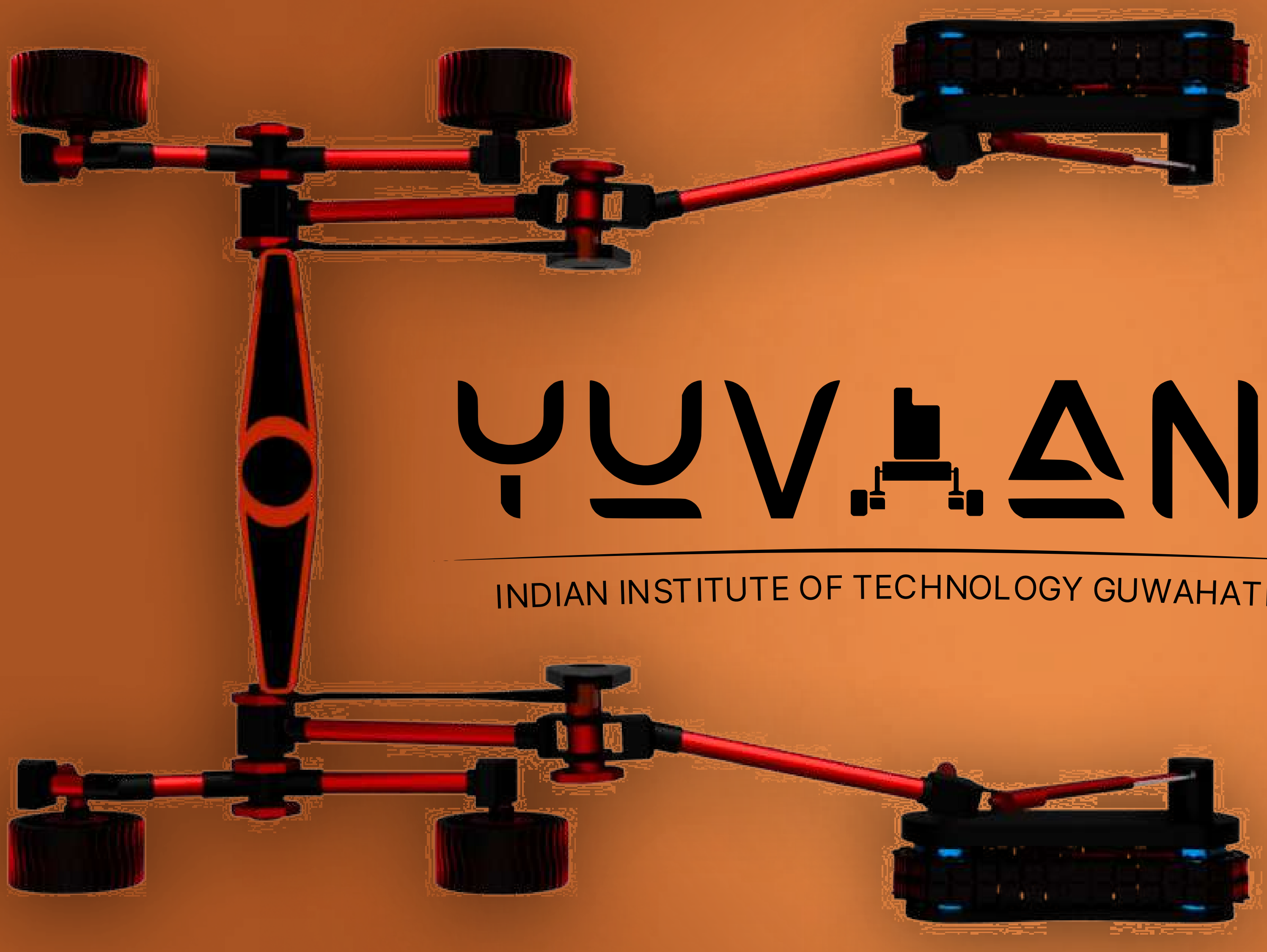

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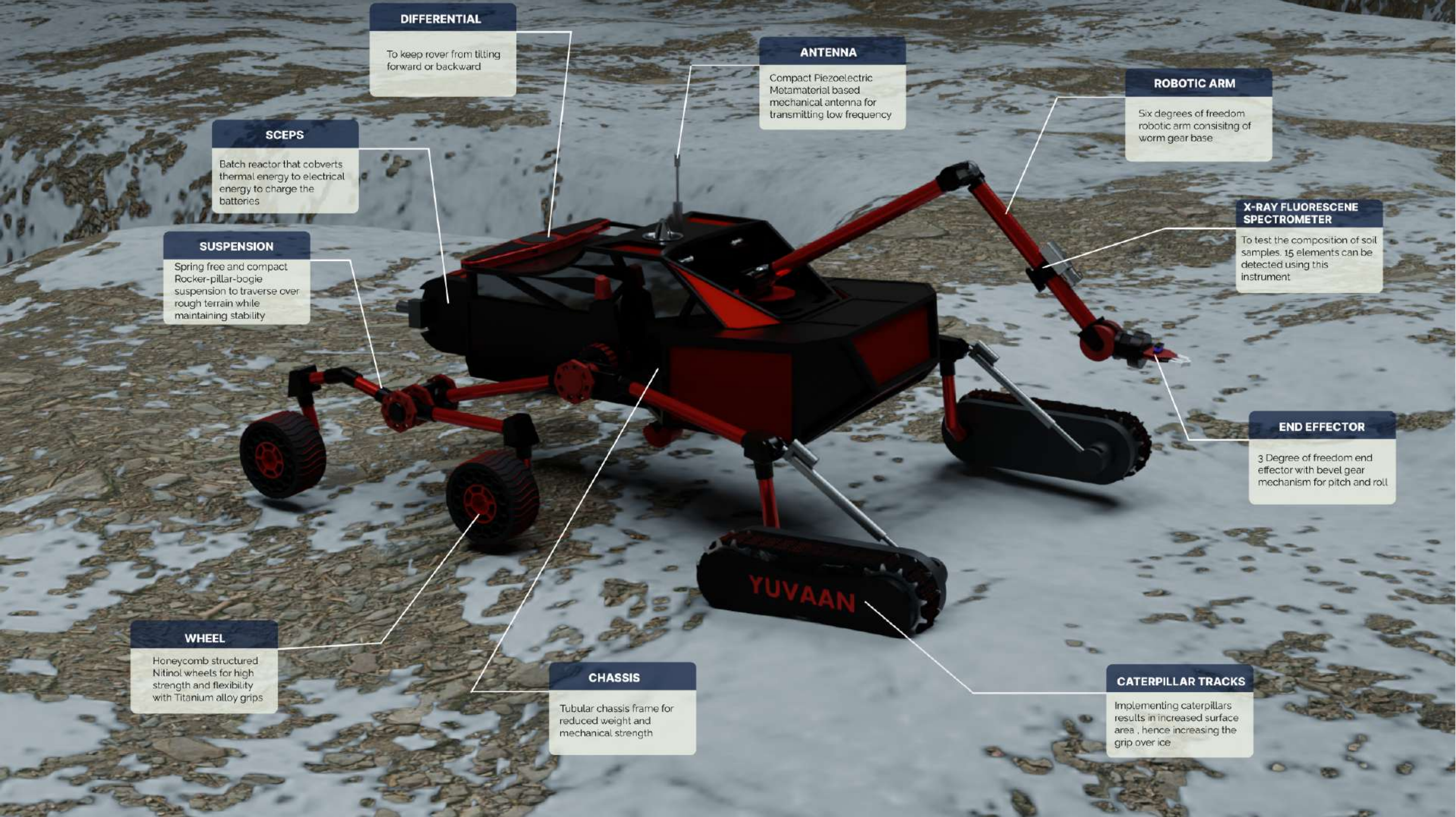

DIFFERENTIAL
To keep rover from tilting forward or backward
ANTENNA
Compact Piezoelectric Metamaterial based mechanical antenna for transmitting low frequency
ROBOTIC ARM
Six degrees of freedom robotic arm consisitng of worm gear base
SCEPS
Batch reactor that cobverts thermal energy to electrical energy to charge the batteries
X-RAY FLUORESCENE SPECTROMETER
To test the composition of soil samples. 15 elements can be detected using this instrument
SUSPENSION
Spring free and compact Rocker-pillar-bogie suspension to traverse over rough terrain while maintaining stability
END EFFECTOR
3 Degree of freedom end effector with bevel gear mechanism for pitch and roll
YUVAAN
WHEEL
Honeycomb structured Nitinol wheels for high strength and flexibility with Titanium alloy grips
CHASSIS
Tubular chassis frame for reduced weight and mechanical strength
CATERPILLAR TRACKS
Implementing caterpillars results in increased surface area , hence increasing the grip over ice

0.0 / Overview

The trend of extraterrestrial exploration is positively influencing people all around the globe, and with growing demands of resources and considering the present conditions of Earth, it would be great to have known the possibility of habituation on other planets. Our mission is to investigate the potential of the presence of existing life and essential natural resources on Mars. We will start by recalling the specifications of our project, followed by detailed research on the project, our objective, and implementation. We recall here the specifications set at the start of the project.

Our team designed the Mars Rover with various sensors and active elements to carry a surface mission in the Planum Australe region of mars to explore and characterize properties. During the mission, the primary objective of the Rover is to carry out the following operations:

- Navigate and traverse successfully through the different types of terrain including both soil and icy surfaces
- Communicate with the base station during the entire length of the mission
- Conduct scientific experiments to study about water on the martian surface and chemical composition of martian atmosphere, thus finding habitable zones analytically
- Checking nutrient contents in soil samples and checking for radioactivity, as well as performing subsurface imaging

The complete rover is divided in 4 subsystems:

- **Mechanical** - Traversing through soil-ice surface conditions satisfactorily
- **Manipulator** - Assist other subsystems for physical interaction with environment
- **Electronics** - Ensuring power, communication, navigation functionalities for the rover
- **Bio-assembly** - Seeks to discover future chances of life survival on Mars by performing overall environment analysis

Mechanical Module

1.1 / Overview

The mechanical design of the rover is done by considering all the factors that are on the designated site of the mission. It consists of the motor hub, links, linear actuators, and caterpillar wheels.

1.2 / Mission

1. To traverse over both even and uneven surface
2. Help traverse over thin ice sheets with proper traction and weight distribution
3. Provide overall stability to other subsystems

1.3 / Solutions

1. Rocker Bogie mechanism is employed for stability during uneven terrain traversing
2. Caterpillar wheels are have tank-like tracks which provide greater traction
3. Titanium chassis is employed stability

1.3.1 / CHASSIS

Chassis consists of internal supporting frame which encompasses the bio-assembly system, robotic arm, suspension system etc.

The chassis is designed using **Grade 5 Aerospace Titanium Alloy (Ti_6Al_4 V)**. The material is chosen owing to its **exceptional strength-density ratio and resistance to corrosion**.

We decided upon using **square cross-section** Titanium Alloy hollow bar. Square bar was chosen because load was anticipated only in one direction, also it has higher moment of inertia so it has **lower bending stress** compared to circular or any other bars.

Fig 1.3.1.a Structure of Chassis

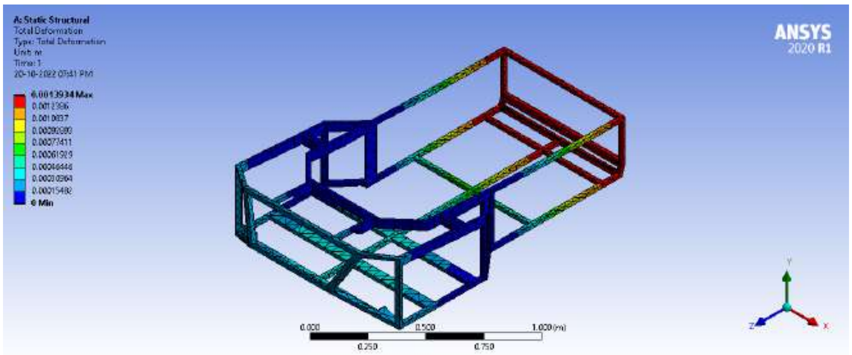


Fig 1.3.1.b Analysis of Chassis

1.3.2 / SUSPENSION

In our rover, we have used a **rocker-pillar-bogie suspension**. It has two caterpillar tracks, and four wheels. Rocker-bogie is a spring free, compactly constructed suspension, based on **bar-differential drive system** that allows the bogie to move over rough terrain while maintaining stability. Relative to the chassis, the rockers will rotate in opposite directions to maintain equal wheel contact.

Some of its main advantages are:

- Due to rocker-bogie suspension, the weight of the rover is distributed uniformly.
- As six wheels of **classic rocker-bogie was not enough for grip in icy-slippery surface** like southern poles of Mars, we **replaced front two wheels with caterpillars**.
- Due to **increase in surface area** by implementing caterpillars, pressure applied on ice sheet is reduced, which **decreases the risk of cracking of ice** in an unfavorable manner.
- We can control these two caterpillars by **actuators** by lifting from an end as per requirements.
- This rocker-pillar mechanism also helps the rover to cross over **holes larger than diameter of its wheels**.
- It also helps the rover to climb up steep obstructions without a frontal slide.
- The Rocker-bogie mechanism **reduces jerk and vibrations** to sensitive components like sensors and camera which must be stable to work properly and to increase life span.

Fig 1.3.2.a Suspension

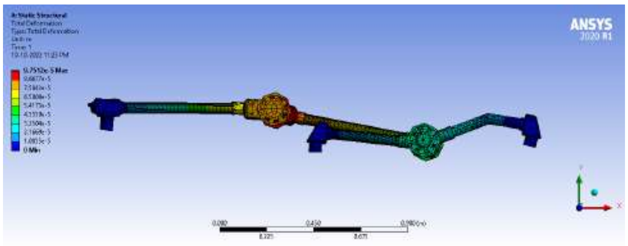


Fig 1.3.2.b Analysis of suspension

Suspension of the rover is classified into further sub-components:

- Links and Joints
- Wheels
- Differential
- Caterpillar Tracks

1. Links and Joints

Links are made up of **Grade 5 Aerospace Titanium Alloy (Ti_6Al_4 V)** owing to its high strength, lower density (compared to structural steel) and exceptional resistance to corrosion. Each link is joined to another link using **custom made titanium joints**.

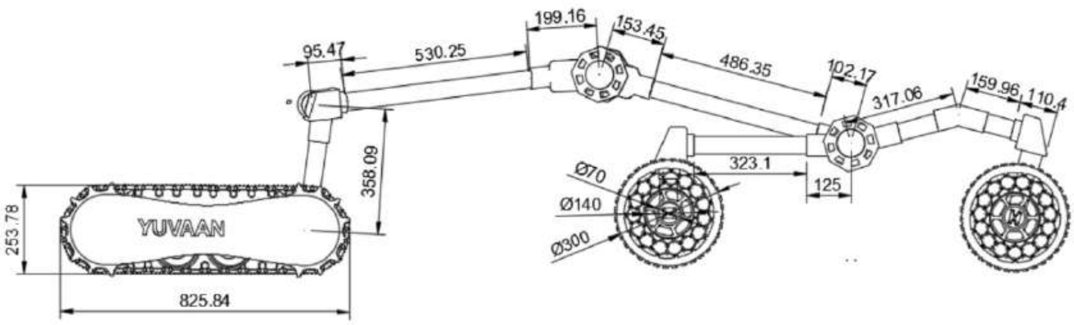


Fig 1.3.2.c Link, suspension and wheel dimensions

2. Wheels

Our wheel is constructed using **Nitinol(NiTi Alloy)**, which has high corrosion resistance and strength-to-density ratio so that the wheel can easily withstand high outer shocks and impacts.

Hexagonal Celled honeycomb structure is chosen as our rim design. Nitinol is chosen over other materials owing to its high strength and flexibility. Nitinol can undergo significant reversible strain (up to 10%), enabling the tire to withstand an **order of magnitude** more deformation than other non-pneumatic tires before undergoing permanent deformation.

Hexagonal cell structures are known to be **flexible** in both axial and shear loadings. In order to provide an even greater measure of load distribution to the plurality of spokes, the preferred embodiment of the rim includes a central wall.

The central wall and inner and outer rims form an **annular I beam** which is particularly well suited to transmit load into each of the spokes due to its very high area moment of inertia. Therefore, it can be concluded that Honeycomb Structure Wheel Design is better suited for high load carrying capacity.

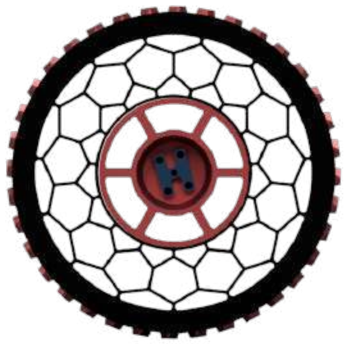


Fig 2.2 Wheels

Owing to comparatively slippery surface of exploration region, grips are added to the outer surface of the wheel. The grips are made up of **Ti_6Al_4 alloy**. The grip, in absence of grip, would start digging into the solid ice, scraping the surface and **creating rough surface** which would provide the required grip.

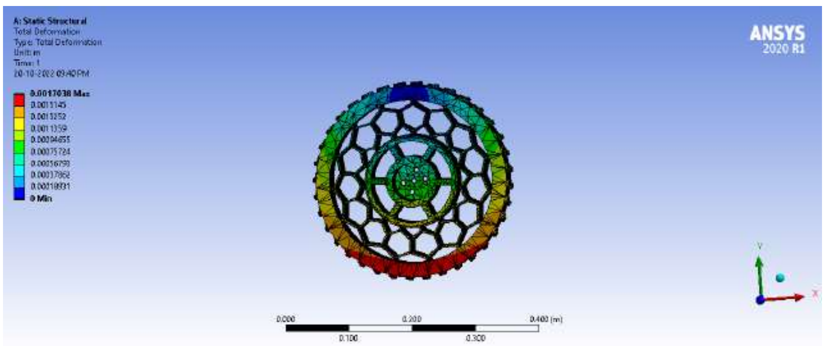


Fig 1.3.2.d Analysis of Wheel

3. Caterpillar Tracks

Caterpillar with **2 sprockets and 2 support** wheels, completely made up of Ti_6Al_4 alloy is used. Main goal of implementation of caterpillar is to **increase grip** owing to slippery condition prevalent in the exploration region. To further increase grip, Titanium grips are spread all over the outer surface of the chain **to increase shear force provided by the caterpillar**.

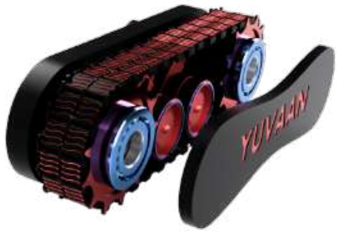


Fig 1.3.2.e Caterpillar

A linear actuator of stroke length 300mm is used to change the orientation of the caterpillar for required terrain traversing. The change in orientation results in greater control over traversing capability and the amount of grip provided by the caterpillar.

Fig 1.3.2.f Caterpillar

3. DIFFERENTIAL

A differential bar made up of **Ti_6Al_4 Alloy** is used. The middle of the bar is connected to the body with a pivot and the two ends are connected to the rockers through rod end ball joints. If one of the rockers passes through an obstacle then the other end of the bar will move in the opposite direction so the other rocker will tilt down.

Fig 1.3.2.g differential bar

Manipulator Module

2.1 / Overview

The Robotic Manipulator has **6 Degrees of Freedom**. It consists of a **worm gear** base, planetary gearboxes, motors, links and end-effector. The major functions of the manipulator include lifting loads.

2.2 / Mission

The major problems that can be faced by rover, which can be solved using the arm are:

1. Assisting astronauts in manipulating caches, etc.
2. If some obstacle comes in front or near the wheels of the rover, the rover may get stuck.
3. If the rover has to traverse on an icy surface, then it may slip.
4. While climbing/descending on extreme slopes, the rover may topple.
5. Various soil and rock samples have to be collected.
6. Visual reconnaissance of the region need to be done for good peripheral vision

2.3 / Solution

1. Easily **handle caches** like screw-drivers, wrenches, etc. and drawers.
2. **Remove obstacles** like stones, rocks, gravel, etc.
3. .Scrap ice. on the surface to make it rough, thus increasing the coefficient of friction and hence providing good traction.
4. Extend or retract itself in order to shift the overall center of mass. of the rover when on extreme slopes.
5. .Collect various samples. and they can be further sent to the bio-assembly for analysis.
6. .Provide the visual feed. of the region using the mounted camera, which can help traversing and controlling

2.3.4 / Base

The base consists of a truss-shaped. structure, plates and shaft of diameter 75mm to improve the stability of the arm and also to decrease the weight of the material used.

The base plates are mounted over the worm gear. which are controlled by DC motors, are used for their high bearing capacity and high load-carrying capacity. used to resist the external loads and weight of the manipulator. It also has the ability to convert the rotatory motion about one axis to translatory motion in other axes.

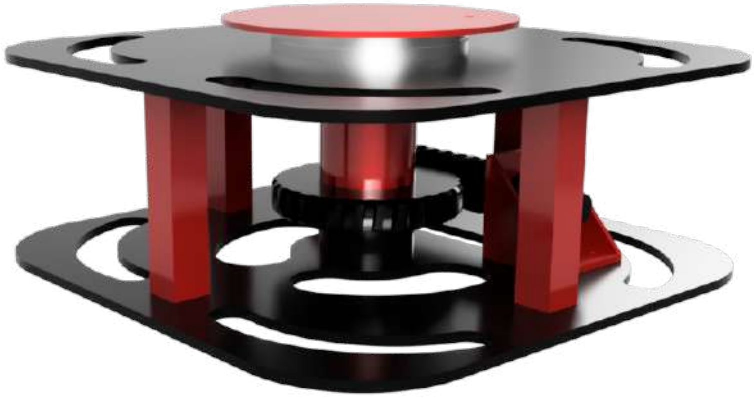


Fig 2.3.4.a Base

1.**Gear Box**:

- The gearbox is included in the rotatory actuator which is driven by planetary geared DC motor. It has two .epicyclic gear trains. (also known as planetary gear set)- both having a 4:1 gear ratio, complementing each other, increasing the gear ratio to **16:1**. The two planetary gear systems are connected by a .sun-gear carrier., which is used to connect the centres of the two sun gears. There are 4 planetary gears (connected to the sun gear) that drive the outer gear ring. There are bearings below the sun gear. In addition to this, there is an outer bearing connected to the face plate.

Fig 2.3.4.b Gearbox (inside)

2. Links:

- We have used 2 links, which are connected to the gearbox using the revolute joints. The longer link connects the rotatory actuator at the base to the other rotatory actuator, which in turn drives other link connected to the end-effector. The length of the links, are chosen in accordance to the approximate constraint equations of our design workspace and to keep the whole arm stable owing to its weight constraint.

Fig 2.3.4.c Links

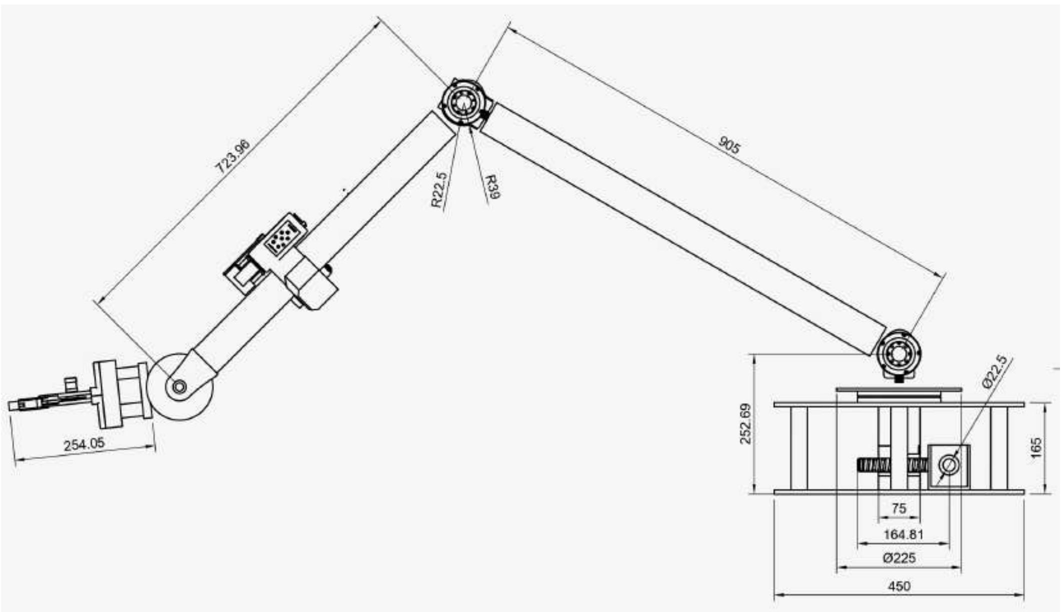


Fig 2.3.4.d Arm dimensions

2.3.5 / End Effector

The end effector used in the rover is an adaptive gripper model. It has **3 DOF**: **Pitch, Roll, and Grip**. The Pitch and Roll controls are provided by a **Bevel gear Differential** mechanism, provided by a combination of 2 DC geared motors.

Fig 2.3.5.a Gripper

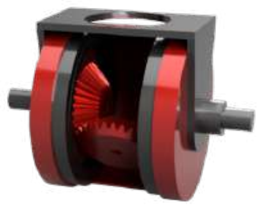


Fig 2.3.5.b Bevel gearbox

It has **flexibility in the fingers**: the unique design allows the fingers to stay straight when an item is picked by the tips of the gripper and will wrap around it if a larger object is picked up. It is expected to carry more than **5kg of weight**.

The gripping action is controlled by a small servo motor with the handspan being approximately **8cm**.

The end effector is well-equipped to perform various tasks including:

- Picking up objects (or obstacles)
- Open a drawer
- Switching On/Off
- Collecting Samples for bio-assessing
- Operating a joystick

Electronics Module

3.1 / Challenges

There are three major challenges that the electronics module need to overcome-

- **Navigation and Control** - There must be a method for controlling the rover, i.e., sending commands to the rover from the base station and receiving sensor data and video feed from the rover.
- **Power** - The rover's power module is in charge of ensuring sufficient power supply for the complete duration of the mission, keeping its electronics warm and efficiently supplying power from batteries to individual components according to their power requirements while preventing any short-circuit or overload current within the circuit.
- **Communication** - A reliable connection between the rover and the base station across a 20-km distance is to be made, while maintaining data transmission speed for effective communication.

3.2 / Solution

Electronics Module is hence designed to tackle the aforementioned challenges. The module has been divided into three subsystems which are as follows: -

3.2.1 / Navigation and Control

For controlling the rover, various subsystems such as BioScience or Robotic Arm can be separately controlled by a microcontroller such as the Arduino Mega. To complete our mission of visual reconnaissance, 2D cameras and depth cameras are used. All of these devices, such as microcontrollers and cameras, can be connected to a small computer. **Jetson Nano** was chosen as our onboard processing unit since it can be directly linked to the antenna to receive commands from the base station and send signals to the Arduino, as well as relay sensor data, camera images, and the created depth map back to the base station.

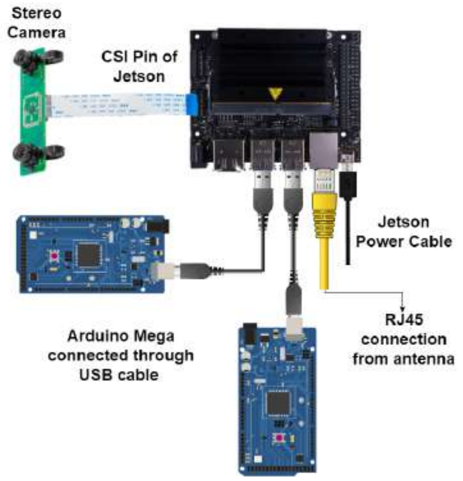


Fig 3.2.1.a Jetson connection circuit

The rover's control code is written using the ROS framework (a middleware package).

A graphical user interface (GUI) operating on the base station would display all sensor readings, camera feeds, and other crucial parameters for controlling the rover. Control commands will be delivered from the base station to the rover based on the video stream from the rover.

On Jetson these commands will be published on different ROS topics.

Each Arduino Mega linked to the Jetson via USB will function as a separate node, subscribing to control topics to carry out specific activities such as -

- sending signals to motor drivers as necessary for moving the rover
- operating the robotic arm
- carrying out tests on BioScience

Arduino nodes will also be running ROS action servers to initiate sensor readings and publish the collected data.

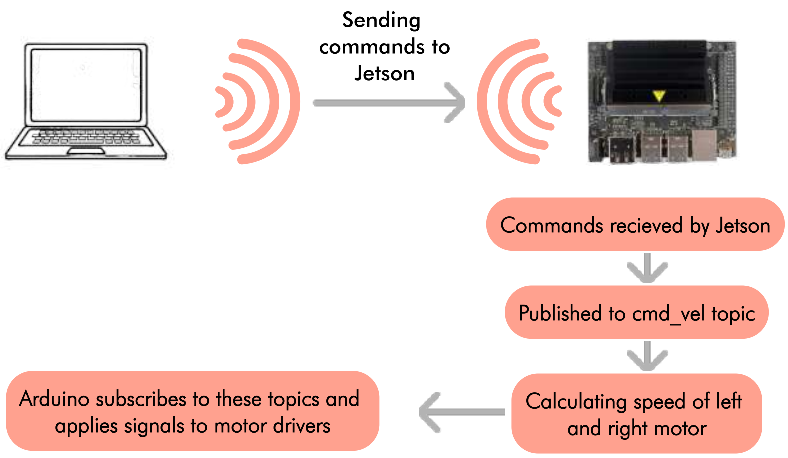


Fig 3.2.1.b Navigation workflow

All the cameras in the rover are connected to Jetson and their output can be viewed separately. Visual reconnaissance is achieved using a stereo camera. This camera gives 2D RGB images as well as depth data. Panoramic images of areas around the landing site can be generated by rotating this camera in different angles and stitching together the collected images to generate a panoramic image.

3.2.2 / Power

One of the major challenges of the Electronics module is to power the rover for the extensive duration of the mission. A single battery pack won't be sufficient. So batteries are used as a primary source of power and after they discharge they'll be charged using a secondary source. Two battery packs are chosen and we will use them alternately, so that when one is powering the rover, the other one is being charged and vice versa.

According to Rover's power requirement **24 Volt 18Ah LiFePO4 batteries** were chosen, which have in-built BMS that prevents the battery from overcharging above 29.2V and also prevents it from over discharging below 22.5 volts.

3.2.2.1 / Charging the batteries

Some methods which can be used to charge the batteries after they have been discharged during mission are -

- **Solar Energy** - Solar panels could be used to harness electrical energy from sunlight. But there were some disadvantages regarding that -

    1. Dust storms in mars are frequent and blowing dust during the mission can enormously reduce the energy produced by solar panels.
    2. The Sun doesn't shine with the same desired intensity all the time, so we can't always produce energy efficiently.
    3. Large solar panels would be required to provide the rover's power requirements for the mission, eventually adding to the rover's weight.

- **RTG (RadioIsotope ThermoElectric Generators)** - Decay of radioactive materials can be used to power the rover but these are expensive, also they release dangerous radioactive particles that can interfere with rover's electronics adding unnecessary noise to its data gathering. The size as well as weight of MMRTG adds to its disadvantages.
- **Stored Chemical Energy Power Systems (SCEPS)** - SCEPS take the form of a batch reactor with a metal fuel and gaseous oxidant. Combustion of a gas can be done and generated thermal energy can be converted to electrical energy to charge the batteries.

Among them SCEPS was chosen as it can entirely power the rover for the duration of the mission. Second, the heat created by SCEPS can be utilized to keep the rover's electronics warm, allowing it to function even in cold conditions. Also we need to carry only small amounts of Lithium Nitride as fuel and we can get CO_2 from the atmosphere as it is present in abundance.

3.2.2.2 / Process Description

The reaction between CO_2 and Li_3N is extremely exothermic and to start the reaction we need to raise the temperature of the reactor to 250℃.

$$3CO_{2(g)} + 4Li_3N_{(s)} => C_3N_{4(s)} + 6Li_2O_{(s)}$$

As a result, the reaction chamber is composed of materials that can withstand high temperatures and is insulated from the exterior so that heat created inside the chamber is not lost to the environment. Upon landing both rover batteries would be fully charged. One of these would be used to initiate the reactor (heating to the reqd temp.)

while the other would be used to power the rover for its functioning. The reactor temperature is raised to 250℃ using electric coils around the reactor and then the process is as follows:

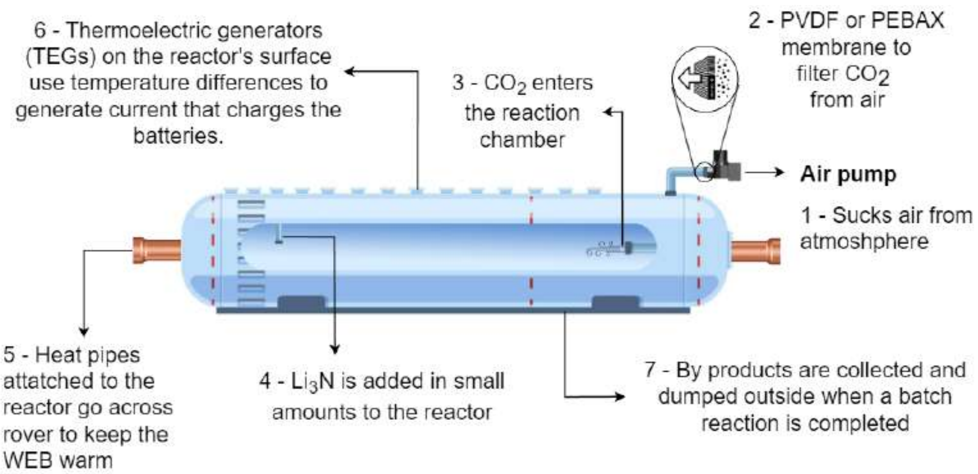


Fig 3.2.2.2.a Reaction chamber

The reactor's temperature climbs to 750°C, and the electric coils are shut off. When the batteries are charged, the reaction is stopped, and the circuit charging the batteries breaks, avoiding overcharging. When the temperature falls below 260°C, the reaction is restarted to keep the temperature stable.

Temperature control mechanism

Why Temperature control is required? :

Surface temperatures of Mars may reach freezing low temperatures that can reduce battery efficiency. The temperature range of the rover and in particular the Warm Electronics Box (WEB) in which all the electronics equipment are housed should be between 10-30°C for the rover to work properly.

The Mechanism:

The heat released during combustion in the reactor is conducted to a THERMAL CONTROL SUBSYSTEM consisting of heat pipes spread across the rover.

The heat pipes have one of its ends in contact with the hot surface of the reactor and goes around the rover body (the WEB and the bio-assembly module) maintaining the temperature of the rover body.

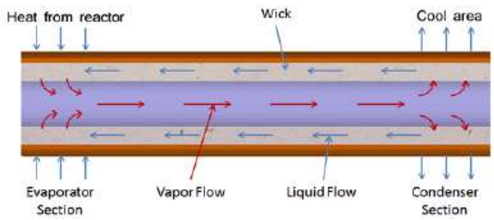


Fig 3.2.2.2.b Heat pipe

The exterior surface of the rover's WEB is coated with gold paint, and the interior is covered with insulation like aerogel to minimize heat loss through radiative heat transmission.

There is also a heat rejection system (HRS) based on a mechanically pumped single-phase liquid cooling system. Its working fluid is CFC-12. The temperature sensor records the temperature of the box. When the temperature rises over 25° C, the heat rejection system comes into force and the pumps start working to shuttle the waste heat from the box to the surrounding environment.

Fig 3.2.2.2.c DC - Heat pipe Distributed in Chassis

Rover Power Management

The various components of our rover are connected via a power management board. This board has many buses that connect the battery to various components of the rover's subsystems. Each bus provides proper power to the components that require it and also features short circuit protection to prevent damage.

To provide the required voltage to different subsystems from the main source: **VPT's Space DC-DC converters** are used to supply required voltage from 24 Volt battery. These converters are space qualified, used mostly in space missions with various ratings that make them a good choice for our mission. They are radiation tolerant or radiation hardened isolated DC-DC converters along with various protection circuits. After these convertors short circuit protection circuits are implemented to further protect the electronics.

3.2.3 / Communication

For communication between the rover and the base station there were some specific requirements -

1. The connection has to be wireless. A wired connection to the rover is not feasible.
2. Communication must work seamlessly upto a range of 20km
3. Line of site might not necessarily be available, so the connection must be feasible even if the line of sight is not available.

This can be achieved by normal radio waves based 2.4Ghz and 5Ghz antennas, available off the shelf, but they cannot be used for following reasons -

1. Because 2.4GHz is a fairly high frequency, it has a limited range. Antennas that provided a range of 20km were too bulky to be added to the rover.
2. All these antennas are direct transmission antennas and need line of sight to work properly. In order to maintain line of sight for a distance of 20km we need to place these antennas in the base station at a height of about 60 meters which is not feasible.
3. Also any raised surface in the line of sight can block the communication, as these high frequencies are easily attenuated by obstacles.

In order to overcome these problems the Sky Wave Propagation method was used. In this the transmitted wave reaches the ionosphere and is reflected back to the ground.

The radio wave must be less than a particular frequency for this to be achievable . The maximum frequency is determined by the ionosphere's characteristics and the angle at which the wave strikes the ionosphere.

The essential frequency for skywave propagation on Mars was determined to be **4MHz** with a 20km range.

Normal antennas cannot be used to transmit signals at 4MHz owing to transmitter antenna size constraints.

So compact **Piezoelectric Metamaterial–based mechanical antennas** are used. These antennas were capable of transmitting frequencies in the range kilohertz and are of few tens of centimeters in size. The frequency of these antennas depend on the PZT material chosen and the shape of the material.

While there was a size issue with the transmitters, receivers do not have to exactly adhere to the (wavelength/4) rule. Small sized antennas can be easily used for recieving.

So the overall communication is done with a pair of antennas on both the rover and the base station in which the transmitters and receivers are operating on different frequencies to avoid any miscommunication.

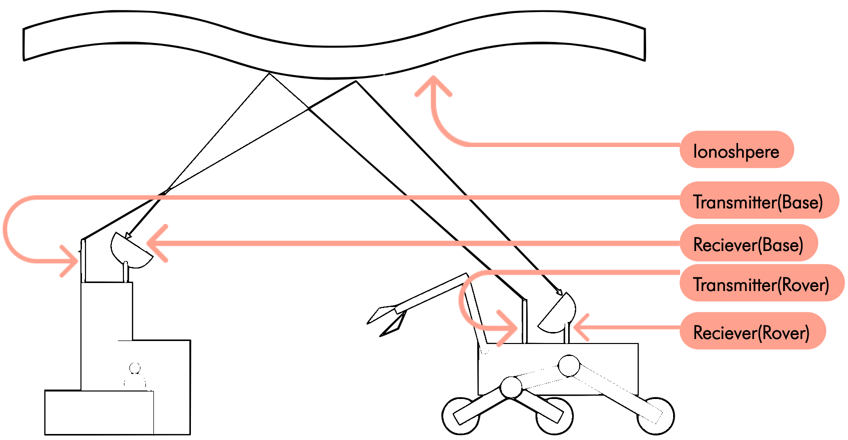


Fig 3.2.3.a Communication

To send the data, Amplitude Modulation technique is used to encode the data to be sent and the resulting signal is applied to PZT material.These signals will then be received by the receivers and will be decoded and the data will be extracted from it.

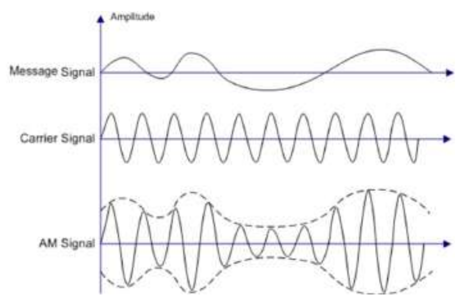


Fig 3.2.3.a Amplitude Modulation

BioScience Module

4.1 / Assembly

The assembly consists of 2 subparts, the drill mechanism to collect soil and ice samples from the soil-ice boundary and the testing assembly which consists of various instruments where the collected samples are being tested.

Drill mechanism

Auger bits are used to drill the soil/ice. Once drilled, the sample is collected by claw-shaped collector and deposited to the testing assembly.

Fig 4.1.a Drill Mechanism

Fig 4.1.b Testing Mechanism

Testing mechanism

Whole assembly is placed on the chassis considering weight balance, reliability for sending and receiving signals by various instruments and accessibility of sensors.

4.2 / Mission

The missions of the BioScience module of our mars rover are:

- To study the history of **water on martian surface**
- Search for **evidence of a habitable zone** to support life forms
- Study the **chemical and isotopic composition** of the **martian atmosphere** that can favour chances for survival of life.

4.3 / BioScience Analysis

4.3.1 / Environment

1. Thermal & Electrical conductivity

The rate at which **heat and charge may be transmitted** from the interior to the surface and vice versa depends on **the thermal and electrical conductivity** of the soil. The martian soil's conductivity provides insight on its bulk porosity, composition, and grain size. The instrument is designed to emplace **thermocouples** into the martian subsurface thus determining the planetary heat and charge flow.

Fig 4.3.1.a Thermocouples

2. UV Radiation detector

Higher radiation levels represent an additional difficulty for the survival of life on the surface.

UV radiation detector is employed to measure rays with **absorption spectra in the ultraviolet** or visible range. The sensor linked to the screen will detect the desired wavelength and will eventually deliver readings based on the results acquired.

3. Pyranometer

- Life on Mars highly depends on the quantity of **solar flux/energy** that falls on the surface. Hence, a detailed report on solar radiation characteristics on Mars is a necessity.
- To Measure **solar radiation flux density** on a planar surface within a range, **Pyranometer** is used, in which the **thermoelectric detection** principle is employed

4. Radioactive Elements

- The Martian surface is constantly exposed to high levels of **cosmic radiations**, without any protective magnetic shield or thick atmosphere, radiation from space can reach the Martian surface almost **unimpeded**. The higher radiation levels on the surface of Mars will undoubtedly present challenges for discovering a habitable zone.
- **Geiger counter**, exploits the natural process of ionization to detect and measure ionising radiation in Martian atmosphere. **Placed on the robotic arm**, it detects radioactive emissions, mostly sensitive to beta particles and gamma rays.

Fig 4.3.1.b Geiger Counter

4.3.2 / Soil

The soil on Mars is almost entirely composed of **mineral matter**. The **composition and texture** of the soil on Mars' surface have a role in determining survival of life forms. To evaluate soil composition and texture, the following tests are carried out:

5. X-ray Fluorescence Spectroscopy

XRF spectroscopy is a non-destructive analytical technique used to determine the elemental composition of soil/ice in which **15 elements** can be assessed (K, Ca, Ti, Cr, Mn, Fe, Co, Cu, Zn, As, Rb, Sr, Zr, Ba, and Pb).

Fig 4.3.2.a XRF Spectrometer

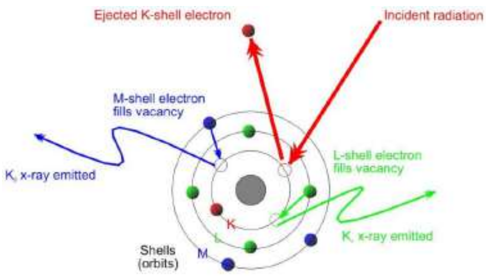


Fig 4.3.2.b Working

The **fluorescent X-Ray** released during dislocation of electron from higher to lower energy shell of the atom, is measured by the **spectrometer** which hence is used to detect the elements present in the soil/ice sample.

6. Thermal and Evolved Gas Analyzer (TEGA)

The major scientific objective of **TEGA** is to search for the evidence of organic materials such as **carbon based compounds, oxygen, nitrogen** and is also useful in searching for **traces of organic material** that may potentially exist on the Martian surface.
The Thermal and Evolved Gas Analyzer (TEGA), is composed of two separate components which are closely coupled:

- Scanning Calorimeter (SC)
- Mass spectrometer as an Evolved Gas Analyzer (EGA)

Fig 4.3.2.c TEGA

Soil/ ice samples collected approximatel y 0.1g → Heated to 1,000°C → Nitrogen gas passed through SCs → Developed gases delivered to EGA → Isotopic ratios of C, N, O, H, Ar determined in EGA Mass Spectrometer

Fig 2.2 Thermal and evolved gas analyzer

4.3.3 / Subsurface

7. Neutron Spectrometer

The hydrogen present on the surface of Mars is interpreted as **water molecules or hydroxyl ions** bound within minerals or water absorbed onto minerals in the rocks and soil.
Neutron Spectrometer - Used for sensing the amount of **hydrogen in the subsurface area** as it is quite sensitive to the presence of

hydrogen on the surface which is quite helpful for **evidence of water in liquid or ice form**.
It works by measuring changes in the number and **energy of neutrons**. When these tiny particles strike a hydrogen atom, they lose a lot of their energy. This change is detected by the spectrometer and used to infer the presence of hydrogen.

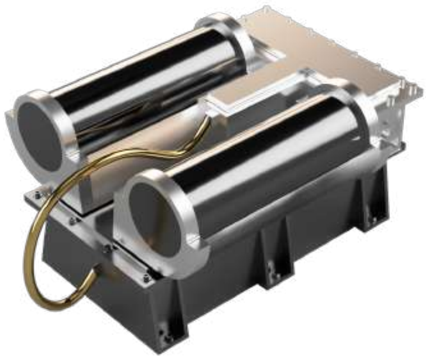


Fig 4.3.2.d Neutron Spectrometer

8. Ground Penetrating Radar (GPR)

Subsurface imaging is a geophysical technique where data is turned into **digitized images** of the structures that lie beneath the Martian surface.
GPR uses pulses of **electromagnetic radiation** to image the subsurface. It captures images below the surface of the ground and detects variation in the composition of the ground material.
GPR requires 2 main pieces of equipment – **a transmitter and a receiving antenna**. It emits a pulse into the ground and records the echoes that result from subsurface objects.
The receiver detects the returning signals and records variations within them. The integrated software translates these signals into images of the objects in the subsurface.

Fig 2.2 GPR

4.4 / Inference

- BioScience module undoubtedly holds the most significant role in the whole martian expedition.
- A thorough process of collection, experimentation, and analysis is done on the body of the rover presenting us with insights on Martian life and the planet itself.
- Documenting radiation levels, Electrical and thermal conductivity, soil compositions,tracking hydrogen presence, etc have all proved to be instrumental for further planning and scientific research, inspiring hopes of life thriving on the Red planet one day.

4.5 / Sensors

1. Thermal Camera

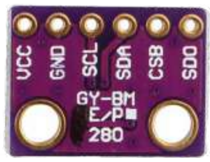
When the camera is pointed at a surface having geyser eruption, it shows temperature difference at the point of a leak caused by the pressure variance.

2. *Anemometer*

Used to measure wind speed and direction. It is mounted on the top of the assembly.

3. *BME 280*

It reads barometric pressure, temperature, and humidity. Altitude can also be detected by pressure variation



4. *Soil Moisture Sensor*

Measures the volumetric water content in soil using some properties of soil such as electrical resistance, dielectric constant.

5. *USB Microscope*

It is used to detect the texture of soil samples.

6. *PH Sensor*

Analog pH sensor has been used to measure the pH of the soil.

7. *Microphone*

Used to detect geysers using sound waves. The sound vibrations obtained from the microphone can be used to identify the locations of geyser eruptions.

5.1 / Appendix

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