Teacher's Guide

Planning a Trip to Mars

Introduction

In the 21st century, NASA is planning a mission to Mars. You and a group of your peers are about to set off on this mission. The trip will take 240 days to get to Mars. Once there, you will explore the surface for fossils for 3 years. The return trip to Earth will take another 240 days. A concern exists for how the crew will be protected from radiation over-exposure during the 4-year expedition in space. You will assume during the trip that your shielding is the same as NASA uses on the Space Shuttle.

Objective

Students will calculate the cumulative radiation dosage for a trip to Mars, and participate in a probability-based exposure simulation.

Procedure

1) Read the introductory paragraph to the students.

2) Allow sufficient time for the students to complete questions #1 and 2 on the Student Worksheet. Discuss student results and answers.

3) Group the students into either pairs or groups of four.

4) Provide each group with a dice. Conduct the simulation and complete the remaining activities.

5) Discuss the outcome of the simulation, and review possible responses to the remaining exercises.

For a possible extension:

Have the students use the graph created in the first activity in this book "**The Sunspot Cycle**" to determine when would be the best opportunities in the next centur to leave for the trip.

Materials

—A dice

—Student Worksheets

—Graph paper

—Calculator

Key Terminology:

SPE: Solar Proton Event. An unpredictable, major burst of high-energy particles from the sun which take less than 20 minutes to reach the orbit of the Earth.

Rad: The amount of radiation needed to deliver a specific amount of energy into a fixed mass of biological tissue. 100 rads equals one Joule of energy per kilogram of mass. One Joule is the amount of energy a 1 Watt bulb produces in a second.

Rem: A number that tells the actual damage done per rad of dosage which accounts for the fact that charged particles are 10 times more damaging than electromagnetic radiation.

Name ____________________________ Date_________________

1. NASA is concerned about the amount of radiation that your crew will be exposed to while on your trip. The table below shows the minimum and maximum dosages (in rems) that were received for different Space Shuttle flights, and at different altitudes given in Nautical Miles (NM). Find the combined average dosage.

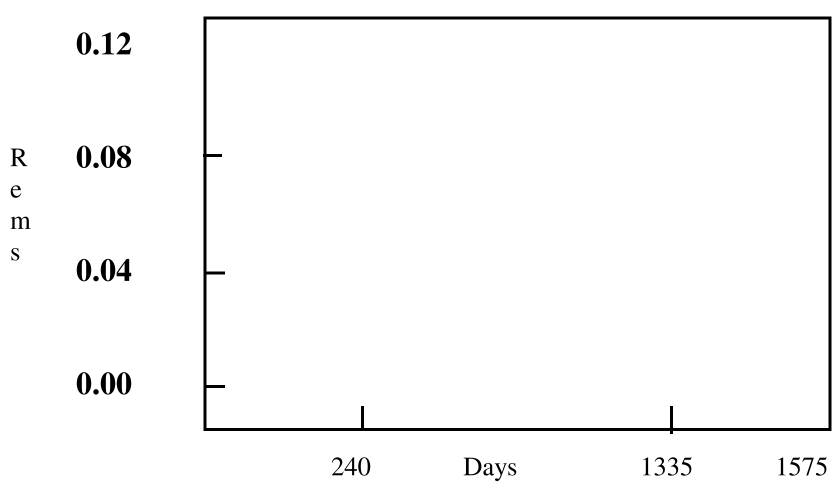
Mission	Altitude	Minimum	Maximum
STS-38	**125 NM**	**0.003**	**0.004**
STS-51G	**200 NM**	**0.015**	**0.020**
STS-37	**245 NM**	**0.040**	**0.070**
STS-31	**330 NM**	**0.140**	**0.220**

Average combined dosage in rems = ___________________

2. Suppose that NASA decides to send the expedition at a time near solar maximum. By the time you return, the conditions in space will be near those at solar minimum during the solar cycle which occurs about 5.5 years after solar maximum. During solar maximum, the sun is very active and effectively shields the inner solar system from most of the galactic cosmic rays (GCRs) which contain very high energy particles. During solar minimum, the Sun is relatively inactive and allows GCRs to reach the inner solar system in greater numbers. The integrated dose of GCRs is about 2.5 times higher at solar minimum than at solar maximum. Using the data in the table above during conditions of solar maximum, calculate the average dosage in rads/day during solar minimum.

Average dosage in rems during solar minimum

3. The next step in the process is to determine the number of rems for the crew. Also, you will need to calculate the total exposure over the entire 4.3 year trip. Total exposure is measured in units of rems. Your trip begins during solar maximum and ends during solar minimum. On the graph below, calculate the number of rems for each time period. Assume that while on Mars that you are adequately shielded with a natural background dose of 15 rem per year (or 0.04 rems/day). To calculate rems: Rems per day multiplied by the number of days of exposure = number of rems of total radiation dosage.



Number of rems on trip to Mars:

= ___________

Number of rems on Mars:

= ___________

Number of rems on trip to Earth:

= ___________

Name ____________________________ Date________________

4. **There is an event that occurs in space known as a Solar Proton Event (SPE). SPEs are the most dangerous to astronauts because of our inability to predict them. They occur about once every month during solar maximum, and once every eight months during solar minimum. Typical radiation dosages are about 0.4 rems inside a spacecraft or similar shelter. The amount of rems varies due to the intensity of the SPE. During your trip, assume that you will encounter 3 SPEs on your way to Mars, 10 SPEs while on Mars, and 1 SPE on your trip home. To simulate the random amount of rems received from SPEs, toss a dice and using the chart below, the number on the dice equals the corresponding dosage. Example, a roll of 5 gives you a dosage of 2.0 rems. Repeat for each SPE and add the amount of the total SPE rems for each part of the trip.**

Dice	Dose
1	0.1
2	0.3
3	0.4
4	0.8
5	2.0
6	10.0

Trip to Mars:

SPE	Dose
1	
2	
3	

On Mars:

SPE	Dose
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Trip to Earth:

SPE	Dose
1	

Total Rems..... ______________ ____________ ______________

7. **Calculate the mission's total dose by filling in the numbers below:**

Amount of rems on trip to Mars + total SPE on trip to Mars = ______________

Amount of rems while on Mars + Total SPE while on Mars = _______________

Amount of rems on trip to Earth + Total SPE on trip to Earth = ______________

Total dosage for entire trip = ___________

Name ______________________________

Date________________

8. NASA's career equivalent doseages for astronauts is computed as follows:

200 + 7.5 (age - 30) rems (males up to 400 maximum rems)
200 + 7.5(age - 38) rems (females up to 400 maximum rems)

Using these formulas, answer the following questions:

How many trips to Mars could a 40 year old man take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

How many trips to Mars could a 40 year old woman take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

Name some ways that the amount of radiation you received on this trip could vary.

Which of the two sources of radiation, cosmic rays and SPEs, are the most hazerdous and how would you try to minimize its risk to the crew?

Based on what you have learned, what are some things you could do to minimize the amount of radiation that you would receive on a trip to Mars?

Teacher's Answer Key

1. NASA is concerned about the amount of radiation that your crew will be exposed to while on your trip. The table below shows the minimum and maximum dosages (in rems) that were received for different Space Shuttle flights, and at different altitudes given in Nautical Miles (NM). Find the combined average dosage.

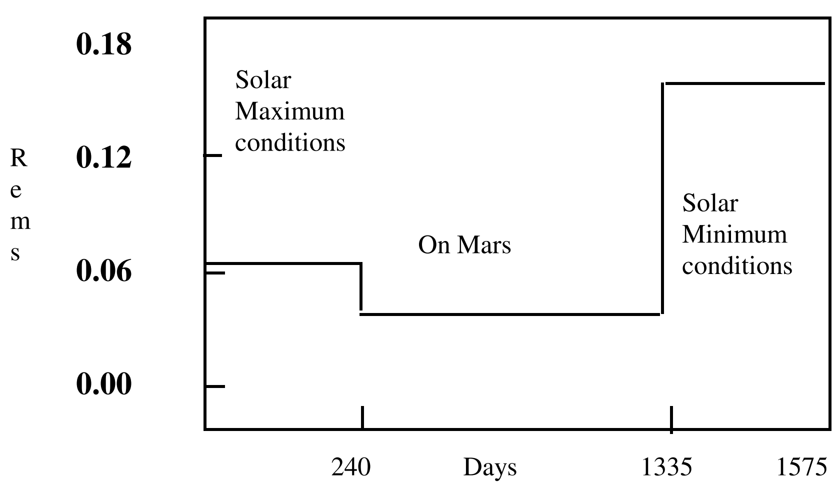
Mission	Altitude	Maximum	Minimum
STS-38	**125 NM**	**0.003**	**0.004**
STS-51G	**200 NM**	**0.015**	**0.020**
STS-37	**245 NM**	**0.040**	**0.070**
STS-31	**330 NM**	**0.140**	**0.220**

Average combined dosage in rems = **0.064**

2. Suppose that NASA decides to send the expedition at a time near solar maximum. By the time you return, the conditions in space will be near those at solar minimum during the solar cycle which occurs about 5.5 years after solar maximum. During solar maximum, the sun is very active and effectively shields the inner solar system from most of the galactic cosmic rays (GCRs) which contain very high energy particles. During solar minimum, the Sun is relatively inactive and allows GCRs to reach the inner solar system in greater numbers. The integrated dose of GCRs is about 2.5 times higher at solar minimum than at solar maximum. Using the data in the table above during conditions of solar maximum, calculate the average dosage in rems during solar minimum.

Dosage in rems during solar minimum = **0.064 x 2.5 = 0.16 rems**

3. The next step in the process is to determine the amount of rems for the crew. Also, you will need to calculate the total exposure over the entire 4.3 year trip. Total exposure is measured in units of rems. Your trip begins during solar maximum and ends during the solar minimum. On the graph below, calculate the number of rems/day for each time period. Assume that while on Mars that you are adequately shielded with a natural background dose of 15 rem per year (or 0.04 rems). To calculate rems: Rems per day multiplied by the number of days of exposure = number of rems of total radiation dosage.



Number of rems on trip to Mars:

= 0.064x240 = 15.4 rems

Number of rems on Mars:

= 0.04x(1335-240) = 43.8 rems

Number of rems on trip to Earth:

= 0.16x240 = 38.4 rems

Teacher's Answer Key

4. There is an event that occurs in space known as a Solar Proton Event (SPE). SPEs are the most dangerous to astronauts because of our inability to predict them. They occur about once every month during solar maximum, and once every eight months during solar minimum. Typical radiation dosages are about 0.4 rems inside a spacecraft or s similar shelter. The amount of rems varies due to the intensity of the SPE. During your trip, assume that you will encounter 3 SPEs on your way to Mars, 10 SPEs while on Mars, and 1 SPE on your trip home. To simulate the random amount of rems received from SPEs, toss a dice and using the chart below, the number on the dice equals the corresponding dosage. Example, a roll of 5 gives you a dosage of 2.0 rems. Repeat for each SPE and add the amount of the total SPE rems for each part of the trip. Here is a sample result of the dice tossing outcomes:

Dice	Dose
1	0.1
2	0.3
3	0.4
4	0.8
5	2.0
6	10.0

Trip to Mars:

SPE	Dose
1	0.4
2	2.0
3	0.1

On Mars:

SPE	Dose
1	0.3
2	2.0
3	0.4
4	0.3
5	10.0
6	0.4
7	0.1
8	2.0
9	0.3
10	0.3

Trip to Earth:

SPE	Dose
1	0.8

	Trip to Mars	On Mars	Trip to Earth
Total Rems.....	**2.5**	**16.1**	**0.8**

7. Calculate the mission's total dose by filling in the numbers below:

Amount of rems on trip to Mars + total SPE on trip to Mars = 15.4+2.5 = 17.9

Amount of rems while on Mars + Total SPE while on Mars = 43.8+16.1 = 59.9

Amount of rems on trip to Earth + Total SPE on trip to Earth = 38.4+0.8=39.2

Total dosage for entire trip = 117.0

NOTE: The values for the SPE contribution will vary depending on the dice tosses that come up for each group, but you may combine the results for all groups to get a 'class average' SPE dosage! These SPE doses assume the astronaut is shielded inside a spacecraft. If they are caught outside a shelter, the dosages from the SPEs are about 8-10 times higher!

Teacher's Answer Key

8. NASA's career equivalent doseages for astronauts is computed as follows:

200 + 7.5 (age - 30) rems (males up to 400 maximum rems)

200 + 7.5(age - 38) rems (females up to 400 maximum rems)

Using these formulas, answer the following questions:

How many trips to Mars could a 40 year old man take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

Total recommended dose = 200 + 7.5(40-30) = 275.0
Mars trip dose = 117.0 so number of trips is 2

How many trips to Mars could a 40 year old woman take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

Total recommended dose = 200 + 7.5(40-38) = 215.
Total trips = 215/117 = 1.8. This could either be stated as 1 or 2 trips.

Name some ways that the amount of radiation you received on this trip could vary.

Higher SPE exposure; more solar storms; defective shielding; less solar activity; better shielding. These are all possible answers.

Which of the two sources of radiation, cosmic rays and SPEs, are the most hazerdous and how would you try to minimize its risk to the crew?

SPEs are unpredictable and can deliver significant doses, especially if an astronaut is 'spacewalking' during which time little shielding is available. Some type of early warning system is required to anticipate when these storms may be starting on the solar surface. Either constant telescopic monitoring is needed, or some other method to sense the buildup of SPE conditions.

Based on what you have learned, what are some things you could do to minimize the amount of radiation that you would receive on a trip to Mars?

Stay in the spacecraft. Staying on Mars less than 2 years is not an option because you can only return when Mars and Earth are closest to each other every 2.1 years. It is not the stay on Mars that hurts you, it is the changing cosmic ray conditions during solar maximum and solar minimum. One possibility is to start and end your trip during the time that the sun is near its maximum in the solar cycle. This would reduce your non-SPE cumulative dose, which is the factor that dominates the total dosage. Start the trip 2 years before solar maximum, and end it 2 years after solar maximum would be a better strategy, provided you can reduce your risk for SPE events.