Earth Space Mission and Gravity: Mission to Mars

6-8
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Adapted from the Teaching Channel/Boeing Partnership
Brighton School

Anchoring phenomenon:
Students will use their understanding of gravity, scale properties, and force to describe the cyclical pattern of movement among Earth, Sun, Moon, and Mars to determine how and when would be a good time to launch a mission to the Moon and later to Mars.

Essential question about phenomenon/for unit: When is the best time to launch a mission to the moon and later to Mars?

Big Idea:
The gravity of the Sun, Earth, and Mars results in attraction between the objects, but since the Sun is so much larger than the Earth and Mars,, the Earth revolves around the Sun every 365.5 days and Mars revolves every 687 days. There is also a gravitational force that causes the Moon to revolve around the Earth approximately every 28 years, and the Moon revolves around the Earth because it is smaller and much closer to Earth than the Sun. In order to show the difference in distance to the Sun, we used a scale model, but had to focus on distance rather than the size of the objects because we would have to have much larger distances to accommodate the size of the objects. There is an ideal time to launch to the moon based on when the Moon is closest to the Earth, but we also have to take into account the idea time to launch from the Moon to Mars. We have to consider when these are aligned.

Scientific explanation:
Since the Sun is so much more massive than the Earth and Mars, both Earth and Mars revolve around the Earth. There is a gravitational pull between the Earth and Sun, and they are attracted to each other. The Earth pulls on the Sun, but it only moves a little, more like wobbles. The Sun and Mars also have gravity that attracts them to each other, but again the more massive Sun results in Mars revolving around the Sun rather than the Sun revolving around Mars or Earth. With increased massive of the Sun, the gravitational pull would be even greater, which would mean both Earth and Mars would be pulled in closer to the Sun and they would revolve faster. It'd be similar to them being closer to the center of a coin well. In a centripetal force lab, when the mass is increased in order for the object to spin around the same amount, there has to be a greater force from the person. This shows that an increase in mass, leads to an increase in force.

The Sun is so much more massive than the planets and even bigger than our moon. In order to show these differences in size, we *have to sacrifice the accuracy in showing the scaled distances between the objects. Another factor in determining gravitational force is distance. The moon is smaller than the Earth, and definitely smaller than the Sun, so why doesn't the moon revolve around the Sun rather than it revolving around the Earth every 29 days. This happens because it is so much closer to Earth, so the close distance makes more of a difference compared to the size of the objects. So the Earth has a greater gravitational pull on the Moon than the Sun. Additionally gravity explains why Mars and Earth have different orbital speeds and take different amounts of time to orbit around the Sun. Mars is further away from the Sun and it's less massive, so there is less gravitational pull between the Sun and Mars compared to the Sun and Earth. The result of less gravitational pull is a slower orbital speed and a bigger orbit around the Sun, thus taking almost twice as long to revolve around the Sun.*

The Earth revolves around the Sun every 365.25 days and Mars revolves around the Sun every 676 days. Since it takes about twice as long for Mars to revolve around the Sun compared to Earth, then theoretically they would be aligned about every 2 years, so the second revolution of Earth around the Sun. However the orbital planes of the planets also have to be aligned and that does not happen every 2 years, so a true alignment of the Sun-Earth-Mars and their orbital planes happens even less than 2 years. Additionally to also have the Sun-Earth-Moon-Mars all aligned is even more rare.

To plan a mission to Mars where we landed on the Moon and then took off to land on Mars would have to be timed perfectly, at best every 2 years. Fortunately our technology does not require us to have orbital plane alignment though. But assuming this perfect alignment was necessary, when the moon was on the other side of the Earth (and Sun was on the other side) that is a full moon. From the human perspective we would be able to see the ½ of the moon that is lit, so it would appear very bright and a full circle. After 14 days the moon will be on the other side of the Earth, and we could not see the ½ that is illuminated, so it is a new moon. It takes about 3 days to travel to the moon, and assuming you wanted to be on the moon for a short period of time perhaps 3-4 days then you should leave the Earth at a first quarter moon, you'd like on the moon at a waxing gibbous. Then you'd stay on the moon until it was a full moon and then leave the moon for Mars.

NGSS *Performance Expectations* addressed in this unit:

Standard	PE	DCI	CCC
MS-PSS2-4	Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.	PS2.B Types of Interactions	Systems and System Models
MS-ESS1-3	Analyze and interpret data to determine scale properties of objects in the solar system.	ESS1.A The Universe and Its Stars	Scale, Proportion, and Quantity
MS-ESS1-2	Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.	ESS1.B Earth and the Solar System	Systems and System Models
MS-ESS1-1	Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.		Patterns
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	ETS1.A: Defining and Delimiting Engineering Problems	Influence of Science, Engineering, and Technology on Society and the Natural World All hum

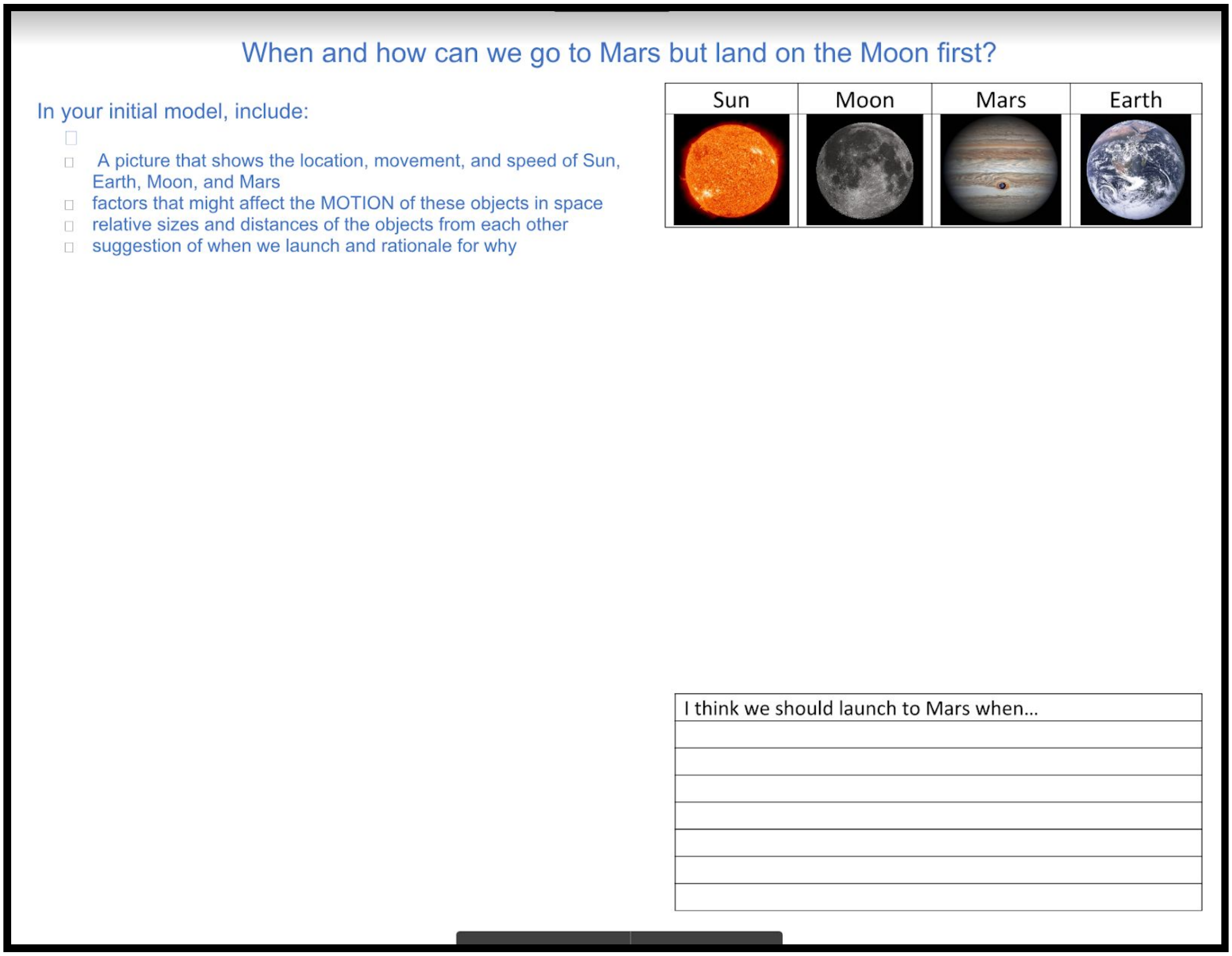
Summary Table of Activities in Unit

Activity	***Learning Target*** *(Color code 3-dimensions: Blue = SEP; Orange = DCI, Green = CCC)*	***Evidence Students Could Gain/Key Learning***	***Connection to explain part of the phenomena***
Activity 1: Initial Model	Students will create an initial model that shows the motion of Mars, Moon, and the Earth to explain their proposed timeline to leave for Mars and explain why we'd want to do that.	Objects move around each other. One object makes the others move around it. There is a specific amount of time for these movements that are predictable.	The Moon predictably moves around the Earth and both the Earth and Mars move predictably around the Sun, so there is a supposed ideal time to launch to go to the Moon to later go to Mars.
Activity 2: Criteria and Constraints of the Mission ETS1-1 Exit Ticket: What are the criteria for the mission and justify which are most important. What are the most influential limitations and why?	Ss brainstorm criteria and constraints for different elements of the mission by learning more about the mission.	Going out into space requires understanding gravity and its role in the movement of objects. The more we define the criteria the more successful we can be.	We need to know the distance to get to the Moon and Mars and the velocity of their orbits as well as the velocity of our spacecraft. Additionally we need to know the environment so we can protect our bodies in space.
Activity 3: Mission #1 - Travel to Mars (pgs. 19-24) ESS1-3 Exit Ticket: How does the distance to the Sun compare from the Earth to Mars? What do you think the Sun looks like on Mars compared to Earth? Scale Properties for Student Scale Properties KEY	Students study interplanetary distances and scale to revise their models and predict when to launch.	Mars is 1.5x further away from the Sun compared to Earth, resulting in it moving slower around the Earth and it takes almost twice as long to orbit the Earth. A scaled model requires choosing between distance or diameter of planets and each has a strength and weakness.	Mars is further away from the Sun, so the model shows that it is has a bigger radius and orbit around the Sun compared to Earth.

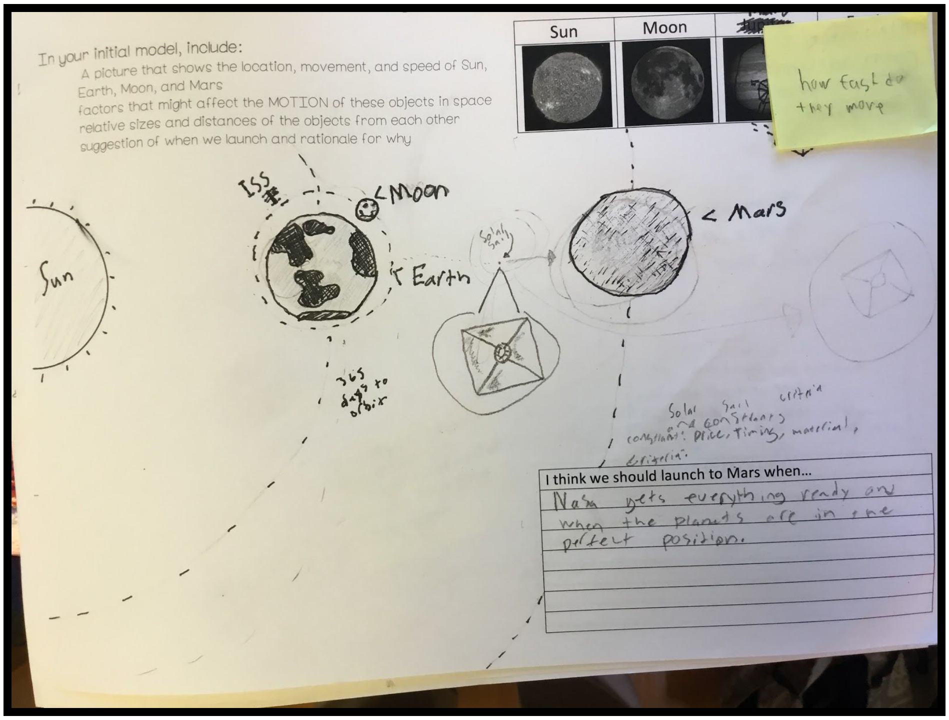
Activity 4: Build solar sails to explore how propulsion is used for spacecraft. (Optional - cont'd of previous lesson, starting on page 6) ETS1-1	Students will construct a scale model solar sail and experience the tradeoffs, criteria, and constraints.	Students will research and build a scale model of a solar sail and habitat pod. Students will discuss the tradeoffs of their model as well as the criteria and constraints.	When engineering a product, there are criteria and constraints that you must work with. Additionally there are tradeoffs, like size vs stability or size vs cost that have to be considered.
Activity 5: Gravity and Orbital Motion ESS1-2 [Reading](#) [Gravity and Orbits Phet simulation](#)	Students will determine how distance and mass affect gravity resulting in a difference in orbital motion in a simulation model.	Gravity is an attractive force that keeps planets in orbit around a more massive object. As the distance increases the force of gravity is less, so the planet travels slower and in a larger orbit. Planets that are closer to the Sun and more massive have a greater gravitational pull, so they move faster around the Sun and in a smaller orbit. The phet simulation shows that the moon also orbits around the Earth because it have a greater gravitational pull towards the Earth since it is so close.	Mars is further away from the Sun and less massive, so it moves slower and has a larger orbit around the Sun compared to the Earth. Earth is closer and more massive, so it moves faster and has a smaller orbit around the Sun. They're both attracted to the Sun because of gravity and therefore orbit around the Sun.
Activity 6: Moon Phases ESS1-1	Students will explain how the movement of the moon and our perspective results in cyclical moon phases we see.	The moon is always half lit up, but as it travels around the Earth approximately every 29 days, our perspective changes. Each day we see a different part of the lit up moon as it travels. When the moon is between the Earth and Sun, we do not see the lit side, so we only see the dark full moon. But after 7 days of travel, it is now at	It takes us approximately 3 days to travel to the moon. Depending on how long you want to spend on the moon (in my model approximately 3-4 days), you could leave the Earth when the moon was a first quarter moon, but you'd arrive at the moon when it's a waxing gibbous. You'd stay on the moon for 3-4 more days and leave when it was aligned as the

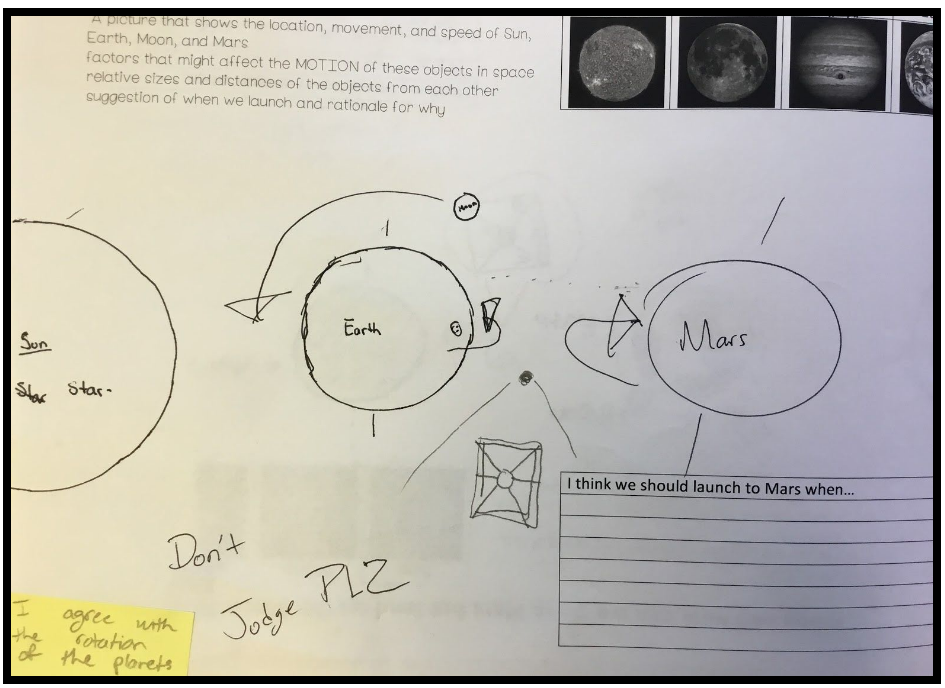
		a 90 degree angle, and we see a first quarter moon. Seven days later, the moon has traveled so the Earth is between the moon and the Sun, and we see the full lit up side of the moon, which is a Full moon.	Sun-Earth-Moon, so it'd appear as a full moon from the Earth.

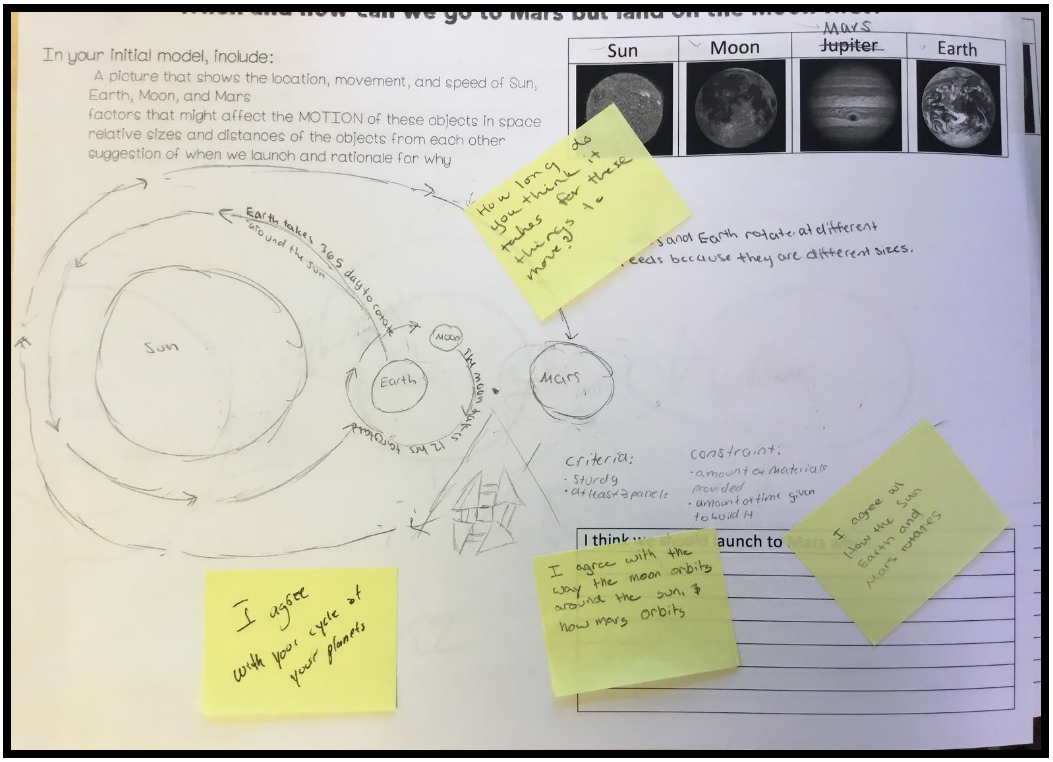
Model Template

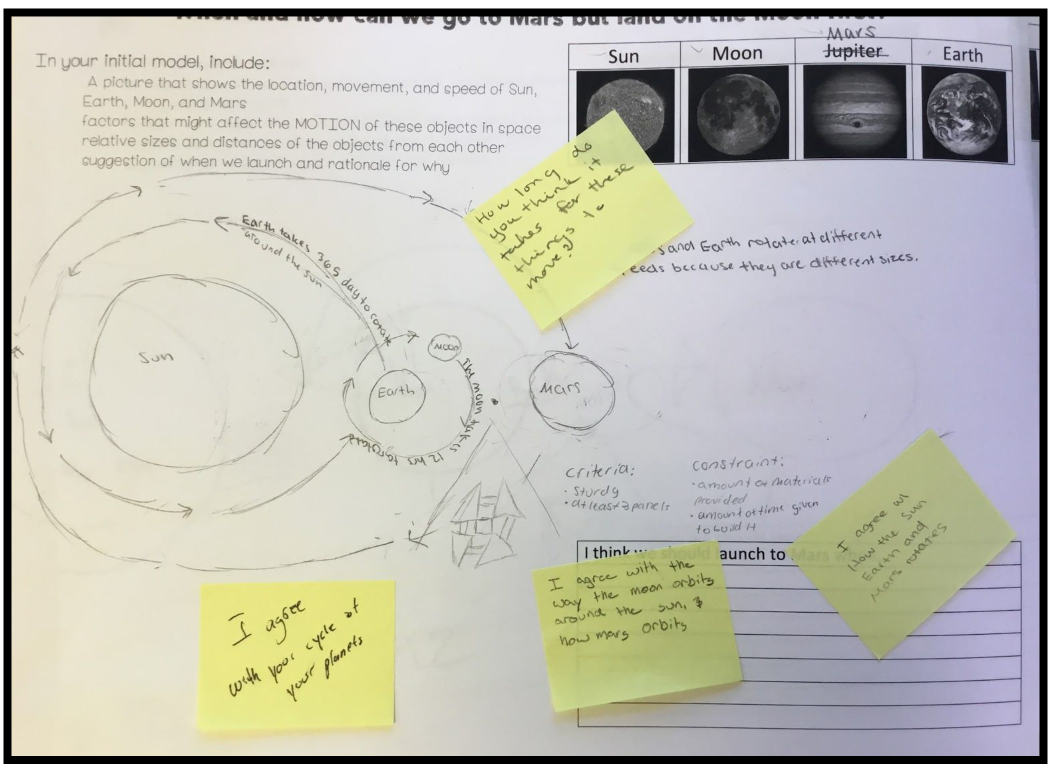


Initial Models






In your initial model, include:
A picture that shows the location, movement, and speed of Sun, Earth, Moon, and Mars
factors that might affect the MOTION of these objects in space
relative sizes and distances of the objects from each other
suggestion of when we launch and rationale for why
Sun
Moon
~~Jupiter~~ Mars
Earth
How long do you think it takes for these things to move?
Earth takes 365 day to cycle around the sun
Sun
Earth
Moon
Mars
The moon takes 12 hrs to cycle
s and Earth rotate at different speeds because they are different sizes.
Criteria:
· sturdy
· atleast 3 panels
constraint:
· amount of materials provided
· amount of time given to build it
I think we should launch to Mars
I agree with your cycle of your planets
I agree with the way the moon orbits around the sun, & how mars orbits
I agree w/ how the Sun Earth and Mars rotates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Sun
Moon
~~Jupiter~~ Mars
Earth
How long do you think it takes for these things to move?
Earth takes 365 day to cycle around the sun
Sun
Earth
Moon
Mars
The moon takes 12 hrs to cycle
s and Earth rotate at different speeds because they are different sizes.
Criteria:
· sturdy
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I agree with your cycle of your planets
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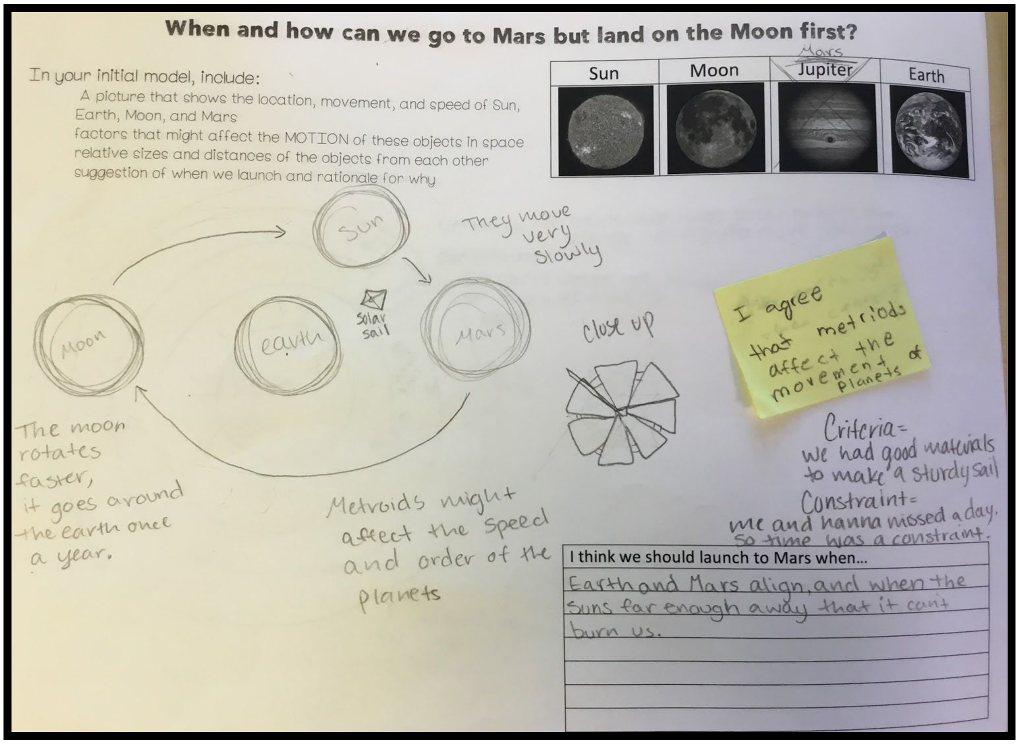
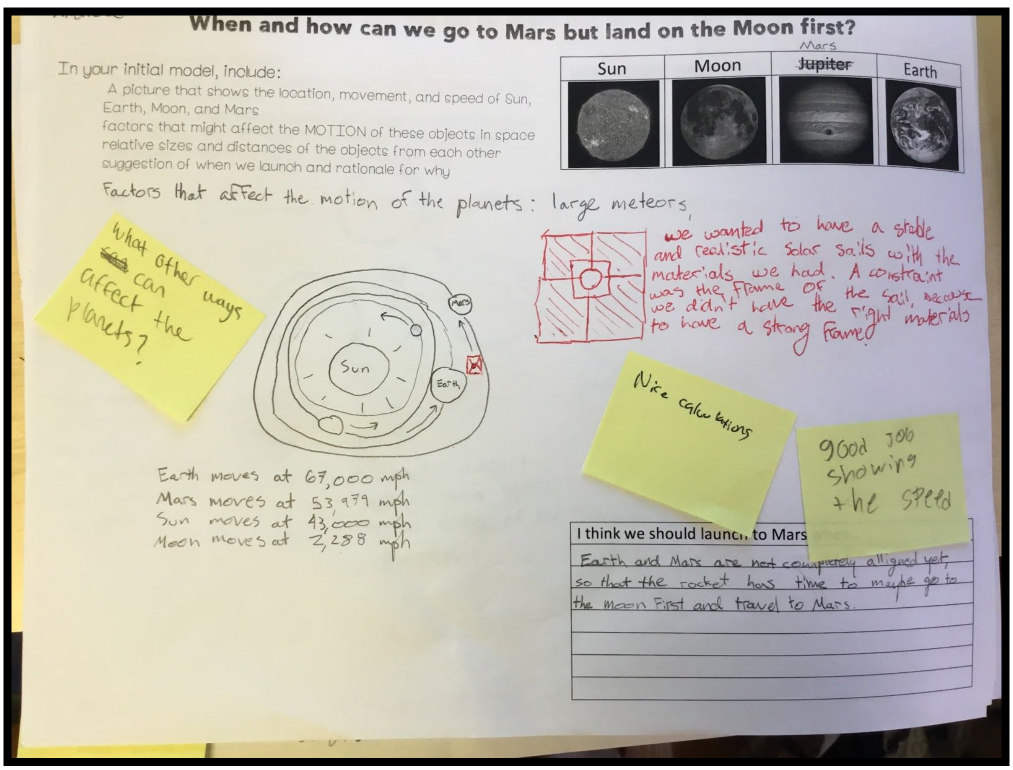
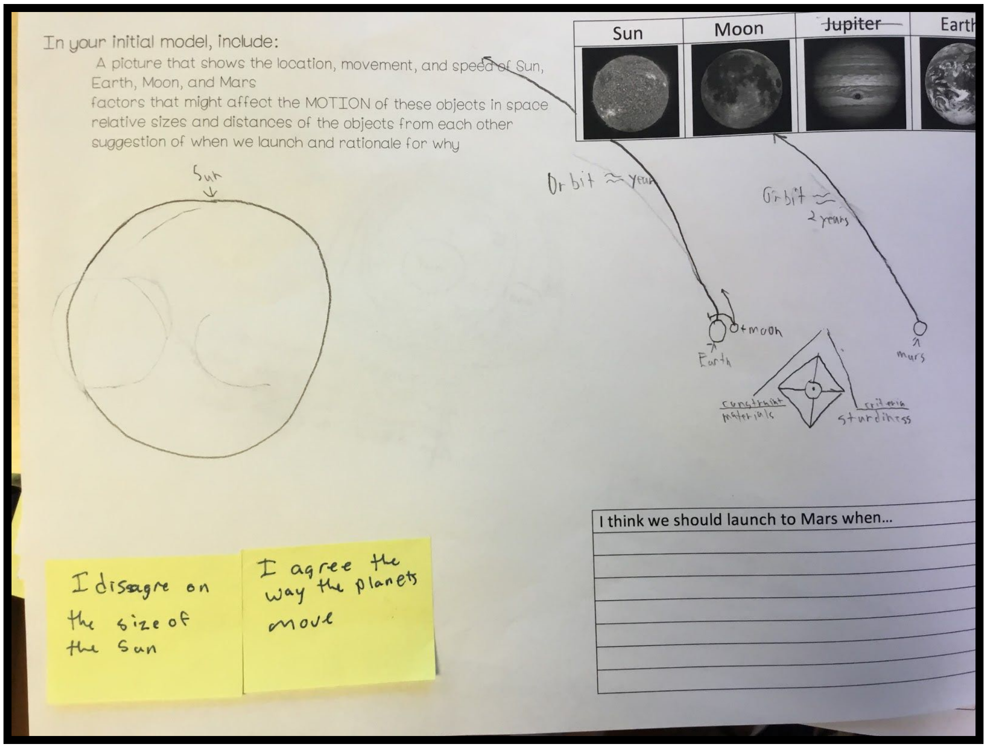

When and how can we go to Mars but land on the Moon first?
In your initial model, include:
A picture that shows the location, movement, and speed of Sun, Earth, Moon, and Mars
factors that might affect the MOTION of these objects in space
relative sizes and distances of the objects from each other
suggestion of when we launch and rationale for why
Sun
Moon
Mars
~~Jupiter~~
Earth
They move very slowly
Moon
earth
Solar sail
Mars
close up
I agree that metriods affect the movement of planets
The moon rotates faster, it goes around the earth once a year.
Metroids might affect the speed and order of the planets
Criteria= we had good materials to make a sturdy sail
Constraint= me and hanna mised a day. So time was a constraint.
I think we should launch to Mars when...
Earth and Mars align, and when the suns far enough away that it can't burn us.


When and how can we go to Mars but land on the Moon first?
In your initial model, include:
A picture that shows the location, movement, and speed of Sun, Earth, Moon, and Mars
factors that might affect the MOTION of these objects in space
relative sizes and distances of the objects from each other
suggestion of when we launch and rationale for why
Sun
Moon
Mars
~~Jupiter~~
Earth
Factors that affect the motion of the planets: large meteors
What other ways can affect the planets?
we wanted to have a stable and realistic Solar Sails with the materials we had. A constraint was the frame of the sail, because we didn't have the right materials to have a strong frame.
Sun
Mars
Earth
Nice calculations
Good job showing the speed
Earth moves at 67,000 mph
Mars moves at 53,979 mph
Sun moves at 43,000 mph
Moon moves at 2,288 mph
I think we should launch to Mars
Earth and Mars are not completely alligned yet, so that the rocket has time to maybe go to the moon first and travel to Mars.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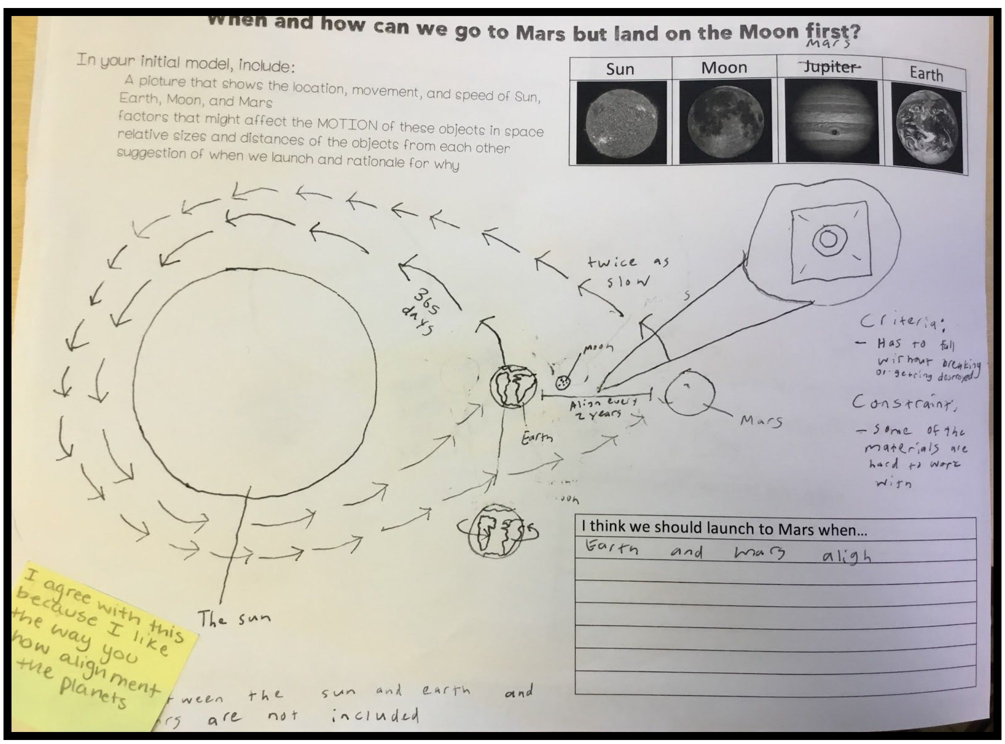
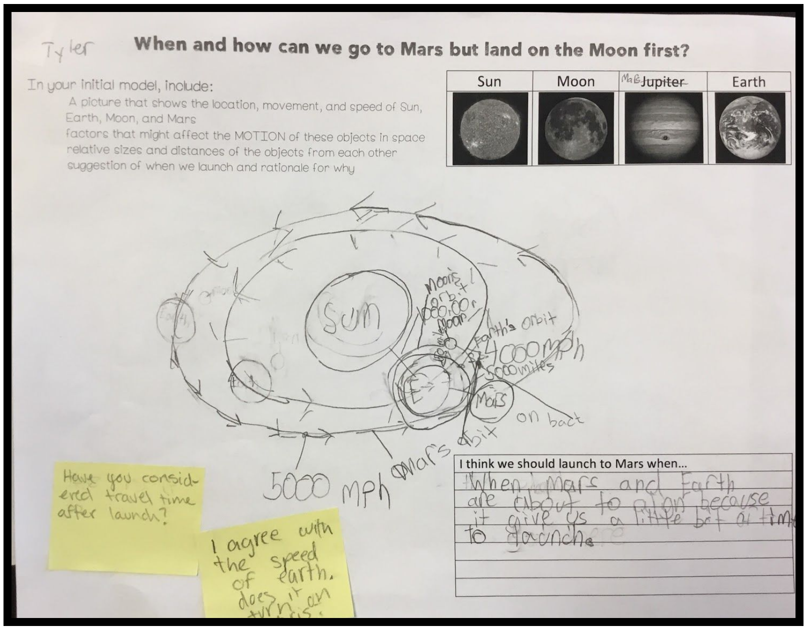
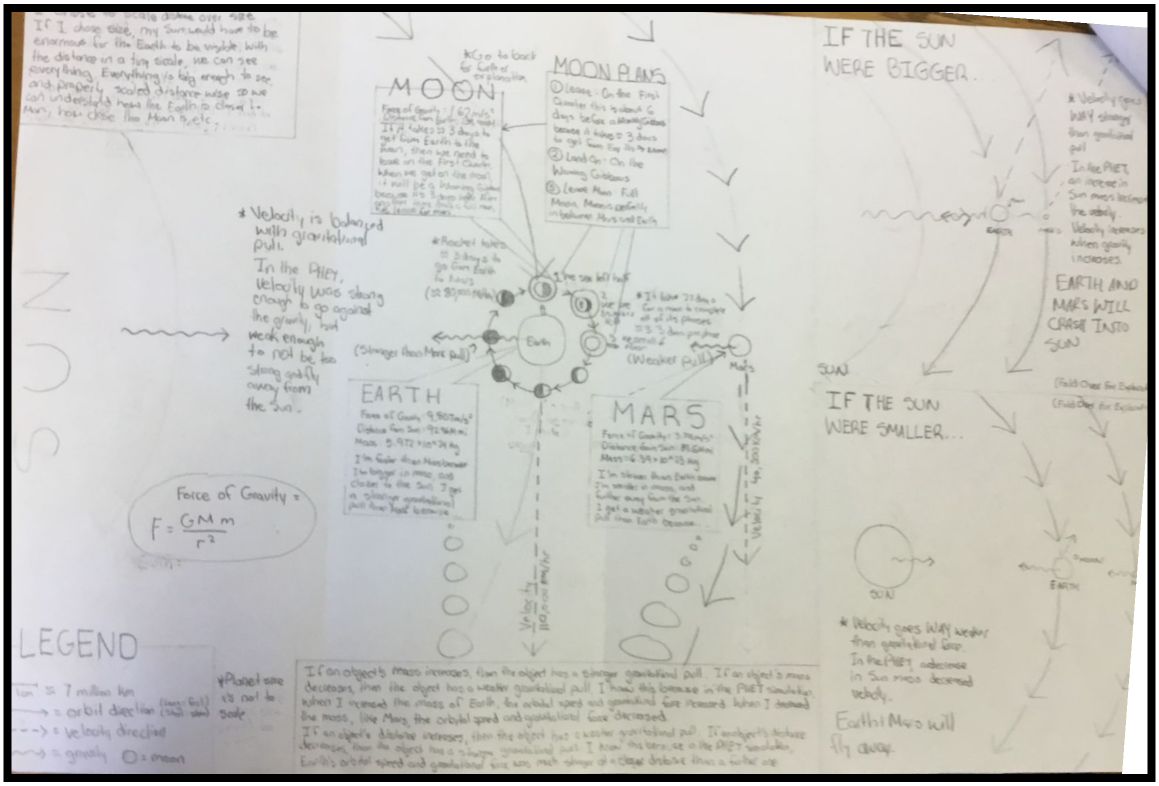
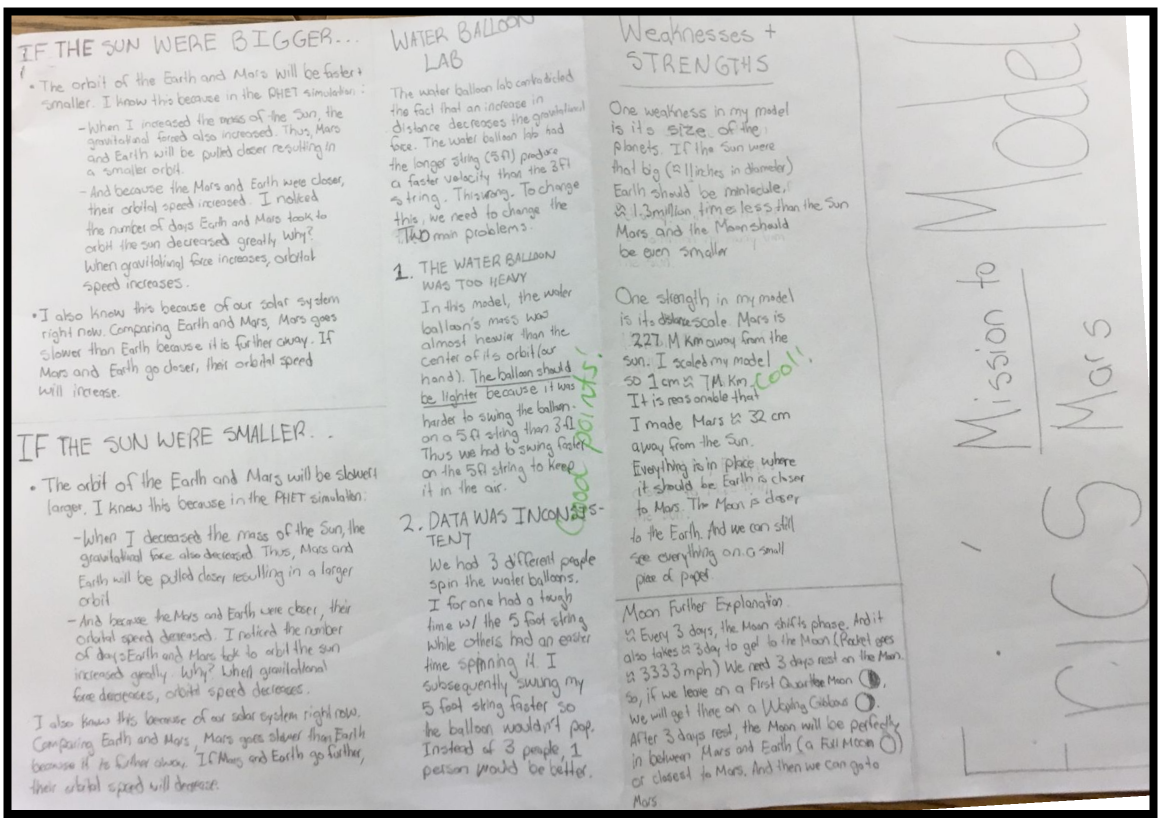
A picture that shows the location, movement, and speed of Sun, Earth, Moon, and Mars
factors that might affect the MOTION of these objects in space
relative sizes and distances of the objects from each other
suggestion of when we launch and rationale for why
Sun
Moon
~~Jupiter~~
Earth
Orbit ≈ year
Orbit ≈ 2 years
Earth
moon
Mars
constraint materials
criteria sturdiness
I think we should launch to Mars when...
I disagree on the size of the Sun
I agree the way the planets move

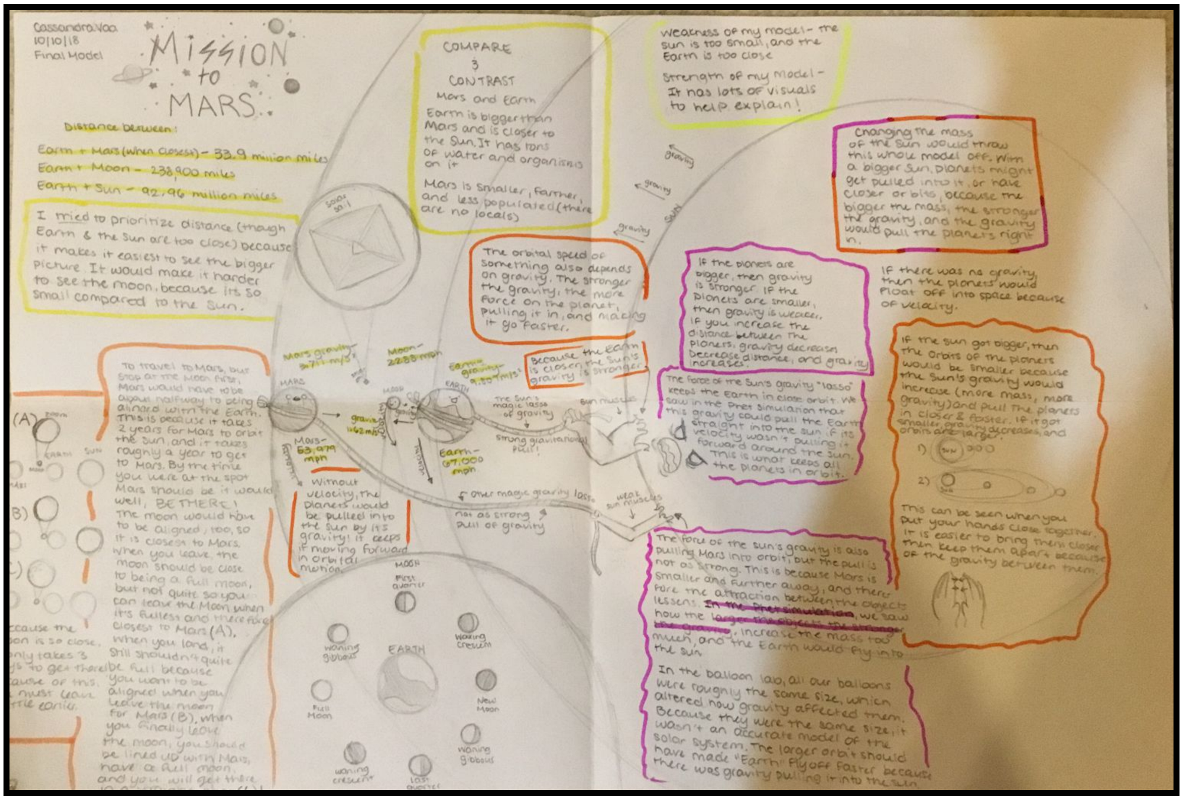

When and how can we go to Mars but land on the Moon first?
In your initial model, include:
A picture that shows the location, movement, and speed of Sun, Earth, Moon, and Mars
factors that might affect the MOTION of these objects in space
relative sizes and distances of the objects from each other
suggestion of when we launch and rationale for why
Sun
Moon
~~Jupiter~~ Mars
Earth
twice as slow
365 days
moon
Align every 2 years
Earth
Mars
The sun
Criteria:
- Has to fall without breaking or getting destroyed
Constraint:
- Some of the materials are hard to work with
I think we should launch to Mars when...
Earth and Mars align
I agree with this because I like the way you how alignment the planets

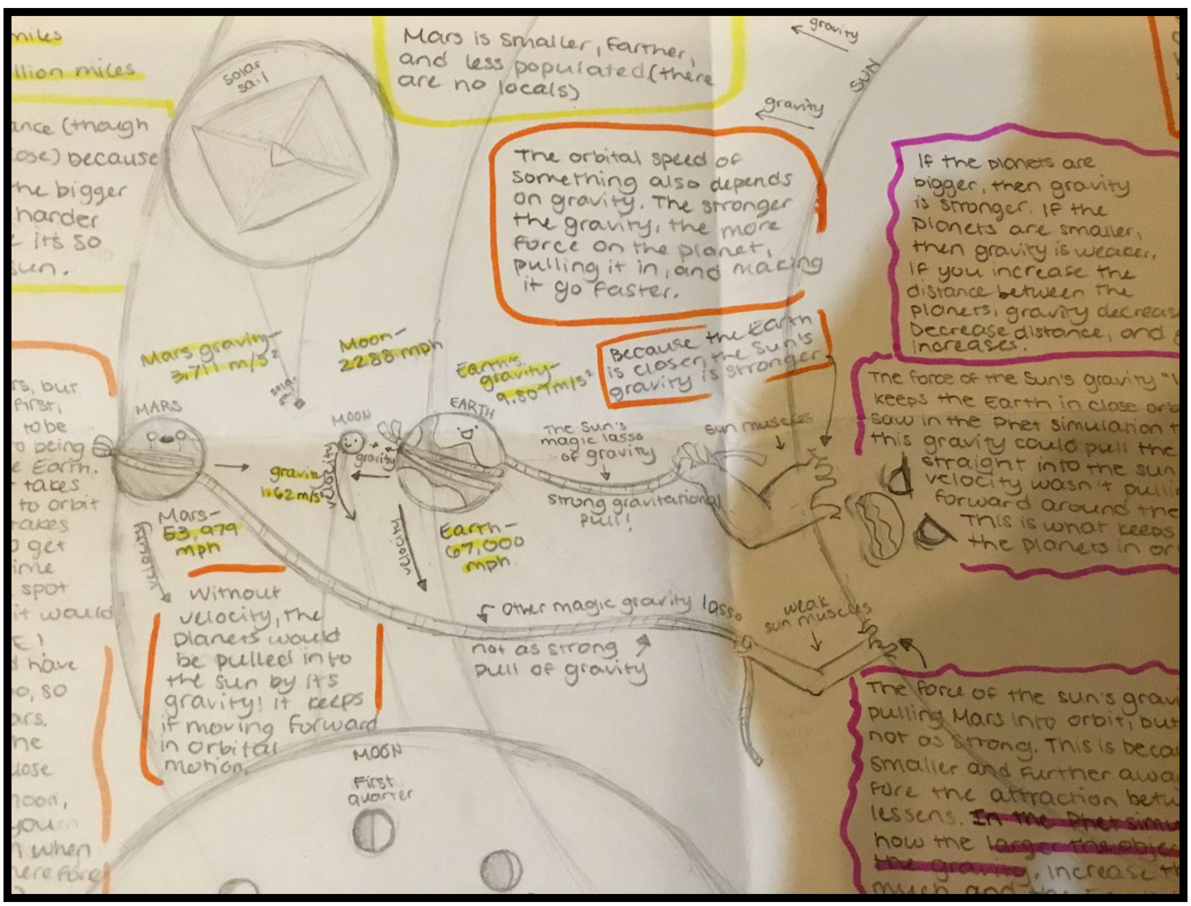

Tyler
When and how can we go to Mars but land on the Moon first?
In your initial model, include:
A picture that shows the location, movement, and speed of Sun, Earth, Moon, and Mars
factors that might affect the MOTION of these objects in space
relative sizes and distances of the objects from each other
suggestion of when we launch and rationale for why
Sun
Moon
Jupiter
Earth
Sun
Earth's orbit
4000 mph
Mars
on back
5000 mph
Mars orbit
I think we should launch to Mars when...
When Mars and Earth are about to align because it give us a little bit of time to launch
Have you considered travel time after launch?
I agree with the speed of earth.

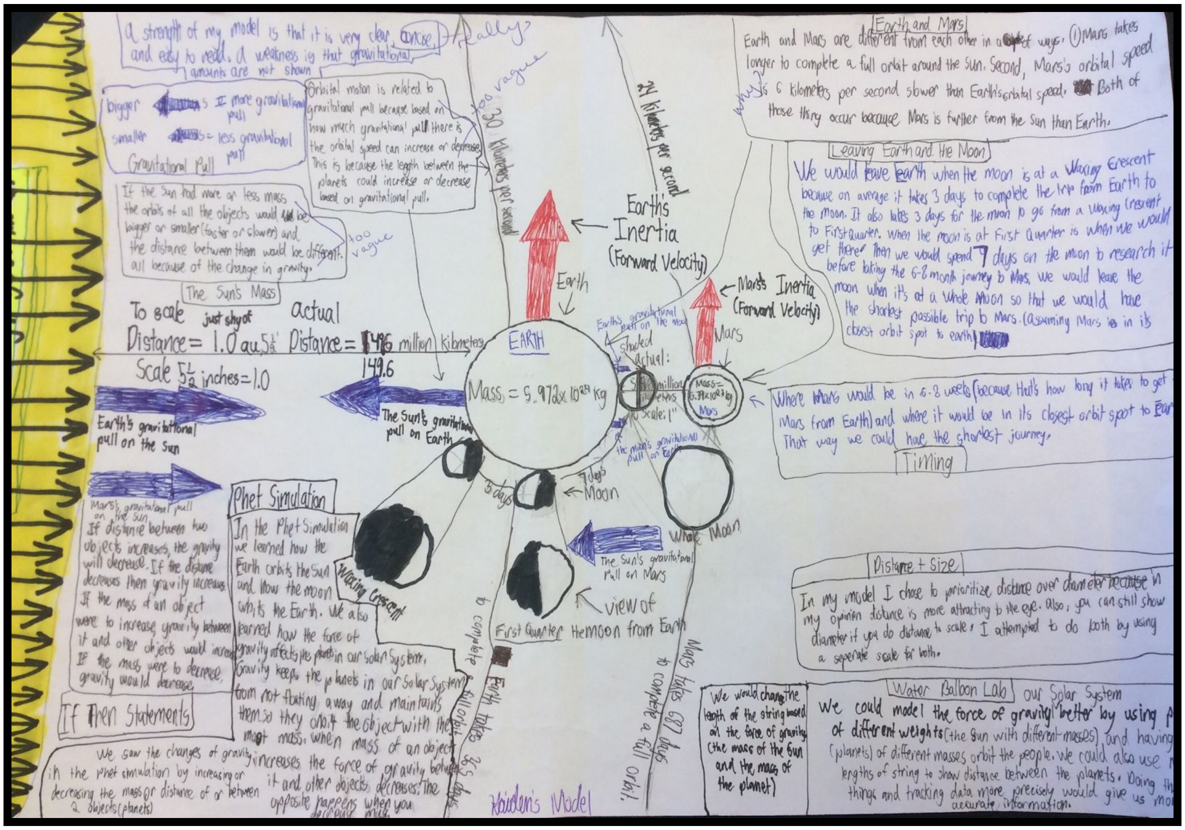
Final Models



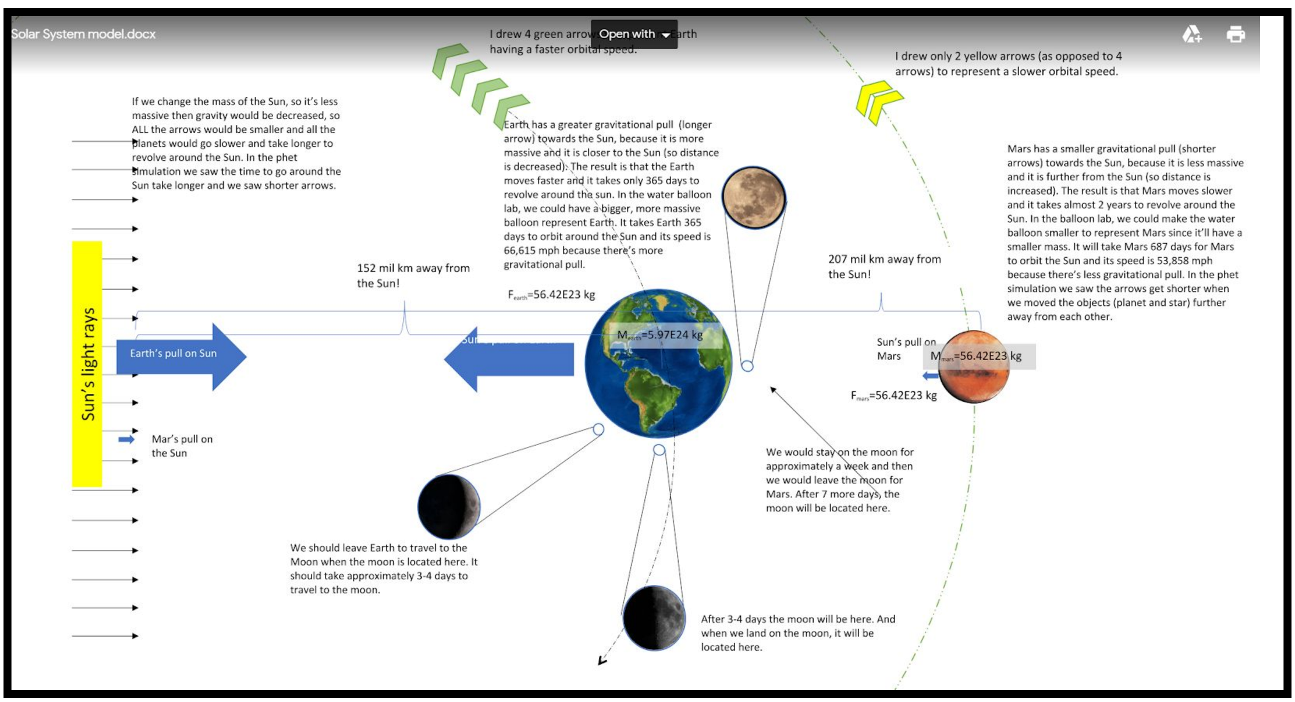



Cassandra Voa
10/10/18
Final Model
Mission to MARS
Distance between:
Earth + Mars (when closest) - 33.9 million miles
Earth + Moon - 238,900 miles
Earth + Sun - 92.96 million miles
I tried to prioritize distance (though Earth & the Sun are too close) because it makes it easiest to see the bigger picture. It would make it harder to see the moon, because its so small compared to the sun.
COMPARE & CONTRAST Mars and Earth
Earth is bigger than Mars and is closer to the Sun. It has tons of water and organisms on it
Mars is smaller, farther, and less populated (there are no locals)
Weakness of my model - the sun is too small, and the Earth is too close
Strength of my model - It has lots of visuals to help explain!
Changing the mass of the sun would throw this whole model off. With a bigger sun, planets might get pulled into it, or have closer orbits, because the bigger the mass, the stronger the gravity, and the gravity would pull the planets right in.
If there was no gravity, then the planets would float off into space because of velocity.
The orbital speed of something also depends on gravity. The stronger the gravity, the more force on the planet, pulling it in, and making it go faster.
If the planets are bigger, then gravity is stronger. If the planets are smaller, then gravity is weaker. If you increase the distance between the planets, gravity decreases. Decrease distance, and gravity increases.
If the sun got bigger, then the orbits of the planets would be smaller because the sun's gravity would increase (more mass, more gravity) and pull the planets in closer & faster.
This can be seen when you put your hands close together. It is easier to bring them closer than keep them apart because of the gravity between them.
In the balloon lab, all our balloons were roughly the same size, which altered how gravity affected them. Because they were the same size, it wasn't an accurate model of the solar system. The larger orbit should have made "Earth" fly off faster because there was gravity pulling it into the sun.


Mars is smaller, farther, and less populated (there are no locals)
Solar sail
gravity
SUN
The orbital speed of something also depends on gravity. The stronger the gravity, the more force on the planet, pulling it in, and making it go faster.
If the planets are bigger, then gravity is stronger. If the planets are smaller, then gravity is weaker. If you increase the distance between the planets, gravity decreas
Mars gravity - 3.711 m/s²
Moon - 2288 mph
Earth's gravity - 9.807 m/s²
Because the Earth is closer, the Sun's gravity is stronger
MARS
MOON
EARTH
gravity 1.62 m/s²
The Sun's magic lasso of gravity
Sun muscles
strong gravitational pull!
Mars - 53,979 mph
Earth - 67,000 mph
velocity
Without velocity, the planets would be pulled into the sun by its gravity! It keeps it moving forward in orbital motion.
other magic gravity lasso
not as strong pull of gravity
weak sun muscles
MOON
First quarter



A strength of my model is that it is very clear, concise and easy to read. A weakness is that gravitational amounts are not shown
Really?
bigger = more gravitational pull
smaller = less gravitational pull
Gravitational Pull
Orbital motion is related to gravitational pull because based on how much gravitational pull there is the orbital speed can increase or decrease. This is because the length between the planets could increase or decrease based on gravitational pull.
too vague
If the Sun had more or less mass the orbits of all the objects would be bigger or smaller (faster or slower) and the distance between them would be different. All because of the change in gravity.
too vague
The Suns Mass
To scale just shy of Distance = 1.0 au 5½
actual Distance = 149.6 million kilometers
Scale 5½ inches = 1.0
Earth's gravitational pull on the Sun
The Sun's gravitational pull on Earth
30 kilometers per second
24 kilometers per second
Earths Inertia (Forward Velocity)
Earth
EARTH
Mass = 5.972 x 10²⁴ kg
Mars's Inertia (Forward Velocity)
Mars
Mars
Moon
Whole Moon
The Sun's gravitational pull on Mars
view of the moon from Earth
First Quarter
Waxing Crescent
Mars's gravitational pull on the Sun
If distance between two objects increases, the gravity will decrease. If the distance decreases then gravity increases. If the mass of an object were to increase gravity between it and other objects would increase. If the mass were to decrease gravity would decrease.
If Then Statements
Phet Simulation
In the Phet Simulation we learned how the Earth orbits the Sun and how the moon orbits the Earth. We also learned how the force of gravity affects the planets in our Solar System. Gravity keeps the planets in our Solar System from not floating away and maintains them so they orbit the object with the most mass. When mass of an object increases the force of gravity between it and other objects decreases the opposite happens when you decrease mass.
We saw the changes of gravity in the Phet simulation by increasing or decreasing the mass or distance of or between 2 objects (planets)
Earth takes 365 days to complete a full orbit
Mars takes 687 days to complete a full orbit.
Kaiden's Model
Earth and Mars
Earth and Mars are different from each other in a couple of ways. (1) Mars takes longer to complete a full orbit around the Sun. Second, Mars's orbital speed is 6 kilometers per second slower than Earth's orbital speed. Both of those things occur because Mars is further from the Sun than Earth.
why?
Leaving Earth and the Moon
We would leave Earth when the moon is at a Waxing Crescent because on average it takes 3 days to complete the trip from Earth to the moon. It also takes 3 days for the moon to go from a Waxing Crescent to First Quarter. When the moon is at First Quarter is when we would get there. Then we would spend 7 days on the moon to research it before taking the 6-8 month journey to Mars. We would leave the moon when it's at a whole moon so that we would have the shortest possible trip to Mars. (assuming Mars is in its closest orbit spot to earth)
Where Mars would be in 6-8 weeks (because that's how long it takes to get Mars from Earth) and where it would be in its closest orbit spot to Earth. That way we could have the shortest journey.
Timing
Distance + Size
In my model I chose to prioritize distance over diameter because in my opinion distance is more attracting to the eye. Also, you can still show diameter if you do distance to scale. I attempted to do both by using a separate scale for both.
We would change the length of the string based on the force of gravity (the mass of the Sun and the mass of the planet)
Water Balloon Lab
Our Solar System
We could model the force of gravity better by using different weights (the Sun with different masses) and having (planets) of different masses orbit the people. We could also use lengths of string to show distance between the planets. Doing things and tracking data more precisely would give us more accurate information.



Solar System model.docx
Open with
I drew 4 green arrows to represent Earth having a faster orbital speed.
I drew only 2 yellow arrows (as opposed to 4 arrows) to represent a slower orbital speed.
If we change the mass of the Sun, so it's less massive then gravity would be decreased, so ALL the arrows would be smaller and all the planets would go slower and take longer to revolve around the Sun. In the phet simulation we saw the time to go around the Sun take longer and we saw shorter arrows.
Earth has a greater gravitational pull (longer arrow) towards the Sun, because it is more massive and it is closer to the Sun (so distance is decreased). The result is that the Earth moves faster and it takes only 365 days to revolve around the sun. In the water balloon lab, we could have a bigger, more massive balloon represent Earth. It takes Earth 365 days to orbit around the Sun and its speed is 66,615 mph because there's more gravitational pull.
Mars has a smaller gravitational pull (shorter arrows) towards the Sun, because it is less massive and it is further from the Sun (so distance is increased). The result is that Mars moves slower and it takes almost 2 years to revolve around the Sun. In the balloon lab, we could make the water balloon smaller to represent Mars since it'll have a smaller mass. It will take Mars 687 days for Mars to orbit the Sun and its speed is 53,858 mph because there's less gravitational pull. In the phet simulation we saw the arrows get shorter when we moved the objects (planet and star) further away from each other.
152 mil km away from the Sun!
207 mil km away from the Sun!
F = 56.42E23 kg
M = 5.97E24 kg
Sun's pull on Mars
M = 56.42E23 kg
F = 56.42E23 kg
Sun's light rays
Earth's pull on Sun
Mar's pull on the Sun
We would stay on the moon for approximately a week and then we would leave the moon for Mars. After 7 more days, the moon will be located here.
We should leave Earth to travel to the Moon when the moon is located here. It should take approximately 3-4 days to travel to the moon.
After 3-4 days the moon will be here. And when we land on the moon, it will be located here.

Final Model Rubric

Mission to Mars Modeling Rubric		
PSS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.		
Approaching (2)	Meeting (3.6)	Exceeding (4)
❑ Describes the phet simulation, but does not explain any patterns we saw.	❑ Explains how the force of gravity changes when the mass of objects change. ❑ Describes how we saw those changes in the phet simulation and how that helps explain how Earth and Mars are different (need to find their masses).	❑ Explains how we could change the water balloon lab to try to model this. ❑ Explains how changing the mass of the Sun would change your entire model.
ESS1-1 Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.		
Approaching (2)	Meeting (3.6)	Exceeding (4)
❑ Draws where the moon would be positioned when we leave for, land on, and leave from the moon and determines how long it would take.	❑ Shows where the moon would be when when we leave for, land on, and leave from the moon. ❑ Draws and explains the moon phases during those 3 times.	❑ Justifies why we would leave Earth and Moon based on how long it takes to travel in the rocket and the distance the moon is from the Earth.
ESS1-2 Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.		
Approaching (2)	Meeting (3.6)	Exceeding (4)
❑ Makes basic "If, then" statements about the role of gravity in the motion in our solar system.	❑ Shows and explains bigger and smaller gravitational pull ❑ Shows the "balance" between gravity and inertia that results in orbital motion ❑ Relates orbital motion (speed) to gravitational pull.	❑ Calculates the force of gravity for the different planets and the moon ❑ Explains how the gravitational pull and motion of planets would change if Sun became bigger or smaller. ❑ Shows these changes if Sun were bigger or smaller. ❑ Uses evidence either from demonstrations or data to support ideas.
ESS1-3 Analyze and interpret data to determine scale properties of objects in the solar system.		
Approaching (2)	Meeting (3.6)	Exceeding (4)
❑ Communicates data about either the distance, mass, or velocity of objects in the solar system.	❑ Model is scaled either with the size of the objects or their distance. ❑ Explains how Earth and Mars are different	❑ Explains why you chose to prioritize distance or size. ❑ Describes a weakness and a strength of your model.

Additional Unit-Related Documents

[Assessment on Google Form]