QUADROCKET based Flying Vehicle Mission Concept to Provide Transportation Needs to Astronauts during Manned Mission to Mars

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The ongoing quest for space exploration and the search for new home to human being in deep space demands challenging tasks in developing new systems and technologies to enable success in this direction. Today when Planet Mars is being seen as the most suitable alternative for long term human habitation in deep Space after Earth hence there is a great need of development of new technologies and systems both for pre and post arrival of humans on Mars to provide them necessary support for survival on the Red Planet. Considering the fact that the future Manned Missions will be based on Human and Machine interaction to carry out various activities on the Martian surface hence there is a great need of developing new systems and technologies to enable it. Transportation of equipments and machines from one location to another would be one of the requirements to fulfill the various needs of astronauts once they arrive on Mars and perform various activities. The Mission concept that I would like to introduce in the paper is the Development of an Unmanned Aerial Vehicle, a general X-Shaped QUADROCKET based UAV for transporting the equipments and hardware during the prospective manned mission and colonization of Mars. Since ground vehicles will not be able to go to certain locations on Mars due to rocky terrains and certain other geological constraints hence the concept of a flying vehicle is the best option to carry out transportation.

Keyword: Mars, Extravehicular, Transportation, QUADROCKET, Instruments

[1] INTRODUCTION

The paper presents a novel mission concept development of a Flying Vehicle for Space Exploration, QUADROCKET. The mission concept is inspired from the conventional propeller based QUADROTOR or QUADCOPTER (**Fig.1**). A Quadcopter also called QuadRotor helicopter or QuadRotor is an unmanned aerial vehicle UAV which uses rapidly spinning rotors to push air downwards and gain thrust [1]. Unlike helicopters, Quadcopters use two set of identical fixed pitched propellers spinning in opposite directions (in order to balance the torques exerted upon the body of the QuadRotor). These vehicles were among the first successful heavier-than-air vertical take-off and landing (VTOL) vehicles. A QuadRotor is an autonomously working miniature aerial vehicle (MAV) of small size and agile maneuverability. UAVs are small enough to be man-portable. Miniature UAVs range from micro air vehicles (MAVs) that can be carried by an infantryman, to man-portable UAVs that can be carried and launched like an infantry anti-aircraft missile. The UAVs find application in military operations, aerial imagery and filming, for search and rescue operations or to search for an object of interest and transmit the video footage of the object location to the ground station. The ongoing era of Space exploration in search of life on Mars and beyond, the UAVs have a great role to play. The ongoing exploration of the Planet Mars for the prospective human habitation on the Red Planet, there is a broad role UAVs can play both during manned and unmanned exploration of the Planet. The Rovers and Landers are effectively exploring the Martian conditions but in certain areas like rocky terrains and craters the Landers and Rovers can't go. In this direction the application of a Flying Vehicle can be very effectively used to explore those regions. The Flying Vehicle concept of QUADROCKET is a prospective Flying Vehicle Mission Concept to implement it in Exploration of Mars. The paper focuses on the Concept Design,

Development and its application to provide transportation support to the astronaut crew during manned mission to Mars.

Fig.1 Rotor Based Quadcopter

[2] DESIGN PRINCIPLE

The Design of the QUADROCKET is inspired from the conventional QUADCOPTER based Unmanned Aerial Vehicle. In a QUADCOPTER the lift to the Vehicle is provided by the four rotor motors placed at four corner of the vehicle, which is the primary difference between the QUADROCKET and the QUADCOPTER. The main Structural part of the Vehicle is built upon a either in (X) Configuration or (**+**) Configuration Body [2] **(Fig.2)** with the Centre of gravity of the Vehicle is located at the intersection of the two diagonally cutting arms and the flight control system located at the intersection with a Navigation Camera placed atop it to help the vehicle to move towards the desired location. Considering the dusty conditions on Mars, the camera is enabled with Night Vision System to allow it move smoothly even in dusty conditions. The transportation bay **(Fig.6)** to hold and transport the equipments is located below the Flight Control System area so that the Center of gravity is not shifted and allows the vehicle to move smoothly.

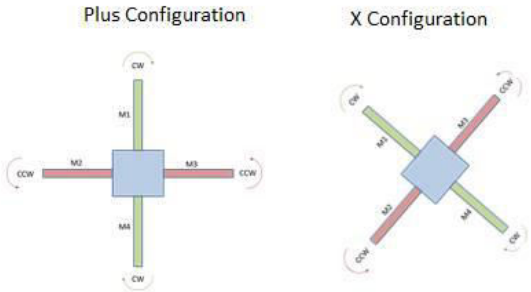

Fig.2 The Two possible configuration for the QUADROCKET, Plus Configuration (+) and X Configuration

The Propulsion System and the Attitude Control of the Vehicle is provided by the Four Monopropellant Rocket Engines with Hydrazine as the propellant for the Engines. The performance of a propeller based Flying Vehicle is not strongly feasible in the Martian Conditions hence the vehicle is replaced by four Monopropellant Rocket Motors placed at each corner of the Vehicle for providing propulsion as well as Attitude Control. These four Rocket Monopropellant Rocket Engines [3] provide the necessary propulsion support to the Vehicle for its flight. The operation of a monopropellant rocket Engine with the same kind of propellant in Martian and Earth conditions varies

significantly. The reduced Gravity conditions on Mars possess an advantage in operating the Vehicle with the same type and amount of propellant on Mars as it enables the Rocket Engines to produce three times more the Thrust than in Earth conditions.

$$Isp = \frac{F}{mg} \qquad (i)$$

We see from the Equation (*i*) for the Specific Impulse (I_{sp}) is dependent upon the acceleration due to gravity. The acceleration due to gravity on Mars which is $\frac{1}{3}$ of the acceleration due to gravity [3] on Earth so once we substitute the value of *g* for Mars in the equation (*i*), the equation becomes

$$Isp = \frac{F}{m\frac{g}{3}} = 3 * \frac{F}{mg} \qquad (ii)$$

So we observe from the equation *(ii)* that for the same type and amount of propellant the specific impulse in the Martian conditions becomes 3 times the specific impulse in Earth conditions. The much higher specific impulse in the Martian conditions allows the vehicle to generate 3 times the thrust it will produce with the same on Earth. The advantage of reduced gravity conditions on Mars possesses a great help in designing the propulsion system for the Vehicle which not only provides the necessary thrust for flight but also for the Attitude control of the Vehicle. The propellant which is used in the Vehicle is Hydrazine or Nitrogen Tetra Oxide (N_2O_4) considering the fact that it's storable and Hypergolic [4]. By comparing the vehicle with the same frontal area and weight of the Vehicle in Earth and the Martian conditions, it can travel at a much greater speed in the Martian conditions than in Earth conditions due to less dense atmosphere of Mars which results in lesser drag force allowing the vehicle to cruise at a greater speed hence allowing it to travel to a greater distance in lesser amount of time. The Fig.4 and Fig.5 shows variation of Density with altitude for Mars [5] and Earth [6] respectively.

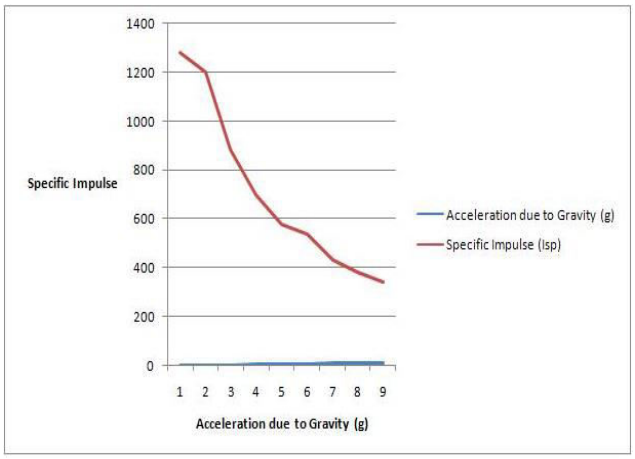

Fig.3 Variation of Specific Impulse with Acceleration due to Gravity for Hydrazine with exhaust velocity of Hydrazine taken as 3369 m/s[7]. Higher the Specific Impulse implies higher the Thrust for the Rocket Engine with the same type and amount of the propellant.

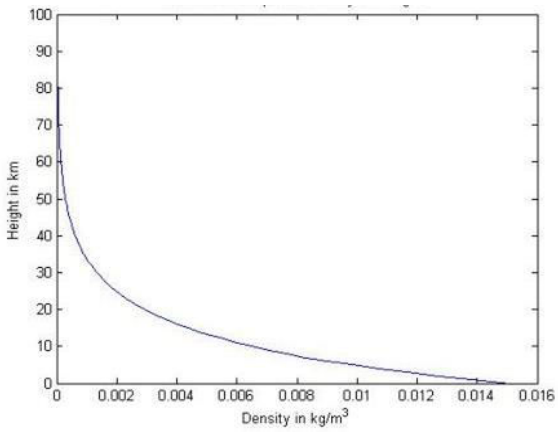

Fig.4 Variation of Density with Height on Mars

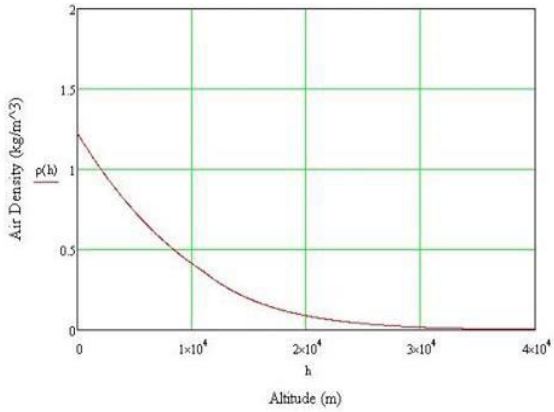

Fig.5 Variation of Density with Height on Earth

The transportation storage capability of the vehicle is determined by various factors like mission duration and mission type and the Lift off weight of the Vehicle will vary depending on payloads and onboard systems. The minimum amount of Thrust that Rocket boosters will need to provide the lift to the Vehicle in the Martian condition is calculated using the *Thrust to Weight Ratio (TWR). In general the body will be able to generate lift only when TWR is greater than 1.* [8]

$$TWR = \frac{F_T}{m.g} > 1 \qquad (iii)$$

$$F_T = Thrust\ of\ the\ Engines$$
$$m = Total\ mass\ of the\ craft$$
$$g = acceleratioin\ due\ to\ gravity$$

Product Image	Product Number	Description
	MR-103	1 N Class Mass: 0.33 kg
	MR-111	5 N Cass Mass: 0.33 kg
	MR-106	22 N Class Mass: 0.59 kg
	MR-107	275 N Class Mass: 1.01 kg
	MR-104	440 N Class Mass: 1.86 kg
	MR-80	3,100 N Class Mass: 8.51 kg

Fig. 6 Mono Propellant Rocket Engines (Hydrazine) [9]

[2.1] TRANSPORTATION BAY

The transportation Bay of the Vehicle is located below the main Vehicle structure over which Rocket Engines are mounted at each of the four corners of the structure. The transportation bay is designed in such a way that the instruments and hardware are attached with it using two arm (HOOK) shaped structure. The prospective design of the transportation bay in the Vehicle is shown in Fig 7.

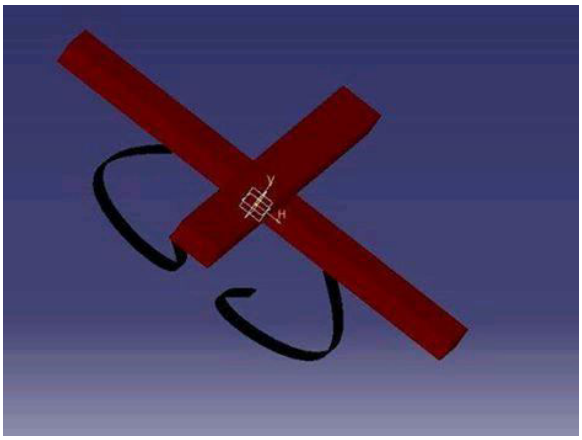

Fig.7 Prospective design of the Vehicle, the transportation bay to hold the instrument and hardware depicted with black color

The transportation bay is not a closed one rather it's made open so that the instruments and parts can be put inside a box and be attached with it. The reason behind not making the transportation bay in the form of closed chamber is due to the fact that while making it closed, only instruments and equipments those can fit inside the chamber can occupy and in case there is need of transporting any such instrument or hardware which is greater in dimensions than the chamber space, it would not be possible to transport them. So making the Transportation bay open, two arms at the center of the vehicle structure are designed with which the box containing the instruments and hardware is attached and transported. In order to avoid detaching of the box from the base arms, the boxes are tightened with screw with the arm and can be easily mounted and un-mounted using screw drivers.

[3] WORKING PRINCIPLE

The Working principle of the Vehicle is based on balancing the torque by controlling the thrust generated by the rocket Motors placed at each corner by increasing thrust on one rocket motor and equally decreasing thrust on the other. This equal increasing and decreasing of Thrust on the Motors generates a couple which balances the Vehicle to create a stable flight. These four Monopropellant Rocket Engines generates the necessary Thrust to achieve Lift and also helps in Attitude Control of the Vehicle. The Three axes of rotation namely Pitch, Yaw and Roll are controlled by controlling the amount of Thrust produced by them to allow the vehicle to move into desired direction.

[4] MISSION OBJECTIVE

The primary mission objective of the Vehicle is to provide the transportation needs to the astronauts once they arrive on Mars. One of the most possible transportation need on Mars will be during the EXTRAVEHICULAR ACTIVITY when crew will move from their base camps to various locations on Mars to carry out field activities. Once the Astronaut Crew leave the base camp to carry out exploration activities on the surface of Mars they will be dependent upon the instruments and equipments to carry out the exploration activities and in case of need of any other instruments or hardware either due to failure of their available equipments or further need of any other equipments for carrying out the exploration activity either they will need to go back to the base camp to bring them back to the exploration site or call the base camp crew to bring them to the exploration site. The land vehicle possess drawback to fulfill the need of transporting the instruments and equipments in the Martian conditions like their inability to move into certain locations and reduced speed. In this situation the role of the flying Vehicle QUADROCKET can be very effective to help the EVA Crew to get those instruments and hardware just by sending a command to the base camp crew with the necessary requirement and the base camp crew will load the QUADROCKET with the required instruments in its TRANSPORTATION Bay and the vehicle travels to the EVA Activity location with it. The EVA Crew unloads the instruments and allows the Vehicle to fly back to the Base Camp. It will subsequently capitulate the need of arrival of someone in person from the base camp to the Extravehicular activity location to carry them, consequently saving time and improving the overall mission efficiency.

[5] CONCLUSION

The application of Flying Vehicle in context to Planetary Exploration hasn't been implemented yet and considering the ongoing developments in the field of Space Technology and the future exploration of Moon and Mars, the flying vehicles have a great role to play in carrying out the space exploration activities. The application of flying vehicle to carry out exploration activity on the Red Planet can be very crucial considering the inability of the Landers and Rovers to move into each and every location of Mars like in terrains and inside craters. Those regions can be very easily explored by a flying vehicle as it can easily move into such locations. As well as the application of Flying Vehicle during the Manned Mission to Mars can play an important role in providing the transportation needs to the astronaut crew. In this direction the development of the QUADROCKET Flying vehicle to provide the transportation needs to the humans can be very effective in the Martian conditions considering its various advantages over surface based vehicles subsequently reducing the load on humans, saving time and consequently improving the mission efficiency. While there are advantages of designing and developing such vehicle, some of the major challenges in designing and operating such vehicle are refueling of the propellants, inability to lift heavy instruments and inability to function in strong dust storms.

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