Cold Storage without electricity

Project II

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Co-Guide: Prof. Dipankar

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13.01.14

LEVEL 0	**Topic finalization and Pre research**	Oct 12t
LEVEL 1	**Evaluation of technique, Topic justification, User study (Stage 1)**	Oct 22
LEVEL 2	**Evaluation of technique, Market study, Start ideating,sketch, digital renders (Stage 2)**	Nov 28
LEVEL3	**Concept finalization, CAD Model, Make test prototypes, Evaluate, (Stage 3+Report)**	
LEVEL 4	**Make final form model/prototype (Jury)**	Jan 13t
LEVEL 5	**Up for manufacturing.!**	

Food Wastage - India.

Nearly 30 per cent of the country's fruits and vegetables perish due to lack of cold-storage facilities

Despite millions of Indians going to bed on a hungry stomach, the country is letting food worth a whopping Rs 44,000,While the wasted fruits and vegetables alone was estimated at Rs 13,300 crore.

Effect

- This is not just a matter of crores of rupees.
- It is wastage of water used in agriculture, manpower and electricity lost in food processing industries.
- Also contributes to so much of deforestation.

Reference : http://www.deccanherald.com/content/352942/india-wastes-rs-44000-cr.html

Need

Refrigeration

Need

Refrigeration defined as the process of achieving and maintaining a temperature below that of the surroundings.

Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning.

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- One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures.

- Basically slow down the activity of bacteria (which all food contains) so that it takes longer for the bacteria to spoil the food.

Reference Only

Refrigeration

Natural

&

Artificial

Reference Only

Refrigeration

1. Transported from colder regions, (Ancient)
2. Harvested in winter and stored in ice houses for summer use or, (Ancient)
3. Art of ice making by nocturnal cooling / Radiative cooling from stratosphere
4. Evaporative cooling,
5. Cooling by salt solution,
6. Draft fridge

Refrigeration

Artificial

1. Domestic refrigeration system / Ice box (Ancient)
2. Vapour compression systems,
3. Vapour absorption systems,
4. Gas cycle systems etc.
5. Solar energy based refrigeration systems
6. Air cycle refrigeration systems
7. Steam and vapor jet refrigeration systems
8. Thermoelectric refrigeration systems and
9. Vortex tubes

Hybrid techniques:

some **cold facts** about our daily refrigeration!

why natural?

Reference: Table 15, 38,40: Article of The World Bank; India: Strategies for low carbon growth

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Table 15: Parc Average per-Unit Annual Operating Time

		2006	2011	2016	2021	2026	2031
General							
Lighting	Hrs/Year	913	913	913	913	913	913
Entertainment							
Radio	Hrs/Year	2190	2190	2190	2190	2190	2190
CD Player	Hrs/Year	1460	1460	1460	1460	1460	1460
TV	Hrs/Year	1460	1460	1460	1460	1460	1460
DVD / VCR	Hrs/Year	156	156	156	156	156	156
Computer	Hrs/Year	803	803	803	803	803	803
White Appliances							
Washing machines	Loads/Year	364	364	364	364	364	364
Refrigerator	Hrs/Year	8760	8760	8760	8760	8760	8760
Electric Oven	Hrs/Year	91	91	91	91	91	91
Toaster	Hrs/Year	91	91	91	91	91	91
Microwave	Hrs/Year	37	37	37	37	37	37
Heating / Cooling							
Electric Water Heater	days/Year	140	140	140	140	140	140
Fans	Hrs/Year	2520	2520	2520	2520	2520	2520
Air cooler	Hrs/Year	1440	1440	1440	1440	1440	1440
Air-conditioning	Hrs/Year	575	575	575	575	575	575

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Table 38: Total Power Consumed by Lighting

Lighting			2006	2011	2016	2021	2026	2031
	Operating	GWh/yr	41,440	57,786	73,676	91,092	107,890	125,601

Table 40: Total Power Consumed by Kitchen Appliances

White Appliances			2006	2011	2016	2021	2026	2031
Refrigerator	Operating	GWh/yr	23,490	32,706	43,472	57,349	70,844	84,244
Washing machines	Operating	GWh/yr	312	672	1,433	2,742	4,439	6,328
Electric Oven	Operating	GWh/yr	509	909	1,564	2,484	3,553	4,687
Toaster	Operating	GWh/yr	261	646	1,359	2,404	3,583	4,742
Microwave	Operating	GWh/yr	320	495	761	1,138	1,582	2,063
	Standby	GWh/yr	297	408	562	787	1,062	1,372
	Total	GWh/yr	617	903	1,323	1,925	2,644	3,434

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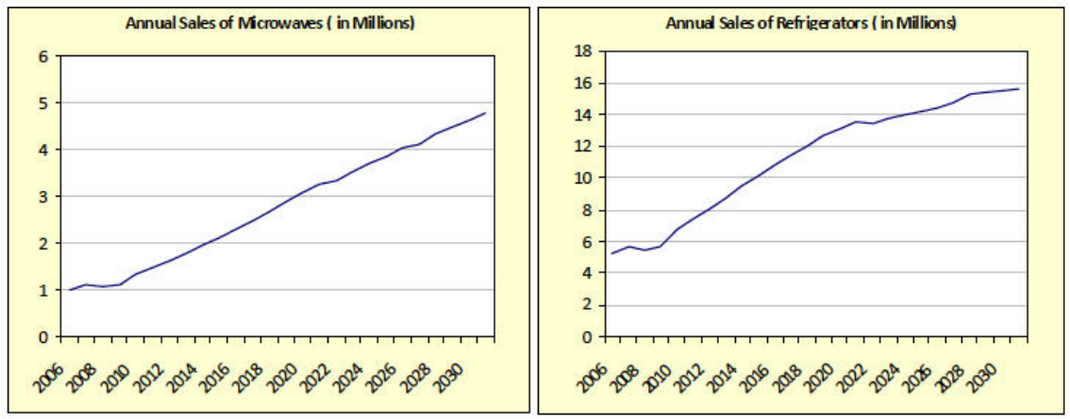
Table 10: Population of Kitchen Appliances (millions)

White Appliances		2006	2011	2016	2021	2026	2031
Refrigerator	Urban	26.0	41.4	59.4	76.1	88.8	101.1
	Rural	7.3	16.2	32.6	57.0	81.0	100.3
	Total	33.3	57.6	92.0	133.1	169.8	201.4

Figure 58: Annual Sales of Microwaves and Fridges



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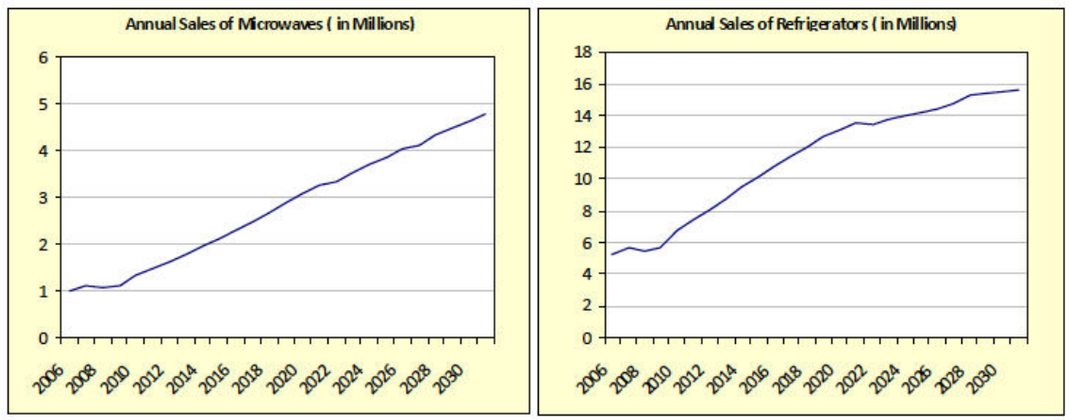

so, what is the alternative way to go about?

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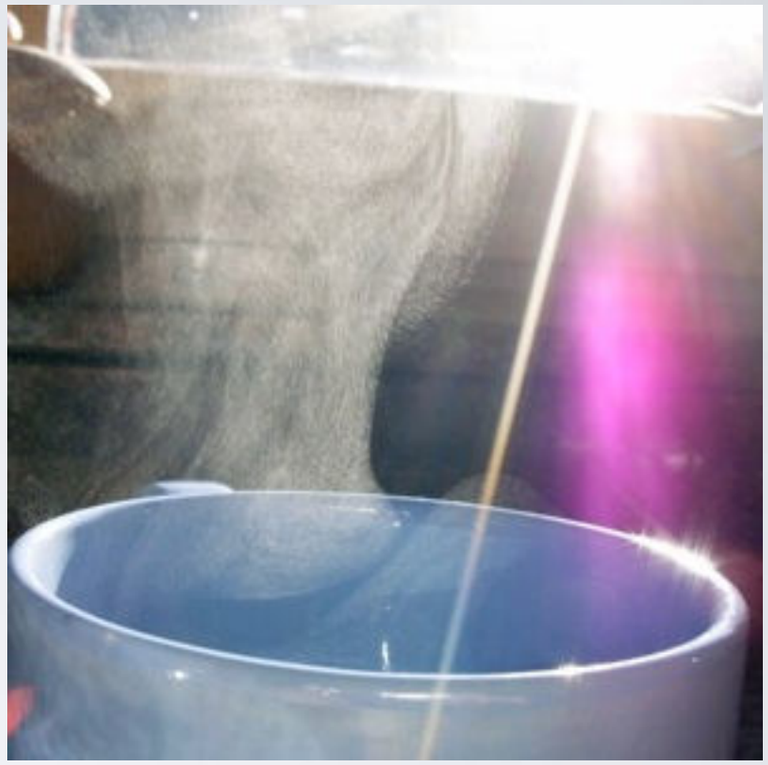
cold storage

Evaporative Cooling

- Evaporation is vaporization of the liquid to gaseous state

- when water evaporates it draws energy from its surroundings which produces a considerable cooling effect

- Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling.



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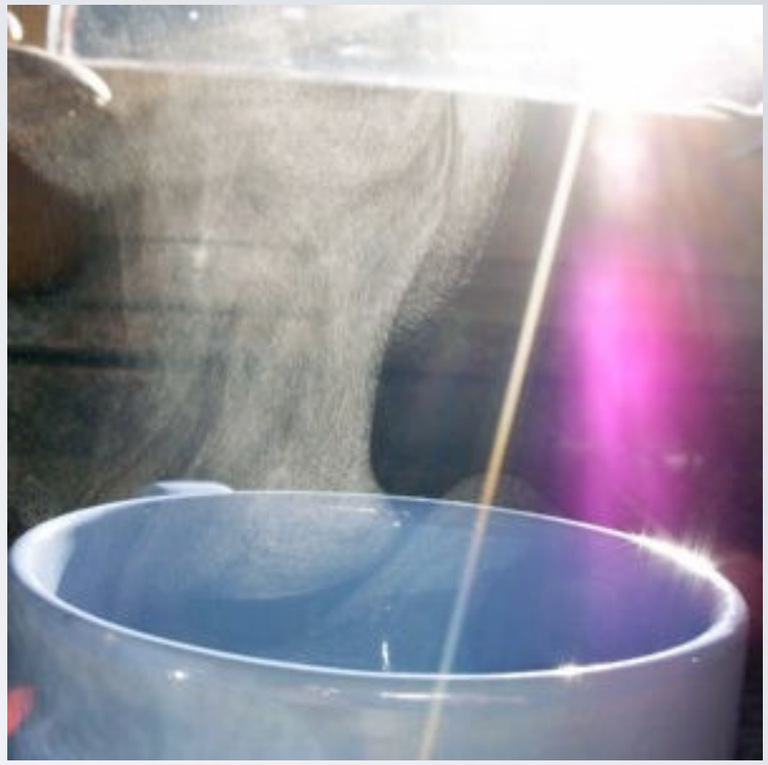


Types:

- clay pot based cooling
- bamboo refrigerator
- charcoal fridge

cold storage

Products using evaporative cooling

Evaporative cooler fridge
(using continuous water dripping)

cold storage

Products using evaporative cooling

Evaporative cooler fridge
(using continuous water dripping)

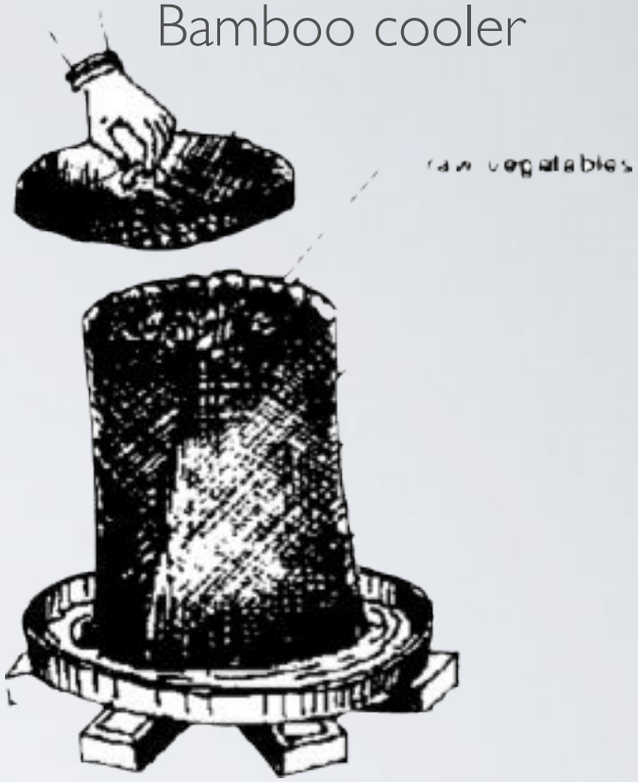
ZEER pot
(An African technique using two pots one inside the other and wet sand layer in between to absorb the heat)

Products using evaporative cooling

Mitti Cool

Charcoal cooler

Bamboo cooler



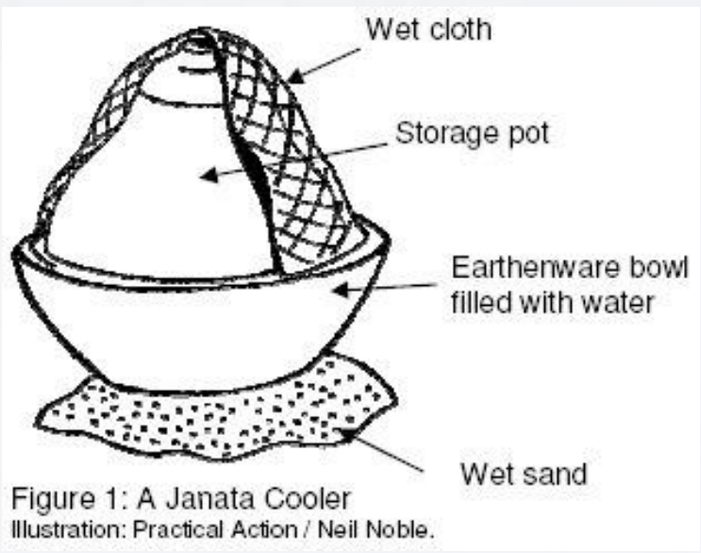


Figure 1: A Janata Cooler
Illustration: Practical Action / Neil Noble.

Coolridge

Insights:

- People don't really care about going for eco responsible design unless it adds to their convenience.
- The cooler cant be a alternative for refrigerator but can reduce the usage of fridge and electricity

Radiant cooling

A radiant cooling system refers to a temperature-controlled surface that cools indoor temperatures by removing sensible heat and where more than half of heat transfer occurs through thermal radiation

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Ice making by Nocturnal Cooling

The evaporation of water in almost cool dry air and radiative heat transfer between the water and the deep sky that is at a very low temperature (much below the freezing point of ice) caused the formation of ice even though the surrounding air was at a higher temperature than the freezing point of water.

Ice maker

Night sky - Invisible Freezer!

- Night sky radiant cooling is a natural process that helps the earth maintain thermal equilibrium in the planet and it is the only way earth can lose heat.

- Heat lost from the surface of the earth at night is comparable to the heat gained by the sun.

- A layer of frost will form on rooftops and on automobiles (moisture condenses out of the air) even though the outdoor air temperature is well above freezing is an obvious example of radiant cooling.

Night sky radiant cooling has in modern times all but been forgotten due to widespread use of modern mechanical cooling systems and refrigerants.

Reference: Img: http://mynasadata.larc.nasa.gov/804-2/measuring-the-temperature-of-the-sky

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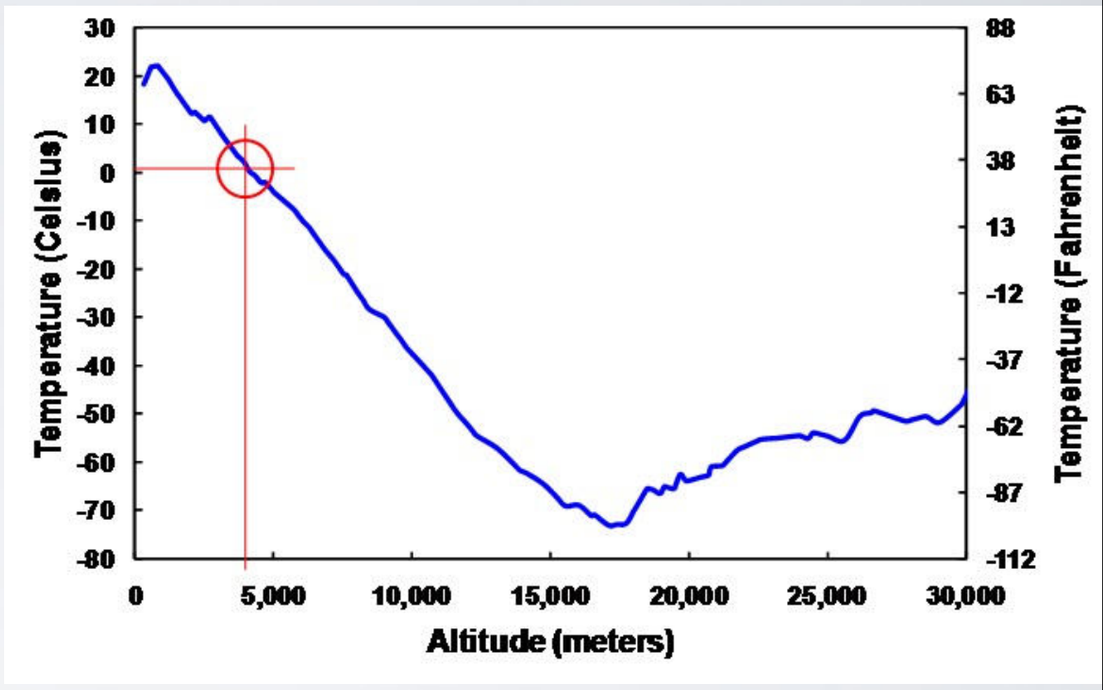

Night sky temperature chart from NASA

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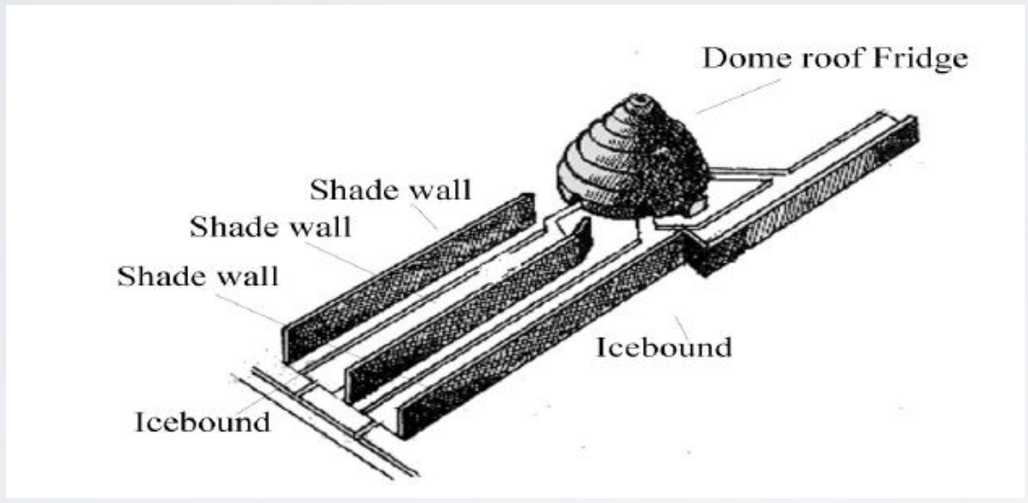
Ancient methods of refrigeration/ Ice making by nocturnal cooling

Egyptians and Iranians made ice from night sky and doomed roof fridge



Reference: Img: I http://upload.wikimedia.org/wikipedia/commons/c/cc/Yakhchal_of_Yazd_province.jpg

Ice maker

Ancient methods of refrigeration/ Ice making by nocturnal cooling

The art of making ice by nocturnal cooling was perfected in India. In this method ice was made by keeping a thin layer of water in a shallow earthen tray, and then exposing the tray to the night sky. Compacted hay of about 0.3 m thickness was used as insulation. The water looses heat by radiation to the stratosphere, which is at around -55°C and by early morning hours the water in the trays freezes to ice.

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Small earthen pots filled with water were placed in an open field with sugarcane husks strewed around, and in the morning the coating of ice formed in the cold temperature of the night was collected and stored in ice-pits.

(From the book 'Indian Science and Technology in the 18th Century" by Dharampal and British archives)

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Market Study



This whole sale vendor shop, sells around 500Kg of ice per day at the rate of Rs.7per Kg.He is getting it bulk from Thane or Vashi.


Nimbu Panni vendor
Place: CST, Mumbai
The person buys 5-10 kg's of ice daily to satisfy his business needs. He is not upto going and making ice of his own.!

Market Study

Kulfi Vendor
Place: Near Dadar station
He is buying ice blocks from the whole sale shop in Dadar for Rs. 8/Kg. He is happy to have a device which can make ice for his business daily and that too if it can increase his income.

Malai vendor
Place: opposite IIT B gate
He buys ice form the powai market, and he is having problem of ice getting melted very quickly though he sells it in the night.
He dosent have a ice box as such.

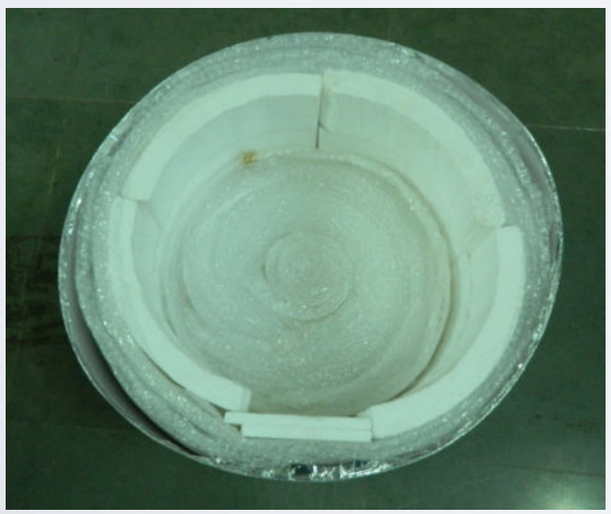
Views from houses with out refrigerator:

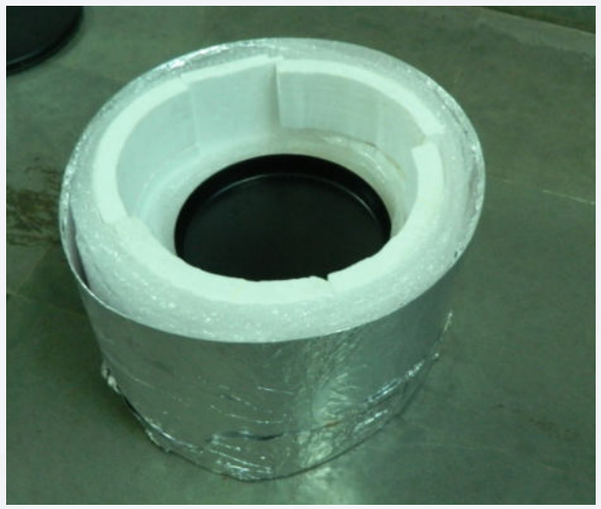
- Their way of using and buying perishable food differs when they dont have a fridge.
- They face problem in storing fast spoiling item like milk, fish and few vegetables which need low temperature.
  Also in summer season they prefer to have cold water using Matka or its kinds.

Insights:

- We need to educate people about possibility of ice making.
- And it has to be cheap enough to compete with the industrial ice production in semi rural areas.
- The people has to be educated about the use of ice and proper storage of food for their health and convenince without them being fallen in to the illusion about cold storage.
- Chances of people seeing an ice maker as cold storage device is high, we should consider that.
- More than making ice, the device should provide freedom and satisfy users in terms of reliability.

Technique Evaluation:





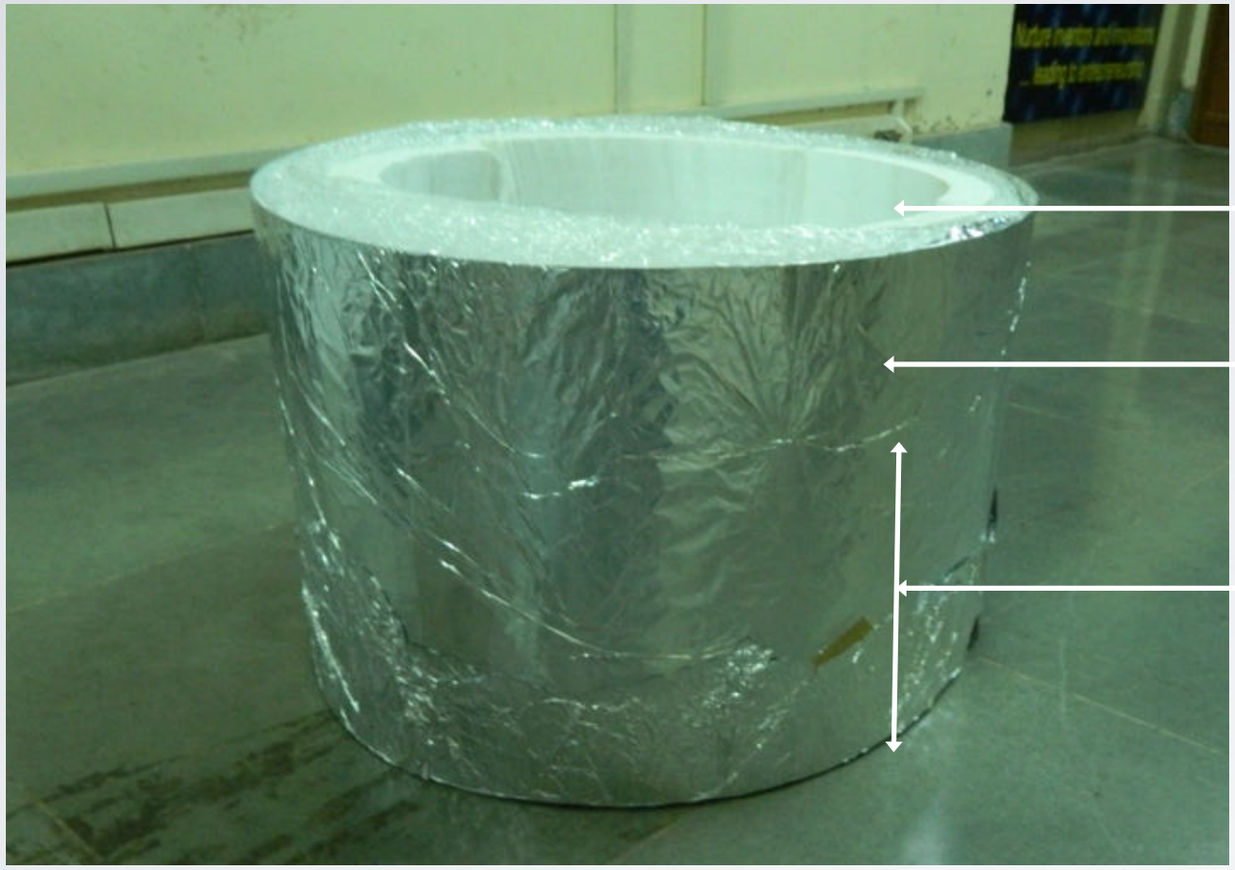
With the help from Treelabs in fixing technical specification, build the alpha prototype for testing.

Making of Alpha Prototypes:

I made a Proto types with bubble sheet wrapped around circular fashion to accomodate a steel thali. Around the bubble sheet for strength,styrene sheet was used, which is wrapped around the with aluminium foil to reflect the unwanted radiation from the ground.
Polystyrene is used inside for strenth and support. Overall the proto is made weight less for easy of transportation during testing.

Prototype

Technique Evaluation:

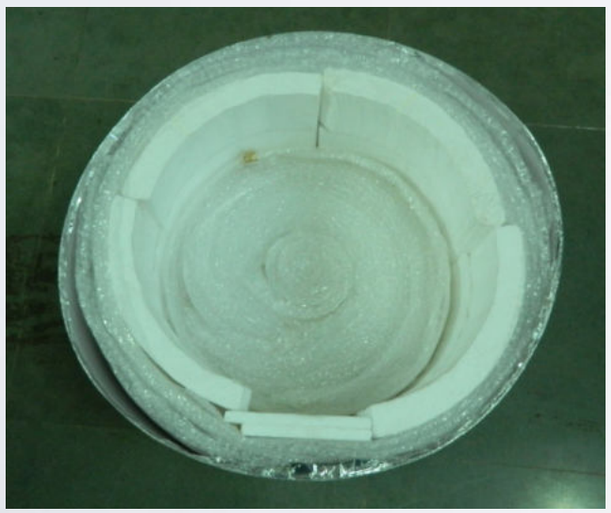


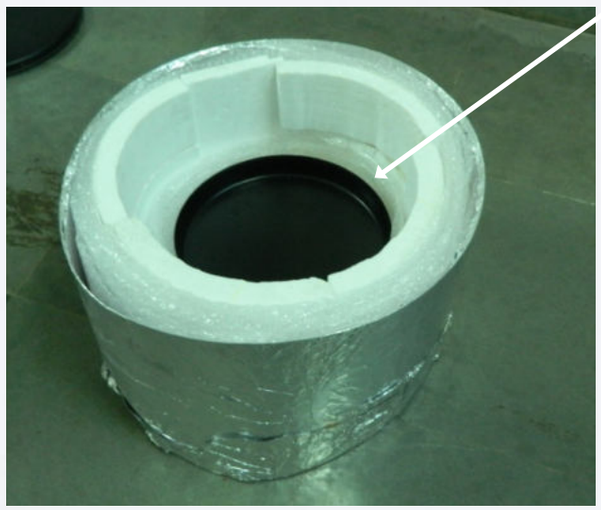
Thermacol and Bubble wrap for Insulation and strength

Aluminum foil as radiation shield

Base Insulation/Bubble wrap

plate for water





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Testing

The making prototype based on calculations alone wont produce results. To get the desired result, there are few environmental parameters which play a key role, like

- **Humidity (Ideally below 25-35%)**
- **Clear night sky (with less haze and pollution)**
- **Wind (speed close to none)**
- **Insulation of the box (thick enough to make sure to stop heat transfer due to convection and conduction.**

Inorder to validate our prototype we conducted experiments in different places to test for suitable condition.

The temperature is measured using IR pyrometer and the humidity and ambient temperature is measured using Hygrometer

Date:	06.11.13			
Location:	Anantha roof top(16 floors), IIT B,			
Ambient Temp.	26.4 C			
Humidity	65% aprox.			
Wind	5-7 kmph (Approx.)			
Experiment Table				
Time(PM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**	**Note**
10.4	23.4	-9.5	23.4	
10.45	23	-9.9	18.9	
10.52	23	-9.6	19.2	
11.01	24	-9.5	18.7	
11.17	23.4	-9.4	19.2	
11.29	23	-9	19.5	
11.41	23	-9.4	22	(with the plastic sheet covered)
Note:				
The sky is not clear and the experiment is done without water.				

Insights:

We wanted to do the experiment far from the humid shores of Arabian sea, hence we choose Shridi which is the nearest (250 Km)dry place from Mumbai. Though faced difficulties from local villagers and the police , we started the experiment very late in the night and was able to attain 0c, which raised my spirit to continue the experiment the next day also.

Date:	14.11.13		
Location:	Shirdi,(3 km towards pimpalwadi)		
Ambient Temp.	21.3	(at the time of starting the exp.)	
Humidity	59%		
Wind	almost no wind		
Experiment Table			
Time(AM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**
2.53	9.8	-22.8	11
3.04	9.5	-23.2	5.3
3.17	9.5	-23	6.7
3.56	9.5	-21.3	
4.42	8.4	-22.7	1.8
5.22	8.5	-22.6	0.6
5.55	8.2	-23.4	0.4

Insights:

The Amanagar which is 90 Km from shirdi, seems to be the right place to continue the experiment (thanks to Avinash and his hospitality), I was able to continue the experiment the next day and temperature reached -0.3c though the humidity was not conducive.

But the data clearly shows the possibility of making ice given the right atmosphere.

Date:	15.11.13			
Location:	Ahmed nagar,(Surya nagar,)			
Ambient Temp.	23.9- 14.4	(at the time of starting the exp.- to its minimum(at 4am)		
Humidity	45%- 67%			
Wind	mild wind throug out the exp.			
Experiment Table				
Time(PM-AM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**	**Water temp.(C)**
10.09	14.6	-23.9	15	
10.31	15.3	-23.2	11.5	
11	17	-22.4	12.8	
11.49	15.3	-22.8	11.8	
12.31	14.7	-24.9	9.9	
1.47	13.8	-24.2	8.7	14.5
2.41	10.5	-24		6.5
3.21	10.2	-24		4.9
4.01	10.5	-26.5	2.8	3.1
4.41	9.8	-27.1	2.2	2.9
5.25	8.5	-27.5	2.5	2.5/3
5.45	7.8	-29.8	-0.3	0.8/1

Insights:
The experiment in gymkhana ground IITB was done to test the IR transparent sheet to control the convection.
The results were not very convincing, but it doesn't trap the temperature.

Date:	16.12.13				
Location:	Gym khana ground, IITB				
Ambient Temp.	22-21c	(avg)			
Humidity	50%- 57%				
Wind	very less wind				
Experiment Table					
Time(PM-AM)	**Ground Temp.(C)**	**Sky Temp.(C)**	**Plate Temp.(C)**	**Water temp.(C)**	**Note**
10.35	12	-25.4	12.8		(w/o IR sheet covered)
11.11	11.4	-25.5	3.6		"
11.34	11.3	-24.8	4.5		"
12.05	11.8	24.6	7.3		(with IR sheet covered)
12.35	11.2	-24.9	7.1		"
1	12	-24.7	3.7	14.4	(w/o IR sheet covered)
1.3	10.5	-26.3	4.7	7	"
4.45	8.7	25.1	2.5	2.6	"

Design Brief:

- To design a low cost Ice maker for rural household without using electricity.
- Consideration for storing ice and food.
- Emphasis on ease of use, maintenance and handling.

Technical Brief:

- Highly insulated walls (6-8cm thickness)
- Mouth of the ice maker wide angled towards the sky to increase radiation.
- Provision for IR transparent lid to reduce convection

User Brief:

The product should be easily understandable by people of rural household.
It should go with the other kitchen products.

LEVEL 0

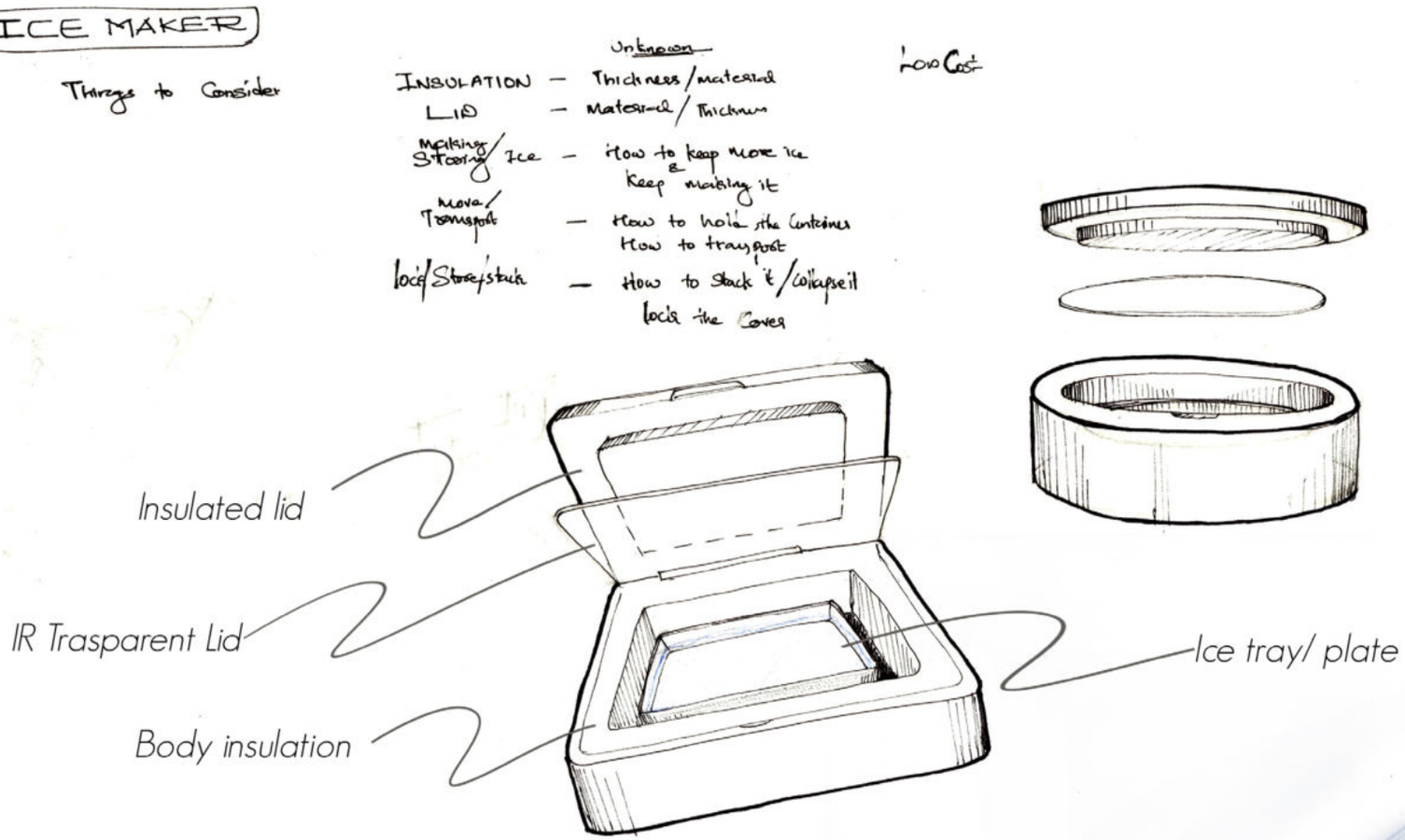
LEVEL I

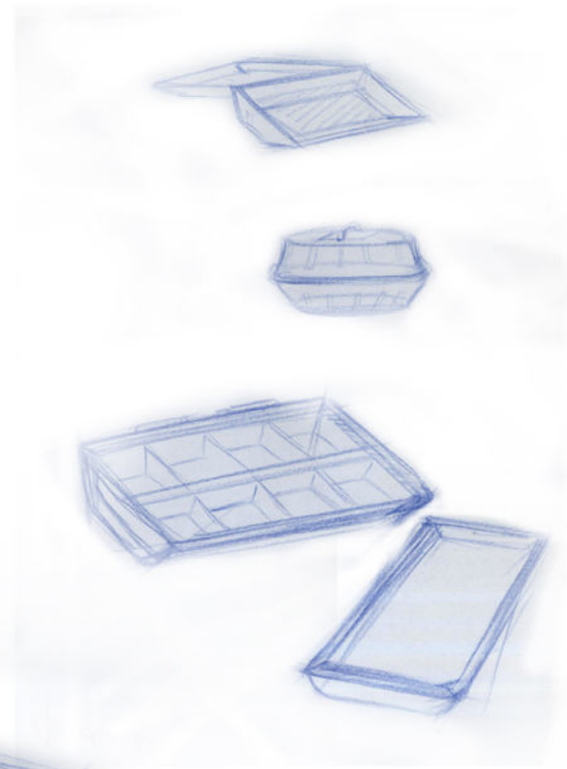
LEVEL 2

LEVEL3

LEVEL 4

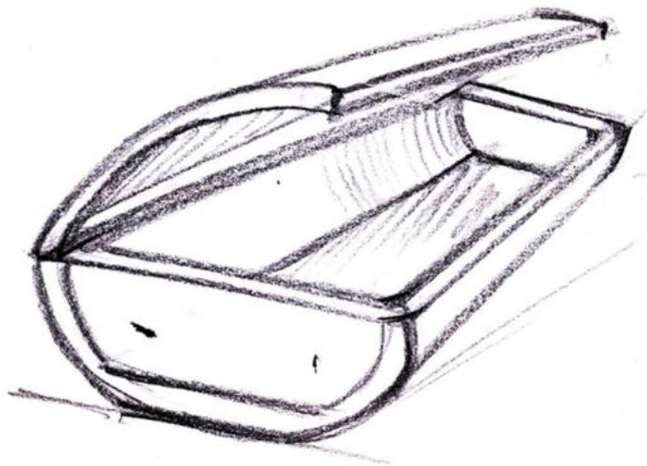
Concept 1: Solid form

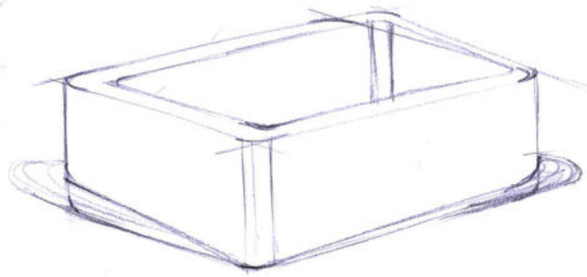


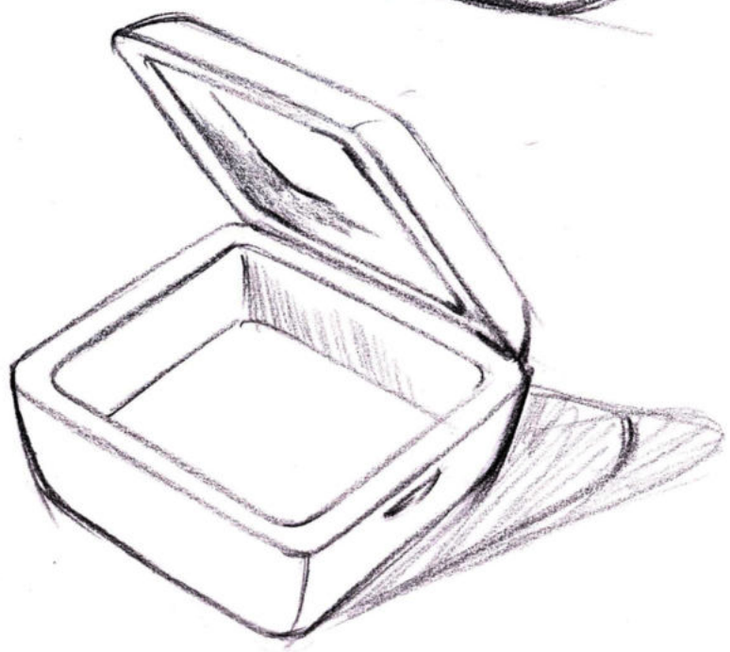


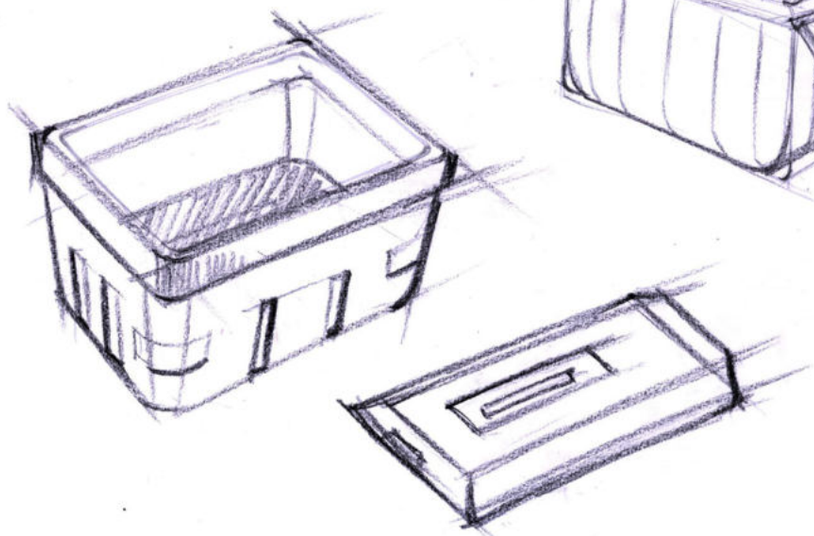
Plus+
This concept is best in terms of efficiency and maintanance
It will serve its purpose of ice making helped by the wide angled mouth.
Minus-
But this is not suited for the storage of food.

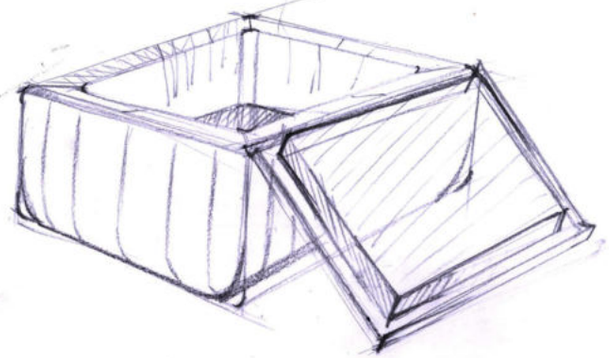
Concepts



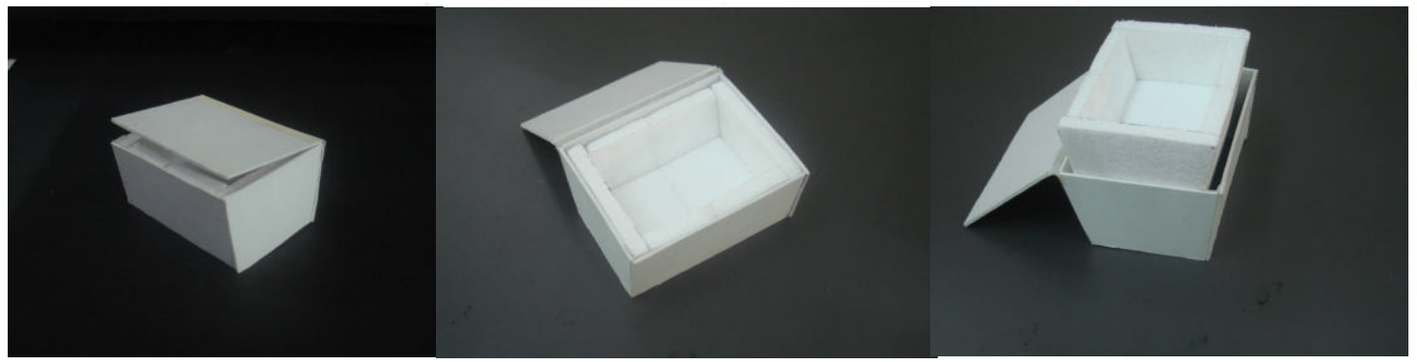








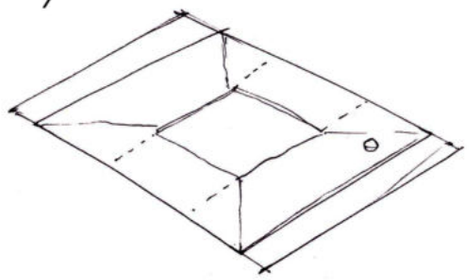
Mock Ups

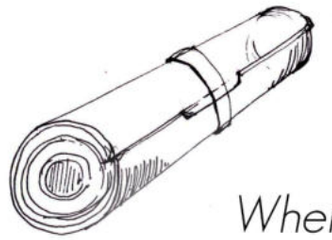


Concepts

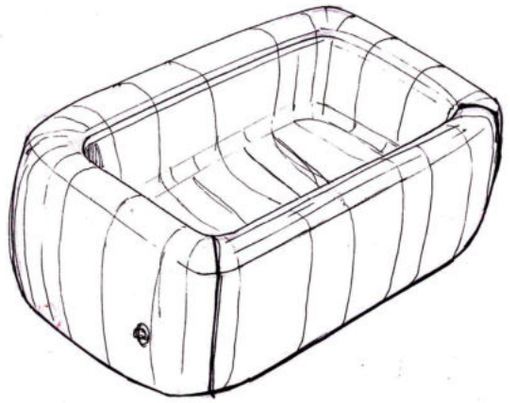
Concept 2: Inflatable

Fully Inflatable

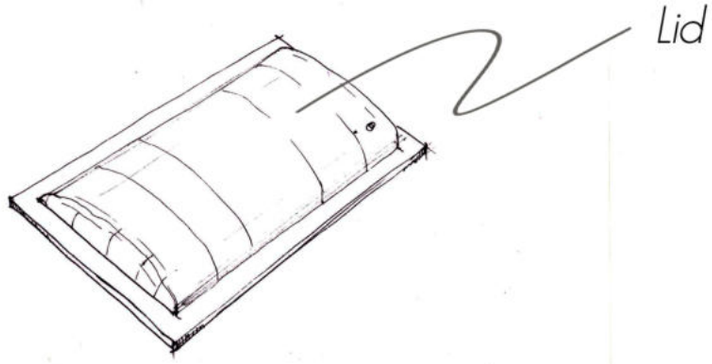




When rolled



Fully inflated body



Lid

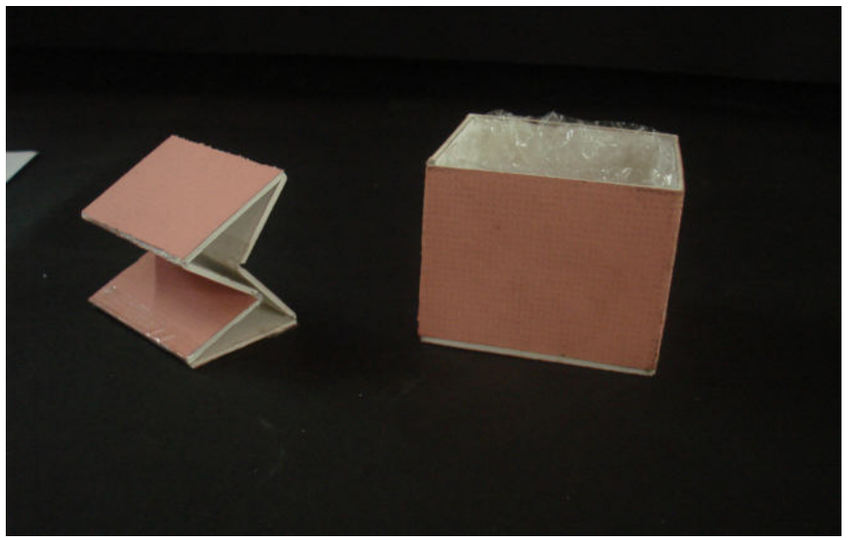
Semi Inflatable

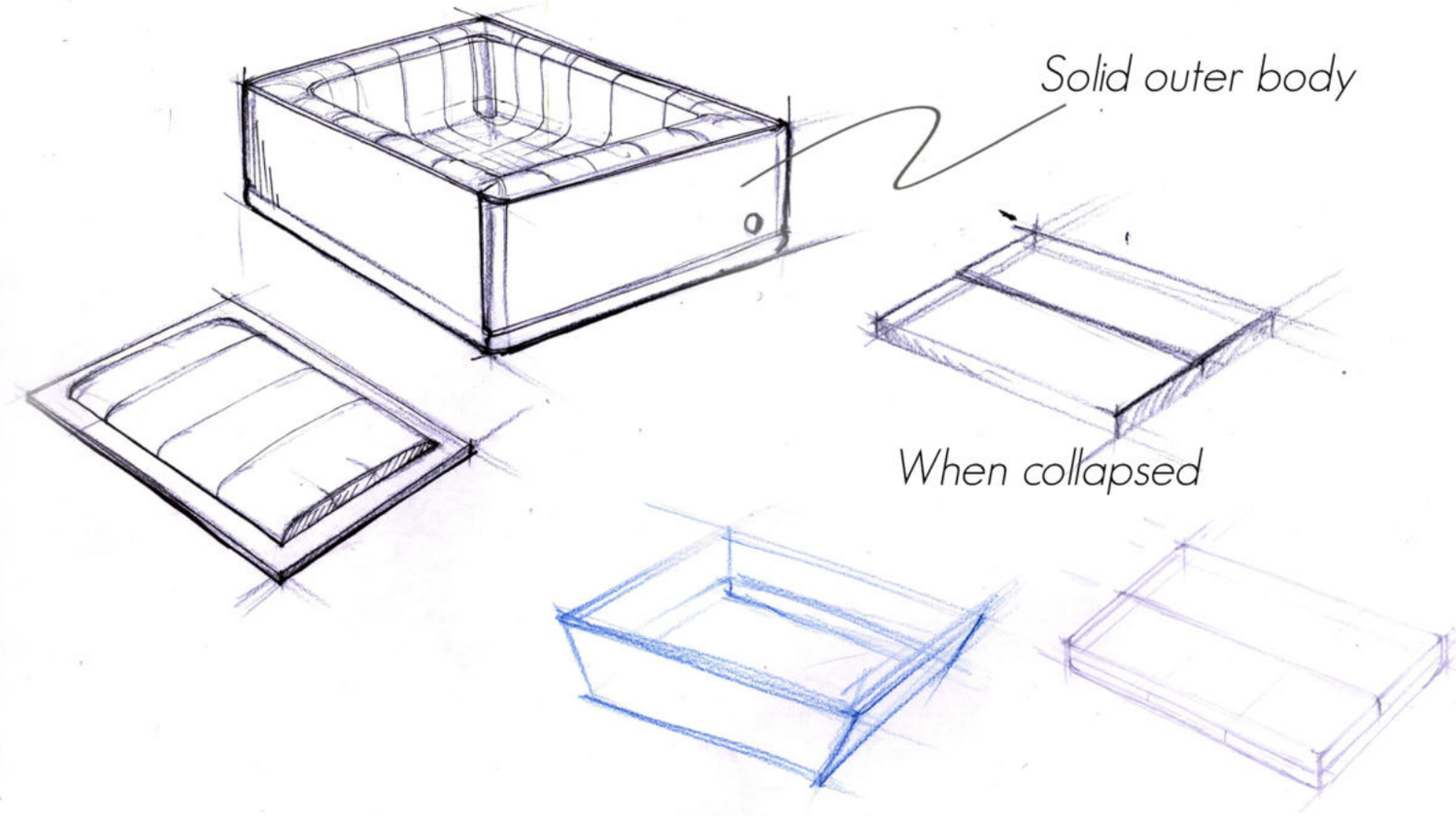
Plus+

The foldablility and collapsibility is the main feature of this concept which helps in transportation and saves space when not in use.

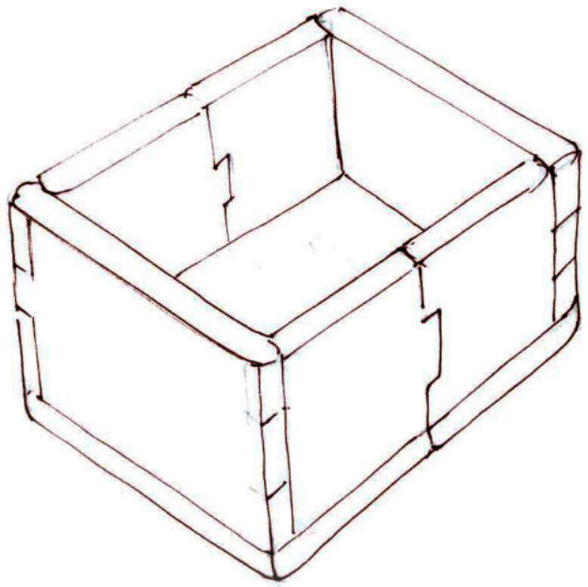
Minus-

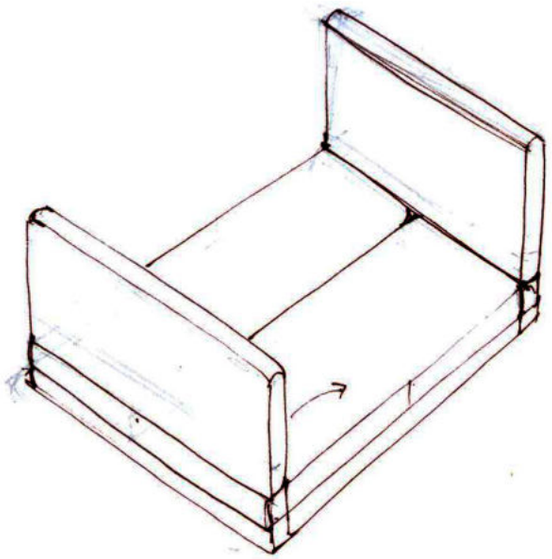
Inflation is not a very reliable option due to its delicateness and prone to maintenance issues

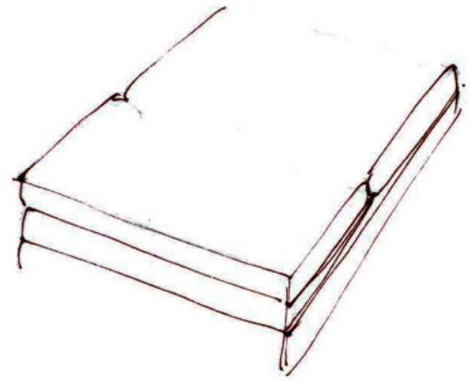


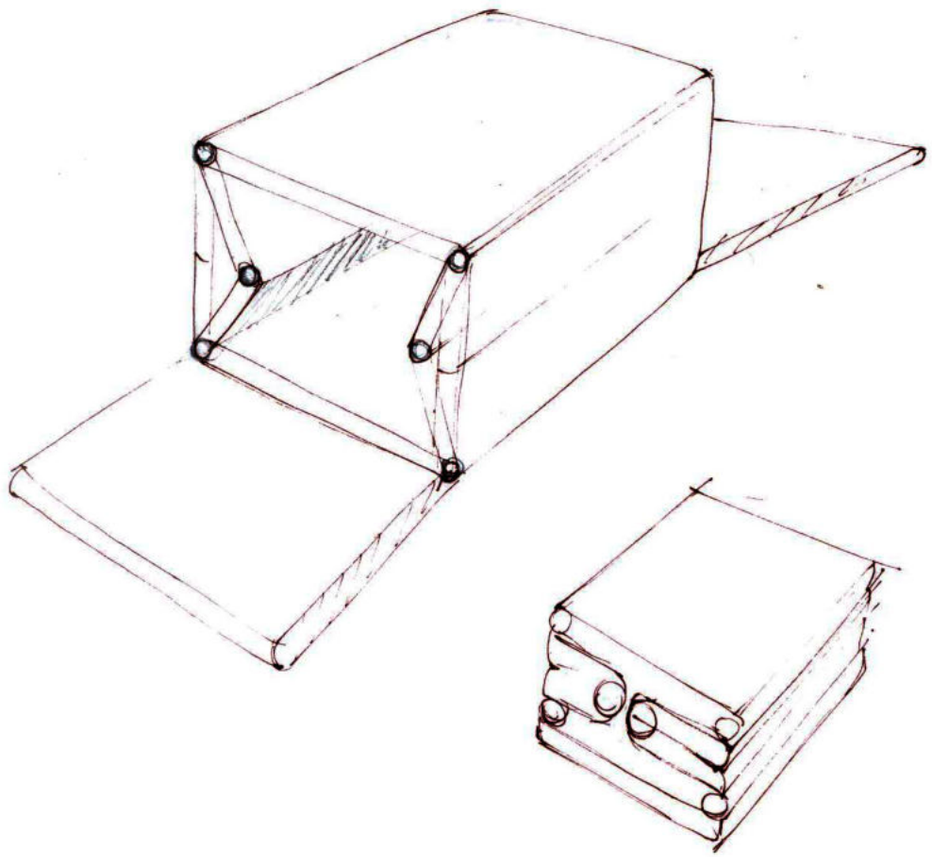


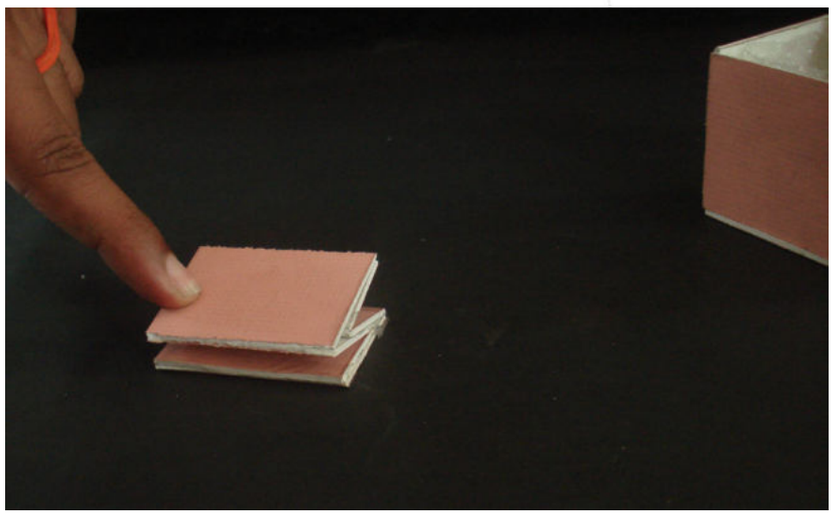
Concepts



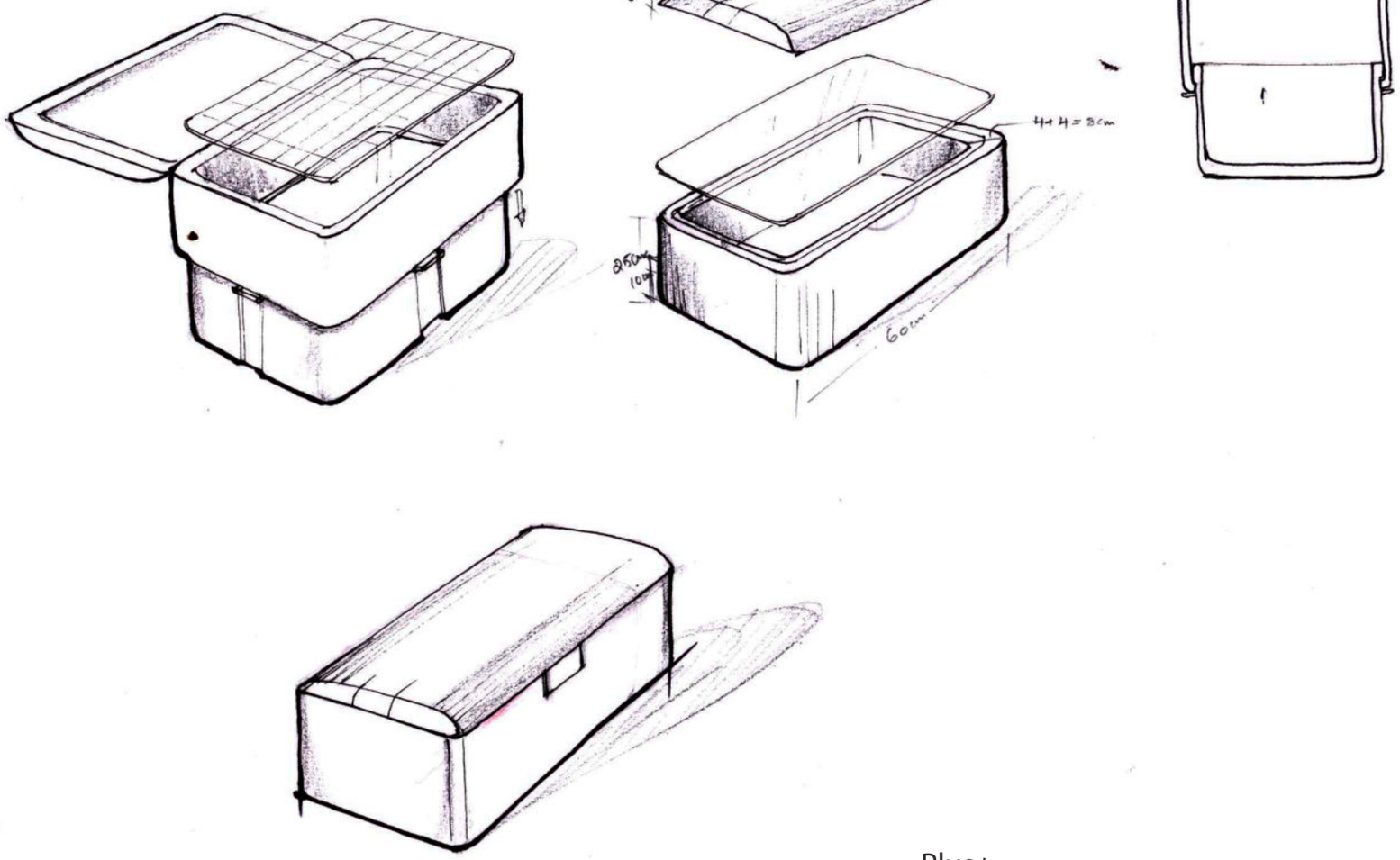








Concept 3: Extendible



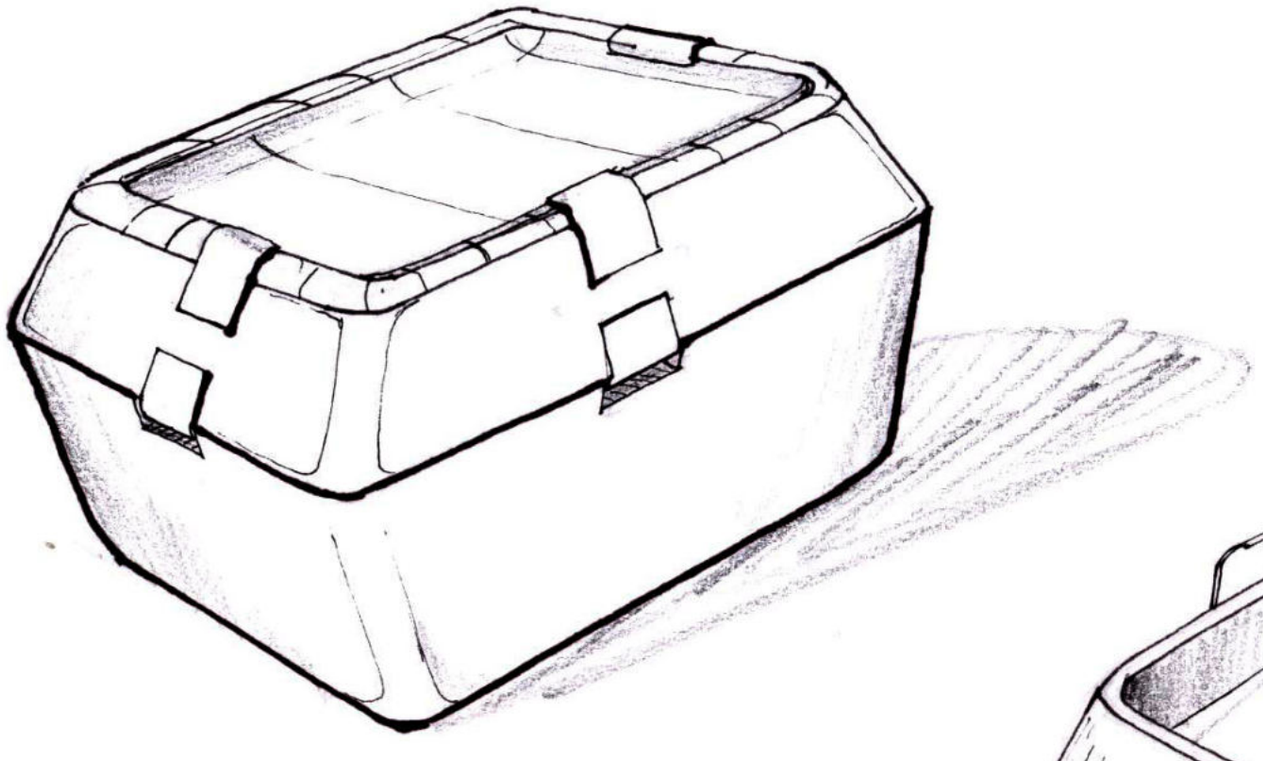
Plus+

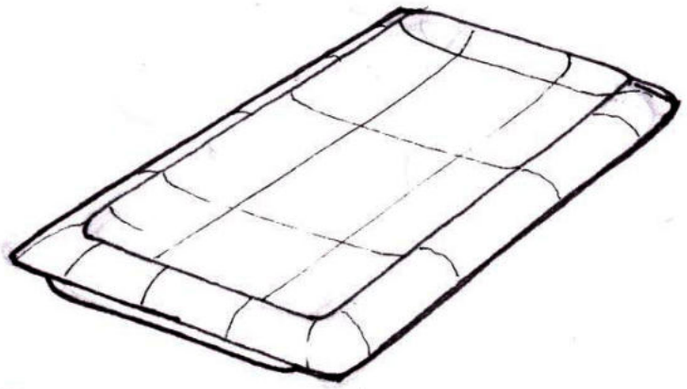
Options for storing food and ice separately stackablility and the container takes a compact form when not in use.

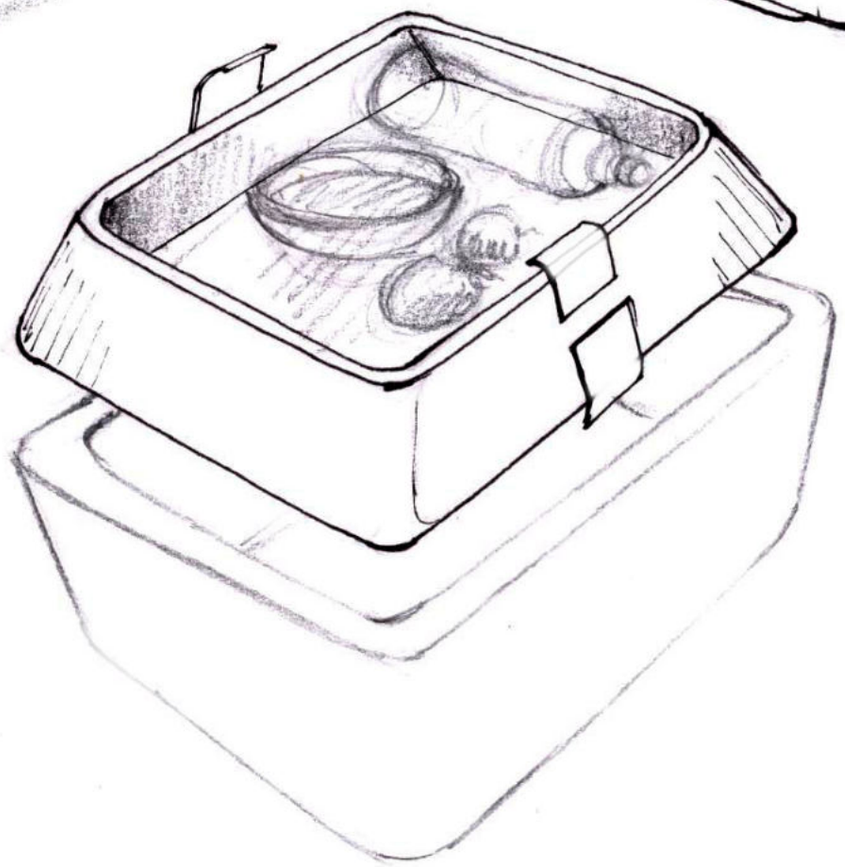
Minus-

Manufacturing difficulty and maintenance issues.
Also it is not supporting the wide angled mouth concept.
Dosen't help in temperature distribution.

Concept 4: Lid storage



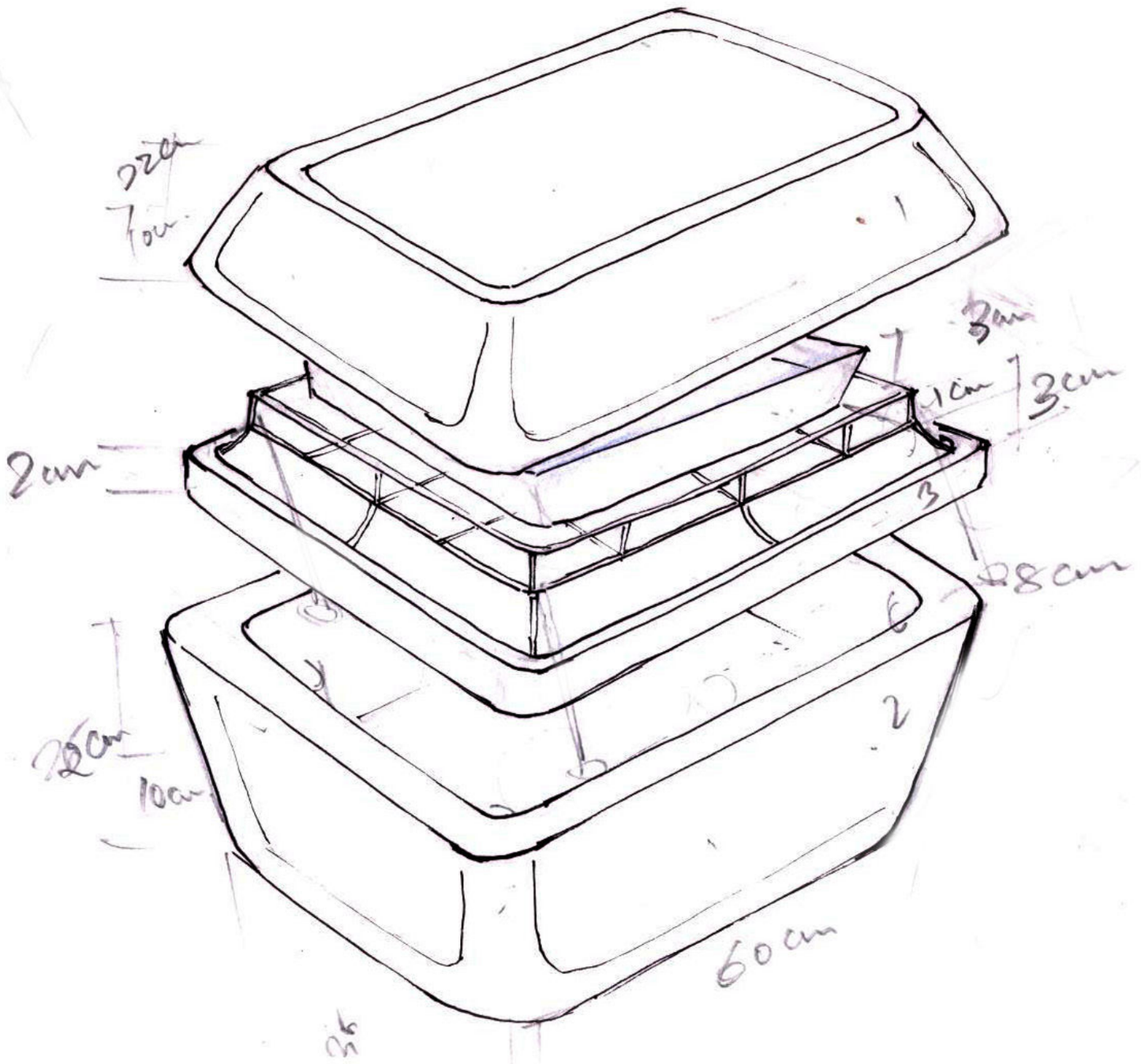




Plus+
Clean and simple design with food storage at the lid, which dosen't disturb the ice storage.
Easy handling and maintenance.

Minus-
Dosen't help in temperature distribution.
Manufacturing complexity
Not suitable for continuous ice making , day after day

Concept 5: Top ice



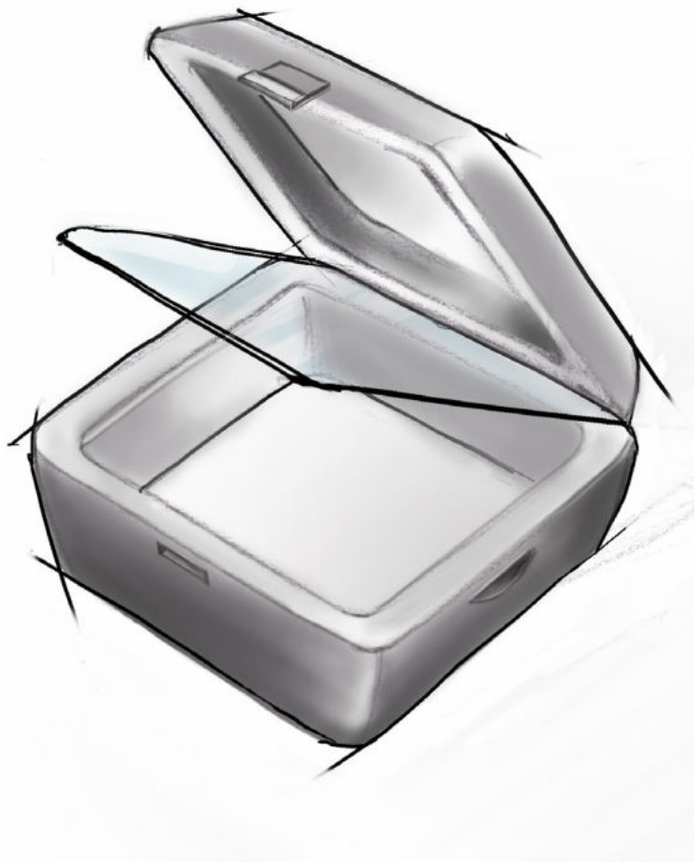
Plus+

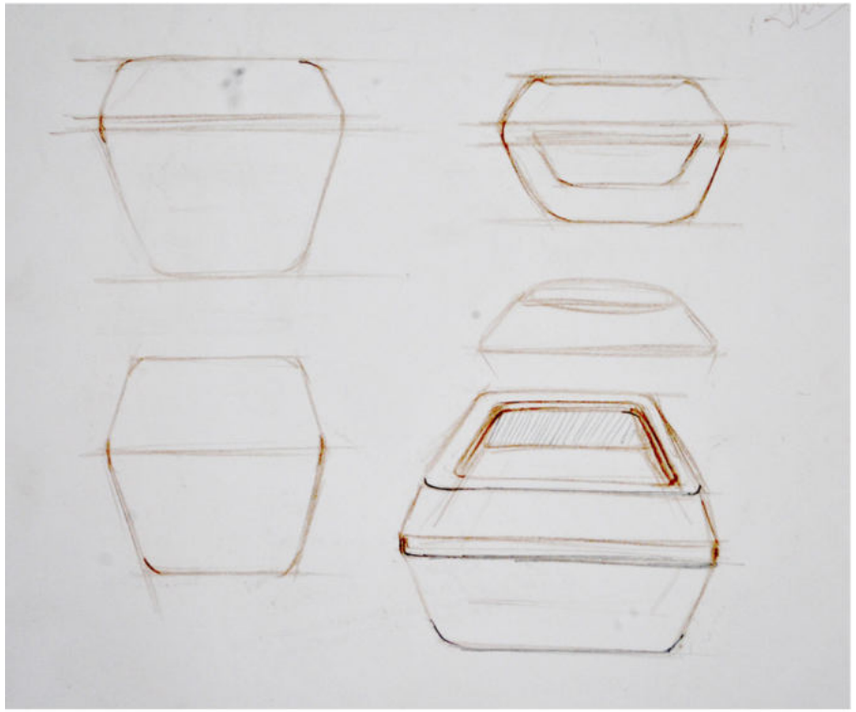
Easy manufacturing using same mould because of the identical parts.
Design helps in temperature distribution.
Supports the continuous ice making, day by day.
Customisable interior space for food and ice storage.
Wide angled mouth increases the efficiency.

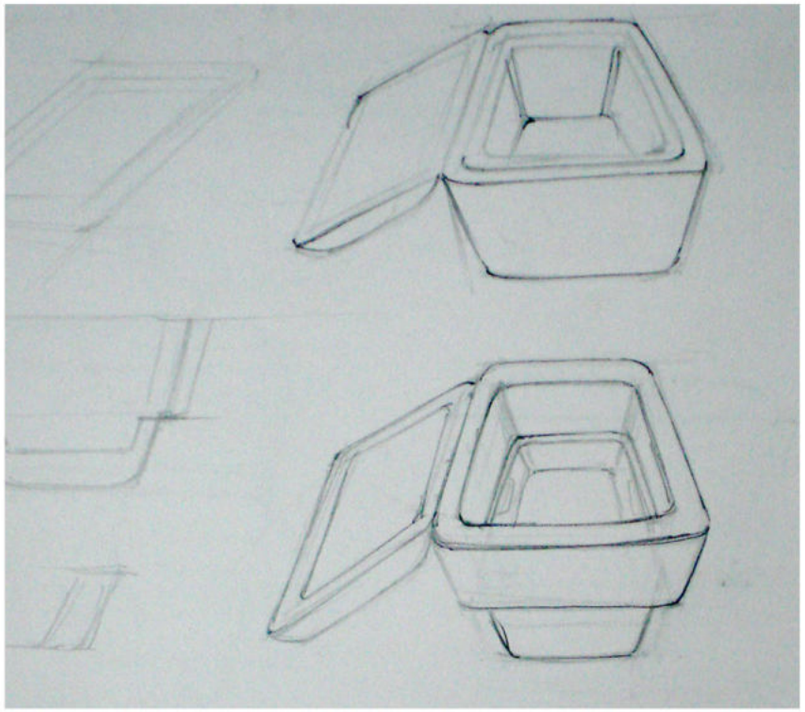
Minus-

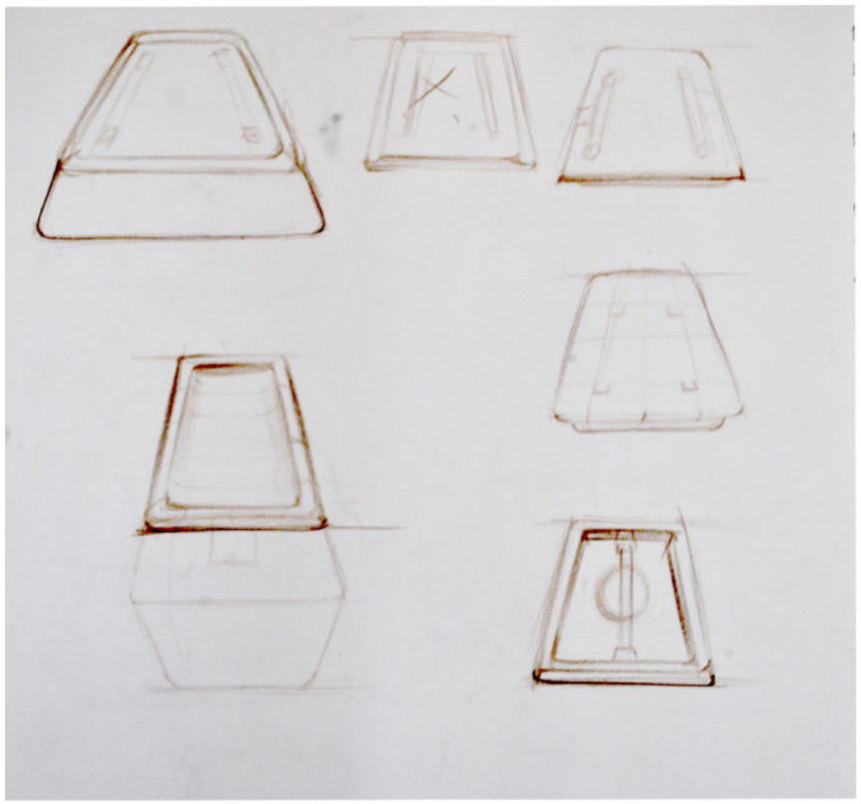
Chances of visual semantics issue.
chances of confusion in operation.

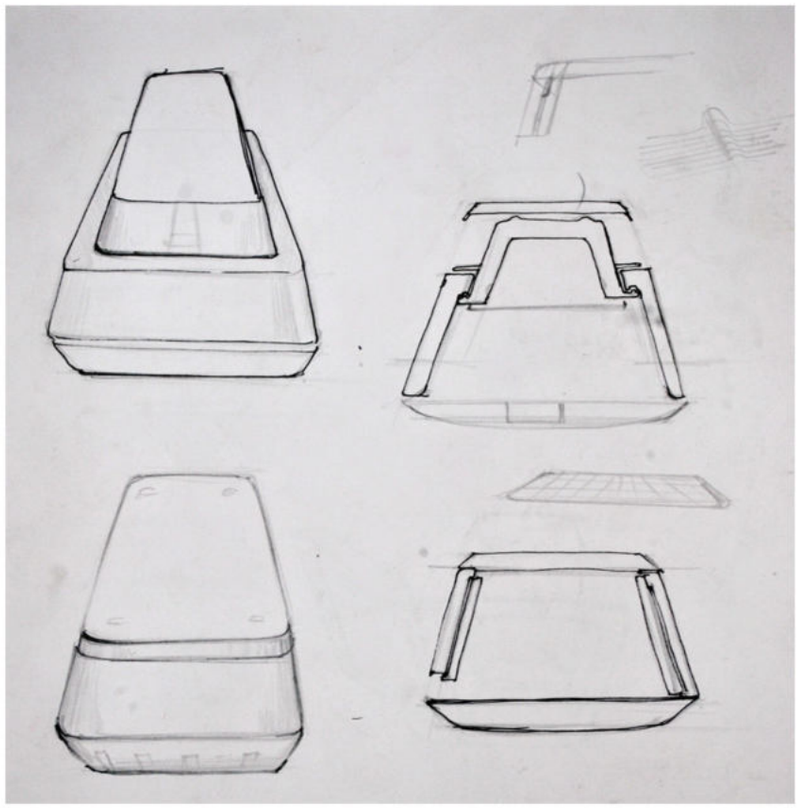
Explorations







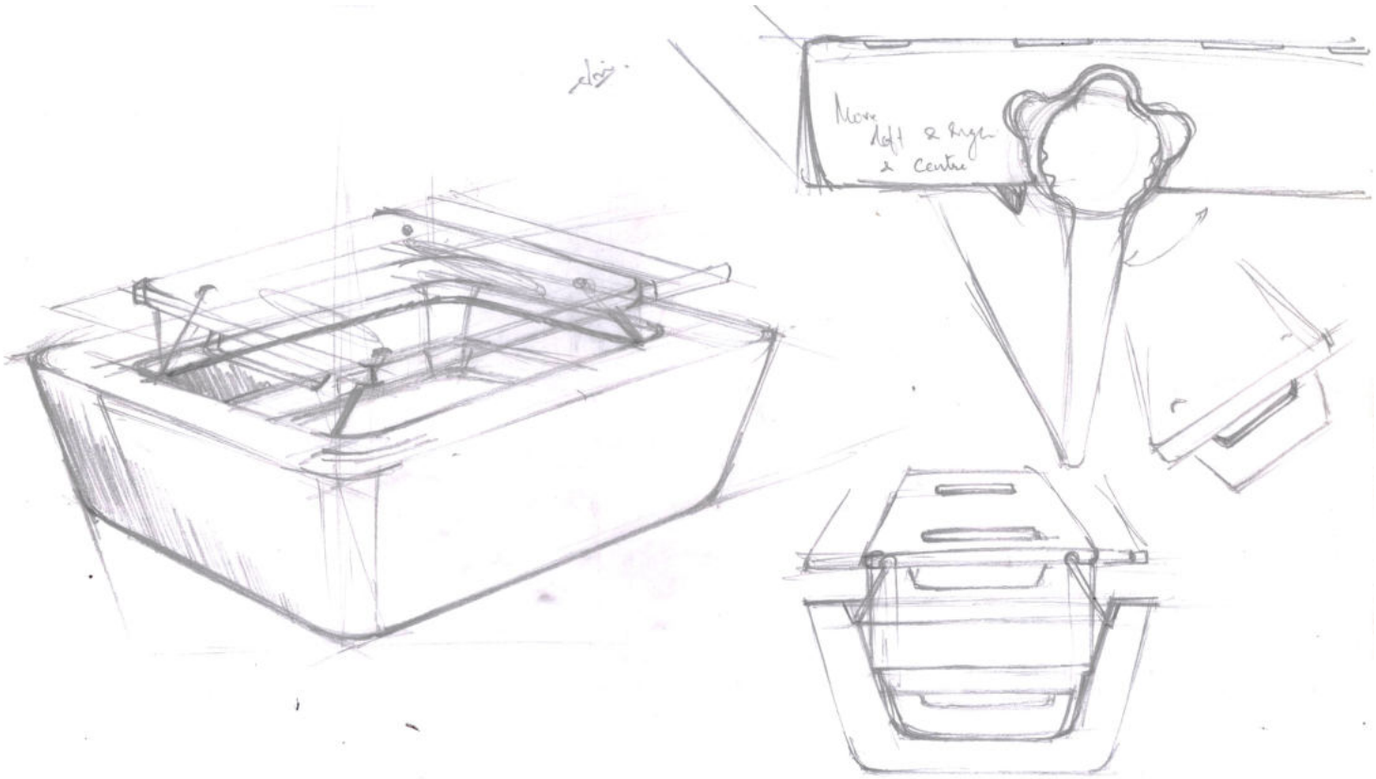


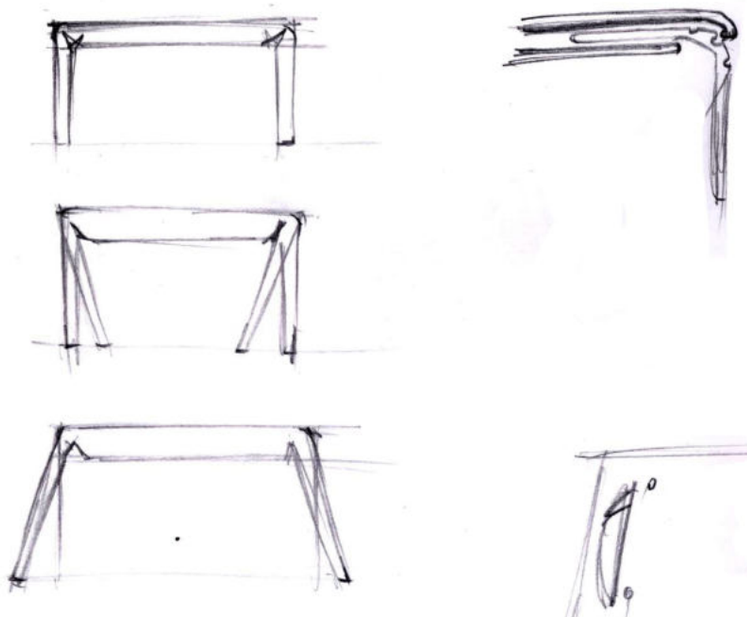


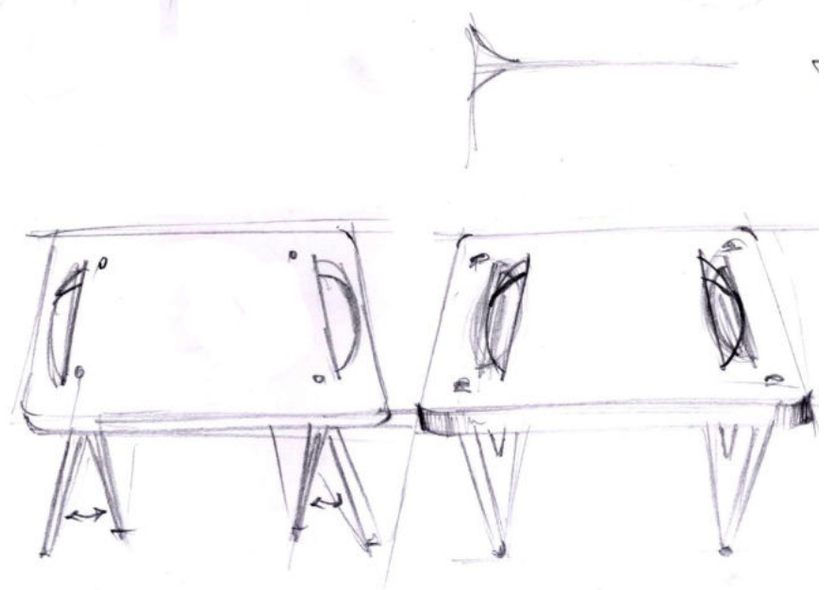
Concept Evaluation

Parameters	Concept 1/Solid form	Concept 2/Inflatable	Concept 3/Extendable	Concept 4/ Lid storage	Concept5/ Top ice
Efficiency	9	5	7	9	9
Maintenance	9	5	7	8	9
Manufacturability	8	8	7	7	9
Cost	8	9	7	7	7
Maneuverability	7	9	7	8	8
Storage	7	5	9	9	8
Stackabality	6	8	9	7	7
Multi purpose/Additional features	5	5	9	8	8
Total	59	57	62	63	65

Explorations







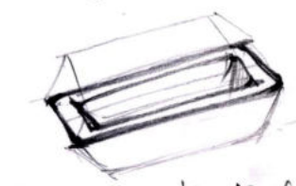


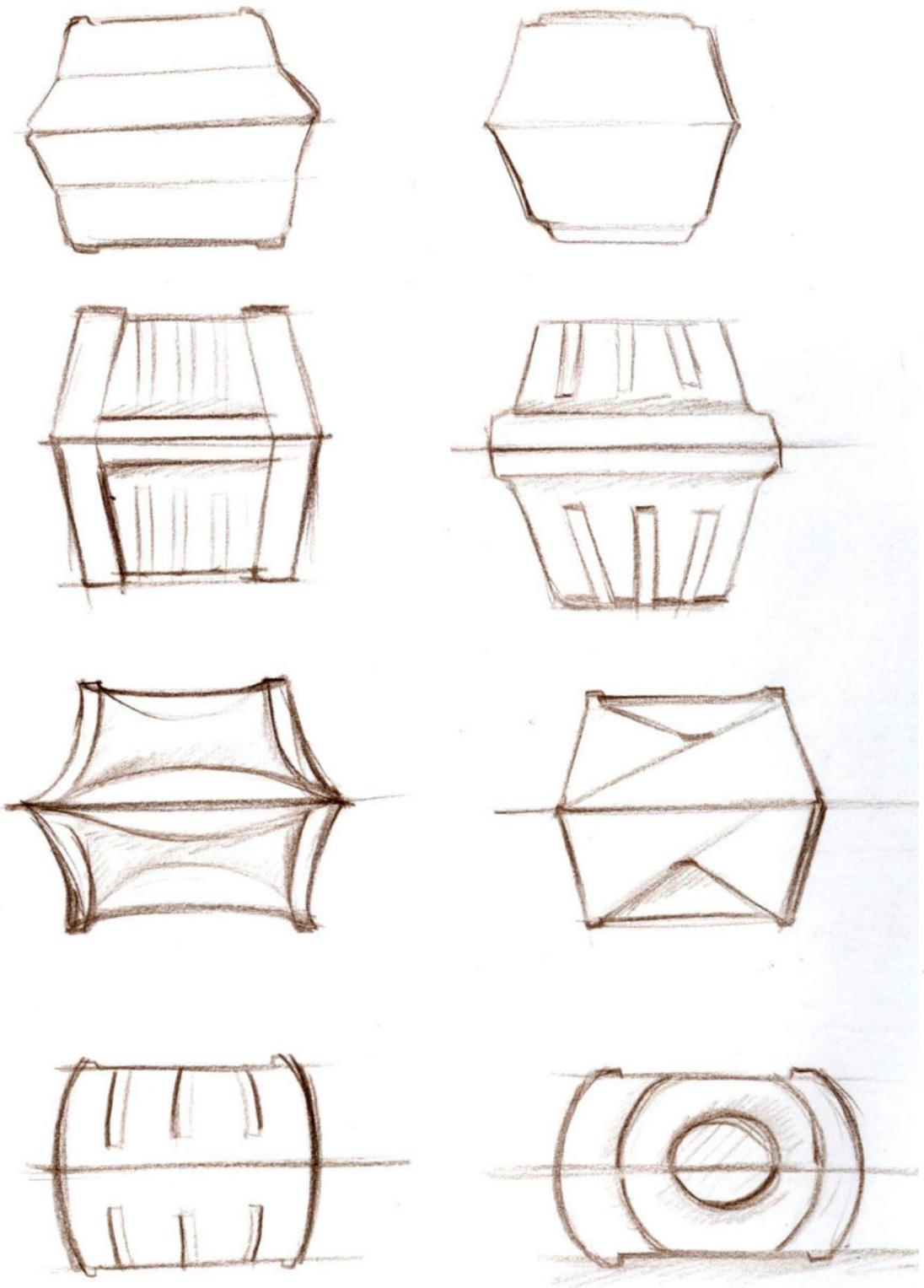
Figure out the middle point
for the Curtain

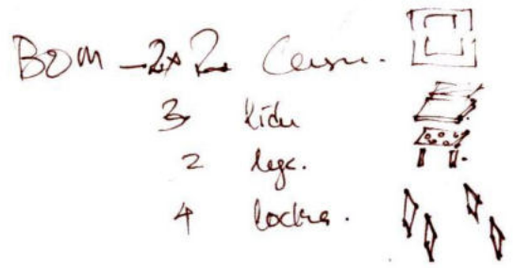
Then the lid to close
the Setup.

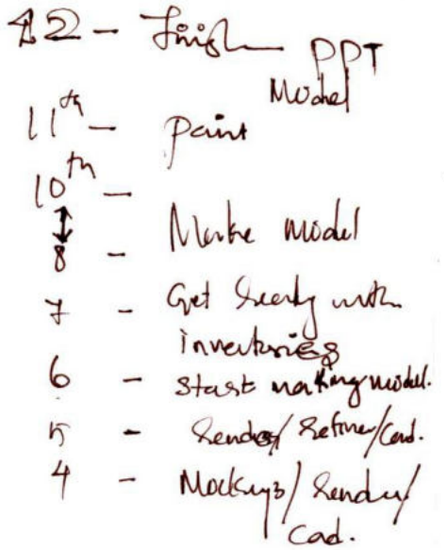
Then, the locking
mechanism.

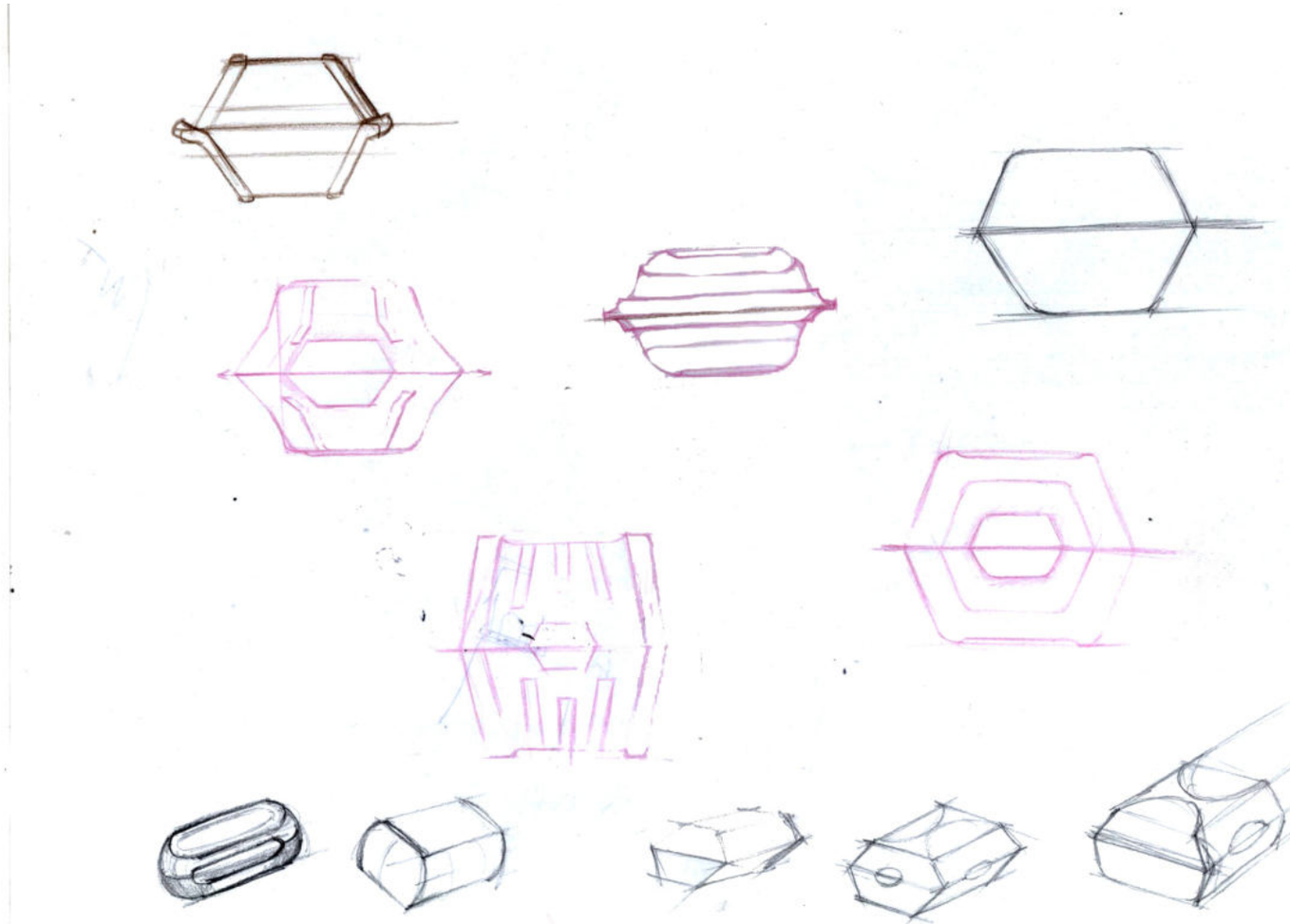
Visual Representation
Intention.

Explorations

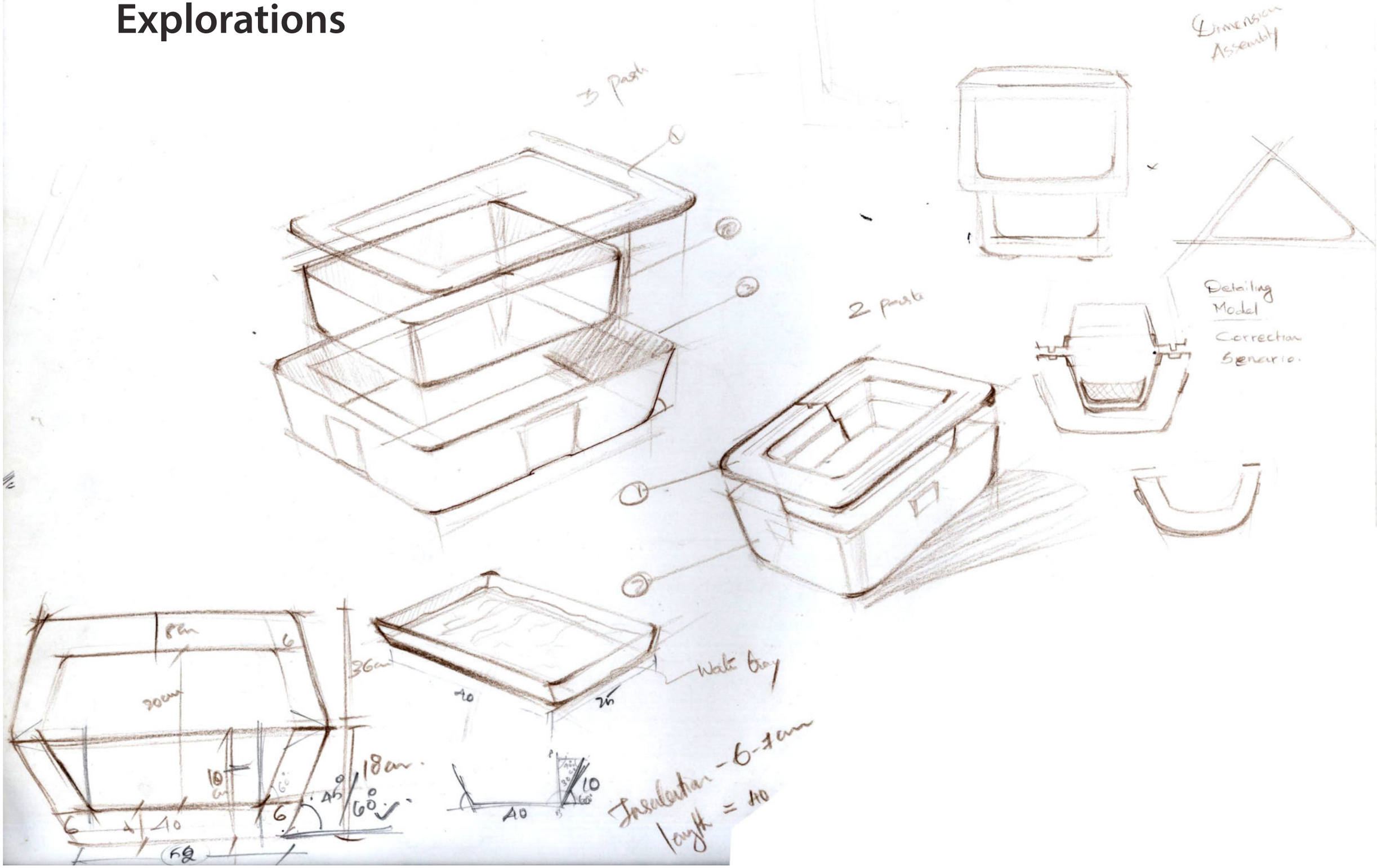








Explorations



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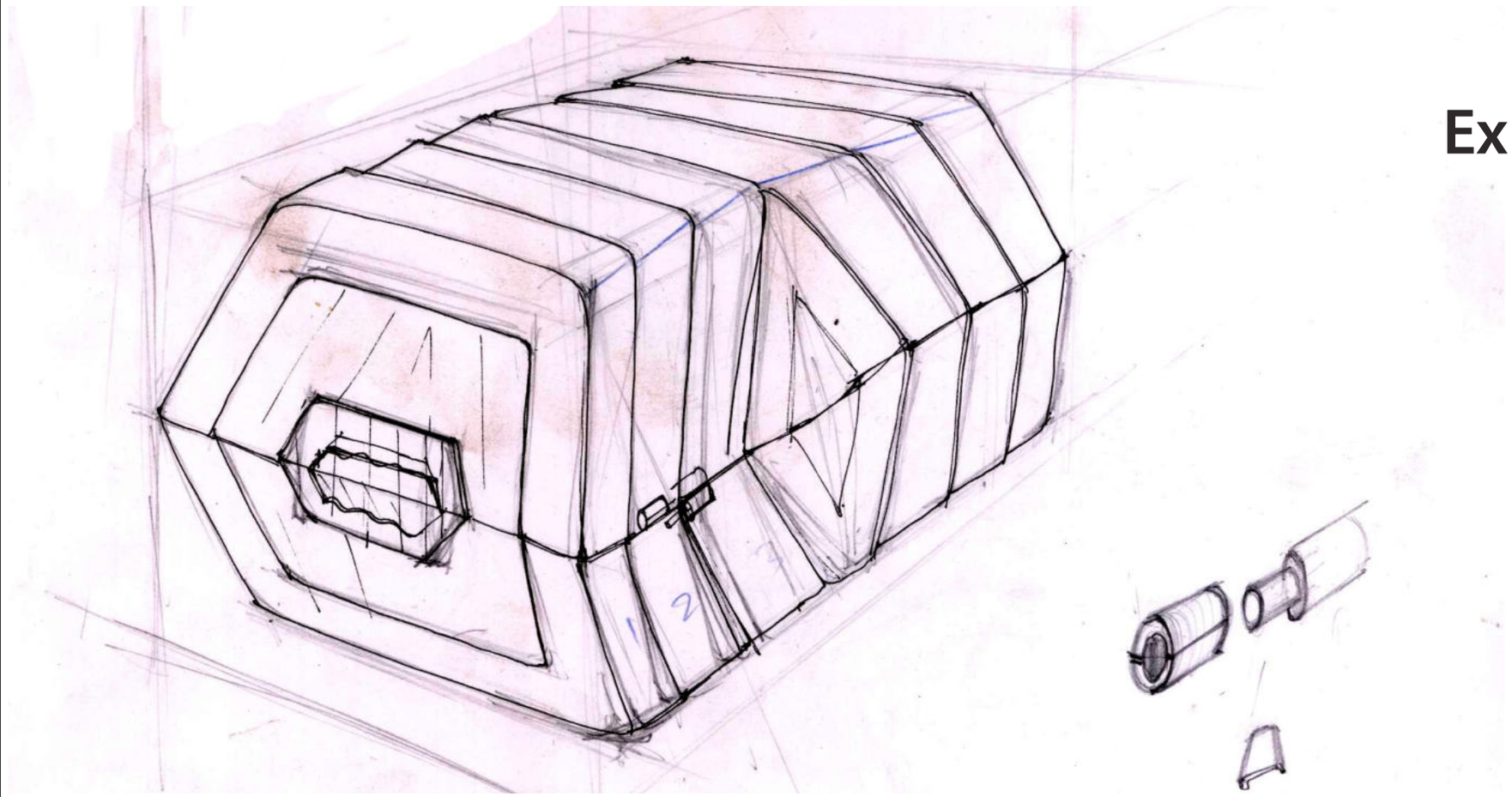
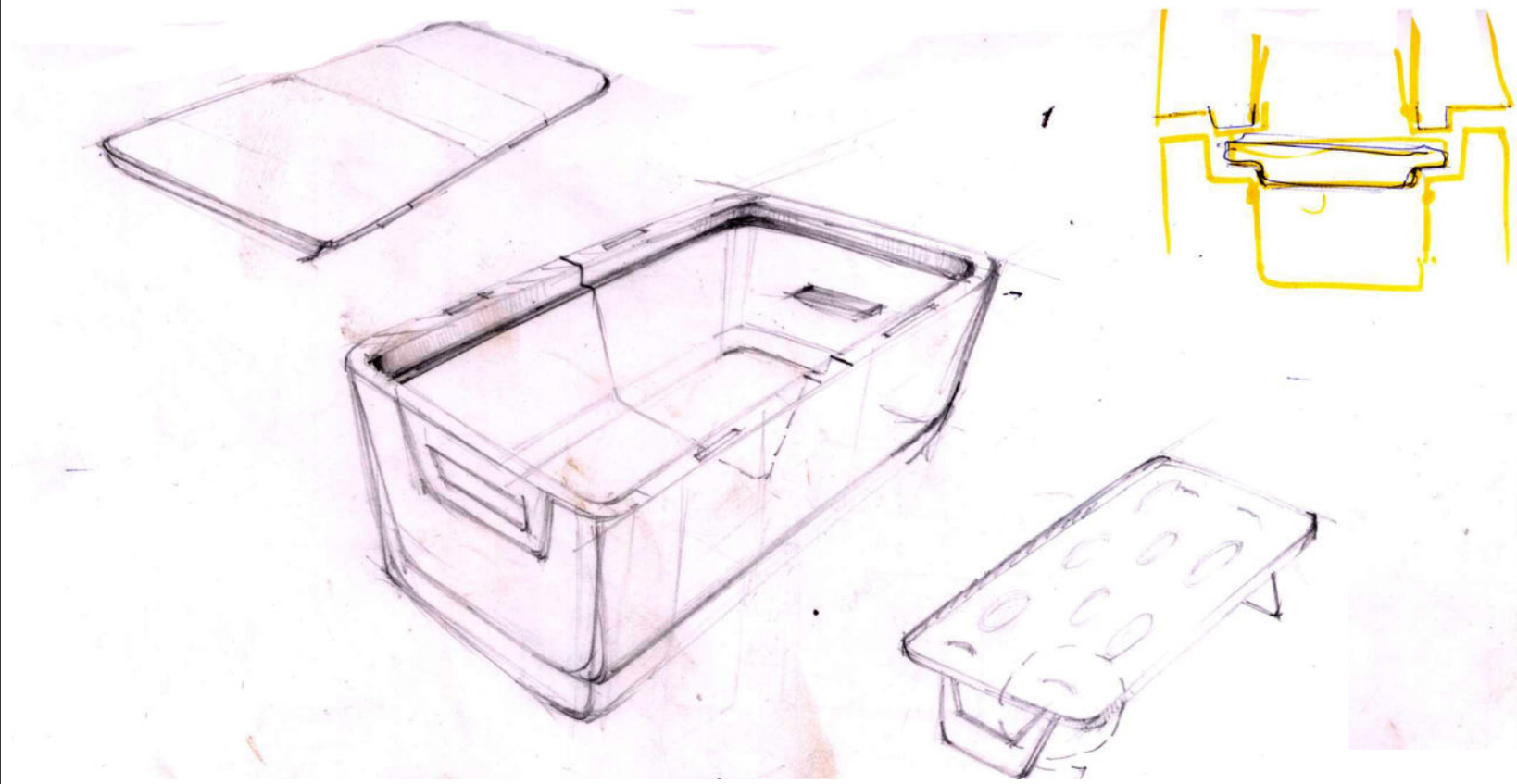
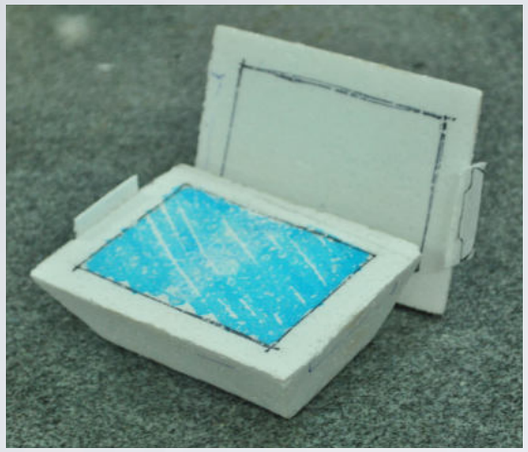
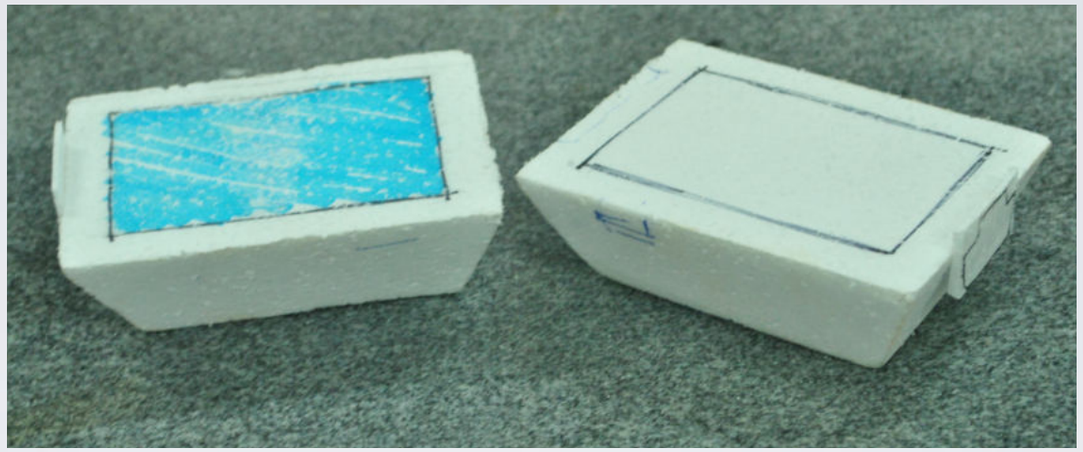
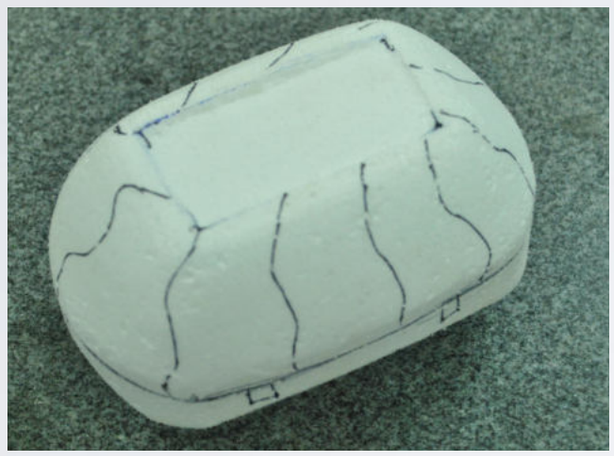


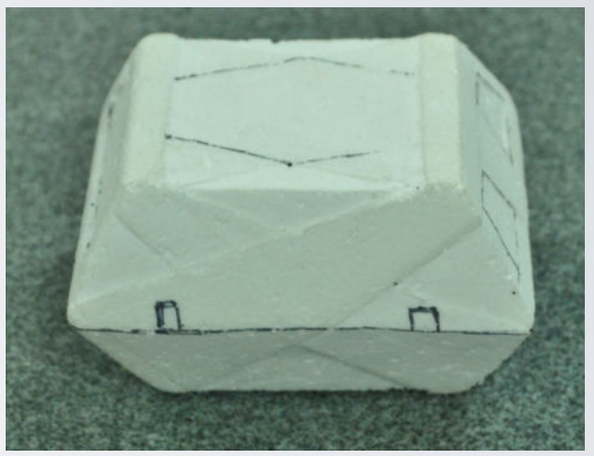


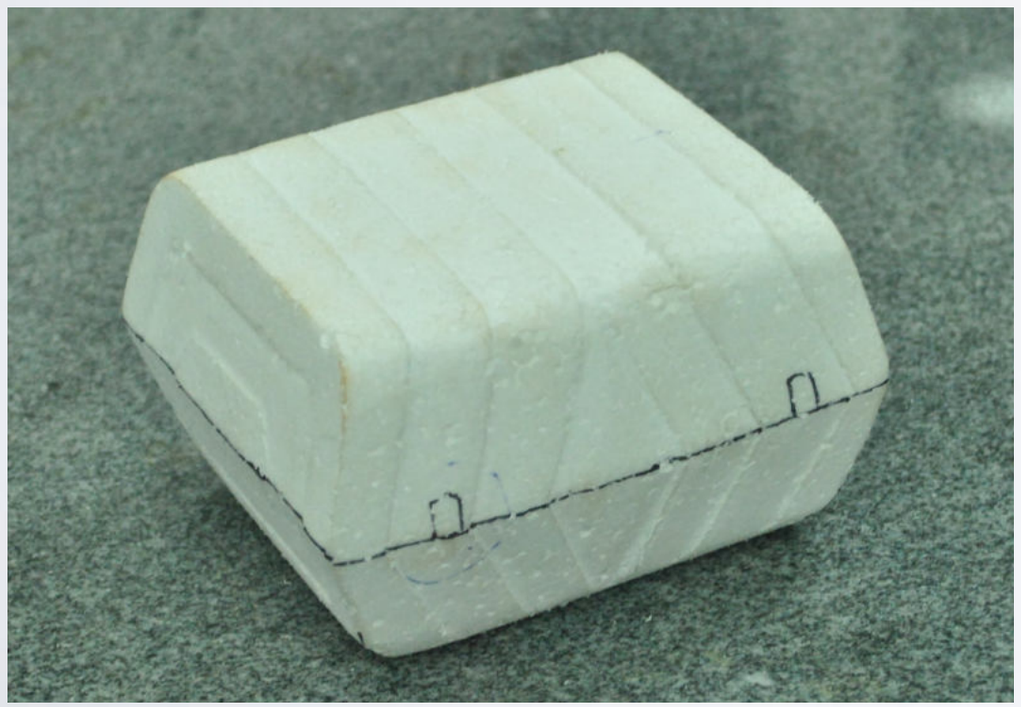
Form explorations

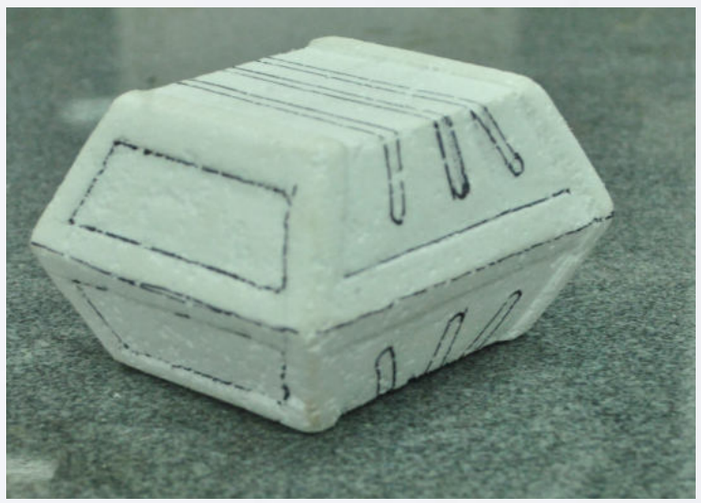


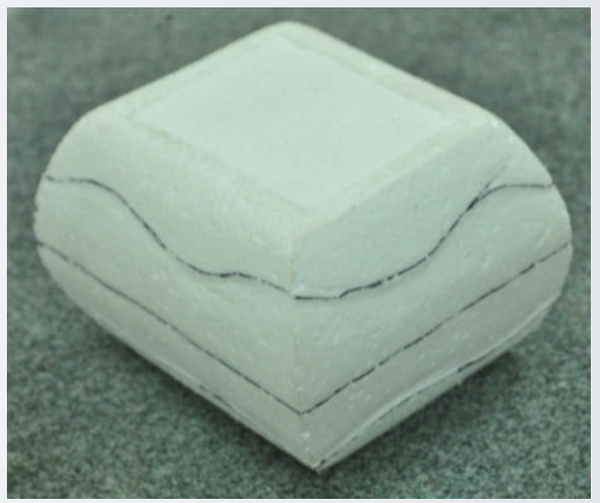


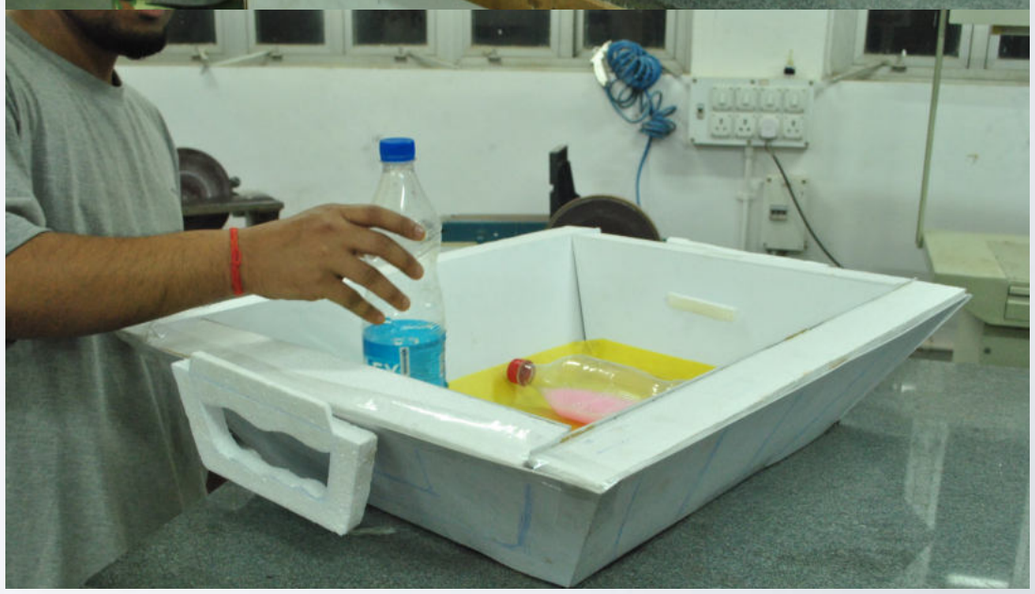








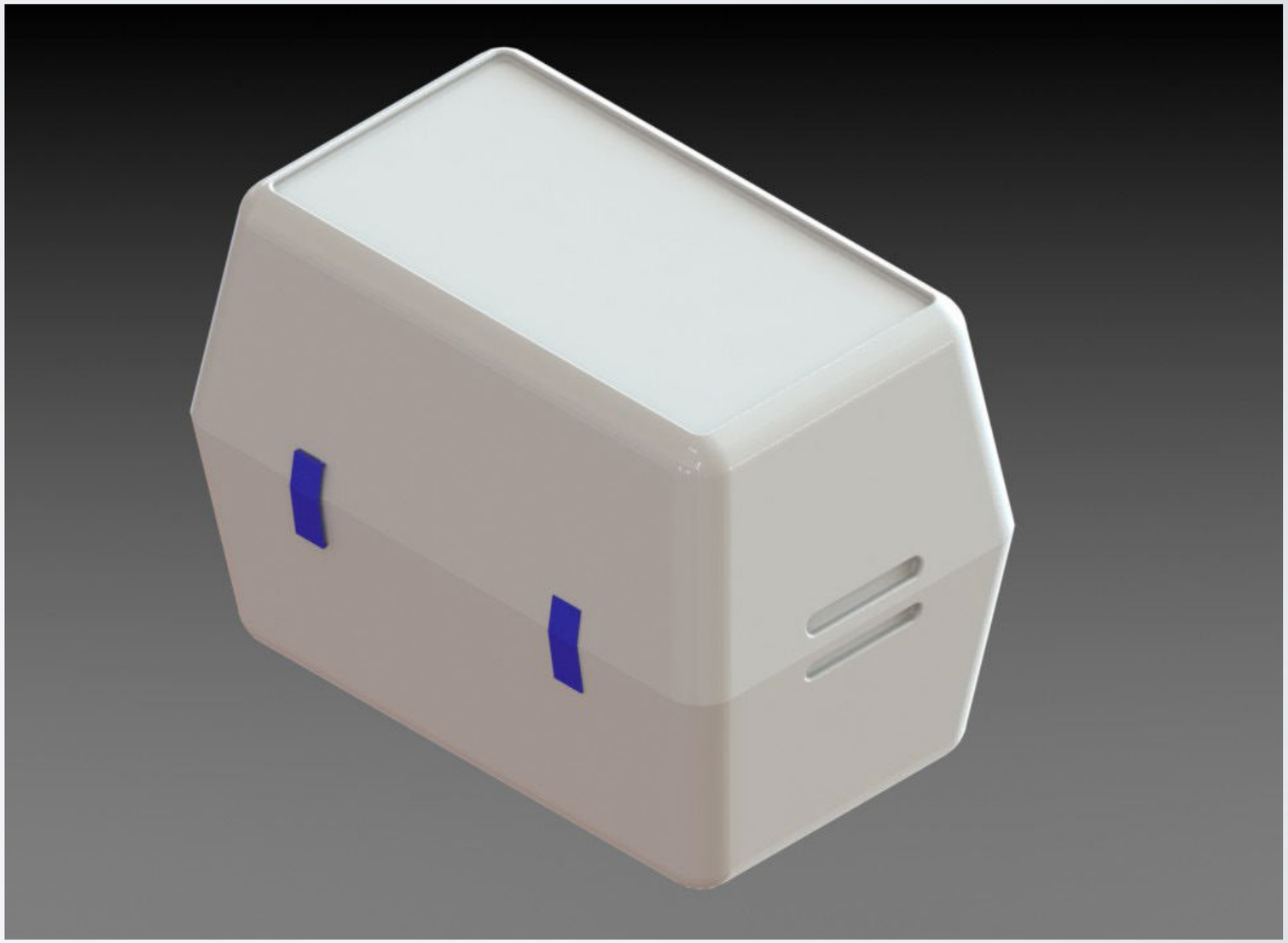




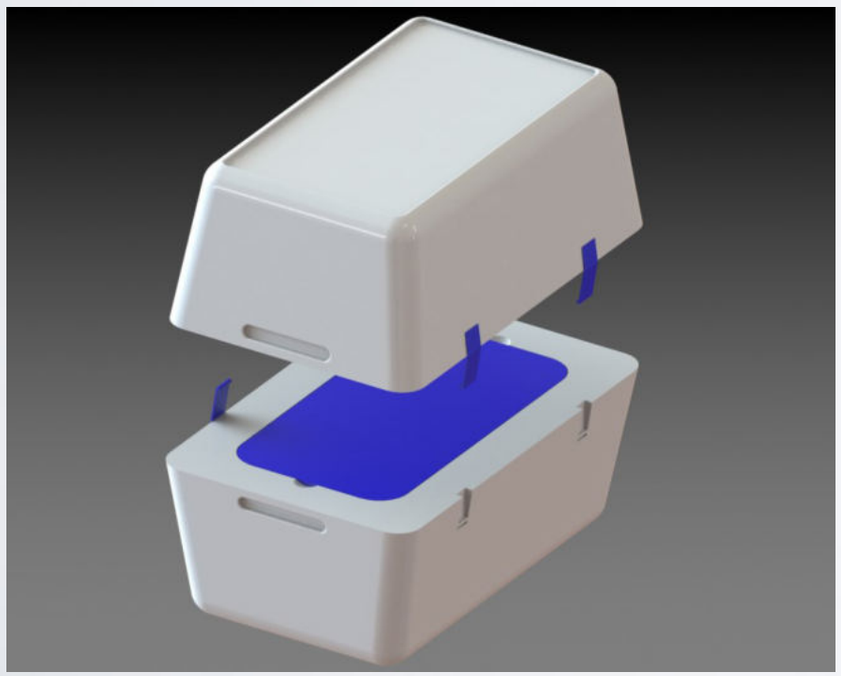
CAD Modelling

Iteration I:

Based on the criterias evaluated, concept 5 has been choosen for further refinement and model making.



- The identical top and bottom part , reduce the cost of tooling.

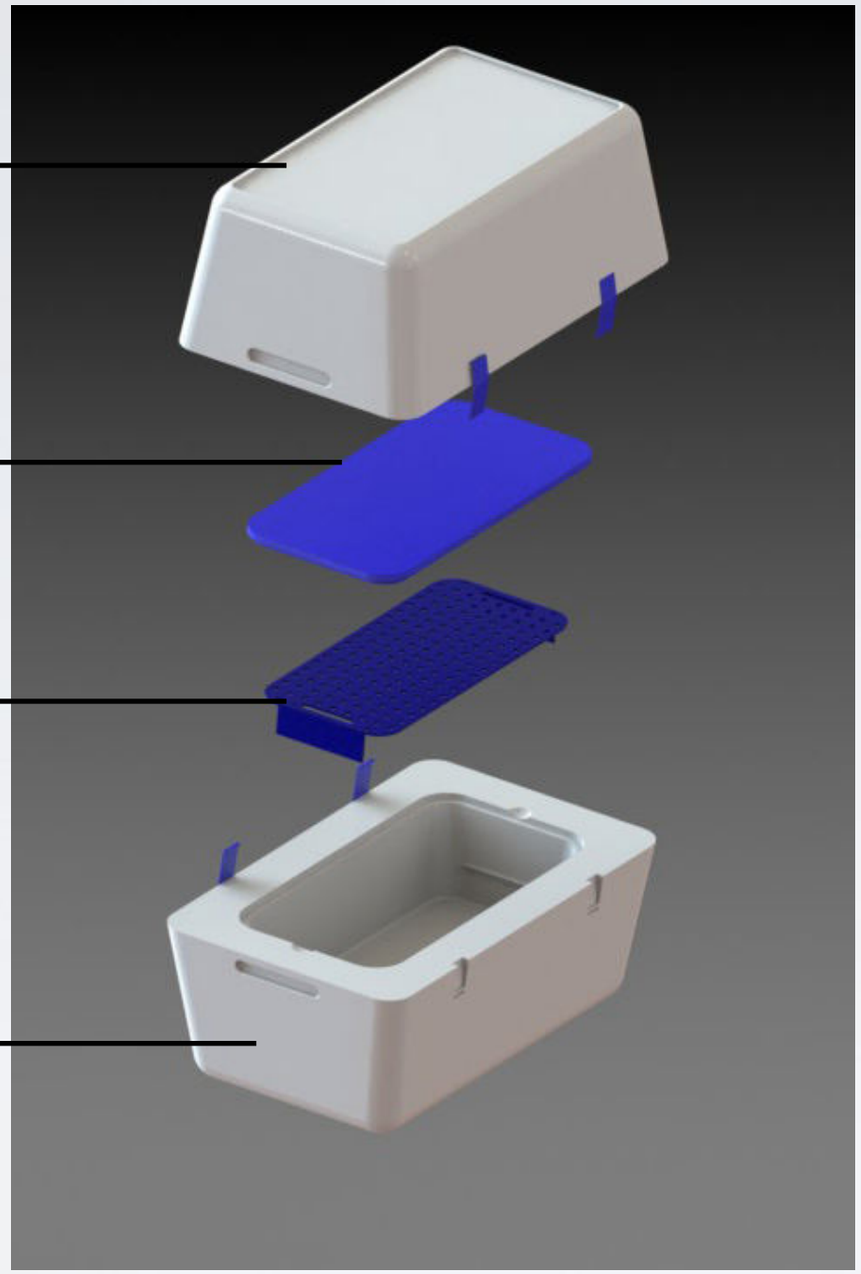


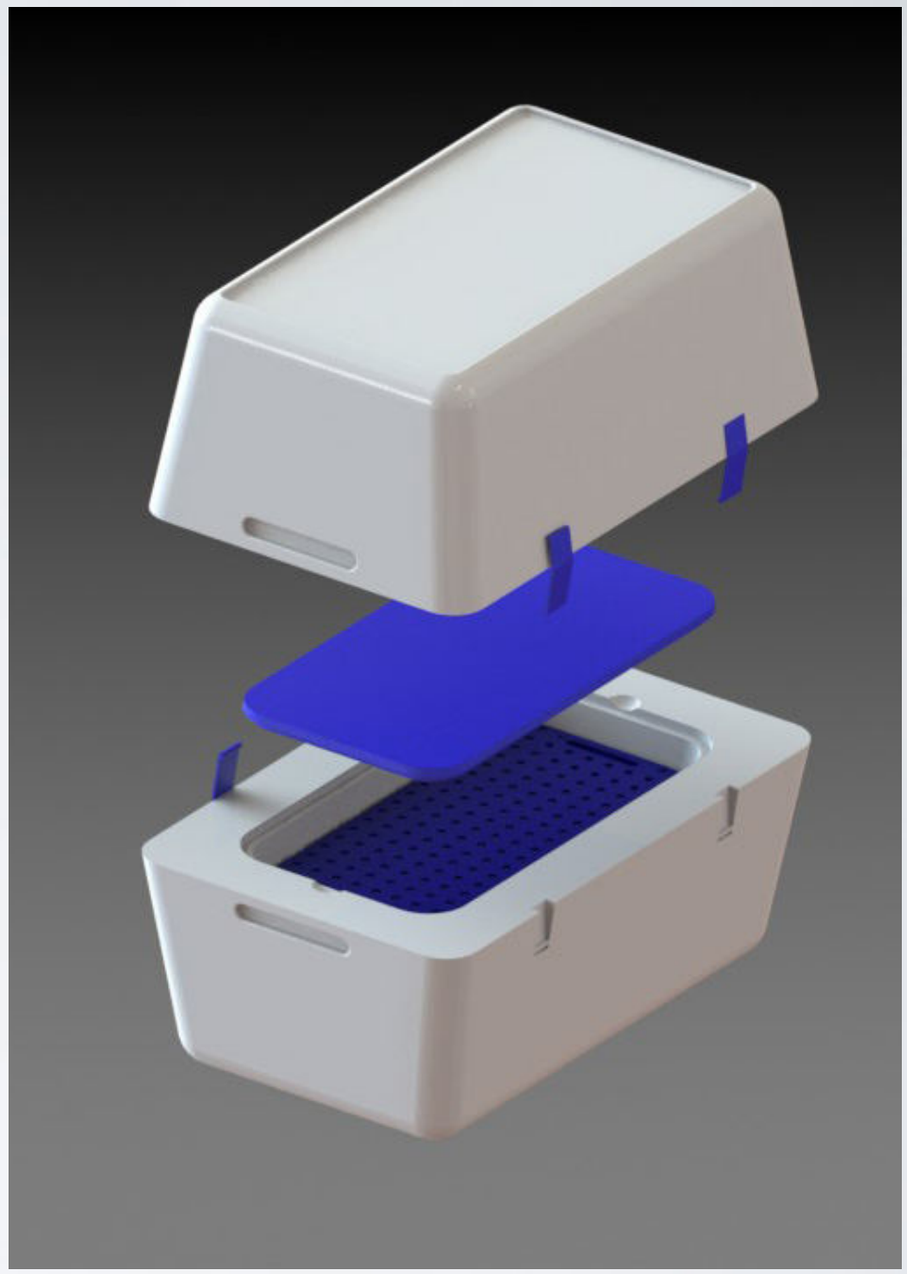
Lid / Ice maker

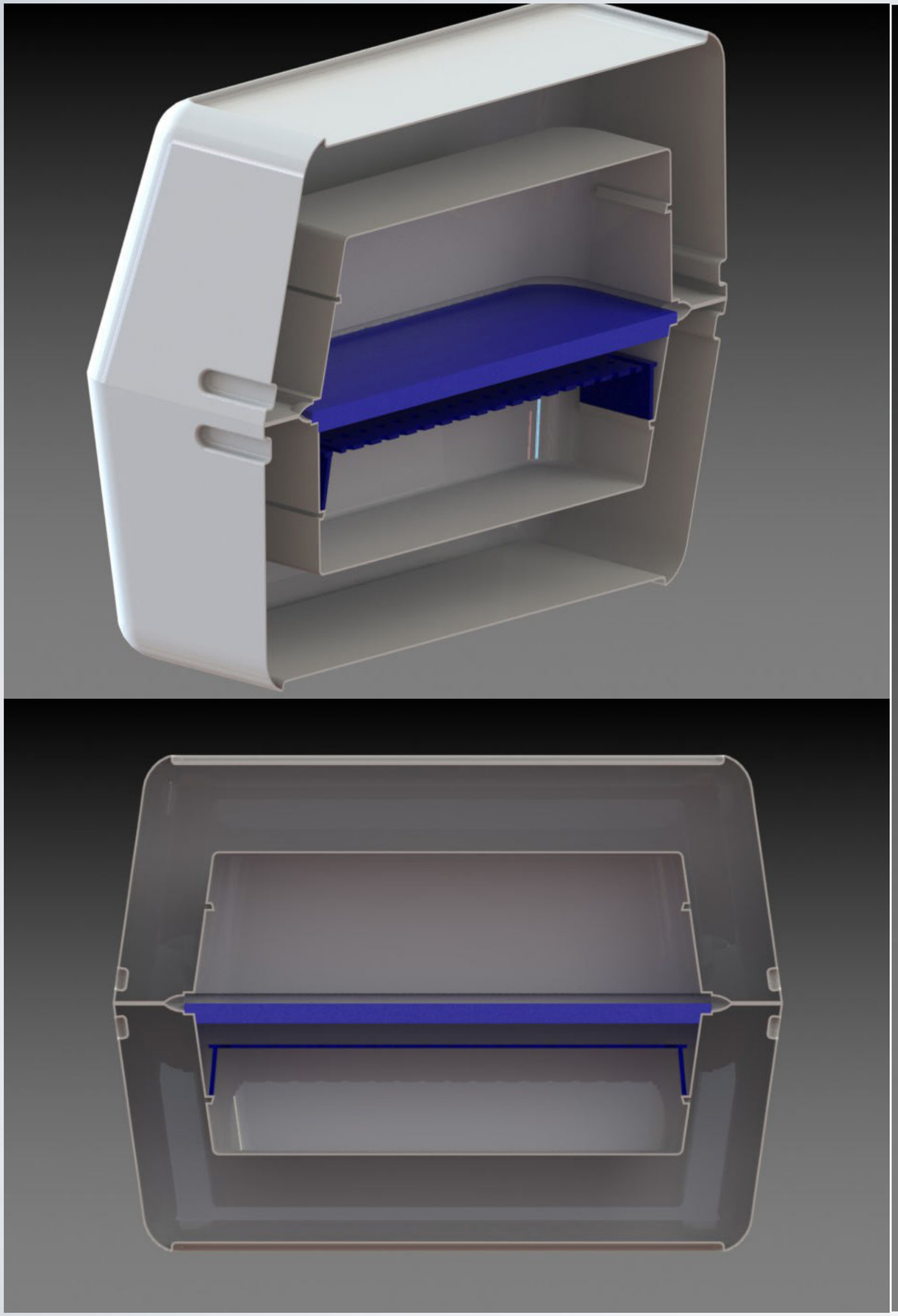
Lid for closing the container when storing ice

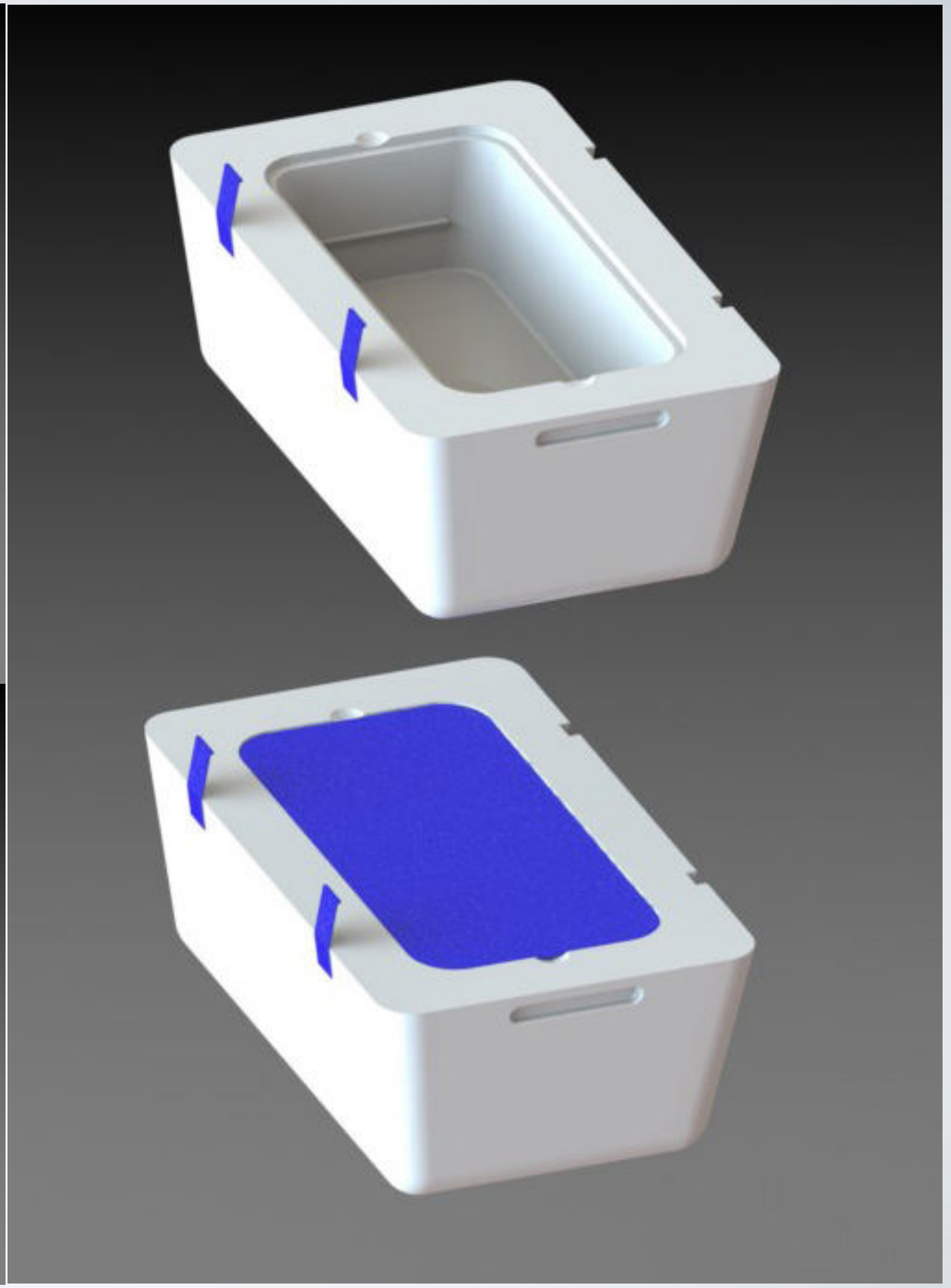
Height adjustable tray which holds ice when there is food to be stored

Ice /food storage, Ice maker





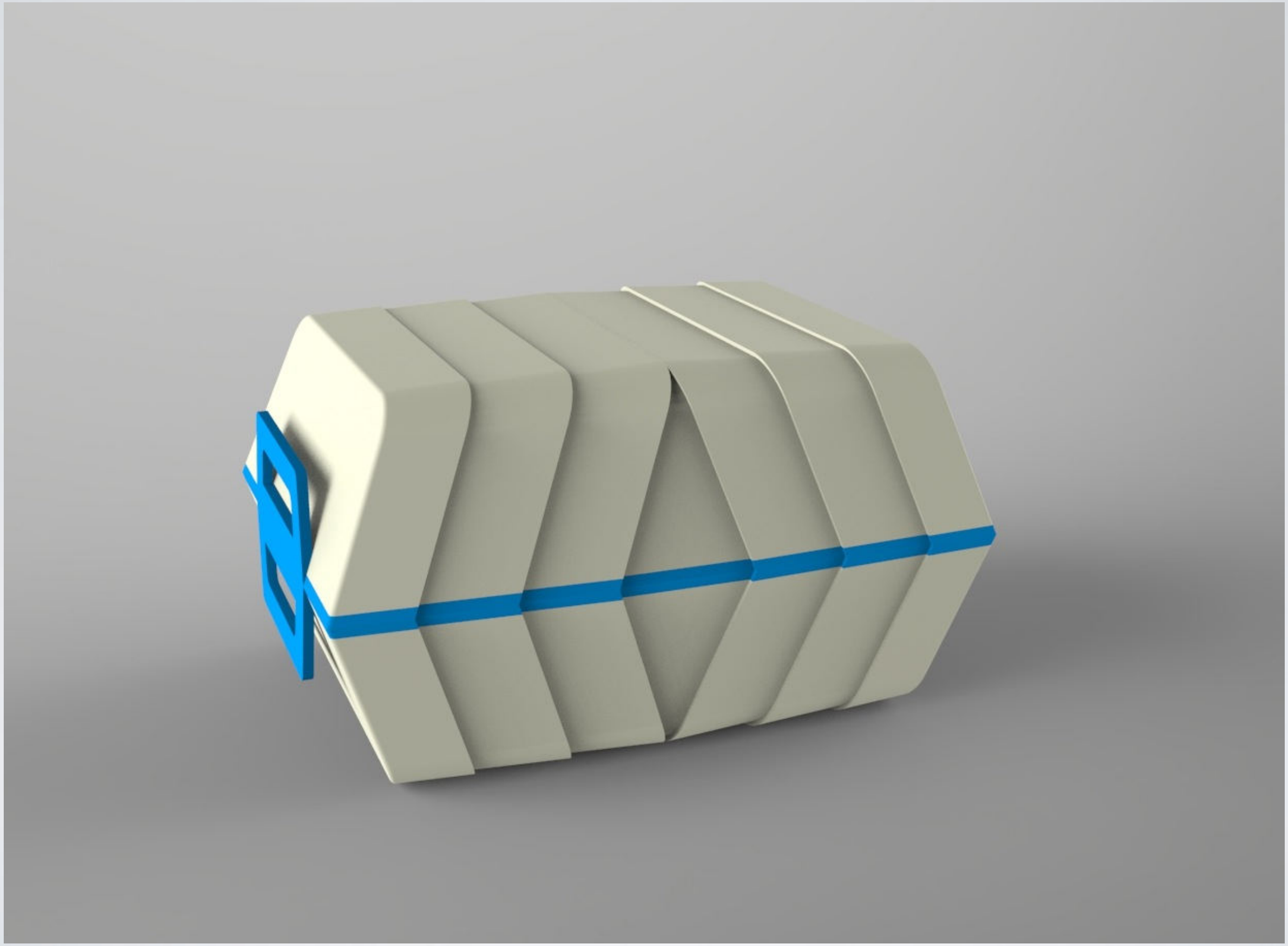


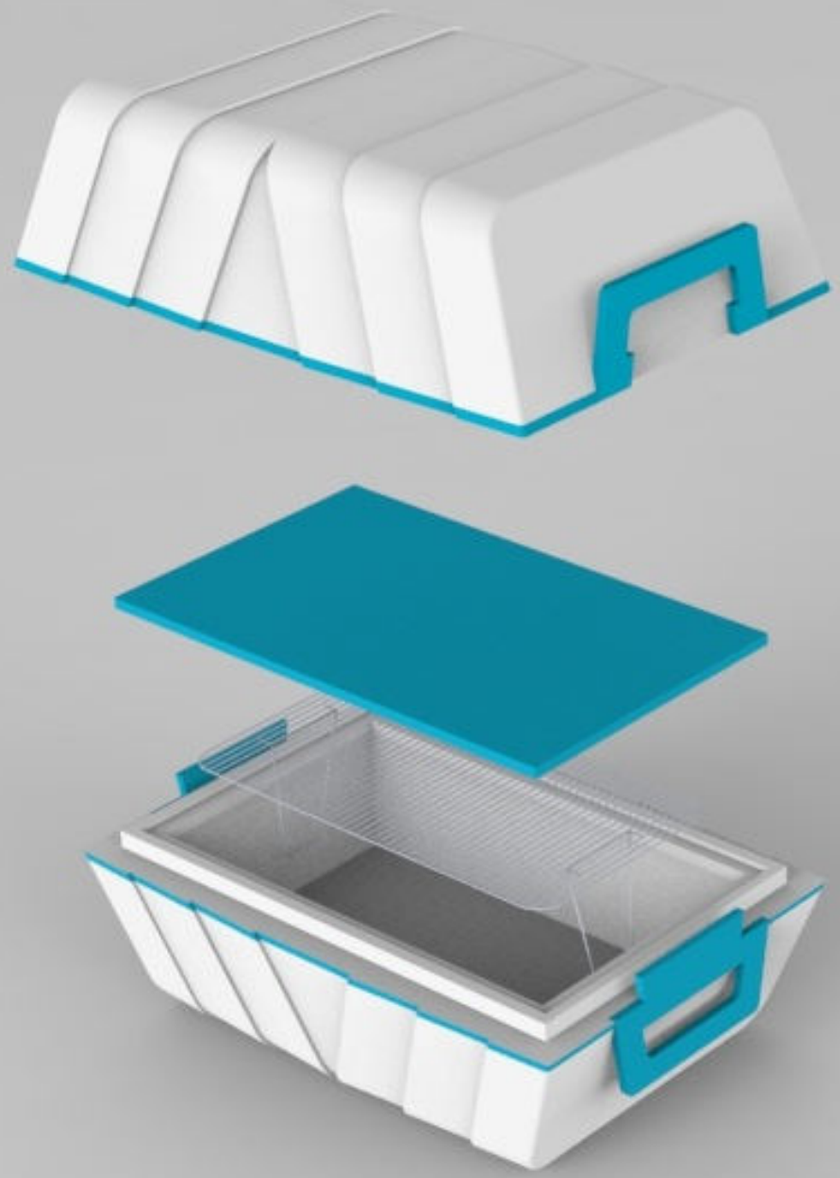


Context :

Rural household kitchen:
The form of the product goes with the corners and shelves of general kitchen room.
The pr oduct holds the symanitcs of existing ice boxes and kitchen utilities.

Iteration II:





Thank You