Design And Anayisis Of Lander Cum Rover For Mars Mission

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MARS MISSION: DESIGN, ANALYSIS, AND SIMULATION OF LANDER CUM ROVER

ABSTRACT

For the past two decades, Mars, the closest planet to the Earth in the solar system, has been investigated for its climate, thermal state, and resources. Space landers are vessels that assist in the landing of the rover that is used to investigate Mars. The design, modelling, soft landing, planet atmosphere analysis, and prototype of a 2-in-1 lander and rover used to explore Mars were all utilized in this project. Ion thrusters which are our radio frequency (RIT) to produce thrust are used for orbital insertion. Because Mars has an atmosphere and gravity, we can use RC motors as a hovering mechanism to study the planet's environment. CATIA V5 is used to design the 2-in-1 lander rover, Ion thruster, and hovering system, while ANSYS is used to analyse the static, thermal, and flow results of the model. From this analysis, we can find whether the designed model can sustain mars' atmospheric condition and thermal condition. MATLAB is being used to simulate a soft landing and space exploration. Many sensors are utilized to investigate Mars and determine weather and temperature conditions. The whole operating and performance of the two-in-one lander and rover is estimated in this project.

Keywords: Ion thrusters, Mars mission, Space lander and rover, Simulation, UAV

Abbreviation	Explanation
NASA	National Aeronautics and Space Administration
RF	Radio Frequency
RIT	Radio Frequency Ion Thruster
UAS	Unmanned Aerial System
GUI	Graphical User Interface
DOF	Degrees of Freedom
PID	Proportional Integral Derivative

1. INTRODUCTION

Since the 1970s, scientists have been sending spacecraft to Mars. Mars, the planet appears as a red dot in the night sky, resembles Earth in many important ways [1]. Robotic science scouts have been sent to Mars previously and have discovered valuable resources such as water ice just beneath the surface that could be used by human pioneers. Several different types of spacecraft have been sent to the Red Planet over the years, and they all have different specialties Mars had conditions suitable for life.

Landers are spacecraft that descend toward an astronomical body and land on its surfa ce. Generally, a rover is a planetary surface exploration vehicle. It is designed to move across a planet's surface or another celestial body of similar mass. In addition to collecting data about the terrain, rovers collect soil, dust, and rock samples from another planet using a lander-style spacecraft. They are therefore vital to the exploration of space [4].

2. METHODOLOGY

2.1. 2-in-1 LANDER ROVER

The Space Lander are usually used to analyze and land some vehicles to analyze the atmosphere of other planetary missions. This may be launched using entering probe into the atmosphere and it some cases may be included with propulsion system, which is used in various mission for the soft and safety landing of Rover. NASA sends a helicopter which will hover for some time named “The Ingenuity”. As it proved that the mars have atmosphere and helicopter model can hover in the Mars.

2.2. PROPULSION SYSTEM

Ion thruster is used for Soft landing after parachute reduces the speed of the lander. RF ion thruster is used in this project. Xenon is used as a Propellant as it is an inert gas and can be ionized effectively.

2.2.1. ADVANTAGES OF RF OVER OTHER TYPES

- Since discharge electrodes and magnets do not exist, the power supply and control units cannot be biased at the high voltage of 4.5 kV. Because the isolating discharge vessel separates them from the high-voltage discharge plasma, the RF generators and induction coils can be kept at ground potential
- If the high-voltage grids are interconnected by sputtered electrode material, no destructive arcs should occur.
- The operator is not compelled to run the RF-engine in strongly throttled mode for reliability or safety reasons.
- Since the RF-discharge is not sensitive to oxygen impurities, the Xenon propellant need not be of high purity, saving much money considering the large required mass (2 tons per engine and 50 000 hours). [5]

2.3. HOVERING SYSTEM

The hovering system used for exploration of Martian surface. This was the same as multi-rotor mechanism grab the idea that to use multi-rotor system as hovering system for the mission. Ingenuity helicopter lets as develop an idea that exploration of the mars not only done with wheels it also can be by flying

FIG 1: THE INGENUITY

1. DESIGN

This project is completely a design based one where main objective includes compact size and 2-in-1 lander rover. So, it took lot in designing process. The entire design process is carried out in CATIA V5. This designing process has three phases:

- Ion thruster
- Hovering System
- 2-in-1 Lander rover

1.1. DESIGN OF ION THRUSTER

1.1.1. Objectives:

- Thrust (F_{ion})
- Fuel Burn Rate=$\dot{m}$
- Mission Time:
- Specific Impulse

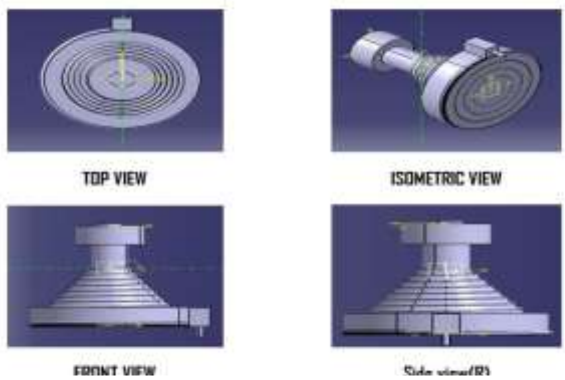


Fig 2: ION THRUSTER DESIGNED

1.1.2. Known:

- Ion Thruster efficiency may be above 90%. Here it is η=95%
- V_{ex}=11.606 Km/s
- Power required will be 1.750 kW
- Fuel mass=5.05
- Delivered mass=10
- Total mass=15.05
- RIT Thruster diameter=15 cm
- Length=19 cm
- Coil winding=11
- Propellant=Xenon [Xe^0]
- g= 3.72(gravitational constant for Mars)

Thrust	246 mN
Power	1750
Beam voltage	1500V
Accelerator voltage	-180V
Beam current	1870mA
Mass Flow Rate	0.2864 g/s
Efficiency	95%
I_{sp}	3120 s
Accelerator current	34.0mA
RF –Input power	384W

TABLE 1: ION THRUSTER SPECIFICATION

Then

The kinetic energy of the xenon ions is converted to a velocity.

The velocity and mass loss rate are then converted to a change in momentum.

The change in momentum is equivalent to force.

So
The formula for thrust, I_{sp} and $\dot{m}$ are

$$I_{sp} = \frac{v}{g}$$

$$F_{ion} = \frac{2 \times P \times \eta}{I_{sp} \times g}$$

$$\dot{m} = \frac{2 \times P \times \eta}{v_{ex}^2}$$

From the above information, we got values for RIT 15 in Table 1.

1.1. DESIGN OF HOVERING SYSTEM:

The system of hovering is designed to replace the rover which is using wheels. Hovering systems comprise the Unmanned Aerial System (UAS). The first step in designing or selecting a platform is to determine the power system: motors, propellers (also known as props), electronic speed controllers (ESCs) and batteries. The platform's power system and electronics should be chosen to optimize the performance goals explicitly stated in the project requirements Power system design is directly related to the payload size and weight. Motor manufacturers list important specifications on operating voltages, maximum current draw and suggested prop options. They often list thrust data with several prop and battery configurations.

1.2. DESIGN OF 2-in-1 LANDER ROVER

Lander which is going to be used to land softly the rover must be designed with lot of things in mind as it is 2-in-1 lander rover it should be compact and at the same time it must be efficient. Lander uses the parachute and ion thruster to descent and land softly. The main objective of the project is to design a 2-in-1 lander rover which must be compact in size.

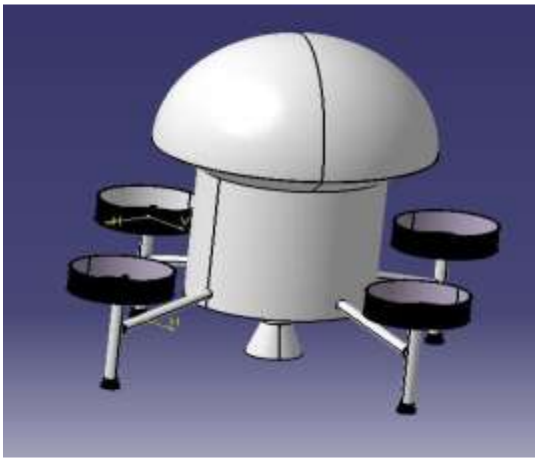


Fig 3: 2-in-1 LANDER ROVER DESIGNED

2. ANALYSIS:

In this project the model going to experience different atmosphere throughout the mission so we in the need to analysis the each and every part of the model for a better understanding on structural and flow properties. For the computational results here ANSYS® software is used.

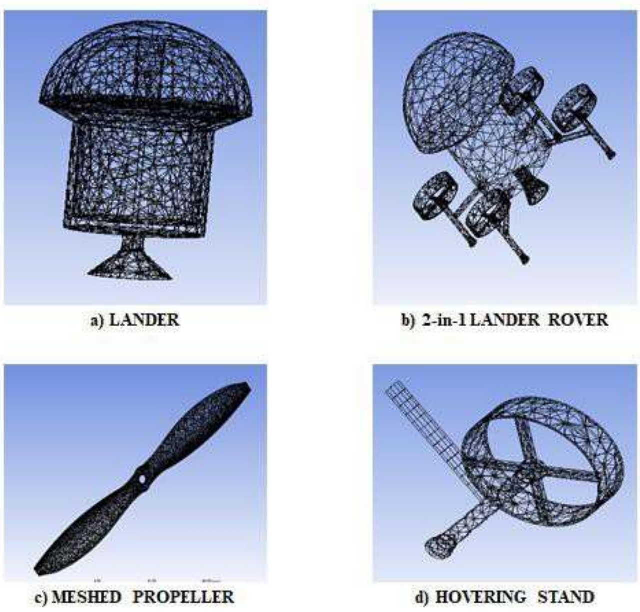


Fig 4: MESH OF THE DESIGNED MODEL

2.1.MESHING:

In engineering simulations, meshing is the process of breaking complexgeometries into simple elements that can be used as discrete local approximations of the larger domain. Simulation accuracy, convergence, and speed are influenced by the mesh. In this work each and every part are meshed separately for good result.

2.2.STRUCTURAL ANALYSIS

An ANSYS® static structural analysis has static conditions. Loads, stresses, strains, and similar physical loads are assumed not to change significantly over time. A static structural analysis investigates the effects of static loading (or steady loading). An analysis can include steady inertia loads (such as gravity and rotational velocity and accelerations) and time-varying equivalent loads that can be approximated.

2.2.1. TOTAL DEFORMATION

Total deformation	**Average**
Model	7.829×10^5 mm
Lander Top	438.86 mm
Hovering system	1.26 mm
Propeller	2.60×10^{-3} mm

TABLE 2: TOTAL DEFORMATION

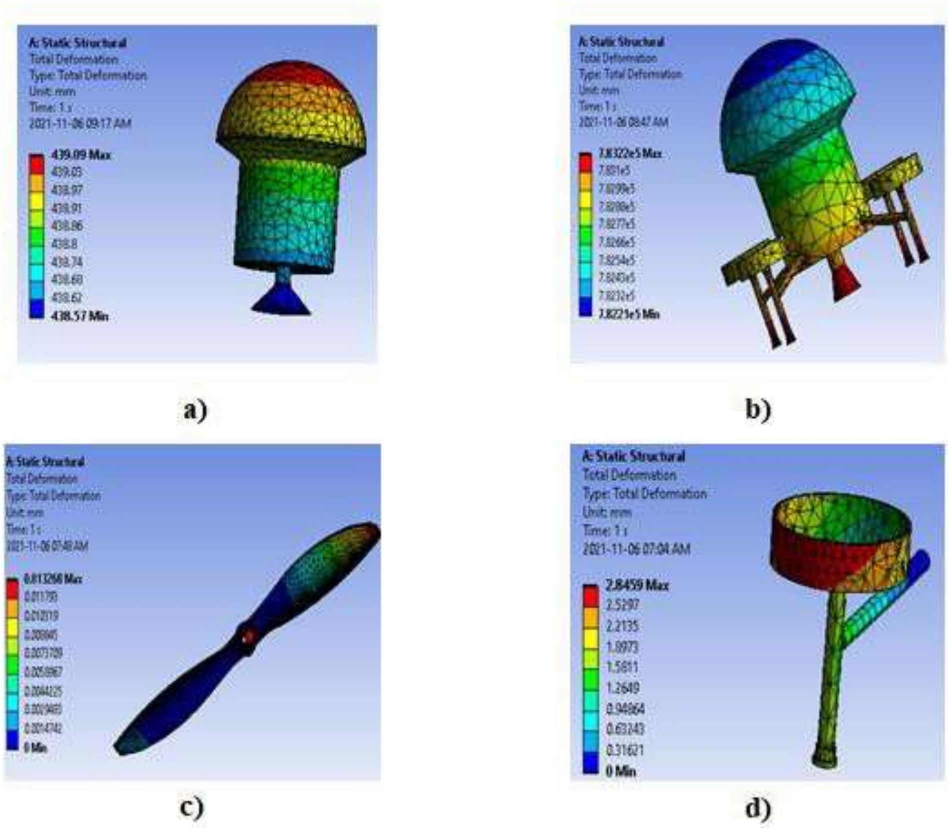


Fig 5: TOTAL DEFORMATION

a) **Model**
b) **Lander Rover**
c) **Propeller**
d) **Hovering System**

2.2.2. EQUIVALENT STRAIN

Equivalent elastic strain	Average
Model	2.24×10^{-3}
Lander Top	1.32×10^{-5}
Hovering system	0
Propeller	2.17×10^{-6}

TABLE 3: EQUIVALENT STRAIN

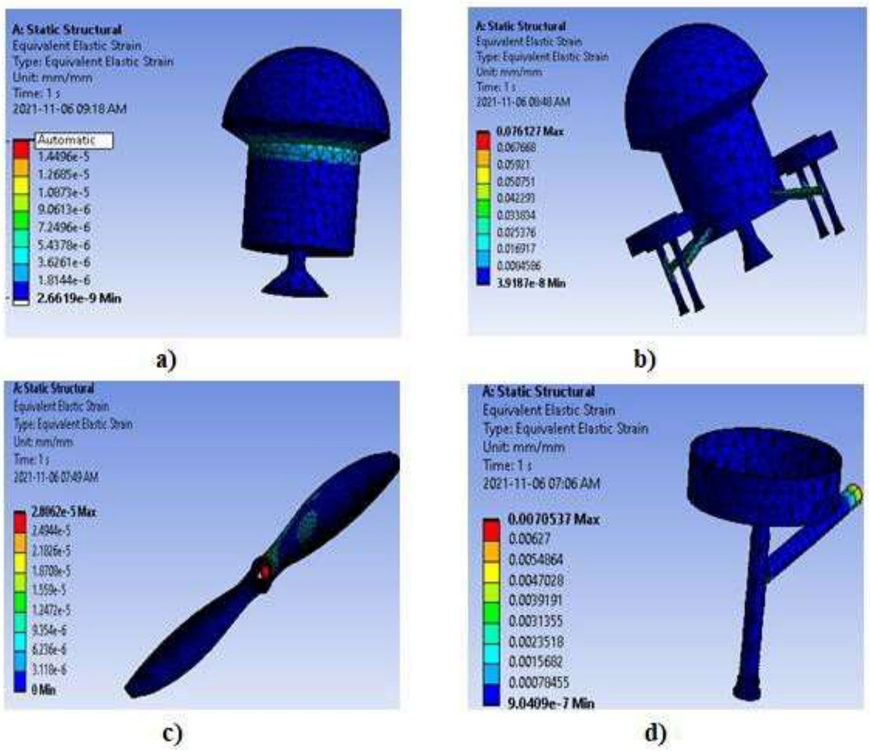
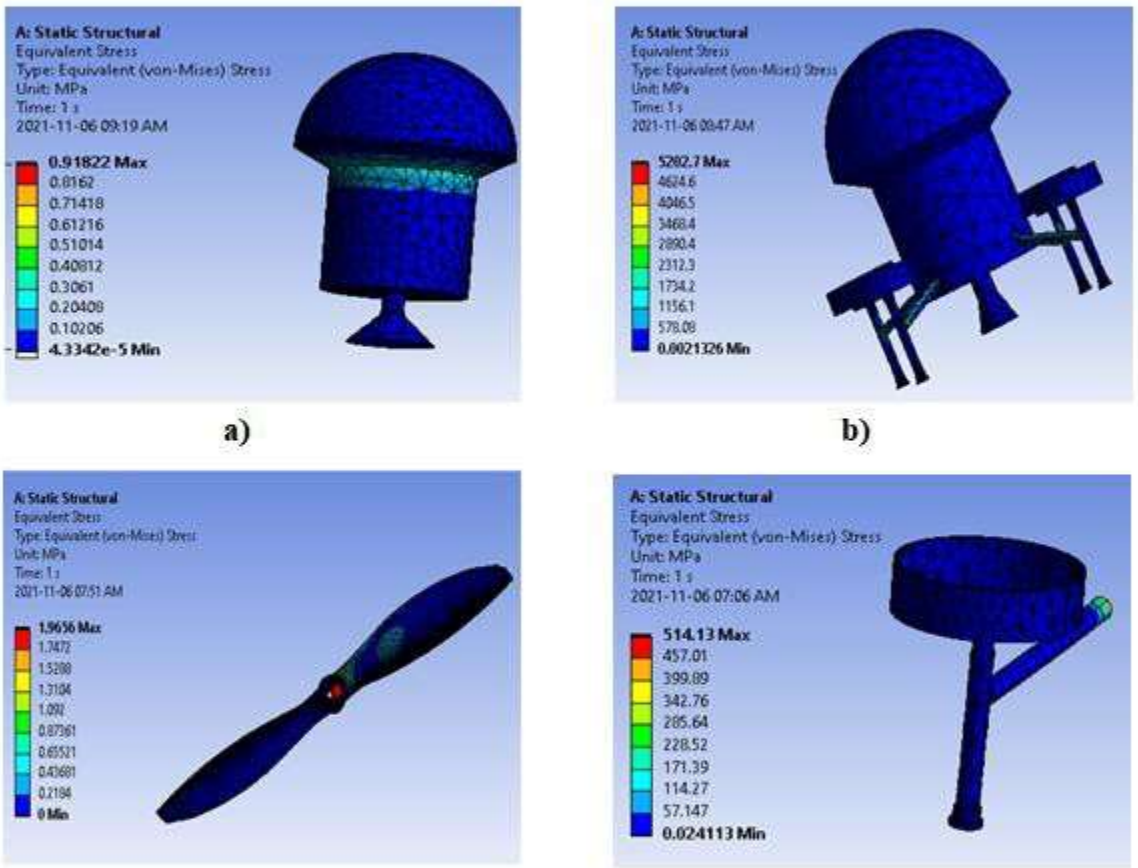


Fig 6: EQUIVALENT STRAIN
a)Model
b)Lander Rover
c)Propeller
d)Hovering System

2.2.3. EQUIVALENT STRESS

Equivalent stress	Average
Model	118.41 MPa
Lander Top	3.43×10^{-2}MPa
Hovering system	228.52 MPa
Propeller	$2.17\ 10^{-6}$

TABLE 4: EQUIVALENT STRESS



a) b) c) d)

Fig 7: EQUIVALENT STRESS
a) Model
b) Lander Rover
c)Propeller
d)Hovering System

2.3.FLUENT

ANSYS Fluent is a highly flexible CFD package that caters to the individual needs of each user. With a fluid simulation program that offers fast pre-processing and faster solve times, you can be the first to enter the market. Fluent features deliver limitless innovation without compromising on accuracy. It is important to analyse hovering systems in both Mars and Earth conditions for this project.

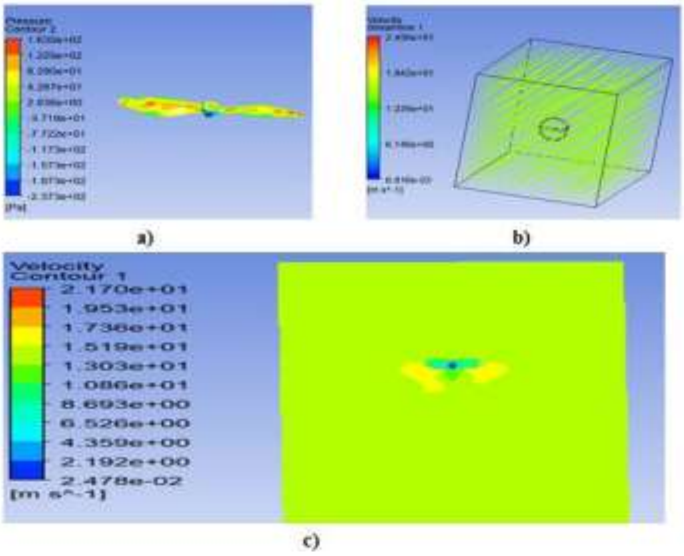


Fig 8a: FLUENT ANALYSIS EARTH

a) Pressure

b) Velocity Streamline

c) Velocity

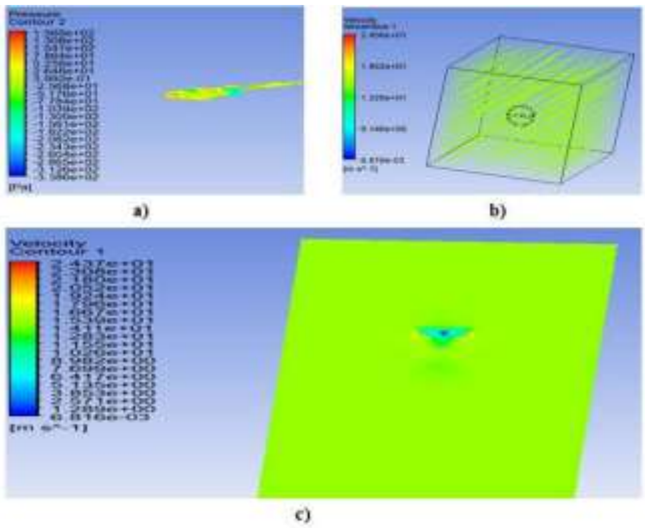


Fig 8b: FLUENT ANALYSIS MARS

a) Pressure

b) Velocity Streamline

c) Velocity

	MARS			EARTH		
	Maximum	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**
Velocity	24.37 m/s	0.68 m/s	15.03 m/s	21.7 m/s	0.248 m/s	13.03 m/s
Pressure	156 Pa	-0.33 Pa	-20 Pa	`163 Pa	-0.237 pa	28.3 Pa
Streamline	24.37 m/s	0.68 m/s	15.03 m/s	21.7 m/s	0.248 m/s	13.03 m/s

TABLE 5: FLUENT ANALYSIS MARS VS EARTH

2.4.THERMAL ANALYSIS

In general, thermal analysis is used to explore gas-solid reactions or solids' decomposition from zero to 100% conversion,i.e. the entire process is monitored. In conventional TA, the experiments are carried out isothermally or with a linear temperature ramp.

Transient thermal temperature	**Average**
Model	74.481ºC
Lander top	160.75ºC

TABLE 6: TEMPARATURE

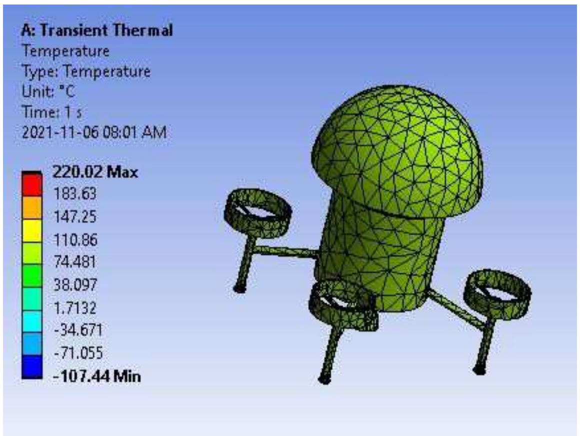


Fig 9a: TEMPARATURE OF MODEL

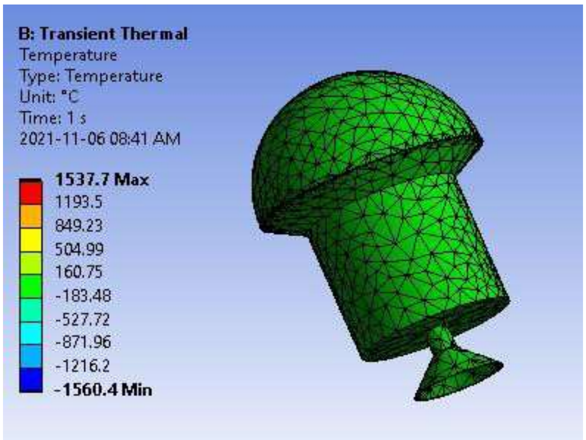


Fig 9b: TEMPARATURE OF LANDER

3. SIMULATION OF MARS MISSION

Simulation of the model is done by using MATLAB Simulink. Simulink is a tool for simulating dynamic systems with a graphical interface specially developed for this purpose. Simulink provides various add ones for perform block-based simulation and calculation to get better solution for the model. By using aerospace block set the mission was simulated. As per this project need simulation of landing and simulation of exploration is done.

3.1. PHYSICAL CHARACTERISTICS MODEL

The following schematic shows the quadcopter physical characteristics:

- Axis – respect to CG point
- Mass and Inertia – in the view of mars
- Rotors- respect to the axis
- Thrusters –thrust ratio of the ion thruster
- Sensors – to determine its state

3.2. SIMULATION OF SOFT LANDING

The landing of mars lander cum rover is carried out by ion thruster its nothing but a thrust vector-based technology. Simulink provides equation of motion block sets in which we can implement Euler angle representation of six-degrees-of-freedom. The 6DOF (Euler Angles) block uses these frame concepts.

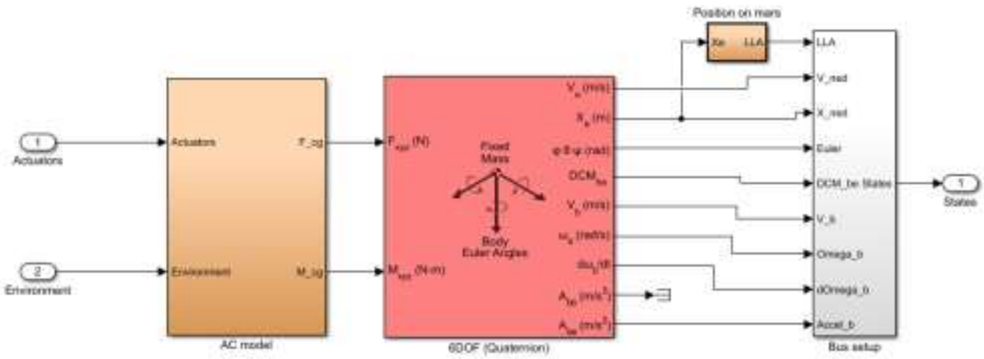


Fig 10: 6-DOF BLOCKSET

3.2.1. AUTOPILOT SYSTEM FOR LANDING

Autopilot system of the landing is connected with hovering system sensors and they interact and perform the landing by measuring the distance to soft landing. PID tune is used for the autopilot plots

3.3. SIMULATION OF EXPLORATION

The exploration of mars lander cum rover is carried out by hovering system its nothing but a quadcopter-based technology. The technology is used to explore the planet mars here by using MATLAB Simulink the simulation is going to done with the help of aerospace block sets by using UAV multirotor guidance model equations the simulation of exploration is coded (m code).

3.3.1. UAV MULTIROTOR GUIDANCE MODEL EQUATIONS

For multirotor, the following equations are used to define the guidance model of the UAV. To calculate the time-derivative of the UAV state using these governing equations, use the derivative function. Specify the inputs using state, control, and environment.

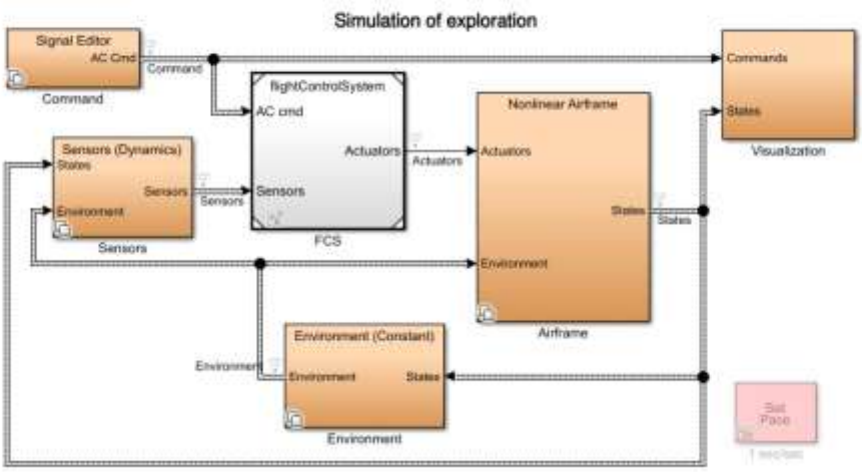
The UAV position in the frame is [xe, ye, ze] with orientation as ZYX Euler angles, [ψ, ϴ, ϕ] in radians. Angular velocities are [p, q, r] in radians per second. By using this algorithm and equation the system is built.

3.3.2. BUILDING THE SYSTEM

This requires having a way to estimate the states yaw, roll, pitch, altitude, and XY position. These are the signals that were feeding back. And second, we need to tune six PID controllers that all interact with each other, and specifically four of them directly coupled in cascaded loops. The way that we're going to handle the first problem is by combining the measurements from the four sensors we have and, in some cases, using a model and a Kalman filter to estimate each of those feedback states.

For the next problem, we need a good model of our system so that we can use Model-Based Design and MATLAB and Simulink to tune our six PID controllers. The outer loop XY position controller is generating the reference pitch and roll angles for the inner loop pitch/roll controller. There is also the Yaw and altitude controller and each of them feed into the motor mixing algorithm.

Here flight controller block set is performed for the mission.



3.4.RESULTS

The simulation of the two above mission was generated by the GUI based animated simulation. the block sets and m code given the exact output for the mission.

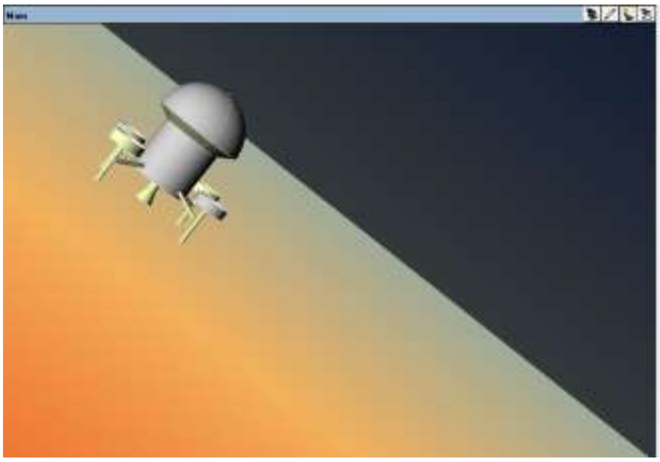


Fig 11: Results for soft landing

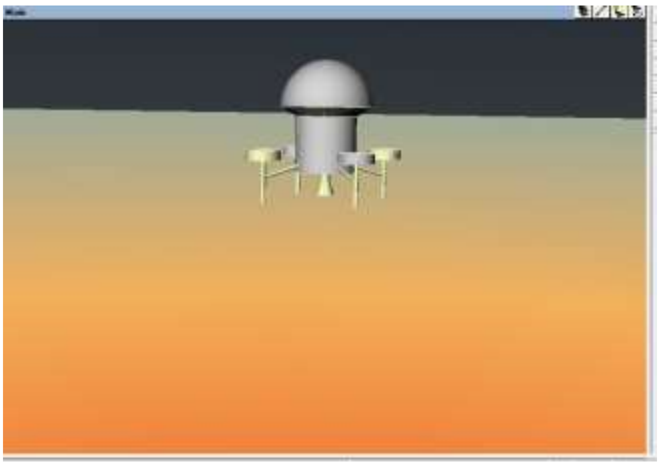


Fig 11: Results for exploration

4. RESULTS AND DISCUSSION

- As we select the fiber glass as material for 2-in-1 Lander Rover it is analyzed statically and thermally.
- From the results of analysis, it gives average deformation for 438.86 mm, 7.82×10^5 mm, 2.60×10^3mm 7689 mm and 1.71 mm for Lander, Rover, Propeller, Aeroshell and Hovering stand respectively.
- Average strain values will be 1.63×10^{-5}, 2.24×10^{-3}, 2.170×10^{-6}, 2.67×10^{-6} and 9.04×10^{-7} for Lander, Rover, Propeller Aeroshell and Hovering stand respectively.

- Average stress values will be averagely 3.43×10^{-2}MPa, 118.41 MPa, 0.1502MPa, 0.1577 MPa and 2.41×10^{-2} MPa for Lander, Rover, Propeller, Aeroshell and Hovering stand respectively.
- Flow analysis of Propeller has been analyzed in Both Mars and Earth condition. As it proves that the hovering system is more efficient in Mars than in Earth as it has less gravity.
- Thermal analysis of Aeroshell proves that the crushed cork can sustain upto 2000 K and other parts like 2-in-1 lander rover also can sustain up to 300 K in Mars as Mars Maximum temperature will be 220 K.

5. CONCLUSION

In this project, we have presented extensive design, analysis, and simulation of the system. For the verification and validation of the lander, rover, Ion thruster, and hovering system, the level integration and computational test was conducted.RF ion thruster is responsible for the propulsion system and with parachute in soft landing on the Mars planet. The successful landing kick starts the mission to start the planetary exploration, surface-based geographical investigation of mars. However the 2-in-1 lander rover is ready to land safely and satisfies the new era of compact size.

The next plan for future is to fabricate the design and make a prototype of hovering system with sensors system and suitable communication system. The fabrication of prototype will be made of locally available material which suits with the property of fibre glass.

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