I. Introduction

Director Gene Kranz,

I hope this report finds you well. I have conducted the necessary calculations regarding gravitational potential and gravitational fields for the Earth-Moon system and the altitude of the Saturn V rocket. You will find crucial information below about the considerations you must make in order to complete the Apollo mission and defend NASA funding. In order to carry out this mission it is important to know why we must understand the gravitational interactions by the Earth and Moon. The knowledge of gravitational forces on objects in space allows us to predict how objects near the Earth and Moon will behave and what the trajectory of spacecraft will look like.

II. The Gravitational Potential of the Earth-Moon system

Gravitational potential is the amount of energy an object has depending on the mass of the gravitational body and the distance from the object to the body. In the case of an Earth-Moon system, gravitational potential is the sum of the gravitational potential on an object at some position due to the Earth and gravitational potential at that same point from the Moon. The gravitational potential of an Earth-Moon system is represented by color mesh grids that display the gravitational potential at a position (x,y). In order to create this plot, I had to define a function that received the position of the object, the position of the moon and earth, and the mass of the moon and earth. Through object-oriented plotting, this color plot was made possible and is equipped with a logarithmic color bar (Appendix 1). This figure informs us that there is a drop in gravitational potential as you travel outward from the Earth, and when nearing the Moon, the gravitational influence from the Moon becomes stronger.

III. The Gravitational Force of the Earth-Moon System

The gravitational force of the Earth-Moon system is reliant on the masses of two objects and the distance that separates them. In order to calculate the gravitational force from the Earth and the Moon, the forces in the x and y direction had to be calculated. To illustrate the combination of gravitational forces from the Earth and Moon, I created a 2d stream plot which shows the direction and strength of a force depending on the object's position. This is crucial for mission planning because the gravitational field changes depending on the object's position. This figure should shed some light on the stronger gravitational forces as you approach the Earth and the Moon (Appendix 2).

IV. Projected Performance of the Saturn V Stage 1

In order to predict the Saturn V performance, we must examine the Tsiolkovsky rocket equation which depends on exhaust velocity, initial mass, mass as a function of time, and gravitational acceleration. First, in order to derive burn time, I calculated the difference between wet mass and dry mass divided by the burn rate. I then integrated the change in velocity to find the altitude that the rocket will reach. In order to integrate I called a function from the scipy library which provided a quicker route to an accurate integral. I found that Saturn V would have a burn time of approximately 157.7 seconds and an altitude of roughly 74 kilometers once it had reached the burn time.

V. Discussion and Future Work

Throughout these calculations, for simplicity, I have made several approximations. When doing calculations involving the Earth and Moon, these bodies were treated as point masses. Additionally, drag was neglected which will affect the motion of a spacecraft through the atmosphere. To be more precise, it is important to consider these factors. In the future, the spherical characteristics of the Earth and Moon should be considered which would affect the distribution of mass. Drag force would largely affect the final altitude of the spacecraft because it is a resistive force. More force, and in turn more fuel, would be necessary to propel the rocket to the same altitude. Including drag would lengthen the burn time and lower the altitude. For this reason, the burn time is an underestimate, and the final altitude is an overestimate. I wish you luck in your efforts to defend NASA's funding and hope these calculations prove to be useful.

Best, Riley Lutz.

Appendix: