# Shielding Travelers To Mars


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## ABSTRACT

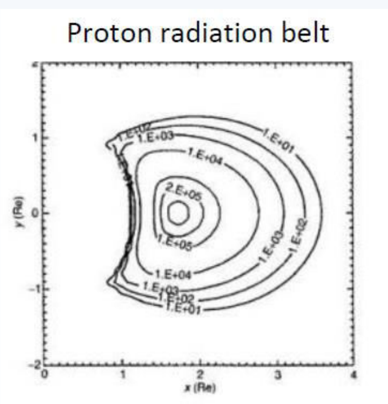
This paper analyses and evaluates a possible flight plan from Earth to Mars such that the radiation dosage absorbed by the spacecraft passengers is the least by launching the spacecraft between 43.64 to 55.31 deg relative to the magnetic axis of the during beginning or end of each solar activity cycle and calculated shortest possible route to Mars, in 259 days. There is also an attempt to find the best possible and practical radiation shielding method for sending a 1000 cubic meters habitat along with all the radiation proof materials like lead, plexiglass, and kevlar, to build the shield, which came out to be around 314381kg of extra mass. Parameters like, shape of habitat, permitted solar radiation levels and different shielding materials, dosage and exposure rate reduction are taken into consideration while designing the shield for habitat.

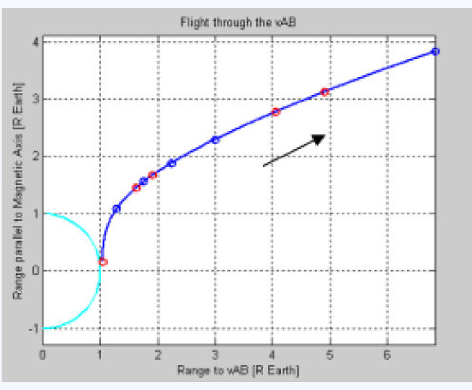

## INTRODUCTION

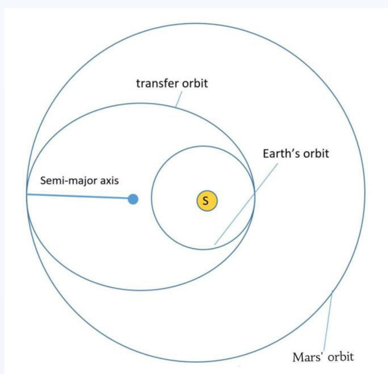
One of the challenges of sending humans to Mars is the significant radiation they would experience during the journey which includes electron and proton belts in Van Allen, solar wind, x rays and galactic cosmic radiations coming from all directions. In reality, there is also presence of extreme temperature, asteroids, etc. in space which might cause damage to the habitat, electronics and the human body. So in order to protect travelers to Mars, a practical shield and flight plan have to be designed to prevent maximum radiation dosage. Here the spacecraft habitat is assumed to be of 1000 cubic meters of volume.

## FLIGHT PATH

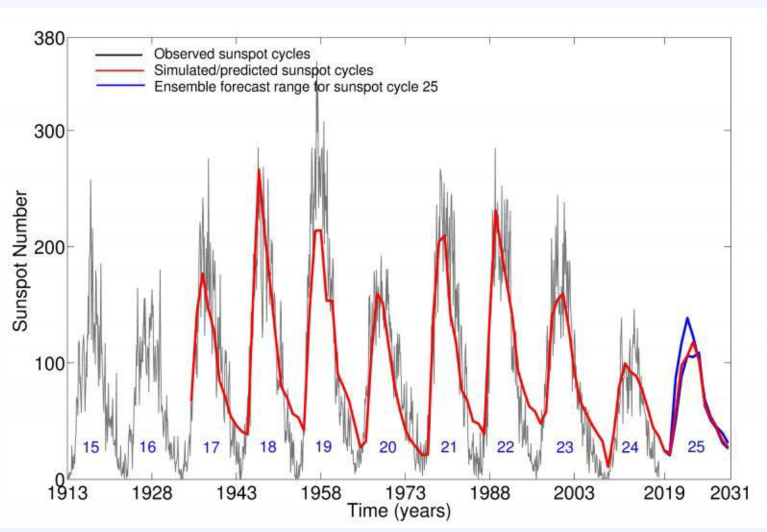
The flight path to the Mars crosses the Van Allen radiation belt, a zone with free protons, electrons and other high energy charged particles which is formed as the Earth's magnetic field captures the charged particles from solar winds. Therefore for the trajectory to avoid the central part of the Van Allen and the free proton belt(i), the trajectory angle should vary from **43.64 °** to **55.31 °** relative to the geomagnetic axis of the Earth(ii). Using Hohmann Transfer Orbit(iii), spacecraft can reach Mars in about 258.68 days when Mars is at the closest distance from Earth.
This plan would allow habitat to spend minimum possible time in contact with galactic cosmic radiations.

(i) 


(ii) 

(iii) 

## SOLAR ACTIVITY & LAUNCH TIME




There are two windows in every **11 years** when the spacecraft can be launched to Mars as Solar cycle, an approximately 11-year period of varying solar activity including solar maximum where the solar wind, is strongest and solar minimum where the solar wind is weakest.

One window is between beginning of solar cycle and middle of the cycle. The other window is between the middle and end of the cycle. Therefore, suitable years for the launch would be **mid-2019** to **early 2021** or **late 2028** and **late 2030** and the journey of **258.686 days** to Mars should be accommodated in these 2 windows to minimize solar and galactic cosmic radiation dosage.

## HABITAT DESIGN

Shape of the habitat is an important factor in minimizing the surface available for direct contact with radiations and also to have the prescribed volume. Thus habitat vessel should be such that it has the least surface area to volume ratio. Therefore the proposed shape is **sphere**.

**Spherical habitat** does not have edges decreasing the probability of radiation leak from corners unlike cubes. Also, in outer space, there is negligible gravitational acceleration so the passengers can easily move about and round the spherical habitat like 'Bernal Sphere'.

Thus inner radius of spherical habitat (1000 cubic meters) = 6.202m

## MATERIAL LAYERS OF SHIELD

i. **Plexiglass** The less penetrating beta radiation can first be shielded with a layer Plexiglass, thereby slowing or stopping the beta particles while reducing the production of bremsstrahlung. Moreover, plexiglass is a hydrogen rich substance which increases efficiency of shielding.

ii. **Lead** Lead is a common shielding material for x-rays and gamma radiation because it has a high density, is inexpensive, and is relatively easy to work with.

iii. **Kevlar** It is an infusible, wholly aromatic polymer that can strictly be described as nylon T,T - but rarely is. Manufactured only as a fiber (by solution spinning), it has a very high thermal stability and temperature and flame resistance.

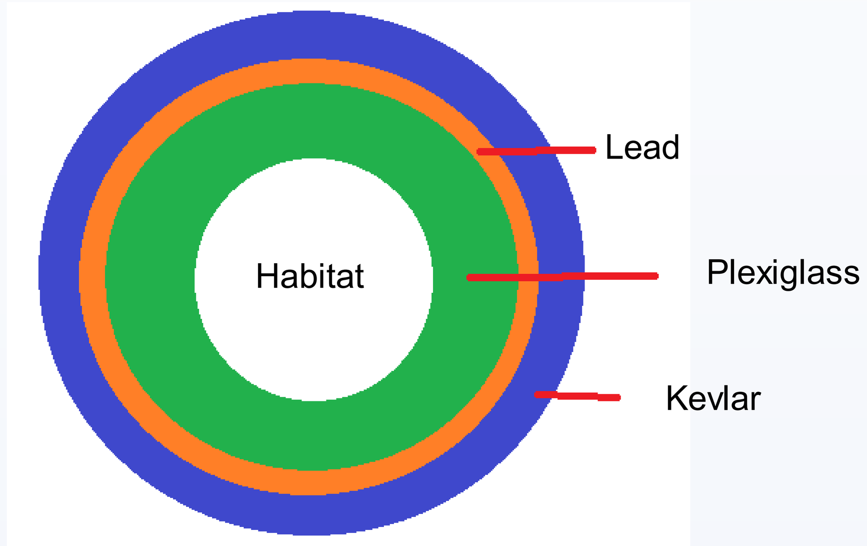
## MATERIAL LAYER THICKNESS & MASS

Assume, there is maximum constant radiation exposure rate from a point source outside the habitat that is 9 R/hr and acceptable radiation exposure rate for humans is 0.0005 R/hr. Let **(x)** be thickness of layer (p) be linear attenuation coefficient of the shielding material. Monoenergetic x- or gamma rays collimated into a narrow beam are attenuated exponentially through a shield according to the following equation: I = Io e^-px. So, I0 = 9R/hr, I = 0.03R/hr.

- Plexiglass: p = 0.12cm^-1. So, **x1 = 40cm.**
  **Mass = 244210kg**
- Lead: p = 1.63cm^-1. So, **x2 = 3.5cm**
  **Mass = 21874kg**
- Kevlar: p = 0.902cm^-1. So, **x3 = 6cm**
  **Mass = 48297kg**

**Total mass of shield = 314381kg**

## 2D VIEW OF SHIELD




## RESULT

Tissue dosage of radiation during journey to Mars (259 days)

1. Without shield

= 9R/hr x 24 x 259 x 10mSv = 559.48 Sv

2. With shield

= 0.03R/hr x 24 x 259 x 10mSv = 1.86 Sv (which is under the limit of dosage per year)

**Reduction in dosage** = (559.48 - 1.86) x 100/ 559.48 = ***99.667%***

## CONCLUSION

The calculated flight path using transfer orbit, trajectory angle and the solar activity minima window are the best ways to avoid most part of the radiations from Van Allen belt and the sun and also the path is such that the passengers spend minimum time among the radiations so that there is enough time for the temporary DNA and tissue damage to repair quickly. The habitat designed, is the optimum one as the shape used is sphere which provides the least surface area to radiations and the materials used to create the shield are also the best as they are cheap, low density, kelvar being highly heat resistant would provide protection in case of temperature increment.

Further extension of this work is required to find a possible way to make such habitat and shield which is lighter, more rigid, provides more protection from charged particles and is more compact. For now, the mentioned solutions in this paper are efficient to overcome the challenge to send humans to Mars while protecting them from radiations.

## REFERENCES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