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Study and Investigation of Past and Future Technologies Implemented on Rovers

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***Abstract*—Vehicles made for extra-terrestrial exploration are required to operate in extreme environments which are unlike the environment on earth.Rover exploration is the next step in exploringthe surface of a planet after the circling exploration.Planning is done to identify a possible path from the initial to desiredtarget area without compromising complex constraints.Which makes it one of the most important part of rover exploration. In this paper, we are presenting the brief information about the past technology that is implemented and future technologies that can be implemented to the rover, like improving in Suspension, Design, Wheels, Environmental factors, Advanced Techniques, Pinpoint Landing. So that a clear idea can be drawn (extracted) from the past and future technologies and accordingly based on the conditions required, techniques can be implemented to the rover.**

***Index Terms*— Rover, Suspension, Design, Wheels, Environmental factors, Advanced Techniques, Pinpoint Landing.**

I. HISTORY

From the past five decades a wide range of effort has been put forth to the development of ideas and real models for mars exploration. In 1963 an autonomous rover was sent to the moon(M.G. Bekker, n.d.). This comprised of a six-wheeled rover driven by Silver- Cadmium batteries and weighed 30 kg on Earth. After 2 years that is in the year 1965 the Soviet Union designed a rover which aimed at examining technical decisions, improvising of regulator systems and studying the interface of the chassis with planetary soil. After 5years they have come up with the 1st robotic planetary rover by the nameLunokhod 1,carried by the Luna-17 probe was a mobile robot which was landed on Nov 17th 1970. This rover along withanother rover by the name Lunokhod 2 robot are the only two rover lead by remote control in 40 years with the aim of determining and transferring of the planetary land. Lunokhod 1 during its journey which is of 11 months, thus increasing the 3 months of its life for which was as expected. Mission purposes were to gather the pictures of the planetary surface, conducting the essential chemical analysis and soil test with in its three months of lifetime. Rover had sent nearly 25,000 television pictures and 250 HD panoramic views covering an extent of about 80km.This has successfully completed 550 experimental tests which comprise the analysis of physical and chemical properties of planetary soil.(Sanguino, n.d.).
Fig 1 and Fig 2 shows the different rover that has been sent for explorations.

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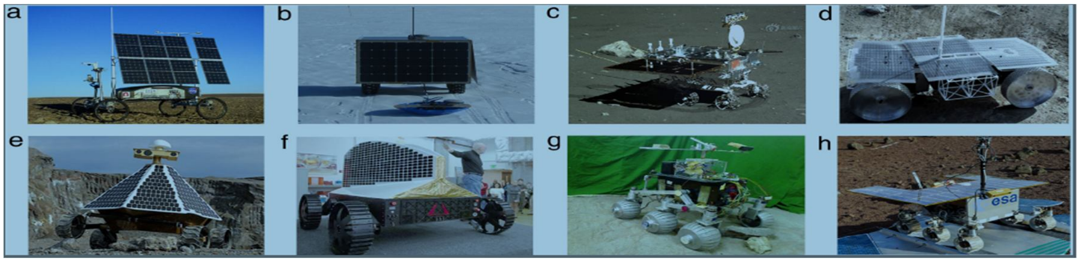

Fig. 1 (a) Hyperion (b) Cool robot (c) Yutu (d) Barcelona Moon Team (e) Red Rover (f) Polaris (g) Chandrayaan- 2 (h) ExoMars.(Sanguino, n.d.)

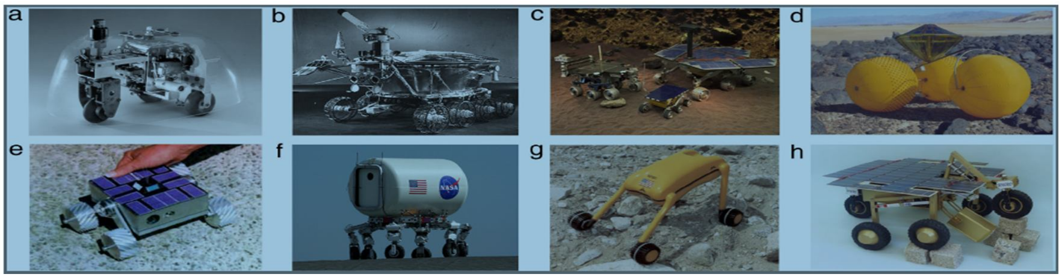

Fig.2(a) Walter's turtle, (b) Lunokhod 1, (c) Sojourner, FIDO and Opportunity rovers, (d) Big Wheels Inflatable Rover, (e) Muses-C, (f) ATHLETE, (g) GoFor, and (h) SOLERO.(Sanguino, n.d.)

II. Introduction

The terrestrial rover is a kind of spaceship or it can be viewed as a space vehicle which could adapt the terrestrial surface environment, carry out experiments, sampling and sending the surface pictures which helps in further research.

Rover mainly has two functions:

- It helps the human to accomplish tasks, wherein it is too tough or extravagant for human intervention.
- To enhance the exactness and accuracy, expand the range and increase the means of scientific exploration.

Roving exploration, gives more accurate and highly precise results when compared to that of an orbital exploration, and also by rover exploration higher range can be achieved than by the fixed landing exploration. Because of this reason it is the most advisable than any other exploration.

Distance between Earth and the Mars will be at a minimum for every 26 months. The NASA Mars Rover mission team takes this as the advantage to send an interplanetary roverevery time during this "closest approach" between the two planets. Fig 3 shows the different mission launched for every 26months from 2001-2009.

Fig.3shows the different mission launched for every 26months from 2001-2009

A. Pinpoint Landing

From the past five decades of Mars exploration, nearly 46 Mars Missions have been launched. But the Only 35% of the mars landing missions have been successful. Among the unsuccessful missions, most of the let-downs occurred during the landing phase. Table 1 gives an idea about the successful and failure percentages.
The below table indicates that, landing phase is a crucial phase in the complete Mars landing mission. Upcoming Mars missions require new technologies and methodologies in landing at specific positions (Pinpoint Landing) in order to safeguard the mission and to accumulate more technical data.

TABLE I. DATA OF THE EARLIER MARS MISSIONS

Mission Type	**Total Mission**	**Success rate**	**Successful Mission**	**Failed during cruise**	**Failed during Mission**	**Failed during Landing**
Orbiting	18	50%	9	4	5	-
Landing	20	35%	7	3	2	8
Flyby	8	37.50%	3	1	4	-
Total	46	41.30%	19	8	11	8

Different Phases Involved in the landing of rover:
The Mars surface is enclosed by a very reedy atmosphere. The Martian atmosphere has a thickness of about 125 km and its density is even lower than 1% of that of Earth's(Zhengshi Yu, n.d.). Rover before landing on the mars atmosphere it undergoes 4 different phase namely:

- Approach Phase
- Entry Phase
- Descent phase
- Landing phase

Approach Phase:
This phase commences 12 h prior the entrance point to the spacecraft reaching the highest atmospheric layer(Piotr Ptak, n.d.).

Entry Phase:
As soon as the rover touches the Martian atmosphere the entry phase is said to start and it ends after the deployment of the parachute. The velocity of the rover can reach up to 4–7 km/s at the initial stage of this phase and gradually increases. The stage is the hazardous and erratic period among all the other phases.

Descent phase:
The descent phase mainly includes 2 sub phases namely,

- Parachute deployment
- Powered descent phases.

Due to the drag of the parachute the velocity of the rover slows down in the initial stage of parachute phase. At the end of this phase, the heat shield is cast-off and different sensors will be prepared for the navigation for the next phase of Descent phase(Zhengshi Yu, n.d.).

Landing phase:
The final stage of the Landing process is the landing phase. Here the rover will have to land carefully on mars. The landing phase of the rover is divided into 2 parts: the passive energy dissipation system and the active energy dissipation system (Zhengshi Yu, n.d.).

Improvement in the landing accuracy:
Since most of the failure occurs in landing phase of the rover in the Future Mars mission some new technologies are implemented which makes the landing accuracy more precise.
For the landing of the perseverance rover, the**range trigger technology** had been used.Which decreases the area of uncertainty landing by over 50%.Therefore, the chances of the rover landing in a hazardous surface decreases. The deployment of the parachute usually takes place once the spacecraft achieves certain velocity but in the case of Mars 2020, the range trigger makes sure that the spacecraft is close to the desired area of landing before it deploys the parachute.Another technology to improve landing of a rover is **TERRAIN -**

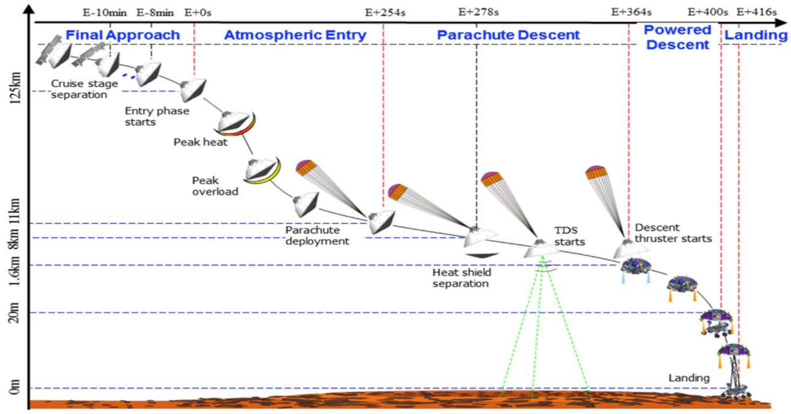

Fig. 4: The 4 different phases of the landing of a rover is shown in

RELATIVE NAVIGATION.

How Terrain-Relative Navigation Works

During descent, images of the surface of Mars are constantly taken.These images are compared with the maps created by Orbiters which are already stored in its memory, this is used to determine its destination and It can change its course if it is headed towards an unsuitable ground.Places scientists find interesting are also the places that are hazardous to the rover. Therefore, by using this technology the rover can be landed in interesting places.

III. DESIGN

Any rover has to be Designed and developed in such a way that it has to withstand all kind of barriers to environmental changes and care to be taken that a rover should not get damaged. The two major parameters that may influence the design are the gravity of the mars which is 3.711m /s2 and the temperature varies between 140K and 300 K. Design necessities are shown in Table II.

TABLE II.

Parameters	**Maximum duration/limit**
Vehicle Lifetime	200 Sols
Motion duration	50 Hours
Maximum Speed	5m/hr
Maximum Obstacle Height	10 cm
Maximum inclination or declination	15 ***degree***(uphill) and 20*(downhill)
Mobility power	2 Watts

Note: 1 Sol =1 Martian day =1479 Minutes.

In this concern based on wheels, legs, and tracks the locomotion has been evaluated. Lastly, a typical rover'sdesign depends on,

- A robust chassis to diminish the mass, storage volume, and complexity.
- Thermal insulating cab to contain the payloads.
- Four or Six actuated wheels, with all the wheels separately powered.
- A chain connected to the lander Communication.

Origami has been a source of inspiration for engineers for all kinds of applications and space being just one of them. Origami inspired deployable structures have been used for space missions since 1995. The simple act of folding a surface affects its rigidity and flexibility, it occupies less space and are being implemented in rovers to come.(A. S B, n.d.).

A. Suspension

While designing the rough terrain rover it was proposed that it is of six-wheel rover, in which all the six wheels are independently driven. In order to attain a better stability in harsh terrain, the wheels of the rover are sited similar as an ellipse. Front wheels of the rover are connected using swing arms. This is accomplished by using slide bushing elements by which it can transmit heavy loads. The rearmost axle of every wheel are depreciated intentionally to attain the high stability and to diminish the vibrations as a result of which there will be no hindrance in control system.In order to transmit power whilst lowering the damage to the engines, the engines are mounted in the interior of the rims. While fabricating the main concern is about the material that is used for the construction of the rover. The material has to be selected in such a way that it should possess high strength, it should be lightweight, and economical too, keeping all these factors in this mind we have shortlisted three materials their corresponding Mechanical properties are shown in TableIII.

TABLE III. MATERIAL PROPERTIES (PIOTR PTAK, N.D.)

Properties	Materials		
	Aluminium alloy PA6	Construction Steel S185	Titanium R50400
Yield strength[N/m2]	$2.45.10^{8}$	$1.75.10^{8}$	$3.7.10^{8}$
Tensile Strength [N/m2]	$3.9.10^{8}$	$2.9.10^{8}$	$3.44.10^{8}$
Longitudinal Elastic modulus[N/m2]	7.10^{10}	$2.1.10^{10}$	$1.05.10^{10}$
Poisson Ratio	0.3897	0.28	0.37
Transversal elastic modulus [N/m2]	$2.7.10^{10}$	$7.9.10^{10}$	$4.5.10^{10}$
Density[kg/m3]	2800	7800	4510

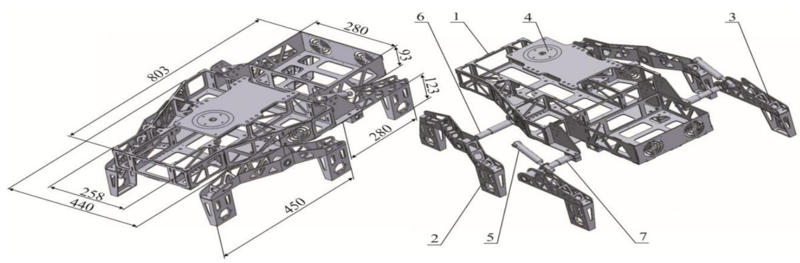

Fig. 5: The system is composed of the main frame (1), front wishbones (2), rear wishbones (3), gripper mounting plate (4),spring shock absorbers (5), bushing elements that connect the front and rear wishbones to the frame (6 and 7 respectively)(Piotr Ptak, n.d.).

Table IV gives an idea about the weight of a frame along with the suspension when made out of different combination of materials. While finding out the mass the thickness of the wall for steel and aluminium materials is assumed to be 3 mm and 1.5 mm for titanium. But for bushing elements only constructional steel S185 is used(Piotr Ptak, n.d.).

TABLE IV. (PIOTR PTAK, N.D.)

Element	Material	Mass (kg)
Frame	Aluminium alloy	7.185
Suspension	Aluminium alloy	
Frame	Constructional steel S185	17.858
Suspension	Constructional steel S185	
Frame	Aluminium alloy	11.879
Suspension	Constructional steel S185	
Frame	Aluminium alloy	8.709
Suspension	Titanium R50400	
Frame	Titanium R50400	6.575
S5uspension	Titanium R50400	

Therefore, it can be incurred that models will be manufactured of these materials which will be used for further analysis that is, frame made of aluminium alloy and the suspension will be made of aluminium alloy or steel or titanium. Because of higher mass of frame, the steel cannot be used, also the use of titanium is vomited to avoid the high production cost. Since rover has to work on the surface which is entirely different and unknown, it requires highly robust and reliable locomotion systems. The suspension is of two types,

- Passive Suspension
- Active Suspension

Most Mars rovers have had little to no problem with the deployment of the passive suspension systems. Some of the problems that are faced by it are terrain such as soft soil. Active suspension systems on the other hand provide a higher manoeuvrability. Leg like structures instead of wheels which are more terrain adaptable are also used in a more complicated level of suspension (Florian Cordes, n.d.)(Lindemann & Voorhees, n.d.).

B. Future Mars Rovers

Currently NASA is in the nth stage for it's another mars mission that is "M2020 mission" which is legitimately called Mars Sample Return (MSR). In this concern, they have received huge number of proposals, research works, papers, prototypes etc. among which they have considered only 58 innovative ideas from various researchers. This indicates that there is a tremendous interest in the around the world for mars exploration. The main aim of this M2020 mission is to help the future human explorers that how they can utilize the natural resources prevailing on the Mars surface. A very interesting instrument called MOXIE –which produces the oxygen using carbon dioxide present in the red planet, will be the part of this mission. The design of the rover may be similar to that of the Curiosity robot but it will have complex hardware and high-end sensors. It may consist of photovoltaic panel, rocker-bogie suspension for traversing harsh terrain with an ability to travel up to several distances.

The China National Space Administration had successfully launched **Tianwen-1** on the 23rd of July 2020.

Hope orbiter by the United Arab Emirates Space Agency was successfully launched on the 19th of July 2020.

Mangalyaan-2 by the Indian Space Research Organisation is planned to be launched by 2025.

Rosalind Franklin rover is an initiative of Exo Mars programme 2022 which will serve as a purpose for conducting science experiments. It is provided with a mass organic molecule analyser which helps us in finding if life ever existed on Mars, along with its source and position. MOMA consists of a mass spectrometer whose function is to find the quantity and variety of chemicals in the organic and inorganic compositions found in the rock samples.

IV. CONCLUSIONS

There were many challenges the project had to face like pinpoint handling, basic mission concept, descent and a significantly modified entry and about landing system even after the success in mars exploration rover missions but fortunately the above mentioned problems were rectified and executed as per the plan .This paper gives the overview of the old technologies that are implemented on the rover and its drawback and the new technologies that can be implemented on the rover like in suspension system , pinpoint landing and the design. The mars rover final prototype is built with an improvised mechanism design as compared to the versions existing already. The vehicles mechanism in present day enables it to climb up steps/ rocks resisting the impacts of varying terrain.

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