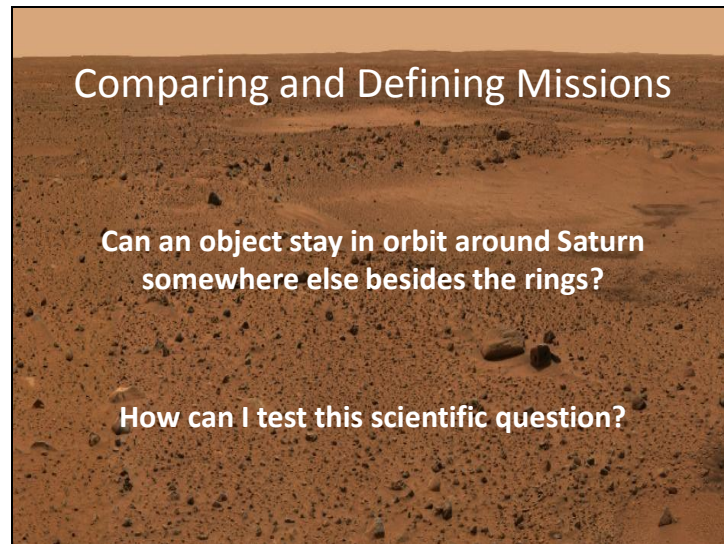


There is more than one way to do almost everything.

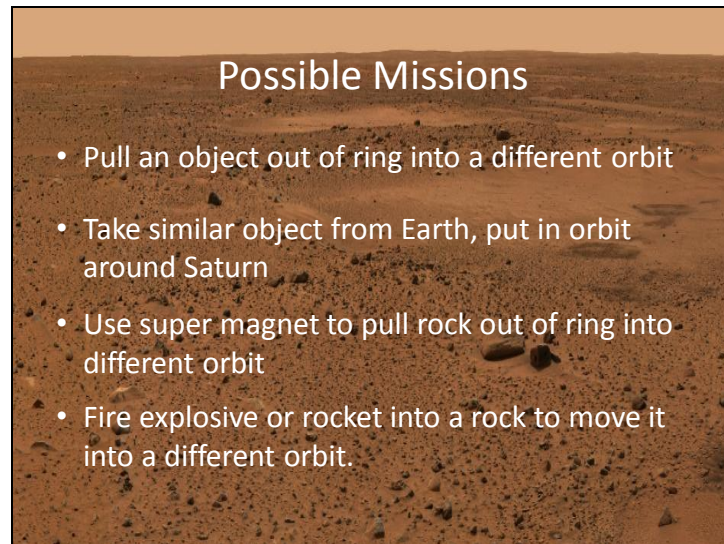
In our last lesson, you wrote your scientific question for your Mars rover mission. Today you will be learning to do the same thing scientists do once they have developed their scientific question. You will be considering all of the different ways in which you can test your question. We will then compare them to each other and decide which method will work best.

I am going to show you how to do this using my example from the planet Saturn. Then you will follow the same process for your Mars rover mission.



Let's review my scientific question from Saturn. (Read it to your students or have them read the sentence aloud). Once a scientist has their scientific question, they next have to decide how to convert this question into a workable mission.

What I am going to do now is to share an internal dialogue with you so you can hear the thinking that is going on in my head as I think of ways to turn my scientific question on Saturn into ideas for a mission. This is what you will be doing for your own mission to Mars.



This slide has 4 CLICKS of animation.

SAY: Hmmm, let me think. How could I test whether an object could stay in orbit around Saturn somewhere else besides the rings...(PAUSE)...Oh I know, I know that most of the objects in the rings are very small...Maybe I could lower a cable or a rope and tie it to or around one of the objects. Then, using the rockets on my spacecraft, we could pull it into a different orbit release it and see what happens. I should write that idea down before I forget it. I will write that briefly as, "Pull an object out of ring into a different orbit." CLICK

Okay, but that isn't the only way I could see if objects will stay in other orbits around Saturn. I need to think about some other ideas...I've got it, From my research, I know that most of the objects around Saturn are made of rocks or ice. Rather than pulling the object out of orbit, I could take some rock or ice from Earth that would be very similar to those in Saturn's rings and bring it with me all the way to Saturn. Once the spacecraft arrives, we would get it into a different orbit and release the rock and see if it will stay in orbit or not. Now I have to write this idea down too. (PAUSE) I know, I'll say, "Take similar object from Earth, put in orbit around Saturn."

I am going to think some more about other possible ways to carry out my mission..... I've got it. I bet some of the rocks in the rings of Saturn are made of iron or other metals. If I place a super magnet on my spacecraft, aim it at a rock and turn it on, I can pull that rock out of orbit and place it into different orbit. Once I have the rock where I want it, I just need to turn off the

magnet and observe what happens to the rock. So, I will write that as "Use a super magnet to pull rock out of ring into different orbit." CLICK

Okay, now is there anything else....hmmmm....what if I load a rocket or explosive into my spacecraft and fire it at one of the rocks in the ring? With the rocket, I could push the stone into a different orbit. OK, so I will write that as, "Fire explosives or rocket into a rock to move it into a different orbit." CLICK

Slide 4

Proposed Mission Matrix

| | Proposed Missions | | | |
|--|-------------------|--|--|--|
| | | | | |
| How might this happen? | | | | |
| What else could happen? | | | | |
| Have I thought it through? | | | | |
| What measurements will I need to make to carry out my mission? | | | | |
| Does this mission make sense? | | | | |
| What problems could cause my mission to fail? | | | | |

Now, we are going to compare all of these plans to see which might be our best alternative. We will use the sheet shown here. This is the same sheet you will use to compare the different plans you come up with for your Mars Mission. You can see there are a series of questions down the left side. On the top, you will write down your different ideas. I have made the sheet with 4 columns, but if you have more ideas than that, you can get a second sheet. You will write the ideas in the area I have circled here.

| Proposed Mission Matrix | | | | |
|--|--|--|--|--|
| | Proposed Missions | | | |
| | Pull object out of ring into different orbit | Take similar item from Earth, put into orbit around Saturn | Use super magnet to pull rock out of ring into different orbit | Fire explosive or rocket into rock to move it into different orbit |
| How might this happen? | | | | |
| What else could happen? | | | | |
| Have I thought it through? | | | | |
| What measurements will I need to make to carry out my mission? | | | | |
| Does this mission make sense? What problems could cause my mission to fail? | | | | |

This slide has 5 CLICKS of animation.

Here is the same sheet with my ideas for Saturn added. Now let's answer the questions so we can compare the different plans for my mission and see which might be the best one to pick. Let's answer the questions one by one for the first mission idea I have. How might this happen? How might I pull an object out of the ring using my spacecraft? (Allow students to make suggestions and accept all reasonable responses.) Those are great answers, when I was thinking about this, I came up with these two answers. CLICK

Let's move on to the next question. What else could happen? This means, besides what I expect, what else might happen I don't expect? What else does this mission make me think of? It could be something good but it also might be something bad that would make the mission not work. What else could happen when I either try to loop cables around a rock in Saturn's rings or drill a cable into one of the rocks. (Allow students to suggest answers, accept all reasonable responses.) Those are great ideas. When I thought about it, I came up with these two answers. CLICK

If the cables aren't strong enough, they might snap and not pull the rock out of orbit. I don't know how powerful the gravity is around Saturn, so if I pick this option, I will need to find out the strength of Saturn's gravity to make sure the cable is strong enough. Then I thought that my spacecraft will have to get very close to the rings and to the rock I chose if I am going to wrap a cable around the rock or drill a cable into it. If I am that close to the rings, a small mistake might cause the spaceship to crash into the ring and ruin the mission.

The next question is, “Have I thought it through?” Some other ways to ask this question might be....Have I considered what I will need to have on the craft or what special abilities my craft will need to carry out the mission? Is there anything I haven’t thought of that I will need to know before I try to carry out this mission? (Many other questions are possible)

Let me think about this question. If I decide to do this mission, I know my spacecraft will need to have precision steering. I will need to go very close to a rock in the rings and either lasso the rock with some cables or drill into the rock so I can attach the cables. My drill will have to be sharp enough to penetrate the hardest rock I might anticipate finding in the rings—so I should probably use a diamond tipped drill. What are your thoughts? (Accept any reasonable answers). Here are the ones I came up with when I thought about my mission. CLICK

The next question is, “What measurements will I need to make to carry out my mission?”. This is a very important question. I have to include the correct instruments to make these measurements on my spacecraft before I leave Earth or my mission will fail. (Allow students to share ideas about measurements they think might need to be made.) Hmm... well, I know for sure I have to measure distances very carefully. I need to make sure my spacecraft doesn’t crash into Saturn’s rings and I need to decide on the distance away from the ring I pull the stone I select.

I will also need to have an instrument that can determine how hard the rock I select is. If the rock is very hard, my drill bit may not work. I will probably need to have several different drill bits on the spacecraft and I will select the one I need based on the hardness of the rock. I may need to add more measurements to this list later as I think more about my mission. But for the moment, let’s write down these two. CLICK

The question in the last row are “Does this mission make sense? What problems could cause my mission to fail?”. Well, let me think about this. As I consider this, I have to think about the answers to all of the other questions above. I would say yes, we can do this and it is reasonable and possible. However, I want to write down that getting the cables to work might be tricky. I’m also thinking that drilling into a rock in space could be very hard. By jotting down these down, I can compare all of the missions to each other and this will help me select which mission would be the best to choose. So this is what I wrote, CLICK.

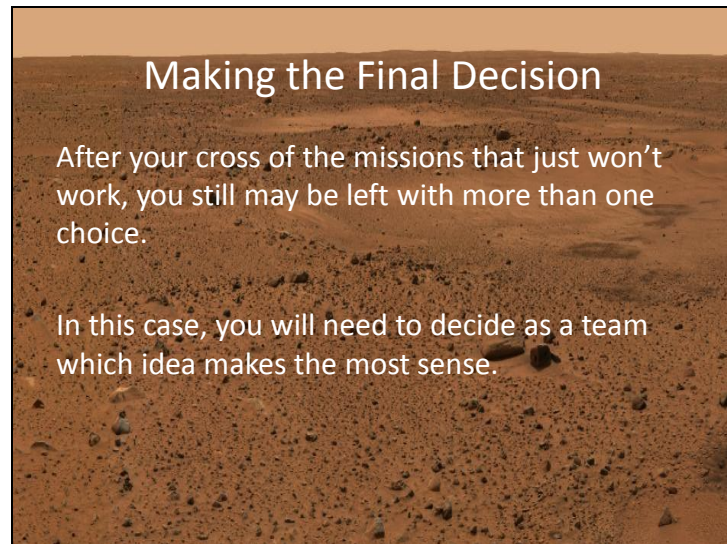
| Completed Matrix | | | | | |
|---|---|---|--|---|--|
| | Proposed Missions | | | | |
| | Pull object out of ring into different orbit | Take similar item from Earth, put into orbit around Saturn | Use super magnet to pull rock out of ring into different orbit | Fire explosive or rocket into rock to move it into different orbit | |
| How might this happen? | Loop cables around rock or drill cables into object | Have payload bay, open bay and drop object into desired orbit | Select rock, aim and turn on magnet, pull rock to proper position, turn off magnet | Have a rocket mounted on the spacecraft, fire a desired rock and have it push it into a different orbit | |
| What else could happen? | Cables might not be strong enough and might snap, spacecraft could crash into object if too close | If rocks not exactly like those in Saturn's rings, they might not behave in the same manner | If no rocks in rings are magnetic, the mission will fail as the super magnet won't pull anything. Do magnets work in space?? | The rocket could destroy the rock or might not be strong enough to move it out of orbit | |
| Have I thought it through? | Yes, need drill and precision steering | Yes, fairly simple. Only need to open payload doors when in proper position | Yes, I am worried about whether this will work | Hmmmy maybe not, this doesn't seem like a good idea now | |
| What measurements will I need to make to carry out my mission? | Distance, Rock hardness | Mass, Distance | Distance, Magnetic fields | Distance, Explosive force | |
| Does this mission make sense? What problems could cause my mission to fail? | Yes. It could be very tricky to loop cables or drill cables into rock correctly so that the spacecraft can then pull it into new orbit. | Yes. Stones will add a lot of weight to spacecraft and it will require a great deal more fuel to leave Earth's gravity. | Maybe. The rings are made of ice and rocks. Magnets won't work on ice, only on some rocks and I don't know if magnets work in space. | No, it's a cool idea but probably won't work. Explosives may not work in space could destroy rock rather than move it | |

This slide has 2 CLICKS of animation.

TEACHER: If time permits, walk students through the answers to the other proposed missions.

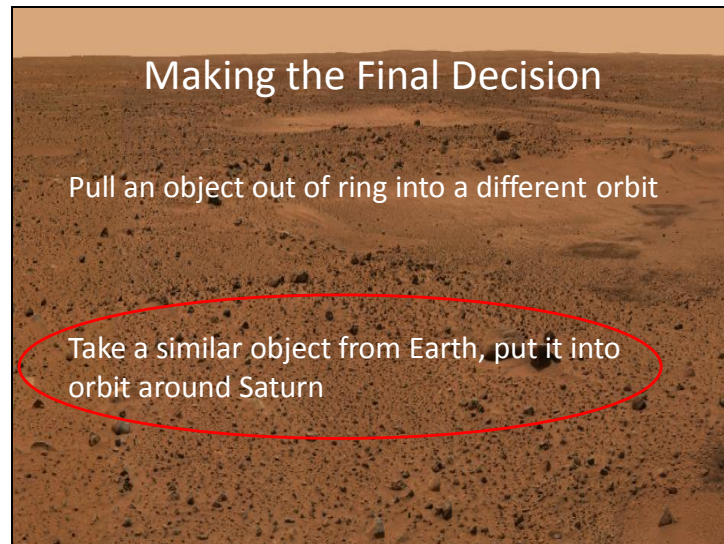
Here is my completed table. Let's see if we can eliminate any of the ideas I thought of right away because they aren't reasonable. Look at the last one. "Fire explosive or rocket into rock to move it into a different orbit." HMMMM. Now that I have thought it through, it is pretty obvious we can eliminate this idea. CLICK.

Let's look at the remaining possible missions. Are there any others we could consider eliminating because it is not quite as practical or reasonable as the others? (Once students suggest the super magnet mission, say...) Good yes, I am not confident that the super magnet idea will work. So, I agree, let's eliminate this idea. CLICK



Paraphrase the information on this slide.

SAY: Now I will share my internal dialogue to decide between the last two choices for my mission to Saturn.



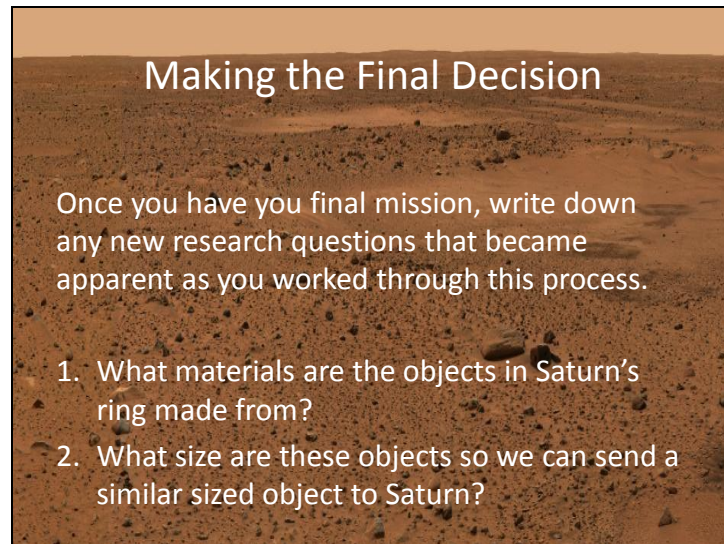
You can see my last two remaining mission choices. Let me think about these. If I were to choose pulling an object out of the rings into a different orbit, my spacecraft will need to make some very complex movements to get into position and either lasso the rock or drill into the rock. I know NASA has done similar things with the Mars rover so I am confident that we could make that work on my spacecraft. The other mission is to take a rock from earth to Saturn. This would be very easy. The only problems I would have is finding out what kinds of rocks are in Saturn's rings so that I choose a rock that is very similar. I would also have to use a bigger rocket so that I could lift off and leave Earth's gravity with that heavy rock inside.

Either mission would work to figure out if something will orbit Saturn in a different orbit. I do know that if something goes wrong with the mission, Saturn is very far away and I may not get a second chance to make the mission work. So, what I really need to decide is which mission is less likely to have a problem. I don't have to worry about blast off or the trip to Saturn. Both missions have those same risks. The real difference is once the missions arrive at Saturn. Clearly, pulling a rock out of orbit presents much bigger risks. If the spacecraft goes a little off target, it could crash into one of the billions of rocks in Saturn's rings. Also, to be successful, the cables have to be properly attached and be strong enough to pull the rock from the ring. If the gravity is too strong, or if the cables snap or if for any reason, the spacecraft can't attach the cable to the rock, the mission is lost.

By contrast, taking a rock to Saturn is simpler. The spacecraft only needs to maneuver to a different orbit, open the payload doors and release the rock. Probably the biggest difficulty

would be determining what the rocks in Saturn's rings are made of so that we can find a similar sized rock made of the same material on Earth.

Given this, I am thinking that we should choose taking an item from Earth to Saturn. [CLICK](#).



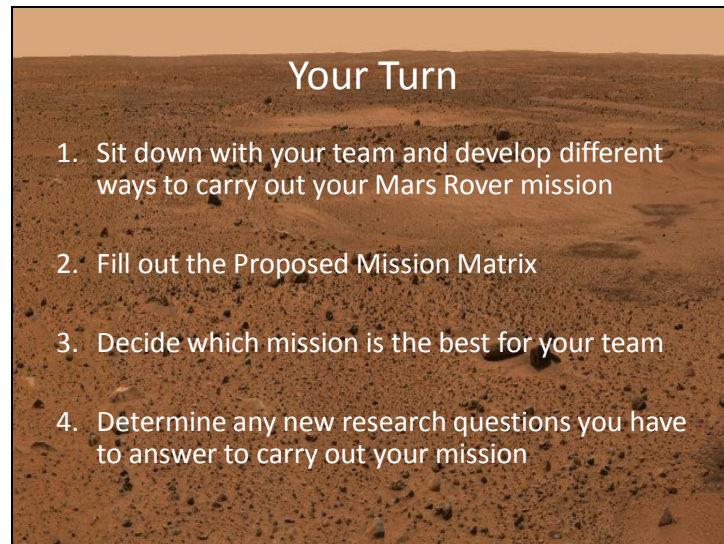
Making the Final Decision

Once you have your final mission, write down any new research questions that became apparent as you worked through this process.

1. What materials are the objects in Saturn's ring made from?
2. What size are these objects so we can send a similar sized object to Saturn?

Paraphrase the information on this slide.

Now that I have chosen my mission, I will need to research these new questions.

A background image of the Mars surface, showing a reddish-brown, rocky terrain under a hazy orange sky. The horizon is visible in the distance.

Your Turn

1. Sit down with your team and develop different ways to carry out your Mars Rover mission
2. Fill out the Proposed Mission Matrix
3. Decide which mission is the best for your team
4. Determine any new research questions you have to answer to carry out your mission

TEACHERS: You may wish to leave this slide up on the screen as your students work through this process.