Planning a Trip to Mars

SpaceX successfully launched the world's most powerful rocket from the Kennedy Space Center in Florida on Feb 6, 2018 but the trip to Mars has many challenges. NASA has said it plans to send people to Mars in the 2030s. SpaceX may send its first crewed mission to Mars as early as 2024.

https://mars.nasa.gov/mars2020/spacecraft/launch-vehicle/

Planning and self-sufficiency are essential keys to a successful Martian mission. Facing a communication delay of up to 20 minutes one way and the possibility of equipment failures or a medical emergency, astronauts must be capable of confronting an array of situations without support from their fellow team on Earth. Read about some of the obstacles that scientists are hurdling to get humans to the Red Planet. https://www.sciencenewsforstudents.org/article/preparing-trip-mars

We have to figure out how space travelers will get any tools they may suddenly need when they're millions of miles from the nearest hardware store. We have to figure out where our food and water will come from. Rather than a three-day lunar trip, astronauts would be leaving our planet for about three years. Once you burn your engines for Mars, there is no turning back and no resupply.

People need water and air, along with some equipment to recycle water and air. Humans need a lot of food for an extended expedition, and some means of recycling solid waste. Space food isn't just that astronaut ice cream you might have tried. https://www.youtube.com/watch?v=vTgnCaBVaj8

The Mars 2020 mission is designed to launch at a time when Earth and Mars are in positions in their orbits that is advantageous for spacecraft traveling to and landing on Mars. This favorable position of the planets means that it takes less launch energy to get to the Red Planet compared to other times when Earth and Mars are in different positions in their orbits around the sun.
https://mars.nasa.gov/mars2020/spacecraft/launch-vehicle/

Launch Vehicle:	Atlas V-541
Height with payload:	191 feet (58 meters)
Mass, fully fueled, with spacecraft on top:	About 1.17 million pounds (531,000 kilograms)

A trip to Mars might take nearly a year — and a huge amount of fuel. To get anything from Earth's surface into space – whether this "anything" is a spaceship, an astronaut, or some fuel for the journey – takes several tons of fuel to use as propulsion per ton of "stuff" launched into low Earth orbit. The Mars spacecraft will need to get into low Earth orbit, then get boosted to high Earth orbit before it can go to Mars. All of these steps require fuel. The trip through space to Mars is essentially "free" from a fuel standpoint. Some energy will be needed to power the spacecraft's systems, but there will not be any need to burn fuel until the spacecraft gets closer to Mars.

Astronaut Don Pettit explained the engineering problems of making a rocket that is 85% propellant and 15% rocket? "The rocket must have engines, tanks, and plumbing. It needs a structure, a backbone to support all this and it must survive the highly dynamic environment of launch (there is fire, shake, and force at work.) The rocket must be able to fly in the atmosphere as well as the vacuum of space. Wings are of no use in space; small rocket thrusters are used to control attitude. Then there are people with their pinky flesh and their required life support machinery. Life support equipment is complex, problematic, and heavy. You can't roll down the windows if the cabin gets a bit stale. If you want to return to Earth (and most crews do), there has to be structure to protect the crew through a fiery entry and then provide a soft landing. Wings are heavy but allow soft landings at well-equipped airfields. Parachutes are light, giving a big splash finale. The Soyuz goes thump, roll, roll, roll; aptly described by one of my colleagues as a series of explosions followed by a car wreck. And finally, you want to bring some payload – equipment with which to do something other than just be in space. Missions into space to do meaningful exploration require bringing significant payload."
https://www.nasa.gov/mission_pages/station/expeditions/expedition30/tryanny.html

Vehicle	Percentage Propellant (fuel)
Large ship	3
Pickup Truck	3
Car	4
Locomotive	7
Fighter Jet	30
Cargo Jet	40
Rocket	85

1. How heavy is the Mars launch vehicle, Atlas V-541? How many tons is this if 2,000 pounds = 1 ton?

2. If typical rockets have 85% of their total weight in fuel. How many pounds of fuel would there be on the Atlas V-541? How many tons is this?

3. Calculate how much is left on the total rocket weight that would account for the rocket itself and the payload (all the other stuff).

4. Landing on Mars has its own challenges. This 60-second video from NASA explains three ways to land on Mars. Which option would you prefer if you were a passenger? Explain
https://www.jpl.nasa.gov/edu/learn/video/mars-in-a-minute-how-do-you-land-on-mars/

5. During a rocket launch and the boost to orbit, the altitude of the rocket changes continuously as the engines provide thrust, eventually lifting the entire payload into orbit. A short table of the rocket's altitude and times is provided below.

Elapsed Time (seconds)	Altitude (miles)	Altitude (kilometers)
160	46	
192	60	
268	81	
274	83	
315	95	
319	97	
339	112	

American engineers use English units for all measurements including the details of the rocket launch where 1 mile = 1.6 kilometers. Use this information to complete the table above in metric units rounded to the nearest kilometer.

From the table, graph the altitude of the rocket in time.

From the data, find the function A(t) that predicts the altitude of the rocket at future times. The function will be of the form

$A(t) = a + b \ln(t)$

Find the constants a and b for A(t) in kilometers and A(t) in miles.

6. How many seconds after launch will it take for the rocket to reach orbit altitude at 420 kilometers?

Answers:

1. How heavy is the Mars launch vehicle, Atlas V-541? How many tons is this if 2,000 pounds = 1 ton?

    1.17 million pounds or 585 tons

2. If typical rockets have 85% of their total weight in fuel. How many pounds of fuel would there be on the Atlas V-541? How many tons is this?

    994,500 pounds of fuel or 497.25 tons

3. Calculate how much is left on the total rocket weight that would account for the rocket itself and the payload (all the other stuff).

    175,500 pounds or 87.75 tons

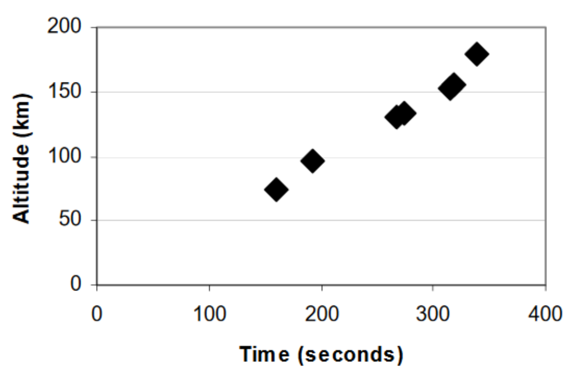
4. Landing on Mars has its own challenges. This 60-second video from NASA explains three ways to land on Mars. Which option would you prefer if you were a passenger?
https://www.jpl.nasa.gov/edu/learn/video/mars-in-a-minute-how-do-you-land-on-mars/

    Answers will vary

5. Question 5 and 6 are from Space Math IX
https://www.nasa.gov/sites/default/files/atoms/files/space_math_ix_2015.pdf

American engineers use English units for all measurements including the details of the rocket launch where 1 mile =1.6 kilometers.

Elapsed Time (seconds)	Altitude (miles)	**Altitude (kilometers)**
160	46	**74**
192	60	**96**
268	81	**130**
274	83	**133**
315	95	**152**
319	97	**155**
339	112	**179**



From the data, find the function A(t) that predicts the altitude of the rocket at future times. The function will be of the form

$A(t) = a + b\ln(t)$ Find the Constants a and b

Answer: Choose (160,74) and (319,155)

then 74 = a +5.1b and 155 = a + 5.8b

Solve by substitution: a = 74 - 5.1b then 155 =(74-5.1b) + 5.8b

So 81 = 0.7b and b = 116. Then a = -518

So with A(t) in kilometers, and t in seconds, we have:

$A(t) = -518 + 116\ln(t)$

In miles this becomes $A(t) = -324 + 73\ln(t)$

6. How many seconds after launch will it take for the rocket to reach orbit altitude at 420 kilometers?

Answer: $420 = -518 + 116\ln(t)$ so t = 3,248 seconds or about 54 minutes.

Note: The actual time is about 3,229 seconds.