Student questions: Bruce Jakosky colloquium on "Results from the MAVEN mission to Mars"

9/23/15

Question 1: Did you have a specific prescribed orbital path around Mars for the spacecraft before launch and if so, how did you manipulate the ship's trajectory to get it into that orbit once it arrived at Mars?
Everything was planned out in detail. We had requirements as to what orbit we needed to be in in order to make our science measurements – it had to have a certain periapsis, and it had to have a certain orbital period and inclination in order to "precess" or walk around the planet to give us different geometries. With that, we also had a specific orbit we had to enter into when we arrived at Mars. We ensured that we had the right approach by tracking the spacecraft and carrying out small maneuvers to adjust the trajectory. Once in orbit, we used about six different maneuvers (rocket motor burns) to get to the right orbit. Again, we did lots of tracking to ensure that knew what orbit we were in and what effect each burn would have.

Question 2: The MAVEN mission spacecraft is unable to make many observations about the dust cloud surrounding Mars aside from the fact that it's present. Are you interested in conducting a future mission that focuses on the composition and characteristics of this Martian dust cloud?
That would be an interesting mission! First, though, we want to learn what we can and try to determine whether the source of the dust is, indeed, from outside the Mars system or whether it's coming from the Martian moons or wafted up from the atmosphere. Then we can decide what the scientific priority of a mission focused on this would be relative to other science priorities. There isn't enough money to do everything we want to do, and we need to carry out the missions that are scientifically most exciting.

Question 1: How would solar winds affect the gas escape on Earth?
Earth has a strong internal magnetic field that pushes the solar wind and keeps it from hitting the atmosphere. Mars doesn't have such a field, so the solar wind can hit the atmosphere directly and strip some of it to space. So, Earth does not lose a significant amount of gas by this process in the same way that Mars does.

Question 2: What controls the speed of gas escape from Mars and Earth? As I know, H_2 gas escaped from the Earth during the early evolution, but H_2 gas escape is slow nowadays.
On both planets, H_2 escape is controlled by how quickly the gases are put into the atmosphere; once there, they are lost pretty quickly. The heavier gases are lost by what are called "non-thermal" processes, such as stripping by the solar wind. The rate of loss of gas today is pretty small, even at Mars. But the rate by the same processes would have been greater in the past, when the solar wind was more intense. One of the goals of MAVEN is to learn how the gas is lost today and how to extrapolate into the past to learn how quickly gas was lost then and how much total gas was lost.

Question 1: What is the time frame involved in the loss of the atmospheric gasses on Mars?
The geological evidence suggests that early Mars had an atmosphere that allowed liquid water, and that that thicker atmosphere must have dissipated over a period of a few hundred million years, by no later than 3.5 billion years ago.

Question 2: What were the most common gasses in the composition of the atmosphere on Mars?
CO_2 is most abundant today, followed by N_2 and Argon. Everything else is pretty much a trace gas. O_2 is present, but in small quantities; it forms when sunlight breaks apart CO_2. (On Earth, O_2 forms from living organisms using CO_2 and giving off O_2.)

Question 1: Does MAVEN need to correct for the loss in velocity after every dip into the atmosphere or is the effect small enought that it only needs to correct occasionally?
Good question. Each time we pass through periapsis, there's a small amount of drag exerted on the spacecraft. The most drag occurs during our deep-dip campaigns, when we lower periapsis and pass through a thicker part of the atmosphere (although still very tenuous). We've had to carry out one maneuver so far during our year in orbit to make up for this drag, and we anticipate doing two or three more over the lifetime of the mission.

Question 2: Is the rate at which the Martian atmosphere is losing ions decreasing as the solar cycle moves towards the solar minimum?
We don't know yet! We have a good estimate of the loss so far, and we'll make measurements to tell us that as the solar cycle decreases.

Question 1: You talked about how Mars had a layer of CO_2 in its atmosphere that was stripped away by solar wind. Could this happen on Earth and, if not, why not?
See earlier answer on the effects of the Earth's magnetic field.

Question 2: What does periapsis and apoapsis mean? You mentioned them in the context of the distances from Mars and what ions reached what distances.
Sorry, it's hard not to use jargon! In an elliptical orbit, periapsis is the lowest point reached in the orbit, and apoapsis is the highest. MAVEN's periapsis altitude is around 150 km above the surface, and its apoapsis altitude is around 6200 km above the surface.

Question 1: How did Mars originally acquire its atmosphere?
The planet formed from the accretion of small "planetesimals"; think of these as analogous to very primitive asteroids. These contained gases, often either bound in minerals or trapped as gas within the rock, and these were released either upon accretion or when Mars' core formed.

Question 2: Is there any possibility that the ~~dendyonic~~ dendritic river beds were formed by a liquid other than water?
Scientists have looked at a lot of different possibilities for the liquid, including water, CO2, lava, even liquid hydrocarbons or carving by the wind. Water is the most straightforward option, in terms of producing the observed features. Plus, among the possibilities, water is expected based on geochemical grounds to be abundant and present, so it's the most likely option. Plus, we see water as ice in the polar regions and bound in minerals, so we know it's present.

Question 1: What does Jean's escape mean?
It's named after the guy who first described the process. It refers to "thermal escape". Gas molecules are moving at high velocities in an atmosphere, even right around us individual molecules move at km/s speeds. At the top of the atmosphere, some will be moving fast enough to escape from Mars completely.

Question 2: Why is it important to measure atomic hydrogen versus deuterium on Mars?
Hydrogen and deuterium are light enough to escape by thermal escape. But D is heavier, so escapes less easily. That means that, as hydrogen escapes, more H escapes than D, and it leaves the atmosphere enriched in D. By looking at the degree of enrichment, you can determine how much hydrogen has been lost to space. As H and D come from water, you can determine how much water has been lost.

Question 1: Are there any plans to use MAVEN for a trip to another planet or object in space? (Obviously the name would have to be changed)
MAVEN was designed to explore Mars. It only has enough fuel to carry out is mission, and the spacecraft and instruments were designed for Mars. Thus, it's neither useful nor feasible to send it elsewhere.

Question 2: You mentioned that there were 3 storm events in March. Do you have any insight to why there haven't been any other events except for those 3 in a short time span?
Statistics of small numbers – sometimes independent events occur at nearly the same time randomly, sometimes not.

Question 1: What are the implications of finding the diffuse Aurora?
The aurora occurs because of energetic particles from the sun that hit the atmosphere. These energetic particles have other effects that are not seen as easily. So the aurora becomes a tracer of processes that might not be easily measured. Plus, it's cool!

Question 2: How is it that the solar winds create a magnetic field around the planet?
The solar wind carries with it a magnetic field, and a moving magnetic field creates an electric field. The electric field acts on ions in the Mars ionosphere and accelerates them. Moving ions create an electric current, and the changing current produces a magnetic field!

Question 1: Why is the aurora on Mars concentrated to the northern hemisphere?
That's a really good question, but we don't know that it's concentrated there. We only see it where we made a certain type of measurement (looking at the limb to see light that is emitted there), and we only made that type of measurement during certain parts of the orbit. We only know that we saw it at the places we looked, and we only looked in certain places; we don't know if it was present in other places or confined to those places where we were looking!

Question 2: The mohawk mars figures showed that more gas was escaping in the mohawk region, how are gases replenished there?
Gases mix throughout the entire atmosphere, and this replenishes the gas that is lost. The escape rates are low at the present epoch, so replenishment occurs more quickly than loss.

Question 1: Does MAVEN have an optical camera as well? If so, are the images posted on the PDS and what is the resolution?
We're the first spacecraft ever sent to Mars without a camera! But imaging wasn't important for our science, and we had to choose carefully because our resources (i.e., budget) didn't allow us to take every kind of science instrument.

Question 2: Does it require propulsion to stay in that crazy eccentric orbit?
The orbit by itself is stable and doesn't require propulsion. However, because we dip into the top of the upper atmosphere, we need to carry out maneuvers to stay at the right altitude and to correct for the effects of atmospheric drag.

Question 1: In your MAVEN slide, it mentioned 'Jeans Escape' leaving the atmosphere of Mars. What exactly is Jeans Escape?
See above, same question.

Question 2: Would the results have been different if the MAVEN primary mission occured during solar maximum?
Yes. All of the processes and the end result of escape depend on the level of solar activity. We wanted to fly as close to solar max as possible. We're on the declining phase, shortly after solar max. That time is okay, too, as it's when we expect the most, and the most intense, solar storms. We're hoping to now see toward solar minimum, and then possibly back up to solar max; that would give us the full solar cycle.

Question 1: One of the large unknowns affecting Mars' climate is the axial obliquity. Is there a way to define its pattern independently of geologic deposits assumed to be made during these shifts on Mars?
The history of the obliquity can be calculated theoretically, based on the mass distribution within Mars and the external gravitational forcing. However, the obliquity is chaotic, meaning in part that it cannot be predicted reliably beyond about 10 million years, either forward or backward. Beyond that, you can only do statistical comparisons and analyses, and these have very large inherent problems.

Question 2: How do you develop science hypotheses about problems that are unconstrained and complex with no Earth analogue?
First, people do look to find analogs to help understand what they're seeing. But we also know that, even if there is no geologic feature (for example) that is analogous, at least the basic physical and chemical laws apply. These do not change anywhere in the universe. That's a big help, in that we can ask how the laws of physics might apply in a given situation. On Mars, we have good geological and geochemical analogs. But on Pluto or elsewhere in the outer solar system, for example, we often have to return to basic physics and chemistry to try to understand what we see. And we often get it wrong, at least initially.

Question 1: How is return flux measured and how does the equipment distinguish the measurement between escaping and returning?
The instrument measures the direction and energy of ions, not caring whether they are headed upward (escaping) or downward (returning, or accreting). But we tally them up differently depending on which it is.

Question 2: If the Earth is closer to Mars, why hasn't it seen the same stripping effect that Mars has seen?
See earlier discussion of the effects of a magnetic field.

Question 1: Are there specfic chemical rates in the martian atmosphere that be indicative of an ancient earth-like Mars?
Not really. The reasons we think that ancient Mars might have had liquid water are: (i) The geological features we see require the presence of liquid water, and these features only occur on ancient surfaces. (ii) Same with minerals and other geochemical characteristics that require liquid water to form and are only present on ancient surfaces. (iii) There is clear evidence that gas has been lost from the atmosphere to space, meaning that the atmosphere must have been thicker early in history.

Question 2: What sort of error analysis is required to sift through large sets of data and quantify meaningful relationships in ionization rates, etc?
That's a really difficult question. Each measurement has its own uncertainty and requires a detailed error analysis. And then the models have an uncertainty in their output because it's not clear that we've included all of the processes. And it's a judgment call, often not amenable to error analysis, as to whether a particular model or scenario fits the observations, or how you decide which of competing models fits the data best. Or even what it means to "fit" data. In many ways, that's at the heart of scientific judgment.

Question 1: You talked about the ions in the Martian atmosphere creating auroras. Would the Martian aurora be a different color from the blue-green we see on Earth?
The aurora we've observed at Mars is light emitted at ultraviolet wavelengths and not visible to the human eye. We can calculate what light would be emitted at other wavelengths based on the composition of the atmosphere. We think that it might be visible to humans on the surface. But it wouldn't necessarily be the same colors as seen on Earth (and blue-green isn't the only one we see on Earth).

Question 2: You mentioned that the atmosphere of Mars was essential blown away by solar storms and that this was a major contributor to the current atmospheric and planetary conditions we see today. Was this an abrupt process or one that took place over millions to billions of years?
It likely took place over a few hundred million years. But the intensity of the Sun's emission and of the solar wind was declining through time, so probably not much longer than that.

Question 1: On your "Aberrated MSO Coverage" Figure towards the end of your slides, there are three colored strips which their orientation with respect to Mars is unclear. What are these strips?
If you imagine a sphere surrounding Mars and look to see where observations were made, those strips show it. It's relative to the direction to the Sun, though, not geographic latitude and longitude. Thus, over the mission so far, we've observed only a small fraction of the directions around Mars. But when you consider the fact that the electric field varies, and that it's the electric field that drives a lot of the processes, then in "electric field" coordinates, we've observed a lot larger fraction of that sphere surrounding Mars.

Question 2: How will the said discovery of diffuse aurora affect the measurements of escape material?
It doesn't affect the measurements of escaping material or escape rates. But it may be telling us about some of the processes that control escape.

Question 1: Is the Earth losing its atmosphere as fast as Mars?
See earlier comment on a similar question.

Question 2: The orbit of the MAVEN satellite looks very complex. How did you guys come up with it?
It's a simple ellipse, but the ellipse "precesses" with time. This means that it rotates around Mars, both in latitude and in longitude. It's the gravitational field of Mars that causes it to rotate, and we know enough about the gravity field to calculate what the rotation will be. We knew this when we started, and could pick the orbit size and shape to give us a rotation that lets us get good coverage of the space surrounding Mars.

Question 1: Why has this atmospheric stripping occurred on Mars but not on Earth (yet?)?
Answered earlier.

Question 2: What changed on warm/wet Mars to cause this process to begin the transition to cold/dry Mars?
We think that the early Mars atmosphere was protected from stripping by an intrinsic magnetic field that Mars had. We see remnants of that today, so we believe it existed. But when the convection in the core turned off, and the magnetic field turned off, the atmosphere was no longer protected and the solar wind could strip it off.

Question 1: How long did it take to strip the atmosphere based on your current models?
Question 2: Is MAVEN able to detect muons in the remaining atmosphere?
Not sure what is being asked here. We don't detect muons.

Question 1: How high would the observed escape flux from the Martian atmosphere have to be in order to conclude that the solar wind played a significant role in removing the ancient water from Mars?
The question isn't how high it has to be today, but how high it was in the past. We think that we can extrapolate backwards and determine the escape rate early in history based on today's rate. Doing this tells us that Mars must have lost a lot of atmosphere to space.

Question 2: Does the ionic Martian magnetosphere have poles where the diffuse aurorae detected tend to cluster (like on Earth), or are the aurorae more or less spread out over the planet's surface?
We see both. We've observed "discrete" aurora near some of the regions of magnetized crust. And now we've seen "diffuse" aurora that we think covers the entire planet.

Question 1: Now that you have measured the mass loss of CO2 on Mars, how much CO2 replenishment is needed to sustain a greenhouse effect at this mass loss rate?
That's a tough one. You'd need enough CO2 to make the Mars atmosphere as thick as Earth's in order to get enough greenhouse warming to allow liquid water. Where would that CO2 come from? Plus, if you have liquid water, you can get the formation of carbonate minerals that would remove the CO2 out of the atmosphere. So this process may be self limiting. The loss out the top of the atmosphere is slow enough TODAY that you probably don't need to worry about it.

Question 2: MAVEN measures the escape rate of ionized gas, can non-ionized gas escape after being collisionally accelerated by an energetic ionized molecule?
Yes! Escaping neutral atoms are hard to measure, though, so we have to model that loss process. We're still in the process of doing that.

Question 1: Did the atmospheric measurements collected by the rover figure into your models of escape?
They will. We're starting to use the isotopic measurements to determine the loss rates. And measurements from the rovers and from the Phoenix lander determined the isotope ratios in the lower atmosphere. Being able to compare the ratios in the lower atmosphere and in the upper atmosphere is extremely valuable.

Question 2: How is the atmospheric density at those levels known without prior deep dip campaigns?
When we got to Mars, we slowly lowered periapsis because we weren't sure what the density would be at each altitude. And when we lowered periapsis again for the deep dips, we did it in steps for the same reason. We're very cautious, because we would hate to make a mistake that causes us to lose the spacecraft!