GEORGIA INSTITUTE OF TECHNOLOGY

SPACE FLIGHT OPERATIONS - ASSIGNMENT 8

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1 Question 1

1.a

Using the provided delta-v map and equation, we find that the delta-v required to deliver material to the lunar surface is:

$$\Delta \text{v} = 9400 + 3260 + 680 + 1730 = 15070 \text{m/s}$$

We can then use the rocket equation as such,

$$m_i = \frac{m_f}{exp(\frac{-\Delta v}{v_e})}$$

to find the approximate initial mass of our vehicle as,

$$m_i = \frac{1000}{\exp(\frac{-15070}{4400})} = \mathbf{30722.64\ kg}$$

1.b

$$\frac{m_f}{m_i} \times 100 = \exp\left(\frac{-\Delta v}{v_e}\right) \times 100 = \mathbf{3.25\%}$$

1.c

If the Lunar Gateway is positioned at the "Lunar intercept" location, the delta-v required is:

$$\Delta \text{v} = 9400 + 3260 = 12660 \text{m/s}$$

Using the rocket equation used in part a, we find that the initial mass needed to deliver 1 metric ton to the "Lunar intercept" location is **17765.75 kg**.

1.d

To transport material from the Lunar Gateway, positioned at the "Lunar intercept" location, to the lunar surface the following delta-v is required,

$$\Delta \text{v} = 680 + 1730 = 2410 \text{m/s}$$

Using the rocket equation used in part a, we find that the initial mass needed to deliver 1 metric ton from the "Lunar intercept" location to the lunar surface is **1729.31 kg**. The lander mass would therefore be 729.31 kg without the payload.

1.e

$$\frac{m_f}{m_i} \times 100 = \frac{1000}{729.31 + 17765.75} \times 100 = \mathbf{5.41\%}$$

1.f

We can clearly see that the mass fraction to get a 1 metric ton payload from Earth to lunar surface is lower than if we have a stopping point at the 'lunar intercept' location. Indeed, in the former case, only 3.25% of the vehicle will be useful payload once the destination is reached, whereas that number grows to 5.41% in the latter case. While this difference seems small, as most of the delta-v required is used in the trip between Earth and the intercept location, it is actually significant as this implies a large amount of fuel saved. This difference is due to the exponential nature of the rocket equation. Indeed, by spitting the trip in two parts, we reduce the total delta-v required in the first part, causing the initial mass to exponentially decrease. Similarly for the second part of the trip, as the delta-v is low comparatively with the first part, the amount of mass added is almost negligible in comparison. In addition, as there is a stopping point, the fuel needed to reach the Lunar Gateway is less than the fuel needed to reach the lunar surface, implying that the rocket can carry less fuel and save mass to reach its destination.

2 Question 2

2.a

Approximating the daily dose rate every day,

$$25\text{mrad/day} \times 567\text{days} = 14175\text{mrad} = \mathbf{14.175\ rad}$$

2.b

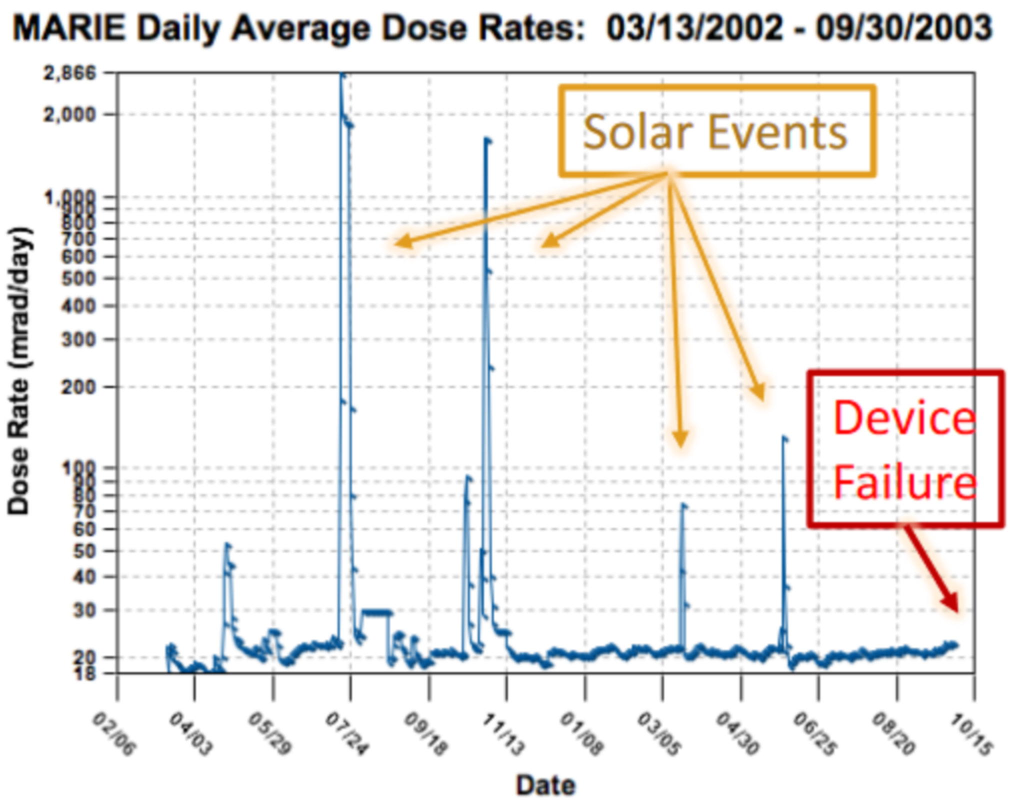

Figure 1: MARIE measured ionizing dose rates in Mars orbit

Only 2 peaks where daily dose rate is >1000 mrad/day, making up 4 total days (3 days in peak 1, 1 day in peak 2)

$$14175 + 2866 + 2000 + 2000 + 1700 = 22741\text{mrad} = \mathbf{22.741\ rad}$$

2.c

We can see a significant difference between the answers found in a) and b). Solar events, even though not fully accounted for in b), still cause a 60% increase in radiation over a period of a year and a half.

According to "https://srag.jsc.nasa.gov/Publications/TM104782/techmemo.htm", the maximum career exposure for a man is 400 REM = 400 RAD. The human body is used to having an average of 0.620 rad/year on Earth, however, the martian environment averages a radiation level of 9 rad/year, over 14 times the earthly amount. Yet, that is not even taking into account Solar events, which can send over 2 rad in a single day. This would be extremely dangerous for astronauts on the surface, as, even though the does of 400 rad in a career is small when compared to 2 rad, that maximum amount of radiation is supposed to be accumulated over years. A single solar event could heavily damage astronaut's cells and cause cancer. With no professional equipment and the closest hospital being months of travel away, astronauts on Mars have a very small chance of survival without heavy protection.

3 Question 3

3.a

Steady-State temperature occur when

$$P_{in} = P_{out}$$

where,

$$P_{in} = I_0 a A_{in}$$

$$P_{out} = \epsilon\sigma A_{out} T^4$$

As such,

$$T = \sqrt[4]{\frac{P_{in}}{\epsilon\sigma A_{out}}} = \sqrt[4]{\frac{I_0 a A_{in}}{\epsilon\sigma A_{out}}}$$

In this case,

$$A_{in_{min}} = 0.1^2 = 0.01\text{m}^2$$

$$A_{in_{max}} = \frac{3 \times \sqrt{3}}{2} a^2 = 0.01299\text{m}^2$$

Here the minimum area is the area of one side of the cubesat, which would occur if one face of the satellite was looking straight on to the sun, and the maximum area is a hexagon, if one node of the cubesat was facing the Sun, 4 faces would be looking at the Sun, with the same cross-sectional area as a hexagon. Here, a is found using Pythagoras's theorem, as each node of the hexagon intersects the cube's side at the center,

$$a = \sqrt{0.05^2 + 0.05^2} = 0.070711\text{m}$$

$$A_{out} = 6 \times 0.1^2 = 0.06\text{m}^2$$

Using $I_o = 1366W/m^2$, we obtain T_{min} =**-38.89°C** and T_{max} =**-23.06°C**.

3.b

As we now have an internal power of 8W, we add this to P_{in} and recalculate to obtain T_{min} =**4.59°C** and T_{max} =**14.55°C**.

3.c

Using the $1/r^2$ relationship for solar flux, we obtain $I_{Mars_{min}} = 607.11W/m^2$. Similarly, as the area of the solar cells stays constant while the distance increases, the power consumed decreases with a factor of $1/r^2$, resulting in 3.56W of power consumed in Mars. As such, T_{min} =**-46.37°C** and T_{max} =**-38.24°C**.

3.d

While this analysis provides us with a good starting point for temperature analysis, it is only a single node analysis, where we assume that there is only one temperature for the entire spacecraft and is highly inaccurate. Indeed, in reality, the spacecraft will have different temperatures throughout, varying radiation coefficient for different materials, internal power usage will not be constant, solar rays will hit the surface at different angle, and the radiation from the body it orbits will generally not be negligible.

This method could be made more accurate by taking into account the radiation of the planetary body it orbits in addition to solar radiation. In addition, multiple nodes should be used to calculate the objects temperature at multiple points rather than at a single node and assuming constant temperature throughout. This could be done using a finite element model of the satellite and using software for the analysis.

Table of Contents

AE 4361 HW 8 Workspace

By: Noe Lepez Da Silva Duarte Created: 02 April 2022

```
clear
close all
clc
```

Q1

Part a

```
mf = 1000;                                       % [kg]
ve = 4400;                                       % [m/s]
dv = 9400+3260+680+1730;                         % [m/s]

mi = mf/(exp(-dv/ve))

% Part b
mass_fac = (exp(-dv/ve))*100

% Part c
dv_intercept = 9400+3260;                        % [m/s]
mi_intercept = mf/(exp(-dv_intercept/ve))

% Part d
dv_int_surf = 680+1730;                          % [m/s]
mi_int_surf = mf/(exp(-dv_int_surf/ve))

% Part e
mass_fac_e = mf*100/(mi_int_surf+mi_intercept-1000)
```

```
mi =

   3.0723e+04


mass_fac =

    3.2549


mi_intercept =
```

```
   1.7766e+04


mi_int_surf =

   1.7293e+03


mass_fac_e =

    5.4068
```

Q3

```
a = 0.6;
e = 0.8;
SB_const = 5.67E-8;                                 % [W/(m^2 K^4)]
A_in_min = 0.1^2;                                   % [m^2]
A_in_max = 0.01299;                                 % [m^2]
A_out = 6*0.1^2;                                    % [m^2]
I_earth = 1366;                                     % [W/m^2]

% Part a
P_in_min = I_earth * a * A_in_min;                  % [W]
P_in_max = I_earth * a * A_in_max;                  % [W]

P_o = e*SB_const*A_out;

T_min_K = ((P_in_min)/(P_o))^(1/4);                 % [K]
T_max_K = ((P_in_max)/(P_o))^(1/4);                 % [K]

T_min = T_min_K -273.15                             % [C]
T_max = T_max_K -273.15                             % [C]

% Part b
P_int = 8;
T_min_K = ((P_in_min+P_int)/(P_o))^(1/4);           % [K]
T_max_K = ((P_in_max+P_int)/(P_o))^(1/4);           % [K]

T_min_b = T_min_K -273.15                           % [C]
T_max_b = T_max_K -273.15                           % [C]


% Part c
I_mars = I_earth/1.5^2;
P_int_mars = P_int/1.5^2;

P_in_min_mars = I_mars * a * A_in_min;              % [W]
P_in_max_mars = I_mars * a * A_in_max;              % [W]
T_min_K = ((P_in_min_mars+P_int_mars)/(P_o))^(1/4); % [K]
T_max_K = ((P_in_max_mars+P_int_mars)/(P_o))^(1/4); % [K]
```

```
T_min_mars = T_min_K -273.15                              % [C]
T_max_mars = T_max_K -273.15                              % [C]
```

```
T_min =

  -38.8920


T_max =

  -23.0580


T_min_b =

    4.5948


T_max_b =

   14.5539


T_min_mars =

  -46.3724
```

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