Astronomy Cast Episode 95:
Humans to Mars Part 2 - Colonization

Fraser Cain: I want to take a moment to announce that our good friend Chris Lintott is having an asteroid named after him, correct?

Dr. Pamela Gay: That is correct. We will get the current designation up on our website and we'd like to congratulate him on this wonderful über-nerdy coolness that he now possesses.

Fraser: Phil Plait has one, as do Derek and Swoopy from Skepticality.

Pamela: David Levy.

Fraser: A friend of mine, Carl from the Netherlands has one. I must say I'm feeling a little jealous.

Pamela: Yeah, me too. But hey, at least we're now on Wikipedia. It's a start.

Fraser: And that Wikipedia entry is just great. So, once again, thanks to everybody who made it stick. Let's move on to the second part of our Humans to Mars – I think the last part. We're going to stick Colonization and Terraforming in together.

So, after Astronauts make the first tentative steps onto the surface of Mars, a big goal will be colonization of the red planet. The first trailblazers who try to live on Mars will have their work cut out for them living in an environment completely hostile to life.

What challenges will they face? How might they overcome them? And maybe one day they'll even be able to change the climate of Mars itself through the process of terraforming.

Okay Pamela, we talked last week about the science side of it where missions will be sent to Mars like the Apollo program. They will be picking up rocks, breaking them open and looking inside, coming back home. But a long-term objective is how they are going to be trying to live on the surface of Mars. So, how do you see that playing out?

Pamela: Slowly. [Laughter]

Fraser: Yeah. Well, okay so we were talking before we prepped on the show we were having an analogy. I always think of it like how hard it is going to be depends on where you are going.

If I wanted to go to New York City to colonize it, I wouldn't have to bring my own oxygen or food. I could buy stuff there so I wouldn't have to bring all of my clothing, all of my tools and equipment.

So in this case you're going to Mars there is more and more stuff that you have to account for. What is the main reason to colonize Mars? Why would we want to do it?

Pamela: It's always good to have a backup. Currently the human race only exists on one planetary hard drive and that would be the planet Earth. If something terrible happens we could lose all of our species because we don't have a backup place in the Solar System where we flung a little bit of our genetic material such that it's capable of taking off on its own.

Fraser: There are so many things that you could imagine like asteroid strikes. It's not a question of if just a question of when something happens.

Pamela: Mad diseases.

Fraser: Yeah, some kinds of worldwide pathogen, crazy nanotechnology run amok. [Laughter] Some physics experiments gone bad that turns the Earth into a black hole. This isn't going to happen with the Large Hadron Collider. What if someone else comes up with a black hole generator?

So, environmental crises – what happens if global warming does something that we weren't expecting? There are a lot of reasons why Earth itself could be rendered uninhabitable for humans and it would be good to have a backup.

Pamela: So it's easy to get to the Moon but Mars is a little bit easier to live on. The temperatures aren't quite as extreme. There are days on Mars that are warmer than you find in the city of Boston. The gravity isn't quite as bad. It's still going to cause osteoporosis given enough time but if you dare to walk around without feeling you're going to launch yourself into a new orbit.

It also has on the planet a lot of the chemical resources we need. There is water, nitrogen, there's all the stuff to make propellants. There are also minerals, most of it tied up with the oxygen. So while you're digging different metal oxides out of the ground you can get yourself something to breathe and something to build out of.

Fraser: Right, the color of Mars, the red color comes from iron oxide so split that apart. You get oxygen, which you need, and iron.

Pamela: So, if we're going to find someplace to set up a secondary place for humanity to try its crazy thing called life, why not Mars? It's not that far away and it has what we need.

Fraser: Let's talk about with my analogy of my attempting to colonize New York City (from Vancouver – setting my next expedition) [Laughter] how is Mars similar to Earth? As you said, the Moon is close but the Moon is really inhospitable. So, what are some of the aspects of Mars that are similar?

Pamela: First of all, there are just the little things that prevent us from going insane. The day/night cycle on Mars isn't all that different from the day/night cycle here on Earth. On Mars it is 24 hours 39 minutes, so going to Mars actually offers us a way to add a little bit more time to each day.

Fraser: Do you think we could adjust to that, an extra 39 minutes?

Pamela: There are people who are working on trying to do experiments by getting poor innocent research schmoes living in caves and such to figure out what's the effect on the human psyche. NASA is running its own inadvertent experiment by asking a lot of the Mars mission leaders to stay up on the Mars cycle while they take care of the robots for a certain period of time.

While it gets stressful in terms of all of your friends have one sleep cycle and you have this other crazy migrating sleep cycle, it seems to be something that humans can handle. Getting 40 minutes extra out of our day probably won't kill us.

There are also things like it has seasons. There are a lot of human beings who just like to have seasons and the seasons that are on Mars aren't that extreme. If you had a planet with a massive tilt, cock it over on its side such that half the year it is an extreme winter where the Sun never comes up for the whole planet and the other half of the planet is daylight. Human minds need our day/night cycle.

The tilt of the planet Mars is not that different from the tilt of the planet Earth. Earth is tilted at 23.4 degrees and Mars is tilted at 25.2 degrees. With that type of tilt you end up with the same lengthening and shortening of the day at mid-latitudes that you get on the planet Earth.

It's something we're used to and comfortable with and not something so extreme that it's going to shock our systems by not allowing us to get the daylight. It's more importantly not going to shock our power generation if we're relying on solar power.

Fraser: You can imagine plants that were growing feeling very comfortable with that. A lot of them will decide to germinate based on temperatures and they get ready for seasons and so on. I think that is just one less thing to worry about.

Pamela: The real killer is the Martian year is a lot longer than ours. That will probably muck up plants but this is why we have greenhouses with artificial lights.

Fraser: So all the seasons are twice as long, right? A summer is twice as long; spring is twice as long, etc.

Pamela: Exactly. We do have to figure out some ways to trick things into germinating and to point out. But in the grand scheme of things we know how to do that. We have hothouse tomatoes no matter how bad they might taste, they're still edible. So we know how to solve that problem.

Fraser: Right, so we've got nice tilt, seasons and length of days. What else does Mars have going for it?

Pamela: Well, while not having a lot of gravity it does have enough gravity that you can cope. You can walk around and we're not sure what the health problems it will introduce will be. It's not terrible. It's not weightlessness.

Weightlessness is a problem with everything you try to do. Plants don't grow right, animals aren't happy. There's enough gravity that we should be able to get plants to grow, fish to swim in tanks and halfway reproduce and all those sorts of things.

Fraser: I know there's a mission that's being developed which will send a team of mice into orbit and then set the spacecraft spinning so that they will enjoy one third Earth gravity, which is the same as Mars. I guess they'll remain in orbit for some period of time and then brought back down to Earth. Scientists will be able to look and see what impact living in one-third Earth gravity had on them. So, hopefully we'll have that question answered fairly soon.

Pamela: They're actually looking to have these mice live out their entire lifetime in the simulated Martian gravity. It should help us start to answer the question of Earth gravity is good, weightlessness is bad, but what we don't know is the difference one that has a linear transition. Is half Earth gravity half as bad? Or, is it something with a steep curve such that half Earth gravity is not so bad – we can cope.

But eighty percent Earth gravity is really, really bad. We need to figure out what is the relationship between negative impact on the human body and how little gravity the human body is being exposed to.

Fraser: Right and I think you can see, as you said, if you're in weightlessness you lose bone mass pretty badly. I know the astronauts do a bunch of exercises to keep their bones as strong as possible and to reduce the amount of muscle that they lose. But it is kinda inevitable.

The question then is if you're going to plan to live generations on the surface of Mars is there some point where you lose bone to a certain amount and you lose muscle mass to a certain point? Then you're able to live for a normal human life span without degrading any further or is it just fatal? Is it like being born with diabetes and not being able to have insulin?

You're born on Mars and you didn't have enough gravity you would inevitably die within X amount of time. And there's pretty much no way you can increase your gravity. It's not like you can spin up to Mars, you know [Laughter] and live on the inside.

The solution is while you're in Space to be able to increase the gravity. But if you're on Mars there's nothing you can do. Everyone would have to be in the weight room all day long, right? To not die, right?

Pamela: The other solution that they are also talking about is if you've ever been to a carnival you might have seen one of the crazy spinning like you're in a salad shredder type device where you stand up against a cushioned wall and then they spin up the device and it plasters you against the wall. Then they can tilt it all different directions and you stay in place.

It might be possible to create one of these spinning rooms for human beings to sleep in or to create some sort of centrifuge. That's the direction that a lot of people are thinking is why not take advantage of the time that people are lying down asleep and bring them up to higher levels of gravity during this period?

Fraser: But I think that would take some of the magic out of it. [Laughter] I think that colonists will have enough problems already. But to go and have to spend six hours in a centrifuge every day just to not die I think would be frustrating.

Pamela: And the other question is: what are all of the impacts of having less bone mass when you're on a planet with less gravity? One of the major problems of having lowered bone mass here on the planet Earth is you trip you break a bone or your hip. You trip too many times and you are no longer capable of walking. Pain and suffering is terrible.

What if you lose bone mass but the ratio of the needed bone strength to the bone stress levels that your body can sustain is at some sort of a constant ratio? We don't know how those things will play out.

There are a lot of questions that we don't know how to answer and throwing mice into Space is a way to start getting at those answers. [Laughter]

Fraser: Go mice. So what else does Mars have going for it?

Pamela: That's actually quite sadly about all it has going for it. It has gravity, chemicals, and minerals.

Fraser: Alright, now what has Mars got going against it? [Laughter] What are the things we're going to have to bring? What are the things we're going to have to change to survive there?

Pamela: Oh, it has so much going against it. Well, yeah, there are days here on Earth that are colder than days on Mars. It still has average surface temperatures between negative 60 Celsius and negative 140 Celsius. Human beings don't survive unexposed at those temperatures very long.

There are algae that are happy at those temperatures, but really beyond the algae, not so much. Right now there is no liquid water on Mars. There is no ability for a human being to walk around comfortably on the surface of Mars.

If a poor innocent astronaut accidentally walked out the wrong door in the middle of the night and ended up on the surface of Mars their skin would start to freeze and bruise simultaneously.

The temperatures are so low that it starts causing problems with flash frostbite and the pressures are so low that the blood vessels on the surface of your skin start rupturing. This is a bad way to die.

Fraser: Right. You're merging two at the same time. You're dealing with the low temperature, which would flash freeze you and then you get the problem of the low air pressure. Why is that happening?

Pamela: Mars is just a little tiny planet. It is total surface area. It has no oceans. It has no seas. Its total surface area is about the same as the surface area of land on the planet Earth.

If you can imagine peeling all of the continents and islands off of planet Earth and pasting them onto a much smaller nerf planet, you can actually take a standard globe and a standard nerf ball and that is the ratio in sizes you're looking at between the two worlds.

When you have a planet that is that much smaller and it is also a lot less dense than the planet Earth, you end up with less gravity. Less gravity means you can't hold on to your atmosphere as well. So, the atmosphere is readily just randomly losing atoms into Space.

They knock about, hit each other and get going in the wrong direction at the wrong velocity and they're gone. Headed for the outer Solar System, they're headed for the inner Solar System. They're not making the atmosphere nice and thick on Mars.

The planet Mars doesn't have a magnetosphere. It has no magnetic field protecting it from the blasting of solar radiation. Cosmic rays, solar coronal mass ejections impacting on the surface of Mars' atmosphere, all these things work to knock particles again out of the atmosphere. So, you have a very thin atmosphere and that's just not good for life either.

Fraser: Now you talked about the bruising so what happens? The pressure is what, one percent of Earth's air pressure I think? If I try to go out into that kind of atmosphere, what would happen to my body?

If the temperature was….[Laughter] one of those nice 20 degrees Celsius days, but the air pressure is still like one percent.

Pamela: If you can imagine taking a vacuum cleaner and attaching it to your arm for a prolonged period of time, that is not as much pull as your skin would feel on it from the lack of pressure on the planet Mars.

Fraser: That's a really good analogy. I never even thought about that – hickies all over your body.

Pamela: Yeah, it's a major pressure difference between the pressure inside your body and outside of your body. Your blood pressure, your cellular pressures, all these pressures are pushing out on the surface of your skin and our normal atmosphere pressure is pushing back on us. If you remove too much of that atmospheric pressure, your body is not a happy thing.

Fraser: I guess the last thing we want to talk about is the ever boogey-man of radiation, right?

Pamela: Yeah. There is actually a mission called the Mars Radiation Environment Experiment. It has been out and happily measuring the radiation levels in low Earth orbit of the planet Mars. They found that in low Mars orbit, the radiation levels are about two and one half times higher than we get on the International Space Station.

They're averaging about 20 millirems a day which isn't the happiest thing for a human being and what's worse is there are occasional spikes due to solar flares that go up generally only up into the 50 to 100 millirem level but can go up into the thousands of millirems. That's a lot of numbers that don't make any sense.

Fraser: Right, but the background radiation is kinda nasty and then it's the spikes that are deadly, right?

Pamela: Right. To give you some context, we are talking about on Mars 20 millirems per day. On the planet Earth what we typically experience is about, and this is like for cities like Denver where it is bad, 300 millirems per year. So, you're looking at about ten times the radiation level, give or take, I'm giving an order of magnitude estimations here.

In the United States our occupational limit for exposure to radiation, what we expect dental hygienists to interact with, people working in nuclear power plants is set at 5,000 millirems per year. We make special exceptions for astronauts because they're doing really cool jobs. They're up in Space so it's a lot harder to protect them. For astronauts we bump this up to about 25,000 millirems per mission.

So you're talking about very quickly surpassing the U.S. safety limits. The thing is that as much radiation as astronauts have taken in with the Mir Space Station, the International Space Station, so far we're not seeing a lot of cancers in our astronauts. They seem to be okay. Again, as we said, the real fear is the spikes, or solar storms. We're getting ready to move into an extremely active solar cycle.

When you get down on the surface of Mars there is more protection than you have in orbit. You're looking at probably more like 10 millirems on the surface but we don't know because we don't have the measurements. We don't know what affect solar flares are going to have on what people experience.

Fraser: Well it sounds unpleasant and sounds like it could be an increased risk but it doesn't sound like the boogey-man that I think a lot of people have made it out to be. That' it's almost a little above what people should normally be getting but it's not like you're going to go out and die.

We were going to talk about colonization. I want to talk about some of the solutions. What kinds of things will the colonists be doing to overcome these problems? Let's talk about the temperatures.

Pamela: The easiest thing to do with temperatures is what we do here on the planet Earth. You wear a jacket. In this case you wear a thick spacesuit that is both pressurized and warm. What you need on Mars isn't nearly as extreme as what you need on orbit.

You also build yourself a nice friendly cave – a Hobbit hole in the side of a Martian mountain where not only are you able to heat it up, and because of the insulation of dirt, one of the best insulators out there, dirt also works to protect you from radiation.

Just 9 centimeters of standard Earth soil is enough to knock the amount of radiation coming through to about half of what it started at. So, a nice good hole in the ground can make a world of difference.

Fraser: You can imagine the future colonists will just dig holes in the ground and pressurize them. They will fill them with oxygen and put them at the right temperature and hopefully they won't have to keep putting a lot of energy into keeping it at a good temperature because the soil is insulating so well. When done, they are protected from the radiation, the low pressure and cold temperatures. They just have to stay inside their hole. [Laughter]

Pamela: You can almost imagine the humans on Mars sort of being like the dwarfs out of Tolkien literature where they're happily digging through underneath the planet finding the reserves of ice and making oxygen and water. They are finding the reserves of metal oxides, making air and metal stuff. You could quite [Laughter] happily burrow around under the surface of Mars.

The only issue starts to become that human beings like sunlight. That's why there is artificial life. You can almost imagine the silly care package of: "can you please send us the correct fluorescent light to give us solar spectrums?"

Some things will be easier to produce than others but it won't be too hard to start setting up manufacturing on Mars. We can send all of the initial things and basically start building factories.

Most factories don't require pressures. They like to be kept warm but factories are pretty good at generating their own heat just through friction and other means. Once you get them going it's a self-contained process that just keeps going.

Fraser: What about power?

Pamela: Yeah, that one is a little bit more difficult. Solar cells are starting to get there. We're starting to be able to build more and more efficient solar energy collecting devices. At a certain level we're going to have to decide it is time for nuclear energy however.

The energy required to start having factories, to start burrowing around under the surface to start producing fuel in major amounts is where nuclear power is one of the easiest ways to go. That may be in our future in well on Mars.

Fraser: Right, it's fairly compact to send a few tons of radioactive elements, uranium to Mars to use that to power their colony for a year, or two years right?

Pamela: And it's easier to cool things on a planet where the temperatures start at negative 60.

Fraser: Yeah. Ideally though they would be able to transition over to solar power to be a lot more sustainable but in the beginning it's probably going to be something radioactive. Now what about getting water, air, those things?

Pamela: We're starting to figure out how to develop those technologies already. With the Mars Society, they want to be up and ready to get a colony going on Mars the second someone says "Go!"

So they've already started developing and doing test runs of technologies that can take minerals similar to the ones we believe are on Mars and transform them into waste minerals and rocket fuel; waste minerals and oxygen.

Ice – you heat something up and the water vapor comes out and then you just let it condense back into liquid water. So everything we need is there and we're testing the technology already to get the needed resources out of the landscape in a format useful for human life.

Fraser: We actually had an article in Universe Today, a bit of a series written by Nancy Atkinson, which was a one-way, one-person mission to Mars. The cheapest way to set up a colony would be to send one person to live there permanently and send all of this stuff and just see how things are going.

Then send more supplies, send more people, and hopefully over a few decades of this you might be able to eventually even have people be able to come back home from Mars. But if you're not really too worried about how you're going to get them all back [Laughter] that really cuts down the cost.

Pamela: There are a lot of articles spread out across the Internet ranging from the idea to send a small group of people and give them cyanide pills so that when winter comes they simply pass into the night. I'm not a big fan of that particular plan.

Another is to send a whole lot of people with the resources they need and plan on every two years when the launch window to Mars opens up we send them a few crates on airbags with supplies that they might need.

Fraser: Yeah, this isn't new. This is called re-supply. This happened in many colonization projects in the past. The explorers will get re-supplied when going to the North Pole. It's very common.

Pamela: Antarctica can't be entirely self-sufficient down there and we have practiced with this re-supply. It's just a little bit easier, in fact a lot easier, to get things down to Antarctica than to get them to Mars.

In time, hopefully things will be more efficient. Rockets will get more efficient, our aim will get better and our ability to consistently get things to Mars will get better.

Fraser: All right, I think we've run out of time this week. Next week I want to talk about the future of colonization where humans take into their own hands and actually stop living in caves. And they try to modify the climate of the planet itself to be more appropriate for human habitation.

We can also talk a bit about terraforming not just Mars but also maybe other planets and maybe even what that may look like way down the road. I think that will be an interesting show as well and then I think we're done with Mars – for now.

Pamela: You said that last week.

Fraser: Did I say that last week? Nevermind…..[Laughter] Mars keeps expanding.

This transcript is not an exact match to the audio file. It has been edited for clarity.
Transcription and editing by Cindy Leonard.