
Product Design Project II

REDESIGN OF USER INTERACTION FOR AIR DEFENSE SYSTEM

By

Ameya S. Naik

Roll No. 07613001

Project Guide:

Prof. B. K. Chakravarthy

Co-guide:

Mr. Mukesh Bopalkar

Larsen & Toubro Ltd., Powai.

Submitted in the partial fulfillment of the requirement of the post-graduate degree of
Master of Design in Industrial Design

**INDUSTRIAL DESIGN CENTRE,
INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY
November 2008**

Approval sheet

The Product Design Project II

REDESIGN OF USER INTERACTION FOR AIR DEFENSE SYSTEM

By

Ameya S. Naik

Roll No. 07613001

is approved for the partial fulfillment of the requirements for
the post-graduate degree of

Master of Design in Industrial Design at

**Industrial Design Centre,
Indian Institute Of Technology, Bombay**

Guide.....

Co-guide.....

Chairperson.....

Internal examiner.....

External examiner.....



Abstract

The role of industrial design in development of defense systems has taken on tremendous importance in past few years. India has grown from just another developing country to a fast emerging superpower. With this growth, the need for better defense mechanisms has also grown. India is making efforts in developing indigenous defense programs. In 1983, the Integrated Guided Missile Development Program (IGMDP) was formed with the aim of achieving self-sufficiency in missile development & production and today it comprises of five core missile programs. Akash is one of them.

With development of more and more such systems there has been realization to the need of addressing the issues related to effectiveness and efficiency of these systems. The crux of these issues lies in the efficiency of the interaction of the system with its user. This magnified the need for better interactive systems at the disposal of the user to communicate with the defense systems.

Also these systems are highly potential targets for enemy attacks. This has given rise to the need for better and effective protection systems.

This project is about achieving better & effective user interaction and protection for the system. It aims at developing a foolproof system that can serve the nation for years to come.

Acknowledgements

There are many people whose assistance helped me in this project and I would like to thank them all.

Firstly, I thank Prof. B. K. Chakravarthy, my project guide for all his time and suggestions which helped at every stage of the project. I also thank him for his initiative in making this project happen.

I want to thank my co-guide Mr. Mukesh Bopalkar from Larsen & Toubro Ltd. for his expertise and experience in developing defense systems.

I would also like to thank the Dept. head Mr. A. T. Ramchandani for providing me the opportunity to work on such esteemed project.

My sincere thanks to everyone in Technology & Product Development Centre and Defense Electronics Dept. from L&T

Many thanks to Abhishek Prasad who, shared his time and gave me valuable inputs throughout the project.

Finally, I thank my family for their patience and support in whatever I have done till date.

Ameya Naik
IDC, IIT Bombay.

Index

Approval Sheet	
Abstract	i
Acknowledgements	ii
1. Introduction	1
1.1 The Project Objective	1
1.2 Need for the Project	2
2. Data collection and Research	3
2.1 About the Project	3
2.2 Larsen & Toubro	4
2.3 Akash Missile Program	8
2.4 The Launch System	10
2.5 Preliminary Data Collection and Research	12
3. Design Insights & Analysis	17
3.1 User Profile	17
3.2 Concern Map	18
3.3 Design Insights	19
3.4 Project Brief	20

4. Section A: User Interaction Panel	23
4.1 Introduction	23
4.2 Design Brief for Control Panel	24
4.3 Operator Console (OC)	26
4.3.1 Study of existing OC and its GUI	27
4.3.2 Colour Scheme for GUI	29
4.3.3 OC Layout and GUI	31
4.4 Control Panel Layout	33
4.4.1 Study of existing Control Panel layout	33
4.4.2 Ideation	35
4.4.3 Concept Generation	41
4.4.4 Concept Evaluation	44
4.5 Control Panel Mounting & Assembly	45
4.5.1 Mounting of Control Panel & Modules	45
4.5.2 Ideation of cross-section for assembly of modules	48
4.5.3 Initial Concept Generation	50
4.5.4 Module Concept Evaluation	53
4.5.5 Final Concept	54
4.5.6 New Module Layouts	58
4.5.7 Final Control Panel Layout	60
4.5.8 Dust Protection and fascia	63
4.6 Single Operator Console (OC)	64
4.7 Ergonomics while using the Control Panel	67
4.7.1 Design insights	67
4.7.2 Design solutions	68

5. Section B: Protection of the Launcher by Camouflaging	72
5.1 Camouflaging of Defense System	72
5.1.1 Thermal Imaging	72
5.1.2 Radar Imaging	72
5.1.3 Visual Imaging	73
5.2 Design brief for camouflaging	74
5.3 Technology Analysis	76
5.3.1 Thermal Camouflaging	76
5.3.2 Radar camouflaging	78
5.3.3 Visual camouflaging	78
5.4 Ideation & Concept generation	80
5.4.1 Cluster 1	81
5.4.2 Cluster 2	85
5.4.3 Cluster 3	91
5.4.4 Cluster 4	95
5.5 Camouflaging Concept Evaluation	101
5.6 Concept Refinement	102
5.6.1 Stage 1	102
5.6.2 Stage 2	106
5.7 Final Concept	108
5.7.1 Concept Rendering	108
5.7.2 Structural details	109
5.7.3 Procedure for Deployment of MSN	110

5.7.4 Technical specification	112
5.7.5 Features	114
6. Conclusion	115
6.1 Final Design	115
6.2 Challenges and Limitation	117
6.3 Future Scope	118
6.4 Learning	119
References	120

1. Introduction:

1.1 The Project Objective:

The project aims at redesigning the user interaction of the control panel of the surface to air missile launch platform. The Launch platform is to be used as a delivery system for Akash Missile. The system being a life critical defense mechanism the safety and security of the system and its users is very important. The project also looks at camouflaging the launch platform for protection from detection by all types of imaging systems.

1.2 Need for the Project:

Larsen and Toubro Pvt. Ltd., has developed a complete working prototype of the air defense system. As this system is based solely on the functionality of various intermediate systems, its end user is personnel of scientist level from '*Defense Research and Development Organisation*' (DRDO) and the expert technicians from '*Larsen & Toubro*'. Hence it is very cumbersome and difficult for the actual end-user, who will be a service level jawan, to operate this system.

As the system is part of the nation's defense mechanism its safety and security is an important aspect. Hence there is also a need to protect the system by camouflaging it against all types of imaging technologies like radar, thermal and photography.

Thus the single basic need, for L&T to take up this project is to make the Air Defense System effective, safe and secure for the new user to use.



2. Data collection and Research:

2.1 About the Project:

In order to identify the lacunae it was necessary to understand the purpose and the background of this project. The development of Akash Missile Program has been taken up by Defense Research and Development Organisation (DRDO). The implementation of the Akash Air Force Launcher has been taken up by Larsen & Toubro. After development of the first version of the launcher, requirement to address several issues related to the usage of the system were identified by the designers at L&T. The user interaction and the camouflaging aspect of the project are taken up by Industrial Design Centre, IIT Bombay.

The basic information about the project was available from the designers and technicians at Larsen & Toubro. Larsen & Toubro being an engineering giant made the availability of data, access to technology and acceptance of design inputs an easy task.



2.2 Larsen & Toubro:

L&T was founded in Bombay (Mumbai) in 1938 by two Danish engineers, Henning Holck-Larsen and Søren Kristian Toubro. Both of them were strongly committed to developing India's engineering capabilities to meet the demands of industry.

Beginning with the import of machinery from Europe, L&T rapidly took on engineering and construction assignments of increasing sophistication. Today, the company sets global engineering benchmarks in terms of scale and complexity.

Larsen & Toubro (L&T), headquartered in Mumbai (Maharashtra) is a technology-driven engineering and construction organisation and one of the largest companies in India's private sector. It has further interests in manufacturing, services and Information Technology. The evolution of L&T into the country's largest engineering and construction organization is among the most remarkable success stories in Indian industry.

Larsen & Toubro Limited (L&T) is a technology, engineering, construction and manufacturing company. It is one of the largest and most respected companies in India's private sector. Seven decades of a strong, customer-focused approach and the continuous quest for world-class quality have enabled it to attain and sustain leadership in all its major lines of business. L&T has an international presence, with a global spread of offices. A thrust on international business has seen overseas earnings grow significantly. It continues to grow its overseas manufacturing footprint, with facilities in



China and the Gulf region. The company's businesses are supported by a wide marketing and distribution network, and have established a reputation for strong customer support. L&T believes that progress must be achieved in harmony with the environment. A commitment to community welfare and environmental protection are an integral part of the corporate vision.

A strong, customer-focused approach and the constant quest for top-class quality have enabled the company to attain and sustain leadership in its major lines of business. It has established an international presence, with a global spread of offices. A thrust on international business across the last few years has seen overseas earnings growing to 18 per cent of total revenue. With factories and offices located around the country, further supplemented by a comprehensive marketing and distribution network, L&T enjoys an image and equity in virtually every district of India. Its signature of excellence is evident on several projects:

- The world's largest Continuous Catalyst Reactor
- World's largest Tubular Reactor for a petrochemical plant
- The world's largest Fluid Catalytic Cracking Regenerator
- The world's longest Product Splitter
- The world's longest LPG pipeline
- Asia's highest Viaduct
- The first to offer electrical distribution products & systems engineered for tropical environments
- India's first indigenous Hydrocracker Reactor
- India's first open sea jetty
- India's biggest Offshore Oil Platform
- India's longest Coal Conveyor
- India's widest range of Low Tension Electrical Switchgear



- World's longest gas pipeline
- World's longest coal conveyor
- Building an international class football stadium in 260 days
- World's largest coal gasifier made in India and exported to China

Operating Divisions:

- Engineering & Construction Projects (E&C)
- Heavy Engineering (HED)
- Engineering Construction & Contracts (ECC)
- Electrical & Electronics (EBG)
- Machinery & Industrial Products (MIPD)
- Information Technology & Engineering Services

Heavy Engineering (HED):

L&T's Heavy Engineering Division has established a reputation in global markets for quality products. The Division manufactures & supplies custom designed & engineered critical equipment & systems to the needs of core-sector industries and the defense sector. It is the preferred supplier of equipment for a select range of products, globally.

L&T has state-of-the art manufacturing facilities, which are capable of meeting the challenges of technology, quality conformance and delivery, while ensuring cost competitiveness.





The manufacturing plants are among the top fabrication facilities in the world with processes streamlined to achieve high efficiency and benchmarked to the latest technologies.

Defense: L&T has licenses for manufacture and supply of a wide range of defense products, after the Government of India's decision to open up Defense production to the private sector. The licenses issued to L&T cover design, development and construction / manufacture of warships, submarines, weapon platforms & launchers, field & air defense guns, anti tank weapon systems, missiles, rockets, torpedoes, land / naval mines including associated systems and subsystems, RADAR, SONAR, sensors, armored and combat vehicles, airborne assemblies, systems and equipment for aircraft, helicopters and UAV, etc.

Current Product Range: Naval Marine Systems, Naval Combat Systems, Army & Air Force Products, Defense (Army, Navy & Air Force) Strategic Electronics, Complete Naval Units, Radars, Advanced Composite Products for various Defense applications.

The department: Technology & Product Development Centre (Special Projects) – This department carries out design and development activities for projects in the Defense, Nuclear Power, and Aerospace sectors. All kind of design (2D, 3D and analysis of the design) is accomplished at this centre that is well equipped with a range of software and prototyping facilities. The department works closely with the Defense Electronics Department in the development of multi-disciplinary defense systems.



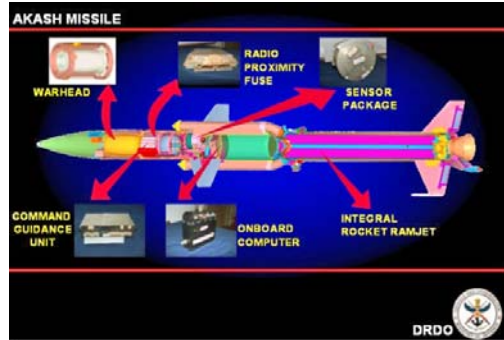
2.3 Akash Missile Program:

Akash (Sanskrit: "Sky") is an indigenously developed Indian medium range surface-to-air missile by the Defense Research and Development Organisation (DRDO) as part of the Integrated Guided Missile Development Program.

Akash is an all weather area air defense weapon system for defending vulnerable areas against medium range air targets penetrating from low, medium and high altitudes. The system is designed to neutralize multiple aerial targets attacking from several directions simultaneously. The system is autonomous and its operation is fully automated. It operates in conjunction with the Rajendra surveillance & engagement radar.

This system will replace the SA-6 / Straight Flush in Indian service and is also expected to be integrated with the S-300V (SA-10 Grumble) low-to-high altitude SAM in an integrated air defense system to counter SRBM / IRBM threats along the Pakistani and Chinese borders. The missile can target aircraft up to 25 km away; at altitudes up to 15,000 m.

Type	Supersonic Surface to Air Missile
Place of origin	 India
Production history	
Development & Mfg.	DRDO
Produced	1990

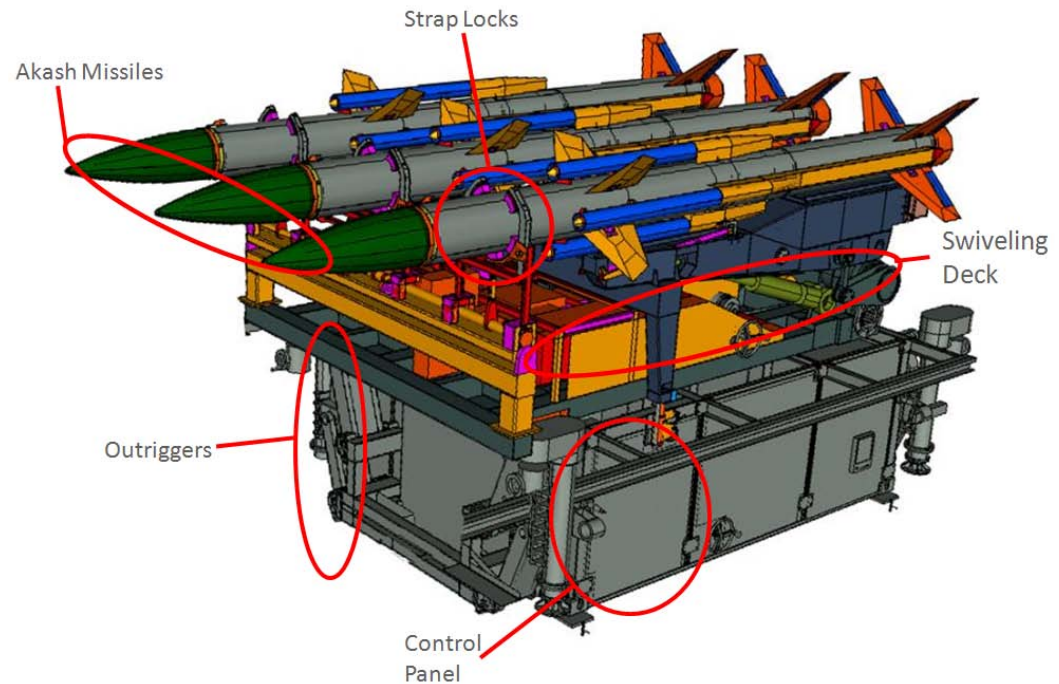


Specifications	
Weight	720 kg
Length	5.78 m
Diameter	0.35 m
Warhead	55 kg Fragmentation warhead
Detonation mechanism	Radio proximity fuse
Engine	Booster + Integral Ram Rocket (IRR) solid propulsion
Operational range	25 to 30 km
Flight ceiling	15 km
Speed	Mach 2.8 to 3.5
Guidance system	Command Guidance
Launch platform	BMP-1, T-72, Tatra chassis



2.4 The Launch System:

Akash Air Force Launcher (AAFL) is developed as a launch platform for surface to air missile for self defense purpose. The launcher remains stationary once deployed. The Launcher is to be deployed near an air-base and is never meant to enter the battlefield. The launcher can be completely remotely operated and the firing of the missiles happens only through the Command Center which is assisted by a separate radar system.



The Launch platform consists of:

Base: This is the housing for all the drive motors, Diesel Generator (DG) Set, Control Panel and all the electronic components. The base also acts as the mounting for the four outriggers which support the entire Launch system.

Outriggers: These are the four arms that are used to stabilize and level the launch platform. They are controlled using DC motors.

Swiveling Deck: This part controls the complete 360° azimuth rotation and 78° elevation for the Akash missiles. It also has strap locks which act as the supports for the missiles.

Control Panel: All the controls, display signals and meters are mounted on the control panel. This acts as the basic interface for the user during training, maintenance and repair.



2.5 Preliminary Data Collection and Research:

This stage started with studying the actual functioning of the Launcher in connection with the separate radar and command centre of the system. The most important part of the Launcher with which the user interacts is the control panel.

The entire procedure from deployment of the launcher to various operation scenarios involving training, regular maintenance, repair and war was studied.

Several insights were identified which involved the system being accessed by several users of different cadre and different skill set. Also the maximum usage of the system is expected to happen during regular maintenance. Though the war situation is a rare possibility all defense systems have to be designed to be foolproof in case a war breaks out. During a war situation the system only needs to be switched ON and then the Battery Command Centre takes control, which is assisted by a battery level radar for tracking and disabling enemy attacks.

2.5.1 International Scenario:

The current international scenario boasts of very varied and advanced surface to air missile (SAM) defense programs.

The major nations leading this race are USA, Russia and Western Europe which includes superpowers like France, Germany, Italy, UK and Sweden. Also countries like Israel have their own independent program.



Patriot Missile, USA



SPYDER, Israel

Some of the major programs are:

Patriot Missile Air Defense System, USA:

This is the most famous Air Defense Program and also one of the most advanced program accepted world over. Similar to AAFL even this missile has a separate and dedicated Launch system and uses continuous tracking system to help maintain the missile on its right path once fired.

Patriot missile systems were deployed by US forces during Operation Iraqi Freedom. The systems were stationed in Kuwait and successfully destroyed a number of hostile surface-to-surface missiles using the new (Patriot Advanced capability) PAC-3 and guidance enhanced missiles.

As well as the USA, Patriot is in service in Egypt, Germany, Greece, Israel, Japan, Kuwait, the Netherlands, Saudi Arabia and Taiwan.

SPYDER (Surface-to-Air Python 5 and Derby) Air Defense Missile System, Israel:

This program is as close as it can get to the Indian Akash Program. Very similar to Akash even this defense system consists of four mobile firing units and one command control unit with a radar having capability of multiple (60) target tracking. It is said that SPYDER was selected by Indian Army in June, 2006 and a battery of 18 systems is required.



Starstreak, UK

Starstreak Close Air Defense Missile, United Kingdom:

This is a very flexible missile system developed in Northern Ireland. It can be fired from an armoured vehicle, Apache helicopter, shoulder launcher, light-weight multiple launcher as well as a self propelled vehicle. It is a very compact and adaptive system. It has been in service with the UK defense since 1997.



Pantsyr, Russia

Pantsyr S1 Air Defense Missile / Gun System, Russia:

Pantsyr-S1 (Pantsir) is a close-in air defense system designed to defend ground installations against a variety of weapons. It has two independent guidance channels - radar and electro-optic – that allow two targets to be engaged simultaneously with maximum engagement rate of 12 targets a minute.

Other than Russia this system services many countries like UAE, Jordan and Syria.

Other than these several other missile systems like ADATS, Canada; Avenger, USA; Spada, Italy; etc were studied to understand the various user interfaces, advanced technologies in use and the industry benchmarked systems in the air defense sector.



Agni and Prithvi missiles

2.5.2 Indian Scenario:

Though Rockets were invented in medieval China (Circa 1044 AD), they were first used in India from 1750 AD to 1799 AD by Haider Ali & Tipu Sultan against British forces.

After India gained independence in 1947, Professor Vikram Sarabhai, an able visionary, gave shape to modern Indian rocketry and space program along with Dr. Abdul Kalam.

In 1983, the Integrated Guided Missile Development Program (IGMDP) was formed with the aim of achieving self-sufficiency in missile development & production and today it comprises of five core missile programs:

- Nag, an anti-tank guided missile
- Prithvi, a surface-to-surface battlefield missile
- Akash, a swift, medium-range surface-to-air missile
- Trishul, a quick-reaction surface-to-air missile with a shorter range
- Agni, an intermediate range ballistic missile, the mightiest of them all

The program has given India the capability to produce indigenous missiles in other key areas as well. Indigenous development was required to overcome attempts by Western nations, to impose their will on developing nations, by enforcing pacts like the Missile Technology Control Regime (MTCR) to control access to and availability of advanced weapon systems. Undaunted, hats off to all the brilliant Indian scientists who have toiled so hard in their dedicated efforts to make the program successful and being on the cutting edge of missile technology.

2.5.3 Technology:

The latest technologies doing service in most of these advanced air defense programs involve complete automatic controlled systems. Also the programs are developed being developed to be flexible to serve all the three wings of defense: military, navy and air force.

Also protecting the system and safety & security of the crew operating the system has been addressed to a large extent. The systems are being made more easy to use by implementing technologies for high power imaging systems and accurate target hitting to increase efficiency and avoid damage to civilian property. The efficiency of the system depends on how easy and foolproof the system is to use.

Also with advancement in tracking systems, there has been fair amount of improvement in the camouflaging systems. Mostly these camouflaging systems are being implemented on mobile systems which will operate in the battlefield during a wartime scenario. There are not many stationary launch systems equipped with complete camouflage cover as these systems do not enter main battlefield and positioned as strategically safe locations. But it has been realized that in future warfare scenario these systems can be easy targets for enemy attacks. Also the huge costs involved in developing these systems and their strategic importance in neutralizing enemy attack have made these systems worthwhile to be given maximum camouflage cover. Developing camouflaging cover for these systems is relatively easy owing to their stationary deployment and lesser space constraints.

3. Design Insights & Analysis:

This phase started with trying to identify and address issues related to the user interaction and issues critical from the safety of the user and the system.

3.1 User Profile:

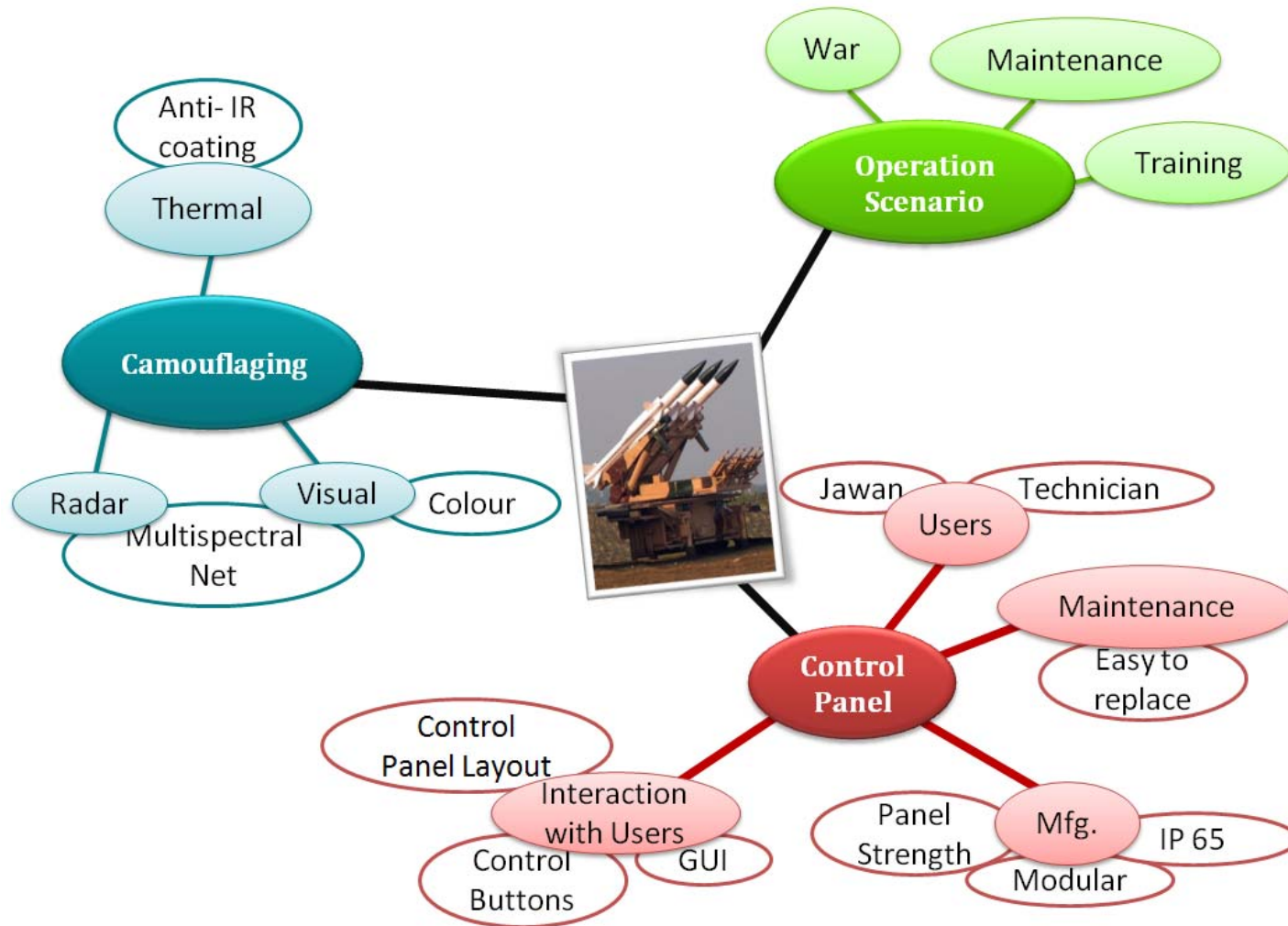
- **Primary User :**

He is a service level Jawan in Air Force. He is generally 10th or 12th pass and has very little technical knowledge. It is assumed that he has received certain amount of formal training in operating this system and few similar systems. He is expected to perform certain maintenance operations on regular basis and report the result to his superiors.

- **Secondary Users**

These users are the people who will be involved in repair work. This comprises of engineers and technicians from Indian Air Force (IAF) and L&T. Scientists looking after the update of the system also come under this category of users.

3.2 Concern Map:



3.3 Design Insights:

Following were the design insights derived from the concern map:

Control Panel:

- To refine the GUI of the operator console.
- To refine the control panel layout for better user interaction.
- To refine the control panel modules for ease of maintenance and assembly.
- To study the operating procedure of the Launcher and identify the anomalies.

Camouflaging:

- To design a Camouflaging system for the Launcher to minimize visual, radar and thermal signature of the launcher.

3.4 Project Brief:

Following is the project brief considering the insights derived from the concern map:

Core Benefits:

The project aims at developing a clean and intuitive interface for the user with the system. The project addresses the issues related to manufacturing of the control panel for the harsh environment of desert region. There is a need to address the issues regarding operation scenarios of War, Regular maintenance & Training and Repair considering user convenience of prime importance.

The system being an Air Defense System, the project answers the need of protection of the system by camouflaging mechanism against visual, radar and thermal imaging.

The USP of the project is the development of:

- An intuitive and clear interface from the point of view of user convenience and thereby keeping the system foolproof.
- Protection of the air defense system from all kinds of imaging using camouflaging

User Profile:

Here the primary user is the service level Jawan in Air Force. He is generally 10th or 12th pass and has very little technical knowledge. It is assumed that he has received certain amount of formal training in operating this system and few similar systems. He is expected to perform certain maintenance operations on regular basis and report the result to his superiors.

The secondary users are the people who will be involved in repair work. This involves engineers and technicians from Indian Air Force (IAF) and L&T. Scientists looking after the update of the system also come under this category of users.

Limitations:

One of the needs for the project is to redesign the system for a new user. The earlier system was designed considering technicians as the primary user. The new user will be a service level Jawan with very little technical knowhow and will be required to be trained to use the launch system. This being the first version, the specific users of the launch system are not available.

Other challenge is accessibility of the user. Information regarding the user is available through the technicians and engineers in L&T.

Maintenance & Repair:

The launch system will be deployed near an air base in the desert region of Rajasthan. The basic operation scenarios are battle (war), Regular maintenance & Training and Repair. Its maximum usage is when it is under regular maintenance & training which generally happens every week. Hence it is necessary that the system is not cumbersome to maintain.

It is necessary that correct and sequential procedure is followed during the maintenance. This involves checking of various interlocks and the motors.

Very minor repairs are carried on-site and hence will require few power outlets. The repair work is done by a technician from IAF with requisite knowledge. In case of failure the entire module should be replaceable and the faulty module be taken to a lab.

Modular Design:

For ease of maintenance and repair the modules on the control panel needs to separate and replaceable without removing other modules. As quite a few modules are manufactured by L&T and few as per DRDO specification, their ease of assembly is critical. These modules have push buttons and toggle switches for input. Introducing modularity aims at addressing the problem of easy removal for maintenance and servicing.

Safety:

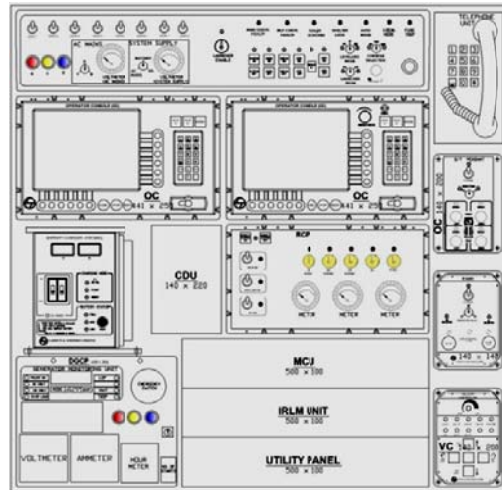
The safety of the product and user is of utmost importance. Protection to the system is provided by a camouflaging system designed for quick removal.

The interface is designed to be intuitive to the user thereby not allowing any error while in operation, and be foolproof.

Thus, the project addresses two important concerns:

Section A: Redesign of the user interface based on the control panel

Section B: Developing a camouflaging system for the Launch system for protection against all types of imaging methods like visual, radar and thermal.

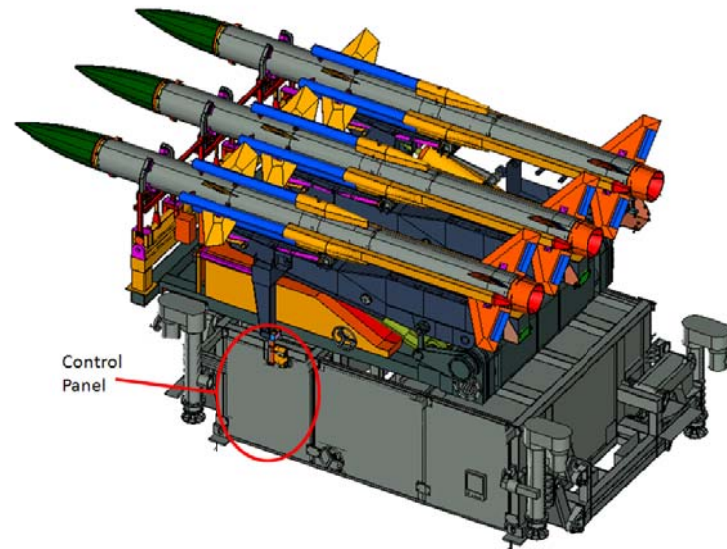


Control Panel

4. Section A: User Interaction Panel:

4.1 Introduction:

The lower section (base) of the launch system houses a user interaction panel (control panel). It acts as the basic interface for the user during training, maintenance and repair. The control panel has various modules fixed vertically and is accessible from outside of the launch system. It has two TFT display units which allow access to all the mechanical controls using a GUI.



IDEAS generated model for the launch system

4.2 Design Brief for Control Panel:

The control panel acts the basic interface between the user and the launch system. The control panel is majorly used during training and regular maintenance of the system. During wartime the launcher is control from a remote location. The performance of the launcher depends on its proper routine maintenance.

The control panel houses certain primary as well as secondary controls. It basically consists of GUI based TFT display unit that performs all the functions that other modules on the control panel perform mechanically. Thus it comprises of two interfaces: GUI based and Mechanical control based.

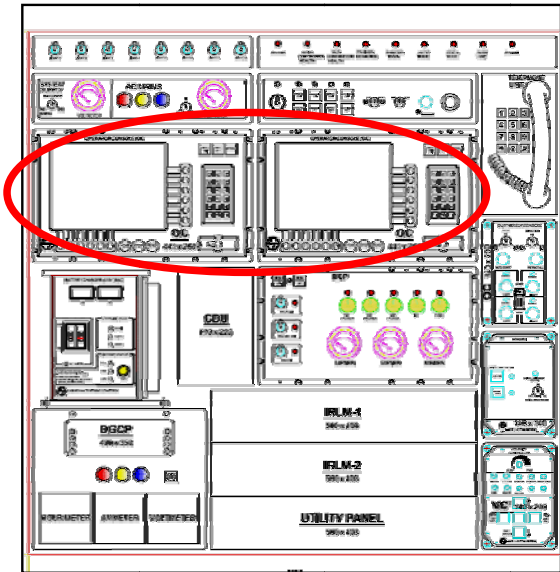
Hence following parameters are critical in the design of the control panel interface:
GUI:

- The GUI should be intuitive to use for the primary user i.e. service level jawan.
- The navigation through the GUI should be easy and predictable.
- Only necessary information should be displayed to the specific user.
- GUI should be expandable for upgrade.
- Colour scheme should not be flashy.

Control Modules:

- The control buttons should be in sequence of operations performed.
- Display units should be separated from control units.
- Units should be positioned depending on their ergonomic requirement.
- All the modules should be easy to assemble and disassemble during repair.
- The modules should be clustered based on the usage of the modules.

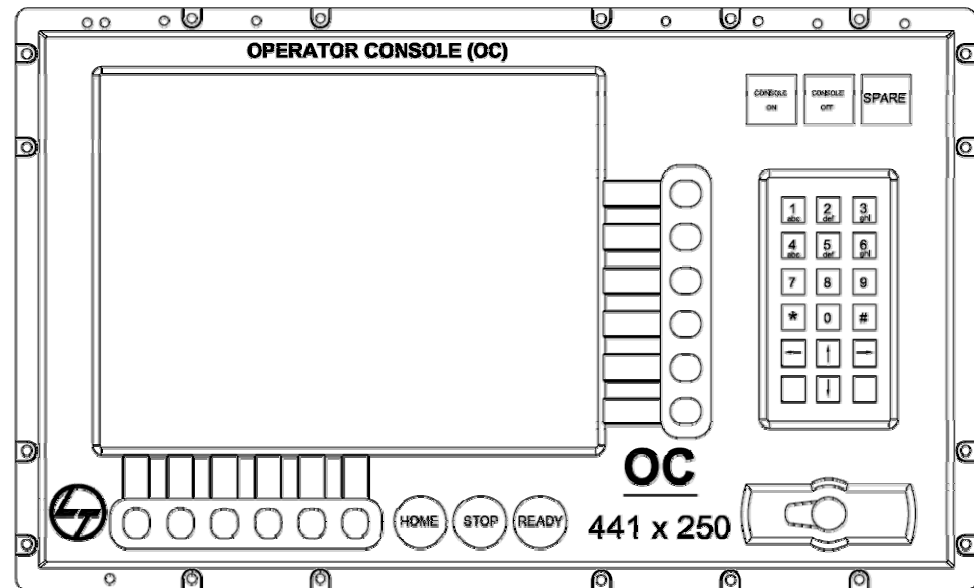
-
- The layout should not look complicated for the primary user and should be arranged to reduce visual noise.
 - The control panel components should be protected from dust and moisture as per IP 65 standards.
 - The eye level of the user should match the distance at which the display unit is placed from the ground



Position of 2 OCs on the control panel

4.3 Operator Console (OC):

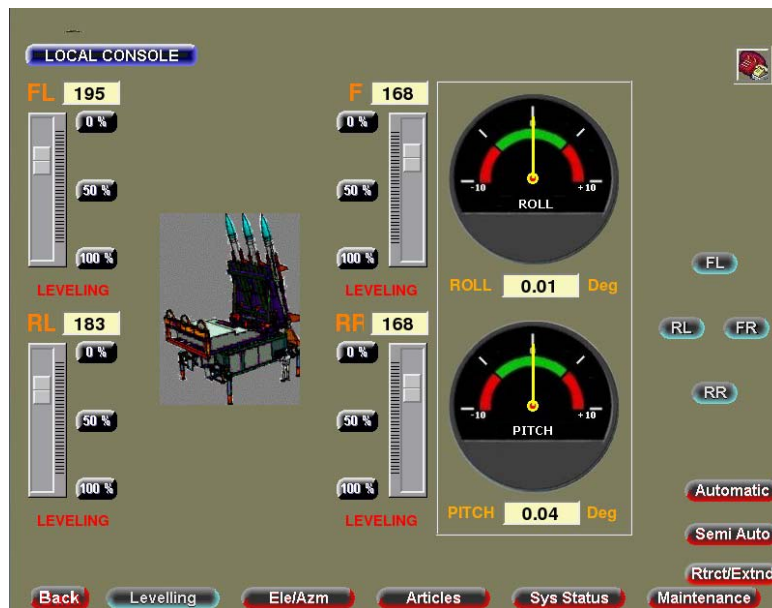
Almost all the operations that can be done manually using various modules on the control panel are available on the OC using a GUI. The OC is the module that will be used for routine maintenance and diagnostics of the system. It basically is a TFT display with buttons to navigate through the GUI and an alphanumeric keypad with navigation key.



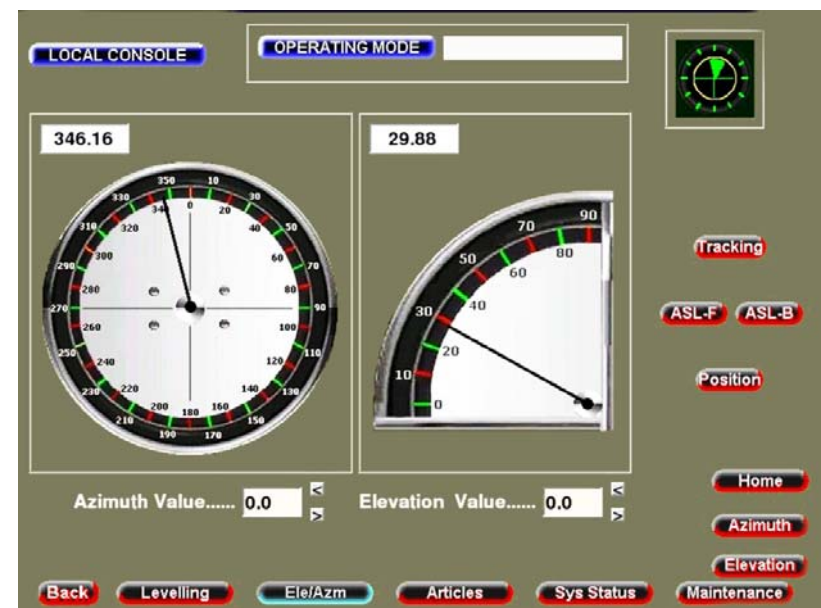
Existing OC with TFT display and control buttons

4.3.1 Study of existing OC and its GUI:

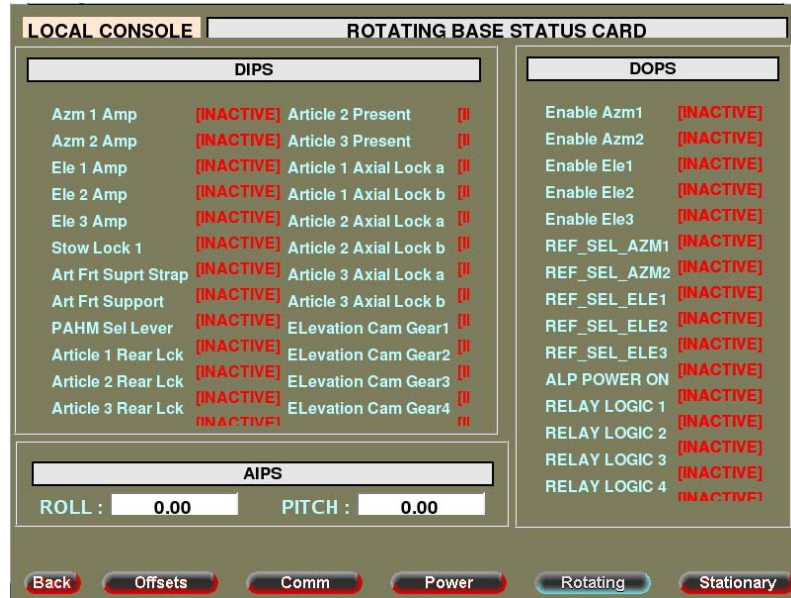
All the existing screens for the GUI were studied trying to understand their actual operation and the type of user accessing it.



Existing GUI showing Leveling mode



Existing GUI showing Elevation-Azimuth mode



Existing GUI showing Rotating mode

After studying the GUI a full scale model of the OC was made for the initial study. While working with the actual size OC, following were the few problems identified.

- The OC was pretty big (441 mm X 250 mm) and had too many confusing keys.
- The screen was barely visible in sunlight.
- GUI was not flexible enough to enable future upgrades.
- GUI had multiple clickable buttons on all screens and for each there was a hardwired physical button on the OC.
- Navigating through the GUI was difficult.
- GUI provided excess information that was of no need and difficult to interpret for the primary user (service level jawan).



Control Panel on external side of the launcher

4.3.2 Colour Scheme for GUI:

The control panel that houses the OC is mounted on the external wall of the lower base of the launcher. As a result this is exposed to sunlight. When direct sunlight falls on the OC display the TFT display becomes unreadable.

Hence, experiments were conducted to check the effect of harsh sunlight on the TFT display. Even though contrasting colours were used it was difficult to differentiate between adjoining buttons and text in harsh sunlight. After doing several experiments it was realized that in harsh sunlight colours were hardly visible, what was visible was their grayscale value.

Hence it was decided that the adjoining colours of the graphics used in the GUI screens should have contrasting colour as well as differing grayscale value. This would help keep the display readable even if direct sunlight falls on the OC.

The results can be seen from the following visuals:

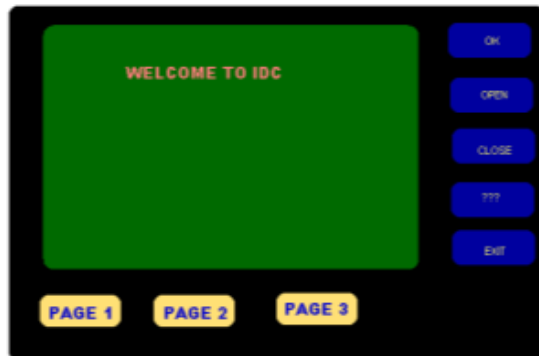


Normal viewing



In harsh Sunlight

Using only contrast colour scheme:



Normal viewing



In harsh Sunlight

Using contrast colour scheme with differing grayscale value:

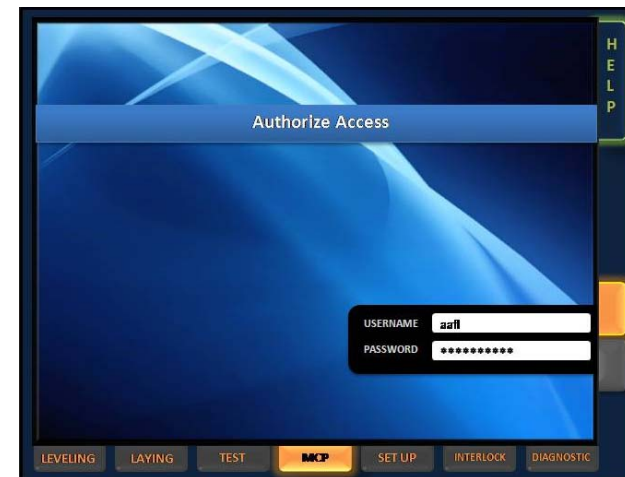
4.3.3 OC Layout and GUI:

After several iterations following was selected as the operating console layout and the GUI.

Also it was decided to have super bright sunlight visible TFT screen.



Few GUI screenshots are as follows:





Scale- 1:20, 95th Percentile Human figure

4.4 Control Panel Layout:

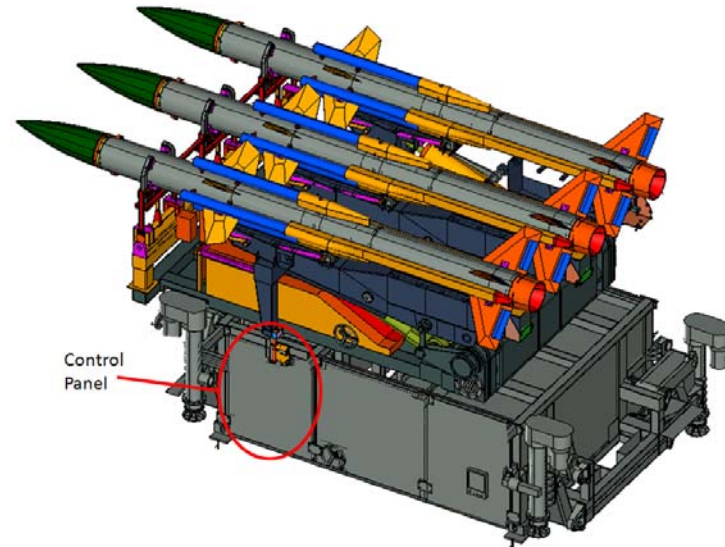
The lower part of the weapon launch system houses the control panel. The control panel has various modules fixed vertically and is accessible from outside of the launch system.

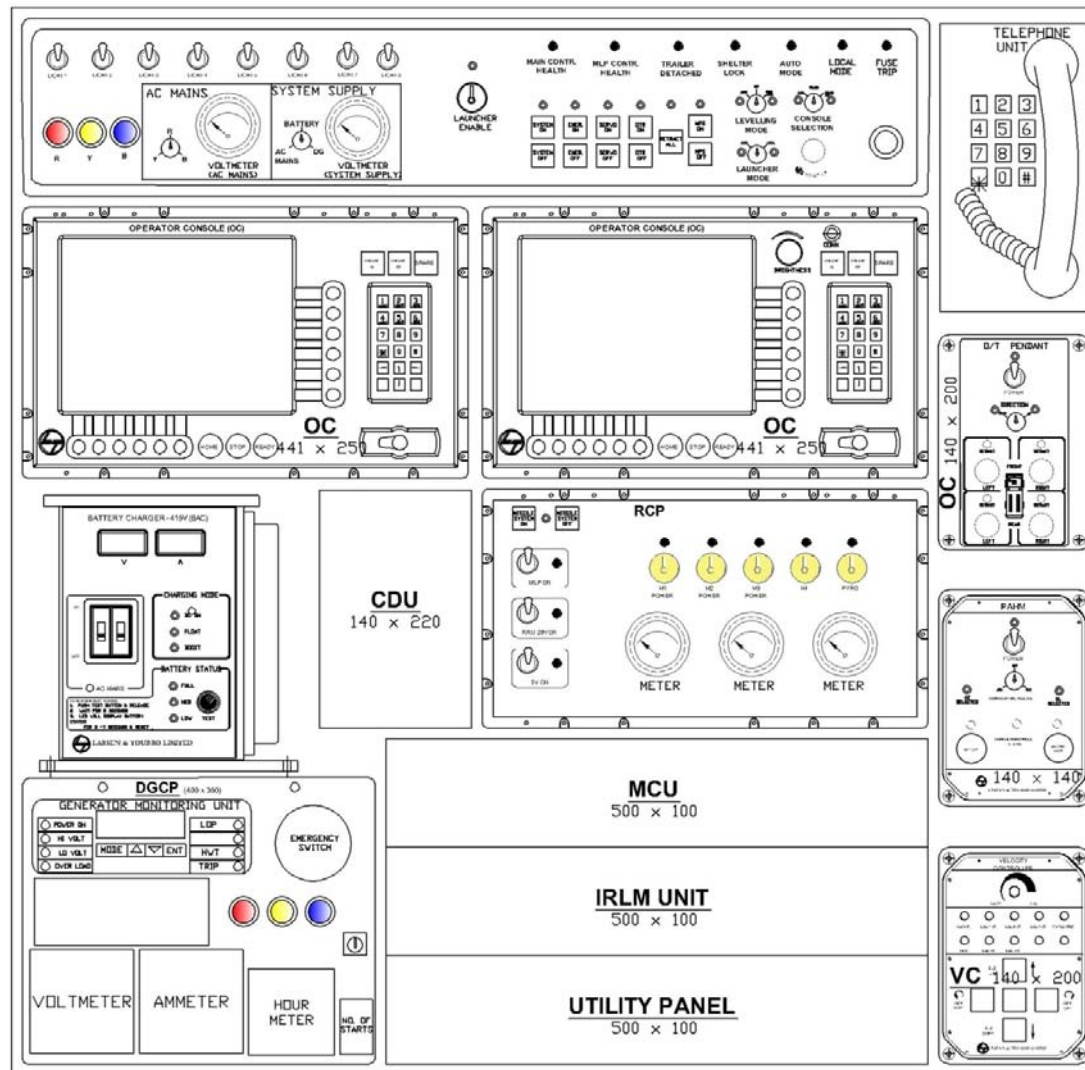
Two layouts of control panel were available:

- Layout suggested by the user (customer).
- Existing layout designed by L&T.

4.4.1 Study of existing Control Panel layout:

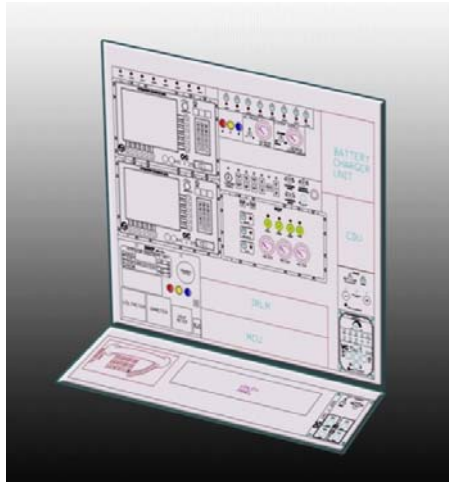
A complete study of the layout including ergonomic placement of various modules and the switches revealed lacunae in the existing layouts suggested by the user (customer) as well as the designers (L&T).





Some of these lacunae were as follows:

- Switches placed above the LCD screen.
- Redundancy in navigation keys on LCD panel.
- Duplication of switches.
- Switches not in order of operation.
- Redundancy in various switches
Existence of mechanical levers as well as electrical switches creating duplication in signals to various mechanisms.
- Unable to read the LCD screen when the Launch system is raised.
- Huge and heavy electronic modules mounted on the panel.
- Confusion in indicator signals.
- Improper placement of the telephone unit.
- No positive locking for the receiver of the telephone unit to stay vertical.



2-stage layout of control panel



3-stage layout of control panel

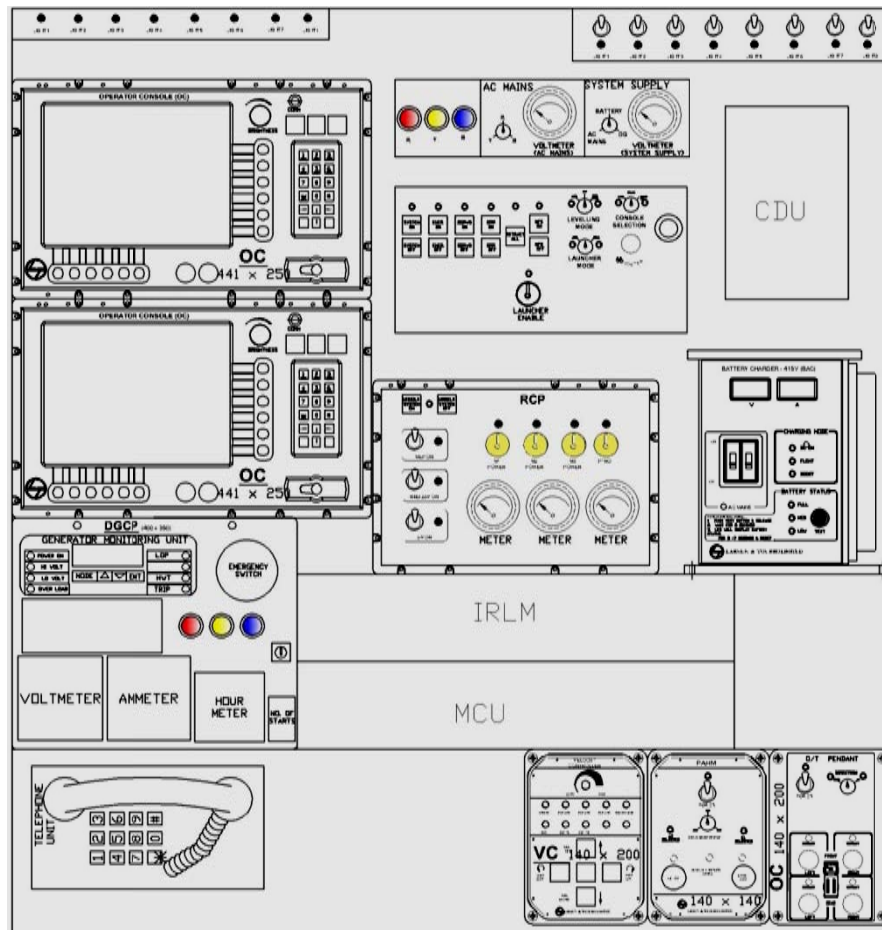
4.4.2 Ideation:

The external dimension of the control panel being limited, hardly any layout using the existing modules and considering ergonomic and operational constraints was possible. As a result the shape of the panel had to be changed all together.

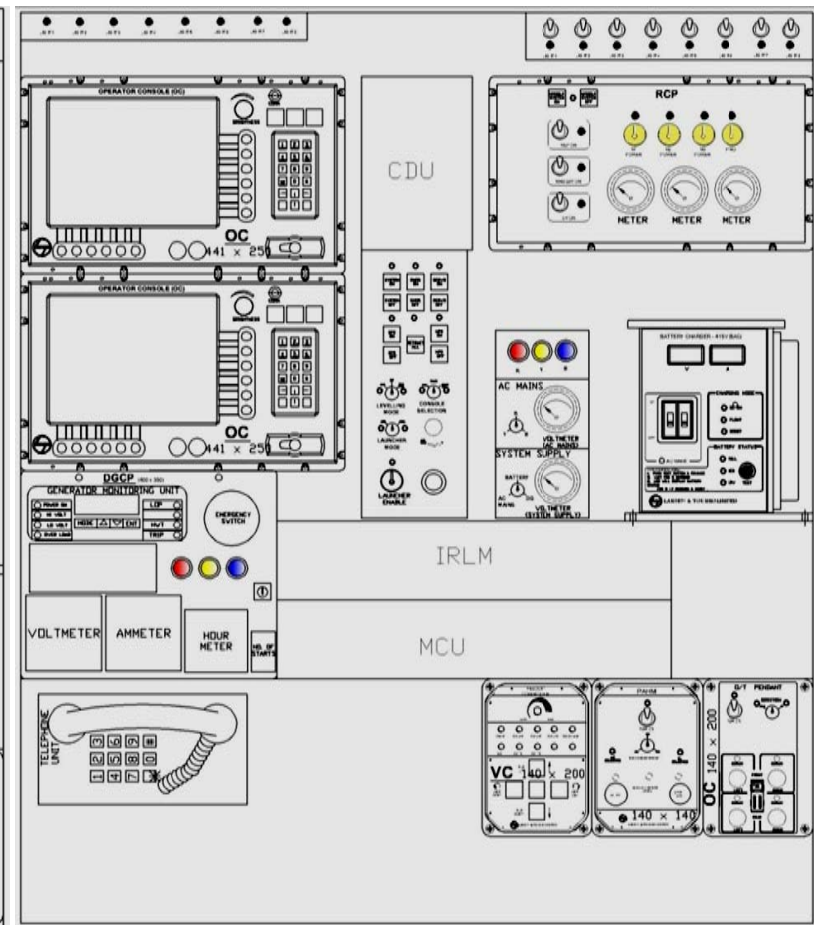
Hence two staged and three staged panel was considered as shown on the R.H.S.

For purpose of generating various layouts, each module was cut from paper and played with in the constrained area.

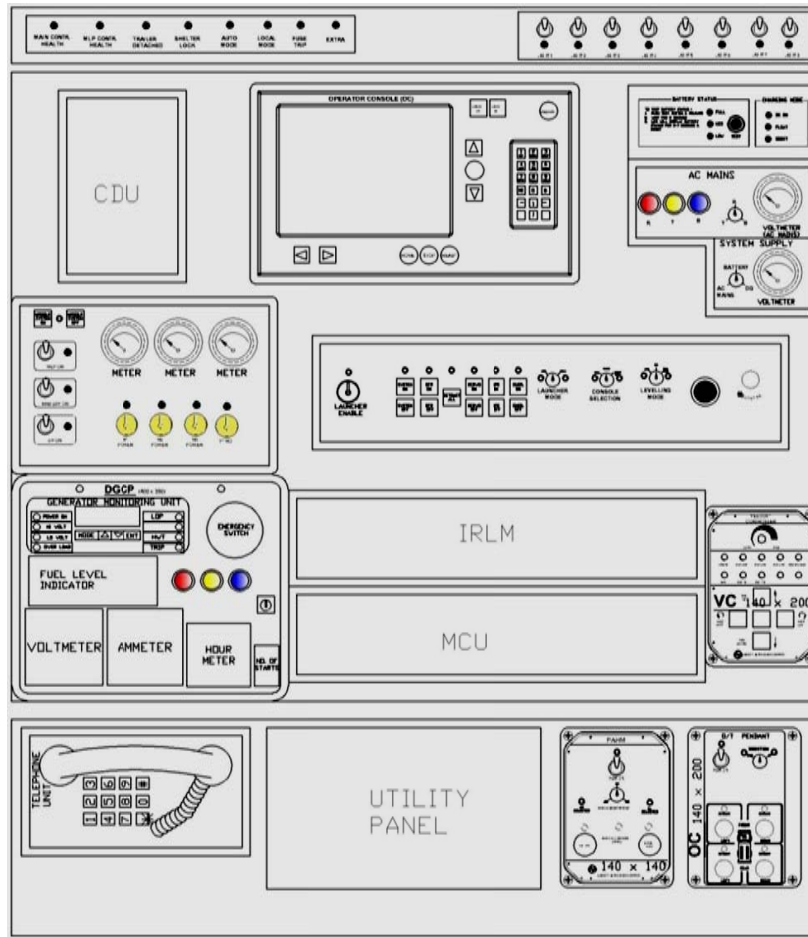
As a result multiple layouts were generated. Few of them are as follows:



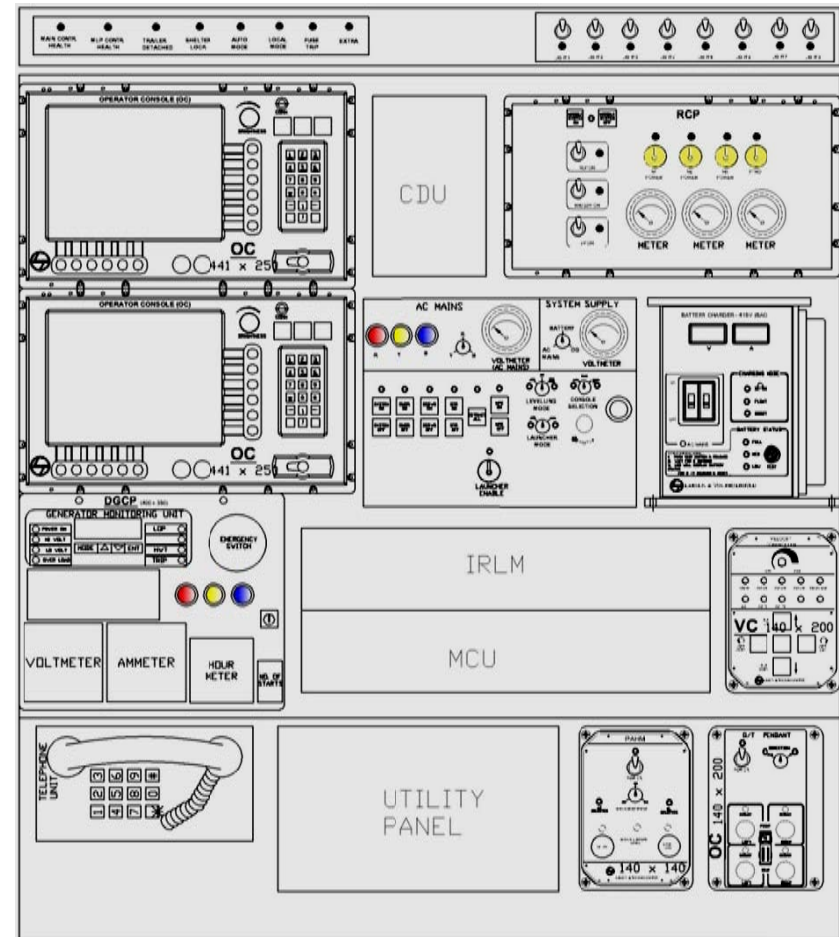
Idea 1: 2-stage layout



Idea 2: 2-stage layout



Idea 3: 3-stage layout



Idea 4: 3-stage layout



Full Scale Exploratory Model:

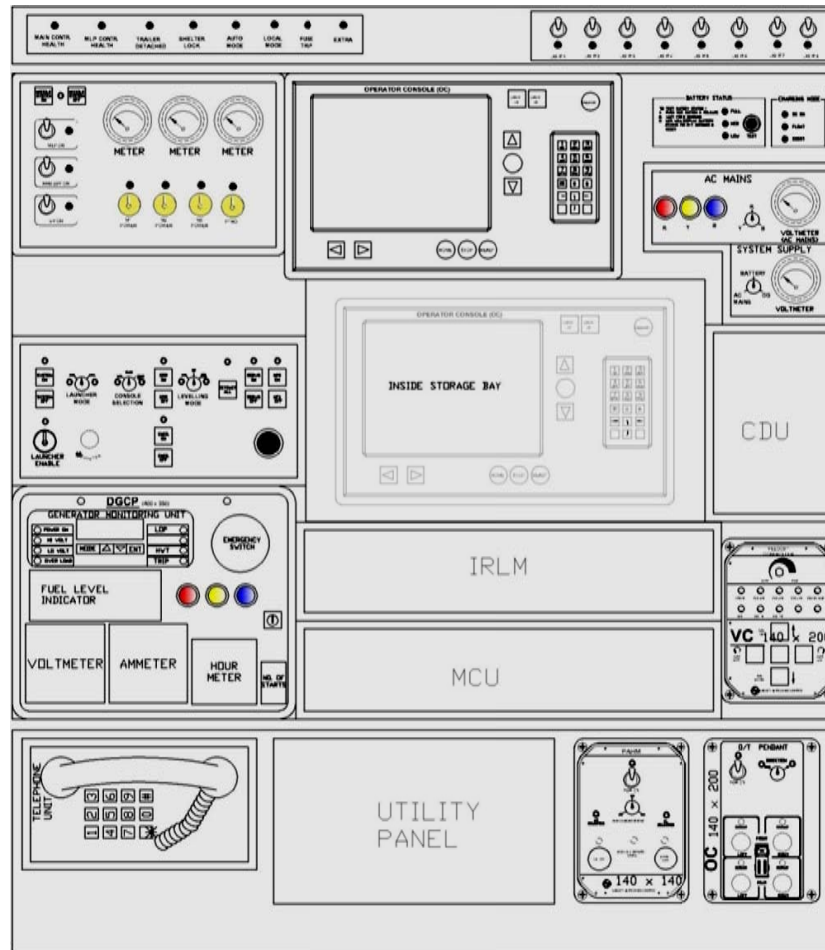
After initial ideation a full scale model of the three stage control panel was made. Also each module was made out of thermacole sheets and their details were pasted in print format to check the functional aspect of the module by enacting their usage but on actual scale.

The previously generated layouts were evaluated based on the ergonomic as well as functional position of each module on the full scale control panel model. Based on the evaluation few more layouts were generated.

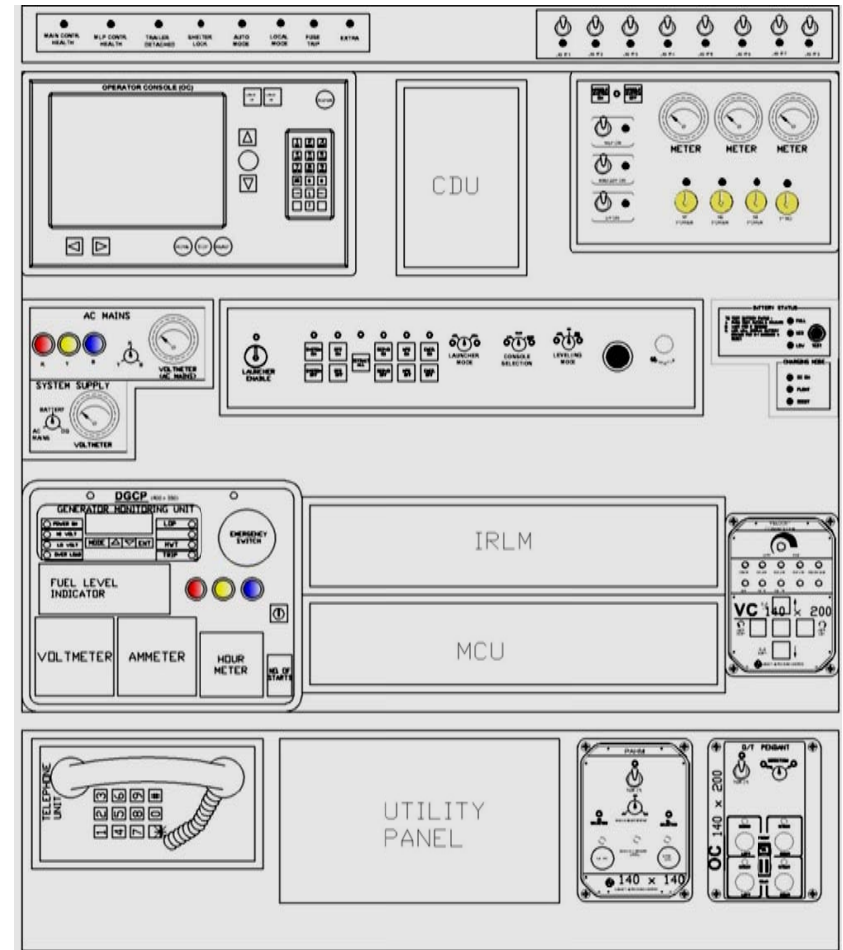
The actual scale of the model gave a better idea of space between the modules and the actual size of various elements making it easy to visualize problems faced while operating the control panel.



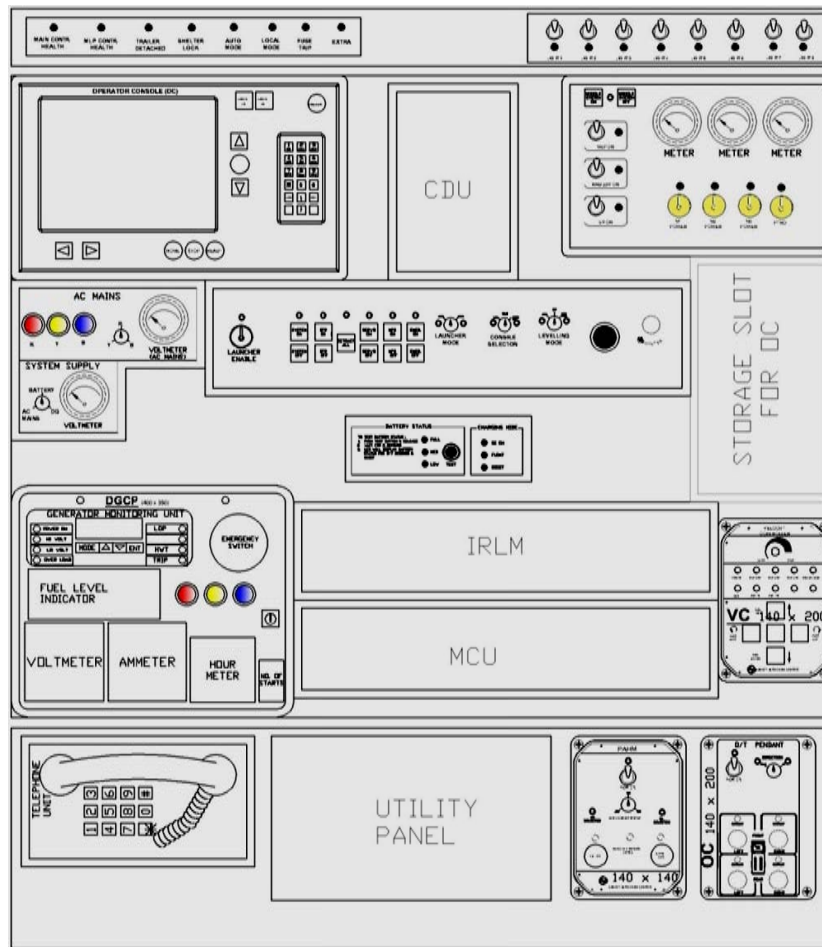
Following were the few layouts generated as a result after evaluating with the full scale model:



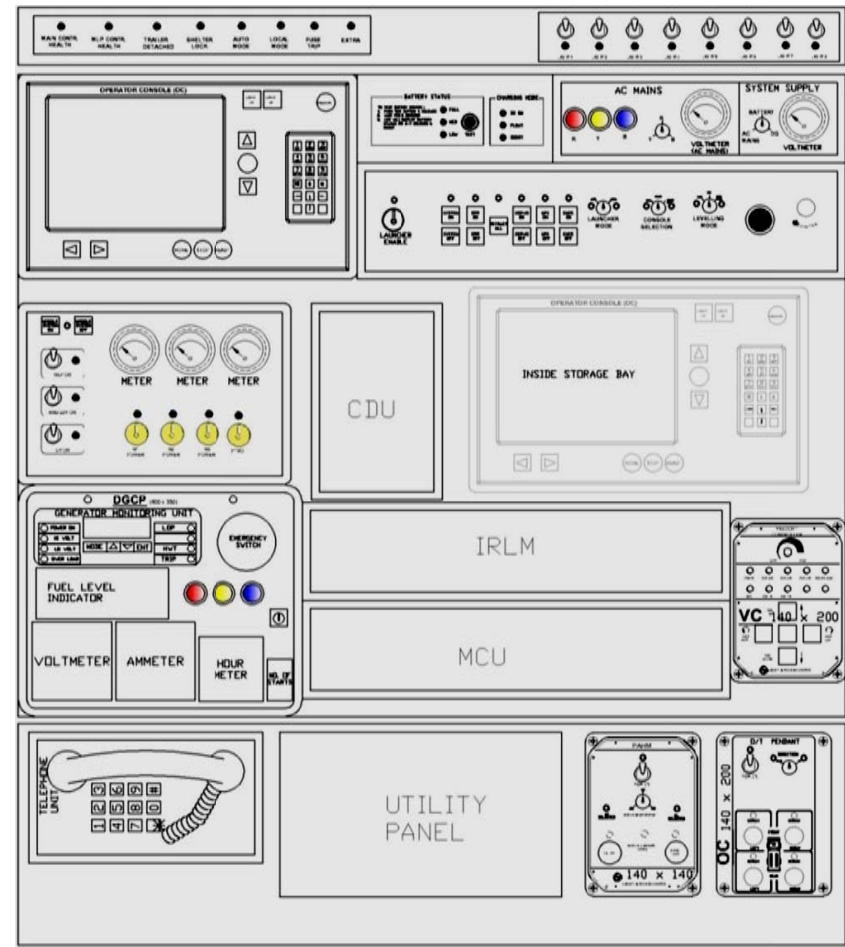
Idea 5: 3-stage layout



Idea 6: 3-stage layout



Idea 7: 3-stage layout



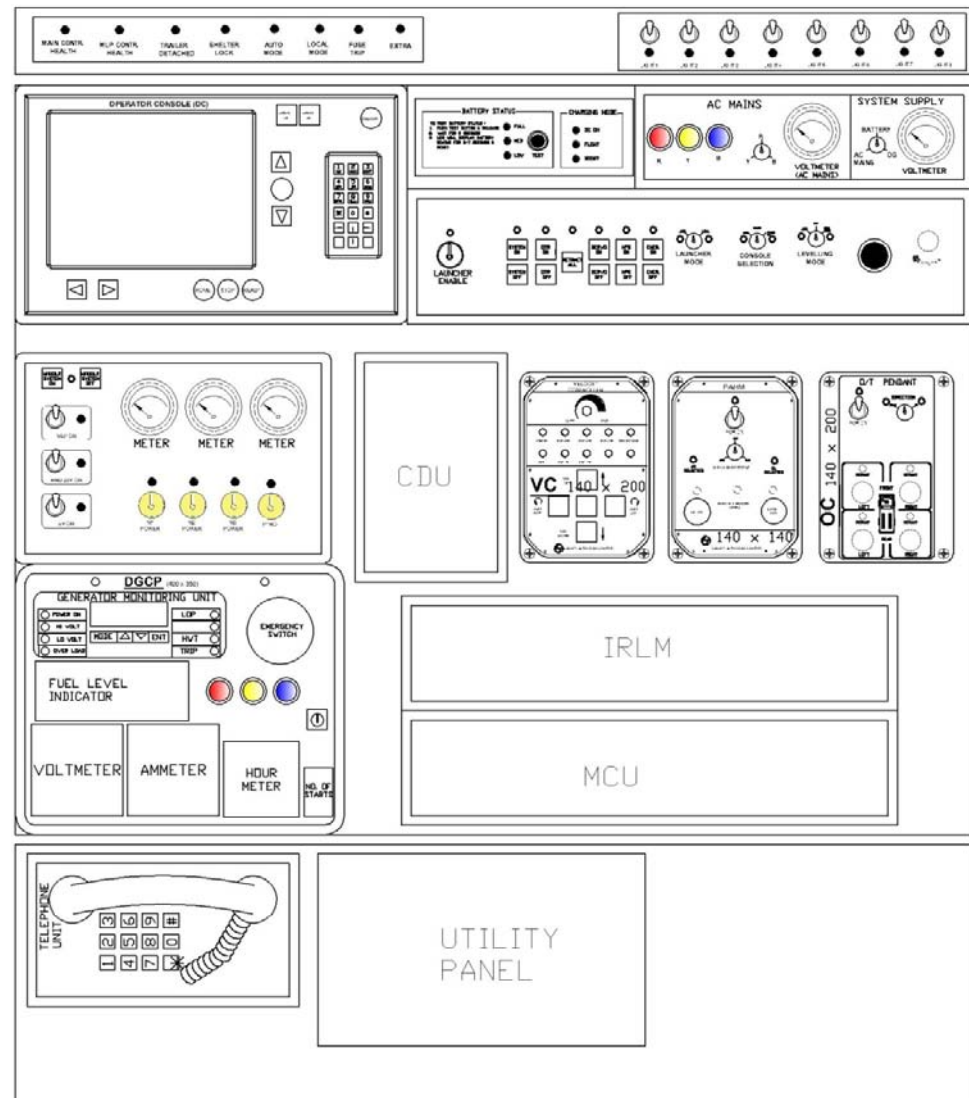
Idea 8: 3-stage layout

4.4.3 Concept Generation:

Following concepts were chosen as the final three concepts based on the ergonomic position and ease of use for the modules each layout having certain functional advantage.

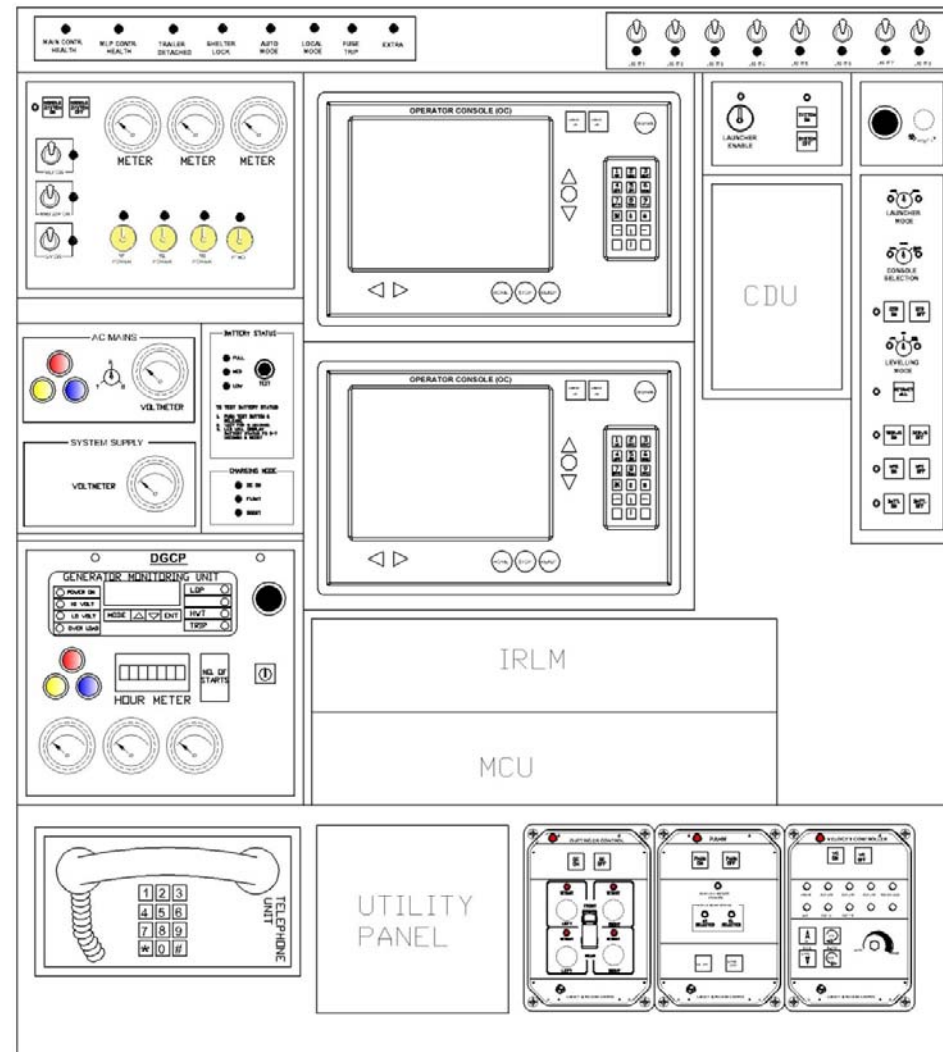
Concept #1:

- Here the second Operator Console (LCD screen) was completely hidden from the user to avoid any confusion, the other display being stored elsewhere in the system.
- Large Space was available on the horizontal panel for keeping the manual, resting the palm during prolonged usage.
- All the display units were placed at the top beside the operator console.



Concept #2:

- Here only one display was visible at a time other being covered by an open able lid but, both the displays were connected all the time.
- The dual display arrangement of one above another made for good use when the launcher had to be raised, as the lower display would still be in line of vision.
- Also the emergency button was shifted to rightmost top corner which is a general norm with such life critical systems.

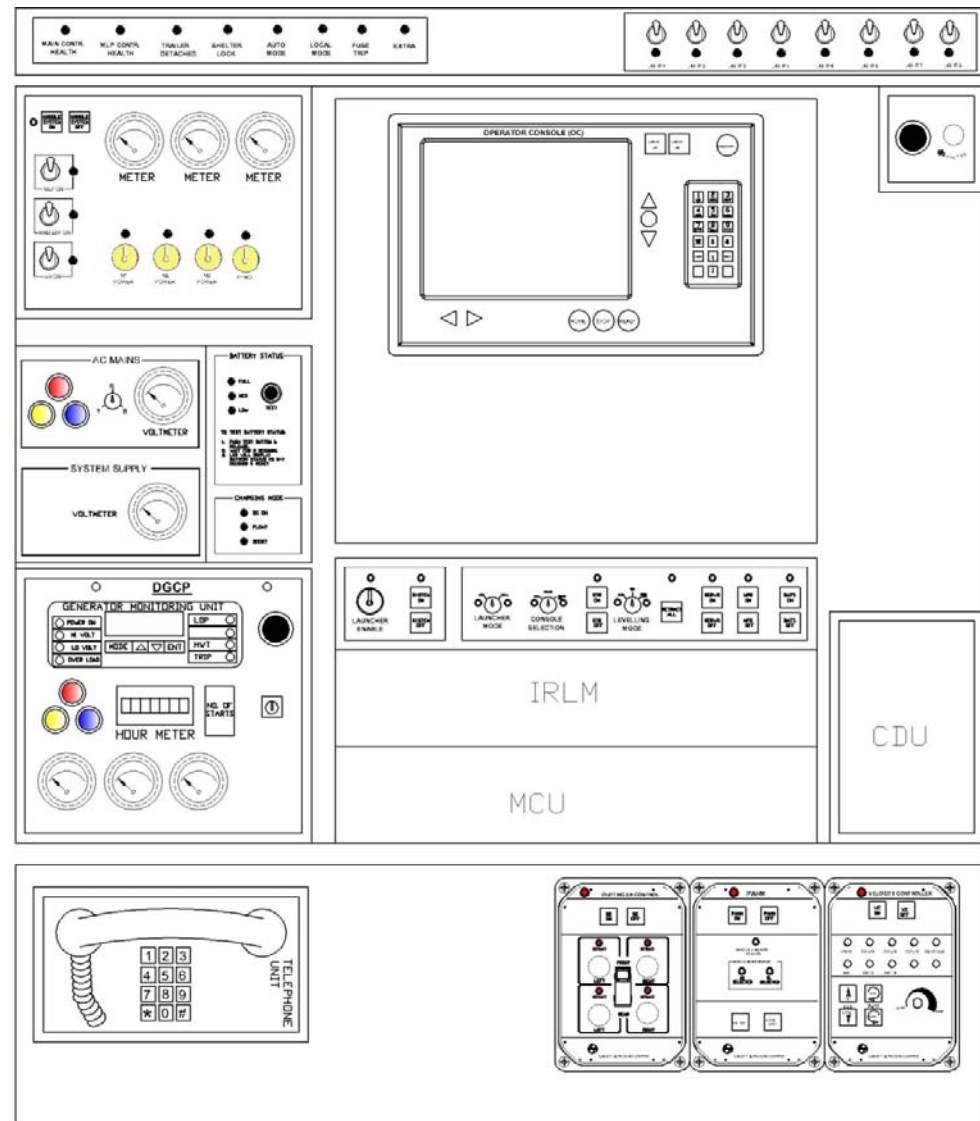


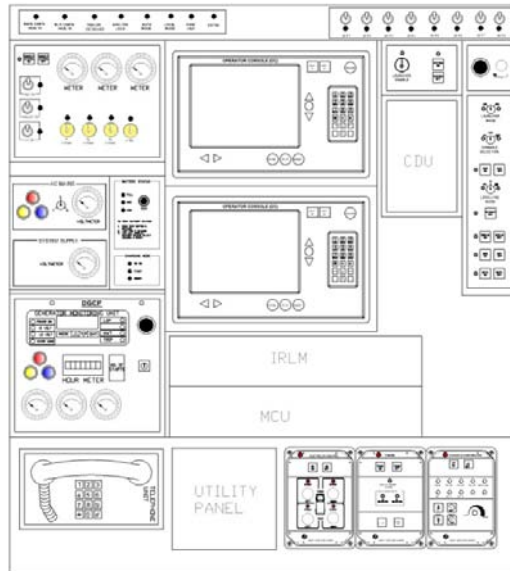
Concept #3:

- Here at any given time only one display would be visible with the other being completely out of sight.
- This would avoid any confusion that may arise due to two displays.
- Also both the displays are hardwire connected and boot with the system simultaneously.



Two OCs one above another





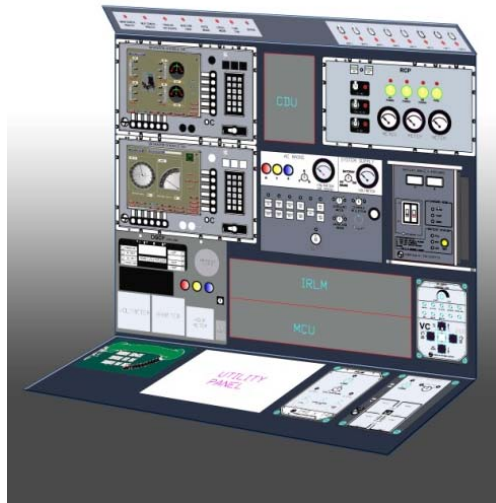
Concept #2

4.4.4 Concept Evaluation:

Out of the three control panel layouts generated concept #2 was selected for following reason:

- Concept #2 had the most optimum layout, unlike concept #1 which had the TFT display unit (OC) at extreme left corner rather than being at centre.
- Centrally located OC made it easy for the user to access the entire control panel without changing his position.
- In concept #1 the auxiliary OC had been placed away from the control panel, and in case of failure of the main OC, it was necessary to remove the main OC, remove its connections and then again connect the aux. OC. This was very time consuming and having an electrically disconnected OC was not acceptable to the DRDO clients.
- Though the aux. OC in concept #3 was hardwired all the time, it was difficult to have so many connectors and entire OC suspended from two points. Also it required a complex door system enclosing the OC not in use. Concept #2 had none of this problem
- Also concept #2 had two OCs vertically arranged enabling users of differing height to use the control panel with ease.

Before working on the refinement of the concept #2, design for assembly of modules was done, thereby deciding the exact space requirements.



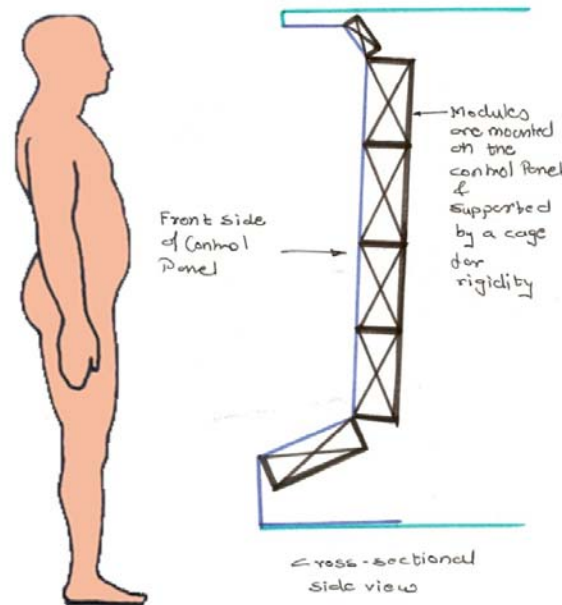
3 stage control panel

4.5 Control Panel Mounting & Assembly:

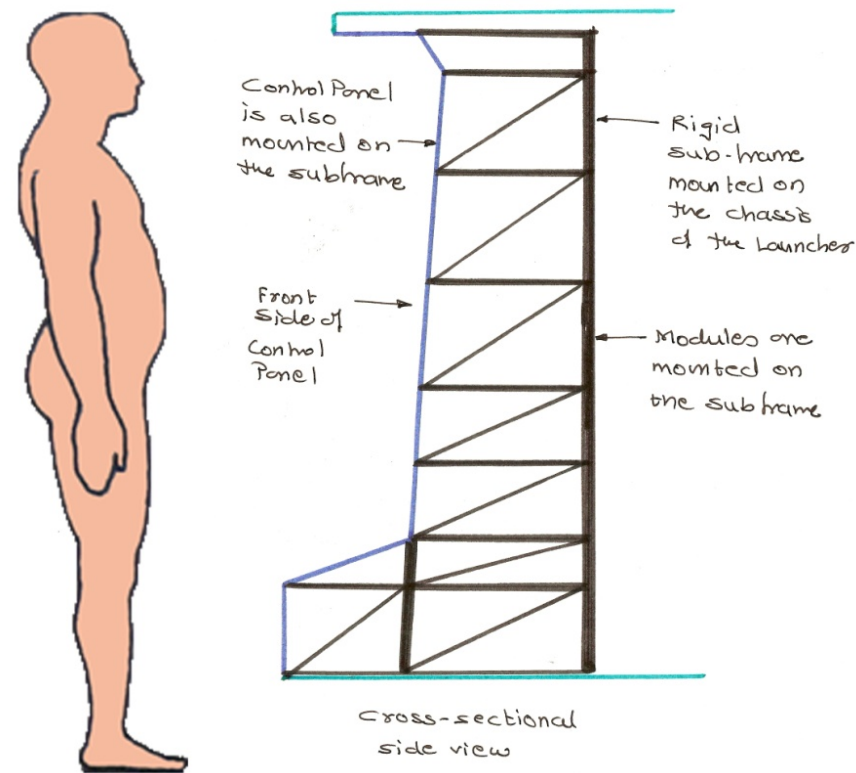
The control panel houses numerous modules which basically act as the interface for the user. These modules have various primary & secondary controls and also have various status signals in form of LEDs and meters. These modules majorly consist of two types of hardware: control buttons & LEDs and electronic circuits comprising of ICs.

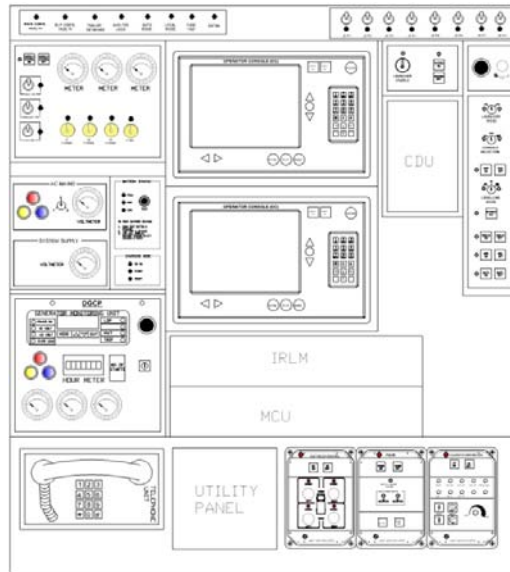
4.5.1 Mounting of Control Panel & Modules:

Initial idea for mounting the modules was to mount all the modules on the control panel itself, the control panel would be fixed on the launcher chassis and would be strengthened by a cross-member cage.



After studying various modules, this method of mounting didn't seem feasible. Various modules like DGCP, IRLM, MCU, etc are very heavy. Also IRLM and MCU module are comparatively very huge (500mm X 500mm X 100mm each). The control panel is not capable of taking such large cantilevered load. Also these two modules require shock mounts. Hence the modules will be mounted on a rigid sub-frame structure. This sub-frame will be mounted on the launcher chassis. The control panel fascia is then mounted on the sub-frame.





Control Panel and old PAHM module

Few modules on the control panel are outsourced by L&T for manufacturing like DGCP, but few like CDU and IRLM MCU are complete bought out items. Also the control panel requires IP 65 standard protection from dust and water.

During usage of secondary controls most commonly used modules are the PAHM, velocity controller (VC) and Outtrigger Control (OT). Their external dimensions are (LXBXD) 200mm X 140mm X 90mm.

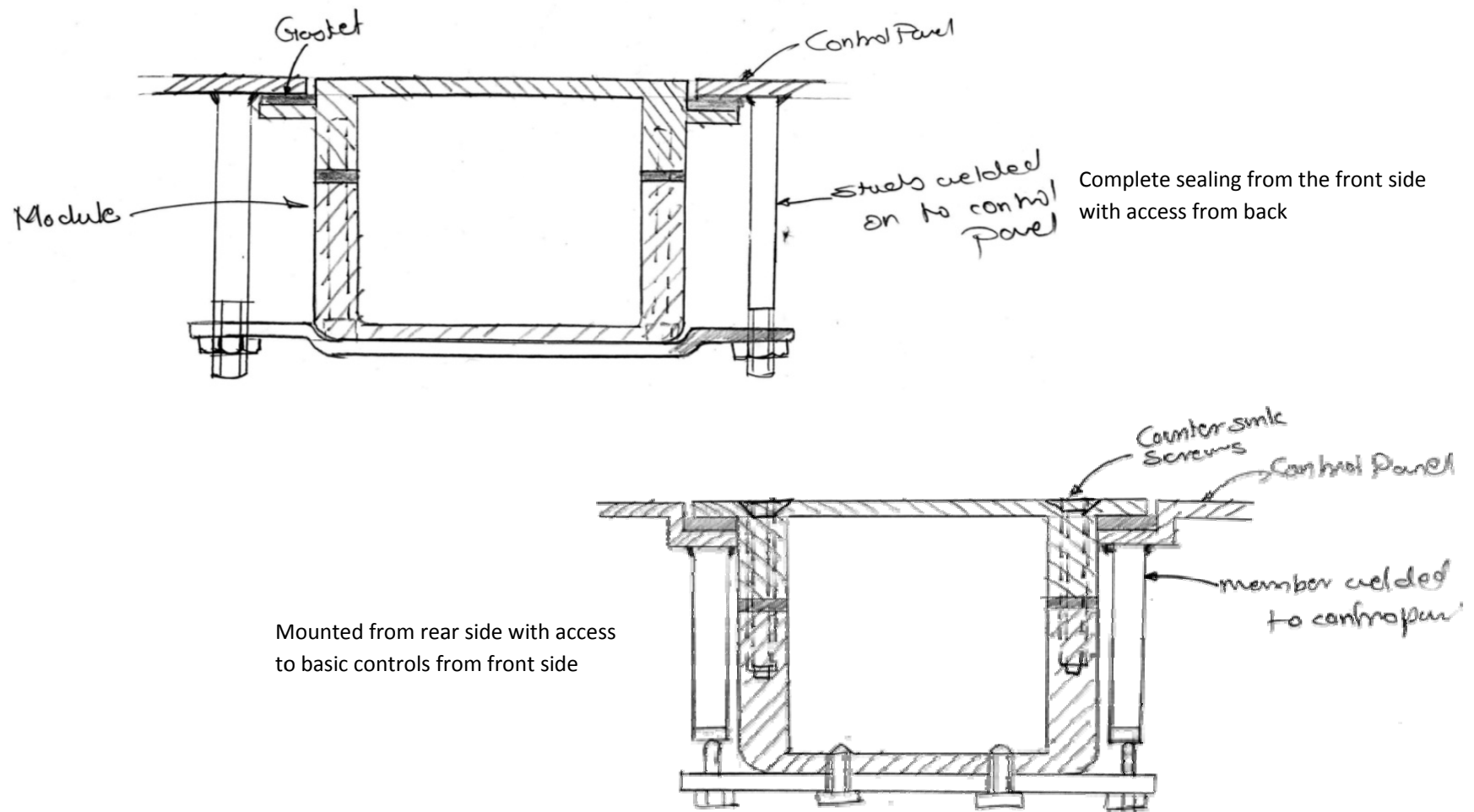
For purpose of servicing and repair these modules need to be removed. This is done by a trained technician and not a service level jawan. Also the repair work happens only in the laboratory and not on-site.

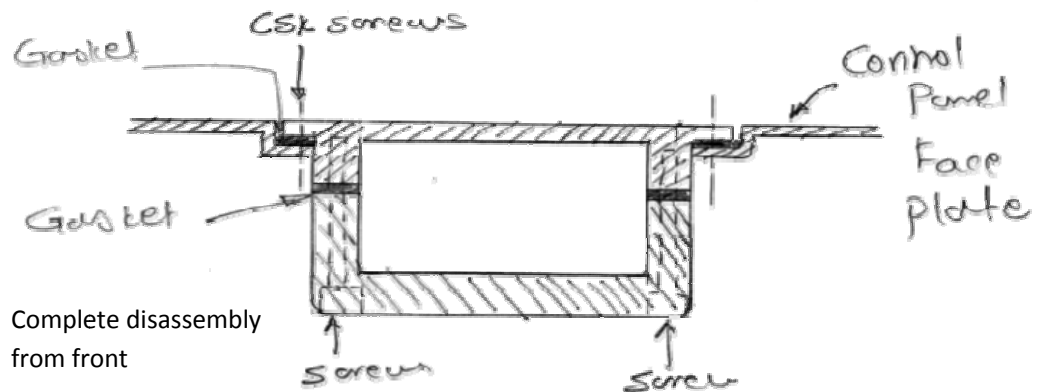
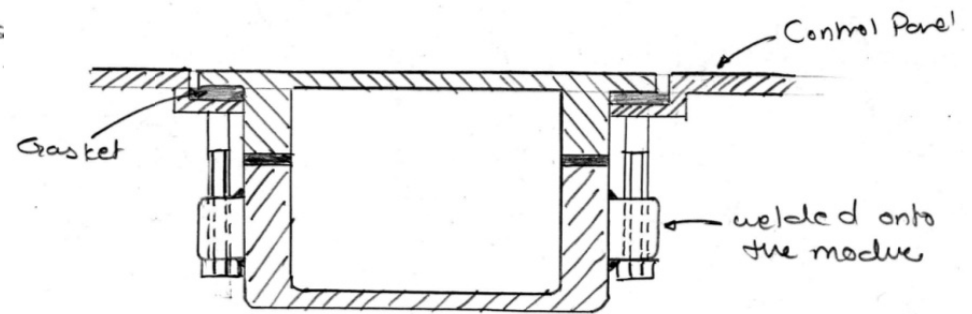
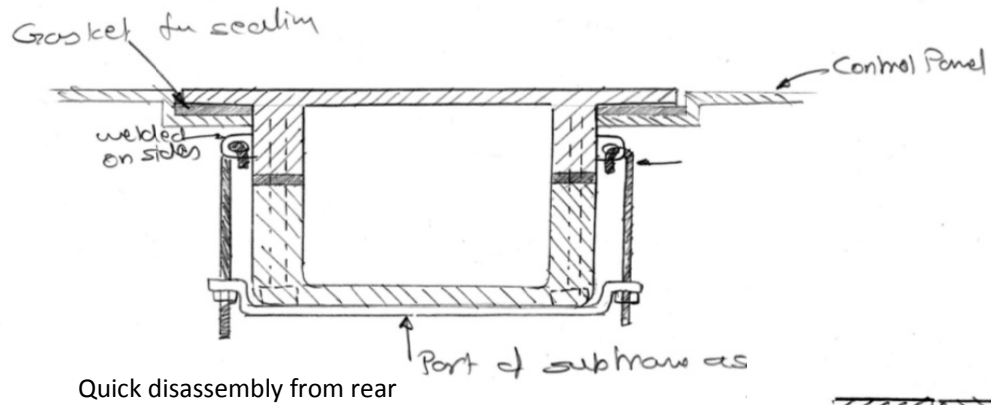
Few lacunae with the existing design of these modules were:

- Lot of space is required around these modules for fixing on the sub-frame.
- Also there was no arrangement to seal the electronic hardware mounted behind the control panel from dust and moisture.
- Also the screws used to fix the parts of the modules were visible on fascia of the control panel spoiling the look of the control panel and adding to the visual clutter.

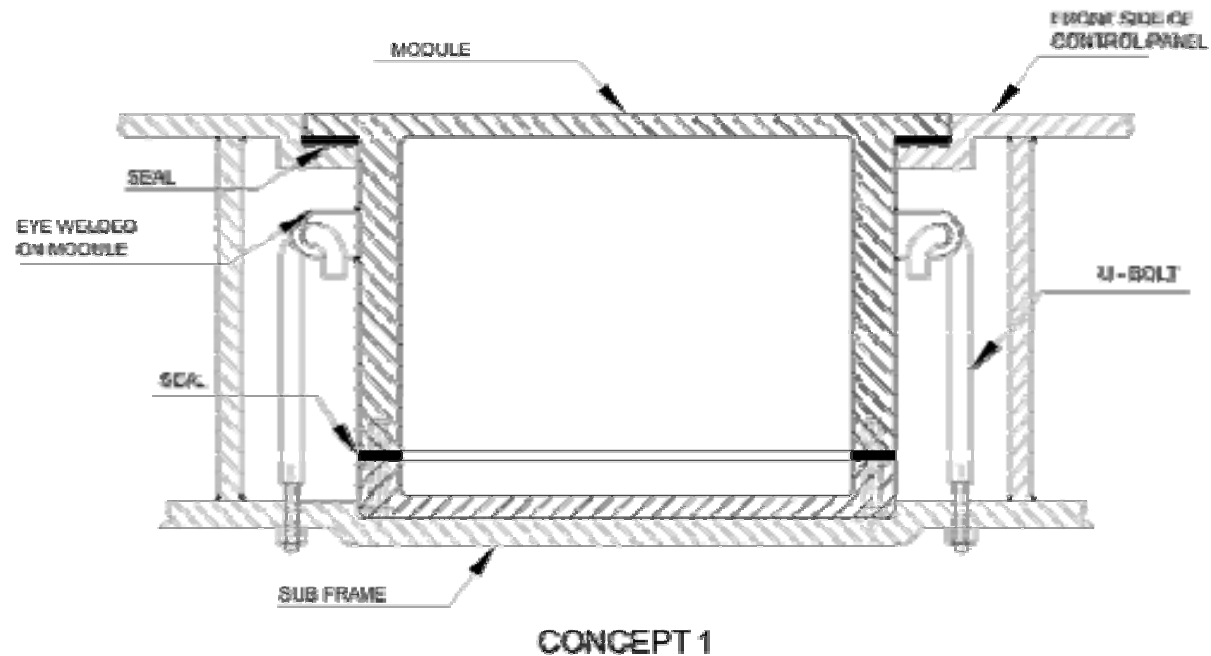
As the basic need was to be able quick and easy maintenance, assembly and removal of the module had to be studied. Hence it was necessary to refine the cross-section of the module. Quick ideation was done to generate ideas to solve the problems.

4.5.2 Ideation of cross-section for assembly of modules:

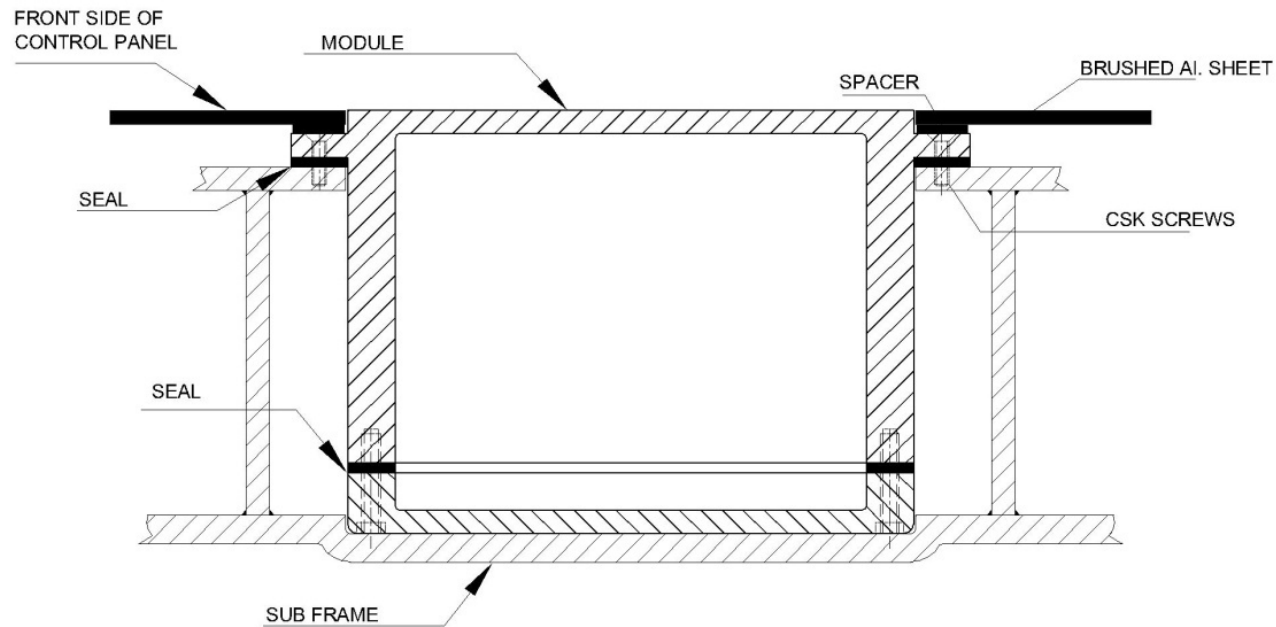




4.5.3 Initial Concept Generation:

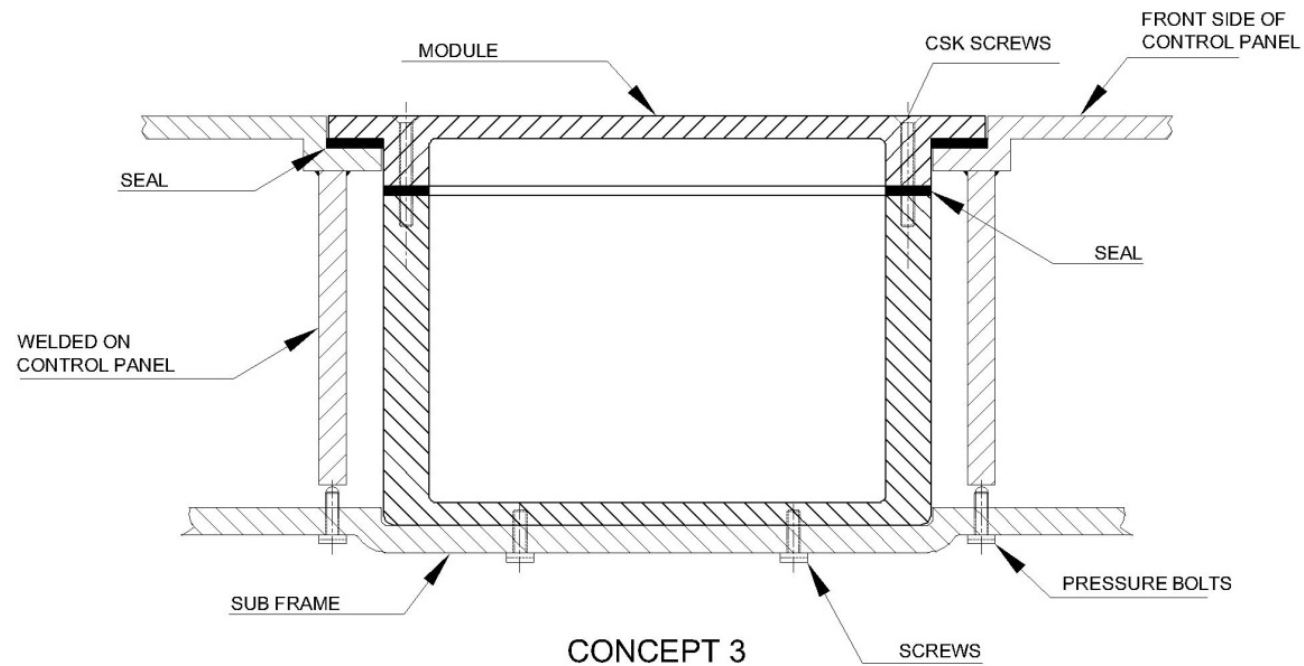


- Use of U-bolts allow for quick assembly and disassembly.
- Proper sealing at the front side.
- No need to remove nuts completely as U-bolts are used. Only loosening of the nuts is enough.
- Clean look on the control panel as no screws are visible.



CONCEPT 2

- Complete module can be removed from the front side.
- Effective sealing of electronic hardware mounted behind the control panel.
- Sufficient grip available for removing the module.
- Complete clean look for the fascia of the control panel due to use of brushed Al. sheet.



- Quick access to the control buttons and LEDs, which are the components that usually fail.
- Complete sealing of electronic hardware mounted behind the control panel.
- Rigid mounting on the sub-frame from rear side of control panel.

4.5.4 Module Concept Evaluation:

	Concept 1	Concept 2	Concept 3
Front fascia(aesthetics)	Completely clean (9)	Completely clean (9)	Screw holes visible (6)
Access for removal (entire module)	From behind CP (6)	From front side of CP after removing face plate (9)	From behind CP (5)
Access for removal of controls buttons & LEDs	Have to remove entire module (6)	Have to remove entire module (6)	Only front plate from front side of CP (9)
Grip for removal	Absent (0)	Available (10)	Absent (0)
Vibration resistance	(7)	(8)	(6)
Volume occupied behind the CP(lesser the better)	(6)	(8)	(6)
Total	34	50	32

Hence concept #2 was selected and refined adding the special features of the other concepts.



Two stage module

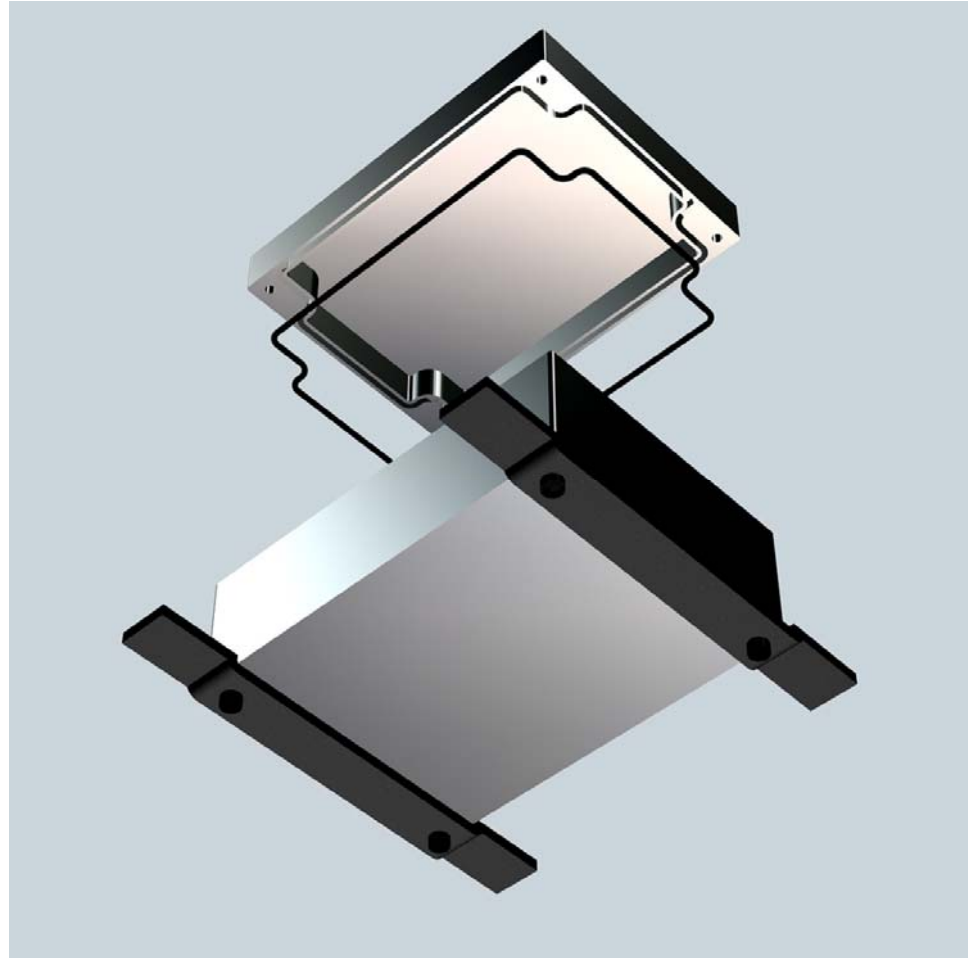
4.5.5 Final Concept:

Considering the features of the concept #2, further refinement was carried out on the module to arrive at the final concept.

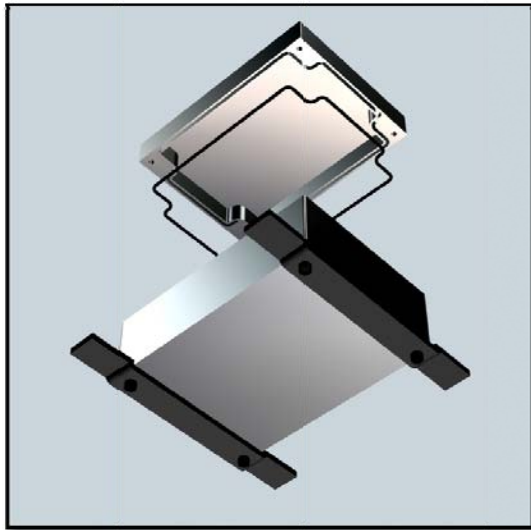
As the most common components to fail in these modules are the control buttons and LEDs, it is necessary that these can be easily removed from front side without dismantling the entire module from the sub-frame. Also it was necessary to mount these modules on the sub-frame only for purpose of rigidity and stability.

Hence the module is made in two parts, upper cover houses the control buttons and LEDs and the lower case houses the electronic hardware consisting of ICs.

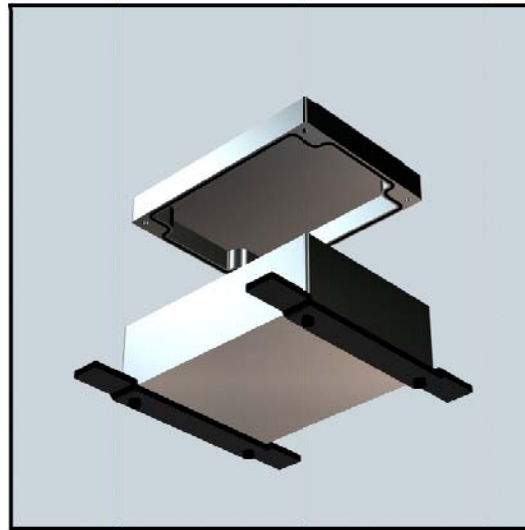
Exploded view of the module showing
all the parts.



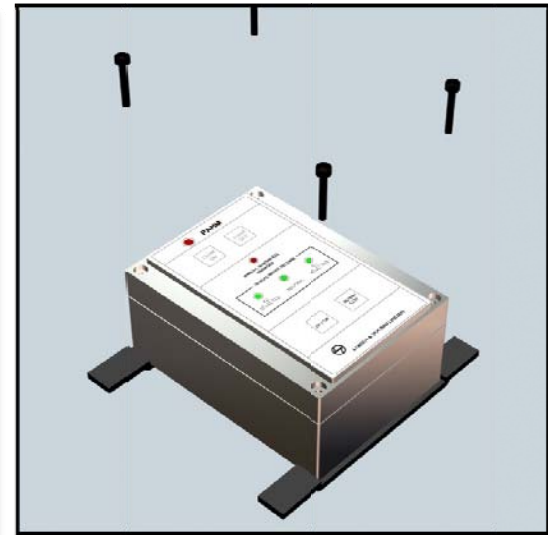
Assembly Procedure:



1. The lower base is first mounted from behind the control panel on the sub-frame using four Allen bolts.



2. A gasket for sealing the two parts for IP 65 is inserted in the groove in the upper cover.



3. Then the upper cover is bolted on the base using Allen screws.

Features:

- Easy to remove face plate front the front side of the control panel.
- Direct access to control buttons and LEDs which are the major cause of failure.
- Clean look on the control panel fascia as all the screws are hidden behind brushed aluminum sheet.
- No extra space required other than the size of the module itself.

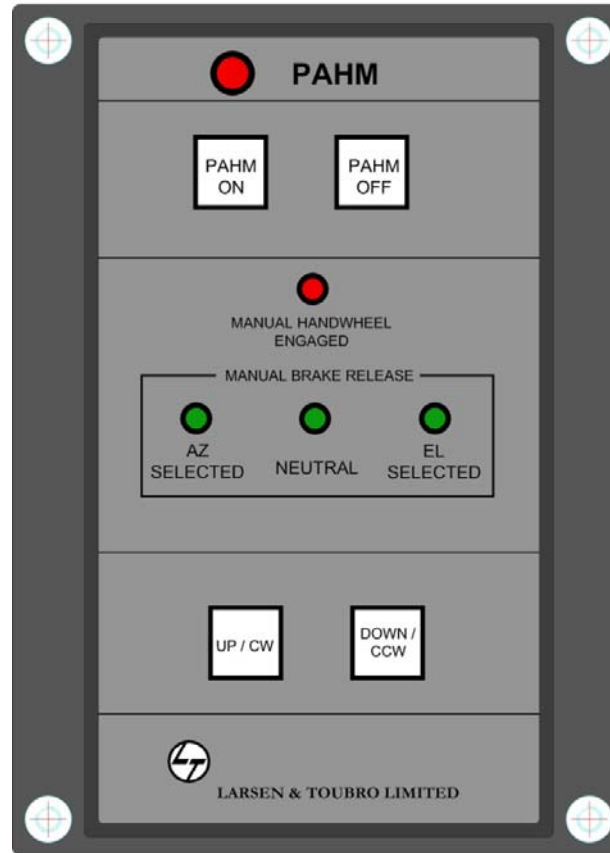
Final rendered View:

(For PAHM module)





Old PAHM Module



New PAHM module

4.5.6 New Module Layouts:

The module layout was clustered as per functions of the mounted components.

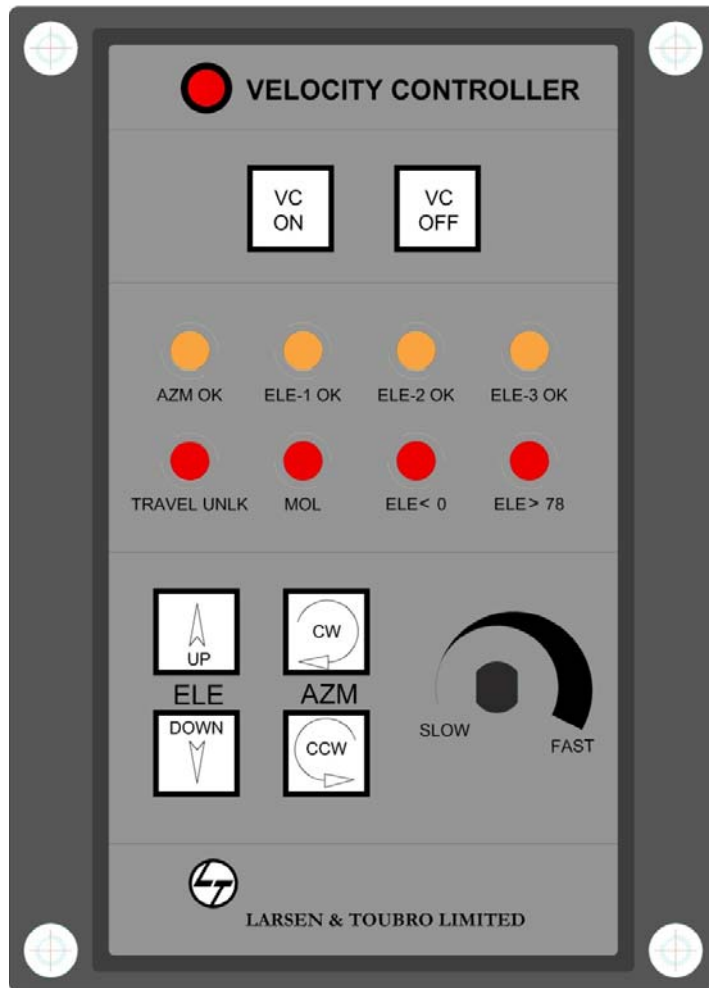
The top level has an indicator to display if the module is ON/OFF.

The next level has the non-latching push buttons for switching ON/OFF the module.

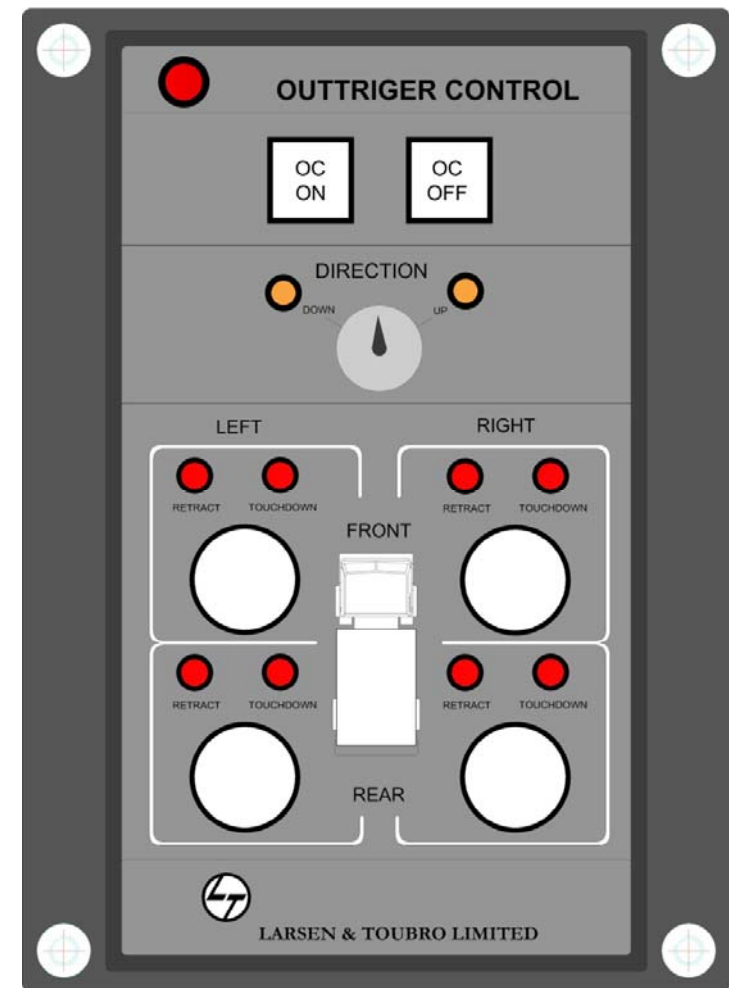
The next level has the indicator LEDs.

The final level consists of the control buttons that execute the basic function of the module

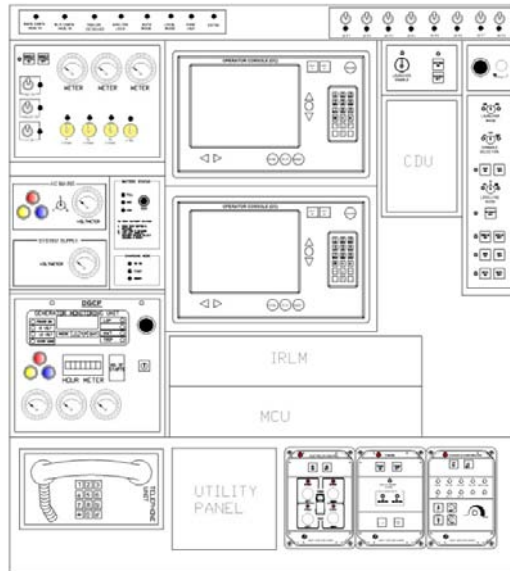
Similarly other modules are designed.



New VC module



New OT module



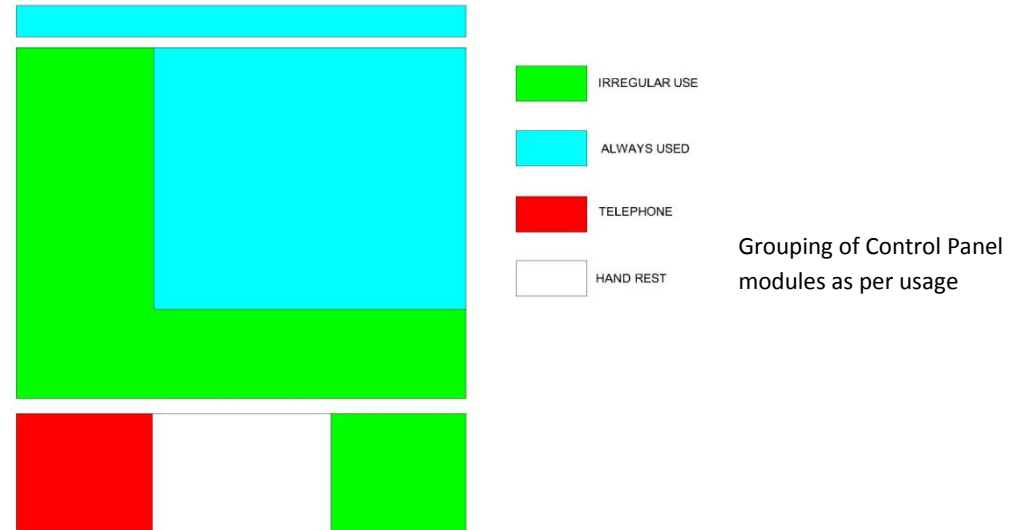
Concept #2

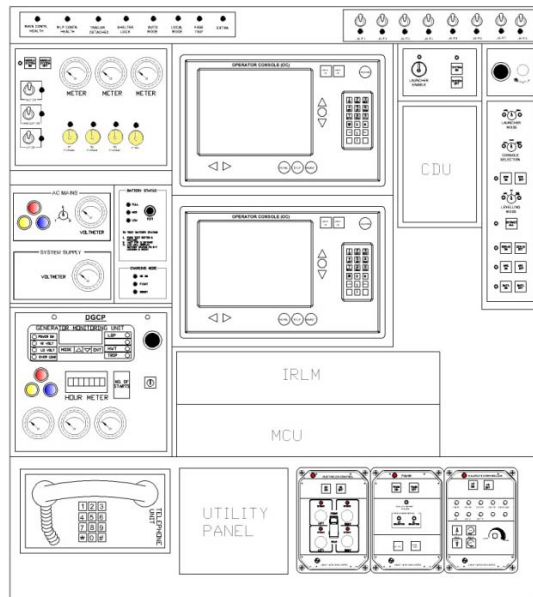
4.5.7 Final Control Panel Layout:

After freezing upon the final form and mounting of the modules, the control panel layout of concept #2 was taken up for refinement.

Following improvements were made to the concept #2:

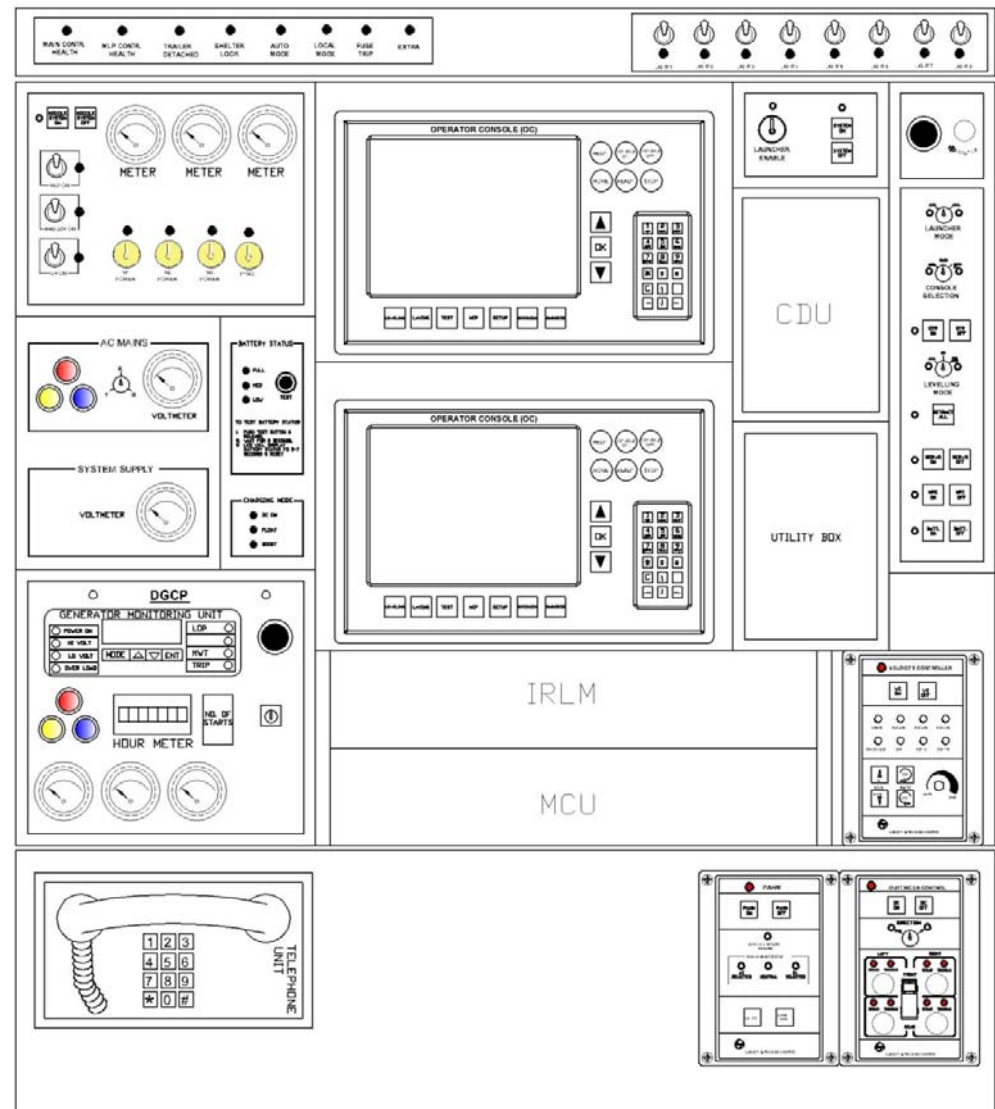
- Reducing the visual clutter by arranging and resizing the modules.
- Hiding the screw holes and creating a clean look for the fascia using a hinged Alucobond sheet with a strengthening frame.
- Arranging the modules according their type and usage: regular or irregular.
- Also the utility panel that provided power source for external electrical requirement was removed as the wires would fall at the feet of the user and will hinder his movement in front of the control panel by getting entangled with legs.





Concept #2

Final Control Panel Layout



Both the Operator Consoles (OCs) have a sliding lid that covers them up



Similar operator console with a closing lid



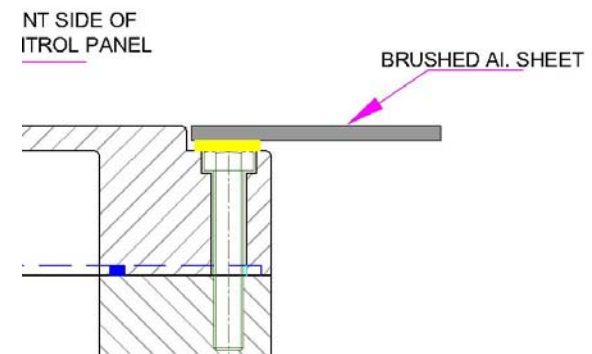
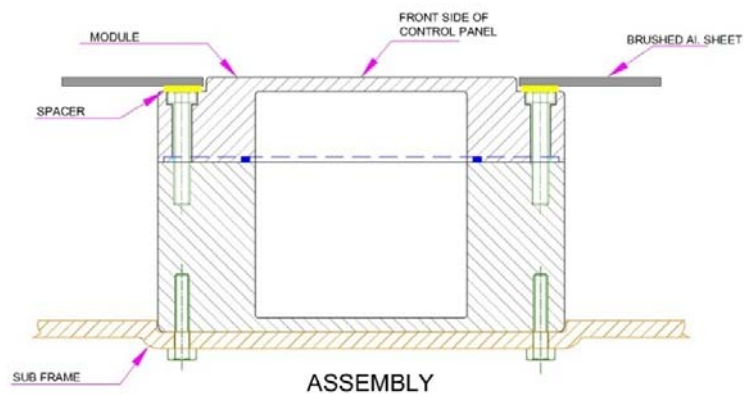
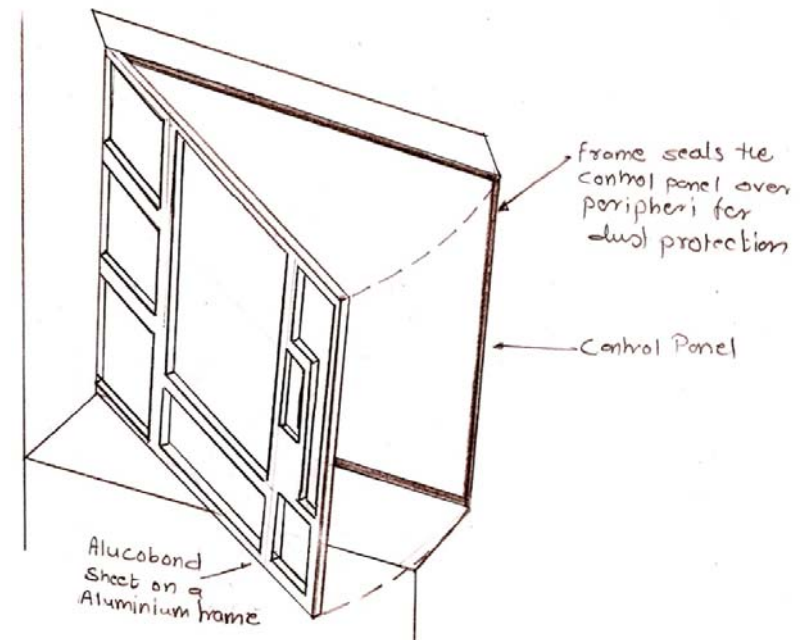
Mock up of control panel during refinement phase of concept #2

4.5.8 Dust Protection and fascia:

For protecting the electronic hardware components mounted behind the control panel it is necessary to seal the control panel from dust and moisture.

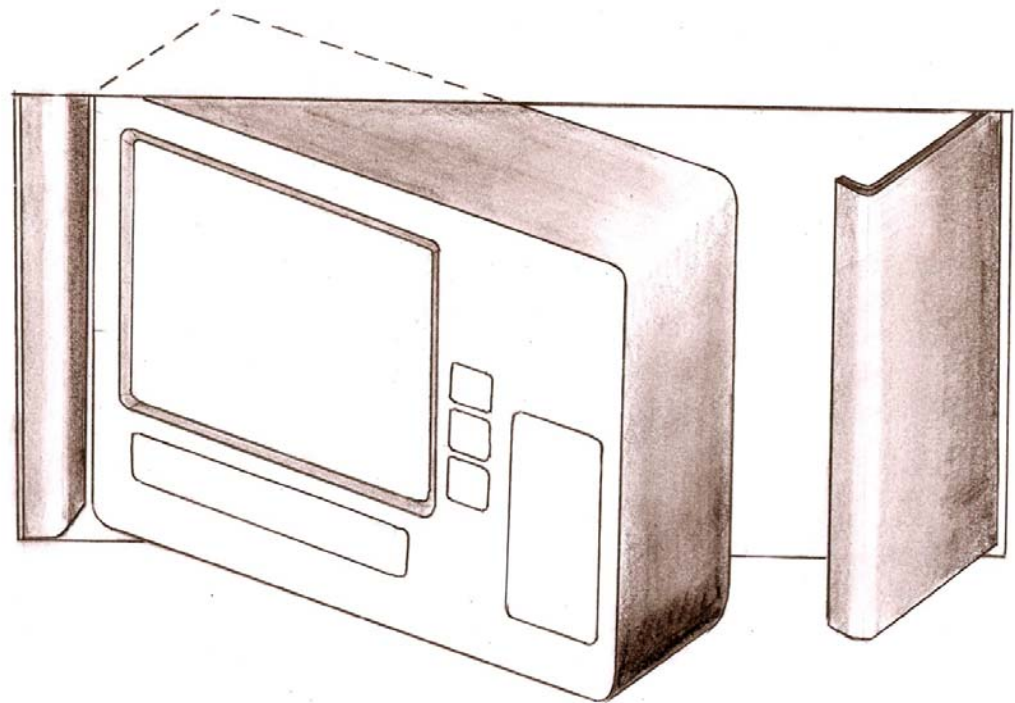
Hence an Alucobond (brushed Al.) sheet hinged like a door which seals the entire control panel on all the four edges is used.

The frame also seals the modules on their periphery (refer assembly figure).



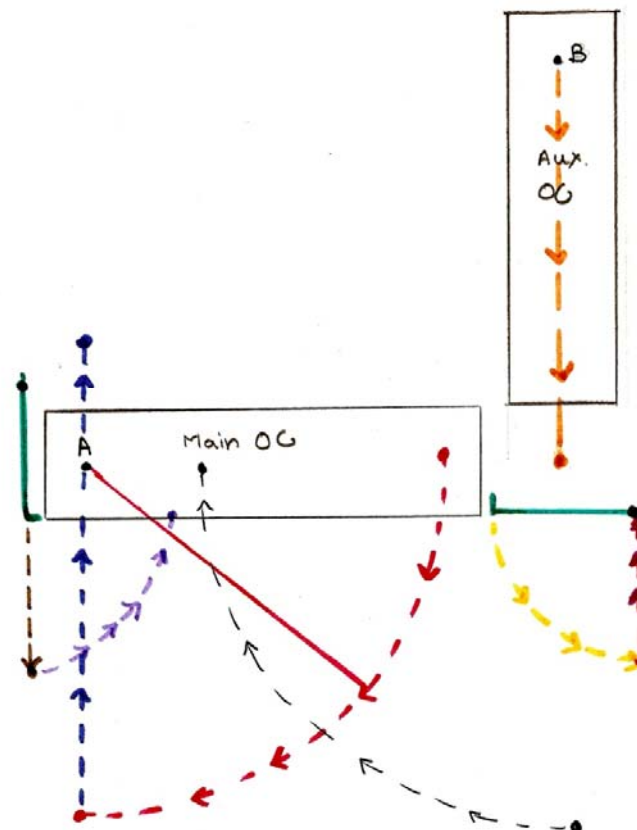
4.6 Single Operator Console (OC):

Clients at DRDO had come up with a specific requirement of having both the main OC and the auxiliary OC hardwired and running when system is switched ON, but only one OC should be visible to the user at any given time. Though the final concept for control panel layout had a provision for keeping the aux. OC hidden another arrangement is suggested which doesn't at all allow to OCs to be visible at the same time by any means.



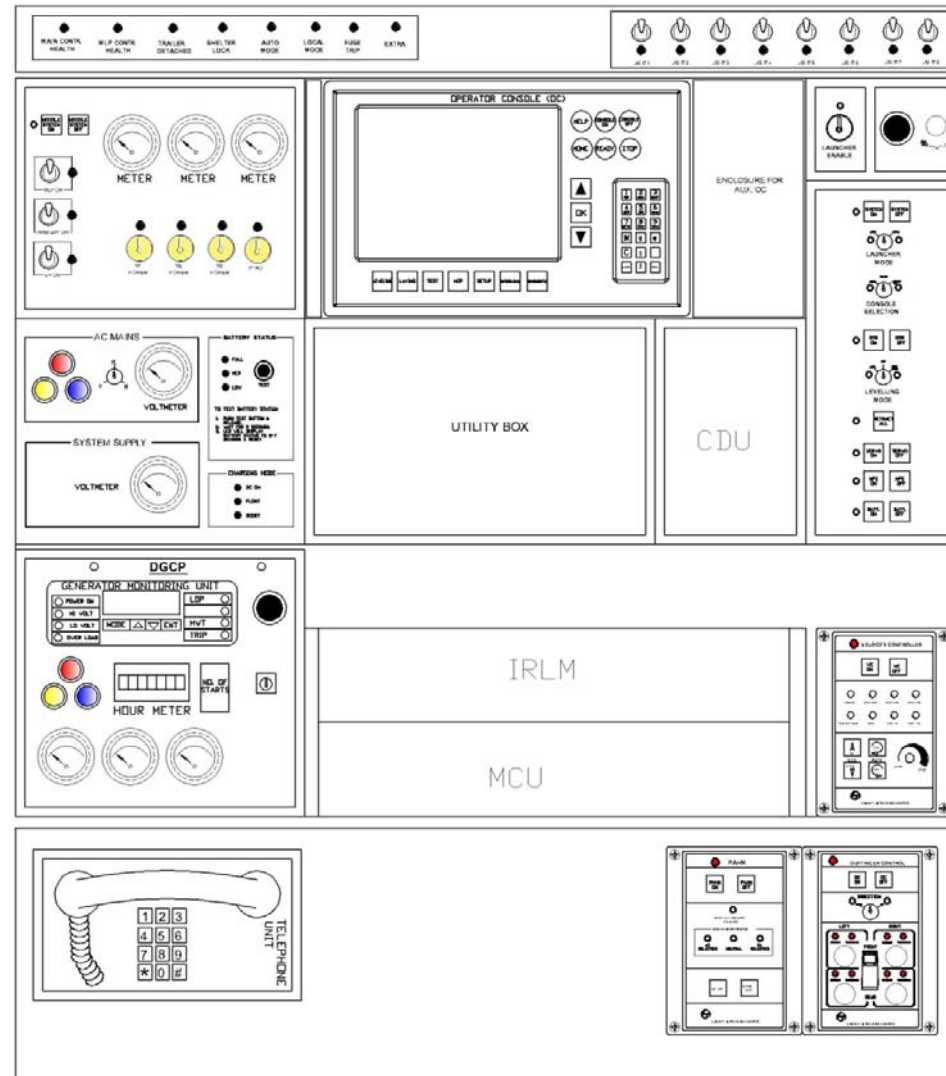
Procedure to change from main OC to aux. OC:

1. Pull out the hinged door 1.
2. Rotate the main OC about hinge 'A'.
3. Push the main OC straight inside.
4. Open the hinged door 2.
5. Pull out the aux. OC.
6. Rotate aux. OC about hinge 'B' and lock it along the control panel surface.
7. Push inside the hinged door 2.
8. Close the hinged door 1.

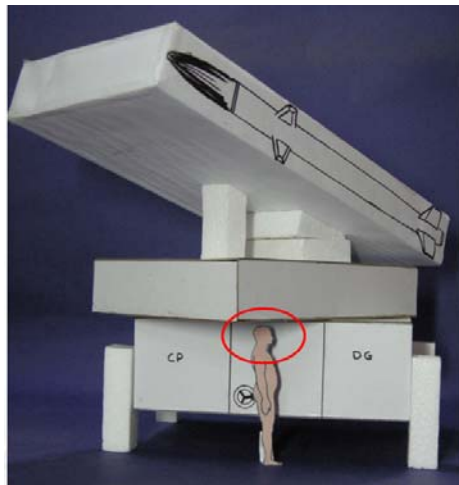


Step 1 ---
 Step 2 ---
 Step 3 ---
 Step 4 ---
 Step 5 ---
 Step 6 ---
 Step 7 ---
 Step 8 ---

New Control Panel layout:



Ergonomic Data	
Human stature (95 th percentile)	1781 mm
Human eye level (95 th percentile)	1645 mm
Height of upper OC from ground	1430 mm
Height of lowermost point of swiveling deck from ground	1785 mm (when launcher is at optimum height of 500 mm from ground)



Scale 1:20

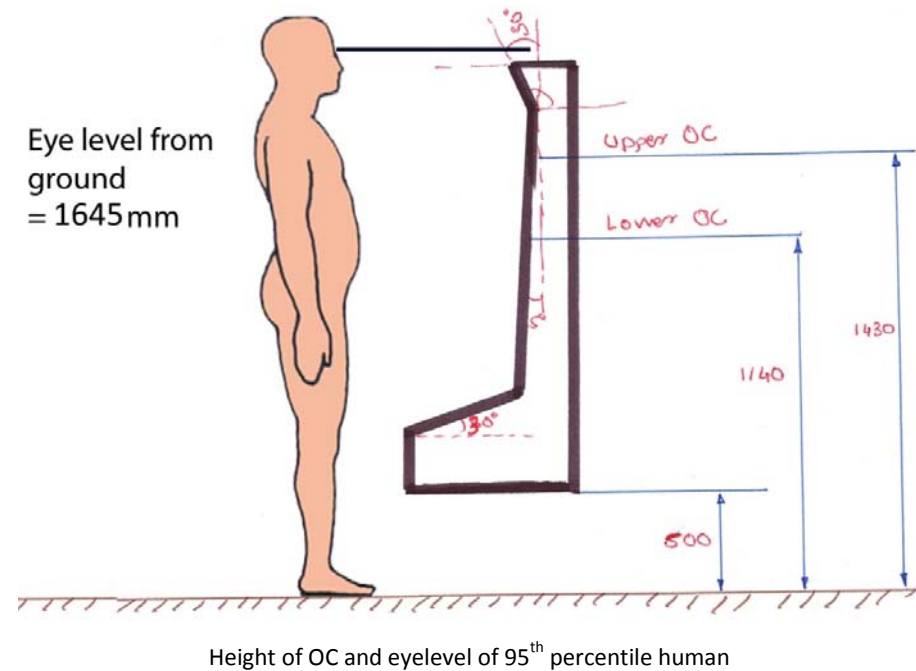
Human Figure 95th percentile

4.7 Ergonomics while using the Control Panel:

4.7.1 Design insights:

With the current system still there are few issues related to the ergonomics while using the control panel. These are as follows:

- Swiveling deck can hit the head of the user.
- Height of the LCD display (OC) is much below the eye level.
- Sunshade is required while working with the OC.



Ergonomic Data	
Human stature (95 th percentile)	1781 mm
Human eye level (95 th percentile)	1645 mm
Height of upper OC from ground	1430 mm
Height of lowermost point of swiveling deck from ground	1785 mm (when launcher is at optimum height of 500 mm from ground)
Height of lowermost point of swiveling deck from ground	1985 mm (when launcher at 500 mm from ground and trench 200 mm deep)

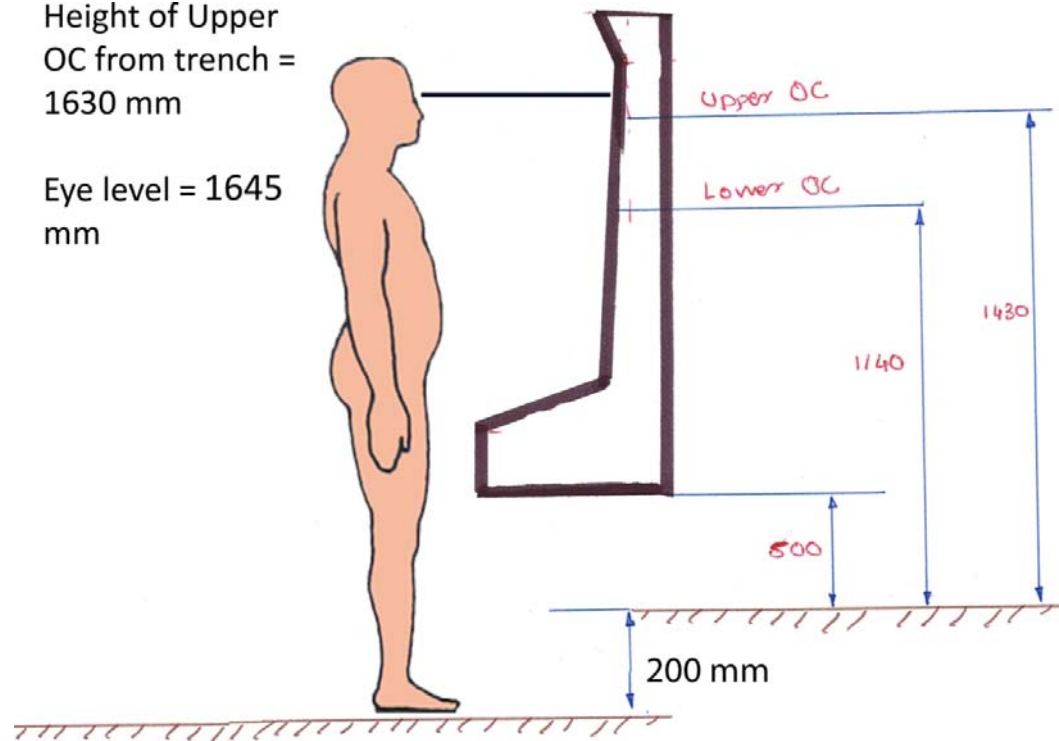
4.7.2 Design solutions:

Trench:

Ergonomic calculations show raising the height of the launcher can solve the problem of deck hitting the user and the height of OC. As raising the launcher by 200 mm will drastically affect the stability of the launcher, the solution is to lower the user by 200 mm. This can be done by digging a trench 200 mm deep along one side of the launcher.

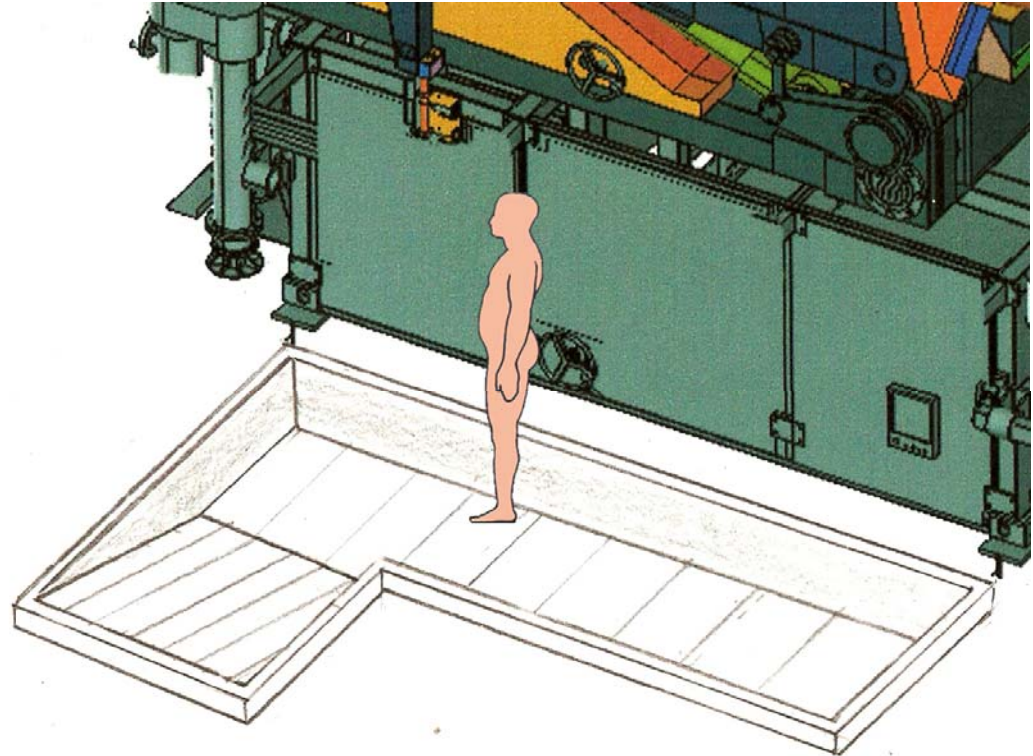
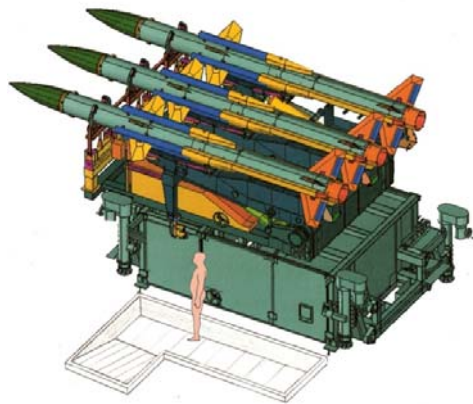
Height of Upper OC from trench = 1630 mm

Eye level = 1645 mm



Height of OC and eyelevel of 95th percentile human standing in a 200 mm deep trench

The trench will be covered with Fiber Reinforced Plastic (FRP) as the material is easy to mould to required shape.



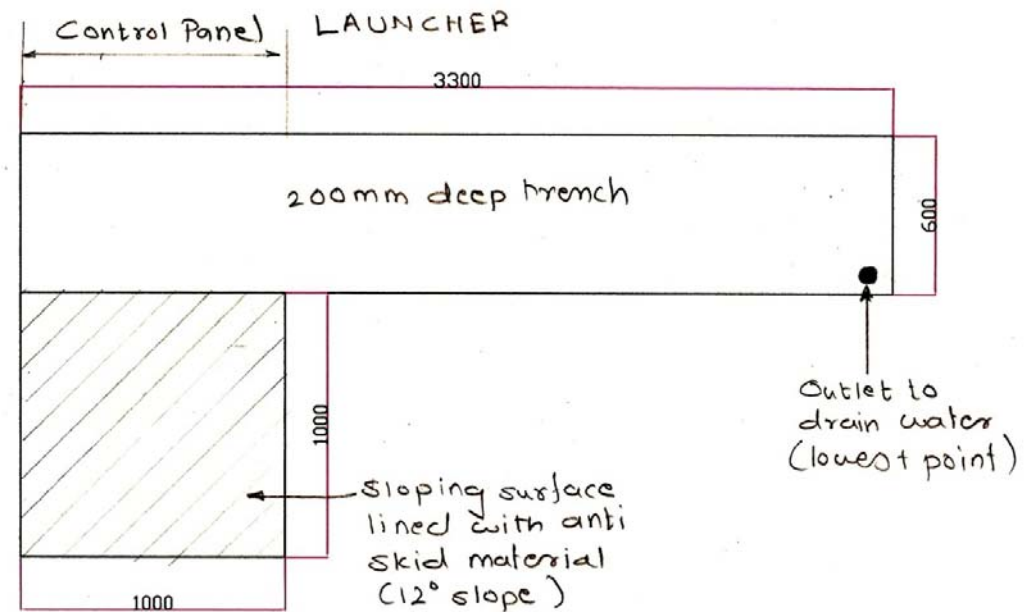
Trench along the side of the launcher layered with FRP

Layout and other details:

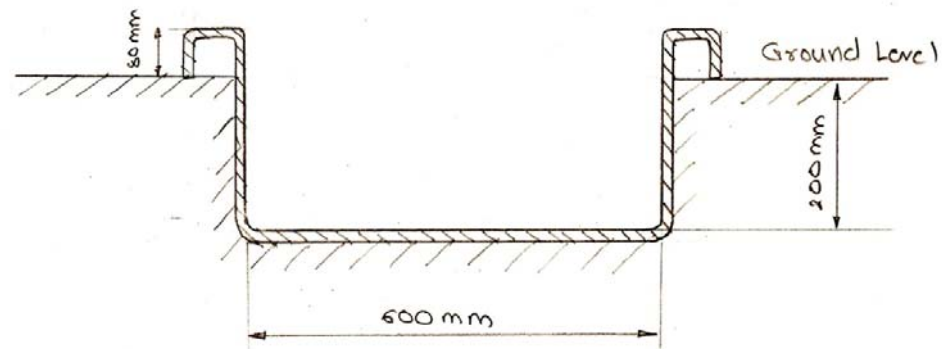
The outlet point in the corner is the lowest point in the trench, thereby allowing water to drain out to disposal tank.

Features:

- It lowers the height of user by 200mm thereby making the working on control panel easy.
- The slightly raised height of the trench above the ground level restricts water from flowing into the trench.
- The surface of the trench being layered with FRP makes it easy to clean.
- Outlet point allows water to drain out.



Trench Layout



Cross-section of trench made in FRP

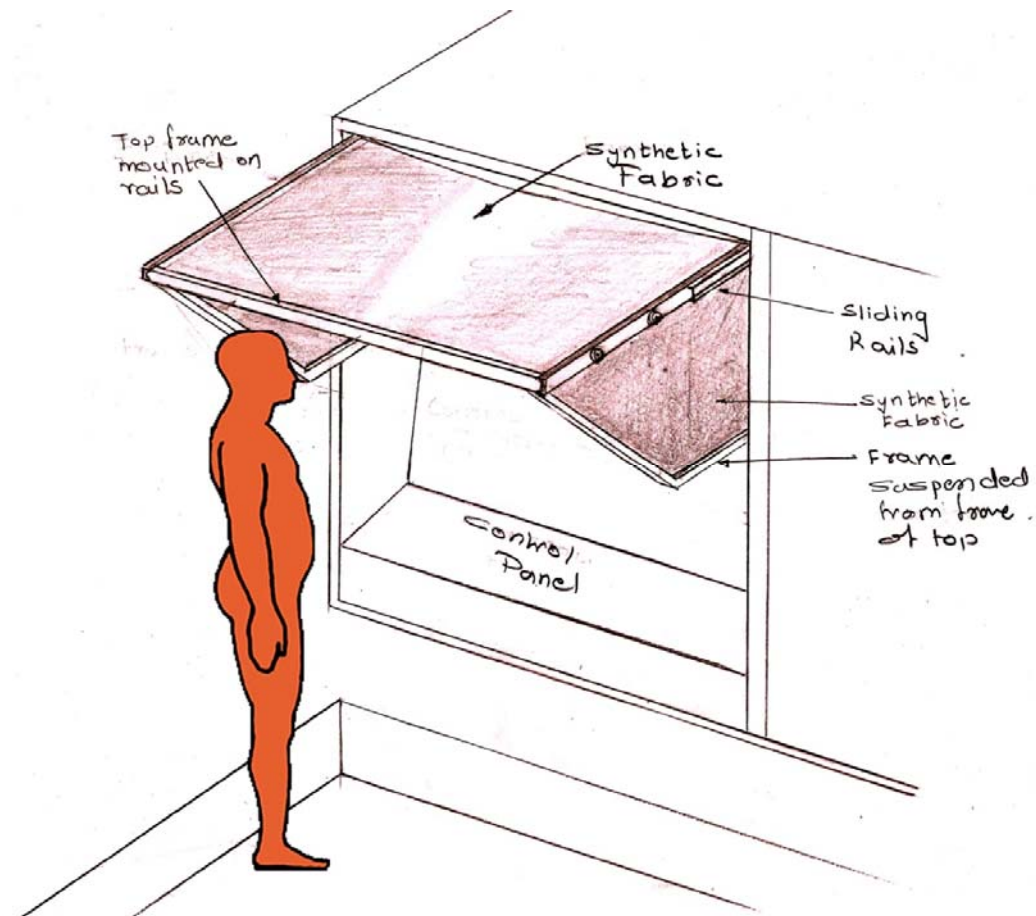
Sunshade:

While using the OC in sunlight a sunshade is required to obstruct any direct sunlight falling on TFT display of the OC.

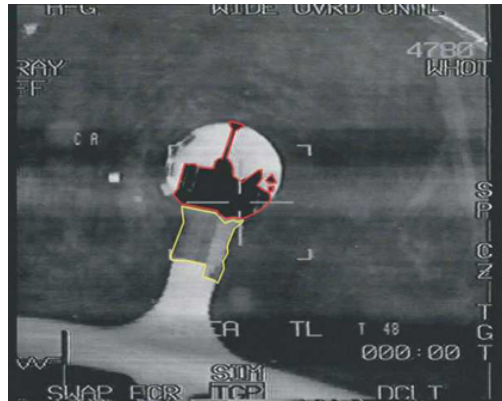
The sunshade is in a form of a thick opaque polyester cloth mounted on telescopic sliding rails as shown.

The sunshade is 700 mm deep when completely out.

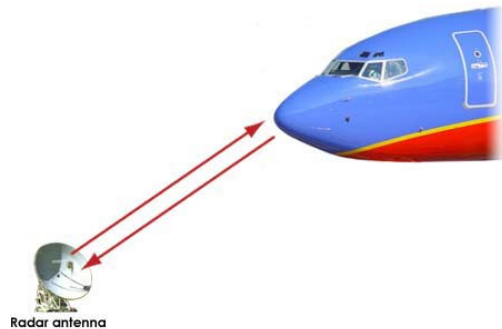
The sunshade also covers from the sides



Sunshade



Thermal Imaging



Radar Imaging

5. Section B: Protection of the Launcher by Camouflaging

5.1 Camouflaging of Defense System:

Safety and security are very critical aspects of any defense system. It has to remain undetected from all types of imaging technologies. Camouflaging provides safety and security not only for the system but also to the users in case of emergencies. The system needs to be camouflaged against the thermal, radar and visual signature of the system.

It was necessary to study the basic working principle of the various thermal, radar and visual imaging systems.

5.1.1 Thermal Imaging:

Here the system comprises of imaging device which captures the heat signature of an object. It uses Infra Red (IR) camera or other heat seeking systems to detect heat signature. This system is very useful for detection during night and low light condition. Infrared photography reveals those objects that are hotter than their surrounding environment.

5.1.2 Radar Imaging:

The idea is for the radar antenna to send out a burst of radio energy, which is then reflected back by any object it happens to encounter. The radar antenna measures the time it takes for the reflection to arrive, and with that information can tell how far away the object is.

5.1.3 Visual Imaging:

This system works on principles of photography, where an imaging device dynamically captures the environment using high power lenses and displays the visuals continuously to the user. The user then identifies the certain characteristics of a weapon or weapon system based on its contrast with the surroundings. Various image processing algorithms are used to achieve high contrast and high clarity images.

5.2 Design brief for camouflaging:

The protection of any defense mechanism from enemy attack is a very important aspect. Imaging technologies like visual photography, radar detection and thermal photography are serious threats to the security of the defense system. The defense system can be protected against these enemy threats by implementing a camouflaging system.

Following parameters are critical for effective camouflaging of the system:

- For the concerned system the camouflaging mechanism needs to be designed for quick removal, i.e. the removal of the camouflaging should happen within 1 minute approx.
- Once deployed the system should be as small in size as possible with minimum surface area and small footprint. Smaller the size of the system more effective is the camouflaging and lesser is the probability of getting detected.
- The system needs to be easy to remove without any preprocesses involved, thereby preventing any malfunctions occurring due to certain tasks not being performed or tasks being performed in incorrect sequence.
- Minimum human intervention is expected for deployment and removal of the system. Ideally, the removal should happen without any human intervention with only a click of a button.
- The deployment of the system has to take care of all the prerequisites of the launcher like, home position for missiles (elevation\azimuth); height (elevation) of the launcher; no system task is being performed during deployment, etc. There should interlocks to check for the required status of the launcher.

Other than the above requirements, there are certain aspects that can help make a camouflaging system more effective. These requirements are not absolutely necessary and a camouflaging system can deliver effective performance without complying with the following requirements.

- Complexity of mechanism can increase more time for foolproof operation. Also with increasing complexity the maintenance time increases thereby increasing the cost.
- The complexity of the working of the mechanism also can be a deterrent to quick operation. Complex and simultaneous functioning of various mechanisms can increase the chances of failure.
- Ease of manufacturing and repair, help to keep the system trouble free and result into quick replacement of any damaged component.
- A system that can camouflage the launcher positioned at any height above the ground can be useful for instantaneous deployment, but as quick deployment is not critical this is only added feature.

5.3 Technology Analysis:

5.3.1 Thermal Camouflaging:

Thermal camouflaging is most effectively achieved using anti-thermal/ anti-IR camouflage coating materials. The assets coated with these coating materials cannot be identified by IR or other thermal devices in the near, mid, or far spectrum (sniper scopes, NVGs, thermal-viewers, laser designators, GPS / INS aided missiles that use IR sensors during final approach, satellites), simply because the asset is not seen or identified as hotter than its environment.

Anti-Thermal/ Anti-IR Coatings:

A Greek company by name 'Intermat Coatings' of 'Intermat Group SA' specializes and claims to be the only company promoting these state-of-the-art, anti-thermal coating materials developed after many years of R&D.



Thermal imaging with and without anti-IR coatings

The figure alongside shows tank images from a thermal viewer (8 μ -12 μ) at 250m while manoeuvring. #1 is commonly painted. #2 is Intermat anti-IR camouflage painted.

Coating materials' characteristics:

- Coating materials achieve up to 50% IR signature reduction (unique feature internationally)
- Reduce external temperature up to 65%
- Effective in the wide IR spectrum of 400nm to 20000nm
- Resemble the assets' thermal signature, with the environment's IR signature
- They can be applied on any asset mobile, fixed, aerial, naval.

Coating materials are passive to the environment and when applied they stay on guard day or night, 365 days per year and for a long time.

Benefits of Intermat anti-thermal camouflage:

- Adaption to the IR environment of your area
- Protection from thermal threat
- Survivability in a complex and advanced military environment is significantly optimized
- Gain a sustainable advantage
- Targeting friendly assets is avoided
- Coating materials can be used as a permanent countermeasure during day or night, 365 days a year
- Can do away with traditional and conventional means of concealment that limit mobility, are user-dependent, require valuable resources, and often undermine the secrecy of the plan

These paints you can make an entire area disappear 365 days a year.

Hence the Launch system will be coated with anti-thermal/anti-IR coatings on the external.

5.3.2 Radar camouflaging:

It can be effectively achieved using camouflaging net and stealth technology. Stealth technology relies on wedge shaped form and radar absorbing paints. As this technology needs to be configured for every system individually it is very costly and time consuming. The cost and time can be justified if it's a mobile system. Camouflaging nets with multispectral properties turn out to be cheaper and more effective alternatives for stationary systems.

5.3.3 Visual camouflaging:

This is easily achieved using colour scheme that matches with the surroundings. This can be easily done for land systems which operate in more or less surroundings.



Multispectral Net based camouflaging

Multispectral Nets (MSN):

The multispectral nets provide very effective camouflaging against visual as well as radar threats. Along with visual & radar camouflaging these systems also provide camouflaging in IR (near, medium, far), thermal and UV spectrum. Also these are made up materials that are flame, water and mould resistant. It also emulates 3-D appearance.

Various companies have specialized in manufacturing of these nets as well as customized complete systems.

Photographs along side show few types of multispectral nets available.



Multispectral Net based camouflaging



Multispectral Net based camouflaging

Some typical specifications of multispectral nets:

Physical specifications	
Composition	Polyester
Total weight	200-350 gm/m ²
Bursting strength	620 K Pa
Technical (Camouflaging) Specifications	
Visual Protective Waveband	0.4 - 1.2μm
Radar Protective Waveband	K, X, C, S, L
Infrared Protective Waveband	3 - 5, 8 -14μm
Radar reflection attenuation	10dB in darkroom test
Difference in thermal reflection between camouflaged target and background noise	Less than +/-4K on average
Reduction in RCS	More than -10dB on average.

Hence implementing a camouflaging multispectral net is chosen as the most viable option for the concerned launch system.

5.4 Ideation & Concept generation:

For implementing a multispectral net system it is necessary to make the system undetectable for all types of imaging devices by providing all round cover using the multispectral net. Brainstorming was carried out to generate multiple ideas.

These ideas were then sorted using card sorting method based on the requirements of the camouflaging systems. These were then formed into clusters with each cluster having ideas having certain common characteristics. The features included in each cluster must be the ideal combination complimenting each other and the whole scenario of the product requirement.

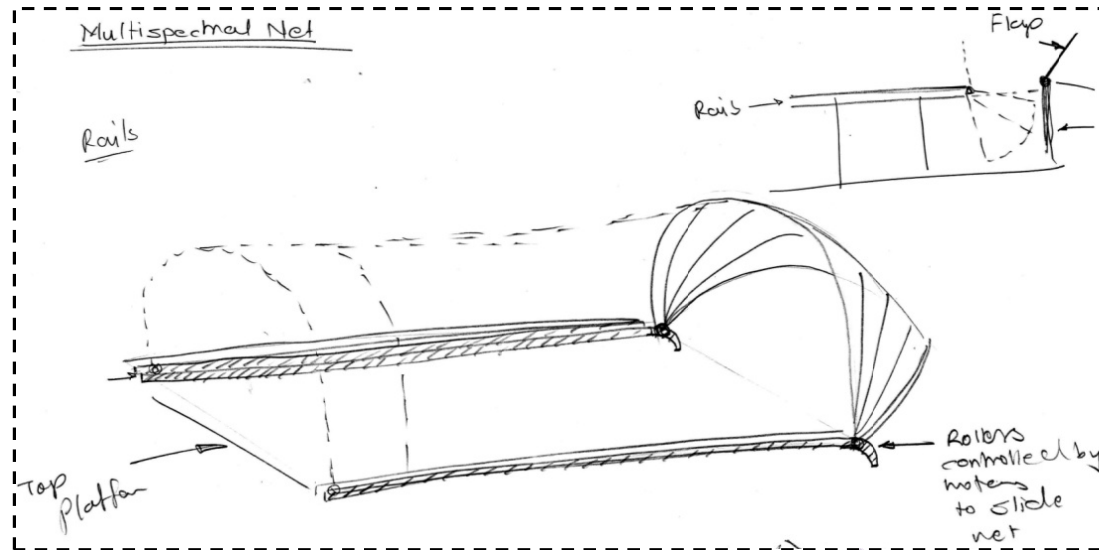
Concepts are developed based on these clusters and the further design process is carried out for the integration of them as a whole concept.

The ideas were clustered based on the type of mechanism used as follows:

- Cluster 1: Ideas based on sliding and rotating mechanism
- Cluster 2: Ideas based on raising and rolling mechanism
- Cluster 3: Ideas based on radical, new mechanism

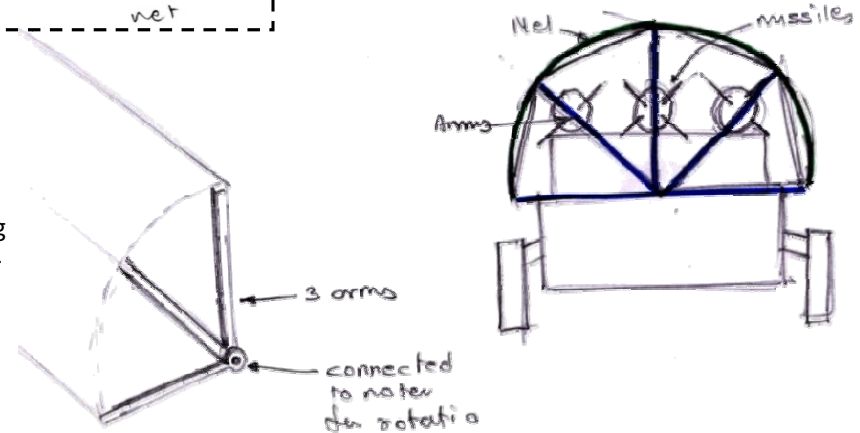
5.4.1 Cluster 1:

Ideation: This cluster consists of ideas based on sliding and rotating mechanism for implementing a camouflaging system.

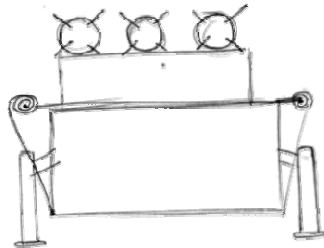


This is the cluster representative. It basically consists of rails that allow canopy members to slide over and cover the system with MSN

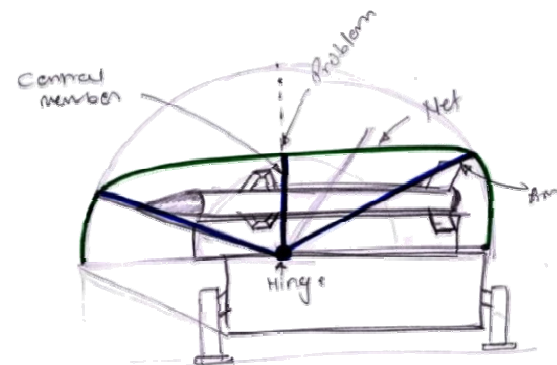
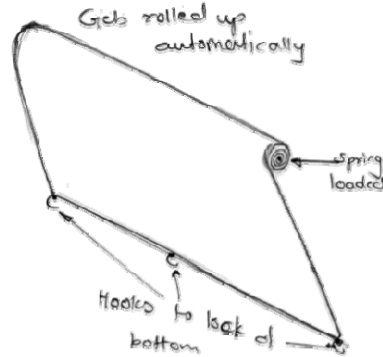
Four arms on either side, with axis along length of the launcher, rotate and cover the system with MSN



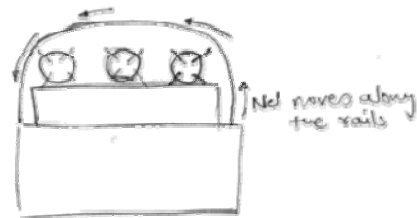
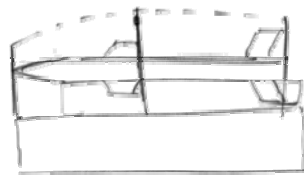
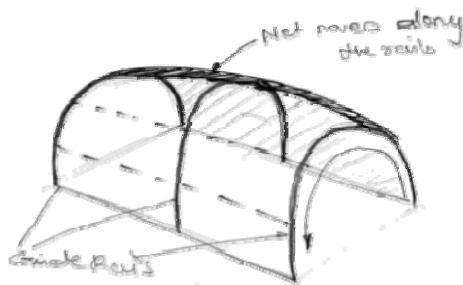
auto roll up
mechanism like
curtain shutter used
in small shops.



The spring loaded, auto roll up mechanism used in window curtains is used. This makes removal quick.

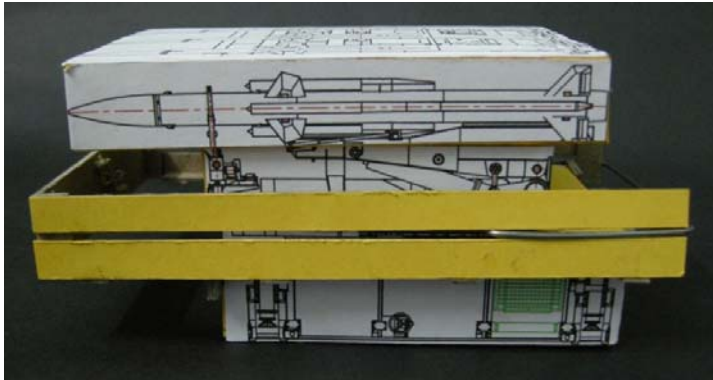


Roller and rail mechanism is used in combination achieve very compact camouflaging system

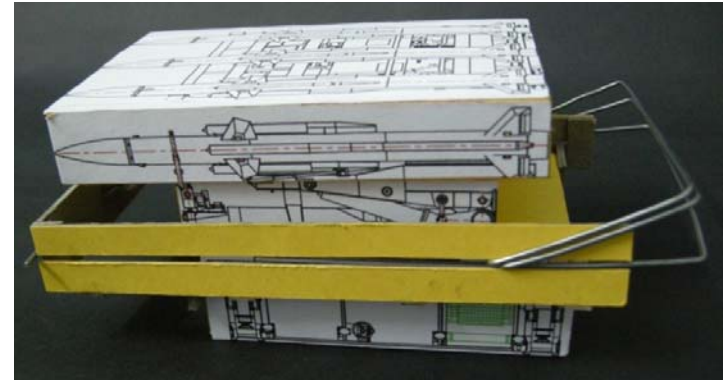


Semicircular members act as rails and cover up the top of the launcher sideways

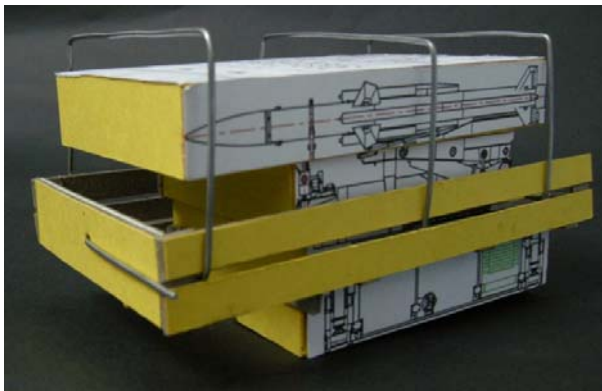
Exploratory Concept 1:



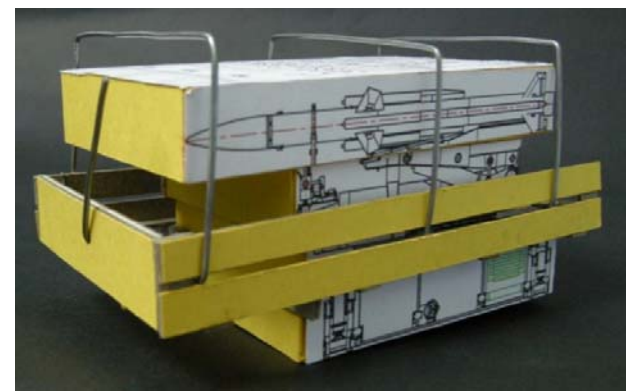
1. In un-deployed state the rails are folded on the top surface of the lower base.



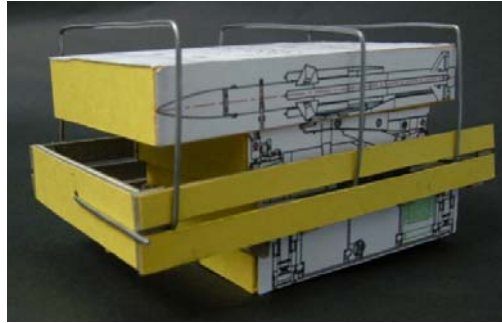
2. The rails are then rotated up against the hinged roller.



3. The rails then slide along the tracks and are locked in upright position.

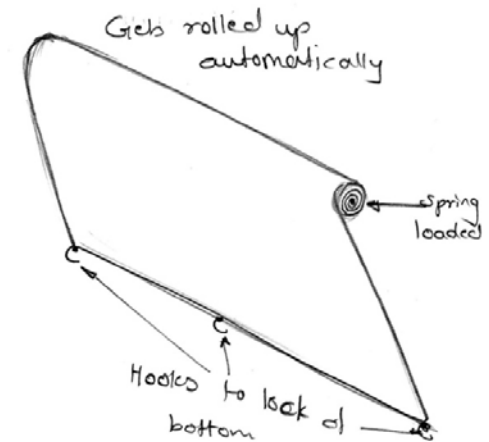
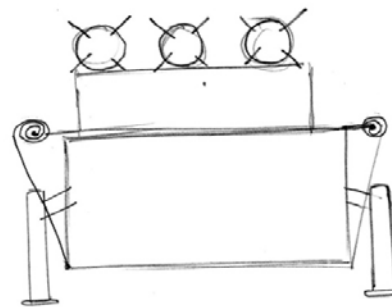


4. A rotating arm glides the net rolled on the side over these rails to cover up the top part of the launcher.



Covering the base:

auto roll up
mechanism like
curtain shutters used
in small shops.



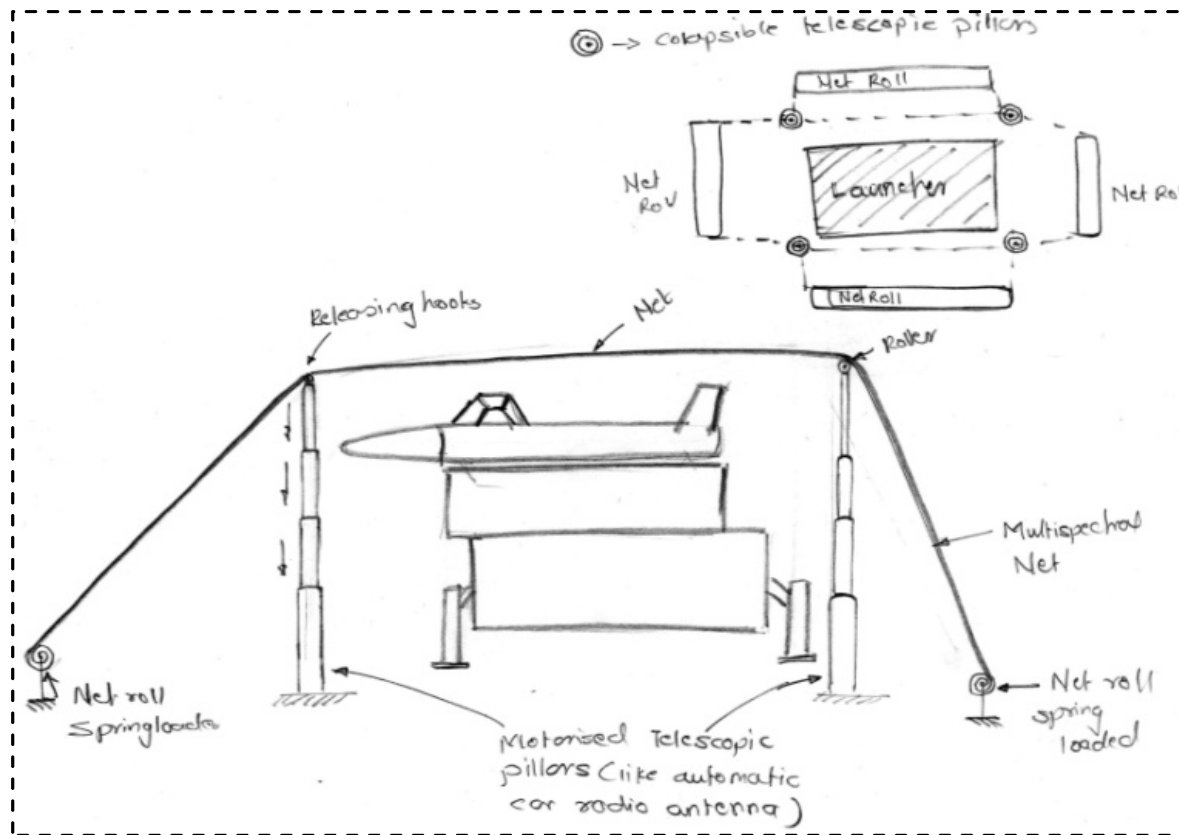
The base of the launcher is covered using spring loaded rolls that auto-roll up when released. The rolls cover all four faces of the base of the launcher.

Features of concept 1:

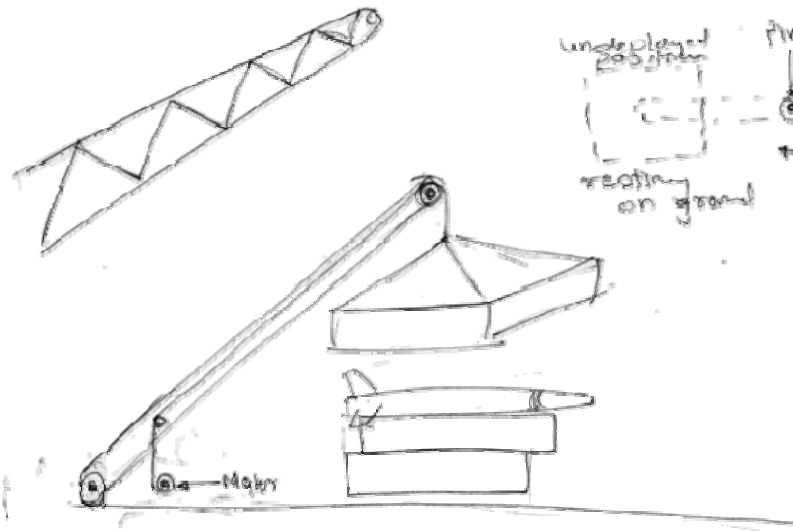
- Very less removal time.
- Very compact in size (small footprint).
- Minimal human intervention required.
- Independent of the height to which the launcher is raised.
- Very low overall weight of the camouflaging system.

5.4.2 Cluster 2:

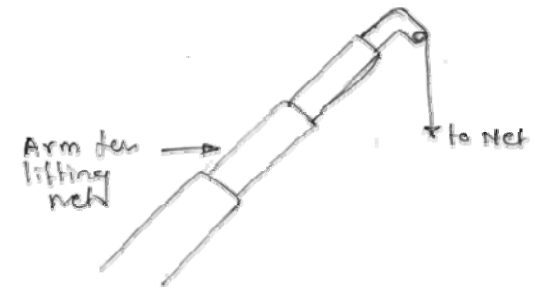
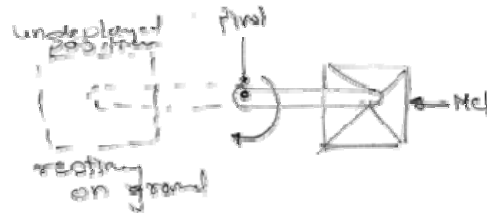
Ideation: This cluster consists of ideas based on raising and rolling mechanisms for implementing a camouflaging system. These types of systems are relatively easy to manufacture and install.



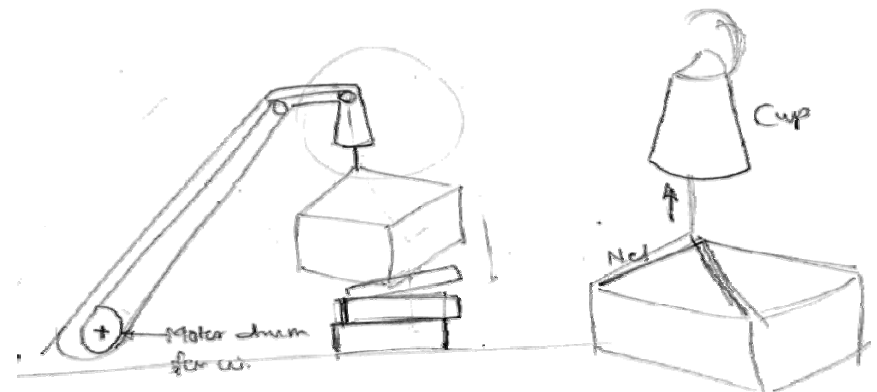
This is the cluster representative. It comprises of rolls of net and collapsible telescopic pillars



Here the net is dropped from the top of the launcher using a rotating arm



Telescopic extending arm for dropping MSN over the launcher

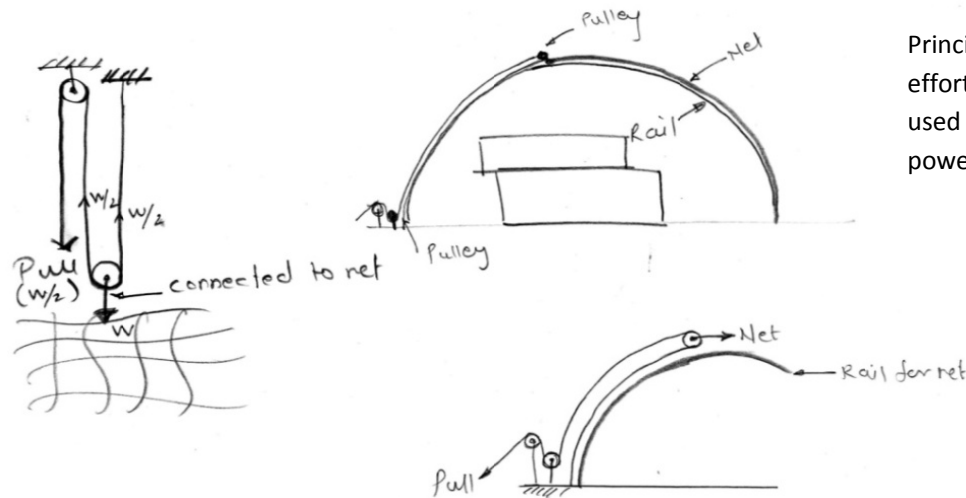


Cone frustum allows for easy and quick folding of the MSN

Net goes into Cup while steering

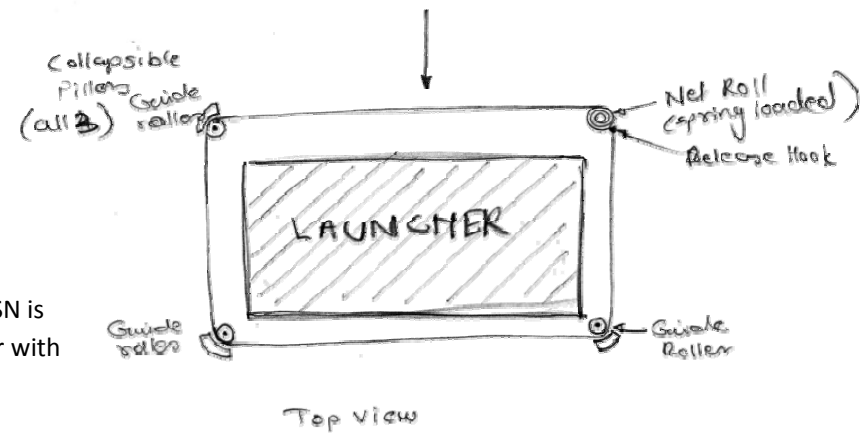
MSN deployment mechanism
like Hoey
(2 pulley system)
manually done

Easy to pull as
weight of net is
halved.



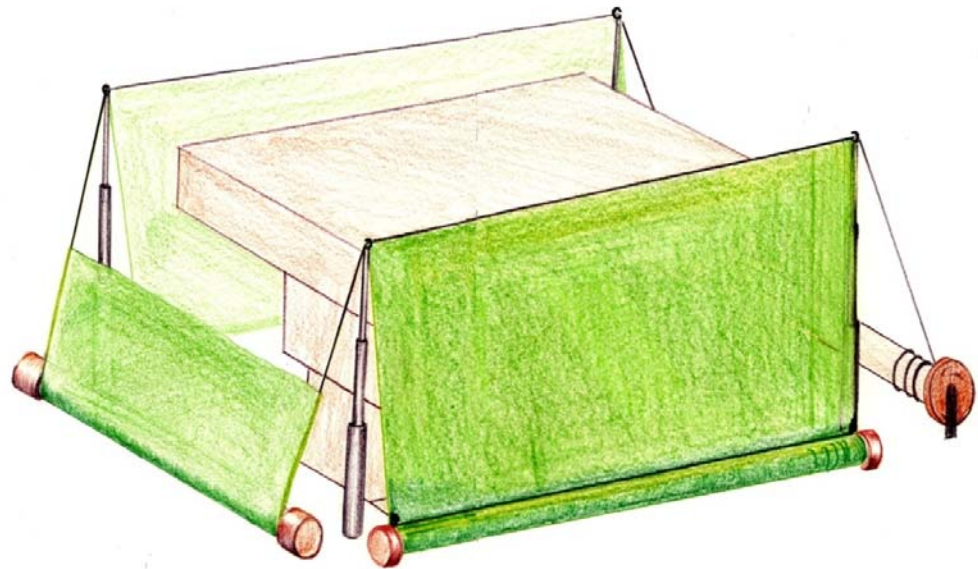
Principle of using 2 pulleys to reduce effort required to pull a load can be used thereby allowing use of small power motor

Here 3 pillars act as guides while MSN is moved around them from a 4th pillar with MSN rolled over it



Exploratory Concept 2:

This system is based externally around the launcher and needs no changes in the structural design of the launcher. It comprises of four telescopic arms that are used to cover up the entire launcher from all five sides.

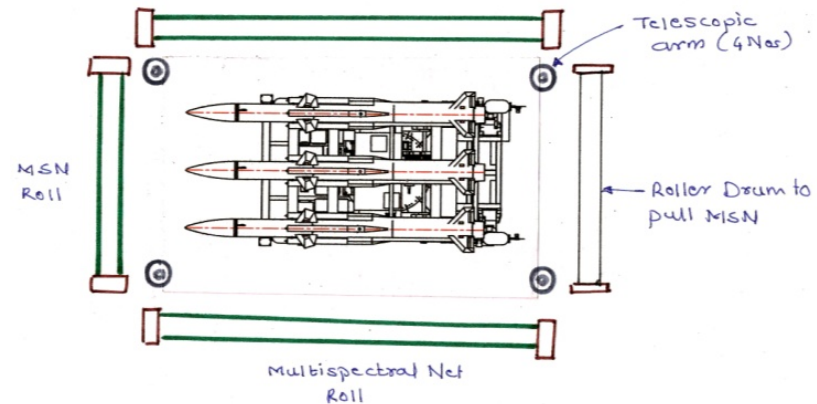


Rolled MSN (side)

Telescopic arms
at 4 corners



Concept 2



Operating Procedure:

- First the two MSN rolls on the sides are connected to the telescopic arm and are raised covering the two sides.
- At the same time the string connecting the MSN roll at front is passed through the loops on the top of the arms. (Refer adjoining fig.)
- Then the drum at rear end winds the string pulling over the MSN from the roll at the front side. This covers the launcher from front, rear and the top of the launcher.

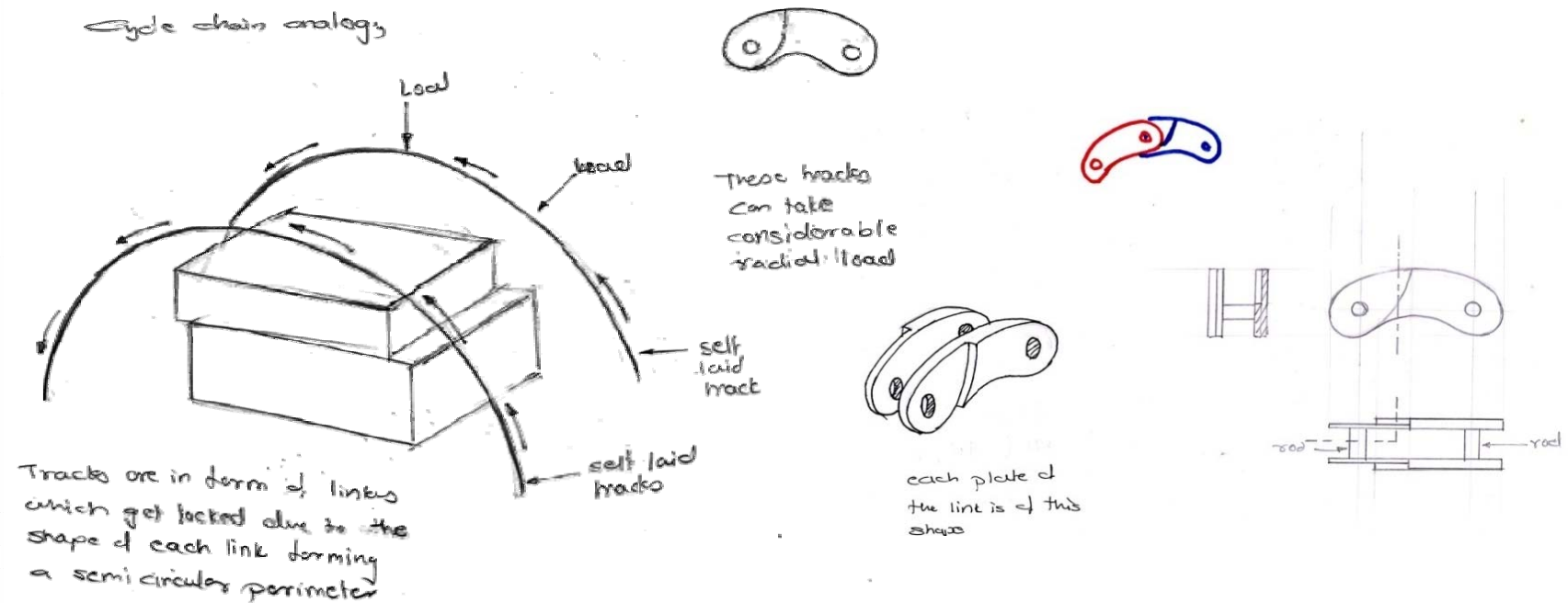
Features:

- Compact in size (small footprint)
- Easy for removal
- Minimum human intervention required for removal

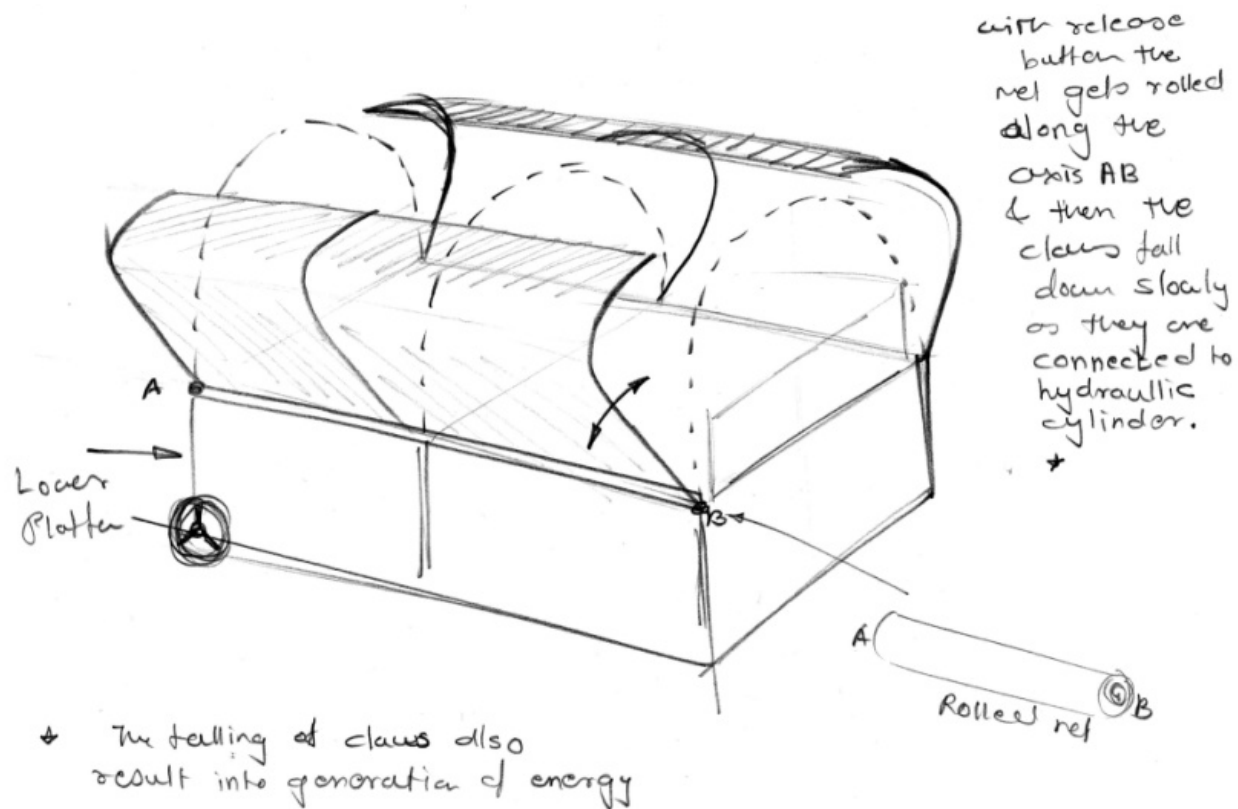
-
- Independent of the height to which the launcher is raised
 - Load on motors moving the net is low as only MSN is pulled
 - Simple to manufacture and implement

5.4.3 Cluster 3:

Ideation: This cluster consists of ideas based on radical and innovative mechanisms for implementing a camouflaging system.

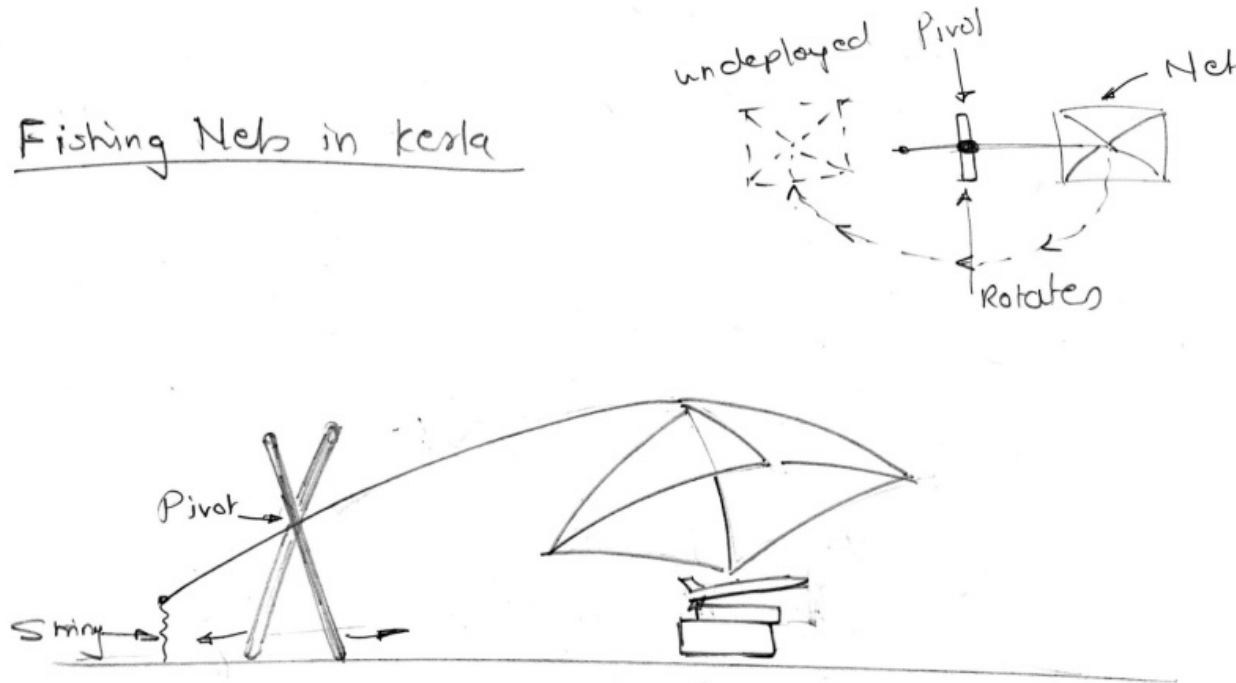


This idea is derived from the analogy of a cycle chain. It is a self laying mechanism wherein the links are of a specific shape such that they get locked when rotated to certain extent about their connecting pins.

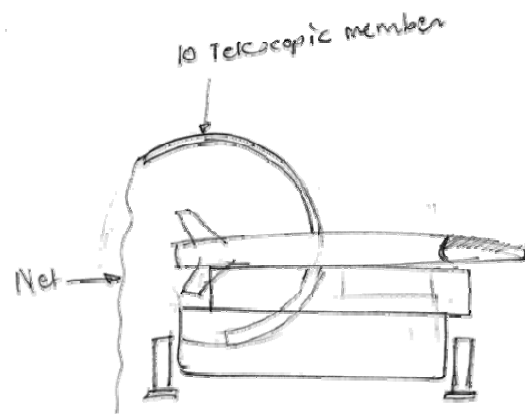


This is a claw based mechanism. The camouflaging is done using opening and closing of claws which are nothing but half rails. The lowering of the claws during removal happens slowly, and the energy generated gets stored.

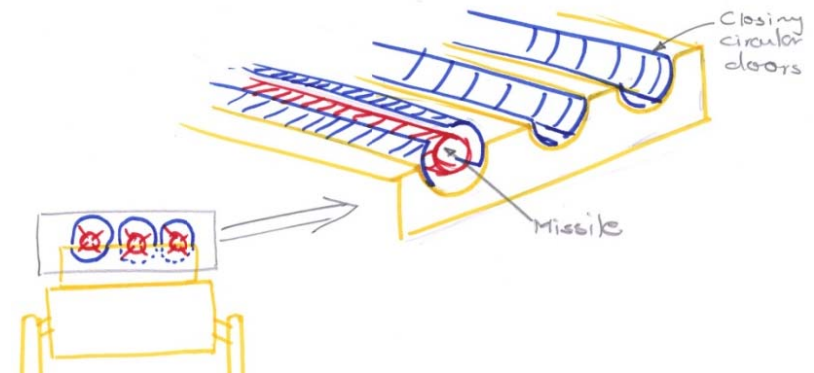
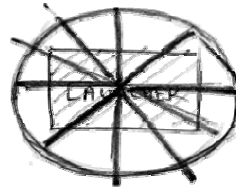
Fishing Nets in Kerala



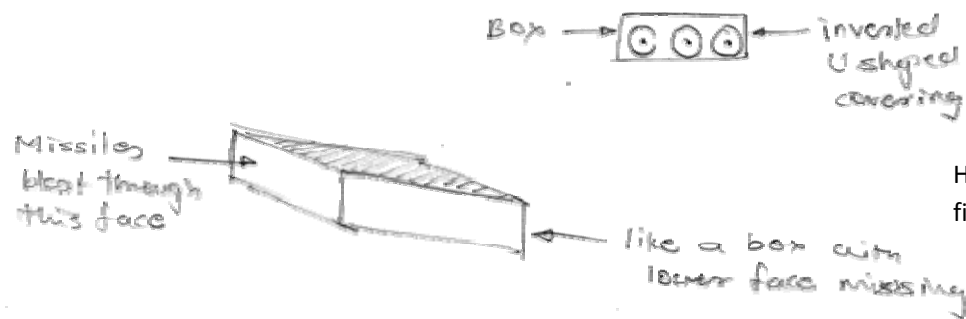
This idea is based on analogy from fishing nets, wherein a lever principle is used to drop the net. The pivot is in form of scissors which open up and drop flat on the floor when in un-deployed condition.



This idea comprises of 10 curved (circular) telescopic members which expand from within the launcher and drop the MSN over the launcher



Here the missiles are covered into cylinders by quarter circle plates that run along the length of the missiles.



Here the missiles are enclosed in a box like structure and fire by blasting off rupturing the front face.

5.4.4 Cluster 4:

After generating two concepts various mechanism with quick deployment were studied like, tents, portable homes, etc. A bellow concept for mechanism was chosen and studied further to develop a concept.

Inspiration:

Inspiration for this cluster is taken from the adjoining image of an expandable caravan (mobile vacation home). This type of structure is very easy to deploy and fold back. Also the bellow structure occupies very little space when folded.

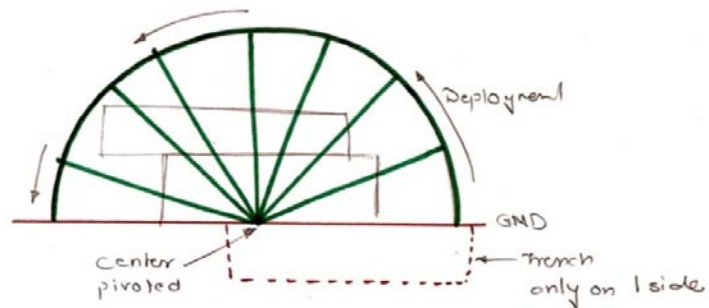
This cluster consists of ideas based on concept of bellows.



Caravan based on bellow concept

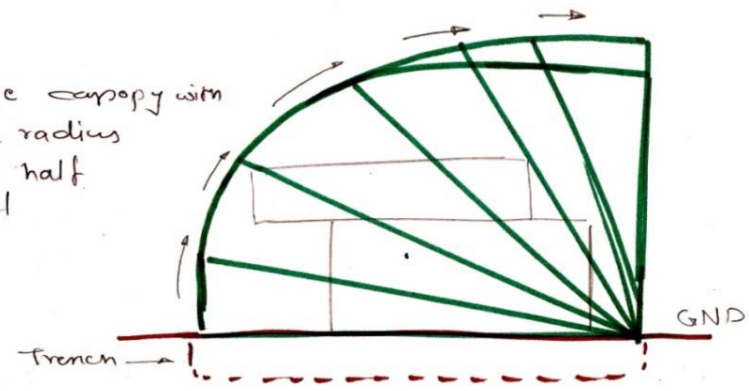
Ideation:

Types of canopy

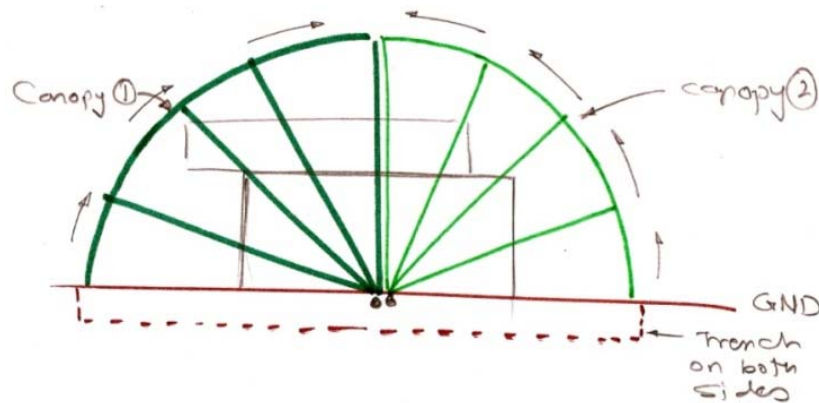


Complete canopy folds/unfolds from single side

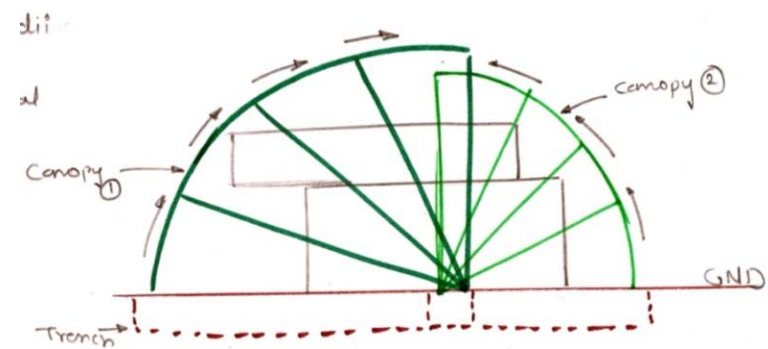
- Single canopy with huge radius
- Only half travel



Canopy with larger radius reducing angular travel to only 90°

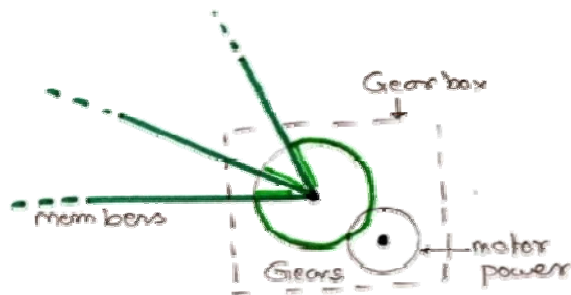


Canopy is formed by two quarter circles and is joined at the top

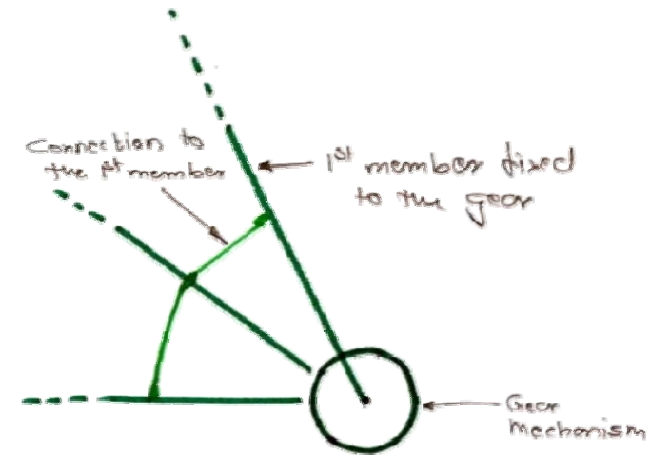


Canopy in two parts which overlap. Structural members may be bigger but smaller footprint

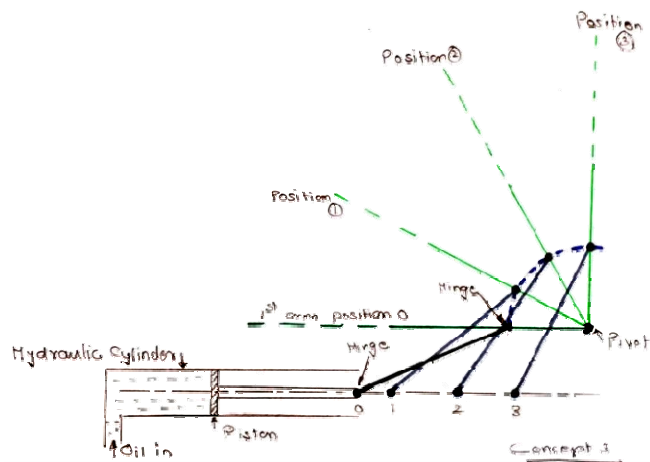
Raising (drive) and locking mechanisms:



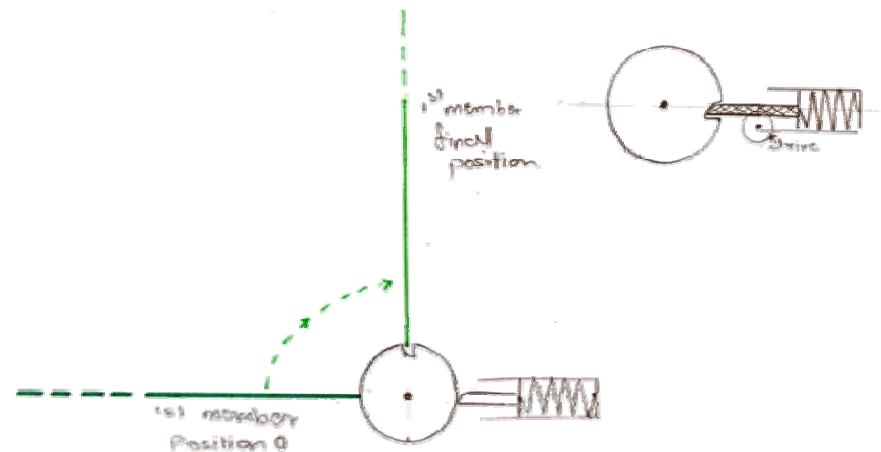
All the members connected to separate concentric gear train.



Only one members is driven by the motor, rest are pivoted about same point and are connected to the drive member using steel cables



Cylinder-piston mechanism is used to drive one member; other members are connected to the driven member



Locking mechanism for holding the driven member in place when in deployed position



Exploratory model showing deployment procedure

Exploratory Concept 3:

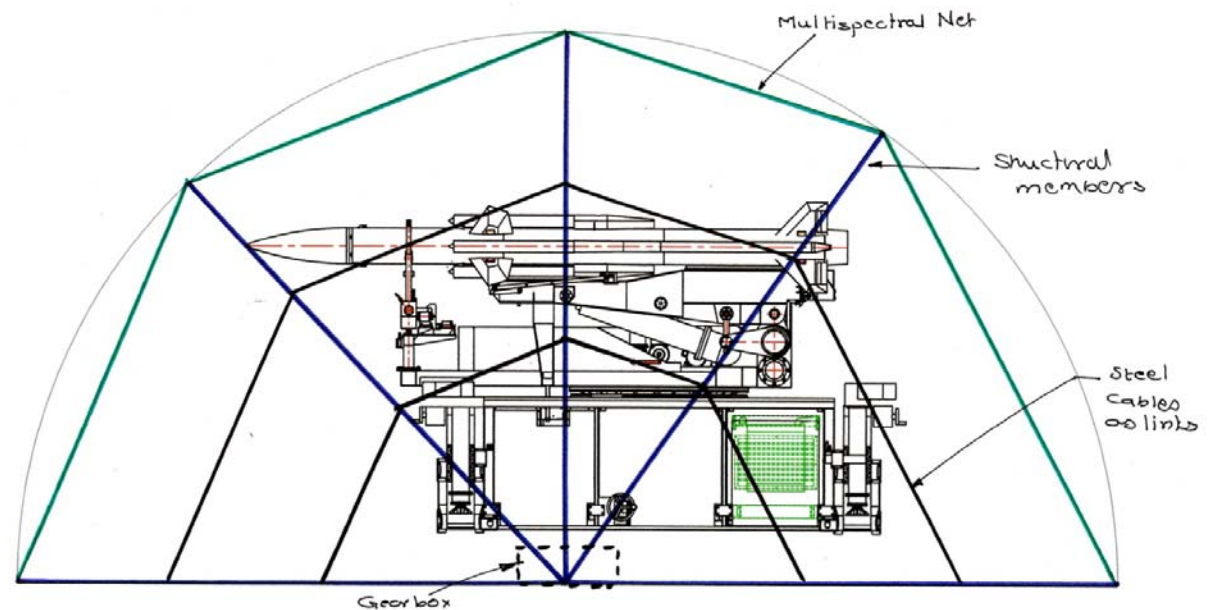
In order to study the various canopy setups and raising mechanisms, an exploratory model was as shown in adjoining figure.

After ideation it seemed that having a canopy in two parts would make the mechanism quick to operate and be more rigid. Contrary to this after making the exploratory model it was realised that single canopy structure was quickest to deploy and remove, and was also very stable due balancing of forces on either side of the vertical member.



Initial form of the concept with semicircular members.

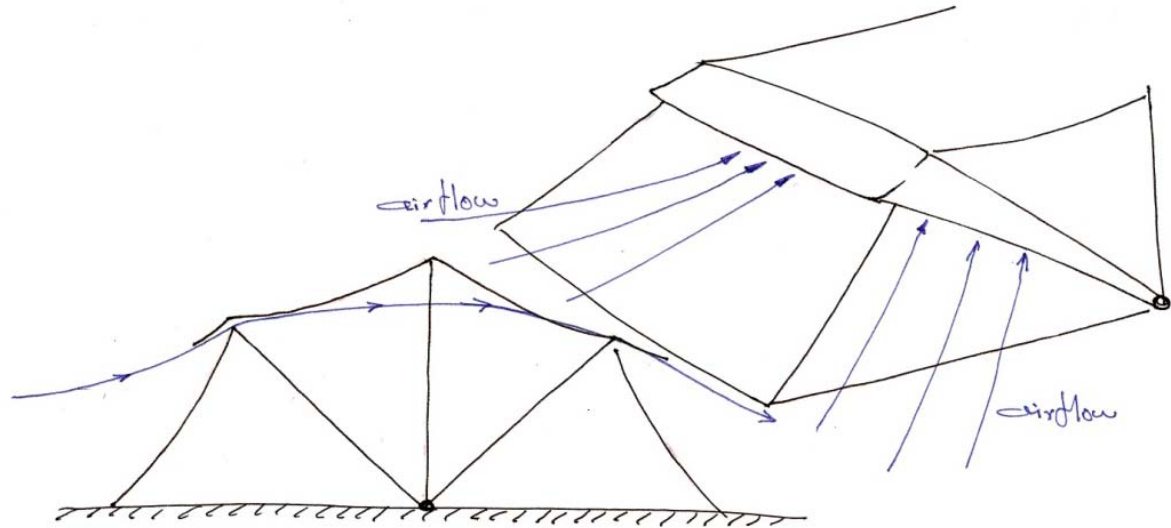
Structural details:



For the raising mechanism, a gear box driving only the first member is used. The rest of the members are connected to the adjoining member using steel cables.

These links not only balance the forces on the central member when in deployed condition and make it stable but also keep the Multispectral net stretched while removal thereby avoiding any sagging and prevent the MSN getting entangled with the launcher.

Resistance to air flow:



As the structure has length of approx. 10.7m and height of approx. 5.4 m when deployed, there is considerable air resistance to the air flow. Hence to reduce the stress on the MSN and the structure the surfaces of MSN are disjoint and have flap to allow escape of air.

5.5 Camouflaging Concept Evaluation:

Later the 3 concepts, generated based on card sorting and clustering technique, were evaluated against the camouflaging design brief. Weighted rating was used to select the concept that matches the brief optimally and further refinements were carried out.

Parameters	Concept 1	Concept 2	Concept 3
Time for removal (higher the no. faster) (9)	(8)	(6)	(9)
Size of system: footprint & surface area (8)	(9)	(8)	(6)
Ease of removal (7)	(5)	(7)	(9)
Min. human intervention (6)	(8)	(7)	(9)
Ease of deployment(5)	(4)	(6)	(8)
Mechanism Complexity (4)	(6)	(7)	(8)
Working complexity level (3)	(6)	(7)	(4)
Manufacturing ease (2)	(4)	(7)	(6)
Height Adjustment independency (1)	(9)	(8)	(6)
Weighted Rating	306	310	348

Hence concept 3 was chosen for final concept development.



Concept #3

5.6 Concept Refinement:

Based on the evaluation of the 3 concepts against the design brief, concept #3 was selected for further refinement.

The parameters against which the concept #3 was rated low are:

- Size of system: footprint & surface area (8)
- Working complexity level (3)
- Manufacturing ease (2)
- Height Adjustment independency (1)

As the last three having a very low rating, the size of footprint of the launch system was taken as important aspect and further refinement was done as follows:

5.6.1 Stage 1:

Though there is no problem with availability of space for developing a camouflaging system around the launcher, the basic principle of camouflaging states that smaller the size of its footprint lesser is its signature.

Features of the refinement compared to concept #3 are:

- Lesser surface area.
- Smaller footprint.
- Irregularity in top surface of multispectral net.

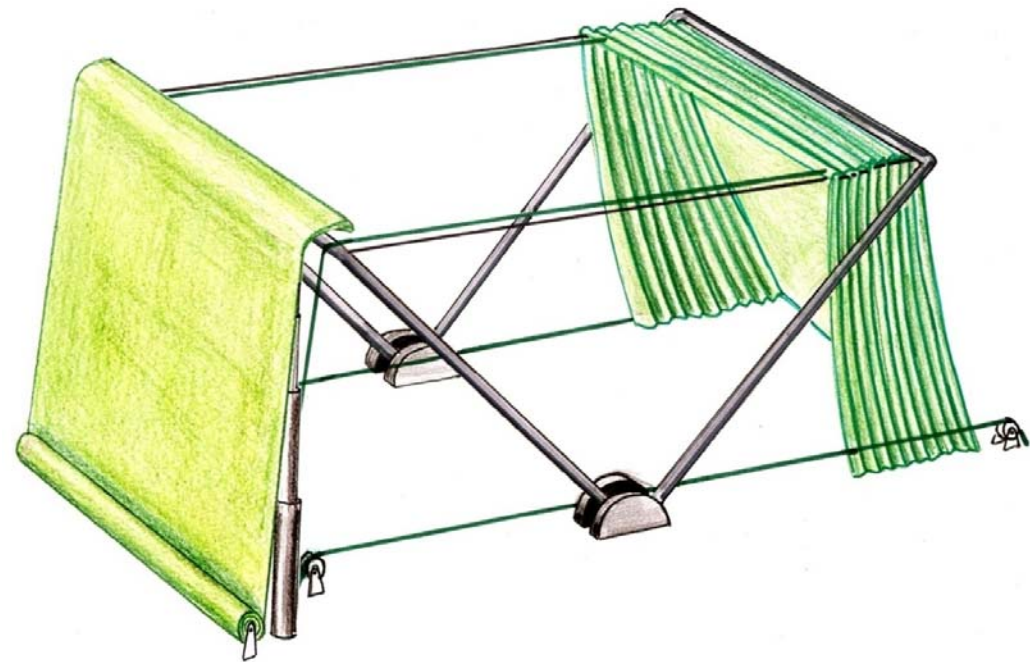
All these features reduce the probability of detection of the Launcher when the camouflaging is deployed.

The 3 major reasons that increased the size of the concept #3 camouflaging system were:

- The completely joint multispectral net sections which increased the footprint
- The high central member that increased the surface area.
- Also the stretched surfaces of the multispectral net formed a regular shape and hence increased the probability of detection.

Approx. improvement:

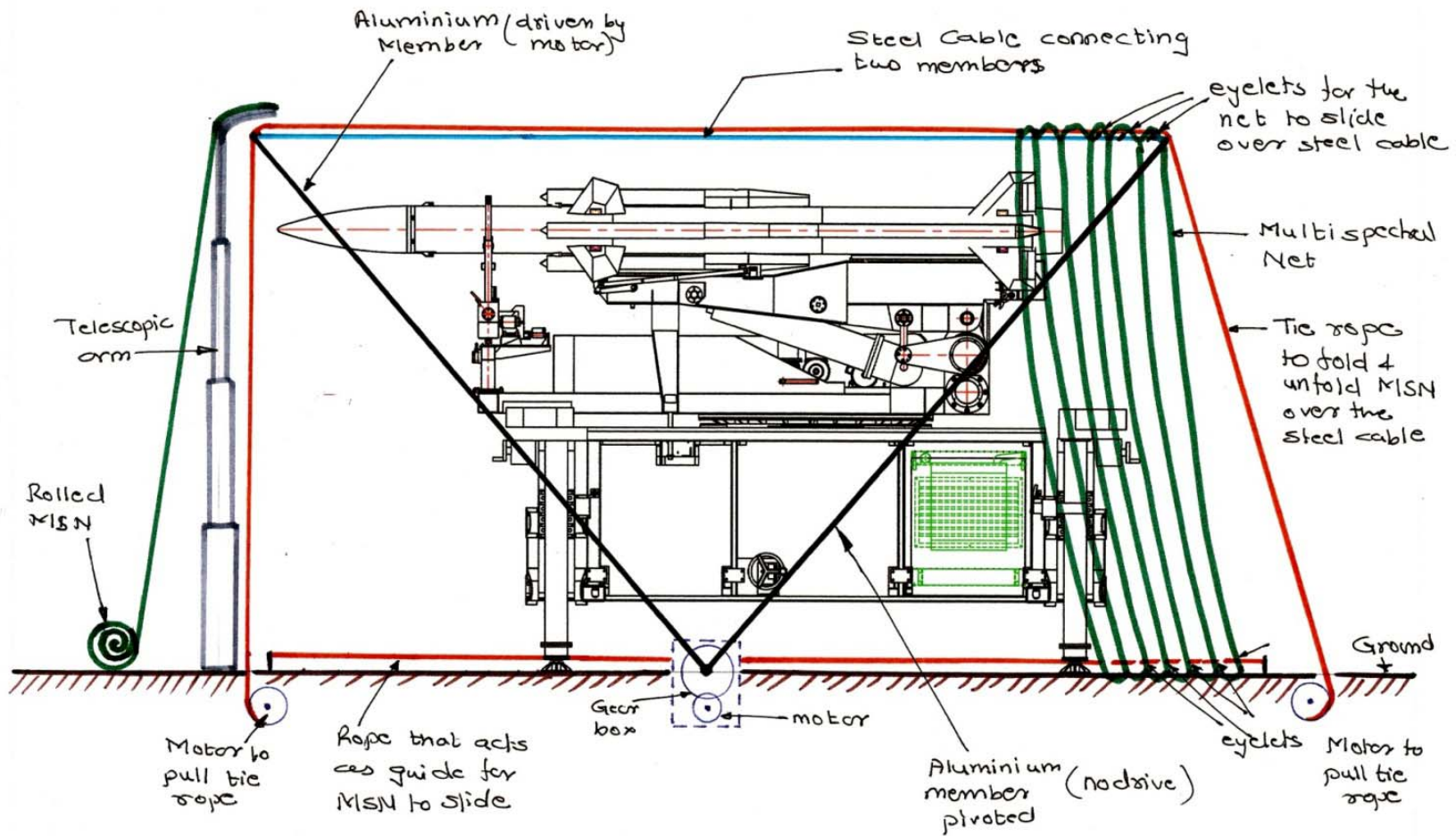
	Concept #3	Refinement: stage 1
Surface area	151.73 m ²	131.71 m ²
Footprint	45.77 m ²	32.64 m ²

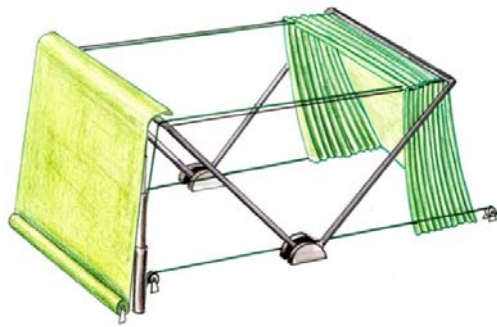


Hence following refinement was made to concept #3:

- After refinement, the number of members was reduced to the minimum required i.e. two. This reduced the surface area and footprint (refer the adjoining table).
- The two steel cables connecting the two members prevented sagging of the multispectral net at the top.
- Also the top surface and the sides have waves due to passing of the multispectral net over the cables through eyelets giving it an irregular shape. This reduced the probability of detection of the system.

Structural details:





Refinement stage 1



MSN covering all faces except front face



Telescopic arm with bend at top

Operating procedure (for removal):

- The motor at the rear end pulls the multispectral net towards the rear member thereby folding it in zigzag manner. The motor at front end is free in clockwise direction allowing the tie rope to loosen out whenever pulled by the rear motor.
- The two telescopic members are raised to allow for clearance for the front member to rotate.
- The two members rotate about the pivot and collapse to the ground, simultaneously the motor at the rear winds the tie rope.
- The telescopic arms are lowered and the multispectral net covering front face gets rolled.

While deploying the system all steps are repeated in reverse order. The only difference being that the motor at the front end pulls the tie rope. The rear end motor is free in counter-clockwise direction.

5.6.2 Stage 2:

With the initial refinement the surface area and the footprint of camouflaging system was optimized, but the time required for deployment and removal increased due to multiple number of operational steps. The system has to be designed for quick removal.

Major lacunae with the refined concept:

- Separate motors were required for pulling the tie rope (MSN) during deployment and removal.
- The collapsing of members and folding of MSN had to be done separately, increasing the time for removal.
- While removal the telescopic arms had to be raised to provide for clearance for the front member to rotate and then the telescopic arms had to be collapsed. This also added to time for removal.
- Multiple strings passed over the top of two members with very little clearance; this increased the chances of failure of system.
- Smooth sliding of the MSN at the lower end could be hampered by dust accumulation resulting into large stresses in the strings and the MSN thereby increasing time for removal.
- In collapsed condition folding of the net is an issue.

Hence further refinements were carried out to reduce the time for removal and also reduce the chances of failure.

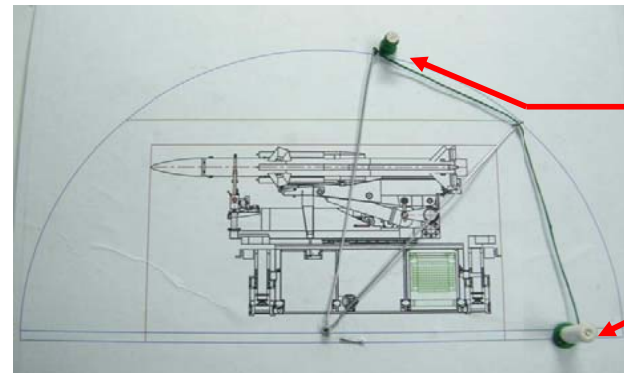


Exploratory model

Exploratory model:

In order to explore the lacunae in the 1st refinement an exploratory model of 1:25 scale based on the refinement was made. The exploratory model helped to highlight the problems like folding of the multispectral net when in un-deployed condition. Also this model was used to study various processes involved in deployment and removal of the MSN. This helped to identify and solve various problems encountered in the initial refinement. Based on the inputs from this exploratory model a new process for quick removal was generated.

A new 2-D exploratory model was made. This model was used to study the procedure for deployment and removal. Also the clearances required to prevent any entanglement of the MSN with the launcher were studied with the model and final concept was made.

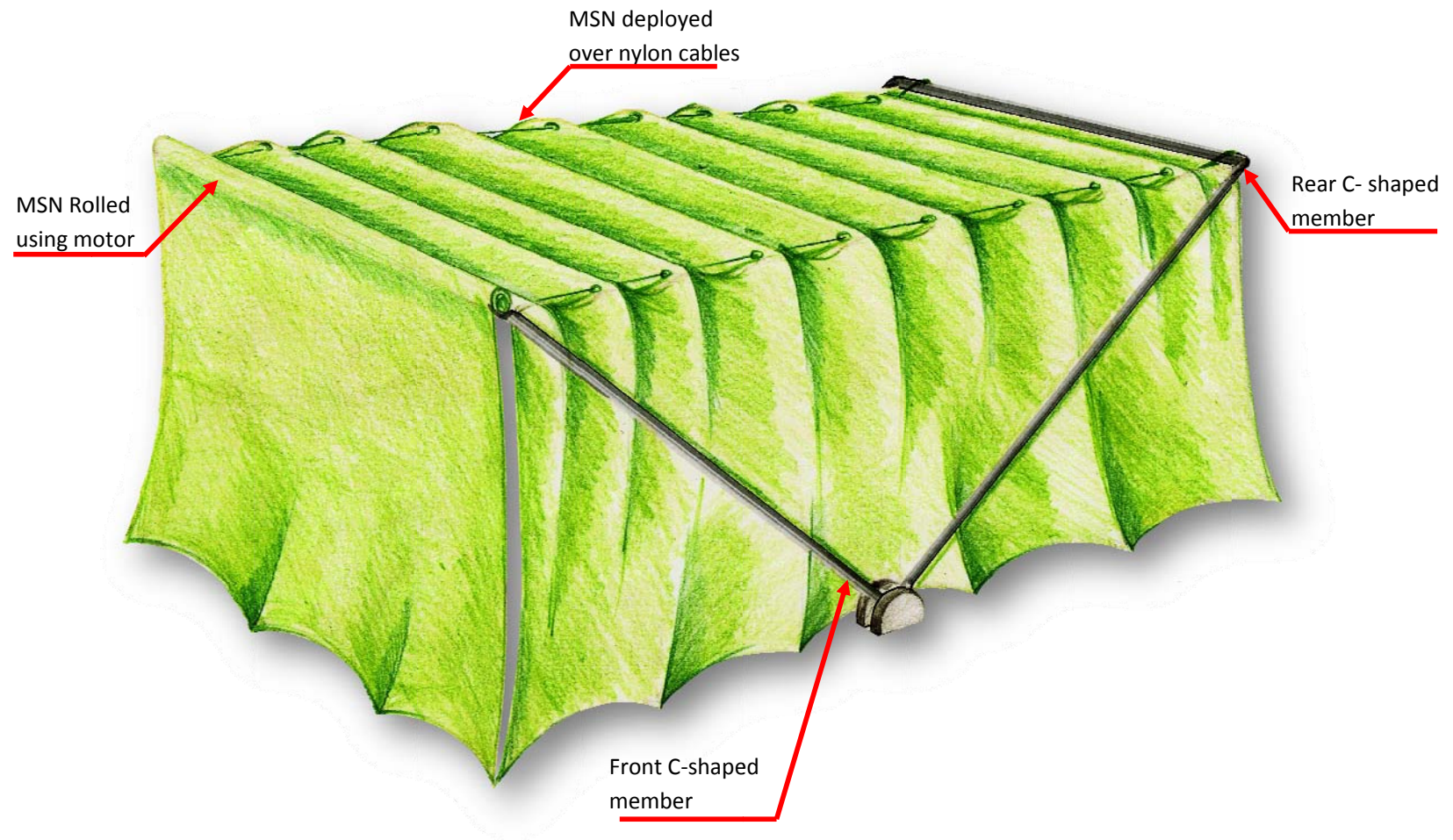


Motor to roll up the MSN
mounted on the front member

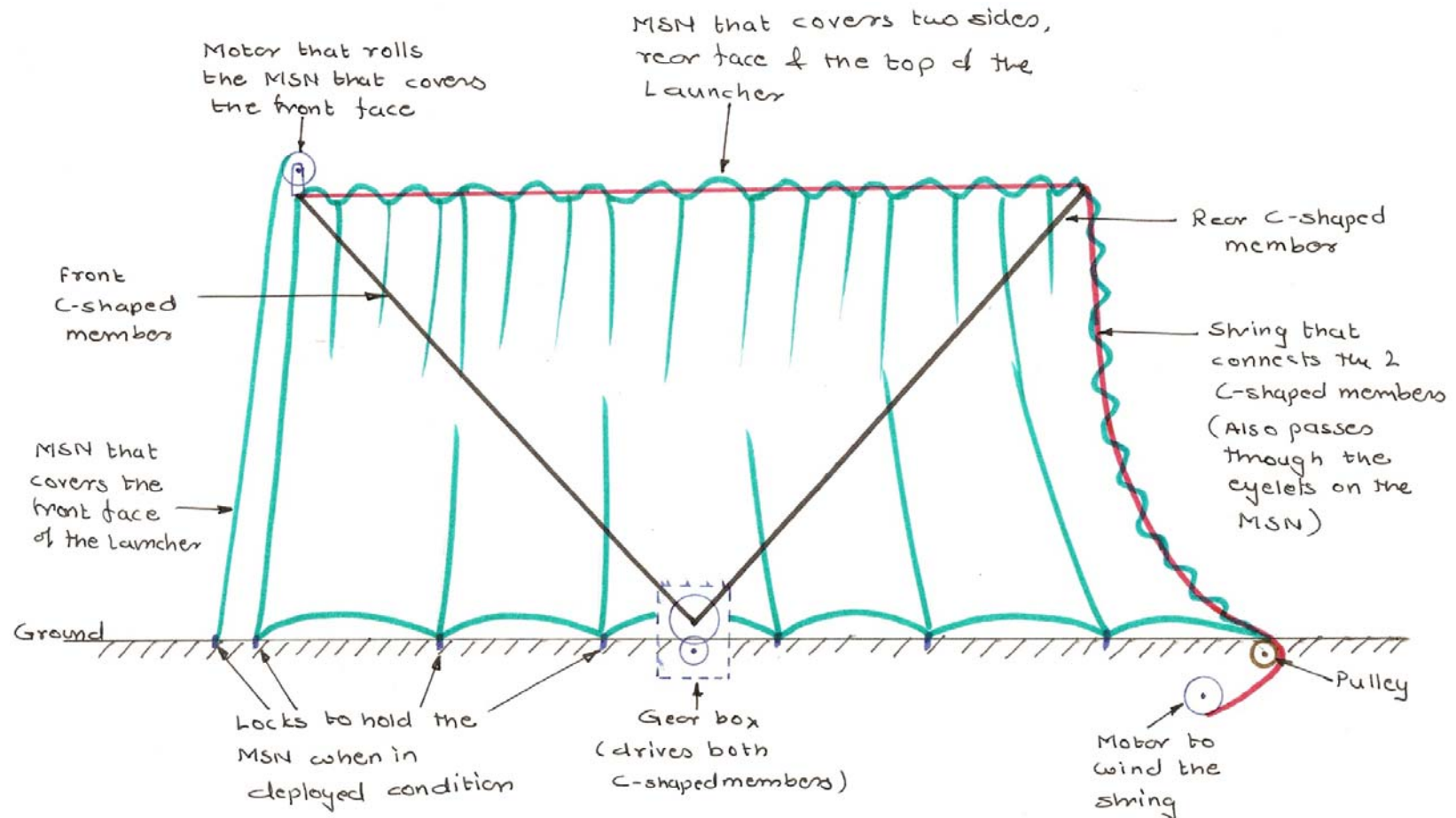
Motor to
wind string

5.7 Final Concept:

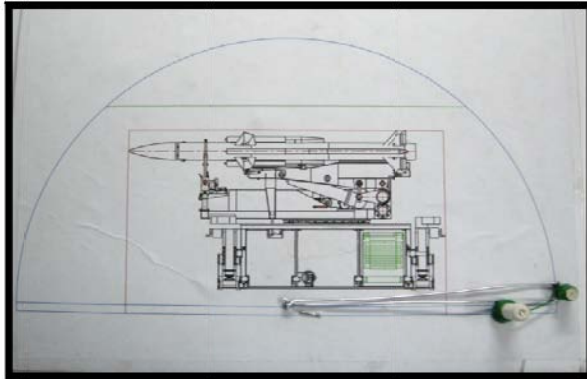
5.7.1 Concept Rendering:



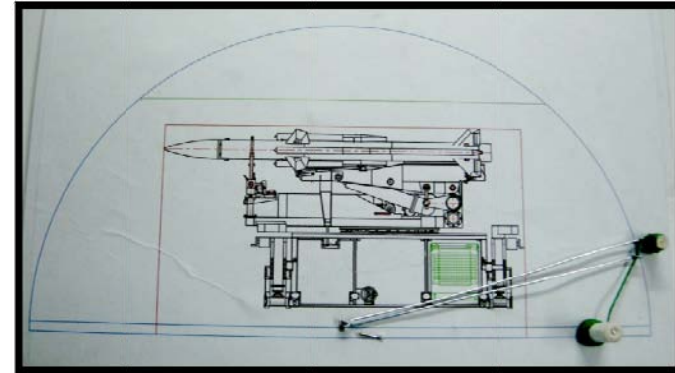
5.7.2 Structural details:



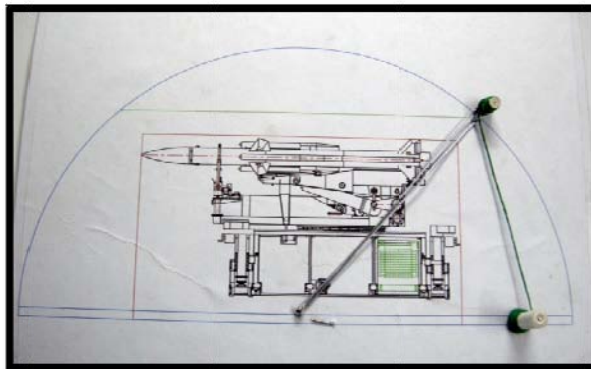
5.7.3 Procedure for Deployment of MSN:



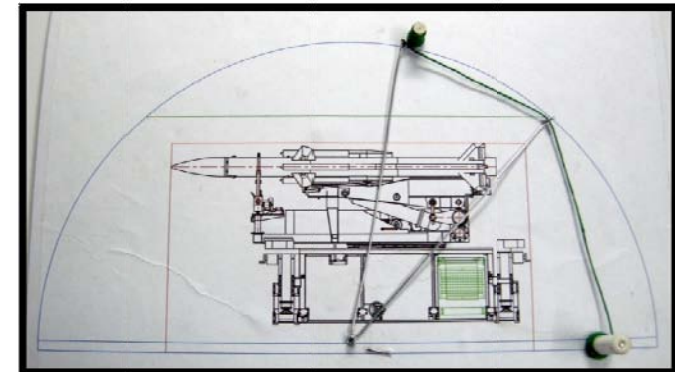
1. In un-deployed position both the C-shaped members lie horizontal on the ground at the rear end of the launcher.



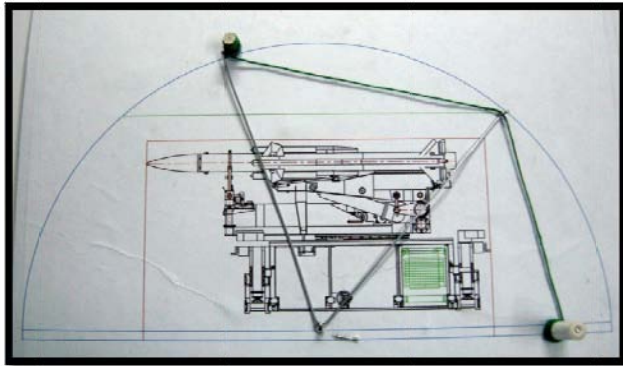
2. Initially both the C-members move together. The motor releases the string, passing through the net eyelets, simultaneously.



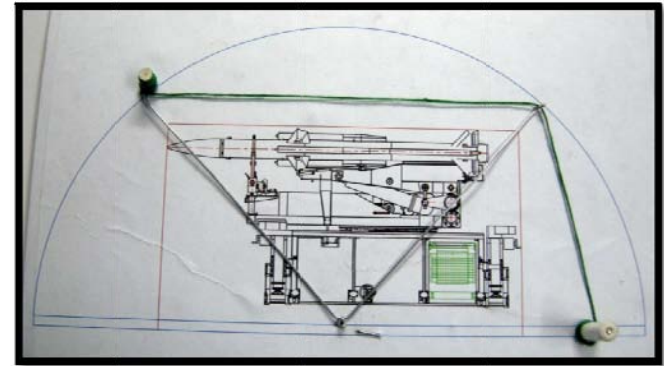
3. As the rear member reaches the top most part it gets locked.



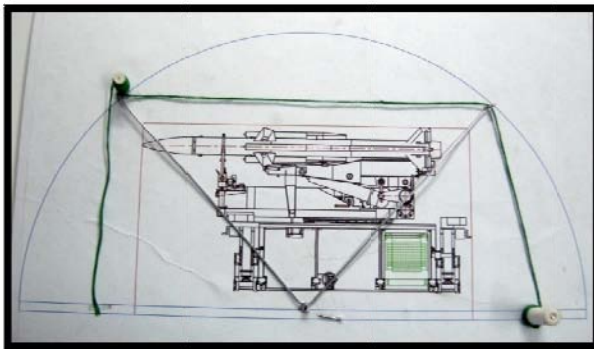
4. Further only the front member rotates with the rear member locked.



5. As the front member rotates the launcher starts getting covered from 2 sides, rear and top.



6. As the front member reaches this position it gets locked and now the MSN completely covers 2 sides, rear and top of the launcher.



7. Finally the motor mounted on the front member rolls down the MSN. Now the launcher is covered from all sides with MSN. After complete deployment the net is locked on the grounds using hooks manually.

Procedure for removal of MSN:

- The removal of the multispectral net has to happen around a minute hence it is completely automated.
- First the net hooks are released automatically and the MSN on the front face is rolled up.
- Next the first member starts rotating in clockwise direction, simultaneously rolling the string on the drum and; lifting & folding the net in zigzag form.
- Finally the rear member also collapses and the MSN is completely removed.

5506 mm

4250 mm

Dimensions of C-shaped member



Shape MSN covering all faces except front face

5.7.4 Technical specification:

Following are the materials and technical specifications of the components of the system:

C-shaped members:

Quantity	2 Nos.
Material	Aluminum 6341
Density	2800 kg/m ³
Weight calculation	Assuming following cross-section of pipe: Outer dia. = 25.4 mm Inner dia. = 10 mm Weight = 73.1 kg ≈ 75 kg Total Weight of two members = 150 kg

Multispectral Net:

Quantity	5 surfaces (including rolled surface)
Material	Polyester based
Surface density	200-350 gm/m ² (depends on manufacturer)
Weight	26.34 -46.1 kg ≈ 50 kg

Connecting Strings:

Quantity	2 strings
Material	Polyamide (nylon)
Tensile Strength	82 N/mm ²
Strength calculation	Assuming following cross-section: Twisted multiple strand rope wire of 2 cm diameter Cross-section area = 314.16 mm ² Allowable maximum load = 25761 N = 2576.1 kg Assuming FOS = 10 Allowable design load = 257.6 kg (for single rope)

Total load on motors driving the C-shaped members:

Maximum load (considering multispectral net density as 350 gm/m²)

=Weight of (C-shaped members + multispectral net + weight of motor and roll on front C-shaped member + extra safety load)

= 150 + 50 + 10 + 10

= 220 kg

5.7.5 Features:

The salient features of this camouflaging system are:

- Minimum size (surface area as well as footprint).
- Quick removal due to lesser number of operations and complete automated removal.
- Easy to deploy.
- Irregular shape due to waved surface at top, hence low probability to getting detected.
- Complete cover but not completely closed envelope of multispectral net with openings at bottom and front face allows for sufficient air flow.
- Very low weight camouflaging system. Hence lower power driving motors required. Energy efficient.

6. Conclusion:

6.1 Final Design:

The project covers the design of two major aspects of an air defense system: user interaction and the protection of the system.

The new design of the user interaction panel (control panel) is a package of unique selling points in terms of intuitive and clear interface from point of view of user convenience. Being a control panel of life critical system like an air defense system the interface does not allow any human errors to go unnoticed thereby, making the system foolproof and safe for use. The ease of use of the system is the major factor in its make-up. The relationship between the user and the machine has been brought close by giving the user a sense of confidence while working with the system.

Any defense system along with being a matter of self defense and security for a nation, involves large amount of expenses in terms of capital and manpower for conceiving, developing and implementing the system. The protection of such system is as important as its function. The protection of the concerned air defense system is done using a technologically advanced camouflaging system. It comprises of latest in technology multispectral net and advanced coatings. The camouflaging mechanism involves deployment of multispectral net around the launcher to provide complete cover against visual and radar detection. The mechanism has been optimized to this system for quick removal. The mechanism optimizes the size of the camouflage to minimize the probability of detection. The advanced anti-thermal/ anti-IR coatings provide the

launcher a very effective camouflage against thermal and infra-red detection by minimizing the difference in thermal values of the surroundings and the launcher.

Thus the requirements set by the design brief have been effectively achieved.

6.2 Challenges and Limitation:

The most important challenge in the project was to redesign the system for a new user. The existing system is a working prototype of the expected final air defense system and is designed considering the technicians and engineers as the primary user. The new user will be a service level Jawan with very little technical knowhow and will be required to be trained to use the launch system. Hence the new design had to be intuitive and foolproof.

The launcher being the first of its kind in Indian defense system, the specific users for this system are not available. The information regarding the user is available through the technicians and the engineers in Larsen & Toubro.

6.3 Future Scope:

The new design of the control panel is based on some specific requirements set by the client i.e. Defense Research and Development Organisation (DRDO) of India. Exploration can be done to altogether replace the existing control panel with new interactive systems. Technologies like touch sensitive screens can be incorporated to enhance the usability of the system.

The ergonomic study of the existing prototype needs to be done which was not done due to unavailability of time and concerned personnel at the site of the launcher. Also user-study needs to be done with the expected users and their feedback needs to be analysed.

6.4 Learning:

This project has been challenging as well as rewarding. It has greatly enriched my knowledge regarding air defense systems and the defense scenario. The project has made me more sensitive towards the aspect of user needs and their convenience. It has further underlined my belief in user driven design.

It has made me realise the importance of design as a process towards solving problems be it any field from life critical systems like the defense systems to everyday products.

I now firmly believe that design is a process and not just the end-result.

References

Literature:

- Indian Anthropometric Dimensions for Ergonomic Design Practice – D. Chakrabarty
- Design Data book for Engineers – PSG college of Technology, Coimbatore
- Collapsibles – Per Mollerup

Websites:

- www.drdo.org
- www.larsentoubro.com
- www.army-technology.com
- www.bharat-rakshak.com
- www.inetres.com
- www.live-fist.blogspot.com
- www.saabgroup.com
- www.oztektekstil.com.tr
- www.wikipedia.org