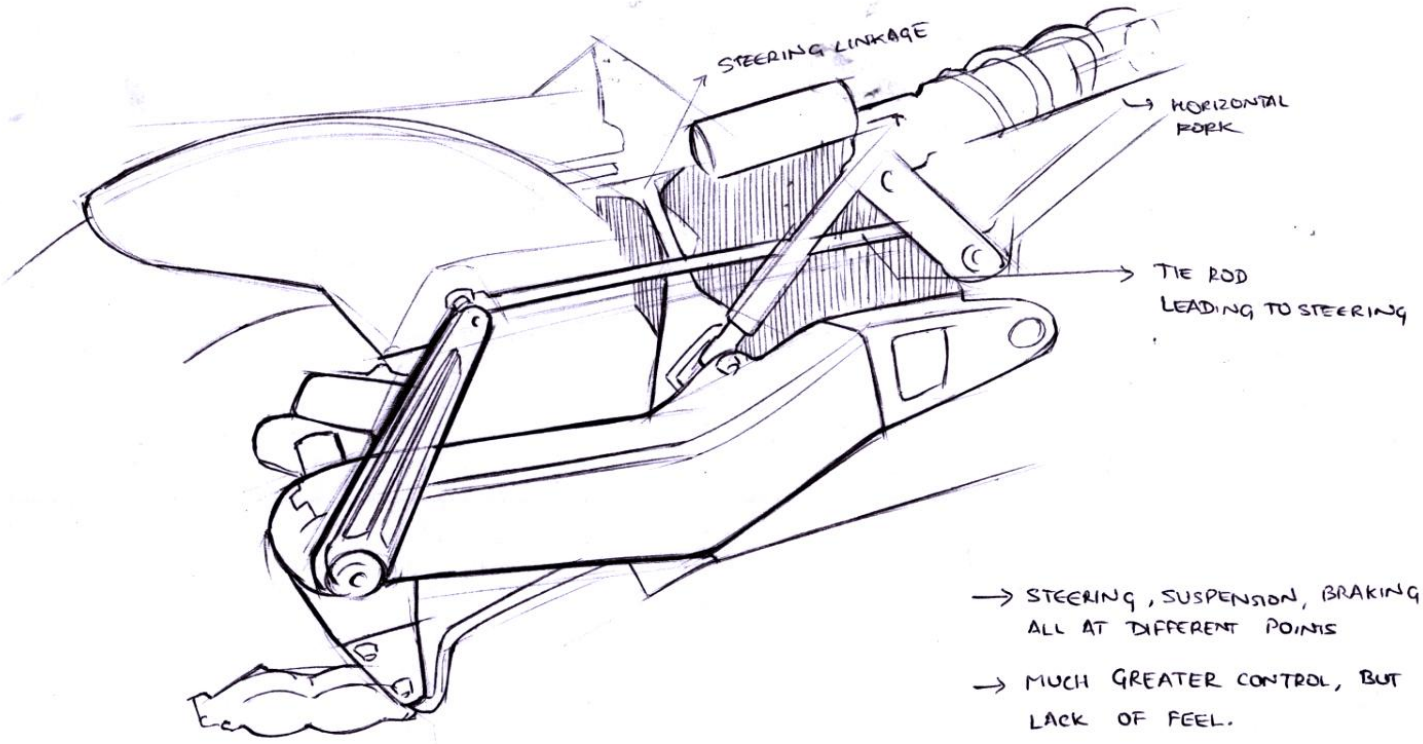
BMW Duolever Suspension

•Damping and steering happen at different points.

•Offers a different sort of riding experience; fewer vibrations without losing out on steering feel



Motorcycle Suspension Types



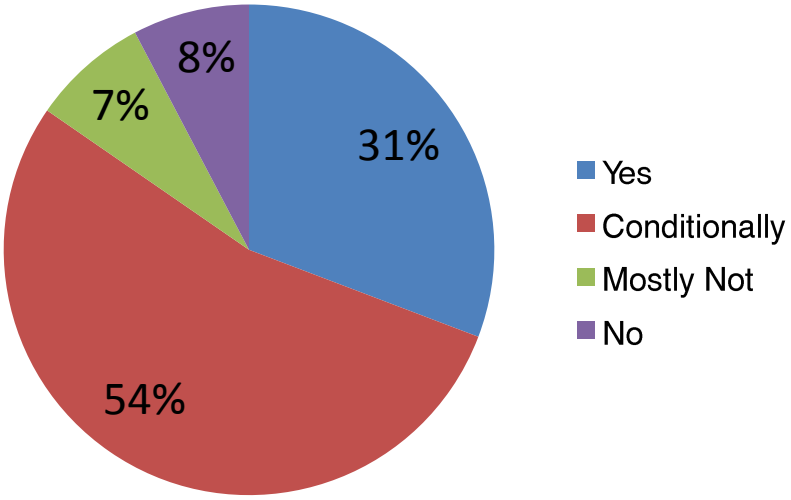
Hub Centric Steering

- Leading arm which steers through a tie rod and a parallelogram steering mechanism
- Steering, Braking and Damping happen at different points
- Results in a precise, yet somewhat vague steering feel.

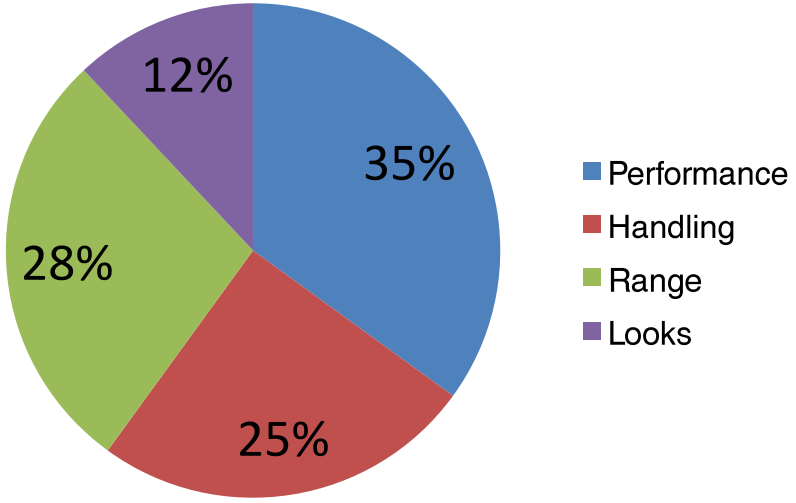
User Study:

Need Analysis:

Would you consider an electric bike?



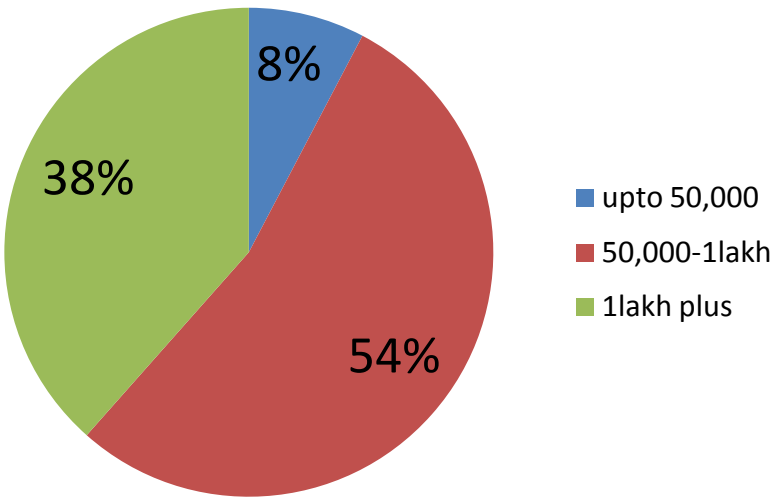
What factors are important to you?



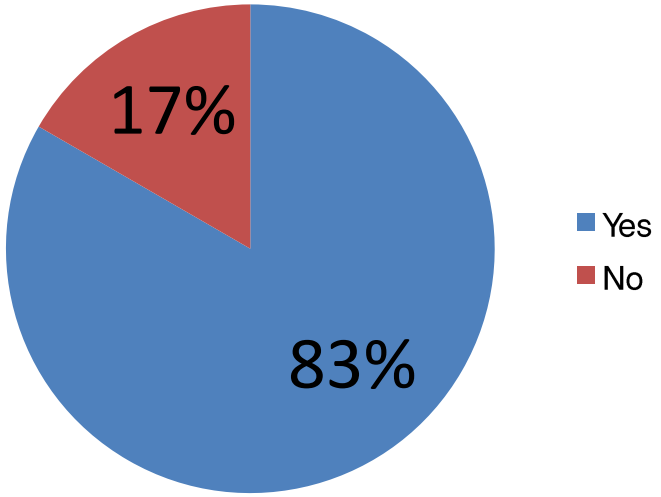
User Study:

Need Analysis:

How much would you be willing to spend?



Should the bike look unique



User Study:

- User Profile
  - Age: 22-28 years
  - Owns a bike/Has owned a bike/plans to buy one in the near future
  - Commuting in urban areas

Biking Experiences

“First Bike was a **HH splendor.** I was usually very cautious while riding it, never really revved it.

Cruiser Fan. Now I own a **Bullet 350**. Love it for it’s **ride, comfort and reliability.** Bikes are the ultimate expressions of singularity.

Urban bikes need to have **good performance** and **handling**
Most of my commuting happens in Delhi”

Chandrakesh, 26

Currently own a Pulsar 150. Most of my riding has happened in Hyderabad. The biker gang scene out there is amazing.

Always a safe rider. Like the pulsar for its blend of power and handling. I’ve scraped the footpeg quite a few times.

Performance matters. The bike should also show itself off.”

Nitin, 24

Biking Experiences

“A bike, to me, is a **symbol of freedom**. Going anywhere you want, anytime you want. The **riding experience** shouldn’t be compromised upon; handling, feel, performance.

An electric bike might not have the same **soul and feel** of a petrol motorcycle.”

Nishant, 24

“I currently own an activa, but am considering a move upto a higher capacity bike.
Not really a performance freak, but the bike should be light enough for **easy handling**, as well as **powerful** enough to get through traffic. Should also **look good**.”

Ayush, 23

Biking Experiences

“I own a Pulsar 200. I love the **acceleration**, **handling** and touring nature of the bike.

I normally like to get away on the weekends, a 200-odd km bike trip. That’s where the P200 excels. Its very **comfortable** for long distances.

The problem in the city is that the bike is too heavy. City bikes need to be **light.**

Pranav, 25

“Own an RX 100, bought it second hand. The kind of **pickup** you get from it is unparalleled. And it’s **light**; it’s the ideal city commuter where you have to cut through traffic; the bike is brilliant for Bangalore roads.

Breaks down a fair bit, though. Maintenance could be easier.”

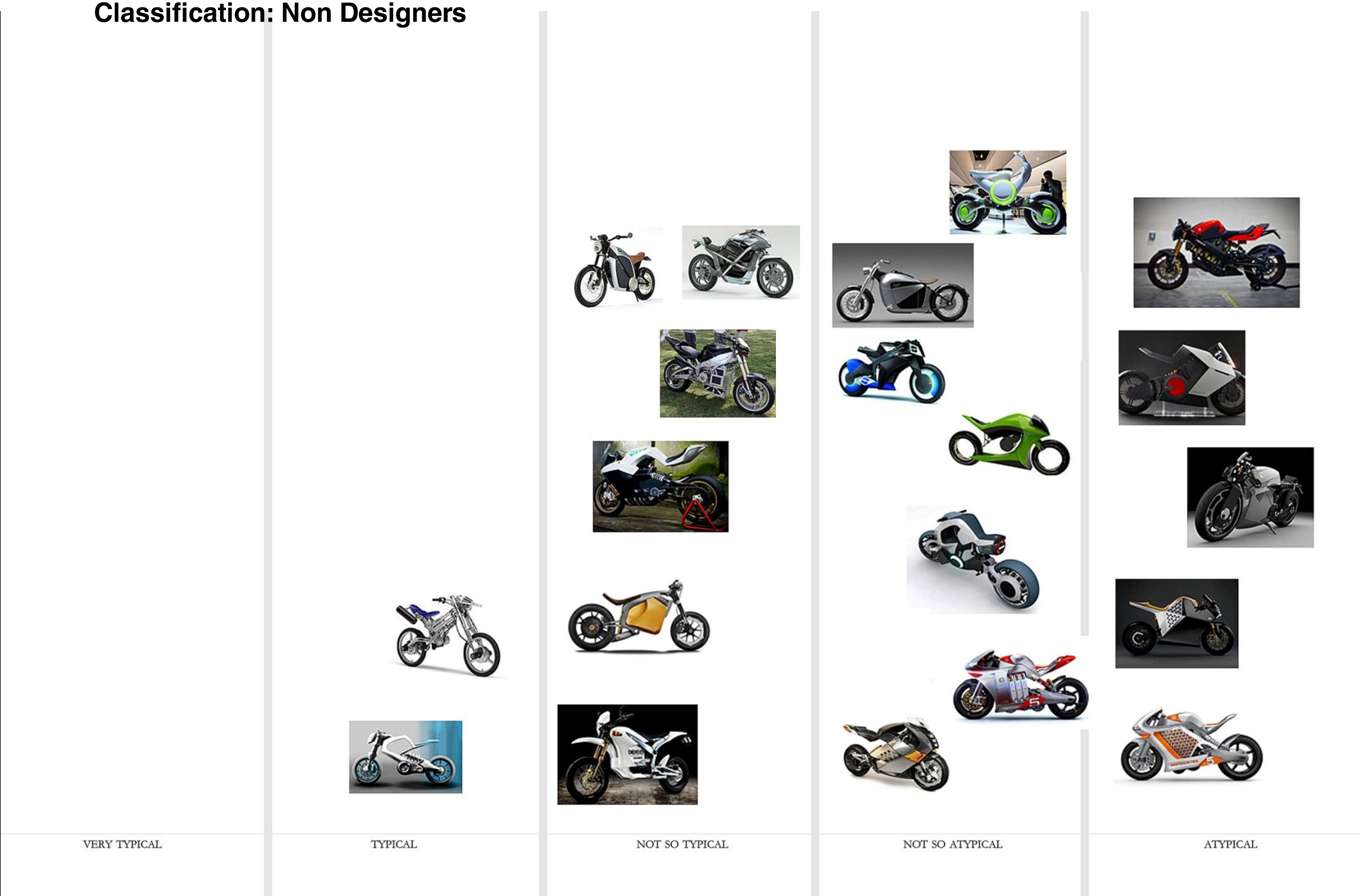
Ankur, 23

Product Semantic Study

- Understand the perception of electric bikes among users.
- In order to better gauge this perception, a product semantic study was done.
- The user would sort the images from typical to atypical.

Product Semantic Study

Classification: Non Designers



Product Semantic Study

Classification: Designers

VERY TYPICAL

TYPICAL

NOT SO TYPICAL

NOT SO ATYPICAL

ATYPICAL

Inference from User study

• People are open to buying an electric bike, if the performance and range parameters are better than existing bikes.

•Users expect electric bikes to be visually different from petrol bikes.

•A light, minimal construction with continuous surfacing is considered to be typical of electric motorcyles.

Design Brief

- Packaging
  - A combination of an electric motor, battery packs, suspension components mounted across a spine frame chassis.
  - The packaging would be tailored to good performance, handling conditions and lightweight construction

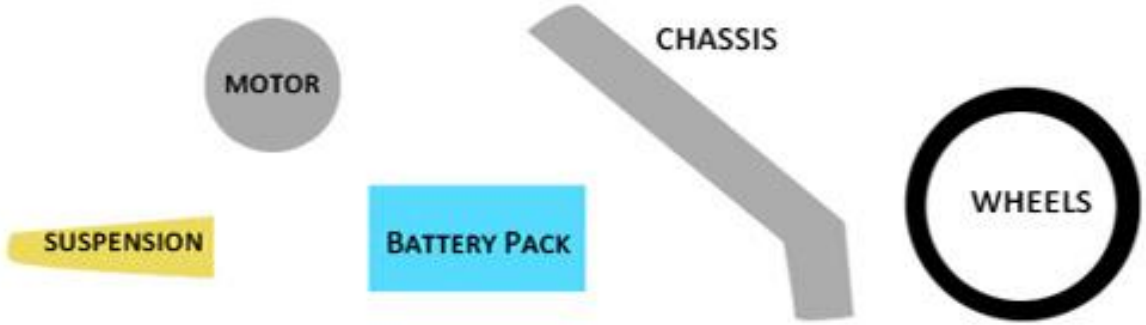
- Aesthetics
  - The aesthetics should reflect the soul of the rider's bike: Fast, agile and highly responsive.
  - A sense of dynamic balance, which is inherent in every motorcycle.
  - Reflecting the inherent nature of the bike; displaying the differences of its packaging from current petrol bikes.

- Technical Specifications
  - Motor: Axial Gap Brushless D.C. Motor with regenerative braking
  - Power: 15KW
  - Battery: 10KWh Li-polymer batteries with Aluminium Celmet additives
  - Wheelbase: 1500mm
  - Length: 2100mm
  - Seat Height: 790mm
  - Height: 1050mm

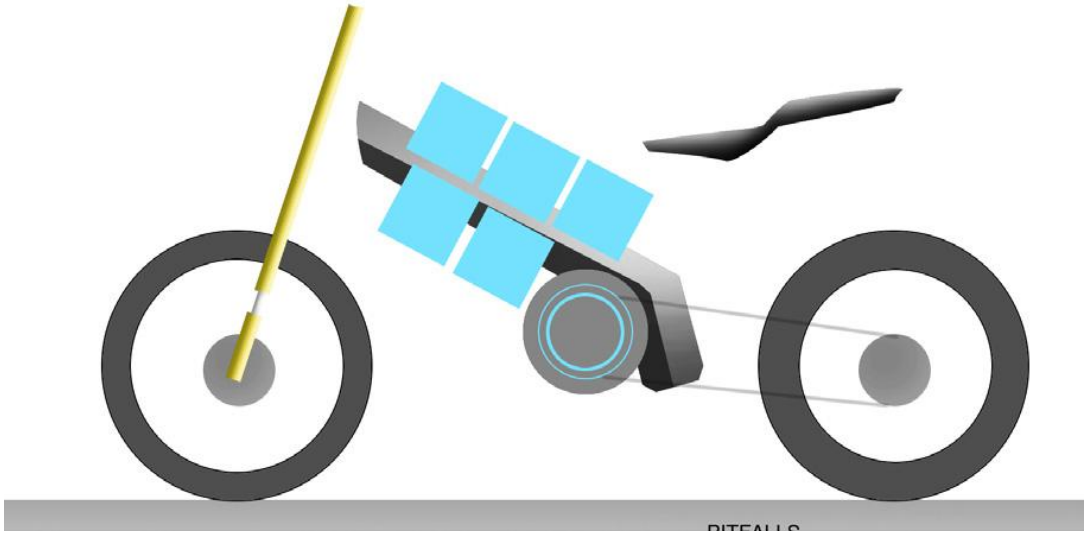
STAGE 2: EXPLORATIONS

Packaging Explorations

Explorations of packaging were done with the elements shown alongside.

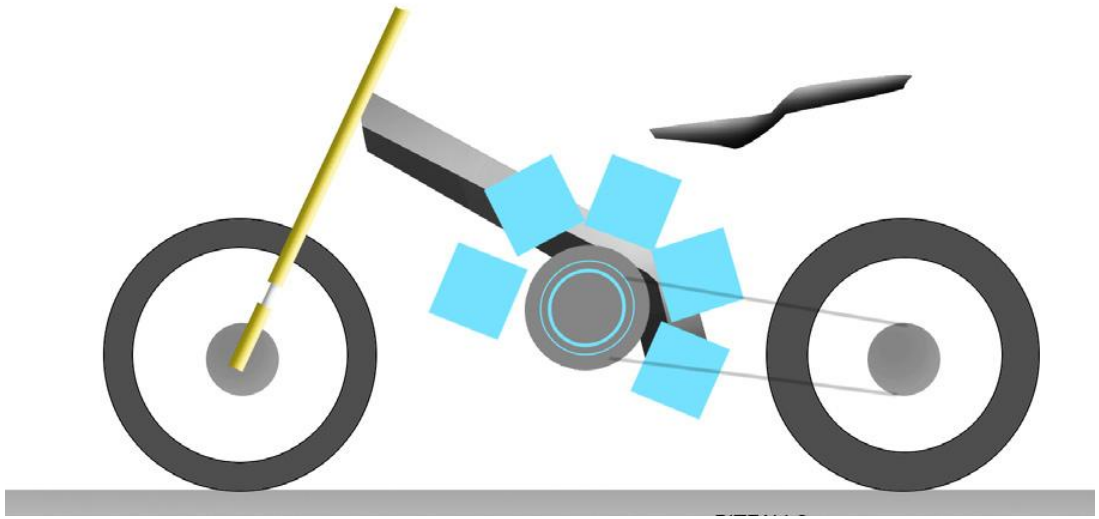


This involves arranging the battery packs along the spine, with the battery at the base of the spine.

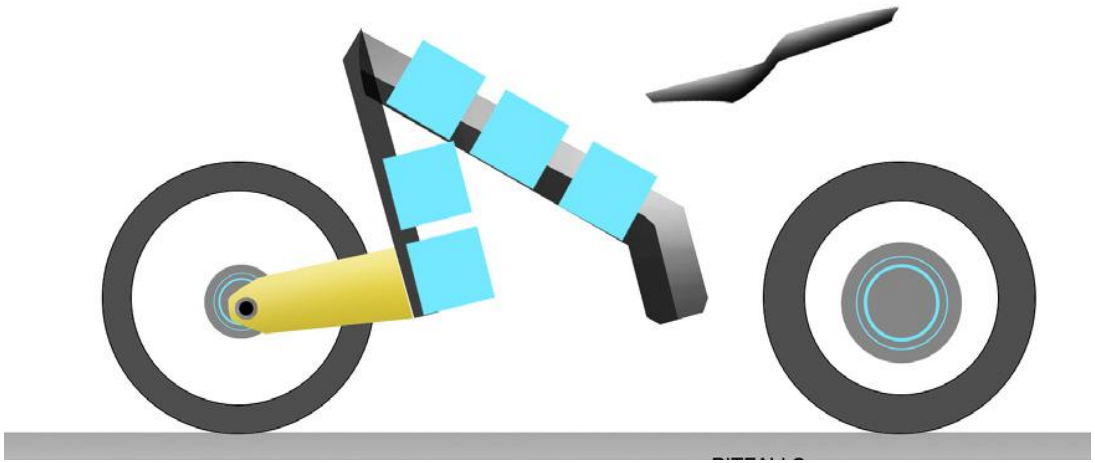


Packaging Explorations

The batteries are laid out in a radial manner, occupying less space and improving weight distribution.

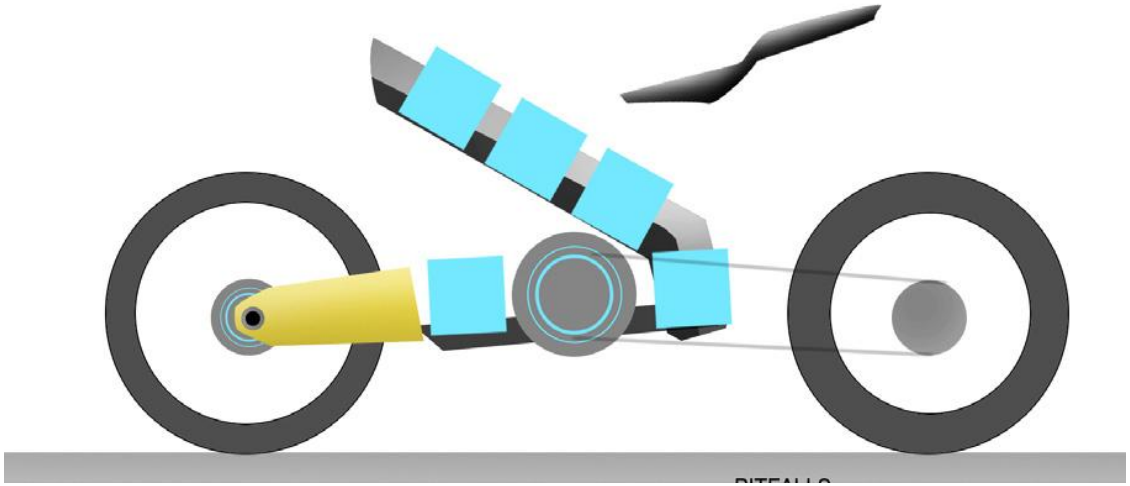


A hub centric steering with batteries along the spine, leads to a cycle like frame.

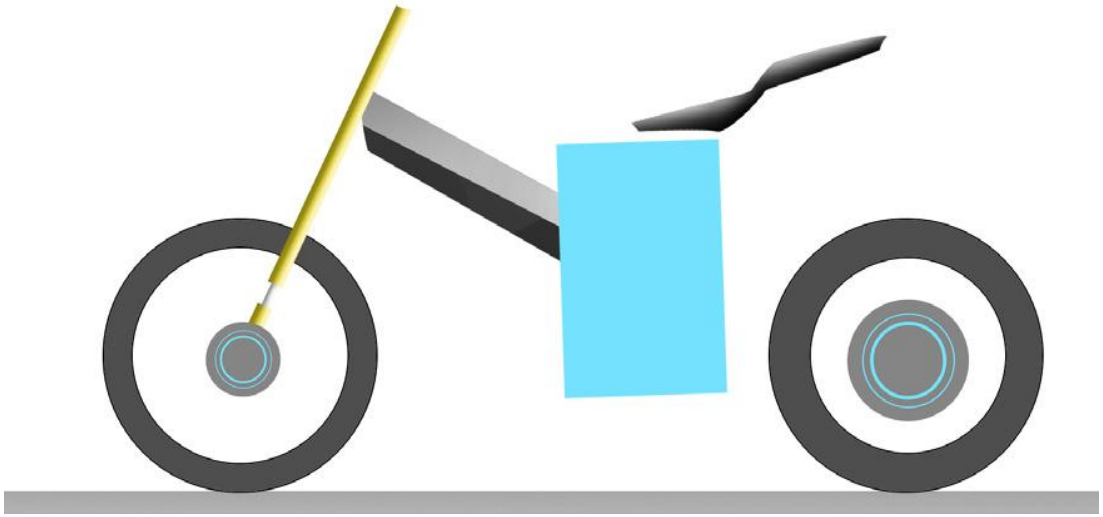


Packaging Explorations

Batteries laid out along the the spine, with a hub centric steering.



A single battery pack mounted below the rider., with in-wheel motors.



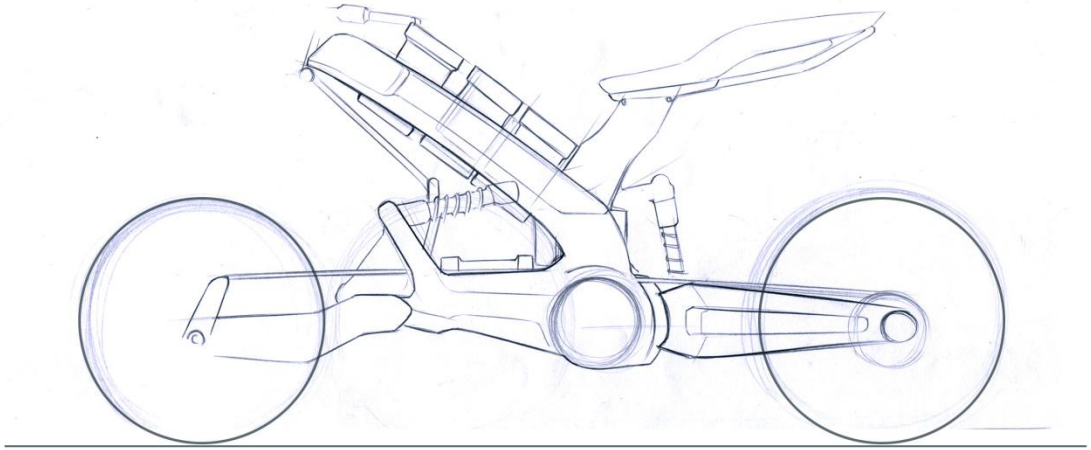
Packaging Explorations

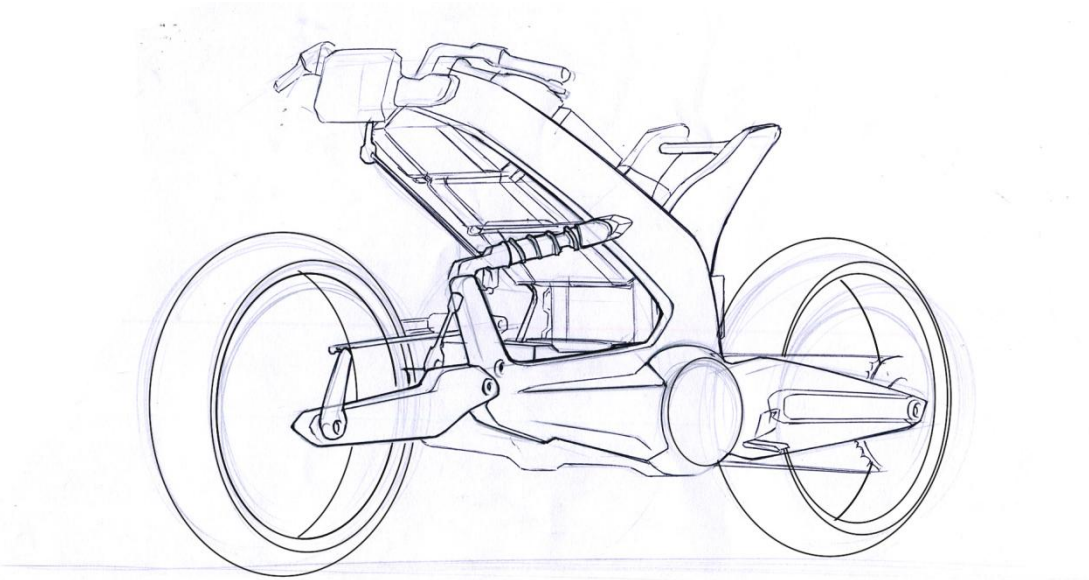
•The motor is positioned in the base of the spine frame.

•The battery units are embedded along the spine, and the front suspension is of a hub-centric type.

•The rear suspension is a monoshock suspension with a trailing arm.

•The drive is a belt drive system, coupled to the regenerative -braking enabled motor.





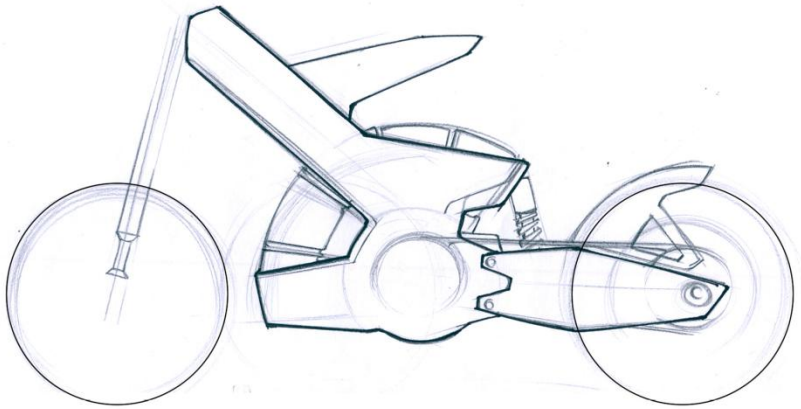
Packaging Explorations

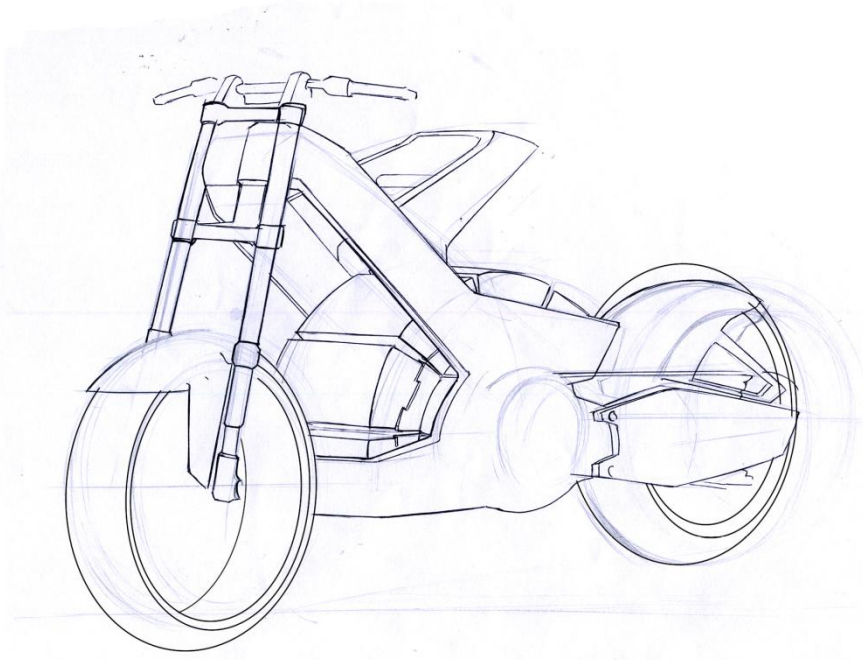
•The batteries are placed radially at the base of the spine of the bike.

•Power is transmitted via a belt drive system.

•Front suspension is a telescopic fork arrangement.

•A monoshock setup does duty in the rear.

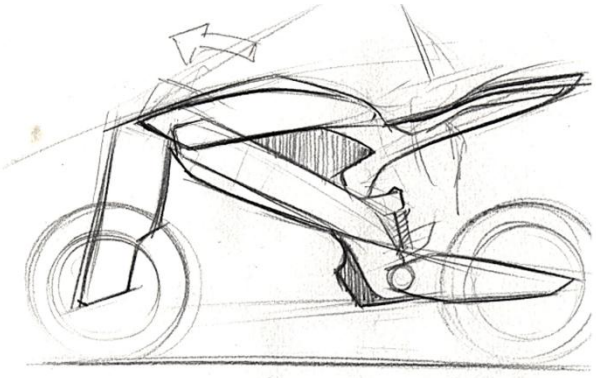


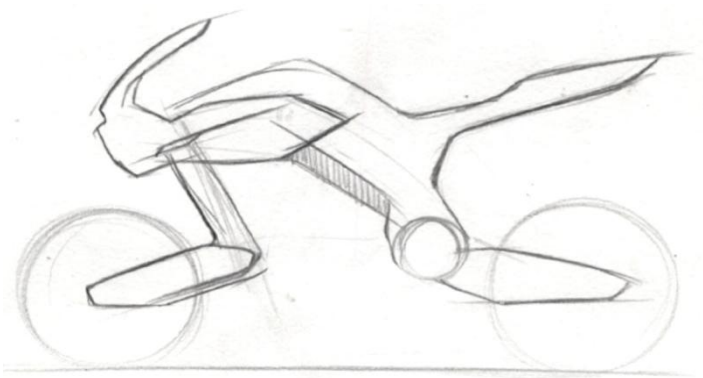


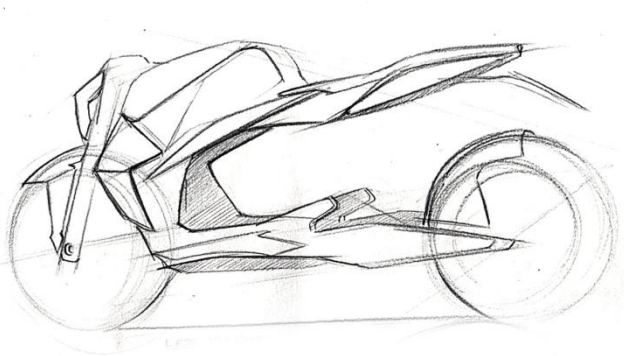
Aesthetic Explorations

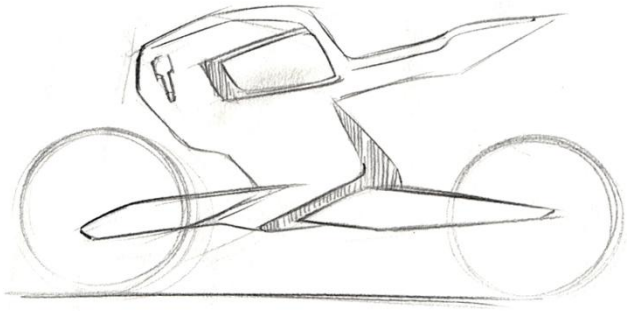
Volume Explorations

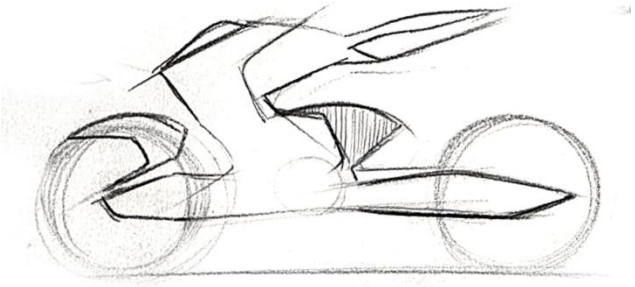
The first explorations focused on blocking volumes, focusing on getting the volumes which best reflect the design intent.

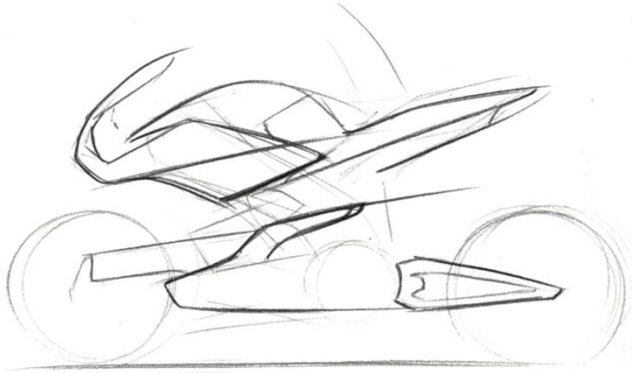








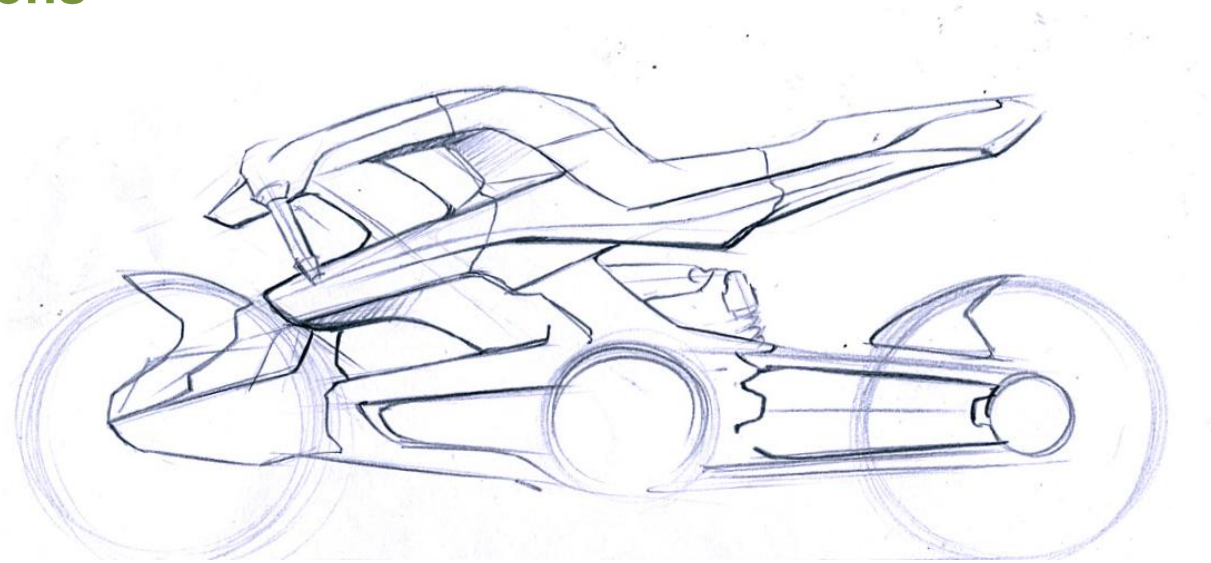


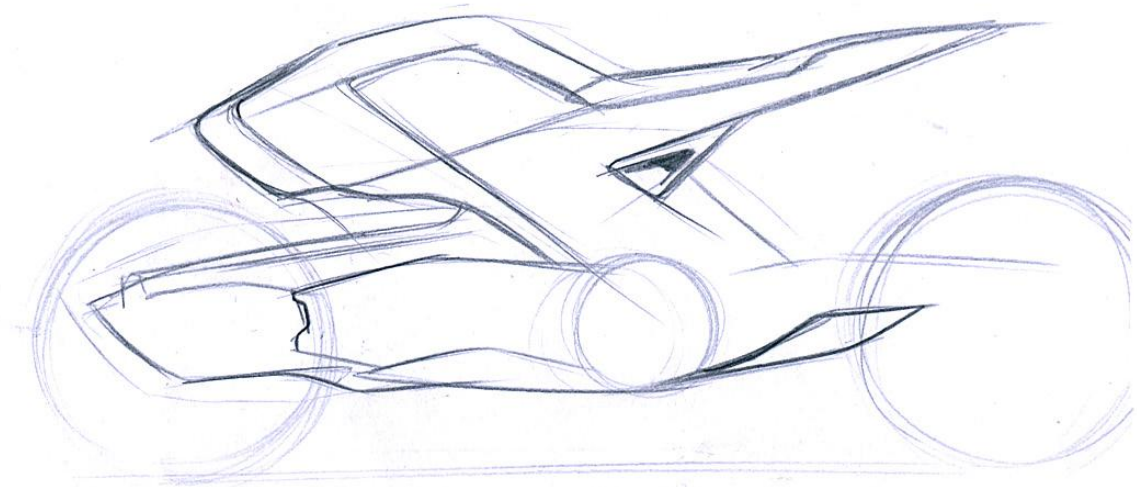


Aesthetic Explorations

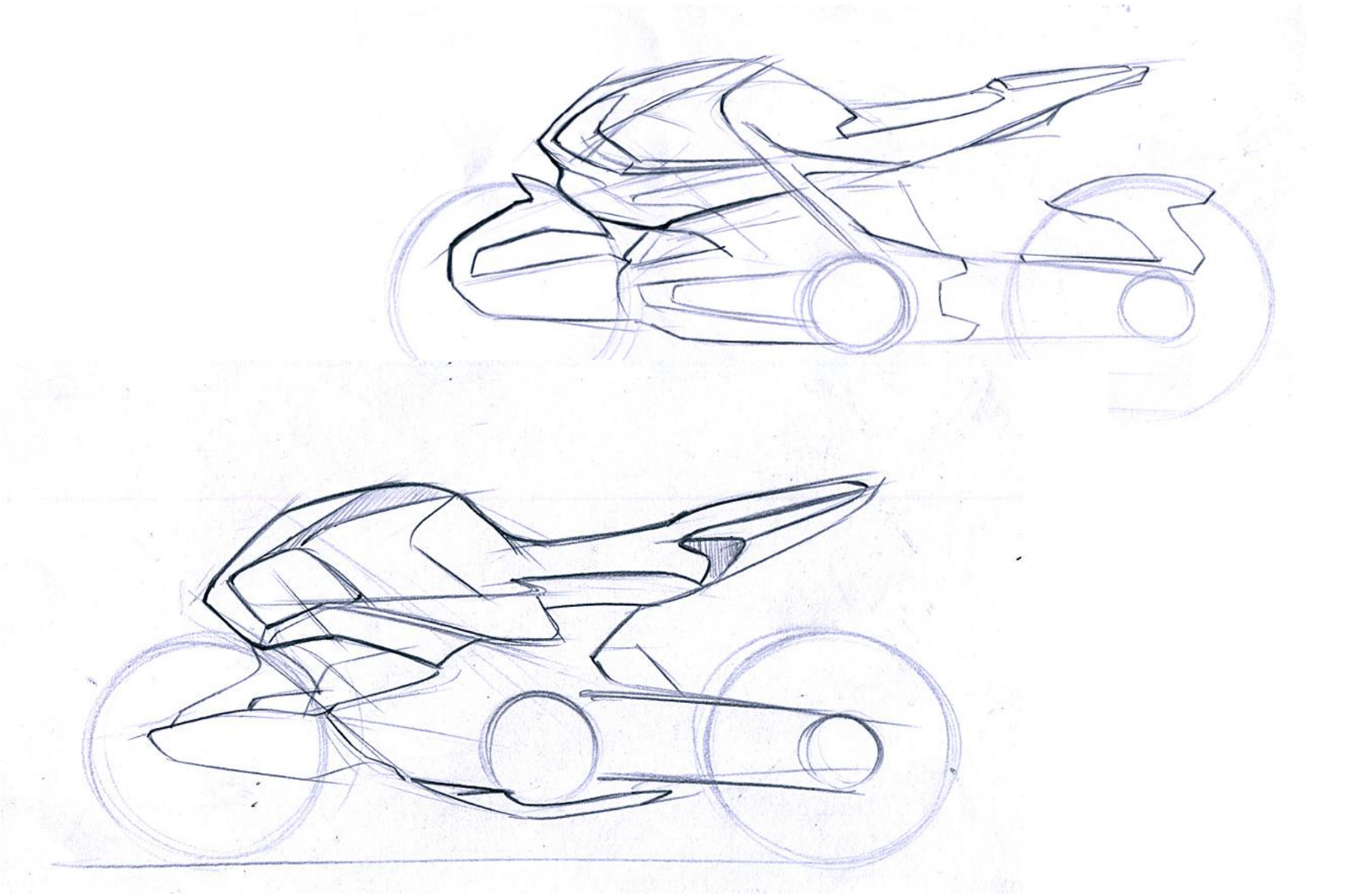
Initial Ideation

Initial ideas came from a combination of the semantic study as well as some of the volumes blocked from the initial explorations.

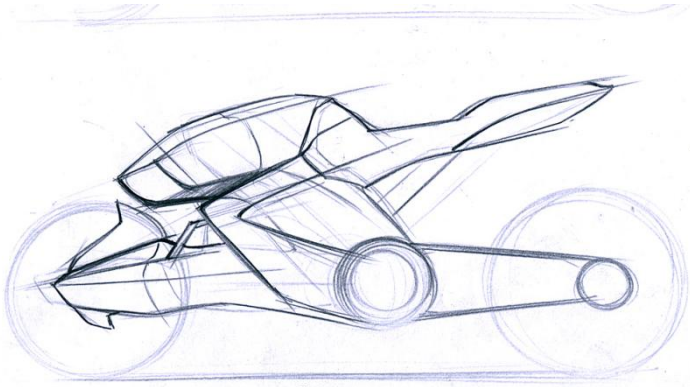


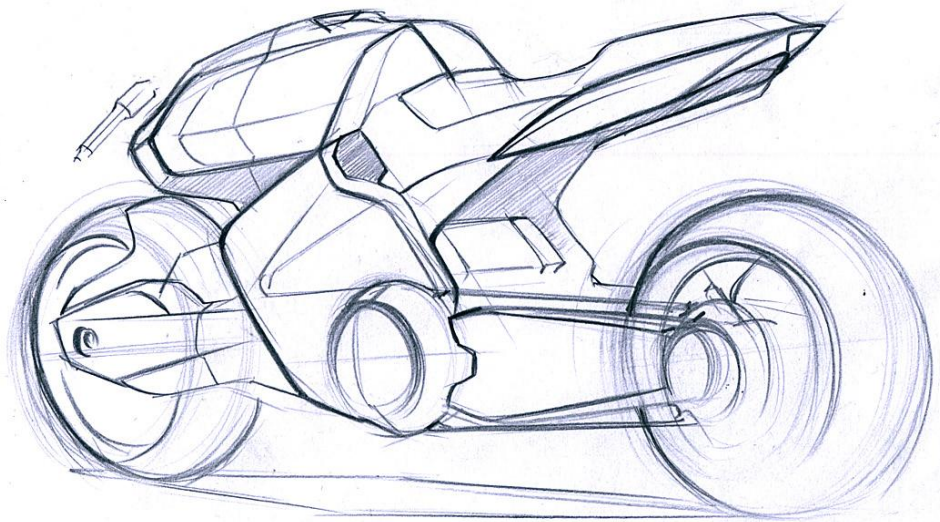


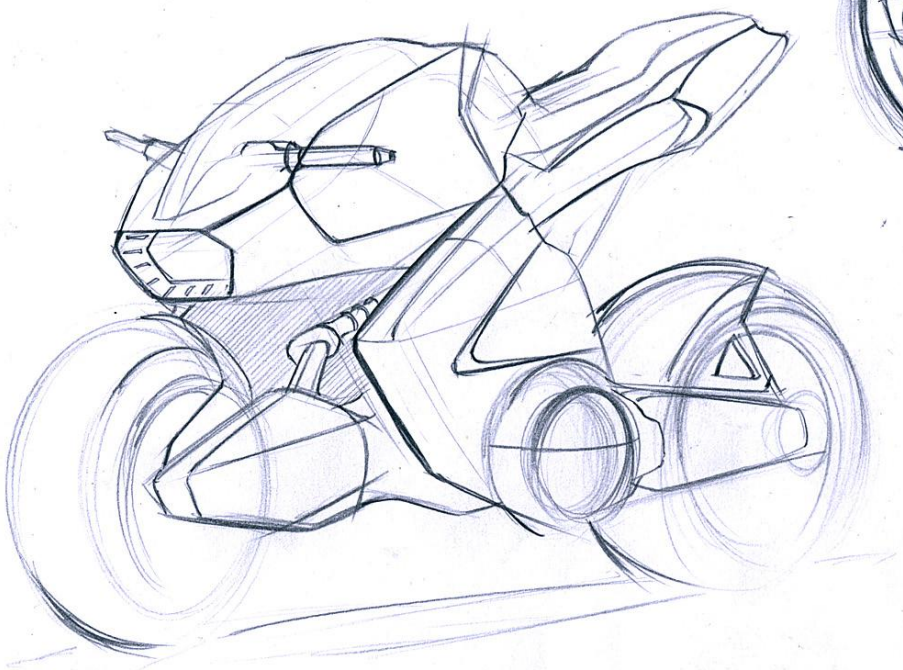
Aesthetic Explorations



Aesthetic Explorations

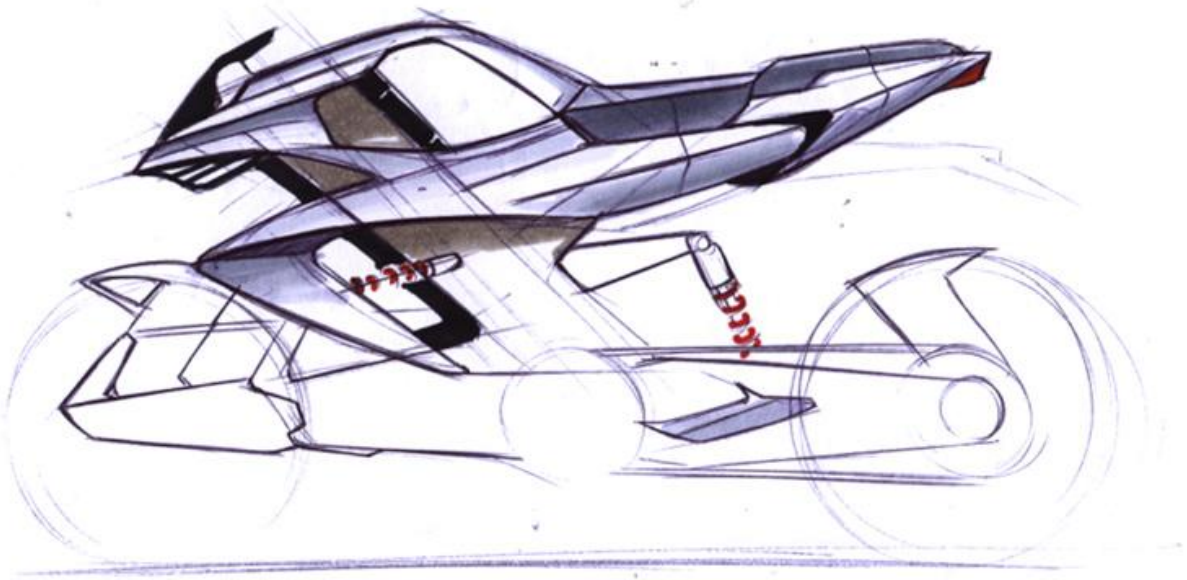


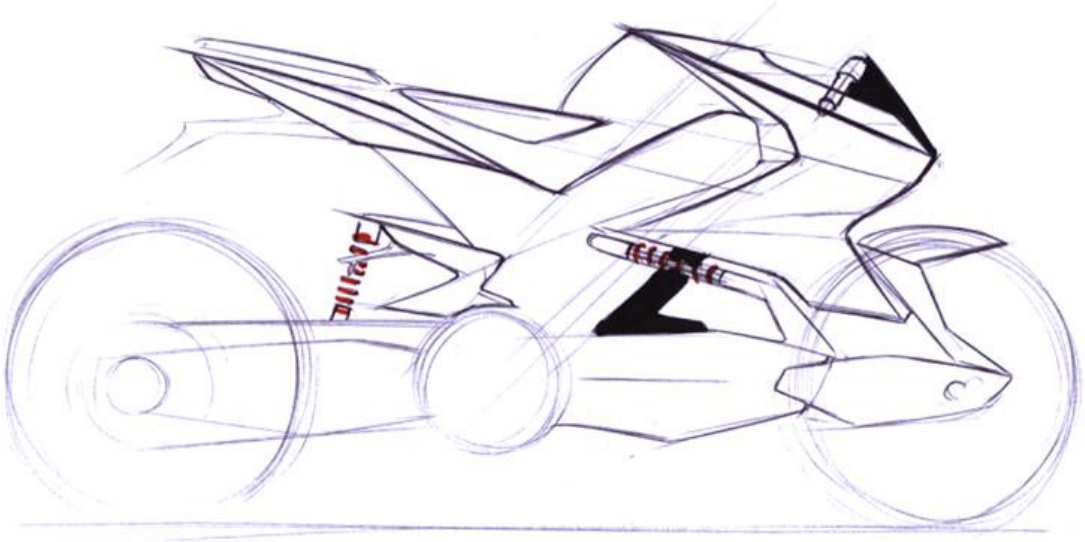




Aesthetic Explorations

The hub centric steering package creates a strong sense of length and dynamism.





Aesthetic Explorations

Metaphor-based form exploration

Motorcycles offer the most visceral experience of speed among all forms of transport, moving where the rider wills them to move. A rider attacks the gaps in traffic on his bike;

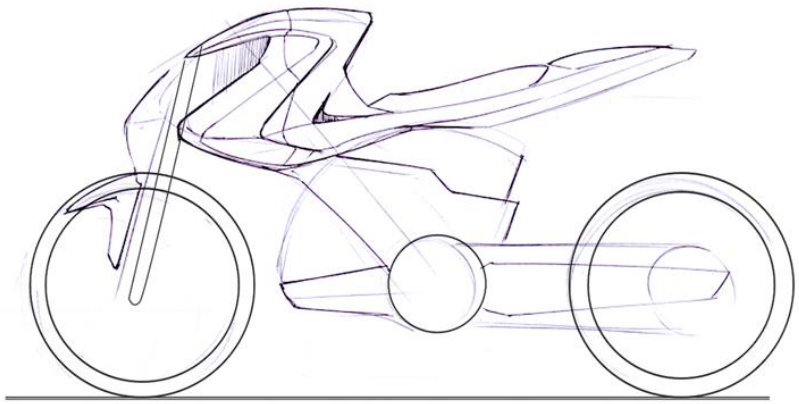
This expression of pure, controlled aggression best seen in a snake rearing up for a strike.

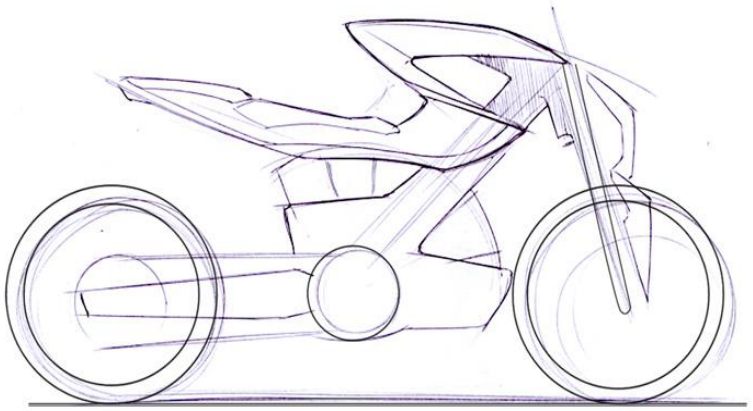


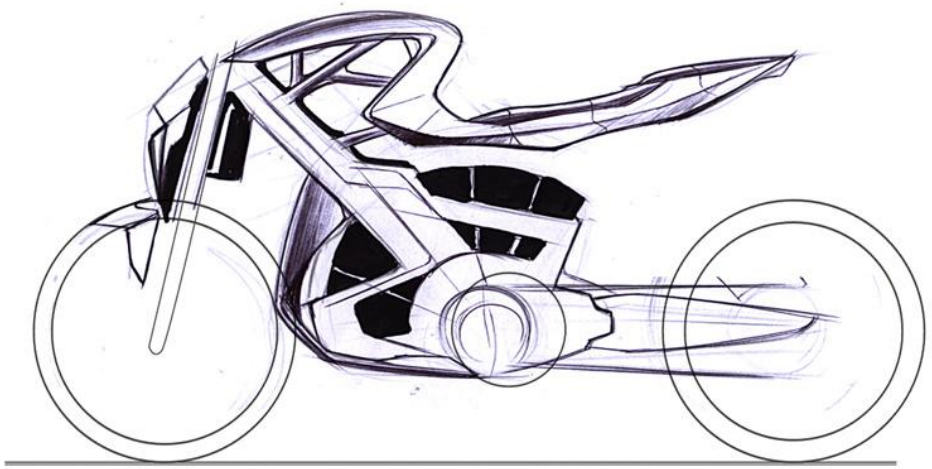



Aesthetic Explorations

Metaphor-based form exploration

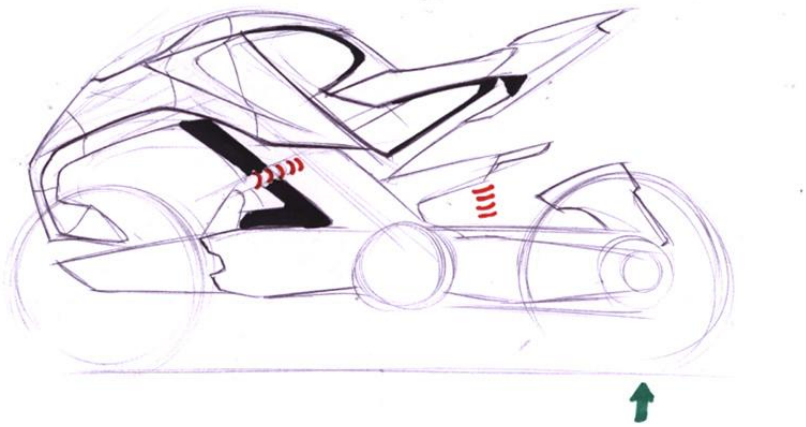




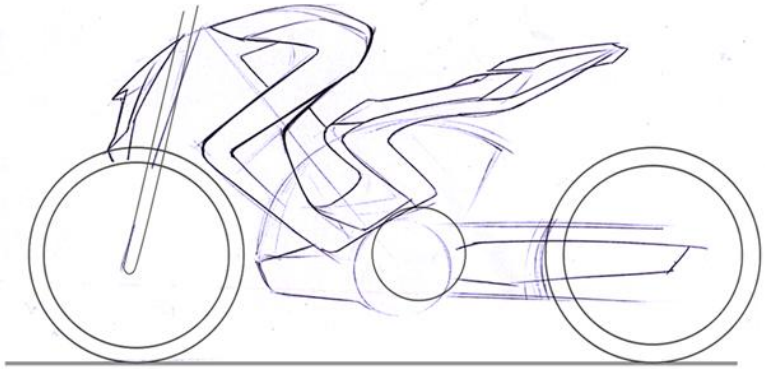


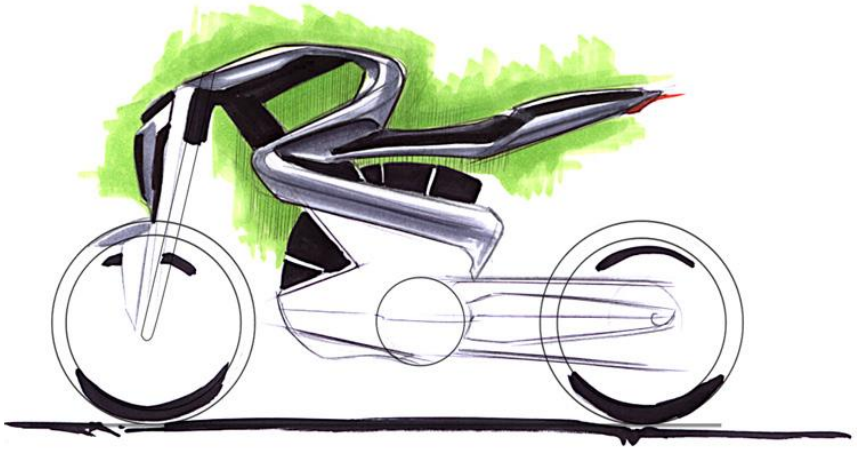
Aesthetic Explorations

Metaphor-based form exploration



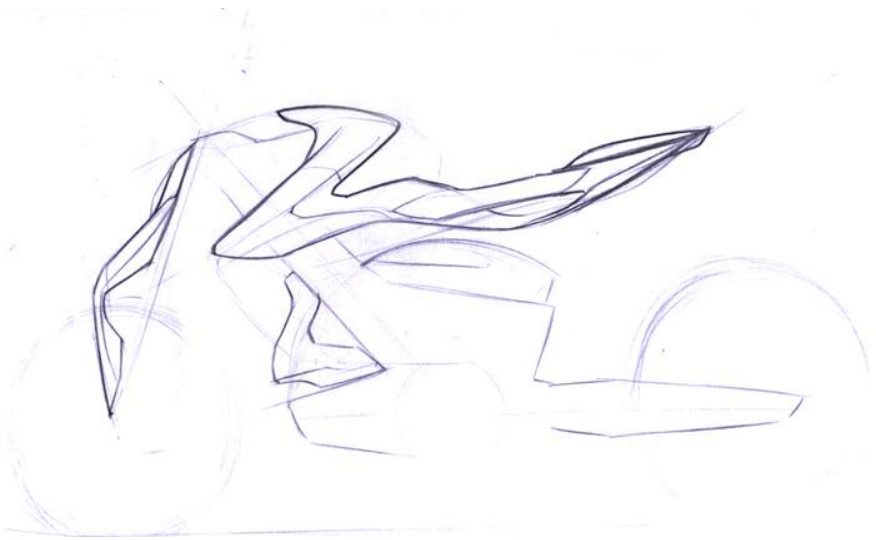
The coiled up energy of the snake as it gathers motion to rise was captured in these explorations

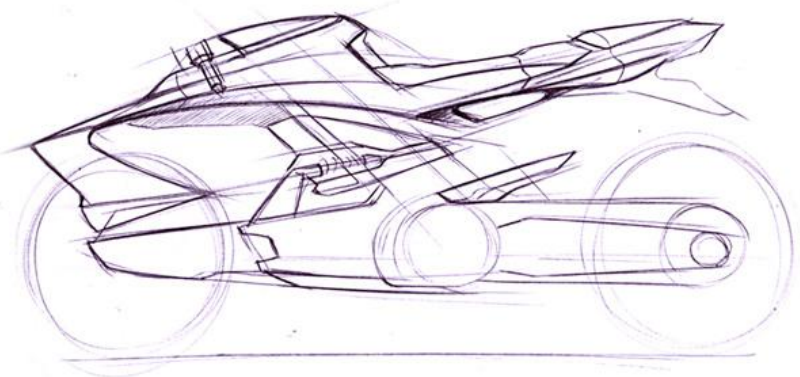


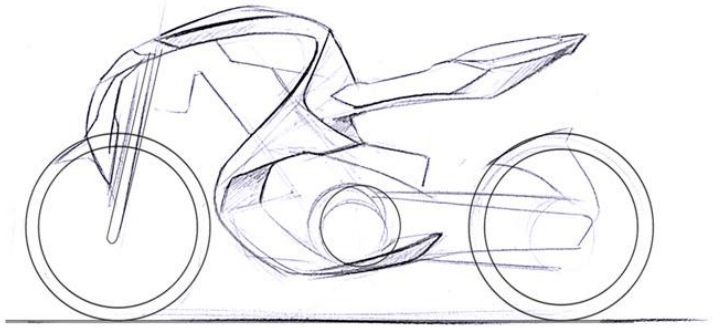


Aesthetic Explorations

Metaphor-based form exploration

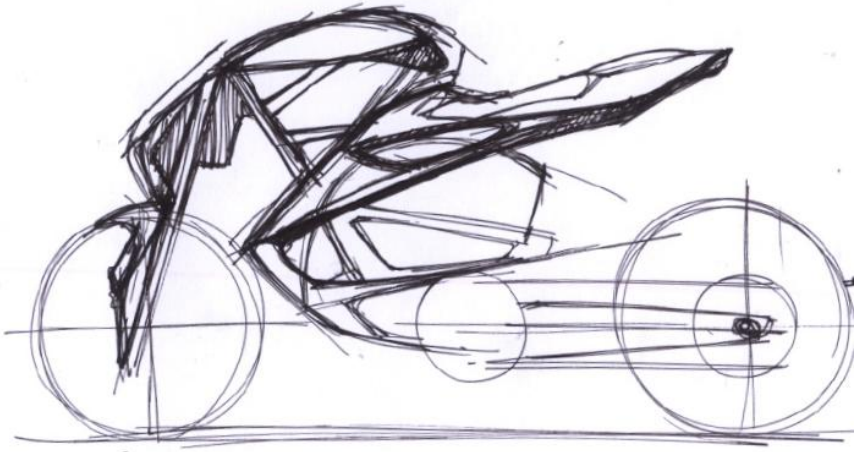






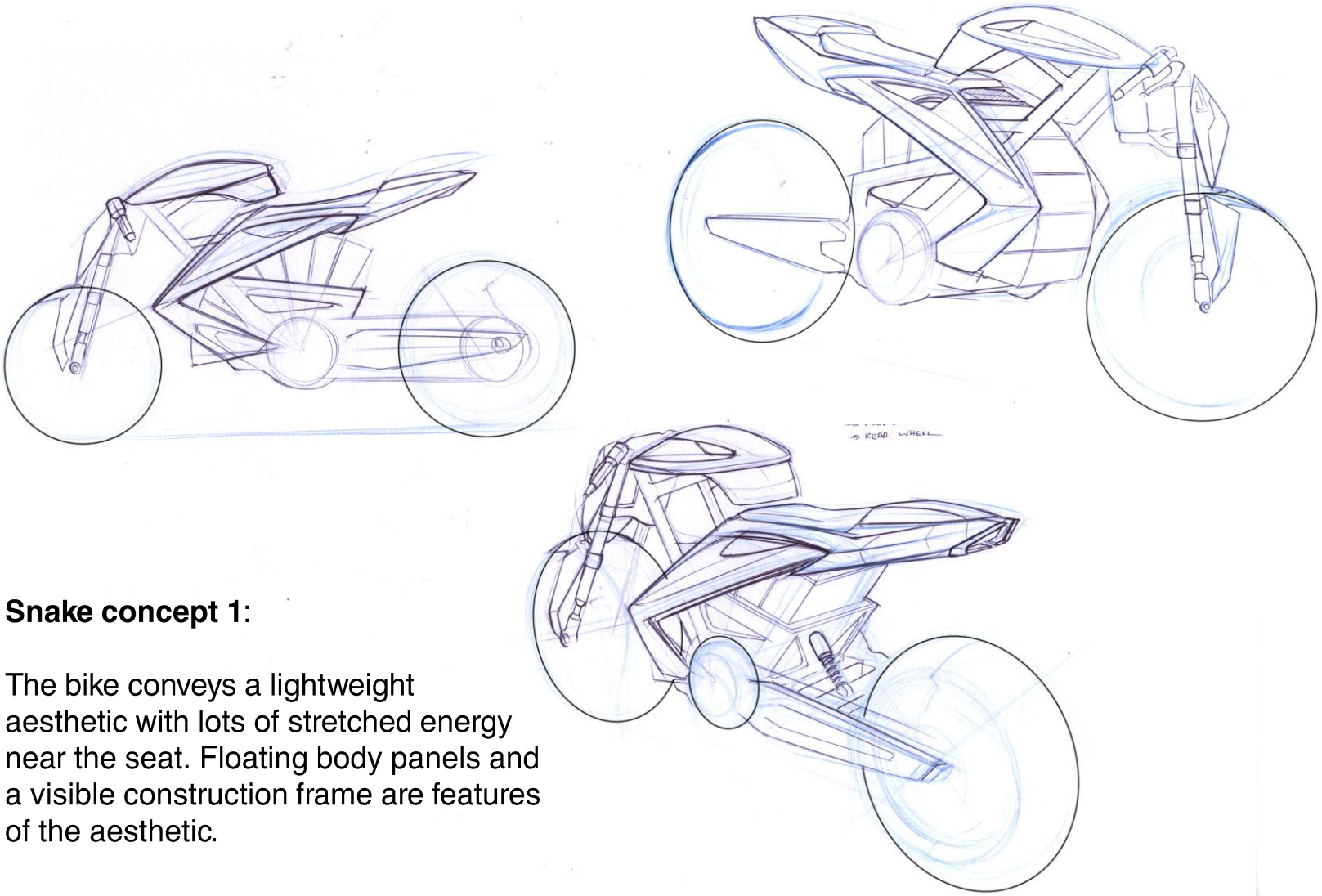
Aesthetic Explorations

Metaphor-based form exploration



Aesthetic Explorations

Metaphor-based form exploration



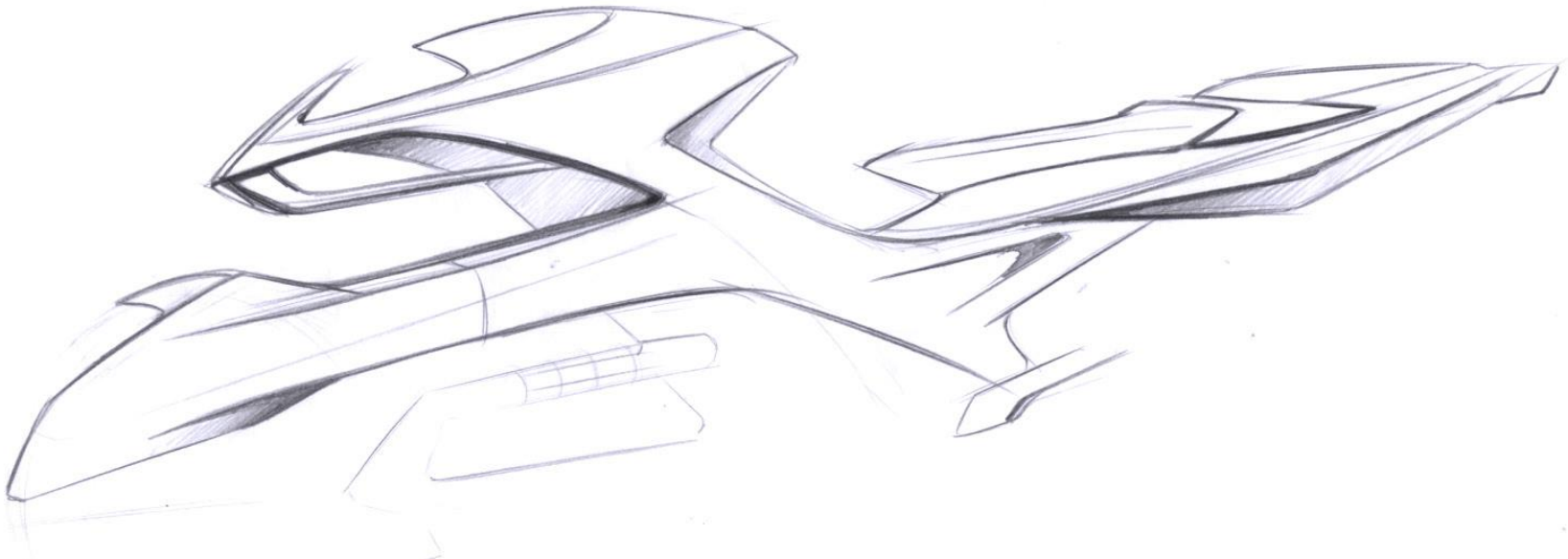
Snake concept 1:

The bike conveys a lightweight aesthetic with lots of stretched energy near the seat. Floating body panels and a visible construction frame are features of the aesthetic.

Aesthetic Explorations

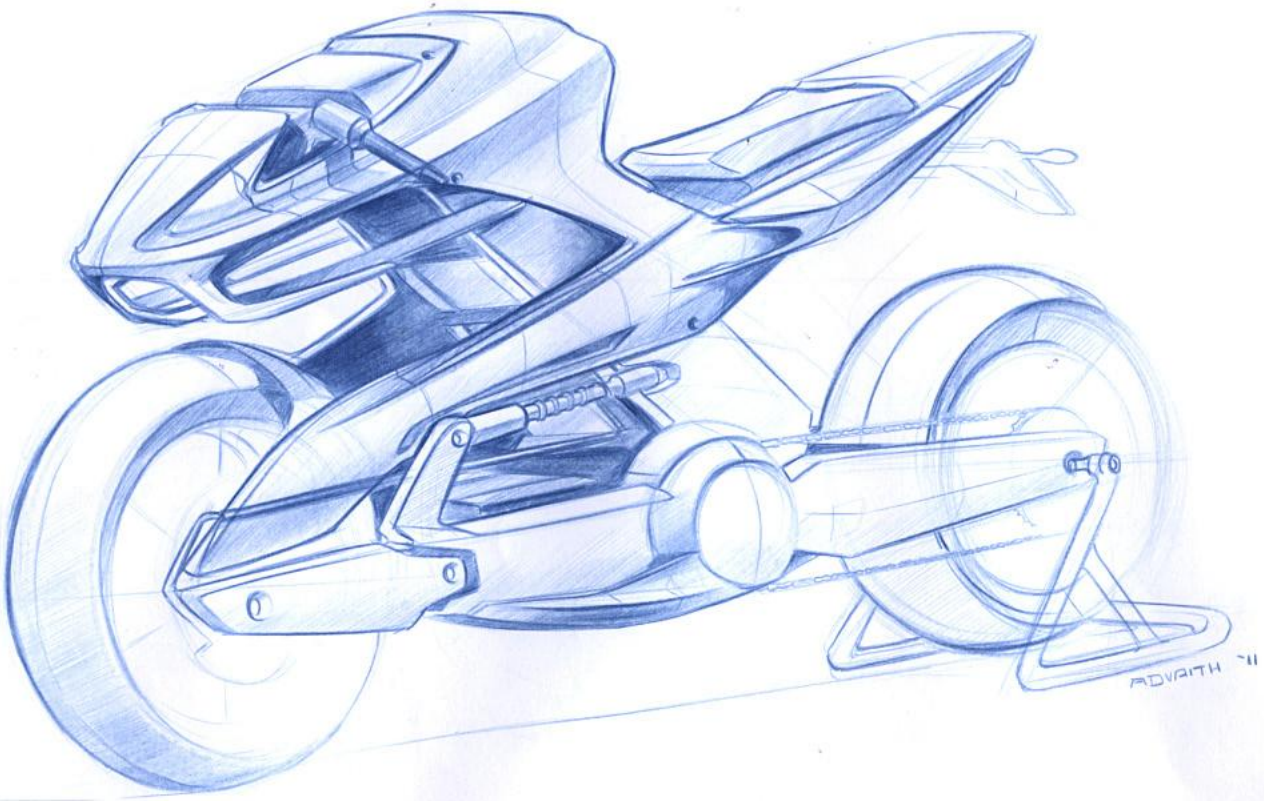
Metaphor-based form exploration

Inspiration



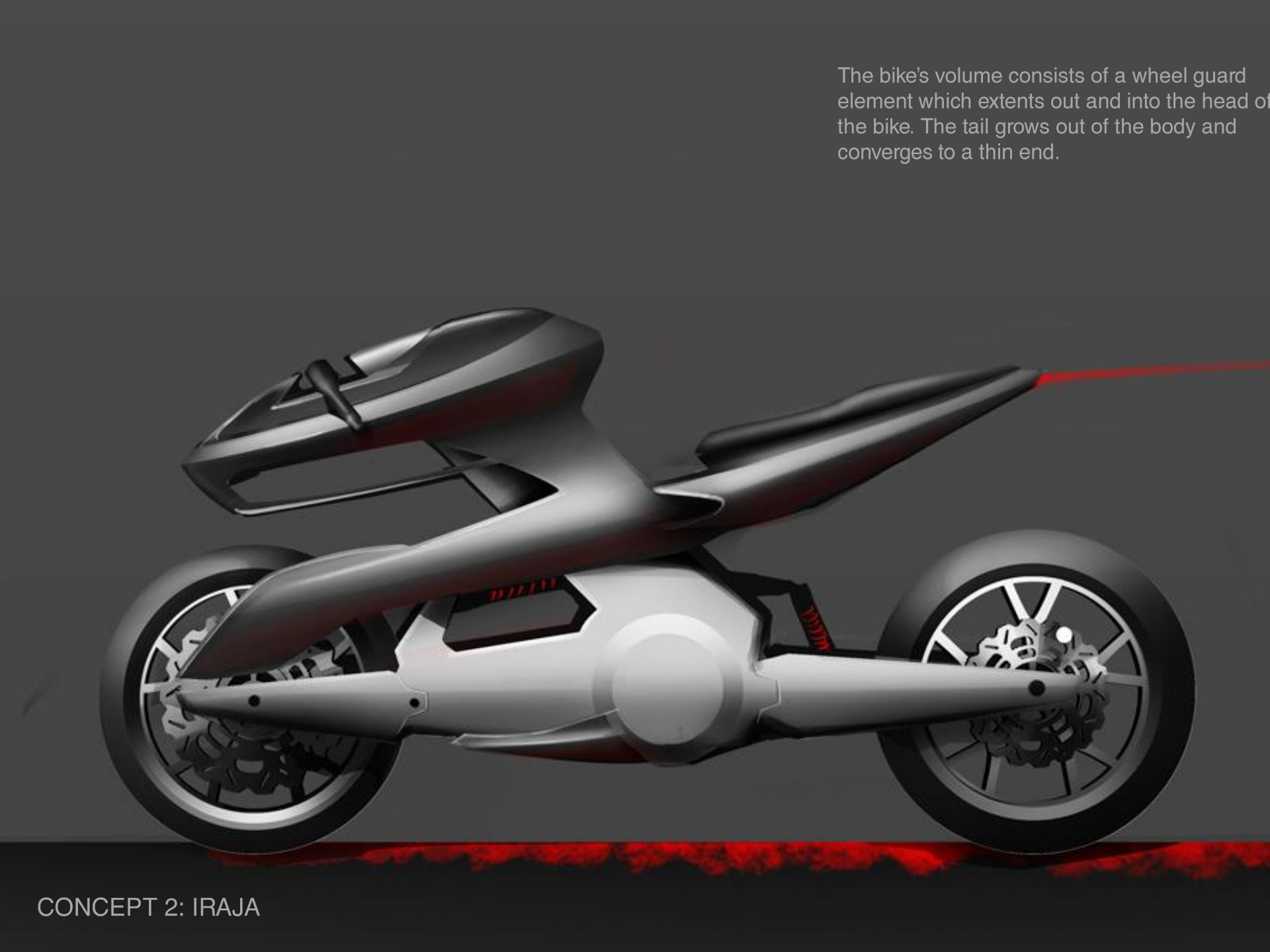
Aesthetic Explorations

Metaphor-based form exploration



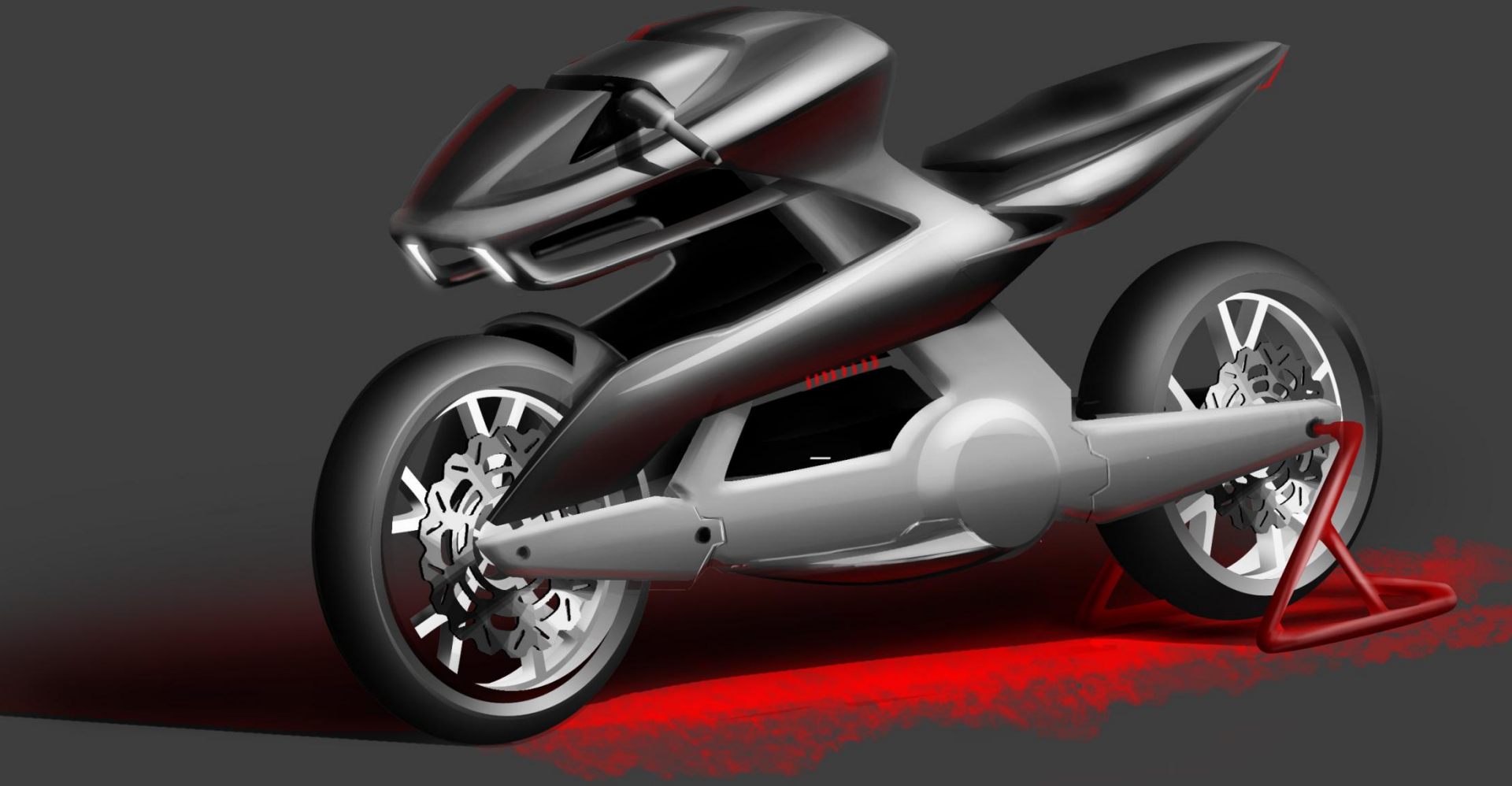
Snake 2: Concept Sketch

The bike's volume consists of a wheel guard element which extents out and into the head of the bike. The tail grows out of the body and converges to a thin end.



CONCEPT 2: IRAJA

Headlights draw inspiration from the snake's fangs, with the headlamp elements flowing backward into the form.



CONCEPT 2: IRAJA

The tail features progressive lighting in
single light would light up under light br
all three lights lighting up under heavy

CONCEPT 2: IRAJA

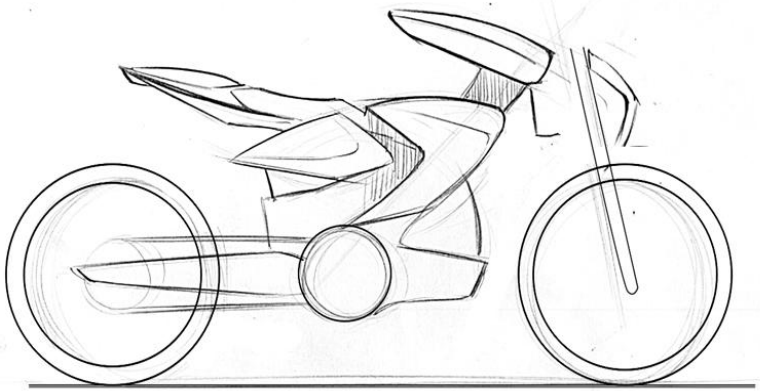
Aesthetic Explorations

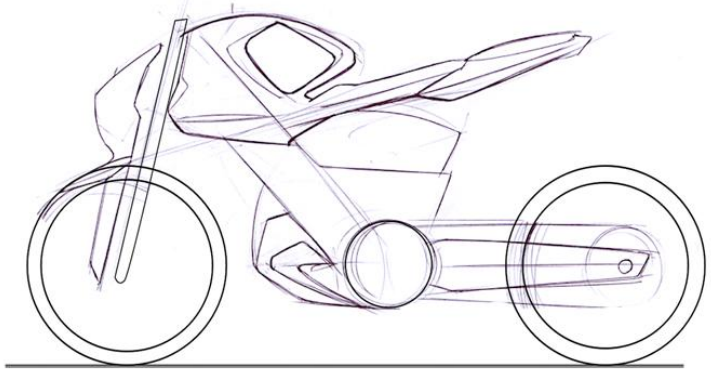
Metaphor-based form exploration

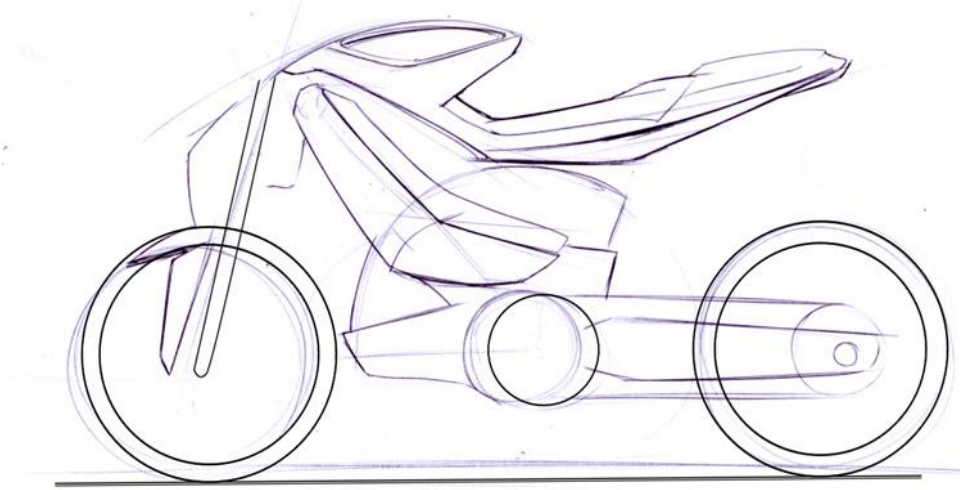
Speed means nothing without balance. Balance determines agility, control, precision; all elements a rider relies on during his ride. The expressions of this dynamic balance were best seen in the motion of a dragonfly preparing to land.

Aesthetic Explorations

Metaphor-based form exploration



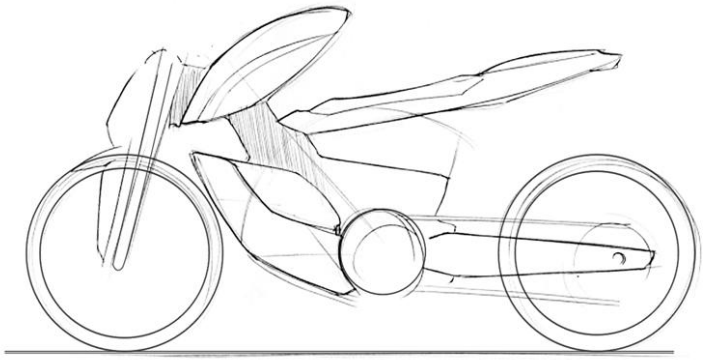


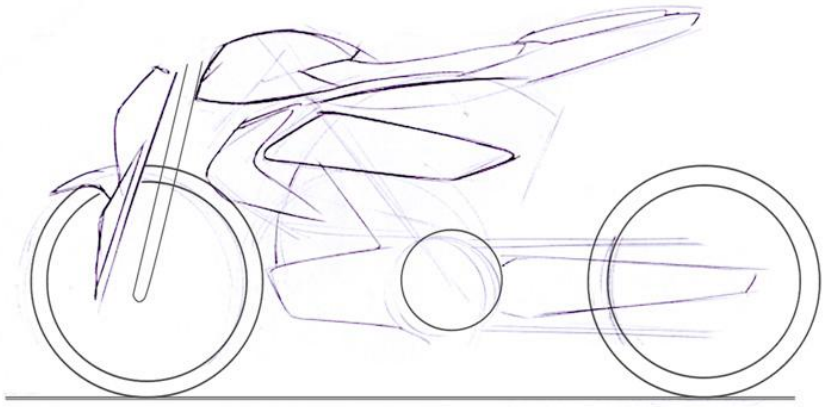


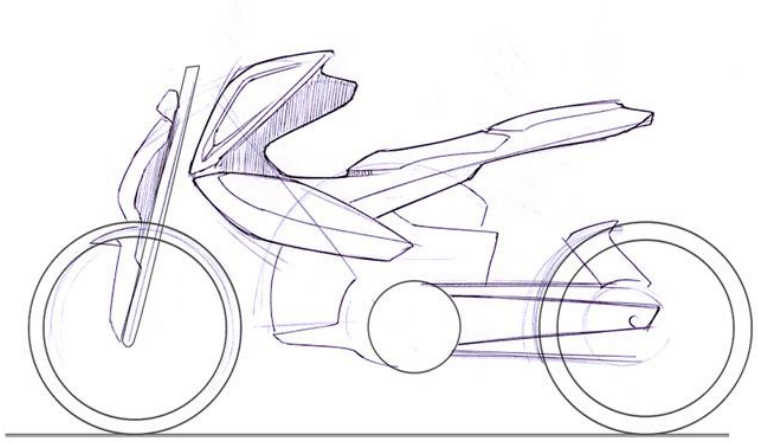
The wings were a strong visual element to draw inspiration from

Aesthetic Explorations

Metaphor-based form exploration



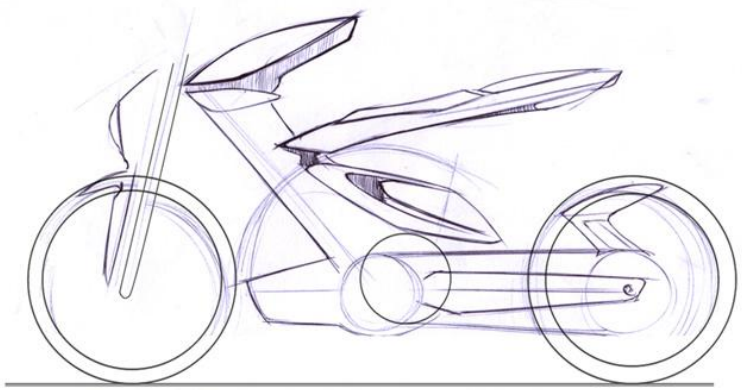


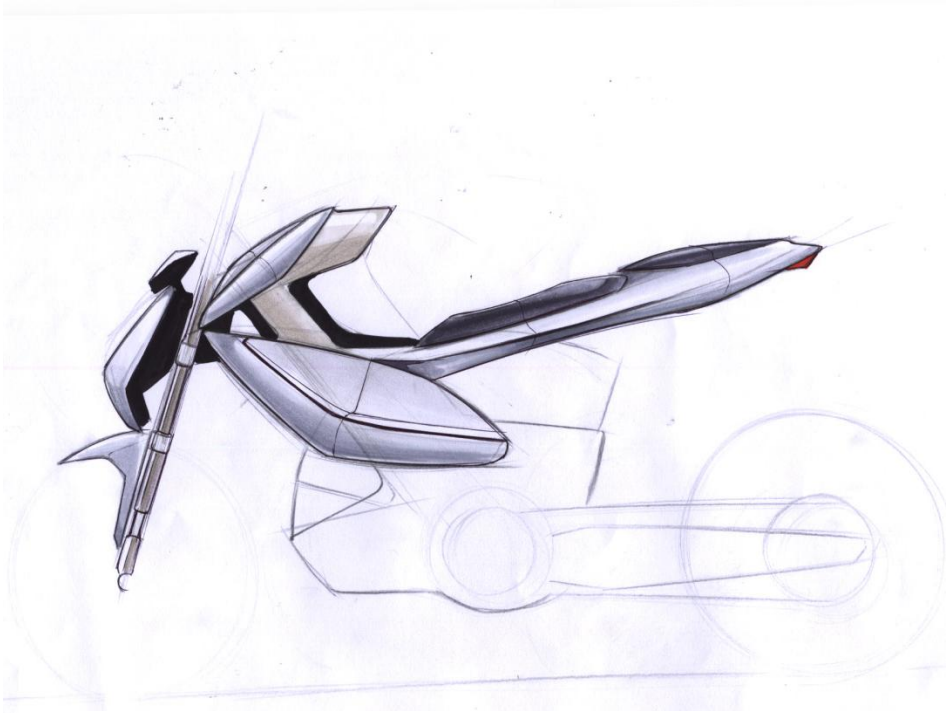


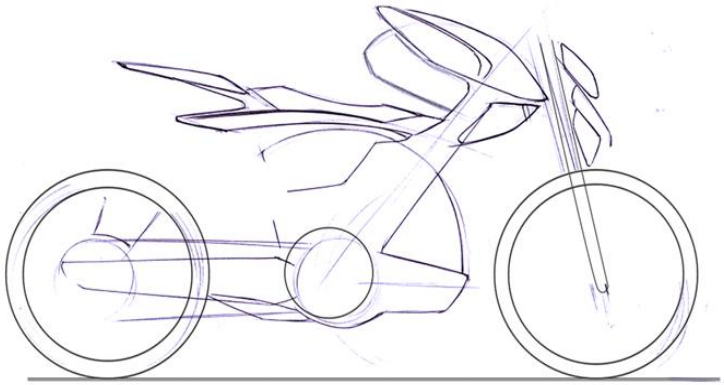
A balanced and fast aesthetic was the aim of these explorations

Aesthetic Explorations

Metaphor-based form exploration

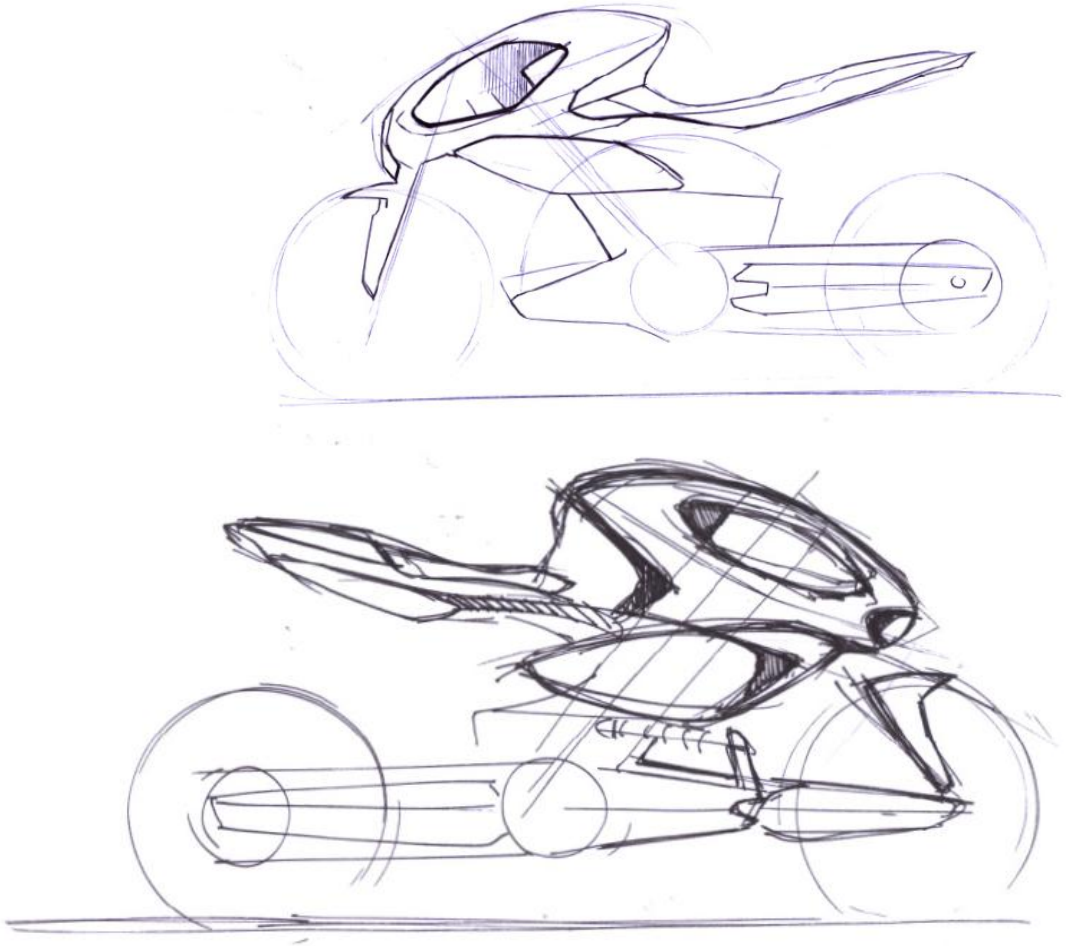






Aesthetic Explorations

Metaphor-based form exploration

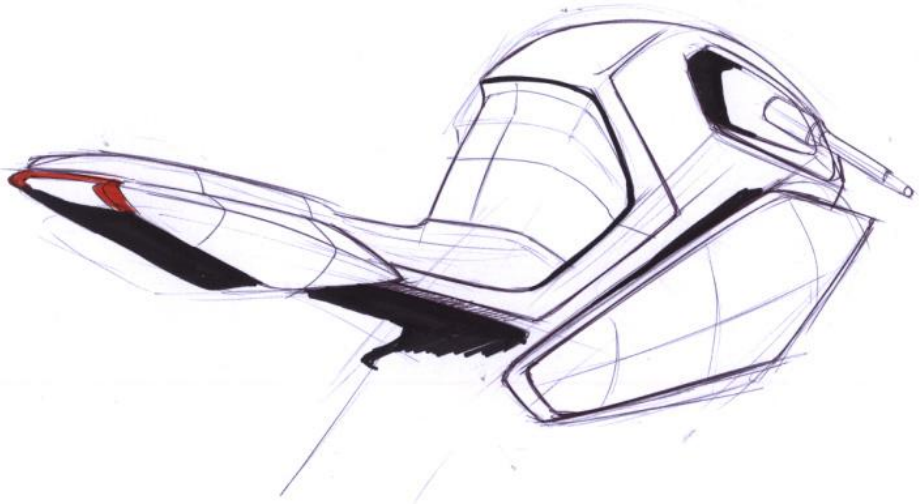


Dragonfly concept:

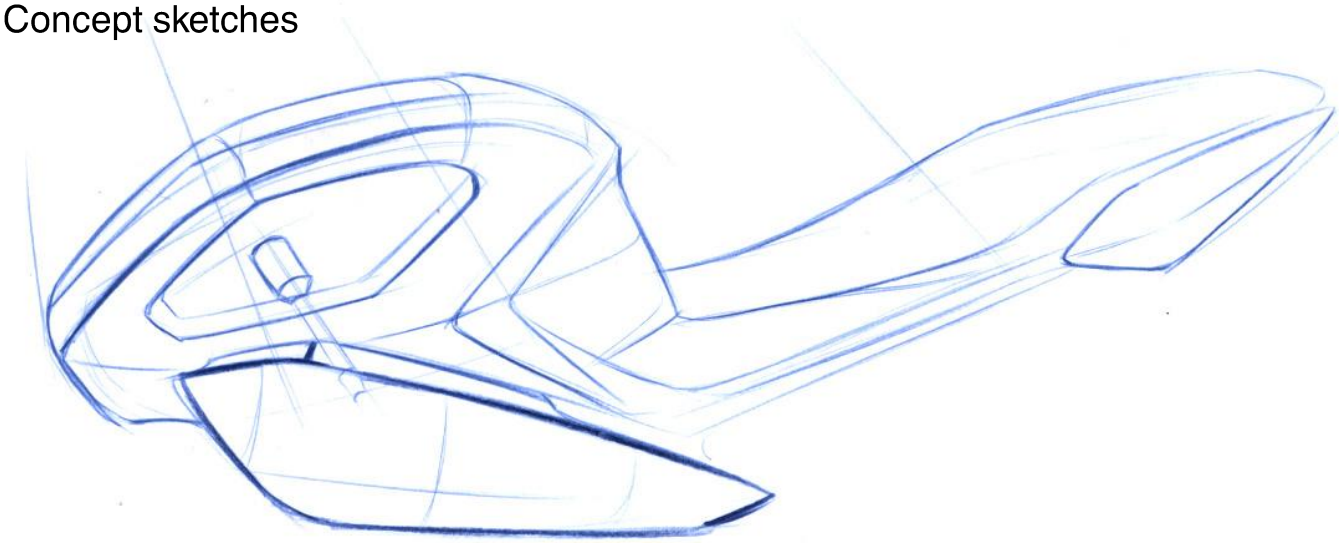
The bike draws inspiration from the volumes of a dragonfly, with wings serving as side panels in which solar cells are embedded.

Aesthetic Explorations

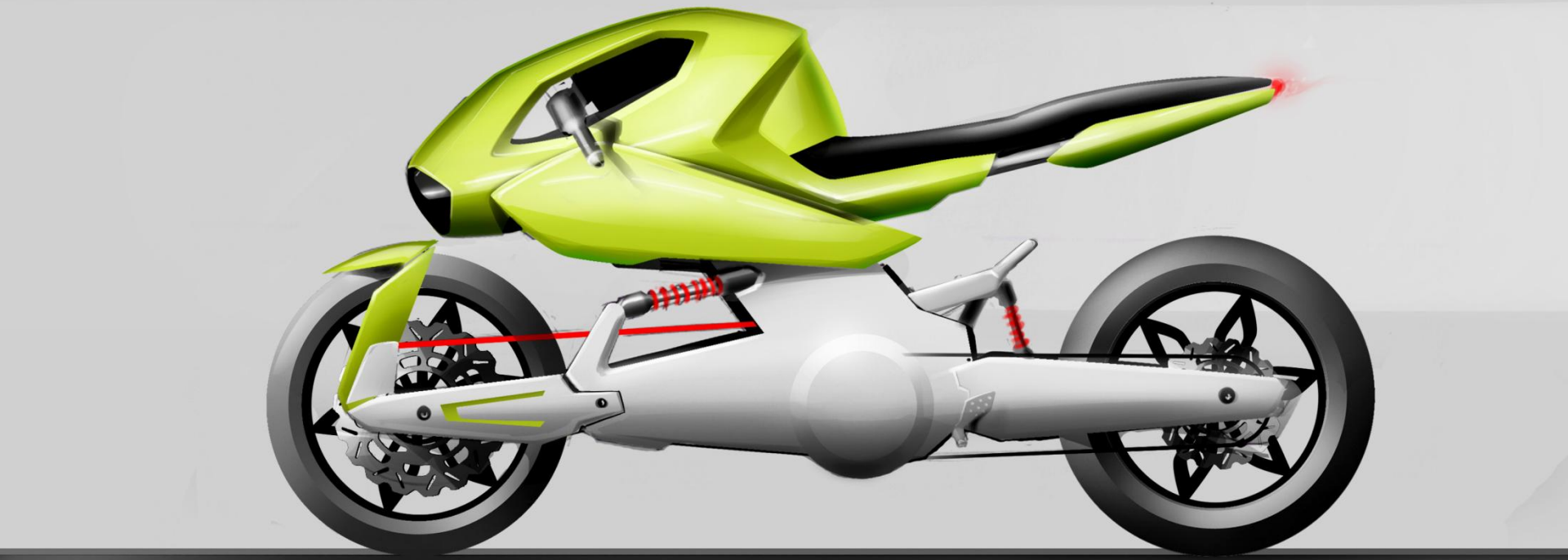
Metaphor-based form exploration



Concept sketches



The bike is characterised by a large head, from which the solar panel wings extend out. The volume attempts to capture a stance of balance along with dynamism.

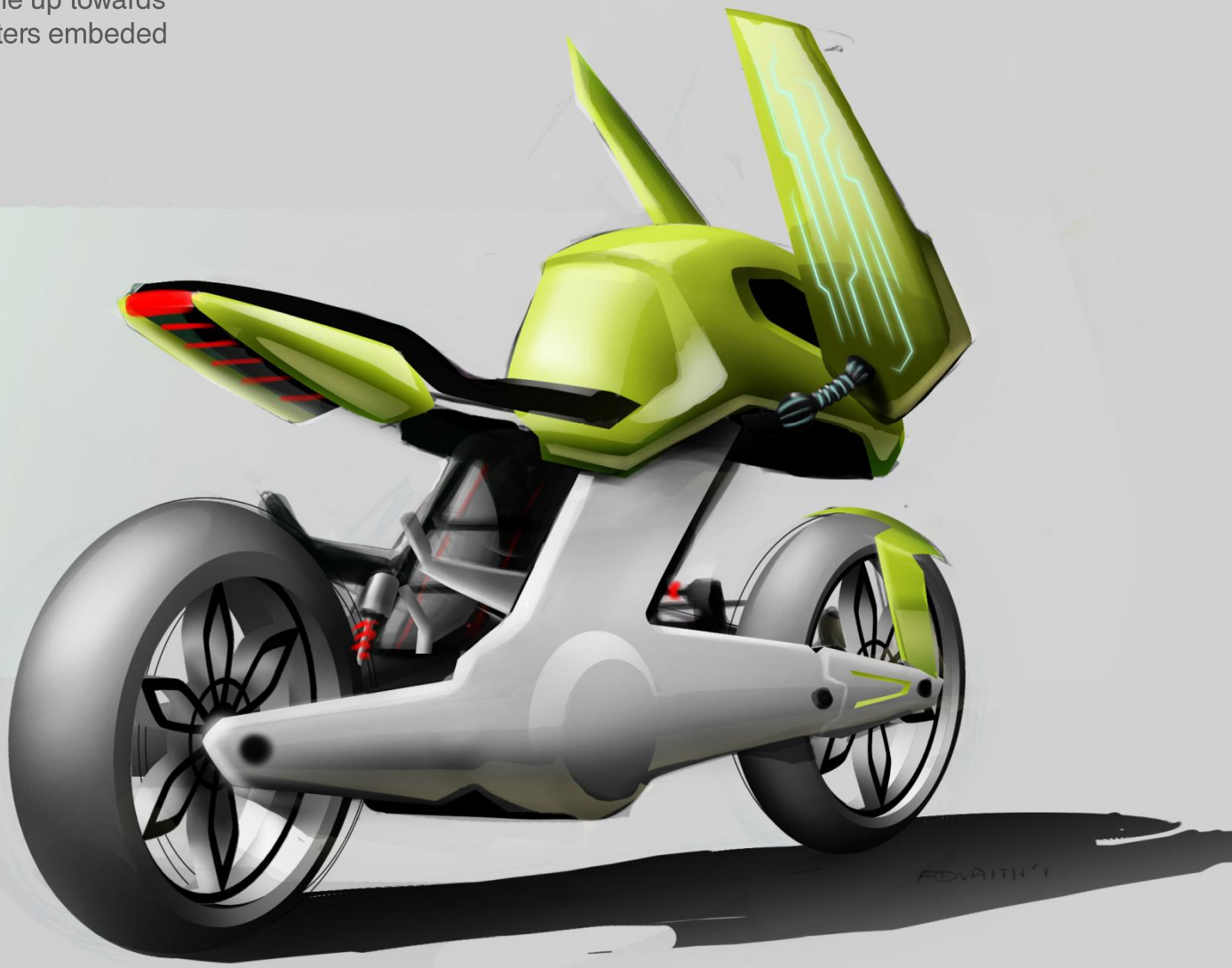


CONCEPT 3: DRAGONFLIGHT

The readout is embedded in a LED display. The handlebars are extended only when the bike is moving and the wings are retracted.

CONCEPT 3: DRAGONFLIGHT

While static, dragonflight's wings angle up towards the sunlight, directed by the light meters embeded on the bike.

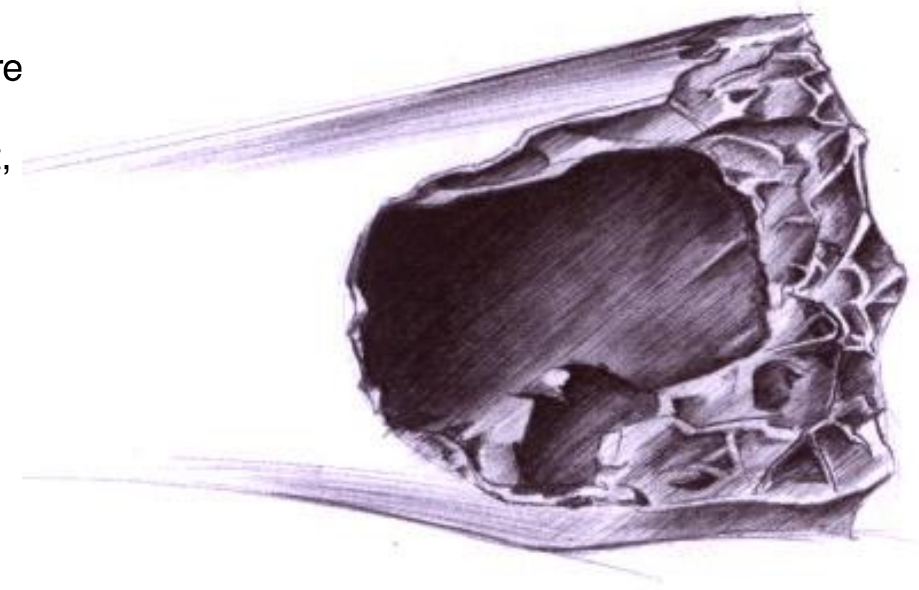


CONCEPT 3: DRAGONFLIGHT

Aesthetic Explorations

Metaphor-based form exploration

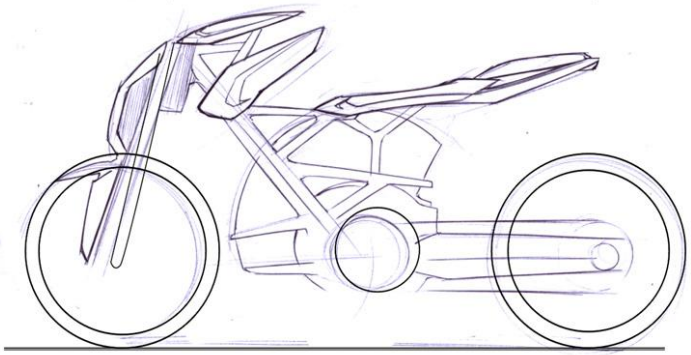
Weight and weight distribution are key to a motorcycle's design. To explore the possibilities of a light, minimal design, inspiration was drawn from the structure of bird's bones.

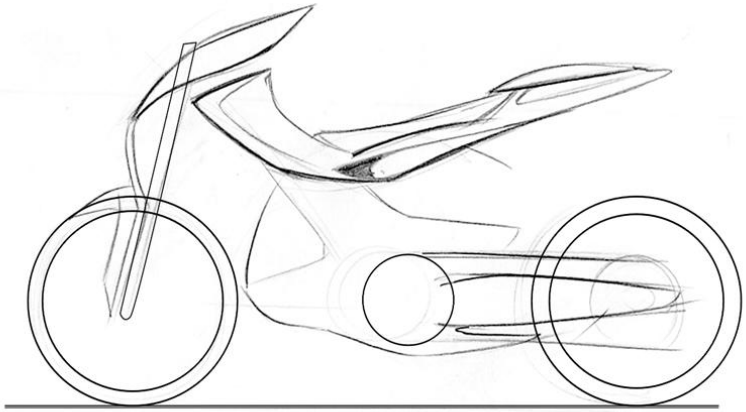


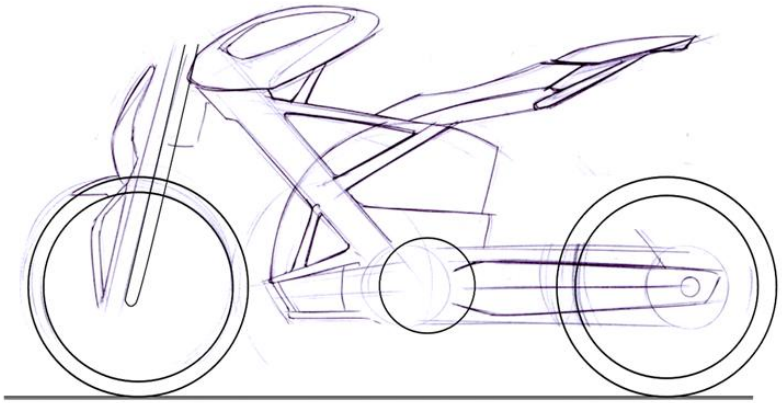
The image is a sketch of the structure of a bird's bone. The structure has an minimal, organic structure which lends strength, as well as being a striking aesthetic element.

Aesthetic Explorations

Metaphor-based form exploration

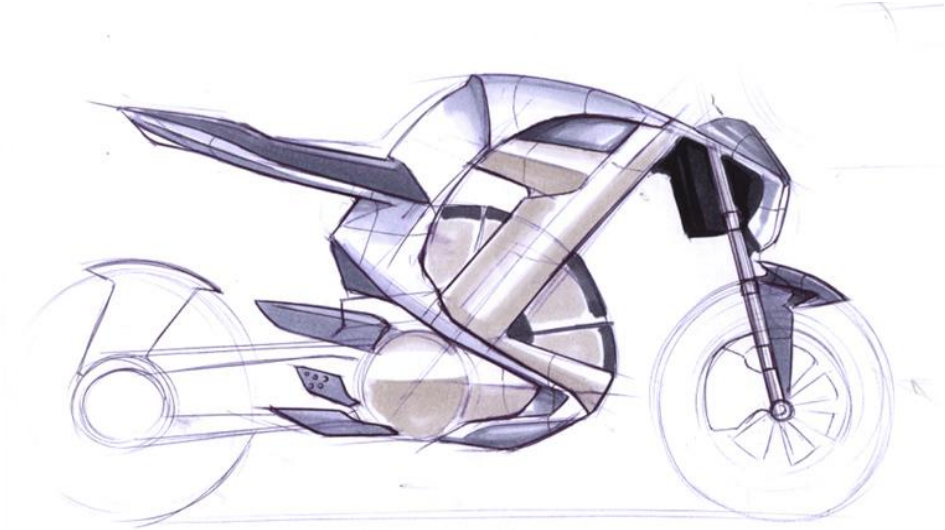


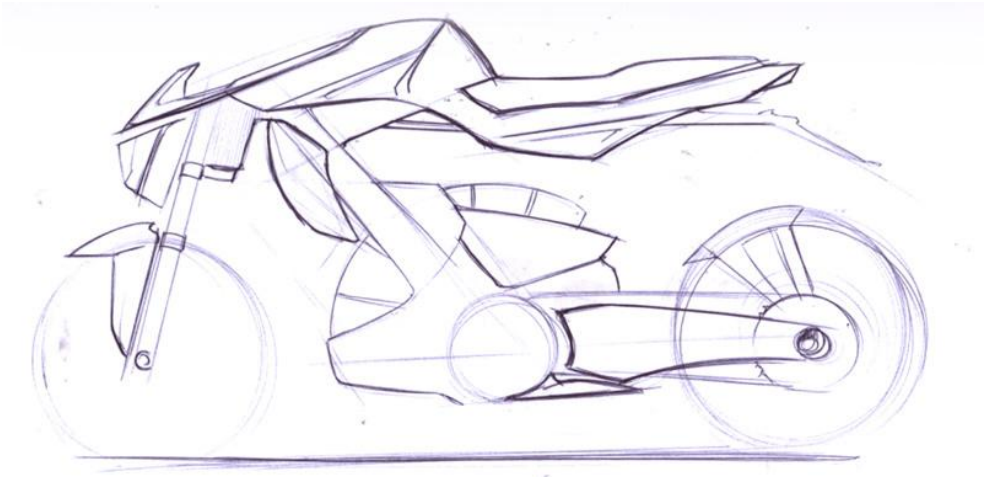




Aesthetic Explorations

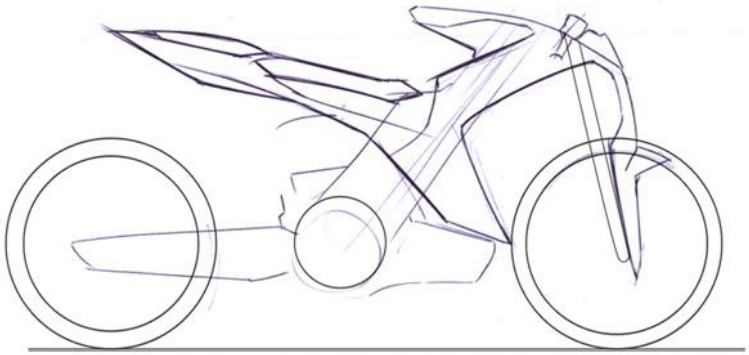
Metaphor-based form exploration

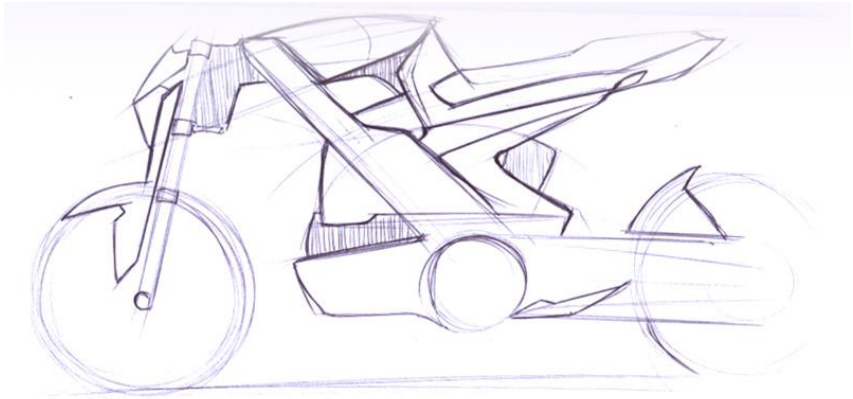


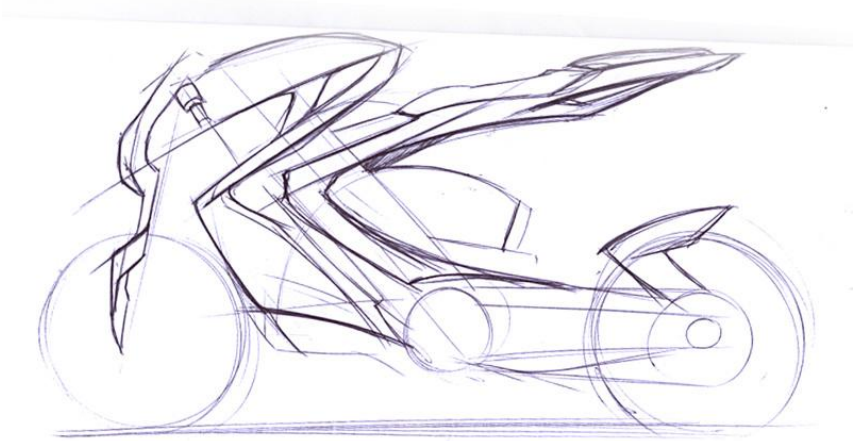


Aesthetic Explorations

Metaphor-based form exploration

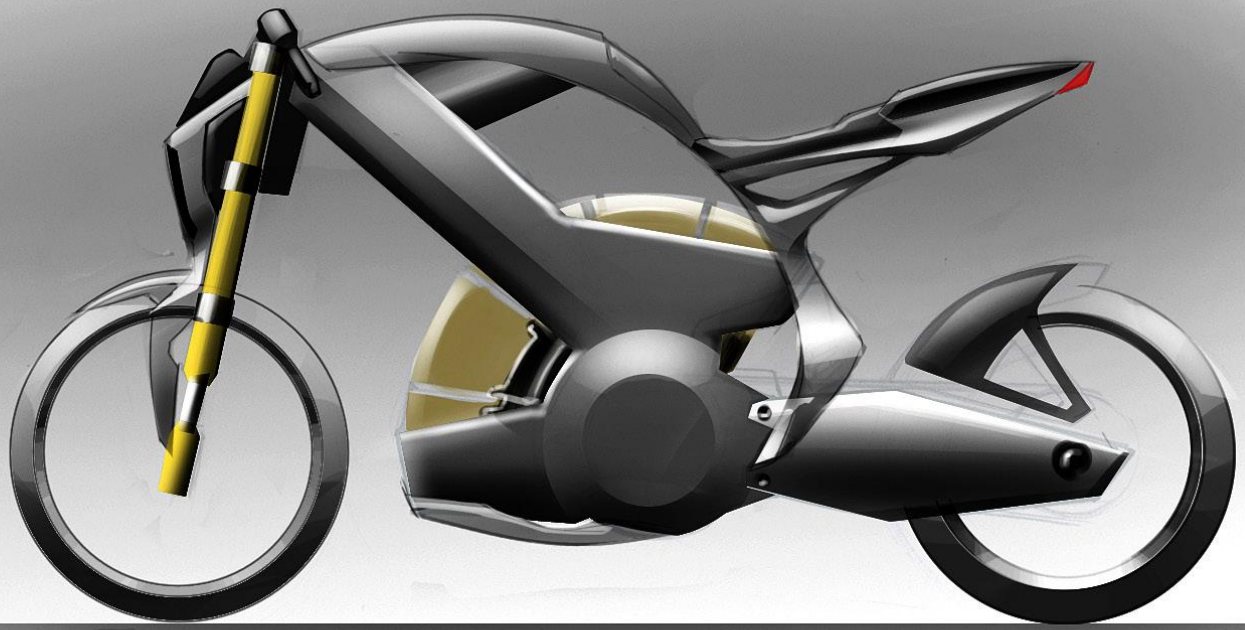






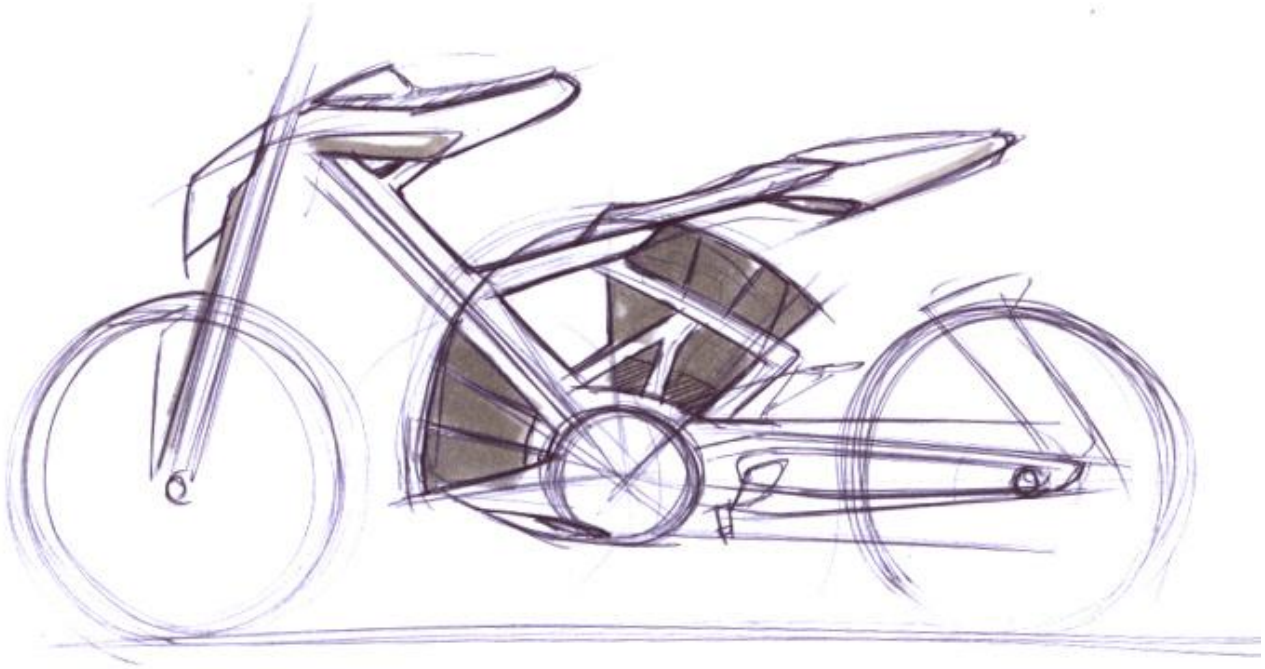
Aesthetic Explorations

Metaphor-based form exploration



Aesthetic Explorations

Metaphor-based form exploration



Thinbike Concept

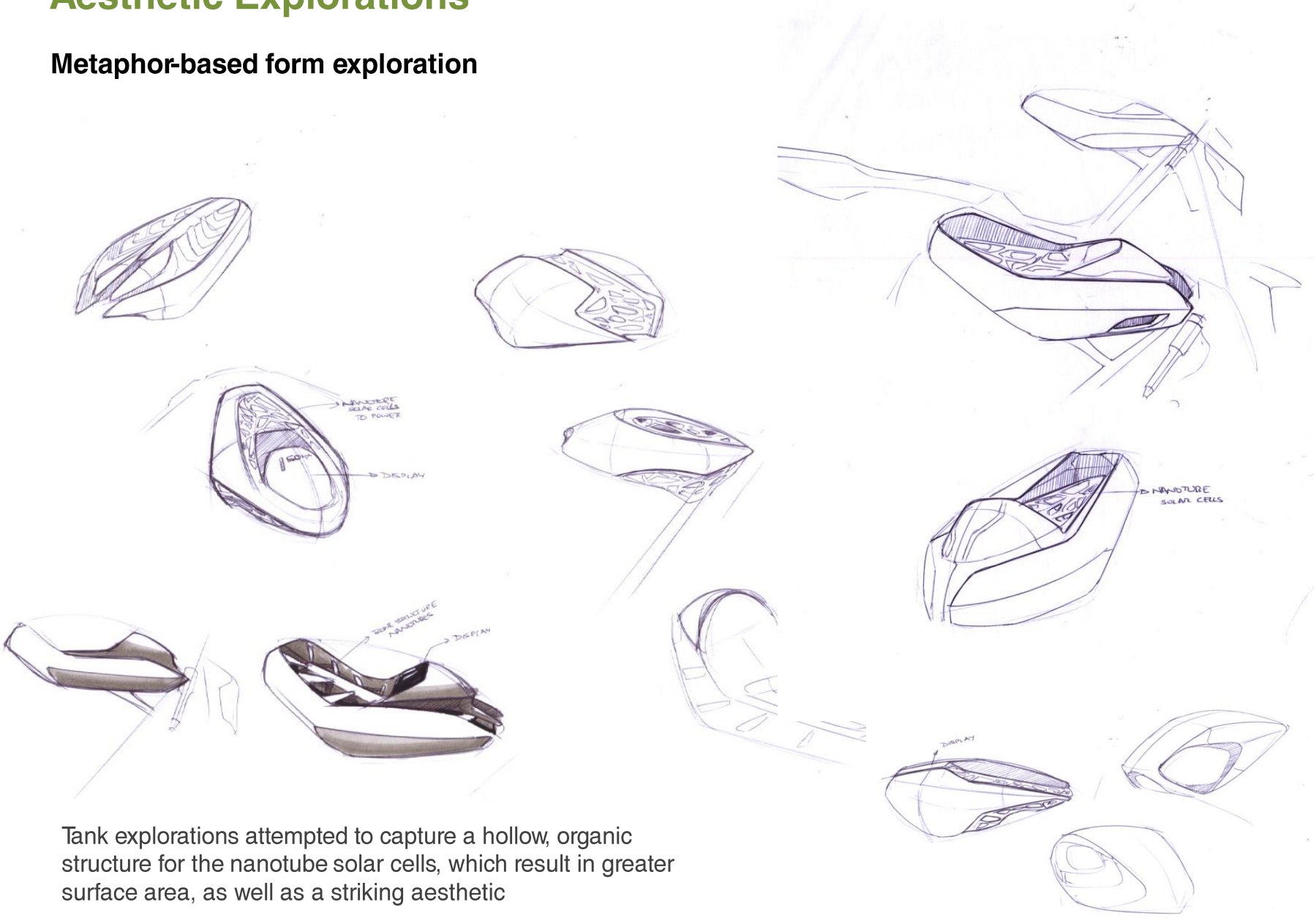
The concept exhibits minimal surfacing as part of its intent, exposing all its mechanical components.

The frame has also lost weight, deploying a trellis construction for strength.

Carbon-nanotube solar cells in the tank serve as an auxiliary power source.

Aesthetic Explorations

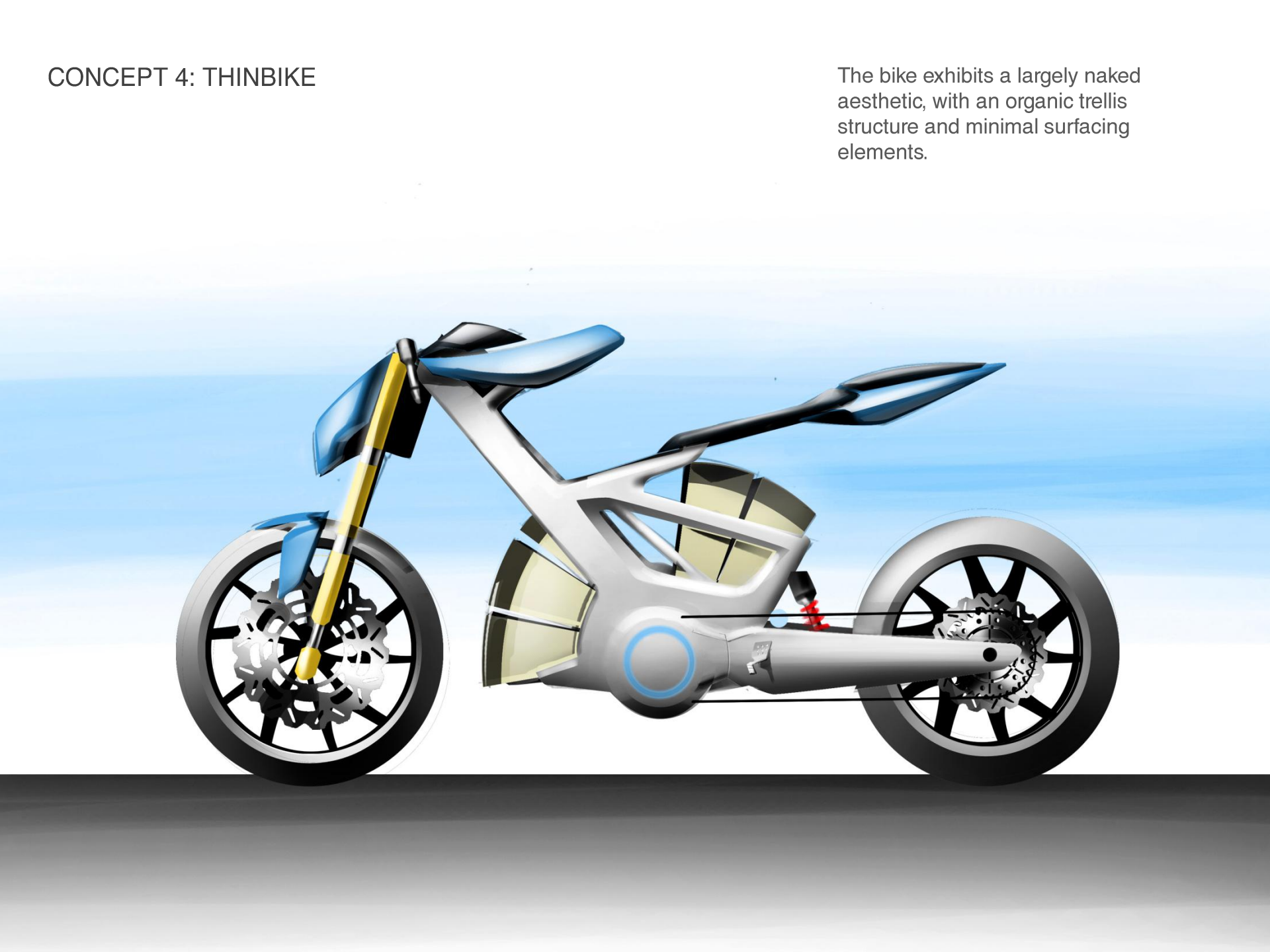
Metaphor-based form exploration



Tank explorations attempted to capture a hollow, organic structure for the nanotube solar cells, which result in greater surface area, as well as a striking aesthetic

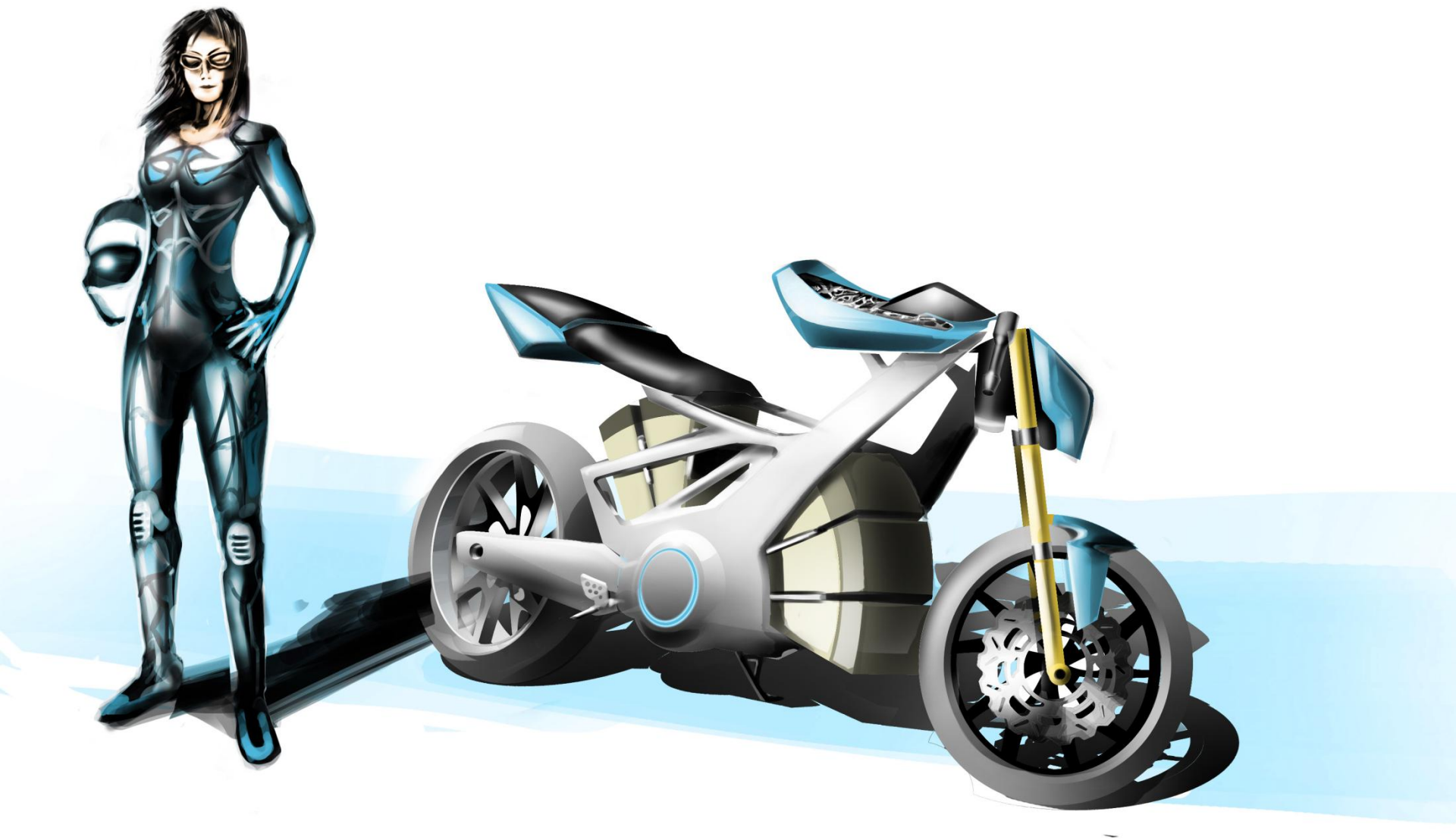
CONCEPT 4: THINBIKE

The bike exhibits a largely naked aesthetic, with an organic trellis structure and minimal surfacing elements.



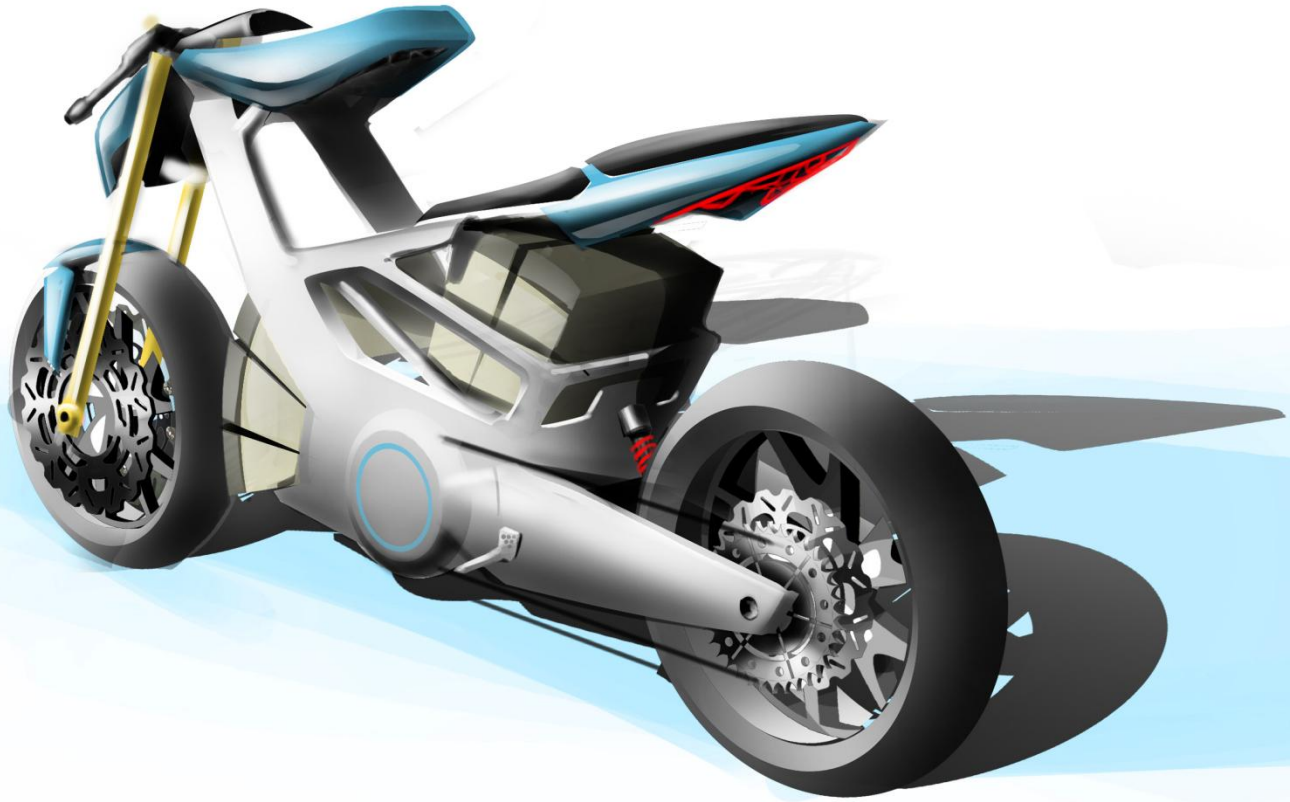
CONCEPT 4: THINBIKE

The circular battery layout is a strong visual element, playing off the hollow structure of the chassis.

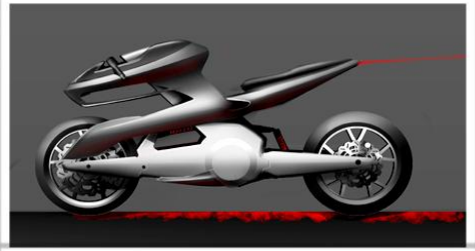
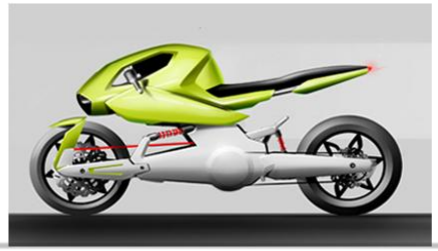
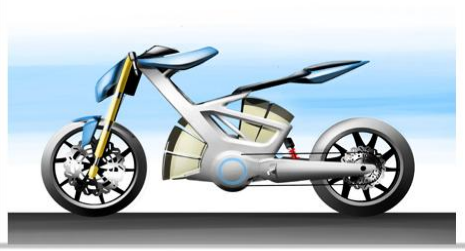


CONCEPT 4: THINBIKE

Tail lights are an organic LED cluster, which vary in intensity as per the intensity of braking.



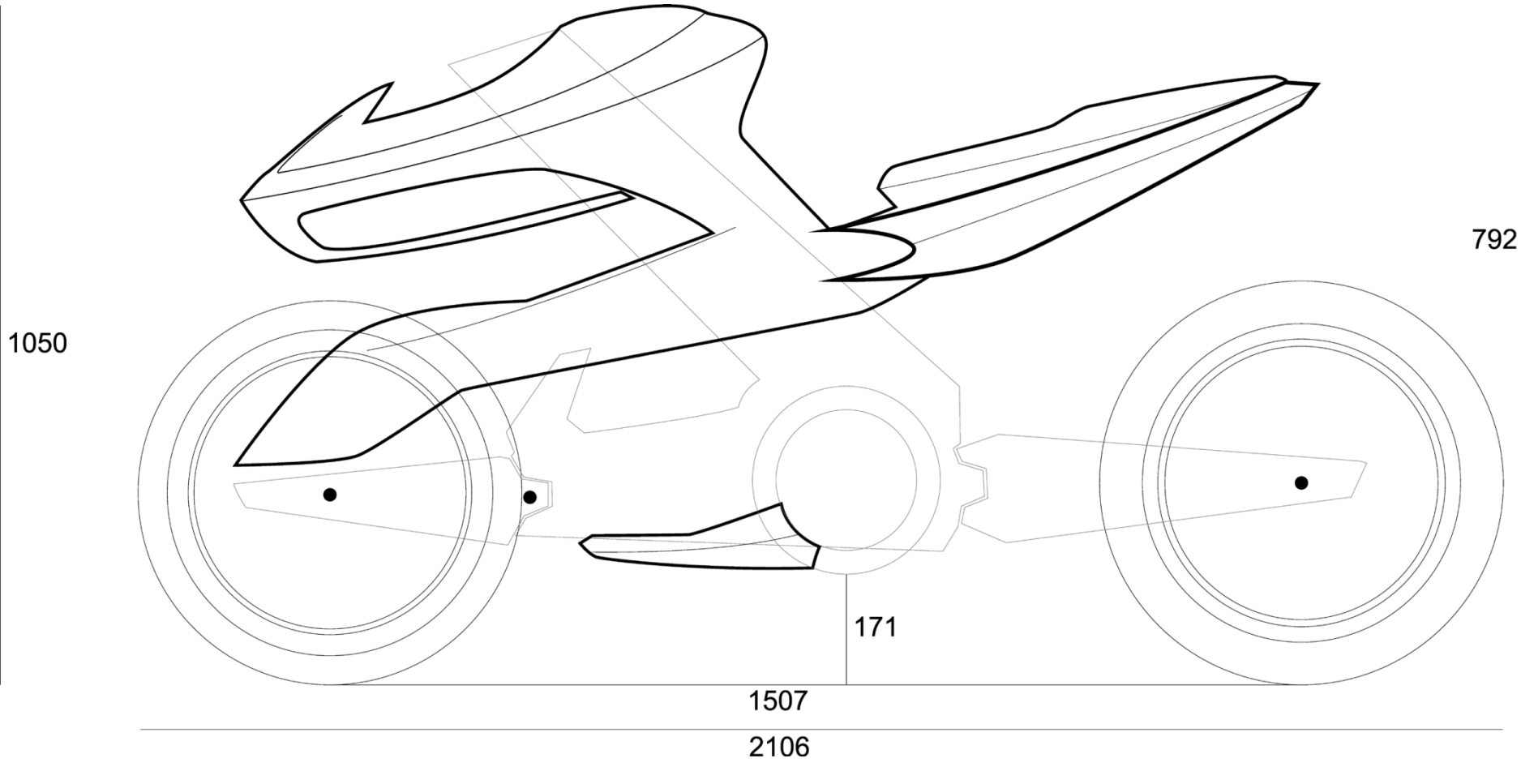
Concept Evaluation Chart

	IRAJA	DRAGONFLIGHT	THINBIKE
			
Aesthetics:			
controlled speed (2)	8.5	7	7.5
lightness (1)	7	6.5	8
electricness (1)	7	7	8
uniqueness of design (2)	8.5	8	7
visceral appeal (2)	8.5	7.5	8
overall	8.125	7.3125	7.625
Use of Green Tech:			
Existing technology (1)	8.5	8.5	8
New age fringe technology (1.5)	7	8	8
overall	7.6	8.2	8
OVERALL (Aesthetics x 3 + Tech x 2) / 5	**7.92**	7.66	7.78

STAGE 3: MODEL MAKING

Tape Drawing

The tape drawing serves as a reference for the dimensions and movements of the model

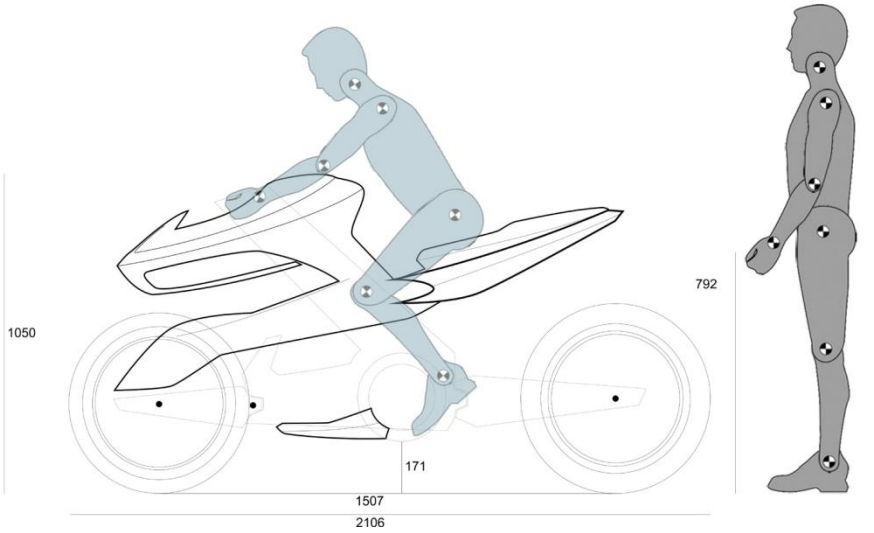


Ergonomic Considerations

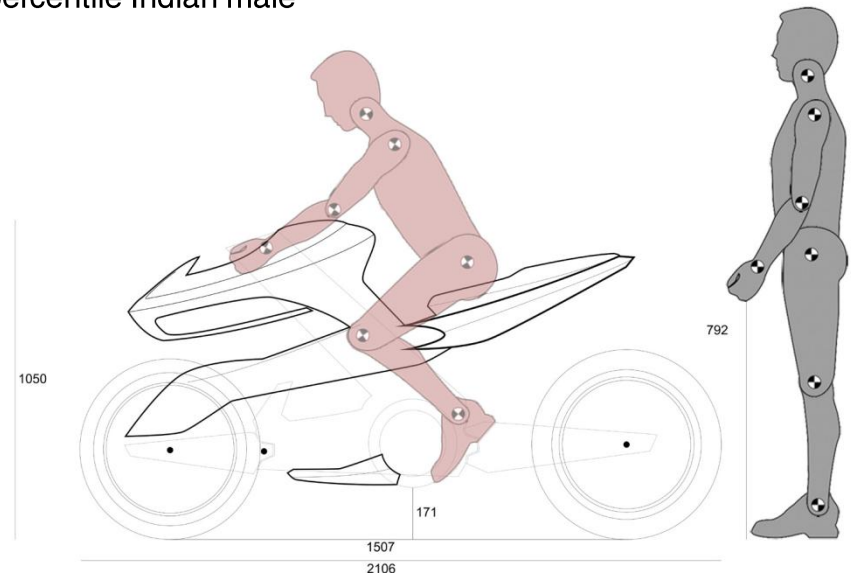
The sitting posture for the 5th percentile Indian male and the 95th percentile Indian male are shown.

The posture indicates that the handlebars would have to be brought further back into the volume of the bike.

5th percentile Indian male



95th percentile Indian male

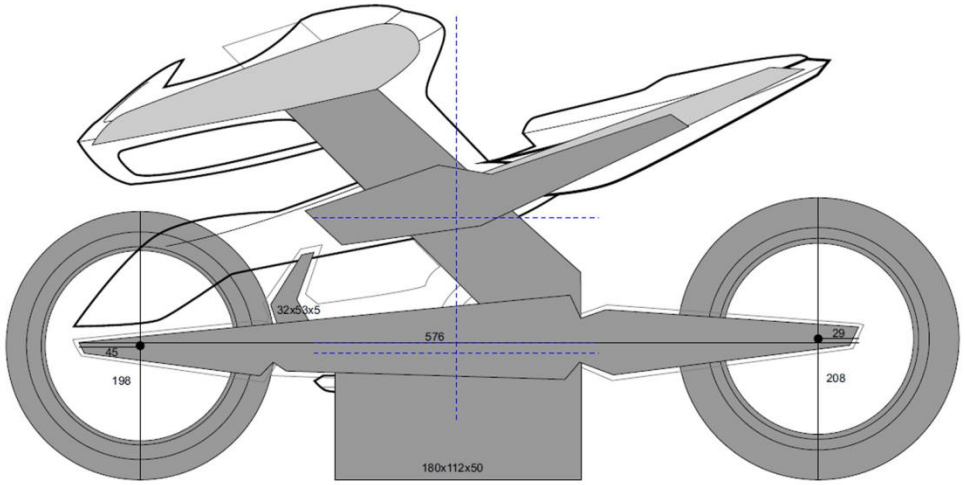


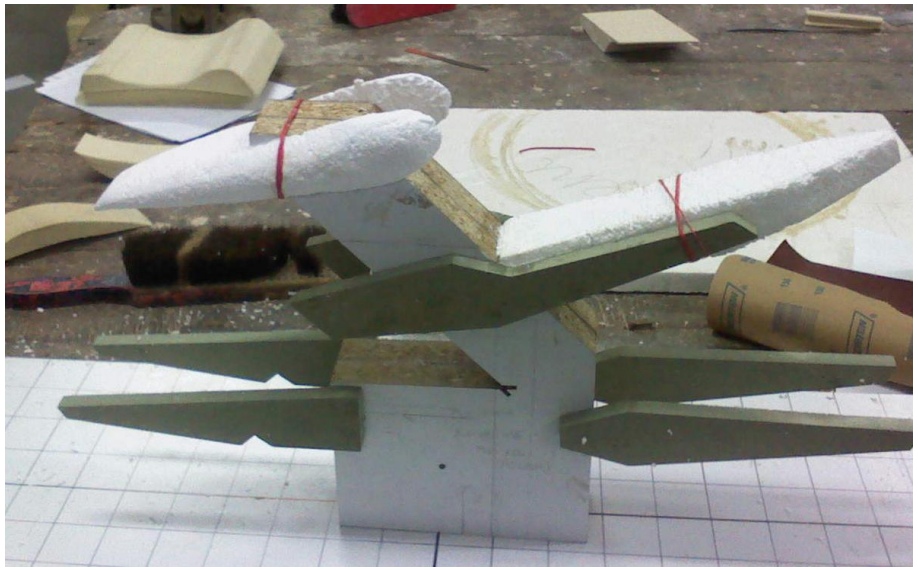
Armature design

The armature is designed to provide a strong base to mount the clay.

Dark grey – Chipboard/ Medium Density fibrewood

Light grey – High density styrene foam.





Clay Modelling

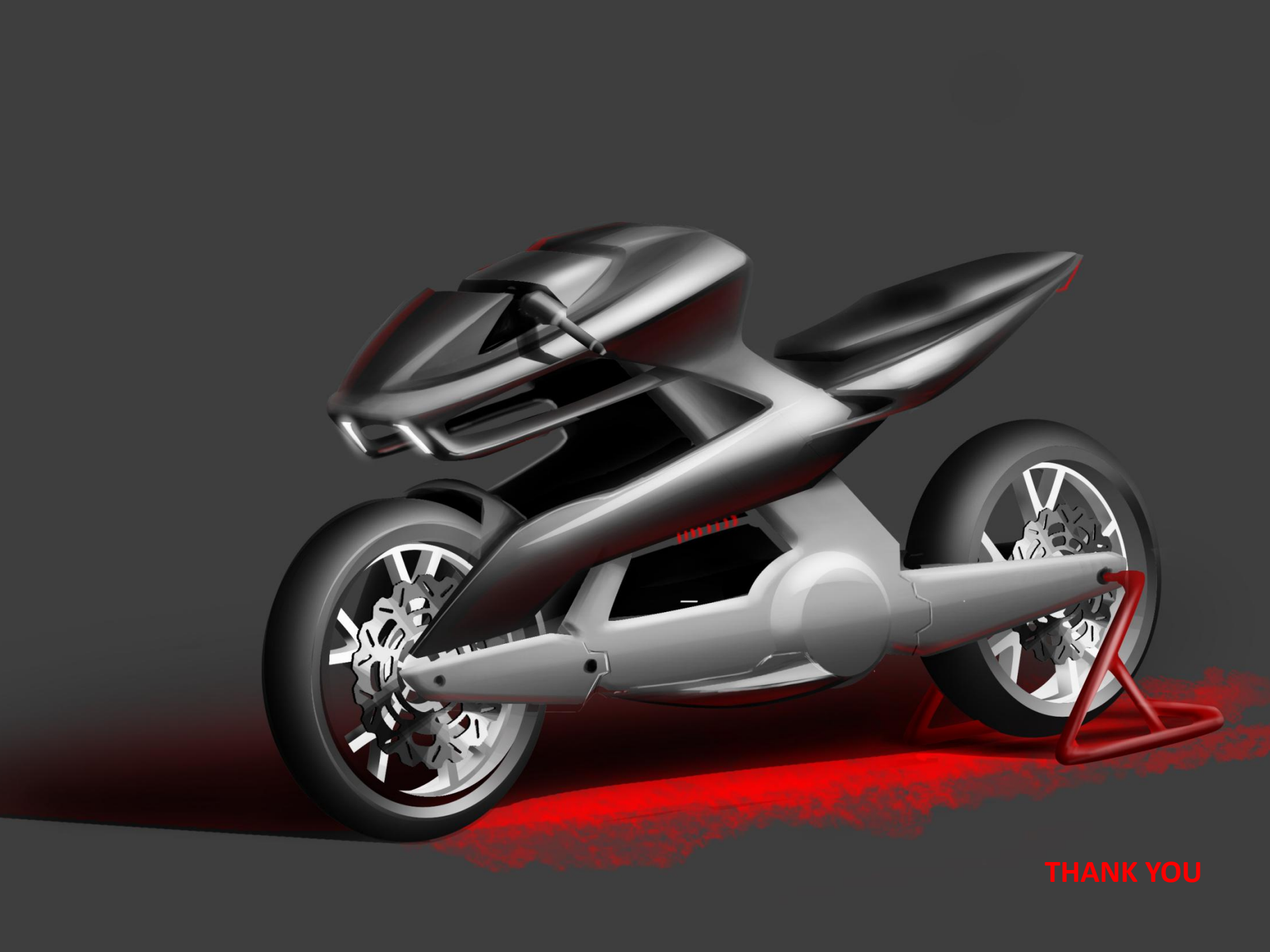
The images indicate the stages of the clay model

•Blocking the basic volumes

•Creating intersected surfaces prior to filleting.

•Using tapes to bring out features and lines.

•Design intent (single side)


THANK YOU