**Discrete Mathematics Project.**

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**A1. Presentation of Problem:**

The Apollo 11 mission that took place in July 1969, marked a turning point for humanity. For the first time in human history, people everywhere understood the brilliance of human ingenuity, even in the most demanding scenarios **(Loff, 2015)**. Conquering space, apart from being one of the most scientifically important ventures in our times, has proven to be the cornerstone of our modern way of life, with most modern technologies we come to rely upon being the results of our need to overcome the great cosmic barrier **(Garcia, 2018)**. Capitalizing on the positive publicity generated by NASA’s Artemis mission to return humanity to the moon **(*NASA’s Lunar Exploration Program Overview*)** it is the perfect opportunity to launch project Zagreus, the first interplanetary expedition, aiming to establish a transport route between several natural satellites of our solar system. This project, bearing the flag of the European Union, not only will provide invaluable scientific data about the moons visited, but will also be the starting point of the first net for economic growth outside the bounds of earth. After the establishment of the projected outposts in key locations in our solar system, a trading route can be established for any privately owned company to engage in colonizing or mining operations in hundreds of possible celestial bodies, all under EU regulation and taxation. With the rise of privately owned space exploration companies like SpaceX, it is paramount to establish governmental presence in order to avoid an onset monopoly of celestial material usage from any one private organization.

**A2. Choosing Destinations:**

The destinations for this project were chosen based on three criteria, habitability, material excess, and fuel cost mitigation. Saturn’s biggest moon, Titan, is considered one of the most habitable celestial bodies in our solar system, its pressure being accommodating to machinery and its atmosphere providing plentiful material for energy and construction purposes **(Hendrix, 2017).**

From Titan, it is important to also move to Triton and establish an outpost, as it will enable the possibility of quick expansion on the surface, providing a base for launch pads that will enable the exploration of the rest of Saturn’s 82 moons.

It is important to note, that the distance between Saturn and Jupiter, is larger that the distance between Jupiter and Earth. Thus, setting up outposts on Jupiter’s moons is advisable, to maintain a flexible set of destinations within the route. For the same reason it is best to make one more stop halfway from Earth to Jupiter, on a dwarf planet called Ceres.

These stops will allow for cargo exchange, refueling, resupplying, and exchanging information, for all patrons of the trading route, thus establishing a safer, and more efficient economic environment.

Another point worth noting, is that we wish to avoid landing on Jupiter or Saturn. Since they are gas giants, it will be extremely difficult to set up outposts on these planets, while their extreme gravitational fields make launching outlandishly expensive and dangerous. Thus, it is better to make use of the more friendly natural satellites like Titan and Triton orbiting Saturn, as well as Callisto, Ganymede, Europa, and Io orbiting Jupiter.

These destinations, apart from being strategically valuable, are also the most well investigated from previous missions, a fact that will allow us to make use of pre-existing data and technologies, instead of wasting decades performing scouting missions to ensure their viability.

**A3. Collecting Data:**

In this section, the relevant data found in the excel file will be explained as well as all the assumptions and calculations made to reach the presented estimates. Please note that excess data have been included to facilitate further optimizing calculation if need arises. These data will not be explained here, however official explanations can be found [here](https://nssdc.gsfc.nasa.gov/planetary/factsheet/planetfact_notes.html#diam).

The distances between moons and their non-primary planets are calculated as follows: Moon to primary planet, then primary planet to non-primary planet.

For the distances between moons are calculated as minimum estimates, since their proximity along with their short orbits, make it easy to execute trips at maximum efficiency.

For interplanetary trips calculations become inherently more complicated, as they have longer orbits, and many celestial bodies in-between, forcing sub optimal routes to move from one to another. Thus, for these calculations, average distances from the sun are used.

To calculate approximate times for travelling, the speed of the vehicle must be known. Since space vehicles are custom made for every mission, and since this undertaking is to be the first of its kind, all the parameters of the journey need to be established and then the type of vehicle can be approximated.

The first wave of Project Zagreus is to be an uncrewed deep space endeavor. Deep space probes are known to reach extreme velocities when airborne, however our vehicle will not simply pass by the celestial bodies or even orbit them. What we need is something close to a lander space probe like the Mars polar lander **(*1998 Mars Missions*)**.

On the topic of energy, there is a discussion to be made about the composition of the instruments that will power this endeavor. Escaping earth’s gravity is no small feat, as it requires trillions of joules of energy; however, the most challenging task will be to land and take off again multiple times during the trip. To overcome these obstacles, we suggest the following. A delta III type rocket **(*Delta* Britannica)** will be used to carry the vehicle outside Earth’s gravitational influence, then the vehicle will be equipped with ion-engines, to efficiently adjust its course over long periods of time **(*Deep Space 1 In Depth* 2019)**, and a Radioisotope Power System (RPS) to maintain the operation of all electrical subsystems and subsequent launches. Probes could be used to scout the area around each landing zone for materials that can be used to refill the RPS power supply.

All the technologies that will be used in the trip add a significant weight to the vehicle, this fact, along with the limited energy supplies for subsequent launches, means that the average velocity will not be as good as other space probes. A very positive estimate for the speed could thus be at around 50,000km/h.

To calculate the time needed to reach each destination, we will divide the distance with our average velocity.

Finally, for the energy calculations we use the [formula](http://webhome.phy.duke.edu/~rgb/Class/phy51/phy51/node9.html) for escape energy and we assume an approximate weight of 308000 kg from earth since we count the weight of the vehicle and the Delta III rocket, while from other planets we use the approximate weight of 8000 kg.

**A4. Project statement:**

As evident from these approximations, this will most certainly be the greatest scientific endeavor, as well as the greatest engineering challenge, of mankind. Due to the extreme lengths of the journey and the cost the entire operation, it is critical to make proper preparations and proceed with utmost caution.

The lack of energy resources and the fact that such long-distance communications will be difficult, the entire task will need to be manned by sophisticated software to control the vehicle along with the several drones and probes that are going to be included.

However, the great cost, and the long years of preparations will be more than worth the effort, as project Zagreus will mark the definitive first step of humanity toward interplanetary economic growth.

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