Astronomy Cast Episode 52:
Mars

Fraser Cain: Today we consider Mars: the next planet in our journey through the solar system. Apart form the Earth, it's the most explored planet out there. Even now, there are rovers crawling the surface, orbiters overhead, and a lander on its way. It's a cold, dry desert – so why does this planet hold such fascination?

Pamela? Why?

Dr. Pamela Gay: Well, it's easy to get to. It's the nearest rock to the Earth, and it's also one that captivates us because if it weren't for the high radiation levels, you could walk around on the surface of Mars in a scuba suit and a winter jacket. That's just kind of cool: you could live on the surface of another planet.

Unfortunately there's this problem with radiation, but that again… now you're wandering around in a scuba suit, lead suit and a warm winter jacket. And you can walk on the surface.

Fraser: Okay, let's talk about the characteristics of the planet. With Venus we had all these different ways that Venus was trying to kill you. With Mars, there's all these ways where Mars is trying to help you out.

Pamela: It's a great little world. It's smaller than the Earth, and has significantly lower gravity. This is part of the reason that it doesn't totally help you out. Its gravity isn't strong enough to hold onto a nice, thick atmosphere. It does have some atmosphere – weather, cloud patterns and the biggest dust storms in the entire solar system.

This atmosphere allows it to hold onto a little bit of the heat that hits it. This means that when the Mars rovers landed, it was warmer on Mars than it was in the city of Boston – it can get as high as 70 degrees Fahrenheit.

That said, it also gets cold enough there that it will freeze carbon dioxide out of the atmosphere to make dry ice polar caps.

This is a planet that has water. It's not liquid water running across the surface of the planet. If you put a glass of water out on the surface of Mars, the atmosphere is so thin that the water will go straight to humidity – straight to water molecules becoming gas, just hanging out and joining the atmosphere until it gets cold enough that then the water, instead of raining out of the atmosphere, freezes out of the atmosphere.

So you have these two poles made out of water ice and dry ice. There's also water under the surface of Mars. This water occasionally comes up to the surface and helps form these gullies and surface features we're still trying to understand.

There are dust devils! A walk across one of the plains of Mars might not look too different from a walk across a desert in the southwest of the United States where you have dust devils, dust storms, and gullies. It's very much like home, with the deadly aspects.

Fraser: Okay, let's talk about the deadly aspects.

Pamela: Well, the atmosphere isn't thick enough to breathe.

Fraser: How thick is it not?

Pamela: (laughing) How thick is it not… it's actually 0.6% of the atmosphere on the surface of the planet Earth. So it's a really, really thin atmosphere.

Fraser: So even if it were pure oxygen, you wouldn't be able to breathe it.

Pamela: Well, you could try, but unfortunately the vessels, the air sacs, and the stuff in our lungs… they need a certain amount of air pressure to work against them, or they're going to rupture. This is such a low air pressure that it can actually damage the inside of your lungs. You're going to want to have (basically) a scuba suit to be maintaining proper pressure inside your lungs while you try to breathe.

Fraser: Right. And you said the temperatures can get up to fairly warm temperatures… but most of the time, for most of the planet, it's pretty cold.

Pamela: Its average temperature is –46 degrees Celsius. It's a bad winter day in Michigan, on average. I've actually seen it get colder than that in Michigan, and really – you don't want to go outside.

Its minimum temperatures are about –87 degrees Celsius. So it gets cold enough that you're going to have the surface of your eyes freezing, you're going to have almost instantaneous frostbite, you're going to start losing fingers and toes and your nose and all the things you hear about Mount Everest climbers losing to cold weather.

So you go out in a scuba suit, or some kind of breathing apparatus. You've got a nice Everest or Antarctica suit on – what else is going to be a problem for you?

Pamela: It doesn't have a magnetic field – this is going to keep coming up over and over as we talk about the planets (the necessity of a magnetic field).

Because Mars is so much smaller than the planet Earth, it was able to cool off faster. It's like making pies. The big pie in the 12-inch dish is going to take a lot longer to cool than the little mini pies you might make to give away to friends. The smaller something is, the faster it can cool off.

Mars already cooled off; this means that it no longer has a liquid iron core to drive volcanism, to drive a magnetic field. The planet is geologically dead, and part of that dying process means the magnetic field goes away. Without a magnetic field, the solar wind can blow the atmosphere away. Mars is suffering from a small atmosphere because it doesn't have a lot of gravity, and what atmosphere it can gravitationally hold onto, the Sun is coming along and blasting away.

So, people trying to figure out how to terraform Mars… we can figure out how to get oxygen to free itself from the water and from the carbon dioxide in the atmosphere, but we can't figure out how to keep it, because the solar wind is constantly going to be blowing the atmosphere away.

Fraser: So any attempt to restore the atmosphere on Mars would just be pointless.

Pamela: It's completely pointless. This solar wind is just constantly blowing it away, and radiation associated with the solar wind can get all the way to the surface of the planet. Our magnetic field is protecting us from these high-energy particles. Those high-energy particles are going to go straight to the surface on Mars, where they can damage human cells and trigger mutations that are harmful for life.

Fraser: All right. Let's talk about the exploration of Mars up until now. How have humans reached out and attempted to visit the red planet?

Pamela: Well, we started off by sending out Mariner 4 in 1965. This was a really exciting mission. We had speculated as a planet that perhaps some of the surface features we were seeing were oceans.

When you look at Mars through a standard amateur telescope, you can actually make out surface features. You can see the white ice caps, you can see the dark regions, and you can see the light dust regions. It leaves the imagination room to imagine perhaps that white you're seeing is oceans. Perhaps that dark you're seeing is oceans.

It turned out that there is no liquid water on the surface. We learned that in 1965 and we're still trying to find water there. The liquid we now know isn't on the surface we now think is below the surface.

Since that 1965 mission we've sent countless small probes that way to go and image. Today, orbiting the planet we have Mars Odyssey, we have Mars Express, Mars Reconnaissance Orbiter. These little satellites are acting as communications relay stations to get information from the Mars Exploration Rovers, back to Earth. So the little rovers, instead of using their batteries to transmit all the way back to Earth (which they can do), can also uplink information to these orbiting satellites and then they relay it back to scientists using their higher power antennas and solar cells.

They're imaging the planet in all different wavelengths, looking for different particles coming off from subsurface reactions. Using these bands of satellites, we've been able to track changes in the surface of the planet. We've been able to see how gullies have grown out of the sides of craters.

In images now spanning over five years, we can look (in high resolution) at one place time after time after time and see how dust devils have left streaks, how mysterious black streaks that we don't think come from dirt devils have emerged out of different hills, how new channels that look like they were cut by water are appearing.

These spy satellites – Mars Reconnaissance Orbiter (sounds like a spy satellite to me) - are spying to see if there's water, to learn about the weather and to help us understand everything we can about this little world.

Fraser: Let's talk about the rovers specifically, because they've got a pretty interesting job to do.

Pamela: The rovers are amazing. They were expected to last just a few months, and now it's been a few years and they're still chewing along.

Fraser: I don't buy that - I don't buy that they were expected to last 3 months. I think they were expected to last years and years.

Pamela: What we didn't know was going to happen was the wind blowing the dust off the solar panels.

Fraser: Right, that was the problem. They thought the solar panels would just clog up with dust from the atmosphere until they stopped working and the rovers would run out of power.

Pamela: As it turns out, the same dust storms that we were worried about depositing too much dust on the little rovers actually blasts the dust off of the rovers now and then. It's sort of like when you have a massive snowstorm, but there are still areas of fields that are completely devoid of snow because of the wind. The Mars rovers are getting that great blast of wind now and then.

The other thing that hasn't happened so far, but we're a bit worried about happening this year, is if the rovers batteries ever go completely dead, then they have no way of rebooting. It's sort of like with my Macintosh computer. It can chew along pretty well without being plugged into the wall. It will eventually put itself into sleep mode if I forget to plug it in for too long.

I can plug it back in and open it up and it keeps going as long as I don't let it stay in that mostly-dead sleep mode for too long. But if I leave it like that, and the battery goes completely dead, all the files I was working on and didn't save are toast. With these rovers, they can go into sleep mode, but if they stay in sleep mode too long, they can't turn themselves back on. We're worried about that happening.

That will happen if the dust storms ever get so thick for so long that the solar cells can't recharge the rovers. So far it looks like they will probably get through this dust season.

Whenever Mars is closest to the Sun, and it's hottest on the planet, you end up with these massive dust storms. We're mostly through the season, but we're not quite there yet. It looks like the storms might be starting to clear up this season; hopefully the rovers will keep going, I know they're starting to resume their science – and they're doing great science.

Fraser: I'm just doing an article right now, with the rovers getting rolling again. They've got enough power now that they're able to start driving and doing more science.

Let's talk about the science they're doing. Why are the rovers there on the red planet?

Pamela: There are some things you can only see by clearing off the surface of a rock. We wanted to go in and observe the actual mineral structures and stratifications and the different layering in the surface. The Mars rovers are equipped to wander around and use this rat arm to go out and burrow a little bit into a rock and look at the detailed mineral structures within the rocks.

They're finding minerals that can only form in the presence of liquid water. They're going around and looking to observe the types of mineral deposits and types of rock formations. We're using this to try and figure out the geological history of the planet.

Different rocks form in different ways, and currently one of the rovers is perched on the edge of a crater getting ready to descend into Victoria Crater, to see what stratifications can be seen in this hole that was dug out by a rock from space, just to see. We know what the surface looks like, so let's see what happened in the different points.

It's just like driving down a highway here and looking into the highway cutouts and seeing the different layers of the Earth's history and geological deposits. They're going and looking to see what the different layers and deposits are on Mars.

Fraser: They're not looking for current water on Mars – they're not really equipped to find it. They're looking for evidence that water was acting on rocks over long periods of time in the past. They're also not equipped to find life at all, are they?

Pamela: No, they were specifically designed without the ability to look for life, and without the ability to actively go far enough ranging distances to search for liquid water. If they find liquid water, they'll know it's there. It's liquid – you take pictures of it, touch it, you can tell it's liquid. But that wasn't part of their mission. Their mission was to go out and be a rock hound, and explore the geological features on the surface. They're doing a great job of wandering all over the place and finding all sorts of neat structures.

One type of structure they're finding has been jokingly called "blueberries". They're these little, tiny mineral deposits that look like berries growing on the rocks. They're getting amazing images of the weather patterns. We can watch clouds coming and going. We can calibrate the instruments to get a sense of the real colours on the surface of Mars. Colours help us understand how the sunlight is passing through the atmosphere – and there's information in that colour.

They're just going around and digging, and seeing what rocks are where, and trying to piece together what was necessary to get those rock formations.

Fraser: Let's talk about the next mission, which is on its way right now, the Phoenix Polar Lander. It should be able to take that exploration a little further.

Pamela: Mars has layered ice deposits on its northern and southern poles. Every year new ice gets deposited. Some of it melts; some of it stays there. When you look at high-resolution images of the poles, you can actually see these layering effects of the changes in how ice has been deposited over millennia.

It's going to be able to go in, dig, see if it's water ice, dry ice – and the proportions the different types of ice exist in, and the gasses trapped within them. By taking samples of ice and looking at the gases trapped in them, you can see how atmospheres have changed over time.

You can also look for life. It's not something that NASA generally has as part of its core mission. You can look at what sorts of nutrients might be trapped in the ice. This again gives us a sense of the geologic history of Mars.

Fraser: That recently launched – just in early August, and is going to be getting to Mars in May 2008, I think. It's just a lander – it's not a rover like Spirit and Opportunity. It's going to land and that's that. It's going to dig wherever it can reach.

Pamela: Exactly. And, you know… that's what scientists tend to do in Antarctica. You go somewhere, set up your equipment, and dig a hole. That's what it's going to do.

This is actually a fairly neat craft because it's in some ways a replacement craft for the Mars Polar Lander that opted to crash into the surface of Mars instead of landing on it. We've been able to take advantage of the technologies that were developed for that mission, update them to modern abilities, and recreate that plan to, in this case try and study the ice a second time. So the name "phoenix" really is a rebirth in this case.

Fraser: The next mission is going to be the Exploration Science Laboratory?

Pamela: It's the Mars Exploration Laboratory, and it is going to have roving abilities. This is the mission that is going to try and search for life. They're working very hard to develop experiments that are capable of settling a question that was actually started by one of the Viking probes.

The Viking probes had very simple equipment on them that would scoop up a sample of Martian soil, introduce water and nutrients, and then look for gases to be given off during chemical reactions, that might be indicative of those chemical reactions taking place in micro bacteria, normal bacteria, microbes. Those original experiments were highly inconclusive.

It turned out that the Mars soil just might have a chemistry that acted like life without having life in it. This is an ongoing debate of whether or not the Vikings conclusively didn't find life, conclusively found life, or just had a null result. Most people are leaning toward it being a null result, which is extremely frustrating.

We're trying to develop new experiments that go, look for chemical reactions in soils that are indicative of life being present in the soils.

Fraser: Mars has some interesting features that are not seen anywhere else in the solar system. You said the planet was dead geologically, and yet it has the largest volcanoes in the solar system. How is that possible?

Pamela: It hasn't always been dead. Its death is actually a fairly recent thing, with several of its surface features only forming in the past several million years. Cerberus Fossae, a giant chasm, we think opened about million years ago. But the volcanoes themselves probably died about a billion years ago.

Once upon a time, just like the Earth, its interior was a whole lot hotter and there was a whole lot more volcanism. Back, 3.8 – 3.5 billion years ago, the Tharsis Bulge area was having extensive amounts of volcanism. This was back during the age that Olympus Mons most likely formed, and the other giant shield volcanoes that form that section of the surface of Mars. There was continued deposition of lava plains all the way up until about 1.8 billion years ago.

But, as the planet cooled, the volcanoes stopped having as much activity and then stopped having any activity at all. There was also a point in time when part of the release of heat also most likely gave off vast amounts of water being melted. Valles Marinares looks (as near as we can tell) like the giant, big sibling to our own grand canyon here on the planet Earth. This valley (we think) was probably formed during some sort of a giant release of liquid water. We're not entirely sure what would've caused that, but its features just look like they were formed by water. This is part of why we need the rovers – to see if you can form these sorts of things with the dust and wind speeds on Mars. The evidence keeps pointing to once upon a time there was liquid that eroded the surface.

Fraser: There are what seem to be ancient coastlines on Mars too.

Pamela: There have been calculation that showed if you take all the water currently trapped in ice and melt it, you can cover the entire surface of Mars in liquid oceans.

When we look at the surface, we see what look like coastlines, and what look like the effects of Mars (just like we talked about with the Earth last week) having true polar wanderer events where the planet rotated itself about its axis of rotation so what used to be a pole was at the equator and what used to be at the equator is now at the poles – in reaction to a redistribution of mass. When those oceans dried up and went away, the mass distribution of the planet changed, and the planet rearranged itself so that it could rotate in a stable way.

Fraser: One of the last things I'd like to talk about is its moons. It has two moons – Venus has none, we only have one, Mars has two.

Pamela: There was actually for a while people wondered if this meant that Jupiter would have three, so if you look back at old documents people used to do all sorts of numerology out of this – Venus 0, Earth 1, Mars 2. That's not the case.

It looks like through some weird event that we can't explain, Mars may have captured two asteroids. The reason we have so much trouble trying to explain this is it's two little moons, Phobos and Deimos, are in close orbits. Their orbits are almost perfect circles. You don't usually end up with that when you're randomly capturing objects.

Not only are they almost perfect circles, but also their orbits are pretty much straight over Mars' equator – again not something you generally end up with randomly. However Mars captured its two moons, these moons are in very close-in orbits (unlike our own moon).

The further out of the two is almost in an orbit equivalent to what we typically have our geo-synchronous satellites in – it almost stays over the same point on the planet. It creeps slowly around relative to the rotation rate. This means if you're watching the moon rise, it seems to take absolutely forever to creep into the sky and slowly wander its way across. So that's Deimos.

Now, Phobos is a lot closer in. In fact, it's so much closer in that as it zips around the planet, it's orbiting Mars faster than Mars is rotating, and Mars' days are only a few minutes longer than our Earth days. As Phobos quickly flies around the planet, it's actually suffering tidal effects that are constantly dragging it closer and closer to the surface. Eventually it's going to get so close that tidal effects are probably going to cause this little moon to shatter.

There are a few people that have speculated that the shattered moon is going to turn into a temporary ring around Mars, and others who say this is going to be one of the worst meteor impact events ever (except in this case the meteor bits are actually broken bits of moon).

So Mars has an interesting future in store for it, when that moon decides to cease to be a moon.

Fraser: Do they have any idea how long it's going to take?

Pamela: There are different calculations, I have to admit those aren't numbers I have in front of me, but we'll try to get those in the show notes. It's not in our lifetimes – it's on the order of millions, billions of years in the future.

Fraser: I guess the last thing is we're going to be sending humans back to Mars – in theory.

Pamela: In theory.

Fraser: we've been promised.

Pamela: (laughing) The US government currently has, as part of its goal for NASA, to get men (or women, or both) to the surface of the planet Mars. This is part of our Moon-Mars initiative. I'm hoping that the commercial space agencies will hop onto this. I think Mars makes a great commercial target, because really – who doesn't want to go there?

There are a lot of complexities though. You have to build a team of people that are going to be able to get along beautifully in very cramped quarters for probably several years. It'll take a year to get there, you'll want to hang out on the surface for a while, and then it'll take a year to get back (if you come back).

If you want to learn what this experience could possibly be like, there's a very good fiction book by Kim Stanley Robinson called *Red Mars* that a lot of research went into in trying to figure out the human dynamics of getting there.

There are also all the medical concerns. There are people saying any astronauts being sent to Mars will have to have their appendix removed, or their gallbladder removed, just in case.

But it's all on the horizon. We're trying to figure out how to do it. There's lots of tantalizing science coming out right now. Methane has been discovered in the atmosphere of Mars. This indicates that there might be methanogens, little bacteria that produce methane, active on the surface today, and we'd like to go looking for them. Humans can generally move faster and with higher safety levels than rovers, which you have to worry about falling into holes and tripping over rocks.

So hopefully man isn't too far away from going and actually looking for life on Mars.

Fraser: I don't know if you've been looking at your calendar, but this actually warps up 52 episodes – it's a whole year of Astronomy Cast!

Pamela: Oh wow, I lost track of that. That's really cool!

[laughter]

Fraser: I was thinking about that as I was saying the number – episode 52, 52… that's a whole year. So, a whole year – now I hope people can't say they wish we had more episodes – we have 52!

Congratulations Pamela!

Pamela: Congratulations Fraser. It's been a great year exploring science with you.

Fraser: I think our list of outstanding episodes is now more than 50, so we have years to go.

This transcript is not an exact match to the audio file. It has been edited for clarity.