Conceptual Design of Mars Crew Exploration Vehicle

Team Ares

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This research internship work entitled "Conceptual Design of Mars Crew Exploration Vehicle " has been carried out by us under the guidance of Mr. Pavan Kumar who is pursuing PhD in Partial Differential Equation (Variational Formulation) for mechanics problems at IMT School for Advanced Studies and Mr. Mahesh P who is the Head of Innovation of Space Education Research and Development.

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Abstract

Mars once seemed far away, but as each year passes one begins to hear about it more often. The first step on Mars is the next big awaited news. **Team Ares** at **SSERD** believes in this pace of progress and has come up with a conceptual design for a **Mars Crew Exploration Vehicle (MCEV)**. This vehicle will carry 4 astronauts on a journey to various exploration sites within a radius of 10 km from the base settlement in Mars.

Beginning with the selection of landing site on Mars, this report consists of the Wheel Design and Suspension System development. The Environment Control and Life Support System (ECLSS) aboard the vehicle will mimic Earth like conditions for the crew, aided with proper lighting (SSLA) to maintain Human body metabolism. Apart from this, the cabinet material has been chosen considering the harsh climate Mars has in store for us. The vehicle also has a suite of instruments which will aid the exploration tasks and the mission would go astray without the decided communication via satellites in the Areostationary orbit. The report finally gives an insight on Power Generation using Li-SO_2 Batteries along with an auxiliary supply using Solar Cells and its distribution in the MCEV.

1 Introduction

For as long as humans have watched the sky they have wondered whether earth was unique whether other planets might be out there somewhere having life on them. Since time immemorial universe has been a source of fascination and fundamental questions what else is out there and how was all this created, where we come from, can we live on another planet. To know the answers to these questions various exploration missions have been carried out. Many answers are found and many are still to be found.

When it's time to move to another planet Mars is right next door. The 4^{th} planet from sun in our solar system, Mars is the most explored planet with more than 49 missions and counting [1] which can be made habitable in future. The first company planning to colonize Mars is SPACE-X which is working on full thrust to make it possible. The Human Exploring Mars cannot be made effective without the use of Mars Crew Exploration Vehicle (MCEV).

Mars Crew Exploration Vehicle (MCEV) is the vehicle which will be used by the humans to explore the mars. The Atmospheric condition of Mars are very harsh, challenging with average temperature of -81 *degrees* F[3] [2] as compare to 57 *degrees* on earth. The Atmosphere of mars contains mostly Carbon dioxide which is not fit for humans, so for habitation on mars humans need to have a functional base on the mars so that humans can get sufficient oxygen environment to survive and shielding from radiations. Small explorations can be done in spacesuit but when it comes to long explorations spacesuit can't provide oxygen for longtime and physical work in that environment is a different challenge. To make exploration simple we need MCEV and this paper we have provided a conceptual design for MCEV.

When it comes to designing the vehicle for mars, basic fundamentals of vehicle design need to be modified with additional things taking in consideration uneven terrain, Gravity constant (only 38% of earth), radiations, dust storms, temperature etc. The paper starts with discussing the mechanical system's selection and design of Wheel, Suspension and chassis subsystem which forms the base of the vehicle. Then discussion about Cabinet subsystem is done which explains the overall life support system of the vehicle. Then discussion about motor selection takes place which is then continued

[1] https://www.spacex.com/human-spaceflight/mars/
[2] https://mars.nasa.gov/all-about-mars/facts/

with electrical system. The electrical system covers various topic such as navigation, lighting, Camera, sensors and power generation of the vehicle. [3]

1.1 Assumption

When it comes to conceptual design of the vehicle some assumptions are taken. Some of the basic assumptions are-:

1. We are taking assembled MCEV from earth to mars in Starship space vehicle so design is constrained according to Payload bay of Starship.
2. We are assuming to have a fully functional base on mars.
3. The MCEV is designed for carrying 4 humans at a time.
4. Only 2 out of 4 Humans can go out from exploration at a time.
5. The energy for recharging batteries can be used from base settlement on mars.
6. The MCEV is design for exploration of minimum $10km$ radius from the mars base.

1.2 Landing Site

For the selection of the landing site on mars various factors such as topography, sunlight received per day, temperature variations and studies done by exploration organization such as Space-X, NASA, Lockheed Martin, Boeing etc were taken in consideration. We have finalized "Arcadia Planitia" as landing site. Erebus Montes is the local location decided with

$$Latitude(centered)38.993$$

$$Longitude(East)192.111$$

[3] https://www.planetary.org/space-images/marslandingsitemaplakdawalla

2 Design

2.1 Wheel

2.1.1 Background Study

Ever since the humans thinking about exploration, transportation has been the biggest concern. In transportation wheels are one of the most important element on which the success of the mission depends. From past experience in space exploration we found that wheels has been a topic of concern, the pneumatic rubber wheels used on the earth are obviously not a good match for mission like exploration on mars due to the extreme weather conditions. The Average temperature[4] on mars is $-81 degree$ Fahrenheit ($-62 degree$ Celsius) which can go as low as $-195 degree$ Fahrenheit ($-125 degree$ Celsius) at these temperature rubber will perform as a brittle material (like glass) instead of elastic material capable of absorbing stress and will also degrade due to radiation on mars. So we need to choose a wheel which is light weight, robust, cost effective and can withstand high stresses.[7]

2.1.2 Design

For our application we have come with NASA & Goodyear Designed Spring tires[5][6]. This tire is capable of both being light, capable of bending and conforming to the terrain without permanent deformation and capable of holding the weight of the heavier vehicle. The secret of this tires lies in the use of the new age material known as Shape Memory Alloys (Nitinol). Nickle Titanium alloy also known as Nitinol return to its original state after removing the applied stress by either heating or storing the energy in the form of the springs. In addition, the utilization of shape memory alloys provides enhanced control over the effective stiffness as a function of the deformation, providing increased design versatility.

Nitinol also known as shape memory alloy behave differently in stress environment as compared to previously used metal alloys. Nitinol have some unique properties due to internal crystal structure. When Nitinol is below a certain temperature it has a crystal structure called martensite as shown in Figure 1, its crystal structure is arranged in such a way that it accommodates

[4]https://mars.nasa.gov/all-about-mars/facts/
[5]https://technology.nasa.gov/patent/LEW-TOPS-99
[6]https://www.nasa.gov/specials/wheels/

deformation very easily. Martensitic nitinol forms grains of twinned atoms where the direction aligns. When stress is applied these twin grains deforms and align to best to best absorb the stress. Particular twin grain can grow at the expense of the others, this is called detwinning. This distortion in other metals is permanent without external energy providing the energy needed to revert backward, but Nitinol can get that energy from heat or pressure. Upon Heating or Pressurising Nitinol for austenite (as shown in Figure 1) an ordered and regular crystal structure which effectively resets the crystal structure, and when the nitinol cools or comes out of pressure, it remember its original shape. The Properties of the Nitinol material is mentioned in Table 1

After considering the weight of the vehicle as high as 5000kg (on earth) including every instrument, component, and payload, considering the Factor of safety to be 3.5. We have iterated the selection of number of tyres to be considered for our vehicle. After many iteration we have decided to have multi-bogey wheel system considering the total of 10 wheels. 4 Wheels at the front and back of vehicle, 2 wheel each side and 2 wheel in the middle of the vehicle near centre of gravity of the vehicle.The Dimesions of the wheel are shown in Table 2

Table 1: Nitinol Properties

Density	6.45gm/cm$\hat{3}$
Melting Point	1310°C
Yield Strength (austenite)	195-690k MPa
Yield Strength (martensite)	70-140k Mpa
Elastic Modulus (austenite)	75-83k Mpa
Elastic Modulus(martensite)	28-40k Mpa
Resistivity	76ohm-cm
Thermal Conductivity	0.1W/cm-°C
Coefficient of Thermal Expansion	11x 10$\hat{(}$-6)/ °C
Poisson Ratio	0.33

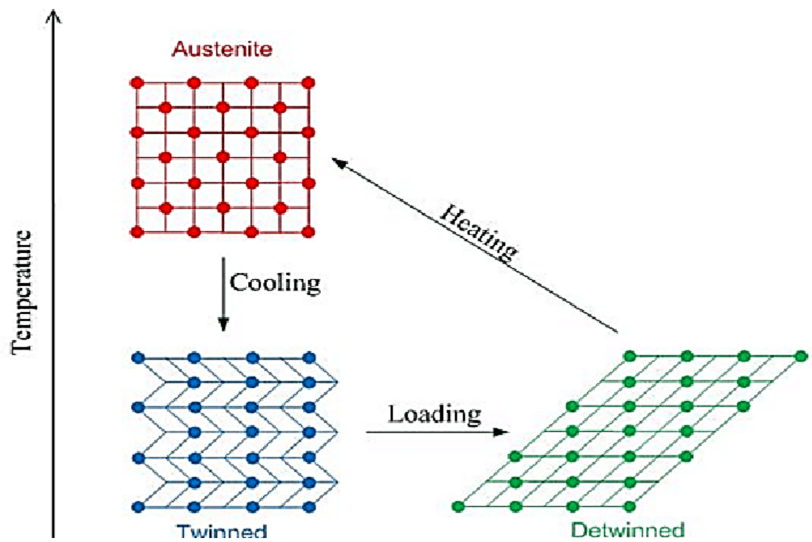


Figure 1: Transformation in Shape Memory Alloys
(Courtesy:Jawaid Daudpoto,Mehran University of Engineering and Technology · Department of Mechanical Engineering)

Table 2: Wheel Dimensions

Parameters	Values
Outer Diameter	900mm
Width	304.8mm
Rim Diameter	200mm
Rim Width	76.2mm

2.2 Suspension System

2.2.1 Choice of Suspension

The Choice of Suspension for The MCEV is heavily dependent on the terrain Conditions. Due to the landing site of chosen rover being Erebus Montes, a relatively flatter plain area on the surface of mars, an Active Suspension was deemed unnecessary.[8]
Based upon these facts three preliminary types of Suspension Systems were Considered for the MCEV :

1. MacPherson Strut suspension
2. Double Wishbone type Suspension system
3. Rocker Bogie Suspension system.

1. Macpherson Strut:[12]
Macpherson strut suspension system is a type of Suspension system which

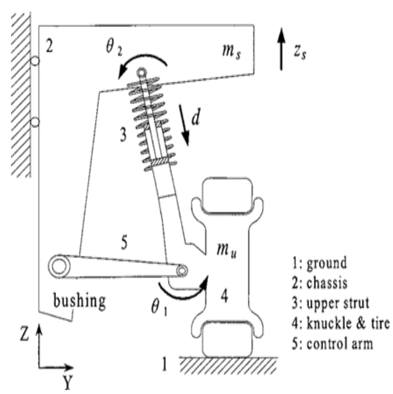


Figure 2: MacPherson strut

uses a telescopic damper as a Steering rod, thus combining the functions of the two.
Due to the relative simplicity of the Mac Pherson strut it was first considered to be a choice for the suspension system for the MCEV, but the limitations that the Macpherson strut faced –

- Vertical variations of the terrain and vibrations get Directly transmitted to the Vehicular body which can result in wear and tear of the exploration vehicle [14]

- Camber angle also keeps changing due to Body roll and Cornering[20]

As these limitations faced increased the risk of safety and durability of the MCEV, the Macpherson Strut Suspension system was not selected.

2. Double Wishbone Suspension:

The Double Wishbone suspension consists of two 'A' shaped arms. One

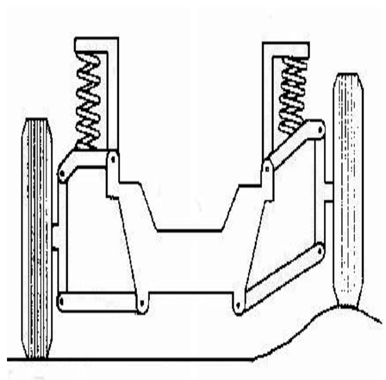


Figure 3: Double Wishbone Suspension

end of the arm connects two joints to the chassis, and other connected to the steering knuckle.

The Advantage that Double Wishbone Suspension possesses over Macpherson strut is that it gains a negative Camber angle when turning or traversing bumps or obstacles, thus maintaining more traction with the surface.[21]

However the Double wishbone suspension system increases the complexity involved in assembling as well as the maintenance and alignment of the components involved which would pose problems in the irradiated Martian atmosphere.[19]

3. Rocker Bogie Suspension system:

Rocker Bogie suspension is a passive symmetric suspension in which, each side contains a Rocker and Bogie. The Rocker is connected to the front wheel while the middle and rear wheel are connected by the Bogie.

The Rocker Bogie mechanism has been used by previous Lunar surface exploration rovers or vehicles[10]

The rocker-bogie suspension is a mechanism that, along with a differential,

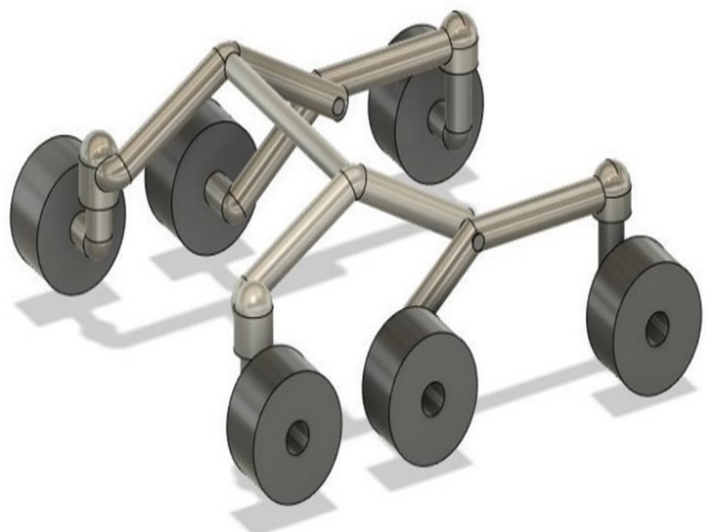


Figure 4: Rocker Bogie Suspension

enables a six-wheeled vehicle to passively keep all six wheels in contact with a surface even when driving on severely uneven terrain [11].
Thus this Suspension provides greater stability when climbing obstacles or traversing rugged terrain.
Based on these factors, the Rocker Bogie suspension was chosen to be the Suspension for the MCEV.

2.2.2 Design and Dimensioning

The Design Parameters for the Suspension system were decided keeping in mind the locomotive capabilities of the MCEV. The metrics for exploration vehicles differ quite a lot from terrestrial vehicles. Safety and stability are of utmost importance.[17]
The key five Design points of this suspension are A, B, C, D, E. The geometric parameters and structural parameters are shown in Fig 5. They reflect the

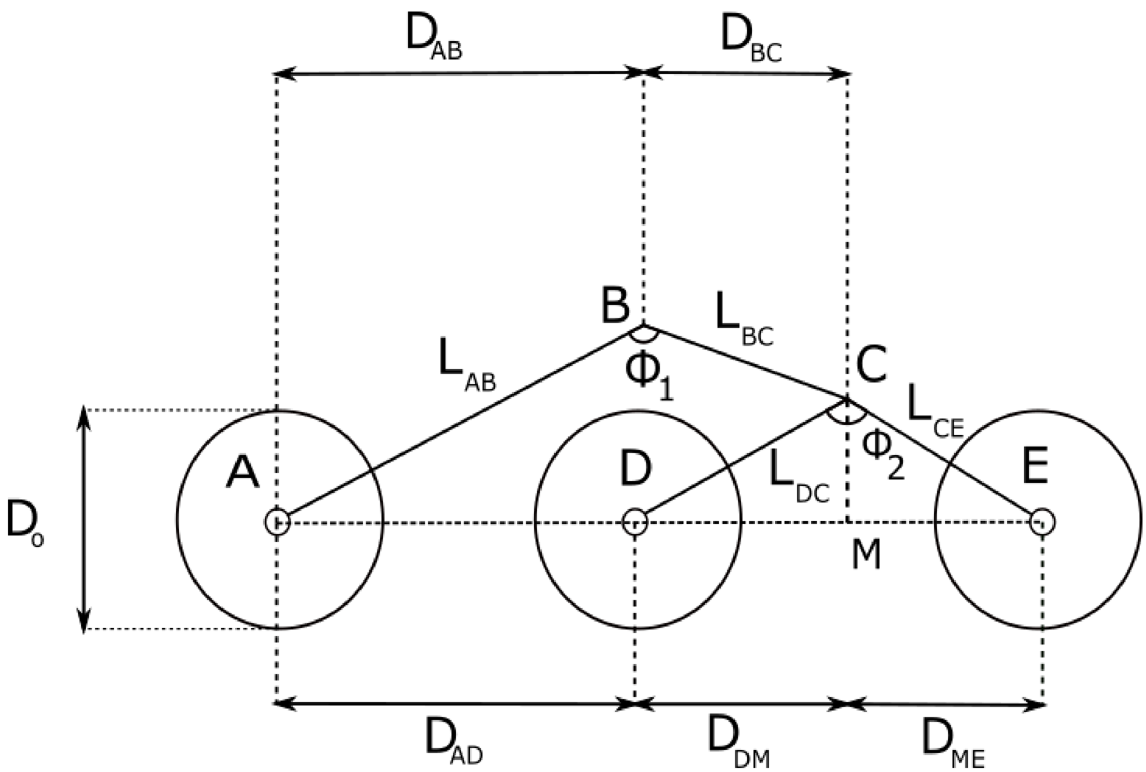


Figure 5: Key Design Point

relative position relationships among those key points.

Further design constraints and structural parameters were introduced to obtain a good locomotive Performance:

- When the rover traverses a flat ground, the pressure on one wheel should be similar to that on any other wheels. The horizontal distance between A and B is twice that between B and C, and the horizontal distance between C and D is equal to that between C and E: $D_{AB} = 2(D_{BC})$ and $D_{DM} = D_{ME}$.
- The rover should have similar forward and backward traverse abilities; as such, the wheel axle distance between the rear and middle wheel is equal to that between the middle and front wheel: $D_{AD} = D_{DM} + D_{ME}$.
- The axle distance is larger than the diameter of the wheel: $D_{AD} >$

D_o *and* $D_{DM} + D_{ME} > D_o$

2.2.3 Body Height Calculations

For the Calculation of the Clearance of the vehicle or Body frame height, we followed an approach similar to this

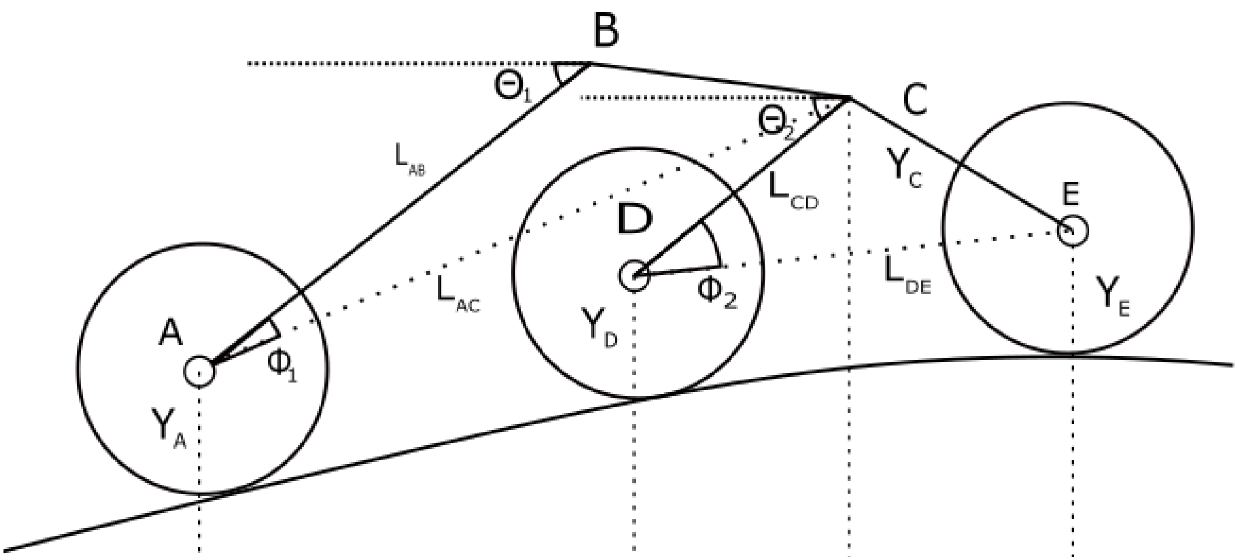


Figure 6: Body Height Calculations

Using the following system of equations derived from geometrical parameters :

$$\theta_2 = \phi_2 + sin^{-1}(\frac{|Y_E - Y_D|}{L_{DE}})$$
$$Y_C = Y_D + L_{CD}sin(\theta_2)$$
$$\theta_1 = \phi_1 + sin^{-1}(\frac{|Y_C - Y_A|}{L_{AC}})$$
$$Y_B = Y_A + L_{AB}sin(\theta_1)$$

We find the final Relation between Body height in terms of Wheel Altitudes as :

$$Y_B = Y_A + L_{AB} sin(\phi_1 + sin^{-1}(\frac{|Y_D + L_{CD} sin(\phi_2 + sin^{-1}(\frac{|Y_E - Y_D|}{L_{DE}})) - Y_A|}{L_{AC}}))$$

2.3 Chassis

Chassis frame is the structure which supports the components and the body of an automobile. Chassis helps to maintain the shape of the body by taking up the most of the load acting on the body. In simple terms chassis is the supporting structure. Chassis mainly contain side members and cross members. Mainly forces acting on the automobile body can be classified into following types:

1. Longitudinal torsion or Twisting
2. Lateral Bending
3. Vertical Bending
4. Lozenging (Due to obstruction of individual wheel while other wheel tends to move)

2.3.1 Chassis Frame

Chassis frame should be designed in such a way that it can withstand any of the forces mentioned above acting on the body without failure. The chassis with high torsional rigidity high bending stiffness and also it should be light in weight. The bending stiffness and torsional rigidity depend on the material properties and the cross-section shape.

Following tables contains for different torsional and bending the constants for different cross-section shapes:

Considering a bending stiffness of 1.0 for the solid square section, the relative bending stiffness for other sections are:

Considering a torsional rigidity of 1.0 for open-channel sections, the relative torsional stiffness for open-channel sections and closed thin-wall box-sections are as follows:

After looking at eth constants for bending and torsional stiffness, it is more preferred to use hollow closed-channel sections are preferred - namely,

Table 3: Relative Bending Stiffness

Cross- Section Shape	Relative Bending Stress
Square bar	1
Round bar	0.95
Round Hollow bar	4.3
Rectangular C-channel	6.5
Square Hollow section	7.2

Table 4: Relative Torsion stiffness

Cross- Section Shape	Relative Bending Stress
Longitudinal split tube	1
Enclosed hollow tube	62
Open Rectangular C - Channel	1
Closed Rectangular box section	105

circular and square/rectangular sections. Due to lesser mass of hollow sections, It helps to maintain the lighter frame.

In conclusion, a hollow circular closed section, which has an additional advantage of light weight and also appreciable bending and torsional constants has been decided to be used as the cross-section shape of the chassis frame members.
From different chassis frame types below mentioned three are mainly used:

1. Space frame
2. Ladder frame
3. Monocoque frame

1. Space frame

The framework of spaceframe is comparatively strong because it uses numerous shaped and cut pieces of structural metal tubing joined together. Framework also contains the diagonal member and forms a series of triangles and pyramids. Due to this triangles the framework becomes more robust. Thus structural loads acting on the body are carried out in only 2 forms – either compression or tension. There are no bending happens in spaceframe or we can say that bending and torsional stresses are converted into either tension or compression axial forces.

Advantages of Space frames:

1. Spaceframe mainly uses hollow tubes and much lesser amount of material. Hence it is much lighter in weight compared to other frames.
2. The frame gets the body close to the ground, hence it provides excellent torsional resistance/rigidity.
3. As mentioned above all the loads acting on the body takes in form of two either tension or compression, hence bending is not matter of concern here.

Its major drawback is that it is difficult to assemble the cross and side member. Apart from that it is extremely preferable for automotive applications.[7]

2. Ladder frame

It looks like a ladder from that it gets the name ladder. The term ladder is widely used when it comes to vehicles that are mounted on a separate frame. It's also referred to as a body-on-frame. The frame consists of two long, heavy beams of steel, held together by two shorter pieces. A ladder frame is easy to design, build and can be used in multiple applications with minimal modification. Vehicles with a ladder frame are easier to assemble as well.

Advantages of Ladder frame:

1. It can support heavy loads.
2. It Has very high side member thickness, hence good bending resistance.
3. It is easy to construct, as it has a very rudimentary design consisting of 2 parallel side members and a few cross members.[8]

Ladder frames also have their downsides: The bending resistance primarily depends on the thickness of the side members. Thus, this frame structure is heavy and bulky, hence, it is not ideal for use in automobiles that aim at minimal fuel consumption or for systems that have power supply constraints. This frame makes the vehicle sit higher off the ground. This makes it susceptible to high torsional flexing, otherwise known as 'leaning through the corners.

[7]://www.leisurewheels.co.za/blogs/ladder-frames-monocoques/)
[8]https://www.leisurewheels.co.za/blogs/ladder-frames-monocoques/

Although the ladder frame is used in 4X4 drive systems for use in off-road terrains, it is not ideal for use in Martian terrains due to high fuel consumption and heavy frame mass.

3. Monocoque frame

It is an integrated structure which composed both body and chassis.

Advantages of Monocoque frame:

1. Lighter in the weight because less material is used compared to space frame.

2. Much more rigid in the construction than the space frame.

Disadvantages of Monocoque frame:

1. If the applied load is not along the designed paths, then failure occurs abruptly. However, the other chassis frames can be more liberal in handling different loads.

2. Above point makes it more difficult to design and analysis.

Conclusion: Choice of the frame:

On weighing the pros and cons of the individual chassis frames, the SPACE FRAME chassis was decided as being ideal for use in Martian terrain, due to 2 primary reasons:

1. Design is uncomplicated.

2. High strength to weight ratio. Favorable load handling and light-weight

3 Cabinet

3.1 Pressurized cabin

Crewed Mars rovers also called as mars crew exploration vehicle are vehicles for transporting people on the planet Mars, and have been conceptualized as part of extraterrestrial mission o that planet. Mars the 4^{th} planet of our solar system it's always been taken in interests by scientists an engineers to explore its atmosphere and terrain region to investigate did life ever existed over this planet and does it holds the key ingredients to colonized by human beings.
To work on these Pressurized rovers have been envisioned for short trips from a Mars base, or maybe equipped as a mobile base or laboratory. For our research project, we selected to work on a pressurized cabin because the pressurized cabin has many advantages like:

Increased Range of Exploration On the surface of the moon and Mars, travel range is limited primarily by how quickly astronauts can get back to a safe, pressurized environment in case of an accident. The pressurized cabin gives more degree of freedom and increases the expedition time.

Astronaut Protection The greatest risk of space explorers is from unanticipated solar particle events. With a heavily shielded cabin, can protect the crew from the storms, low pressure mars atmosphere and radiation. Also, it helps to keep the cabinet free of dust and other contaminants and reducing the chances of failure of expensive instruments and machines.

Intra Vehicular Activity (IVA) Capability By combining a pressurized cabin with a suit port, the crew can perform multi inter-vehicular activities. They can sleep work exercise under one roof comfortably.

3.2 Oxygen generation

Oxygen (O2) the most primary element for survival, must be present in every breathing gas. This is because it is essential to the human body's metabolic process, which sustains life. The human body cannot store oxygen for later use as it does with food. If the body is deprived of oxygen for more then a few minutes, unconsciousness, and death result. For our MCEV we planned for two major gases for pressurization one is oxygen and another is nitrogen. Firstly we calculated the oxygen requirement for four members as given in the table:

After oxygen and nitrogen calculation we choose to use a pressurized portable tank for carrying oxygen and nitrogen on board. Our system comprises of oxygen tank for 10 days travel, the second is a backup oxygen mask, the thin d is an emergency oxygen generator and the last is an onboard oxygen generation system using Sabatier reaction.

Table 5: Oxygen Generator

Sr.no	Parameters	Value (kg)	Value (liter)
1	Oxygen needed(10 days journey)	46.56	32600
2	Oxygen inhaled(Every mins.)	0.00318	2.229
3	Carbon Dioxide exhaled(Every mins.)	0.0036	2.5663
4	Nitrogen needed(10 days journey)	10.55	73893.3
5	Nitrogen needed(Every mins)	0.00721	5.0524

3.2.1 Oxygen tank

We calculated the oxygen requirement for 4 crew an over 10days mission and a for this oxygen tanks would be used to store oxygen.

- Pressure:300bar
- Storage:326000liter(compressed O2 gas)
- Storage:46.56kg
- Cylinder volume:163.33cm^3
- Cylinder specs:Height=10
- Radius=22.8cm

3.2.2 Backup supply system system

In the case of primary oxygen supply failure, there would be a secondary supply system that consists of a breathing mask. The mask would be deployed automatically when an emergency comes. This system is called the diluter demand oxygen supply system. The diluter demand system is designed to

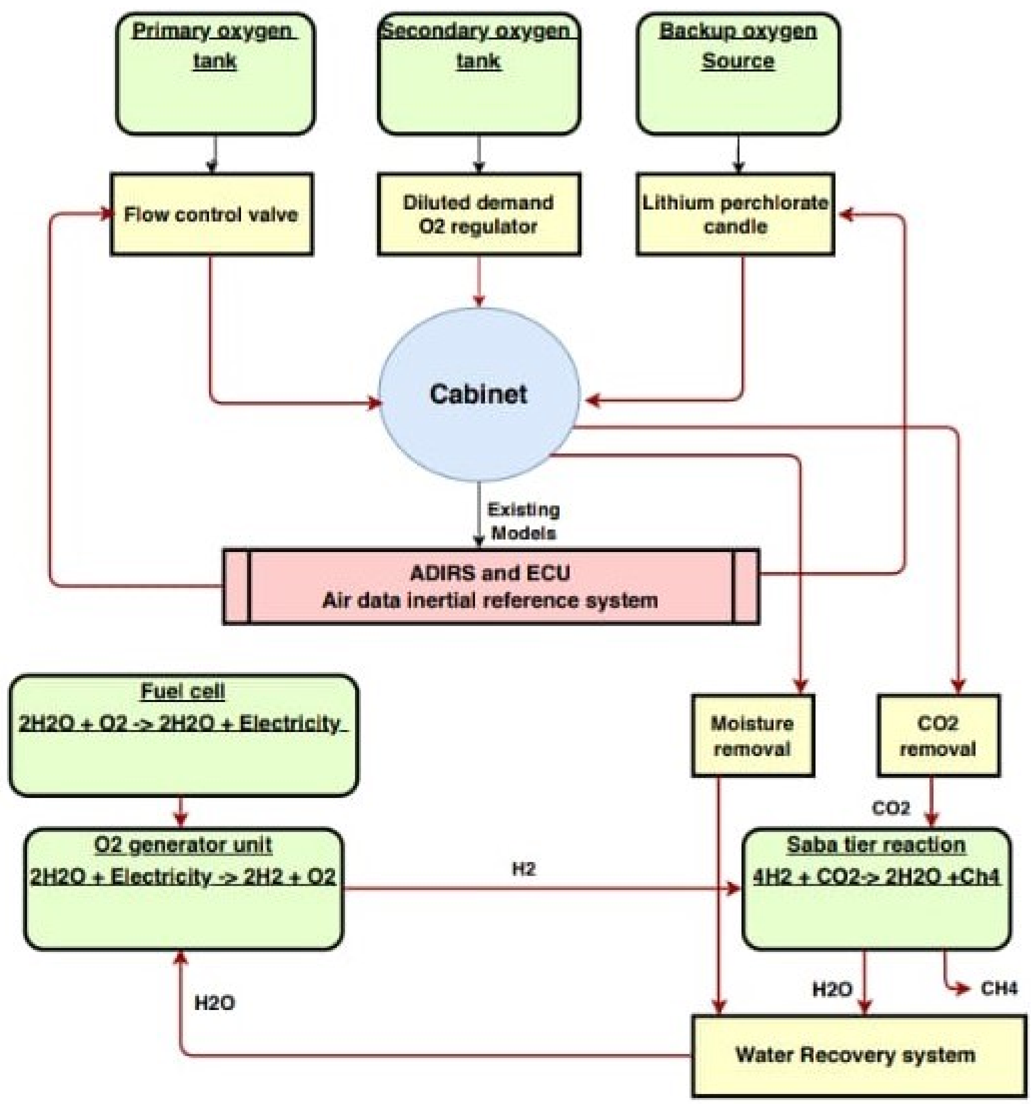


Figure 7: O2 Generator

compensate for the short-comings of the continuous- flow system. It gives the user oxygen on-demand (during inhalation)and stops the flow when the demand ceases (during exhalation).This helps conserve oxygen. Additionally, The incoming oxygen is diluted with cabin air and provides the proper percentage of oxygen.

3.2.3 Emergency Oxygen generator

In case of failure of the first two oxygen supply system, or if the oxygen ceases off, our system would include emerg oxygen supply system. is a SFOG, or solid-fuel oxygen generator, a kind of chemical oxygen generator. It has been used on the retired Mir space station and the International Space Station It was originally developed by Roscosmos to supplement the Electron oxygen system on Mir A Vika module, also known as a "candle", contains about one liter of and can provide oxygen for one person for 24 hours. solid-fuel oxygen generator (SFOG), which contains a replaceable cartridge – a thin-walled steel tube with a three-part block of oxygen-releasing mixture based on lithium perchlorate. Two parts are tablets of the chemical mixture and the third one is the igniter tablet with a flash igniter. The igniter is struck by a firing pin when the device is activated. One cartridge releases $600 litres (160 US gal)$ of oxygen and burns for $5–20 minutes$ at $450–500C (842–932F)$

3.2.4 Oxygen Generators

The last on board, oxygen generation system which can be used. The on board oxygen generators uses Sabatier reaction to produce oxygen. The Sabatier reaction or Sabatier process was discovered by the French chemists Paul Sabatier and Jean-Baptiste Senderens in 1897. It involves the reaction of hydrogen with carbon dioxide at elevated temperatures ($optimally 300–400C$) and pressures in the presence of a nickel catalyst to produce methane and water. Optionally, ruthenium on alumina (aluminium oxide) makes a more efficient catalyst.

3.3 HVAC

For maintaining proper temperature, humidity we are using HVAC system, and this is done by using freon cycle. Generally, HVAC (Heating, Ventilation and Air Conditioning) equipment needs a control system to regulate the operation of a heating and/or air conditioning system. Usually, a sensing device is used to compare the actual state (e.g. temperature) with a target state. Then the control system draws a conclusion on what action has to be taken(eg. drive compressor to heat or cool the cabinet) Freon cycle The Freon Refrigeration Cycle involves four components: compressor, condenser, expansion valve/throttle valve and evaporator. It is a compression process, whose aim is to raise the refrigerant pressure, as it flows from an evaporator. The high-pressure refrigerant flows through a condenser/heat exchanger before attaining the initial low pressure and going back to the evaporator. A more detailed explanation of the steps is as explained below.

3.3.1 Step 1: Compression

The refrigerant (for example R-717) enters the compressor at low temperature and low pressure. It is in a gaseous state. Here, compression takes place to raise the temperature and refrigerant pressure. The refrigerant leaves the compressor and enters to the condenser. Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.

3.3.2 Step 2: Condensation

The condenser is essentially a heat exchanger. Heat is transferred from the refrigerant to a flow of water. This water goes to a cooling tower for cooling in the case of water-cooled condensation. Note that seawater and air-cooling methods may also play this role. As the refrigerant flows through the condenser, it is in a constant pressure. One cannot afford to ignore condenser safety and performance. Specifically, pressure control is paramount for safety and efficiency reasons. There are several pressure-controlling devices to take care of this requirement

3.3.3 Step 3: Throttling and Expansion

When the refrigerant enters the throttling valve, it expands and releases pressure. Consequently, the temperature drops at this stage. Because of these changes, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around $75\% and 25\%$ respectively.

Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.

3.3.4 Step 4: Evaporation

At this stage of the Vapor Compression Refrigeration Cycle, the refrigerant is at a lower temperature than its surroundings. Therefore, it evaporates and absorbs latent heat of vaporization. Heat extraction from the refrigerant happens at low pressure and temperature. Compressor suction effect helps maintain the low pressure.

There are different evaporator versions in the market, but the major classifications are liquid cooling and air cooling, depending whether they cool liquid or air respectively.

3.3.5 Humidifier

Also the system has humidifier in build, it adds moisture to the air to prevent dryness that can cause irritation in many parts of the body. Humidifiers can be particularly effective for treating dryness of the skin, nose, throat, and lips.

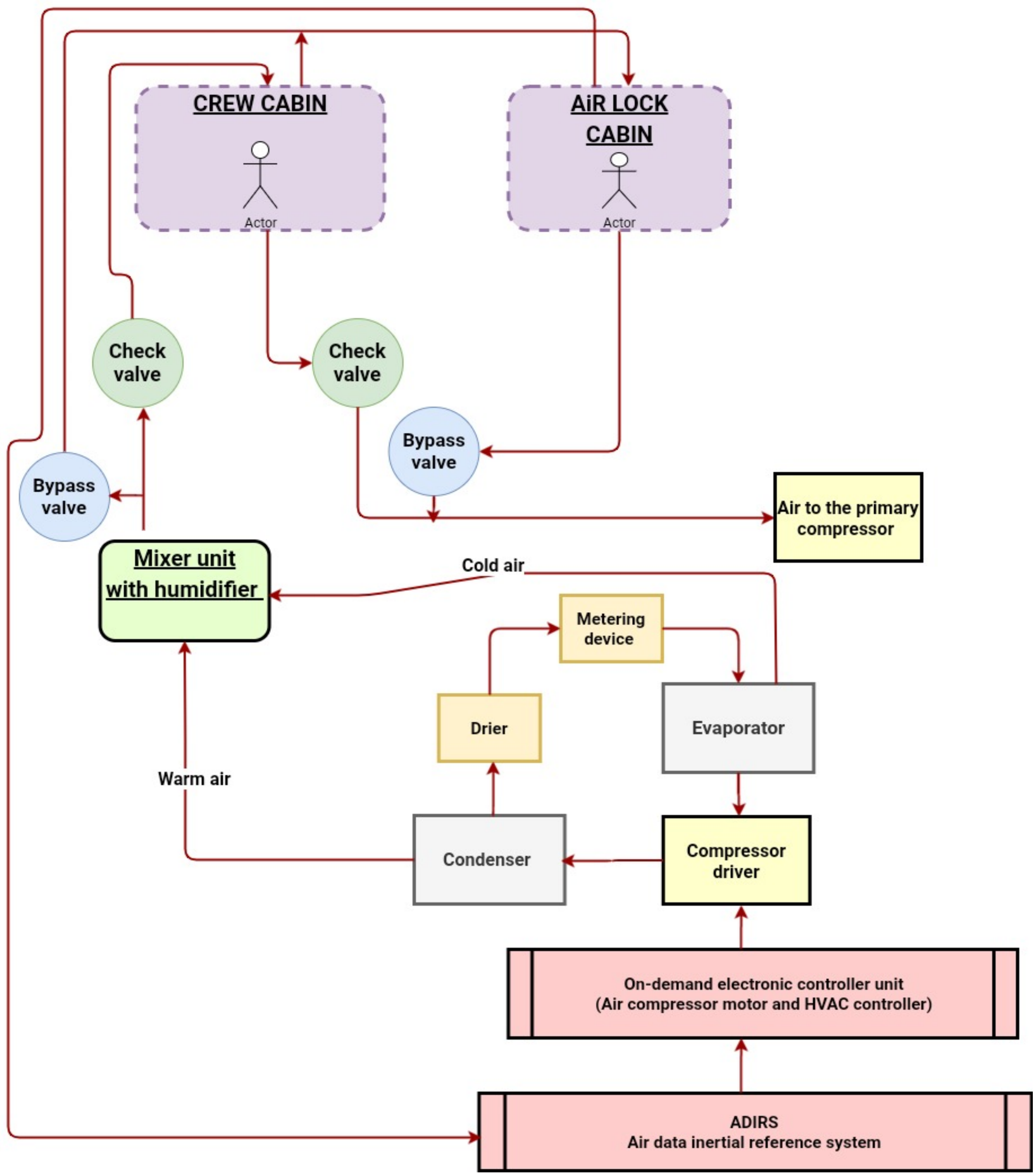


Figure 8: HVEC System

3.4 Air Revitalization

Through the respiration process, humans consume oxygen (O2) while producing carbon dioxide (CO2) and water (H2O) as byproducts. For long term space exploration, CO2 concentration in the atmosphere must be managed to prevent hypercapnia
For this air revitalization is necessary.
For internal cabinet air revitalization, Carbon Dioxide removal assembly (CRDA) system is used CDRA is a regenerative system whose principal operation utilizes 2 beds. Each bed O contains a desiccant bed and a CO absorbent bed. The system relies on one desiccant bed to condition the air prior to entry into the adsorbent bed. The adsorbent bed selectively removes the CO2, and the air travels through the second desiccant adsorbent bed to replace the humidity. The CDRA system is a water-save system in contrast to the 2-bed Skylab system, which vented adsorbed water overboard. The U.S. Skylab Program successfully demonstrated the use of zeolite molecular sieves in regenerative CO, removal by using a two-bed the subsystem that performed for over 4100 hours without failure. (1before cabin air processing, one carbon dioxide removal bed is in the process of regeneration. Regeneration is accomplished using pressure/thermal swing methodology. First, the two-stage pump removes the free air from the adsorbent bed and returns it to the cabin, reducing oxygen ullage. Then Kapton heaters integrated within the adsorbent bed raise the zeolite temperature, and space vacuum creates a low, partial pressure driving the carbon dioxide gas overboard. Also every after 5 mins the entire air would be recirculated, squeezing out most of CO2 and moisture and either venting it out of me or using it for Sabatier reaction for oxygen generation.

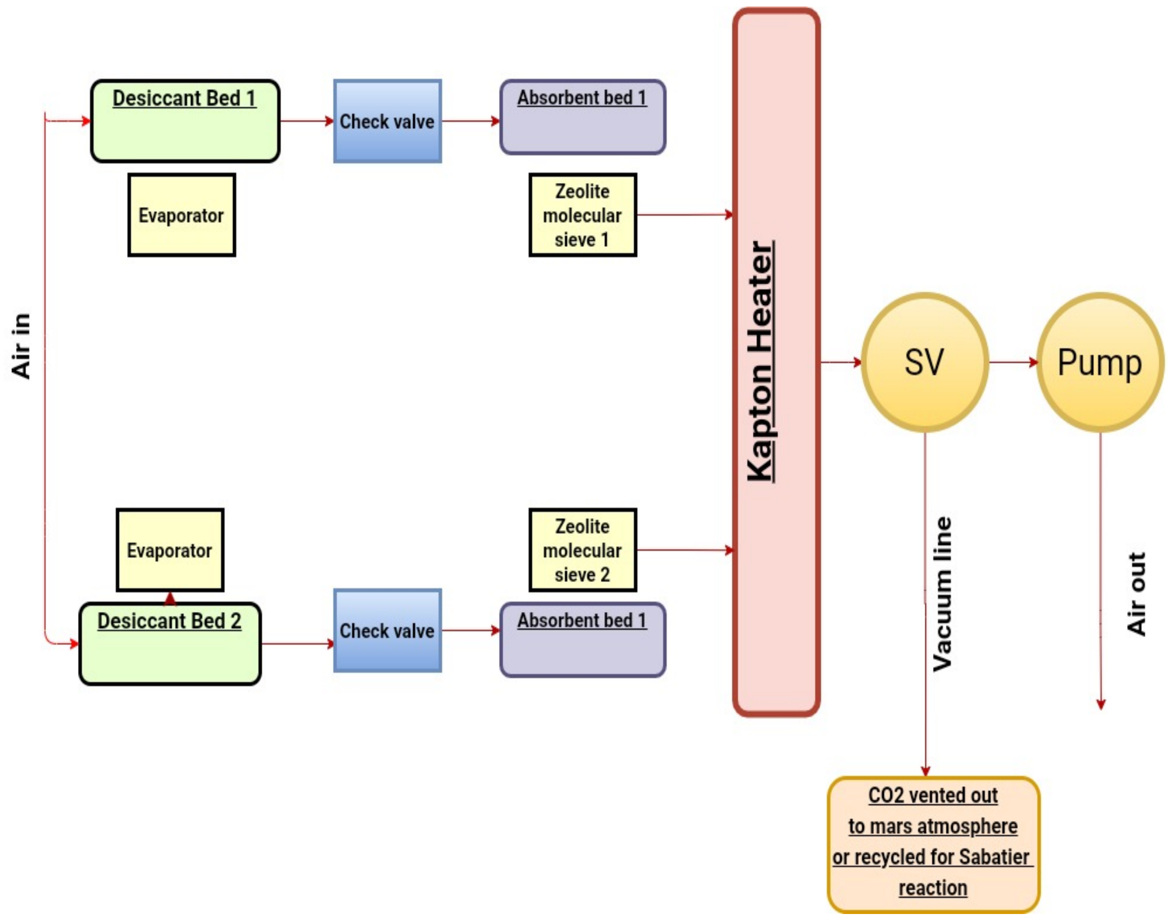


Figure 9: Air Revitalization

3.5 Pressurized cabin

Crewed Mars rovers also called as mars crew exploration vehicle are vehicles for transporting people on the planet Mars, and have been conceptualized as part of extraterrestrial mission o that planet.Mars the 4th planet of our solar system it's always been taken in interests by scientists an engineers to explore its atmosphere and terrain region to investigate did life ever existed over this planet and does it holds the key ingredients to colonized by human beings.

In order to work On this scientist engineers are developing sustainable homes which can support life for human beings over Martian environment, also they are working to develop crew exploration vehicles which can Rover over Martian environment to carry scientific investigation over various region near the base.

Two types of crewed Mars rovers are unpressurized for a crew in Mars space suits, and pressurized for the crew to work without a space suit. Pressurized rovers have been envisioned for short trips from a Mars base, or may be equipped as a mobile base or laboratory. For our research project we selected to work on pressurized cabin because pressurized cabin has many advantages like:

3.5.1 Increased Range of Exploration

On the surface of the moon and Mars, travel range is limited primarily by how quickly astronauts can get back to a safe, pressurized environment in case of an accident. Pressurized cabin gives more degree of freedom and increase the expedition time

3.5.2 Astronaut Protection

The greatest risk to space explorers is from unanticipated solar particle events. With a heavily shielded cabin, can protect the crew from storms and radiation. Also, it helps to keep cabinet free of dust and other contaminants and reducing the chances of failure of expensive instruments and machines.

3.5.3 Intra Vehicular Activity (IVA) Capability

By combining a pressurized cabin with support, the crew can perform multi inter-vehicular activities. They can sleep work exercise under one roof comfortability.
For pressurization we decided to pressure the value of 11psi, which is safe and is below the Armstrong limit.Below table shows air composition inside cabin and there pressure ex,ert n values.

Table 6: Air Composition in percentage

Sr.no	**Parameter**	**Value(%)**
1	Oxygen	30
2	Nitrogen	68
3	Metabolic byproduct	2

Table 7: Air Composition in psi

Sr.no	**Parameter**	**Value(psi)**
1	Total cabinet pressure	11
2	Oxygen	3.3
3	Nitrogen	7.48
4	Metabolic byproduct	0.22

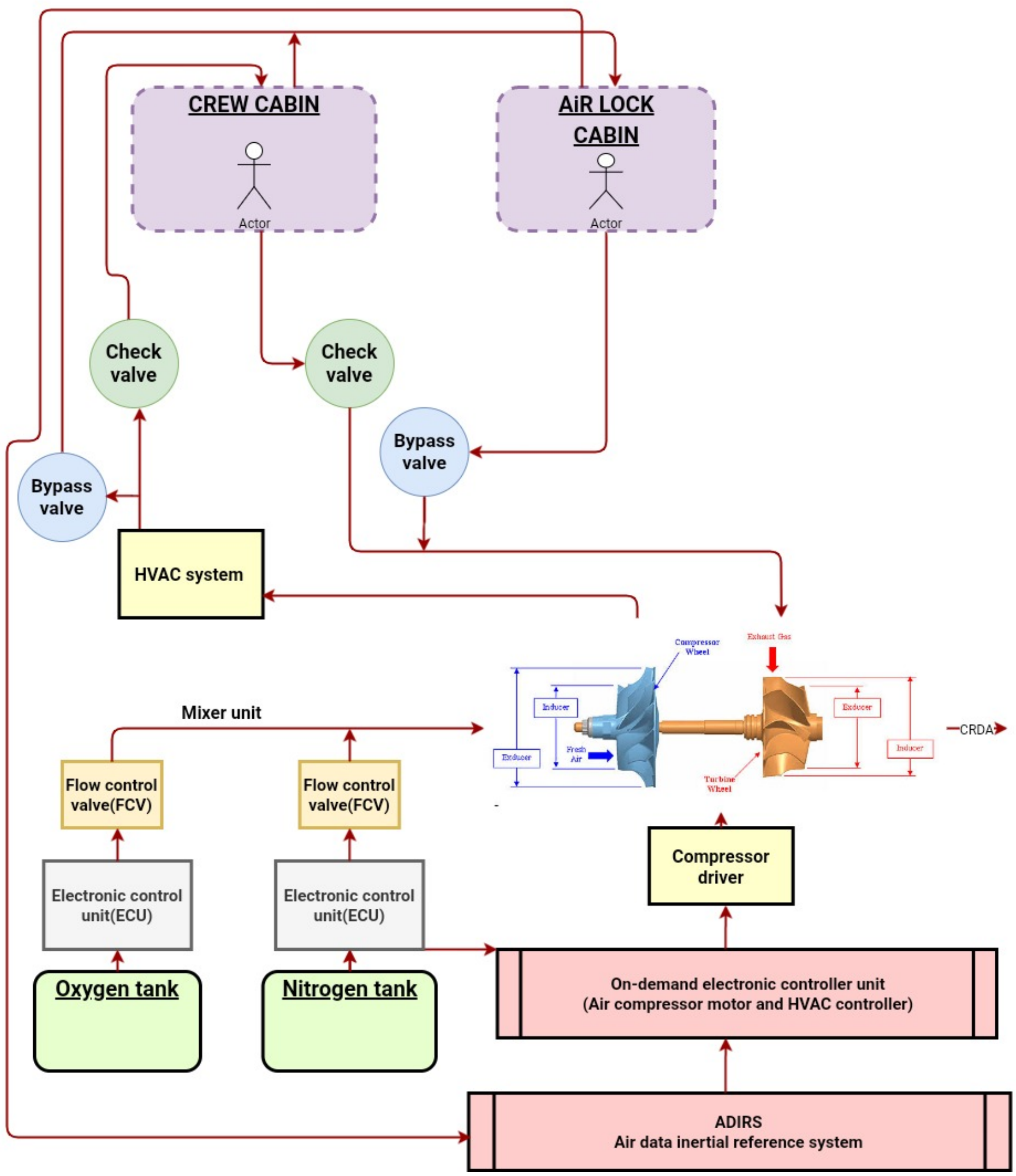
For pressurization our system it uses compressor of special type. It has a compressor and turbine wheel on same shaft, which in turn rotates at same rpm.The compressor compress the air mixture of O2 and N2 and increases its pressure to 11psi.

The inlet of the compressor is from one oxygen tank and another nitrogen tank who's flow rate is the controlled by flow control valve which area electronically monitored actuated by ECU.

The compressed air by the compressor is cooled before it enters the cabinet, then the cooled air is directed via pipes into the cabin from the top. At the same time, the old air inside the cabin is sucked from the bottom using a turbine vacuum wheel. This system runs every after five minutes for a fresh supply of air inside cabin.

The turbine wheel is designed in such a way that it sucks out air from cabinet like vacuum machine by creating negative pressure inside it's volute casing.

The same operation can be performed for compression and decompression inside airlock by means of bypass valve provided inline with system. The block diagram show the process in detail



heightheight

Figure 10: Pressurization

3.6 Multi- Layer Insulation

In order to live and explore comfortably at habitable temperature and to do research at extreme condition of Mars, the Mars Crew Exploration Vehicle (MCEV) need to be lined with Multi-Layer Insulation also known as blankets. Multi-Layer Insulation are the light weight insulation that is done for protection of Humans onboard MCEV, electronics and various equipment from the damaging effects of radiated heat. The Mars has extremely challenging environment. The vehicle can be exposed to direct or indirect sunlight at one moment and then sometimes there is no sunlight at all for days. So we need to protect Humans onboard from these conditions as human body cannot adapt to these changes.

Multi-Layer Insulation material are made up of many different materials which are stacked and sewn together. There are Multi-Layers of thin plastic films, these plastic films are separated by non-woven mesh materials that help prevent conduction between them. This Multi-Layer Blanket is coated either one or both side with aluminized reflective material. A typical blanket consist of 20 or more layer within $\frac{1}{2}$ inch thickness overall. At the point when presented to transmitted heat, MLI works this way: The peripheral cover layer reflects 90% of heat it experiences. The following layer mirrors a similar level of transmitted heat that has gone through the main layer, and each progressive layer does likewise. Collectively, the numerous layers decrease the radiated heat to basically zero. There are few criteria that the material must pass for MLI application. Prior to settling on a choice, specialists will consider a method's absorptive and emittance properties, its reliability, robustness and weight, and afterward comparison is done among cost and performance related with every strategy. The material must be lightweight and cost effective.[9]

For MCEV we choose Kevlar, Aluminized Mylar and Dacron. Kevlar is simply a strong plastic made upon layers upon layer of same molecular chain woven into molecular fibers which gives it a strong hydrogen bond density per unit area. A high tensile strength, Light weight and non-metallic properties make Kevlar a highly desirable material for thermal insulation. Mylar is aluminum polyester film, aluminum is vaporized inside a vacuum chamber using the back of vacuum metallization using the vacuum metallization technique it then bonds with Mylar as it solidifies and settles in the defect of the polyester. Mylar has a high tensile strength, shear strength, elastic modulus,

[9]https://ntrs.nasa.gov/citations/19990047691

high reflectivity and ability to be metallized. In order to prevent the conductive metallized sheet from touching each other and conducting heat inside the MCEV, material must be placed between the sheets to separate them. Dacron is our selection for this role, Dacron is a polyester fiber that comes in form similar to fabric and also has a high tensile strength most important it has low thermal conductivity that allows to prevent conduction of heat through the other metallized layer. [10]

- Temperature Range: $-50° \ to \ 300°F$.
- Tensile Strength: $28,000 \ psi$ (Excellent)

Table 8: Multi Layer Insulation Properties

Material Properties	Values
Denier/Filament	1.5-2.25
Filament Diameter	0.0012-0.0015 cm
Filament Cross section shape	Round
Density	1.44 g/cm$\hat{3}$
Thermal Conductivity	0.04W/mK
Moisture Regain	5-7%

3.7 Crew Characteristics

As the life support system's primary purpose is to maintain the crew, the crew characteristics will drive equipment requirements.
From an analysis perspective, the human metabolic rate and available time are necessary input values.
Table 1 and 2 shows the crew metabolic rate according to equations developed during the update of the NASA HIDH (2014) reference in the past. In much the same timeframe.

1. **Crew metabolic rate**

Metabolic activity as a result of the conversion of food to energy by the crew

[10]https://www.designnews.com/materials-assembly/abcs-multi-layer-insulation-spacecraft

affects air revitalization and heat production directly but will also affect water use, waste production, and power consumption.
The NASA HIDH (2014) lists empirical equations for calculating metabolic energy requirements as shown in Tables1 and 2.
2. Primary inputs and outputs depending on human consumable
To drive human metabolic activities, a human being needs to consume nutrition, water, and air to breathe. The table below shows the primary input for a human being to survey in space also the figure sure the secondary output on the input given by human beings/ metabolic rate byproducts.

3.8 Cabinet Lighting System

The mission to explore the surface of Mars will be carried out by our Mars Crew Exploration Vehicle. And among many factors that affect manned missions, one is the Cabinet Lighting System. The cabinet has tried its best to mimic Earth like conditions, as the Space Explorers will be confined to the Cabinet environment during their Site Exploration. It was found truly essential that we concentrate on lighting system as it will affect the Human Body Metabolism.
Each Martian Sol is 1 *Earth Day* and 37 *minutes* long, and the Human body is used to a Body Clock of 24 *hours* (The Circadian Rhythm).A high workload, the need to work 'nightshifts', the excitement of Spaceflight, entrainment to unusual day-lengths(e.g., 24.65 h Martian Sol) plus the unusual environment can combine to disrupt sleep, which can in turn effect performance.[11]
Light plays a powerful role in synchronizing this Body Clock, and exposure to the proper kind of light, of sufficient quality and quantity is crucial for to ensure adequate vision and to optimise the Circadian effects of light and ultimately Crew Health and Safety.

Interior Lighting

The "Lighting Effects Study by NASA" has provided us with an alternative option to the conventional General Luminaire Assemblies (GLAs) which is dim and produces stress when in prolonged use. It is now decided to use a LED- based Lighting System called "Solid State Lighting Assemblies (SSLAs)" for extended space missions[6]. This can provide light of varying

[11] https://techport.nasa.gov/view/23237

spectrum, intensity and pattern.[12]

Figure 11: Solid State Light Assembly in the ISS(Source credits: NASA)

This will be used in our Mars Crew Exploration Vehicle as well. This is a programmable lighting system that manipulates the blue light content of white light and operates in three different modes:

1. White light for general vision
2. Blue-enriched high intensity white light to enhance alertness and Circadian Adaption
3. Blue-depleted low intensity white light to minimize alertness prior to sleep

The dynamic Lighting Schedule (DLS) developed by NASA helps determine when each of these modes must be used. The Crew members will be able to toggle between various modes according to their needs and work efficiently even during the prolonged confinement from Earth conditions.

[12]https://humanresearchroadmap.nasa.gov/Tasks/task.aspx?i=1645

Exterior Lighting

Unlike interior lighting, the challenges faced by exterior lighting differs very much. The life of a product depends upon the environment it is exposed to and the temperatures it can withstand. This was not an issue inside our Pressurised Cabin, but on the outside, we really need to consider it. Mars is known for its dust storms and the lighting we provide on the outside of the cabin must withstand these wild storms.

Figure 12: Exterior Lighting(Source credits: 2170-WLS28-2CW570SQ-ND)

When lights are installed in hostile environments, it can seriously shorten its life. So, we follow the Ingress Protection (IP) Code of IP67. The exterior walls of the pressurised cabin will be fitted with WLS28-2CW57OSQ LED Strip which can operate in a temperature range of -40 degree Celsius to +70 degree Celsius. It also has an automatic temperature control unit built into it which dims after the temperature goes beyond 50 degree Celsius and thereby increases the product lifetime. It requires a power supply of 12V dc to 30V dc.[13]

[13] 175008 Rev J

4 Instruments

The primary mission of the Mars Crew Exploration Vehicle is to explore sites within a radius of 10km. This exploration task may include Extra Vehicular Activities (EVA) as well as controlled functions carried out by the explorers from within the vehicle. This is aided by a set of instruments aboard the vehicle. These instruments can be of help, from collecting samples to detecting wind storms.
The inspiration for the instruments are taken from NASA Perseverance as they display the latest existing technology.[14] Also, the open access to the power requirements of these instruments make it a healthy candidate for precise calculation of the Power Requirements.

4.1 Weather Station

Measuring the weather pattern, the dust behaviour etc are important tasks to be done to provide further data for safe human exploration on the surface of Red Planet. This weather station will carry out systematic measurement of data.

- Air Temperature – These thermocouples are placed on the exterior of the thermal insulation layers of the cabin wall. Their range of measurement is 150 to 300K, with a required accuracy of 5K and a resolution of 0.1K.

- Humidity – Humidity Sensors mounted inside a cylinder measures the relative humidity of the atmosphere. It is measured in the range of 200-323K, with an accuracy of 10% and a resolution of 1%. The sensor is mounted in a cylinder with a dust filter so as to protect it from dust deposition, which might alter the measurements.

- Pressure – The pressure sensors are placed inside the rover body and is connected to the external environment via a tube fitted with high-efficiency particulate air(HEPA) filter. Protection from Martian dust is so very important to reduce the error in the measured values. It measures in a range of 1 to 1150 Pa and ensures a resolution of 0.5Pa.

[14] https://mars.nasa.gov/mars2020/spacecraft/instruments/

- Radiation and Dust – Solar UV Radiation is the combination of Ultraviolet and visible light. The radiation energy and the capability to produce chemical and biological reactions is more for shorter wavelengths. Also, due to the lack of Ozone layer, the planet's surface is fully exposed to the intensity of Sun's UV Radiation.
  So, the radiation and dust sensors are kept on the deck of rover. These sensors are placed without dust protection, instead they have Magnetic Rings placed around it to reduce dust deposition degradation. The rate of dust deposition is monitored by consistent comparison with the readings of other instruments used, namely Zoomable Panoramic Cameras. These sensors consist of a set of 8 photodiodes placed in various angles
  - 250-400 nm for total UV
  - 950 +/- 50 nm for NIR
- Thermal Radiation - Thermal Infrared Radiation is placed on the front end of the rover. It comprises of a set of thermopiles(an arrangement of thermocouples) to convert thermal energy into electrical energy. It takes measurement from the surface of Mars as well as upward and downward thermal infrared radiation.
- Wind – The wind Sensors attached to the Remote Sensing Mast(RSM) measure the horizontal as well as the vertical wind speed. Horizontal wind speeds are determined in a range of $0\ to\ 40m/s$ and Vertical at a range of $0\ to\ 10m/s$. It is done with an accuracy of $2m/s$ and with a resolution of $0.5m/s$.
  It is important that the boom that holds the detectors out of RSM's thermal boundary as it must not disturb the wind flow which may eventually result in erroneous data.

All the components together weigh upto 5.5 kilograms and consumes a power up to 17W depending on scheduled measurements.

4.2 Sub- Surface Radar

The exploration of the Martian Surface in a manned crew vehicle has broad aims, it can either be to find a habitable site or to check for signs of life for future research. An instrument that helps in this process is the Ground Penetrating Radar(GPR). It helps in looking into the underground structure

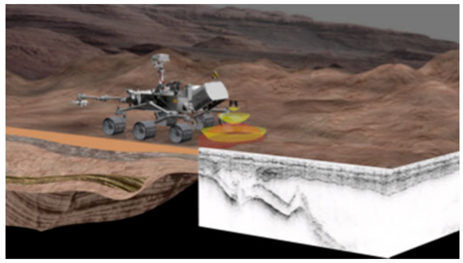


Figure 13: Sub-Surface radar(Source Credits: NASA/JPL-Caltech)

of Mars.

The instrument is installed within the interior of the Rover, and it will operate as the rover drives by. The signals are expected to reach a depth of 10m, or more. It can detect ice, water or salty brines beneath the surface. Weighs less than 3 kilograms and power consumption ranges from 5-10 W.

4.3 Laser Micro-Imager

Analysing rock and regolith of the red planet is an inevitable task to be carried out during the course of exploration travel. This is aided with a Laser Micro-Imager consisting of camera, lasers and spectrometers. This acquires high resolution images of samples of interest with the help of colour remote micro-imager(RMI). It investigates targets using Raman Spectroscopy, Time- Resolved Fluorescence Spectroscopy(TRF) and Visible and InfraRed reflectance spectroscopy(VISIR).
It weighs about 10.6 kilograms and consumes a power of 17.9W.

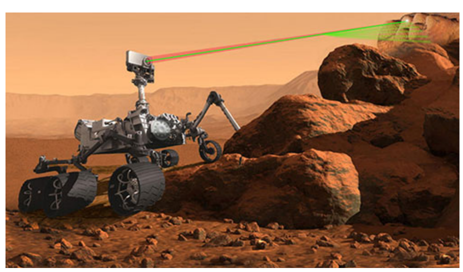


Figure 14: Laser Micro imager(Source Credits: NASA/JPL-Caltech

4.4 Zoomable Panoramic Cameras

This helps us take a look at the Martian surface, take pictures and videos. It has band pass filters which helps differentiate unweathered from weathered material. This camera can also observe and then document dust devils approaching or occurring far from present site. It can also observe atmospherical activity like cloud motions etc. It enables all other instruments to locate their targets.
It weighs about 4 kilograms and consumes a power of approximately 17.4W.

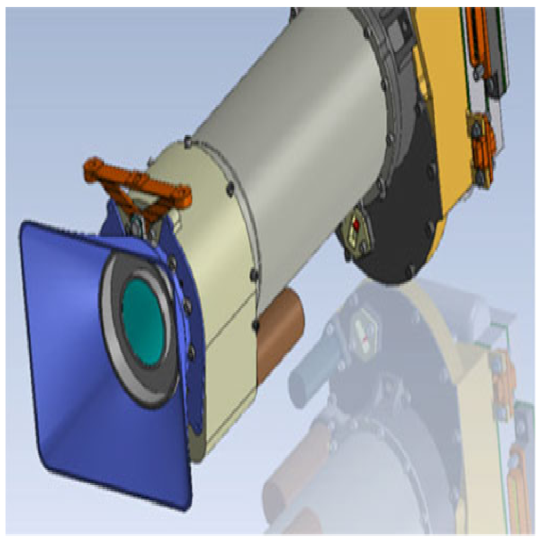


Figure 15: Zoomable Panoramic Camera
(Source Credits: NASA/JPL-Caltech

5 Communication in Mars

Telecommunication is another crucial factor without which the mission would go astray. This is indeed a challenging hurdle to overcome in planetary exploration. Mars was always a subject of interest and we have had numerous Mars Missions, for atmospheric study, dust storm pattern study, for mapping the surface and much more. All these missions were unmanned and had a communication link to Earth which was received via the Deep Space Network, with communication facilities placed approximately 120 degrees apart in three different parts of the world. But the time delay that occurs in communication to Earth from Mars is approximately 14 minutes.

We are still keeping small steps to attain the aim of a fully functional in-situ Mars Communication System for efficient data transfer on manned missions. Our Mars Crew Exploration Vehicle(MCEV) will need this when it goes on its exploration journey within a radius of 10 km from the Mars base settlement. This paper has been included with the choice that is felt best apt for our requirements (based on literature reading of the possibilities of Communication). It has been quite challenging to decide between the two options that we had for Relay Communication. Now the report will quickly take you through the two options that were considered, and what was decided best for the rover.

- **Option 1: Communication with Satellites in the Areostationary Orbit** This is a circular Areosynchronous orbit in the martian equatorial plane analogous to the earth's Geostationary orbit. Located at a height of 17,038.2 km above Martian surface, this orbit lies above Phobos (9,376 km) and below Deimos (23,463 km).To date, no artificial satellites have been placed in this orbit, but scientists forsee a future telecommunication network.

- **Option 2: Communication through an Existing relay infrastructure**
  The spacecrafts currently orbiting mars include the Mars Global Surveyor, Mars Odyssey, Mars Express, and Mars Reconnaissance Orbiter. These are low-altitude spacecrafts orbiting Mars in a sun-synchronous orbit.[9] [5]

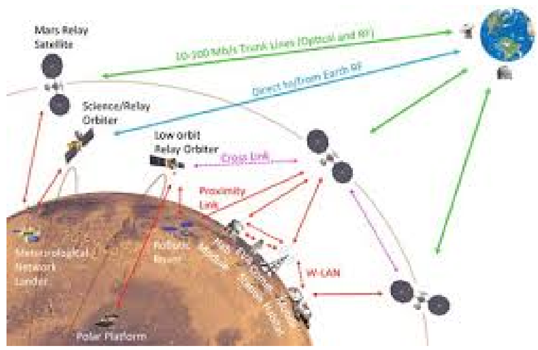


Figure 16: A possible future Mars telecommunications network
(Source Credits: Small Areostationary Telecommunications Orbitter Concepts for Mars in the 2020's, JPL NASA)

5.1 Via Areostationary Relay Satellite

In the decade leading to the era of human spaceflight, telecommunication will largely occur via satellites placed in these equatorial areosynchronous orbits called Areostationary Orbits. Current communication capabilities for Mars are from a Low Mars orbiter satellite but this will not totally cater to the need of constant communication.[15]

So, why not a communication link via Low Mars orbiter satellite?

1. Low altitude results in low slant rates
2. Even though it may enable high data rates with a low gain antenna, but the contact duration will be very short
3. Short intermittent contacts with long gaps may cause difficulty in the MCEV modus operandi
4. Overtime the orbits of the satellites in Low Mars orbit might precess, causing complex difficulties

Hence, Areostationary Orbits will provide a robust, redundant relay services and global coverage to potential users anywhere on the Martian surface or in the Martian atmosphere. We specify about potential users in the Martian atmosphere as we look forward to a system of Areostationary Orbiter along with a low Mars Orbiter for auxiliary Communication in case of emergencies.

Now, the MCEV needs to be equipped likewise so as to support a link to the Areostationary Orbit. There needs to be separate frequency band to avoid possible interference. The Space Frequency Coordination Group (SFCG[4]) has proposed a set of guidelines for communication in Mars region according to which Orbit-to-Surface communication occurs in 435-450MHz and Surface-to-Orbit occurs in 390-405MHz.

The MCEV will be fitted with a low-gain antenna(LGA), an omnidirectional one with a broad radiowave beam width that allows the signal to propogate reasonably even in mountain terrain and is thus reliable, regardless of terrain. Inferring from the prevailing data regarding antennas used in rovers, our MCEV will use a **UHF quadrifilar Helical Antenna[16]**. The detailed antenna gain pattern will depend on multiple factors, including orbiter attitude, lander tilt and azimuthal orientation, distortions of the wide-beamwidth patterns by diffractive scattering off of other spacecraft structures (e.g. nadir deck instruments), and multipath scattering off of the Martian surface. The Network link frequencies from the MCEV to the astronaut performing EVA will be 2.4-9GHz (TBD[15])802.xx[16](MCT[17] Network). In the future, we look forward to equip our MCEV with a potential method that can communicate with the International Space Station (ISS).

[15]Track-Before-Detect
[16]IEEE 802 Standards
[17]Mars Communication Terminal

6 Battery Technology for Mars Exploration Vehicle

The Mars due to its unique topography and atmospheric conditions demands a battery with Specific Energy Density, Superior Shell Life and One that can operate in extreme diverse atmospheric conditions. The LiSO2 battery is the energy storage that has been selected primarily because of its ability to operate under extreme weather conditions it can maintain 50 percent of its initial capacity at -40 degree Celsius. The method of formation of sulphur cathode plays an important role in the performance of Lithium Sulphur batteries.

Anode: Lithium

Cathode: Sulphur Dioxide

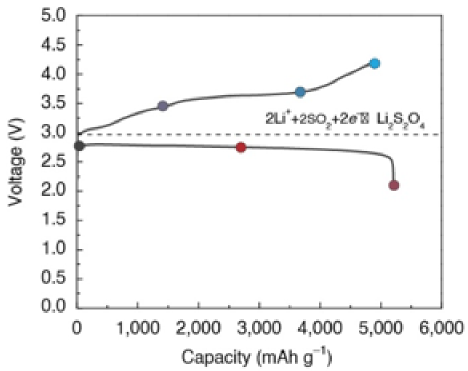
The electrochemical Oxidation of lithium by sulphur dioxide resulting in the formation of Lithium sulphur dithionite $[Li_2S_2O_4]$ [2].

$$2Li + 2SO_2 \rightarrow Li_2S_2O_4$$

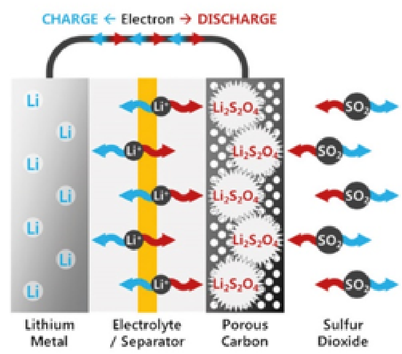
Electrolyte Used: The type of Electrolyte used plays a very important role in determining the nature of discharge products and recharge ability of the system [1]. Electrolyte used should be nonaqueous since the sulphur reacts readily with water [13]. Impurities enhance the decomposition of $Li_2S_2O_4$ which may possibly increase the temperature by around 10 times [3]. The use of ethelyne carbonate [EC] and dimethyl carbonate [DMC] as electrolyte improves power capability and cycling properties of $Li - SO_2$ batteries [1].

6.1 Design

The $Li - SO_2$ system is built in a cylindrical shape since the $Li - SO_2$ system ins pressurised one. Vents are provided while designing the cells to facilitate the escape of the electrolyte to maintain the pressure inside. In designing battery packs rooms must be left for the vent to operate normally. Safety measures including fuses and current limiting resistors need to be selected according to the battery pack design. The assembly of cells into battery pack need to be done carefully and each pack must be designed and tested for worst case scenarios. Design measures also needed to be taken to evenly distribute the current density and heat throughout [2].



Galvanostatic discharge/charge profile of Li-SO_2 cell [ref1]



Schematic Illustration of a rechargeable Li-SO2 battery during discharge and Charge[ref4]

Figure 17: Battery Techniques

6.2 Characteristics [13]

- High Cell Voltage: Has a normalised cell voltage of $3.0V$
- High Energy Density: The Energy Density of around 500 $\frac{Wh}{kg}$, which is fairly higher than the conventional batteries.
- High power density: Capable of Delivering high currents compared to other conventionally available batteries.
- Temperature Range: $Li - So_2$ batteries are capable of operating at a wide temperature range of $-55 degreeCelsius$ to $+65 degreeCelsius$.
- Low Self Discharge: The self-discharge of batteries at low temperature is fairly low.
- Flat discharge Characteristics: The output voltage of the cell is particularly a constant value throughout the discharge cycle.

In rovers that been sent to mars the batteries use around half of its energy to keep the battery itself to its operating temperature because the conventional batteries won't be able work on such a wide range of temperature. The significance of $Li - SO_2$ batteries get more pronounced under these conditions as it significantly lowers the amount of energy required to keep the itself warm. The increase in energy density of the $Li - SO_2$ batteries comes as an added benefit as the power requirement of a pressurized crew vehicle is very high and the usage of these batteries will lower the payload weight by a fair amount.

6.3 Motor selection of the Crew Vehicle

Possible Motors Considered for Vehicles

- BLDC Motors
- Squirrel Cage Induction Motors
- Switch Reluctance Motor Drives

Basic Principle of BLDC MOTOR
A BDLC engine drive comprises predominantly of the brush-less DC machine, a DSPbased regulator, and a force gadgets based force converter, as appeared in Figure . Position sensors H1, H2, and H3 sense the situation of the machine rotor. The rotor position data is taken care of to the DSP-based regulator, which, thusly, supplies gating signs to the force converter by killing on and turning the correct stator post windings of the machine.

Thus, the force and speed of the machines are controlled
Principle of Switch Reluctance Motor Drive
A regular SRM drive framework comprises of the exchanged hesitance engine, power inverter, sensors, for example, voltage, current, and position sensors, what's more, control hardware, for example, the DSP regulator and its peripherals, as appeared in Figure. Through appropriate control, elite can be accomplished in the SRM drive framework. The SRM drive inverter is associated with a DC power gracefully, which can be gotten from the utility lines through a front-end diode rectifier or from batteries. The stage windings of the SRM are associated with the force inverter, as appeared in Figure . The control circuit gives a gating sign to the switches of the inverter as indicated by specific control techniques and the signs from different sensors.

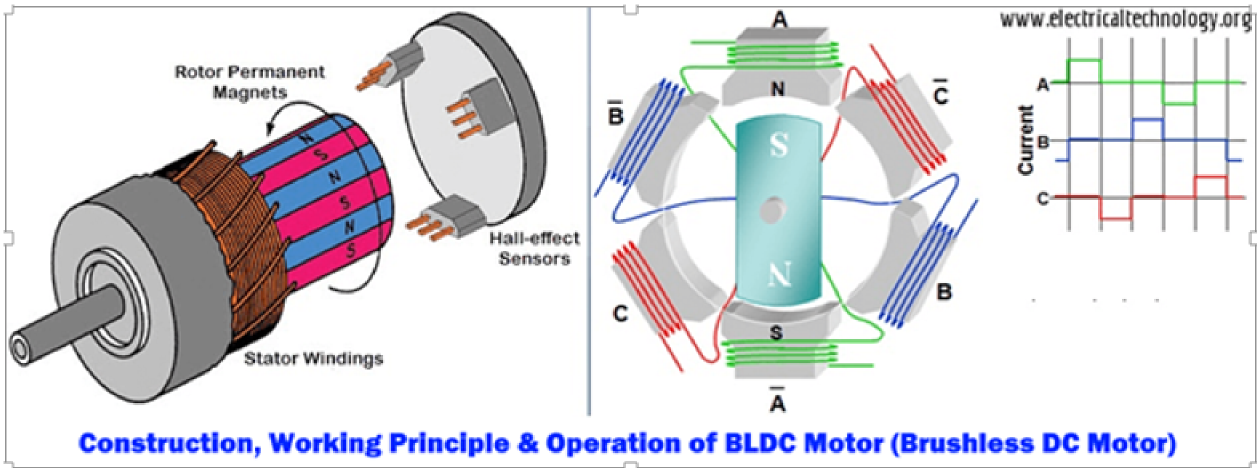


Figure 18: BLDC motor

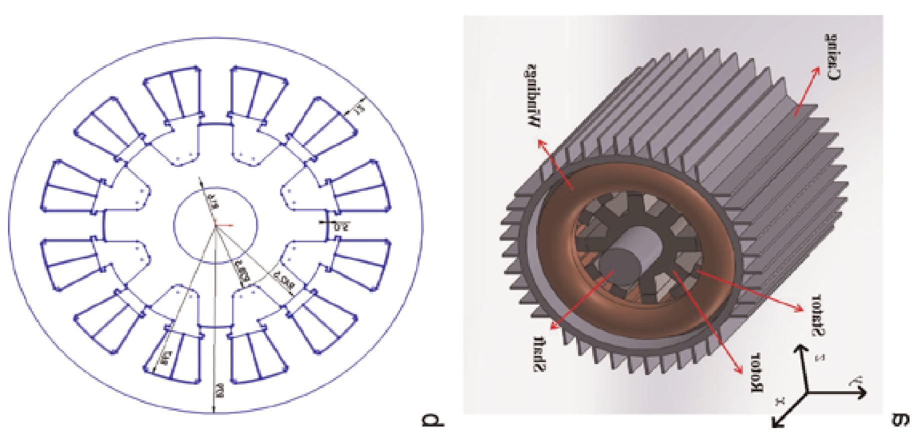


Figure 19: Principle of Switch Reluctance Motor Drive

Figure 20: Principle of Induction Motors

Principle of Induction Motors

The response between the turning stator mmf and the rotor conductors instigates a voltage in the rotor, and consequently electric flow in the rotor. Thusly, the turning mmf produces a force on the rotor, which is conveying the instigated current. Plainly the prompted current in the rotor is fundamental for delivering the force, and thus the prompted current relies upon the relative developments between the stator mmf and the rotor. This is the reason there must exist a distinction between the rakish speed of the turning stator mmf and the precise speed of the rotor. The recurrence ω, or precise speed of the pivoting stator mmf in the condition relies just upon the recurrence of the elective flow of the stator; consequently, it is alluded to as electrical rakish speed. For a machine with two shafts, the electrical precise speed is indistinguishable from the mechanical rakish speed of the pivoting stator mmf.

Result: Out of the researched motors the Induction motor was selected for the vehicle.

Reason for Selecting the Induction Motors

1. Induction motors can easily be utilized for higher torque rating, as BLDC can not be used for higher torque, tuning of reluctance is not easy.

2. Only Induction motor provides steady state performance hence making increasing the efficiency of our vehicle.

3. Induction can be easily used for regenerative braking.

4. Along with power electronics they become effective.

6.4 Solar

6.4.1 Solar Cell

SBT – Semiconductor Wafer bonding Technologies

Semiconductor wafer bonding technologies (SBT). SBT refers to the mechanical connection of one semiconductor wafer on top of another. Significant improvements in solar cell performance are envisioned: a) near-term ($1-2$ *years*): $> 33\%$ efficient, and b) mid-to far term ($5-10$ *years*): $> 37\%$ efficient.[18] [19]

- Solar constant at Mars: $S_c= 598\ \frac{W}{m^2}$
- Attenuation through the atmosphere= 0.8
- Attenuation through accumulated dust= 0.9
- Solar panel fill factor= 0.8
- Availability (night and angular)= 0.25
- Solar cell efficiency: 0.35 (max)

So average power $= 598 * 0.8 * 0.9 * 0.8 * 0.25 * 0.35 = 30.1592 \frac{W}{m^2}$

6.4.2 Solar Arrays

NGU - NextGen UltraFlex Solar Arrays

The "Next Generation UltraFlex" (NGU) system is a highly-evolved and large-scaled version of the previously flight qualified Mars 01-Lander UltraFlex and employs many advanced technologies. The NGU system promises very high specific power ($175\frac{W}{kg}$–$220\ \frac{W}{kg}$)

[18] https://www.google.com/url?sa=t HYPERLINK
[19] https://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html

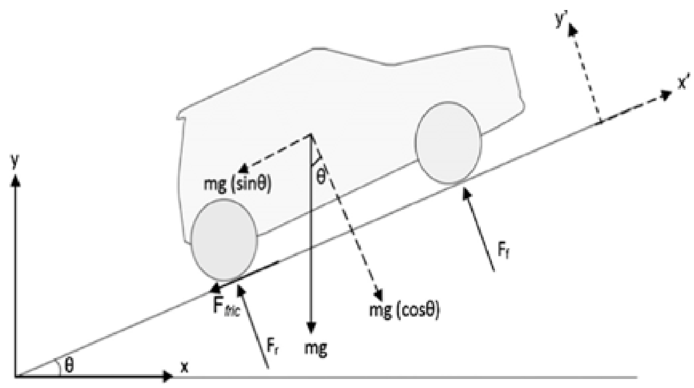


Figure 21: Total Power Calculation

6.5 Total Power Consumption of The Vehicle

The total Power consumption of the vehicle can be calculated as follows:

Total power required = Power required by vehicle to move + power required to by life support system + Power required by sensors and Lighting

Power required to move the vehicle-
Our vehicles Power train comprises of 3 induction motors each powering pair of two wheels.
To calculate the Power we need to calculate the force on each wheel of the vehicle-
The First Question which we first encountered was whether to make the vehicle Front wheel drive or a Rear wheel drive.
Hence we came derived an equation which can provide us with total force on each wheel in a Front wheel or Rear wheel drive.

Equation for Front wheel

$$F_{t_{max}} = \mu M_g \frac{l_b + f_r(h_g + r)}{L(1 + \frac{\mu h_g}{L})}$$

Where,
μ - Coefficient of road due to adhesion

M- Mass of the vehicle
g-3.75$\frac{m}{s^2}$ for Mars
l_b- Distance from the rear wheel to point on CG of the vehicle
h_g – Height of Point of CG from the ground
r- radius of the wheel
L– wheel base of the vehicle

The calculated Ft =12577.642N

Now we calculated the force for the Rear wheel:

Equation for Rear wheel

$$F_{t_{max}} = \mu M_g \frac{l_a + f_r(h_g - r)}{L(1 - \frac{\mu h_g}{L})}$$

μ - Coefficient of road due to adhesion
M- Mass of the vehicle
g-3.75$\frac{m}{s^2}$ for Mars
l_a- Distance from the front wheel to point on CG of the vehicle
h_g – Height of Point of CG from the ground
r- radius of the wheel
L– wheel base of the vehicle

The Force calculated was : 64386.19 N

Hence the idea of designing a Front wheel Powered vehicle was adapted. Here, Front wheel drive means only when the Vehicle starts, when the vehicle attains traction all 3 motors are powered to attain maximum efficiency and equally distribute the required power.

Hence

Torque produced in each wheel= $F_t * r$
F_t-Force calculated
r- radius of the vehicle
The calculated Torque was- 5582NM
Power required= $T * \omega$
T-Torque
ω - Angular velocity
The calculated Power was $-62.5KW$

$$T_p\text{= Power to be used in traction + Power for Life support System+ Power for Sensors or Lighting}$$

$T = 62.5 + 30 + 7.5 = 100KW$

6.6 Power and Torque requirements of Mars Exploration Vehicle

Parameters considered

- Curb Weight of Vehicle = 1100 kg (in Mars) [Mass x Gravity (3.71)]
- Top Speed = 18 $\frac{km}{h}$
- Diameter of Tyre = 0.6 $meter$

Linear Wheel Travel $2\pi r = 1.9$ $meter$
RPM = $\frac{[speed(m/s)*60]}{Linearwheeltravel} = \frac{(5*60)}{1.9}$ = 157.9 revolutions per minute
Rolling Resistance = 8.8 N [18]
Area of the front portion of Vehicle = $2m^2$
Peak Power = (Mass x Gravity x Speed x Rolling Resistance) + (Air Density x Coefficient of Drag x Area x V^3) + (Mass x Gravity x Sinθ)

$$= (1100 * 5 * 8.88) + (0.4x0.5x2x53) + (1100xsin(10))$$

$$= 48840W$$

$$= 48.884KW$$

This calculation demonstrated the amount of total power required to move the vehicle forward. Here the values of Air Density and the Coefficient of Drag are very low because of the low density of the atmosphere and also due to low speed of the vehicle. This gives an idea about the power requirement of the drive motor that has been decided. This unilaterally points to the battery capacity that's been required, because a lion's share of the battery power is consumed locomotion.

7 CAD Model

7.1 Vehicle

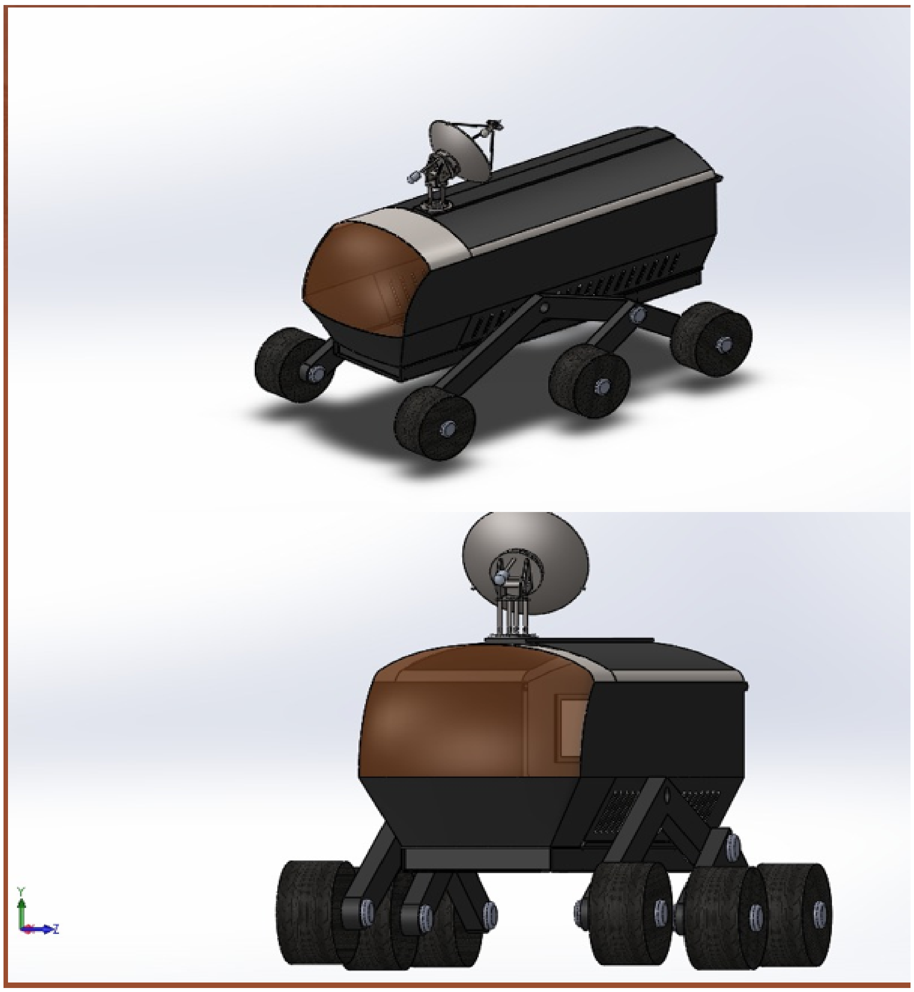


Figure 22: CAD Model Side and Front View

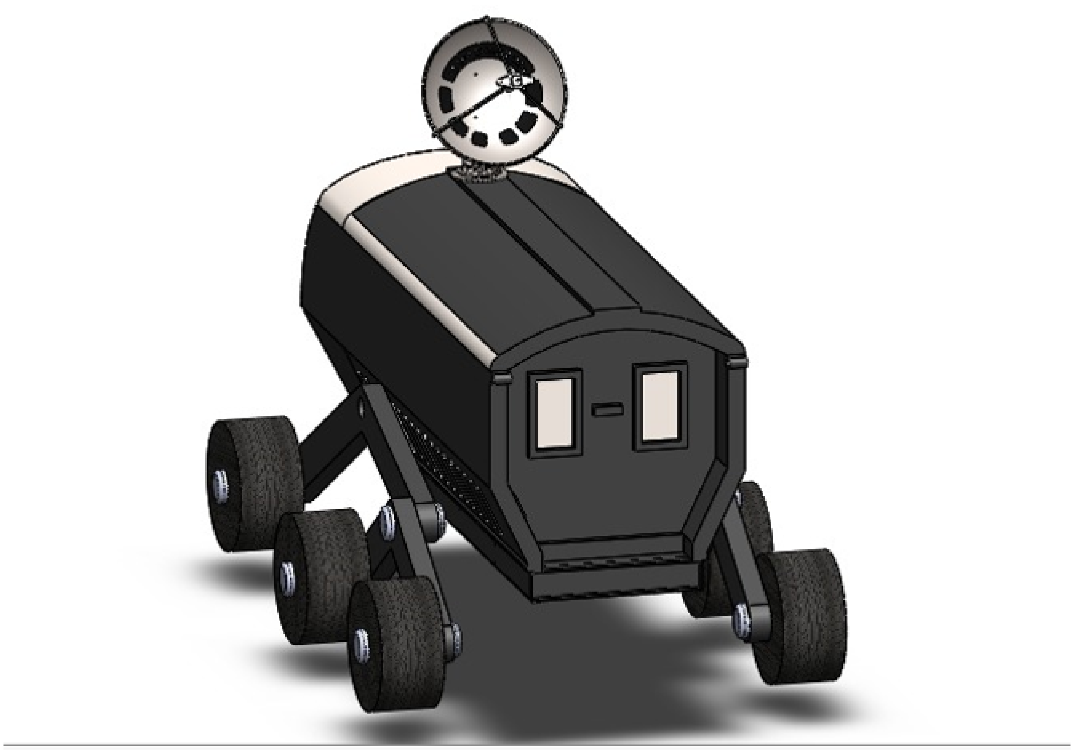


Figure 23: CAD Model Back View

7.2 Interior Design

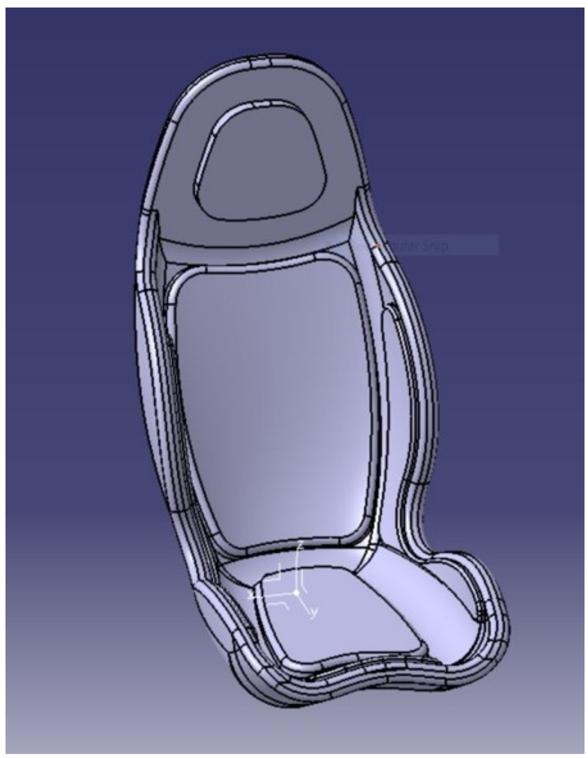


Figure 24: Seat Design

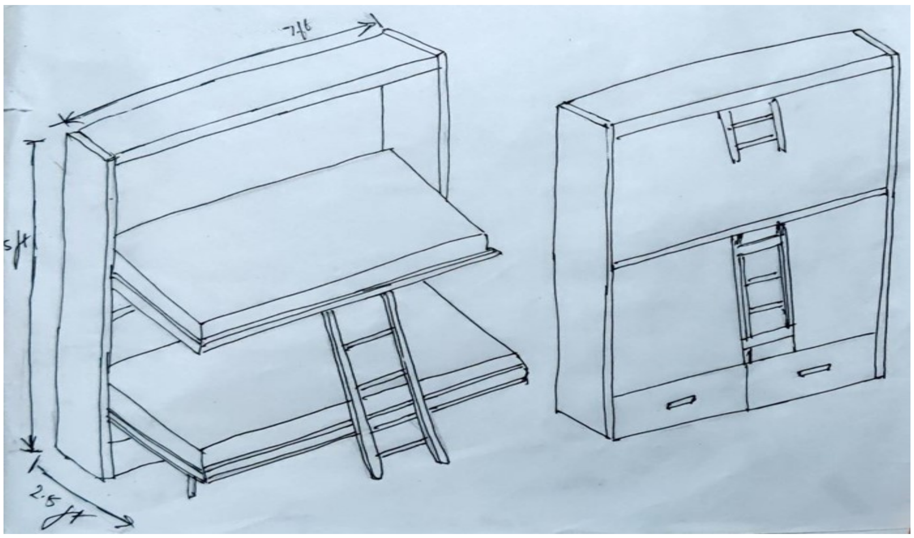


Figure 25: Bed Design

Waste Stream	Source	Content	Fate
1.Solid waste	Crew activities	Paper, plastics, feces, undefined trash	Oxidation
2.Urine	Crew	Urine, urinal flush water	NH_3 recovery, then oxidation
3.Domestic	Crew	Shower water, dish washing, clothes washing, oral hygiene	Removal of organics, then nutrient soln. makeup
4.Nutrient	Plant growth	Spent plant and algae nutrient solutions	Oxidation
5.Inedible biomass	Plant food processing	Roots, shoots, food process waste, water	Digest cellulose, remove sugars, then oxidize
6.Volatiles	Crew and plant volatiles, materials outgassing	Small organic molecules	Oxidation

76

Figure 26: Waste Management

8 Conclusion

Don't think what the cheapest way to do it is or what's the fastest way to do it....thinks what the most is amazing way to do it." - Richard Branson

There are several reasons why our MCEV concept is feasible. The entire vehicles was designed keeping all key aspects of safety, quality and cost in mind. In very initial stage we focused on development of life support system for development of pressurized cabin, where we where able to successfully conceptualize oxygen generation, pressurization system, air revitalization and HVAC system. Very after cabinet work the entire vehicular body was started to design where we used rocker bogie suspension system also we finalized mobility parameters, wheels design, power unit, motors, communication system. From all the above designed system we claim that all the system can run effectively and can sustain over Martian atmosphere and carry forward human exploration .The validity of our design is under the research phase where after more subsequent calculations and software simulations we can say our pressurized crew exploration vehicle can work more effectively over along period of time to help crew for mars expedition.

8.1 Future Scope

This MCEV concept uses unique solutions to most of problems that would be faced over crew vehicle over Martian or Lunar atmosphere. The crew vehicle uses innovative method for pressurization and also emphasis more on cost, quality and safety. Currently thousand of scientist and engineer are working together for colonizing mars and moon. In order to improve the mission and expedition quality the mcev can be used. It can solve transportation problems over mars/moon and also provides more advantages to crew for onsite exploration.

Also more subsequent research on composite materials and new system/technology can help to improve our crew vehicle. Hence the crew exploration vehicle can be used as a part of mars or moon colonization plan, which can help explores to explore more in detail. The Conceptual design of the MCEV is ready but still its far from complete. During the detailed design many of the systems, subsystems while testing may fail and reiterations needs to be done on the calculation, analysis and simulation part. MCEV is a Mission Critical Vehicle as human life depend on it, so thousands of tests and prototypes need to be made which will decide the improvements in it.

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