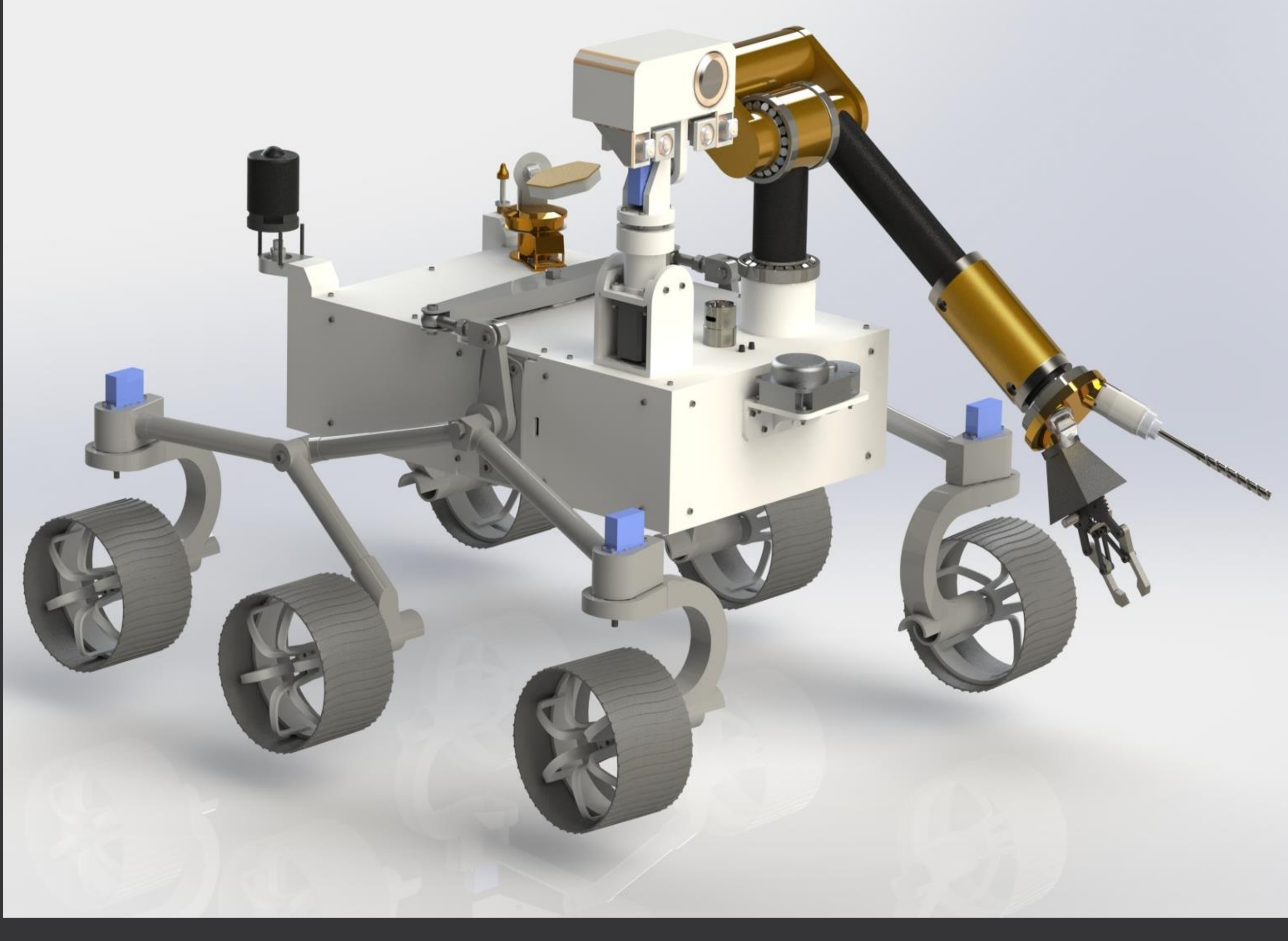
Mars Rover

Project report



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ABSTRACT

We have designed a mars rover capable of moving on rough terrains, with stable body frame and a fully functioning robotic arm, capable of drilling and collecting samples from the surface. The rover can move forward, backward and rotate. The navigation is done with the help of the mastcam which can orient itself in the desired direction.

MOTIVATION

Having seen the successful landing of Mars missions, we were curious to find out how the rover is able to navigate in such harsh conditions and are able to carry out scientific missions on other planets.

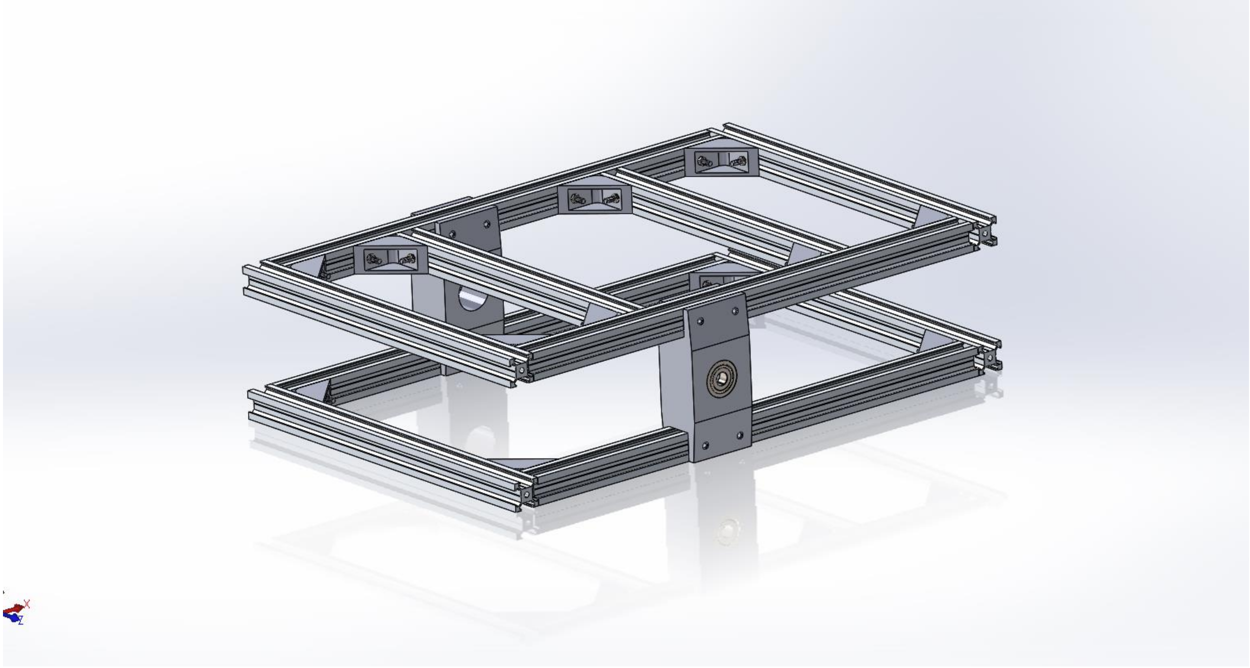
RESEARCH

1) In-depth study of NASA's Perseverance and Curiosity Rover.
2) Components, instruments and features systematically documented.
3) Researched various types of suspension systems and we found the rocker bogie best as it requires less maintenance, and all the wheels stay in contact with the ground.
4) We chose the sensors required for the navigation of the rover.
5) The robotic arm was designed to be able to drill and collect the samples.
6) Most of the parts are designed to be 3D printed and can be assembled or disassemble easily.

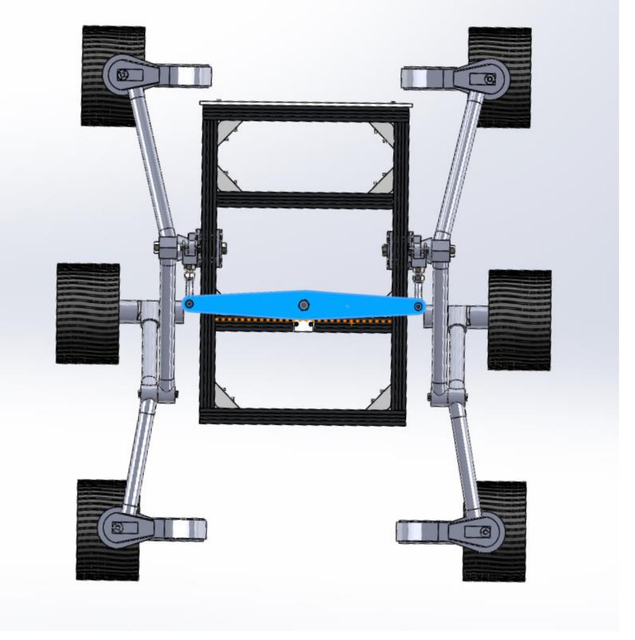
MECHANICAL ASPECTS

1) Chassis:

- The main frame of the rover is made by 20mm x 20mm T-slot Aluminium extrusion. The aluminium extrusions are connected with the help of 3D printed connectors.

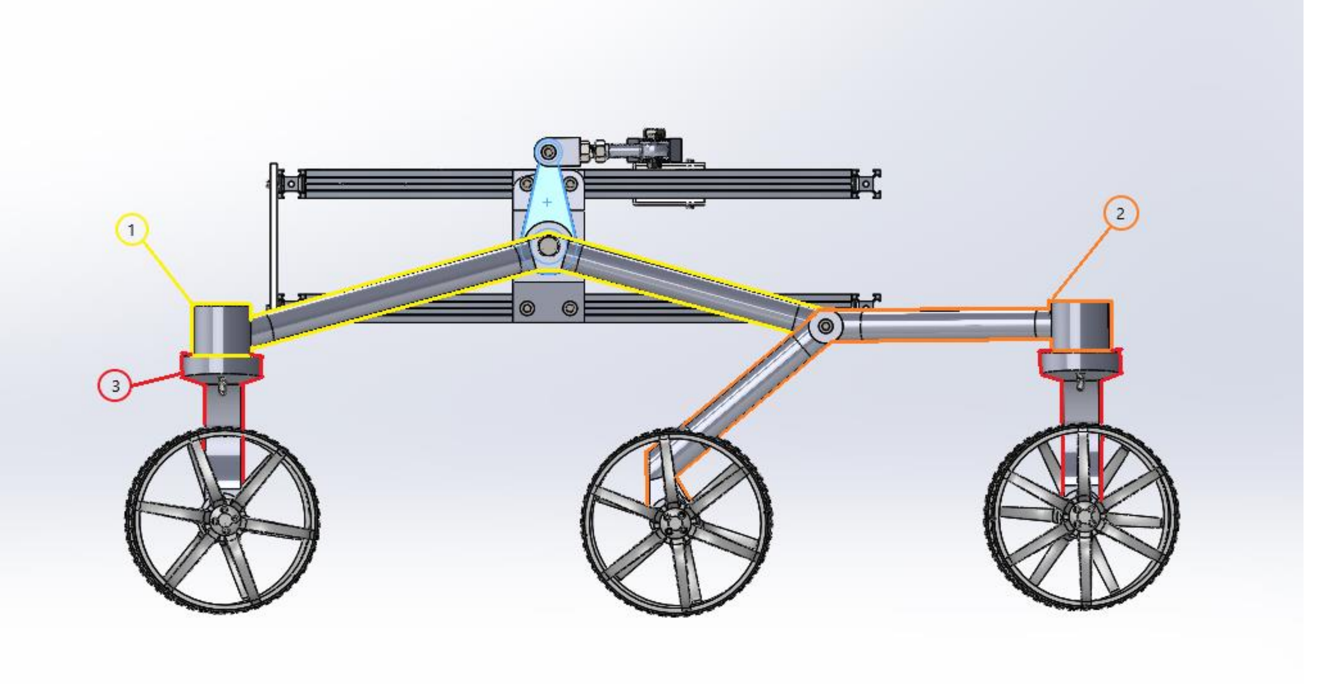


2) Rocker bogie:



- The rocker bogie system maintains a relatively constant weight on each of the rover's wheels. The suspension also minimizes rover tilt as it drives, keeping it more stable.
- The rocker bogie is made with a differential connected to the body of the rover for stability.
- The differential connects the left and right rockers and connects to the body of the rover by a pivot point in the centre of the rover’s top deck.

- We decided on 6 wheeled rocker bogie, so we have three main parts for the rocker bogie-
- The first one is the rocker which connects the front wheel to the differential and bogie in the rear.
- The second one is the bogie which connects the middle and rear wheel to the rocker.
- The third one is the connector for the front and back wheel to the rocker bogie for steering and rotation.

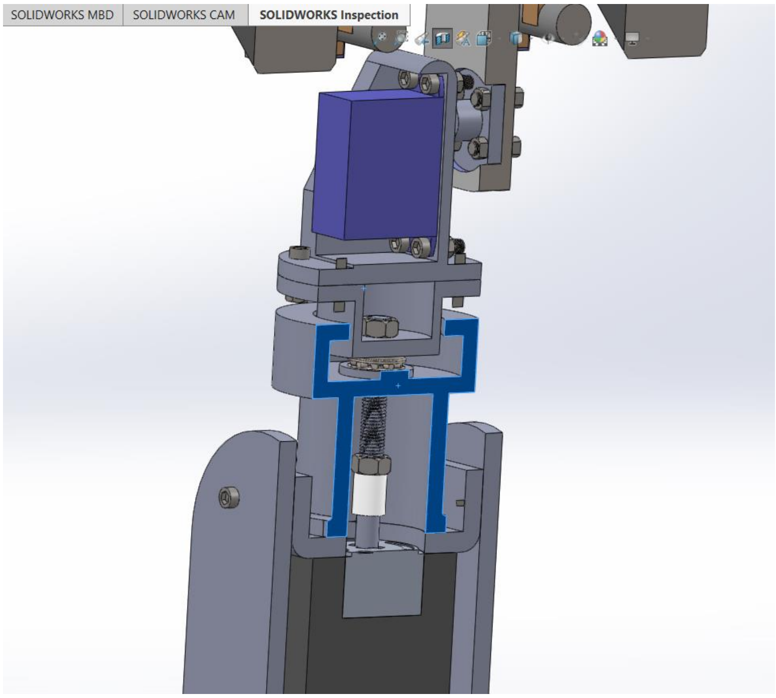


3) Wheel:

- The wheel can be 3D printed by more flexible materials like thermoplastic elastomers which has high impact strength and wear resistant.

4) Mastcam:

- the bottom part of the mast contains the stepper motor which is fixed to the body. A shaft extends to the upper part of the mast which can rotate horizontally and lies on a cylindrical thrust bearing. The camera is attached to the mast with the servo motor for vertical rotation.



5) Robotic Arm:

- The robotic arm is equipped with three modules: a drill, a camera and a sample collector, installed on a rotating disc.

- It has 4 degrees of freedom(DOFs) as follows:

1) The base can be rotated 360 degrees.

2) The rotational joint can be rotated 180 degrees (range is limited by the counterweight)

3) The main link contains a hydraulic/pneumatic cylinder which is used to extend/shorten the length of the link. The length of the link has a range of 33-43 cm.

4)The rotating disc is used to engage either the drill or the sample collector with the Martian surface at a time.

Thus, in a way, we have a handle on the three polar coordinates:

1. The base varies the planar angle 'theta'

2. The rotational joint varies the vertical angle 'phi'

3. Hydraulic/pneumatic cylinder varies radial distance 'r'

This makes inverse kinematics relatively simpler.

- The camera is used all the time for navigation of the arm as well as scanning of the Martian surface.
- Although the links of the robotic arm are light, the weights of the various motors and other components in the end effector cause dynamic instability, which necessitates the usage of a counterweight.
- The counterweight provides front-back stability to the arm, as well as distributes the load between the two left-right bearings that are mounted on the base, so as to minimize the chances of mechanical failure.
- Servo motors are used for precise actuation.
- An air compressor/pump embedded in the rover body is used to create the necessary pressure differential to operate the pneumatic/hydraulic cylinder.

ELECTRONIC ASPECTS

1) Actuators:

a) 12V Brushless DC motors are attached to the wheels and used for the locomotion of the rover.

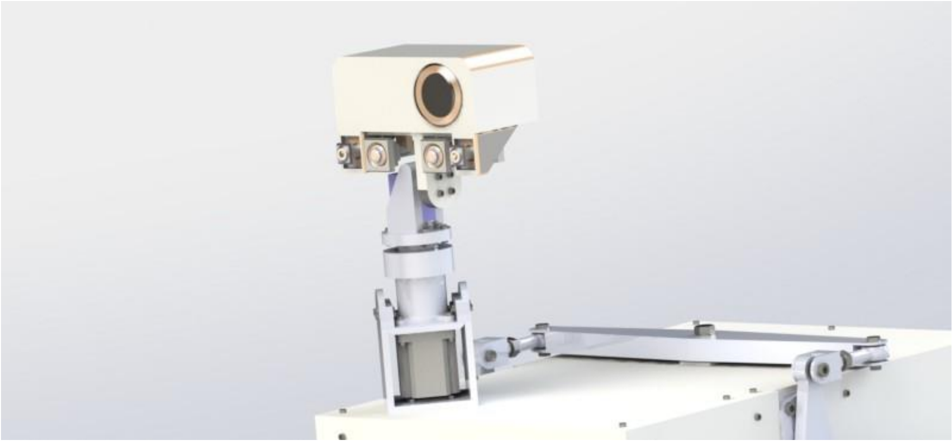
b) Servo motor is used for the movement of the corner four wheels, the head of the mastcam and in the robotic arm.

c) Stepper motor for the horizontal rotation of the camera. The shaft of the stepper motor is attached to a threaded rod with a shaft coupler which transfers the rotation to the top part of the mast.

2) SENSORS:

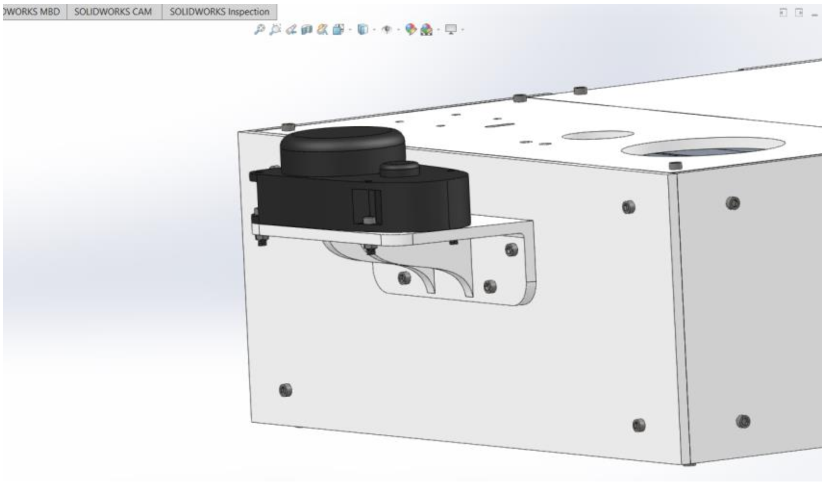
a) Mastcam:

It is used to take images and navigate the rover and can change its orientation to a desired location.



b) Lidar:

It is used for sensing the distance between the rover and its surrounding and helps in navigation.



APPLICATIONS

- The rover can be used to research the areas with highly uneven terrains and surfaces with ease due to its rocker bogie suspension system.

- It is equipped with a robotic arm and drill which enables sample data collection and storage. The rover consists of a camera to take 3D images and high-definition videos for mapping the terrain as well as analyzing it scientifically.

- It can also be used to analyze the collected samples using the various sensors present on the rover

LIMITATIONS

1) The speed of the rover is slow.

2) Life of the rover is short since the charging capacity is less.

FUTURE IMPROVEMENTS

1) Better materials could be used instead of 3D printed plastic.

2) Simulating the model in Gazebo and ROS.

REFERENCE LINKS

Youtube-

- [Mars Rover 2020 Perseverance] Body Assembly- https://www.youtube.com/watch?v=McydwwR8xu4

- How I build mars rover replica- https://www.youtube.com/watch?v=NOZZMsMAGh0&t=142s

- JPL Mars Science Laboratory The Curiosity Rover- https://www.youtube.com/watch?v=007SnaUxi40

Research links-

- https://www.hindawi.com/journals/ijae/2016/5181097/

- https://mars.nasa.gov/mars2020/spacecraft/rover/

- https://llis.nasa.gov/lesson/11501

- http://robotics.estec.esa.int/ASTRA/Astra2004/Papers/astra2004_D-05.pdf

- https://teamares.sserd.org/project_files/Ares_MCEV_Report.pdf