Mission to Mars: A Solution for the Meal Plan

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Summary

In this research paper, we needed to determine suitable crewmates to colonize Mars so first, we found requirements for astronauts in which a master's degree in STEM was needed. We determined what would be useful on the desolate globe. Among our findings, engineers, biochemical engineers, chemists, and doctors are required for the functioning of our colony. We found this by determining needs for colonization such as establishing agriculture, communicating with Earth, and performing maintenance. Furthermore, for a shipment plan, we found the amount of food needed for survival to sustain life for long periods. Meals needed to last crewmembers for six months for the initial trip, the year on Mars with no new shipments, and the additional shipments accompanied by two astronauts to last the crew a year. Further on, for the agricultural plan, by considering variety, nutritional value, and cost of meals we were able to rank meals on a variety-nutrient-cost scale. Taking the calorie intakes of the astronauts and time during both the flight and waiting for new provisions on Mars. In this plan, hydroponics will be set up on the surface of the Martian planet to sustain the colony. Agriculture is split into nutrients, variety, and cost which will incorporate Kale, Beets, and Potatoes. Furthermore, we considered astronauts will not be able to survive from plants alone, so we incorporated Rainbow Trout, through hydroponics. Our plants benefit from this system as well. This provides the crew with an intertwined ecosystem providing all the necessary nutrients required for survival while being self-sustaining and requiring minimal support from Earth.

Mission to Mars

Background Information

Landing on the moon was a major milestone for space exploration and since then mankind has not stopped with ambitious goals. As the earth faces problems like global warming and overpopulation, space agencies have set their gaze on the red planet. This goal comes with its own set of unique challenges such as transportation to Mars, life support, and growing food among other things. Balancing the amount of food taken into space is an important role as not only does the food have to sustain the astronauts but it must not weigh down the ship to the point where it is over optimal weight. It is important to note that in space astronauts have been observed to consume around 80% less of their calorie intake on Earth (Taylor et.al, 2020). The introduction of new technology has made the possibility of a colony on Mars closer to reality than ever before. The food aspect leads to issues not only in rocket science but also in cost, nutritional value, and variety.

Restatement of the Question

In this analysis, our team was asked to determine which skills and how many subjects must be considered to undergo a Mars settlement mission and the amount of food needed based on nutritional content, variety, and cost. The first supply, located with the crew, must last the whole duration of the flight. While the second supply, sent to Mars before the flight, must last the crew until the establishment of optimal agricultural production. Finally, we were tasked to determine an effective agricultural plan for the settlement, which is advanced by additional shipments sent at regular intervals.

Global Assumptions

The following are the assumptions we used consistently throughout the entire model:

- Subjects are used to Mars's features
- A utopia with no economy is instituted into Mars diplomacy (every subject has perfect morals and is not greedy at any point)
- Food survives the trip (exit and re-entry)
- Subjects only need 20% of the recommended caloric intake here on earth because of the reduced energy expenditure from astronauts due to low gravity
- Nothing tragic, such as a heart attack, happens among the crew while colonizing
- Harvests always yield 100% of expected production, both fish and plants
- Food prices are in US dollars

Analysis of the Problem and the Model

Skills and Flight Manifest

Living on Mars will require a great variety of skills to not only survive but to conduct research and perform maintenance on the ship. NASA's current plan is to send a team of four astronauts to Mars. We decided to increase this number to six as the intent of this mission is to colonize Mars. These individuals should have a 1:1 ratio of male to female, so the colony may increase in size over time. Furthermore, with NASA's astronaut selection requirements, an aspiring astronaut should have at least a master's degree in a STEM-related field and be able to pass the physical test. Therefore, to keep the colony functioning, a mix of engineers, chemists, computer scientists, and biomedical scientists should be considered. Since Mars is lightyears away, space agencies will not be able to send replacement astronauts, thus, astronauts should be capable and knowledgeable of the systems intimately to repair specific sections of the ship, hence, engineers are needed, and engineers should be proficient in machining to create their parts. The life support systems responsible for keeping the astronauts alive are sensitive and require someone knowledgeable in its chemistry, meaning a chemist is needed. Water filtration and oxygen filtration will keep the crew alive, so it is crucial to maintain optimal status. A computer scientist is not only crucial to the recollection of data on Mars. Someone versed in physical sciences like geology would be able to translate their degree into farming with hydroponics and traditional styles to help with food growth. Furthermore, someone well versed in medicine will be crucial to be able to use lichenology for medication and maintain the colony's health (Jordan, 2020).

Career Research

Elon Musk

Biography: According to Biography.com and their editors, Elon Musk was born in Pretoria, South Africa. In 1992, Musk left Canada to study business and physics at the University of Pennsylvania and graduated with an undergraduate degree in economics. He stayed for a second bachelor’s degree in physics and later went on to become the founder of SpaceX and now presides as the CEO of the company (2021).

Career: According to Biography.com Musk founded his third company, Space Exploration Technologies Corporation, or SpaceX, in 2002 intending to build spacecraft for commercial space travel. By 2008, SpaceX was well established, and as a result, NASA entrusted Space X with a contract where they would supply the ISS with supplies. On May 22, 2012, Musk and SpaceX made history when the company launched its first rocket dubbed the “Falcon 9” to space with an unmanned capsule. The space craft was sent to the International Space Station with supplies weighing approximately half a ton for the astronauts stationed there. Which incidentally marked the first time a private company had dispatched a spacecraft to the International Space Station (2021).

Adam Steltzner

Biography: According to Davis College of Engineering, Adam Steltzner is an American NASA engineer who presently works at the jet propulsion laboratory in California. Adam Steltzner is a decorated member of NASA who has worked on several missions including Galileo, Cassini, Mars Pathfinder, Mars Exploration Rovers. Currently he is the lead engineer of the mission to Mars. Steltzner obtained his master's degree in applied mechanics from Caltech in 1991 and later, obtained his P.H.D. in engineering physics at the University of Wisconsin-Madison in 1999. (2013)

Career: Today, Steltzner is a member of NASA's Jet Propulsion Lab where he worked on notable projects such as Mars Pathfinder and Mars Exploration Rovers. His most notable achievement being the landing mechanism for the curiosity rover. Which consisted of a rocket-powered landing bay that lowered the curiosity rover via cables. Although the idea was unique in its basis and function, the Curiosity Rover had a successful landing. His brilliant design led him to have himself immortalized in the 2004 book, *Going to Mars: The Stories of the People Behind NASA's Mars Missions.* (UC Davis, 2013).

The Meals

Identifying the Meals

The production of food on Mars is one of the most important ideas regarding Mars colonization as it provides stability and self-reliance. The four main ingredients used in meals were chosen due to their nutritional content and ease of cultivation related directly to their time of growth. The first food, the potato, was chosen for its various nutrients carrying a bit of everything needed for survival lacking only Vitamin A, Vitamin B-12, Vitamin E, and Calcium, ("Potatoes," 2021). Potatoes only take 70 to 120 days to grow (Connexion, 2010) and contain 77 calories per 100 grams (USDA, 2021). Potatoes are also relatively cheap and only cost $0.17 (Coppola, 2021). Kale, a known superfood, is one of the most nutrient-dense foods on Earth while only taking two months to grow (Iannotti, 2021) and thus is a fitting food to bring to Mars. Kale also carries both Calcium and Vitamin A, which accounts for two of the Potato's missing nutrients and contains 49 calories per 100 grams (USDA, 2021). Also, Kale only costs $0.63 (USDA, 2016). Next is Rainbow Trout, a freshwater fish that is rich in nutrients containing B-12 (USDA, 2021) and grows in 9 months (Towers, 2010), which is substantially less than similar fish such as Salmon. Rainbow trout would be introduced into a hydroponics system where it would be placed into an ecosystem of algae, lichens, plankton, and smaller fish to be farmed while also assisting in the growth of the other foods. Rainbow trout itself contains 141 calories per 100 grams (USDA, 2021) which costs $1.93 (City Fish, 2020). Beets are a bit different as they have split into two parts the stem and the root and while both are nutritious the stem has Vitamin K while the root does not (USDA, 2021). They take 7-8 weeks to grow (Masabni, 2021) and while nutrient-rich in both parts, they will be stated as beets unifying them as one entity unless distinguished as beetroot or bulb of the plant. Beets carry 43 calories per 100 grams (USDA, 2021) and cost $0.35 (Park Slope Food Coop, 2021). Blueberries were researched to explore the idea of luxury foods not necessary to a nutritious diet. Blueberries cost $4.39 US per pound (USDA, 2016) and provide 57 calories per 100 grams (USDA, 2021). Blueberries have a growth time of 2-3 years (Madore, 2021), which logically makes them an ineffective ingredient choice for our meals even though blueberries carry many nutrients and antioxidants.

Meals were influenced by calorie intake, nutrients provided, and price in which calories must not exceed 560 calories due to one meal per day system in Mars’s colony. Some meals will lack some nutrients, which will be found in the others, to encourage varied consumption.

Quantity of meals is measured in hectograms (hg) to allow the calculation of calories and cost due to food calorie intake and pricing of food being measured in 100 grams. As an example, there are 100 grams of foodstuff as such it is measured as 1 hectogram and then multiplied by how many calories or U.S dollars are in 100 grams of that foodstuff.

Meal 1: Pan-fried trout with Kale & potatoes

The first meal is a simple meal that is packed with 27 nutrients consisting of 3.5hg potatoes, 1.8hg trout, and 2.7hg Kale. Meal 1 has 270 calories in potatoes $(3.5\ hg \times 77\ calories)$ along with 254 calories in trout $(1.8\ hg \times 141\ calories)$ and 132 calories in Kale $(2.7\ hg \times 49\ calories)$ adding up to 656 total calories. The price comes from $0.60 US in potatoes $(3.5\ hg \times \$0.17)$ along with $3.56 in trout $(1.8\ hg \times \$1.98)$ and $1.70 in Kale $(2.7\ hg \times \$0.63)$ adding up to a total price of $5.86.

Meal 2: Roasted Beetroot & Potatoes

The second meal is a filling entree with 17 nutrients containing 450g potatoes and 470g Beetroot. Meal 2 has 347 calories in potatoes$(4.5\ hg \times 77\ calories)$ and 202 calories in beetroot $(4.7\ hg \times 43\ calories)$ which adds up to 549 total calories. The price comes from $0.77 in potatoes $(4.5\ hg \times \$0.17)$ and $1.66 in beetroot $(4.7\ hg \times \$0.35)$ which adds up to a total price of $2.43.

Meal 3: Kale Colcannon

The third meal is a simple food with 20 nutrients that can be eaten by those with a sensitive stomach consisting of 450g potatoes and 440g Kale. Meal 3 has 347 calories in potatoes $(4.5\ hg \times 77\ calories)$ as well as 216 calories in Kale $(4.4\ hg \times 49\ calories)$ which equals a total caloric intake of 563 for this meal. The price comes from $0.77 in potatoes $(4.5\ hg \times \$0.17)$ as well as $2.77 in Kale $(4.4\ hg \times \$0.63)$ adding up to a total price of $3.54.

Meal 4: Coulibiac of Rainbow Trout with Pickled Beets and Kale with Kale casing

The fourth meal is of a more refined palette as a delicacy originating from Russia containing 25 nutrients and consisting of 330g Kale, 180g trout, and 250g beets. Meal 4 has 162 calories in Kale $(3.3\ hg \times 49\ calories)$ along with 254 calories in trout $(1.8\ hg \times 141\ calories)$ and 108 calories in beets $(2.5\ hg \times 43\ calories)$ which adds up to 524 total calories. The price comes from \$2.08 in Kale $(3.3\ hg \times \$0.63)$ along with \$3.56 in trout $(1.8\ hg \times \$1.98)$ and \$0.88 in beets $(2.5\ hg \times \$0.35)$ at a total price of \$6.52.

Meal 5: Shepherd's pie

The fifth is a traditional dish made up of 550g potatoes and 340g Kale. Meal 5 consists of 424 calories in potatoes $(5.5\ hg \times 77\ calories)$ and 167 calories in Kale $(3.4\ hg\ \times 49\ calories)$ with 591 total calories. The price comes from \$0.94 from potatoes $(5.5\ hg \times \$0.17)$ and \$2.14 from Kale $(3.4\ hg \times \$0.63)$ which adds up to a total of \$3.08.

Justifying the Meals

$$v = 2^{(a-1)} \text{ (Variety value)}$$

v = level of variety in a specific meal

a - # of ingredients in the meal

$$n = 1.22^{(z-17)} \text{(Nutritional value)}$$

n - level of nutrition in a specific meal

z - # of minerals, vitamins, etc

$$S = \frac{vn}{c} = \frac{(2^{(a-1)})(1.22^{(z-17)})}{c} \text{ (Meal ranking)}$$

R - a ranking based on the score value (1-5) (Lower is better)

S - score (Rounded to the nearest tenth)

c - the cost of a specific meal

These equations rank meals regarding their variety of ingredients, nutritional value, and cost. To determine the value level of the variety of nutrients in the food (v) we used a base 2 exponential equation where the exponent is equal to the number of ingredients minus one. This would make our lowest-ranked food have a variety rating of 2. Furthermore, we ranked the amount of nutrition in any given meal by using an exponential equation with a base of 1.22 (would make our range of values from 1-5) and raised it to the power of the nutritional contents (z) minus the lowest nutritional contents in a single meal (17). This in turn would make our least ranked meal a one on a five-point scale. Lastly, we compounded these formulas and divided the products by the cost to produce the meal which ultimately gave us a ranking on the meals on a 5-point scale where we could compare which type of meals should be valued on the trip. By using exponential models, we made sure that a meal with little variable could sway the ranking of the meals disproportionately, therefore, giving us tangible data, we can compare to decide on the best choices. The following table outlines the data used in the equation.

	Cost (c) ($)	Ingredients (a)	Nutrition (z)	Score (s)	Ranking (R)
Meal 1	5.86	3	27	5	1
Meal 2	2.43	2	17	.8	5
Meal 3	3.54	2	20	1	4
Meal 4	6.52	3	25	3	2
Meal 5	3.08	2	20	1.2	3

The outputs of our model assign rankings (where higher values are related to better meals) to different types of meals by considering cost, variety, and nutrition. We will use all 5 provided meals but, this gives insight into which meals are better overall for the trip. The reason nutrition and variety are connected is that they benefit the meals greatly and will help astronauts tolerate the lack of meal diversity for longer periods. Furthermore, while the cost can help make things fairer because, generally, cheaper meals consist of less nutritional value than their more expensive counterpart. This establishes cost as a limiting factor acting on the meals and is something the crew and Homebase must account for.

Food Shipment Plan

This plan is deciding how much food needs to be sent to Mars. Every year, two astronauts will be sent with the appropriate amount of food. This amount of food is dependent on the number of crewmates already on Mars and will increase yearly with the introduction of new crewmates. According to Space X, their estimations on a trip to Mars is 6 months to reach the red planet (2021). Since astronauts and food will be sent yearly, there is no need to procreate or grow food on the Martian planet.

$$F = \frac{wc+yp}{m} = \frac{180c+365p}{5} = 36c + 73p$$

w - # meals for subjects during flight

c - # of people on flight

y - # of days in the year (365)

p - # of people in the total crew (on Mars and flight)

m - # of meals in our plan (5 meals = 1 set)

The following table shows the amount of food shipped for the initial crew and its additions.

Years	People	Flight Food (sets/meals)	Mars Food (sets/meals)
0	6	216/1080	438/2190 (waiting on Mars)
1	8 (+2)	72/360	584/2920 (brought by flight) ↓
2	10 (+2)	72/360	730/3650
3	12 (+2)	72/360	876/4380
4	14 (+2)	72/360	1022/5110

The output value of the equation yields the total number of meals needed for the crew to survive the trip to Mars, the food waiting on Mars to help the crew establish agricultural processes, and the plan for new crew members to be sent to Mars with sufficient food for all the crew to survive at least year while provisions are sent. Astronauts will need their baseline daily caloric needs met both on and off the ship. Since astronauts consume less food in space the amount of food necessary for survival is less than on Mars. When adding two crewmembers each year, they must carry the food they will need for both the trip and enough food for the original crew on the planet and its additions to survive a year.

Agricultural Plan

This plan incorporates the crew needing to farm for food which goes along with our meal sets needing to contain all the necessary vitamins and minerals. During this plan, astronauts and food will not be shipped from Earth and, therefore, will eventually procreate. The agricultural production will be able to be ramped up to fully sustain procreation but overall, these details should have no effect on food needed on Mars or the flight in the beginning.

$$F = \frac{dp}{m} = \frac{6d}{5}$$

F - # of meals (grouped in sets of 5 because of # of different meals)

d - # of days

p - # of people in the crew (6)

m - # of meals in our plan (5) (1 set)

The following table shows the growth rates of ingredients found in our meals.

Food	Time till full production of crops(months)
Potatoes	2 (60 days)
Kale	2 (60 days)
Beets	2 (60 days)
Trout	9 (210 more days)
Blueberries	24 (a luxury that is not a priority but will be incorporated when grown)

The next table shows the incorporation of the previous information to provide the number of meals needed.

Days	Food required (sets/meals)
180 (flight time)	216/1080 (on flight)
60 (production time for Beets, Kale, Potatoes)	300/1500 (waiting on Mars)
210 (Fish needed while waiting for hydroponics)	42/84 (just meals with fish (⅖) (waiting on Mars)

The output value of this equation yields the total number of meals needed to survive the trip to Mars, and the food waiting on Mars to help the crew in starting a sustainable farm. The thought process behind this is that astronauts consume 80% fewer calories in space therefore their consumption of food drops from three meals to one. Therefore, we only account for one meal during the trip to Mars. One meal per astronaut yields six meals daily while on the ship. Therefore, we take the number of daily meals times the number of days and then divide it by the total number of meals available to get a set. A set is one full menu for one person (all 5 different meals)

Strength of the Model

One of the greater strengths of the model would have to be the simplicity of the organizing and ranking systems finding how well meals would be ranked in a way that if new meals with different ingredients were introduced there would be no complications. The intertwined food cultivation system is also a bigger part of the model as it incorporates hydroponics allowing the rainbow trout a place to thrive and the plants a better agricultural system. The change in meals per day from three to one due to humans needing fewer calories also considers the Martian diet. The model also considers the food needed to make the journey to Mars and survive long enough to establish agriculture. The continuation of the colony is also considered quite well with all subjects being highly qualified trained subjects with specific roles. Unfortunately, the model fails to account for Mars taking longer to revolve around the Sun. This will make the flight time to Mars, not a set amount of time which means more food needs to be taken for the two crew members in the shipment plan or more food needs to be brought the previous year. Another fault of the model is to not account for radiation as it is assumed facilities will shield the subjects and the plants. Although there is a chance it may occur, there is not enough research on irradiated foods to come up with a definitive conclusion. Another fault of the system is not considering genetically modified foodstuffs that may be more nutritious than common products as it would be less likely to find a retail price for the lesser-known foodstuffs. Another identified weakness of the model is the assumption that an astronaut’s daily calorie intake is roughly 20% may not be accurate which may increase the amount of food needed. Overall, the model does a proficient job of covering all bases with the information available to us. The organizational system of the meal system allows for consideration of calorie intake with nutrients kept in mind. The agricultural system is tidy and intertwined with careful consideration for planning as food sent on the first voyage to Mars is enough to keep subjects alive while they develop said systems. Our model has shortcomings in the level of math we have available but is made up of representative values that have significance. There is also a clear consideration on the selection of the first Martian colonizers for the establishment, preservation, and expansion of the colony on Mars.

Conclusion

Going to Mars has many challenges that space agencies must tackle for the safety of the astronauts. In our research, we found the future astronauts not only will have to meet NASA’s baseline requirements in both educational and physical prowess but also, they must be able to go above and beyond certain aspects. One of the many aspects they must excel in is ship maintenance. Since Mars is so far from earth, astronauts will be forced to have an intimate understanding of the ship and the equipment they use so they can repair specific sections of the module instead of replacing it entirely like they currently do. In these aspects, we also found the technical skills needed to keep the colony functioning and created a flight manifest taking this into account. Further on, by considering variety, changes nutritional values, and cost of meals we were able to rank meals on a variety-nutrient-cost scale. Taking the calorie intakes of the astronauts and time during both the flight and while waiting for new provisions, we devised a food transport plan where astronauts will be able to survive a year at a time from sent provisions. We also devised an agriculture plan where hydroponics will be set up on the surface of the Martian planet to sustain the colony. Furthermore, we considered astronauts will not be able to survive from plants alone so we incorporated freshwater fish so they could assist their plants in their growth. Colonizing Mars will take extensive planning in multiple challenging areas but if space agencies push each other to innovate, humankind will be able to achieve this historic milestone.

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