SAFE HABITAT FOR EARTH-MARS TRANSIT

TEAM 292

PROBLEM – "A"

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ABSTRACT

This paper analyses the way to protect astronauts from exposure to harmful radiation during the interplanetary transit between Earth and Mars, best configuration taken as that which blocks most amount of harmful radiation. The spaceship is structured in such a way that the astronauts have 1000 m^3 volume of habitable region. We have determined the extra mass required for the journey by altering Tsiolkovsky rocket equation, depending solely on the mass of protective layering apart from payload, $\frac{\Delta v}{v_e}$ being the additional parameter. This flexible workaround provides us with the ability to alter with existing materials, structures and mission design tailored to suit requirements.

CONTENT LIST

NOTATIONS USED

Symbol	Definition
m_{extra}	Extra mass including extra fuel
m_l	Mass of the protection layer apart from initial payload
Δv	Maximum change of velocity under no external changes
v_e	Exhaust velocity
X	Net increase in mass
m_o	Mass of only the payload
m_f	Mass of fuel
m_{f1}	Mass of fuel in case 1
m_{p1}	Mass of payload in case 1
I_z	Intensity of the incident radiation
I_{total}	Total intensity on habitat
A	Cross sectional area perpendicular to the incident radiation
S	Radiation dosage in Sv
Φ_n	The incident flux for the particular frequency
k_n	Transmittance of the material surface at the given frequency
μ	Conversion factor
p	Momentum
F	Forces
v_o	Velocity of rocket at t=0
$(\Phi k)_n$	Surface parameter

INTRODUCTION

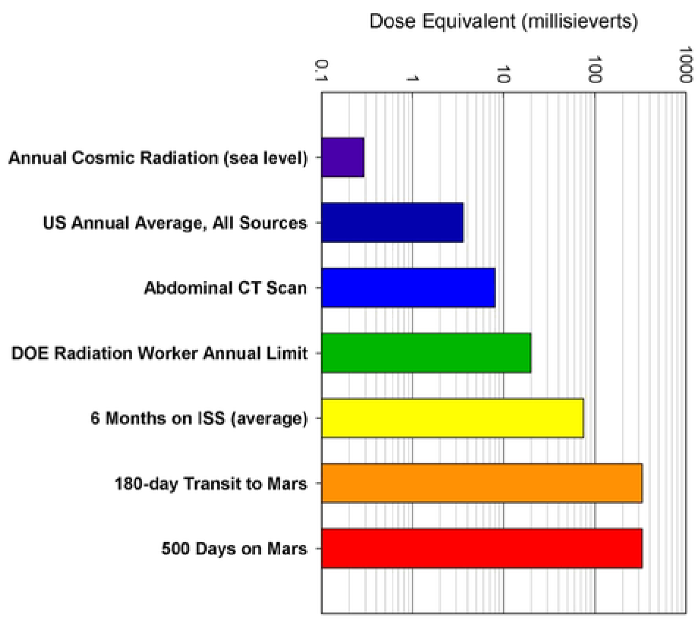
In the 21^{st} century the advent of the scientific era and the dawn of space exploration for the same has generated the thirst for a human conquest to mars. The technological progress involving this has a main figure as the level of radiation the astronauts are exposed to. Rovers have been sent and samples collected from the surface but mankind has yet to step on the planetary body. Without being able to alter the body's radiation susceptibility, in this article we have hypothesised a model spacecraft which can safeguard a human from radiation in deep space.

RADIATIONS

Radiations can be classified into 2 types which are mainly Ionising and Non-Ionising radiation. Ionising radiation mainly consists of Cosmological radiation, Trapped radiation and Solar radiation, whereas Non-Ionising radiation consists of UV radiations.

- Cosmological Radiations
  - Cosmological radiations are those types of radiations which are caused due to Cosmological rays emitted by the destruction of Nebulae in the Universe.
  - Cosmological radiations consist of 90% hydrogen nuclei, 9% alpha particles similar to helium nuclei and 1% of heavy nuclei.
  - Research is still ongoing to protect astronauts from Cosmological radiations during space travel.
- Trapped Radiations
  - Trapped radiations consist of those charged particles which have been trapped in the Earth's magnetic field.
  - These charged particles include ions and electrons.
- Solar Radiations
  - Solar radiations are caused by solar flares emitted by the Sun.
  - These radiations are heat radiations which are harmful to the human body.

Exposed Radiation levels of a normal Human's is quite low than those of Astronauts. The graph below represents the amount of radiation bore by humans through one or the other way.



PREMISE OF THE PLAN

The structure spaceship in such a way that the astronauts have 1000 m3 volume of habitable region.

Optimising propulsion by the existing deployable solar sail hence reducing consumption of fuel whilst minimising the effects of radiation due to extra surface area gives us the net mass of the sunward protection surface.

On the other side facing away from the sun, a coating with a material like lead, which has low attenuation length and is effective against the cosmic gamma ray and x ray radiation, can be used and its mass can be calculated by multiplying its density with the volume of the layer required.

$$(\phi k)_n = \phi_1 k_1 + \phi k_2 + \phi_3 k_3 \dots + \phi_n k_n$$

$$(\phi k)_z = \sum \phi_n k_n$$

$$I_z = A_z (\phi k)_z$$

$$I_{total} = \sum I_z (\phi k)_z$$

$$S\ (radiation\ in\ Sv) = \mu * I_{total}$$

Where z is the number of combinations of surfaces of different incident radiation and/or $(\phi k)_n$ where n is the number of frequency ranges taken of surface A_n .

We have determined the extra mass required by altering Tsiolkovsky rocket equation as follows:

$$\sum F = m\frac{dv}{dt} + v_e\frac{dm}{dt}$$

But total force acting on the body in orbit at that time is 0, implying

$$m\frac{dv}{dt} = -v_e\frac{dm}{dt}$$

Which gives

$$\Delta v = v_e \, ln \frac{m_o}{m_1}$$

If

$$m_{extra} = m_{f_1} + m_l$$

Then

$$\frac{m_o}{m_1} = e^{\frac{\Delta v}{v_e}} = \frac{m_o + m_l}{m_1 + m_{extra}}$$

$$\frac{m_p + m_f}{m_p} = e^{\frac{\Delta v}{v_e}}$$

$$m_{extra} = \frac{m_{layer} \; e^{\frac{\Delta v}{v_e}}}{e^{\frac{\Delta v}{v_e}} - 1}$$

$$e^{\frac{\Delta v}{v_e}} = \frac{m_o + m_f}{m_o} = \frac{m_o + m_f + m_{f_1} + m_l}{m_o + m_l}$$

$$1 + \frac{m_l}{m_o} = 1 + \frac{m_{f_1}}{m_f}$$

$$m_l = \frac{m_o m_{f_1}}{m_f}$$

$$m_{extra}\left(e^{\frac{\Delta v}{v_e}} - 1\right) = m_l e^{\frac{\Delta v}{v_e}}$$

$$m_{extra} = \frac{m_l e^{\frac{\Delta v}{v_e}}}{e^{\frac{\Delta v}{v_e}} - 1}$$

Is the increase in mass we have to take for each manoeuvre to sustain the same path, and m_l is the sum of the individual masses of the layers, that is, sum of (individual density of material) *(volume occupied by it).

ANALYSIS OF PRACTICAL FEASIBILITY

Additional radiation precautionary measures have to implemented to reduce the chances of secondary contamination. Such precautionary measure includes following PPE protocol wherein the spacesuit used by the astronauts will be the ILC DOVER ASTRO SUIT. It provides maximum mobility in micro gravity for astronauts which provides shielding against micrometeoroids and radiation.

Taking the flight from the Van Allen belt (a zone of energetic charged particles, most of which originate from the solar wind, that are captured by and held around a planet by that planet's magnetic field) onwards to the point where Mars orbit injection is performed we have a net Δv of 3.2km/s. The time of flight of the spacecraft in the trajectory is on an average 6 months in duration one way. Taking the exposure on total to be 0.66Sv for a round trip, we can infer that it is viable for human space flight from Earth to Mars. This is only for the travel duration to and from Mars and it does not take into account the stay on Mars. It takes the recommended guidelines of radiation dosage exposure as said by the international standards of safety that is 0.66Sv by approximation according to NASA.

STRENGTHS AND WEAKNESSES

STRENGTHS:

- Flexibility with respect to mission design and analysis.
- Extra mass is dependent on the $1000m^3$ volume's density.
- The quality of surface is not predetermined giving a guided hand in construction.

DRAWBACKS

- The model is highly dependent on a number of parameters which must be taken into account in the designing of the spacecraft.
- Monetary practicality and feasibility must be taken care of by the sponsoring organisation and does not factor into this research.

CONCLUSION

In conclusion the safety habitat would be successful in protecting the astronauts inside from the solar radiations and to some extent from the Cosmic radiations. The inner habitable volume of $1000m^3$ being coated with radiation protective material on the outside and having provision for ample space being shielded. Using a deployable solar sail which can be designed individually, net radiation for the 1 year round trip must be less than 0.05Sv when the exposed radiation of 0.66 Sv will be reduced to a ratio less than or equal to 0.075. Along with the PPE measures taken by the astronauts individually and the protocol implemented for least possible radiation exposure, Mars travel can be a physically viable option for future missions to the beyond.

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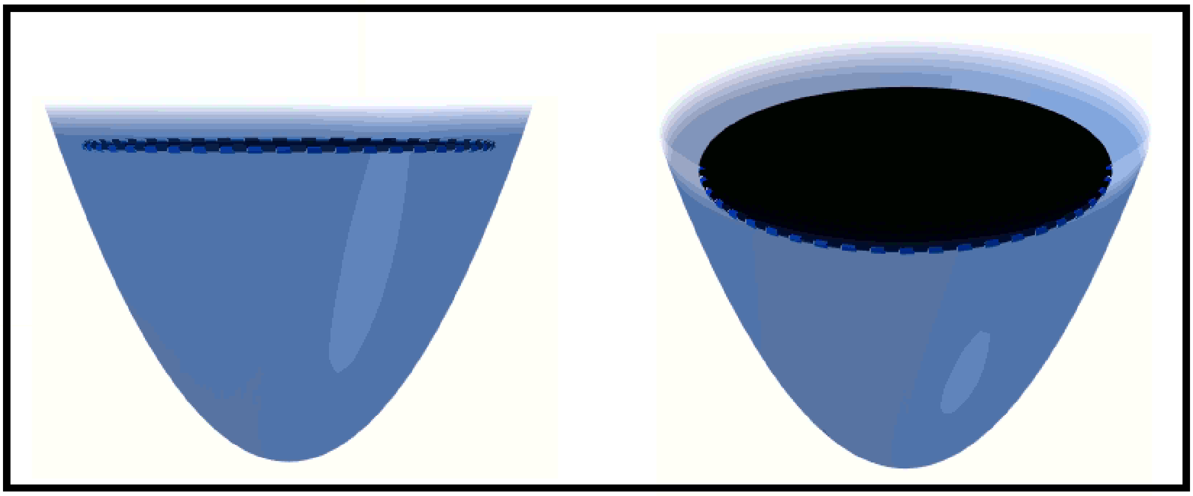
APPENDIX



Cross Sectional views of sample paraboloid and disc model spacecraft where the paraboloid surface faces the sun