In Dialogue with Morgan Irons

iGEM CONCORDIA

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iGEM Concordia Montreal 0:03
As I mentioned, we looked up your information and Deep Space Ecology, and the first thing we wanted to know is can you tell us a little bit about how you personally came along to where you are today.

Morgan Irons of Deep Space Ecology 0:20
I've always had this interest in the natural environment and how systems work and how we, as humans, are part of our natural systems. And This passion of mine was in tandem with space exploration as well, because I also wondered if there was life on other planets and would it be similar to the kinds of ecosystems that we have here or would it be completely different? I grew up with this imagination and having this fascination, but I, at the time, didn't really see it as a viable option to go career wise because nobody was really doing that. So I ended up going to Duke because I was planning on going to medical school and becoming an orthopedic surgeon. I still carry these passions with me.

And so I was always involved in environmental initiatives and space exploration initiatives. In my second year at Duke, as an undergrad, I realized I wasn't truly happy on the path that I was going. My dad was the one who sat me down after a particularly heavy and pretty hard semester, and told me to be honest with myself. What was I really passionate about? What would I really want to do with the rest of my life? I brought back these thoughts that I had about space exploration and how it's connected with environmental science and how I could potentially connect those two together.

The winter of let's see, this would be 2014, I did some research into trying to find that connection between environmental science and SpaceX. And what I found was a paper from the 1960s written by some Soviet Union scientists on closed ecological systems for space habitation. And that was kind of random. It's like the 1960s in the Soviet Union, yes. They had been doing their BIOS (biosphere) experiments.

It was pretty much understanding how we could close off ecological systems for extreme environments and how people can use them to survive in that extreme environment. That was really the connection where I was like, that's where my two passions interlock together. And so that's where everything began. I went through some independent studies because my school didn't really do a lot of space exploration related stuff. A lot of this was me reaching out to professors who were soil scientists or systems ecologists and asking them if they would like to put a twist on what they were doing, and put it in the space environment and think about how these things would change in the space environment.

I started my research with doing these independent studies, majoring in environmental science and biology with a chemistry minor. And out of this research that I was doing, I developed a new system for what I now call a quasi-closed agroecological system, which applies the agroecology, principles and landscape theory and things that have been missing from the conversation that has been primarily dominated by engineers. So that happened and my company Deep Space Ecology came out of my research because when I went to a space conference, nobody was really talking about space agriculture or food security. It was briefly mentioned, but kind of like, we'll handle that when we get there. And in my mind, this is much more complicated than you're making it out to be. I saw this niche that wasn't being filled in the industry, where nobody at that time was really talking about security and space agriculture at these conferences. Deep Space Ecology came out of that and was founded in May of 2016.

We've been working on that ever since I co-founded it with my father, because he has a background in space research, as well as his Master's thesis in physics dealing with high energy particles in space. He was kind of living vicariously through me as well because he's always wanted to do stuff with space as well. It's been a fun time working with him on Deep Space Ecology and moving everything forward. Now I'm a PhD student at Cornell University in soil and crop sciences and continuing my side of my research, but also the Art side of my research as well.

iGEM Concordia 6:04
That's amazing. I connect to what you've said, people will think that this isn't a problem for now. But when you hear things like SpaceX's first cruise flight is scheduled for 2024. I mean, it is in, what, four years?

Morgan Irons 6:22
Oh, goodness, yeah. When we're talking about long duration spaceflight and long duration on planet, habitation, and everything that could go wrong with that, and how the only way we'll be adaptable is by creating an environment where we have the

ability to adapt. Currently, we really don't have that and it's really not being talked about. The research that I've been doing with how can we build ecological systems from scratch so that we can have that adaptability that we get here on Earth with online systems. I think that's something that we need to talk more about. And microorganisms are part of that conversation.

iGEM Concordia 7:11
If we go back to Deep Space Ecology, from what I understand, the original idea came about when you went to a conference and you realized people weren't thinking about this right now, and there was a problem in the future. What are two other things that have brought the concept to fruition? We want to know, what could the company not do about it? What are some cornerstones of Deep Space Ecology?

Morgan Irons 7:38
Deep Space Ecology has definitely evolved over time. Talking with other entrepreneurs and people who've gone through the startup experience, there's definitely a lot of churning especially in the first five years of a startup. The idea of Deep Space Ecology, of course, was based in space exploration and how we can apply principles that we have here on Earth with our ecological systems on Earth and spin it into a space environment. Throughout this process, I've come to realize how important it is that we also have that Earth track as well as how space can feed back into the Earth industries and solving problems here on Earth, especially when it comes to agriculture, agricultural systems that aren't necessarily adhering to sustainable practices, or the degradation of our soils and the degradation of our ecological systems. That once they're gone, it's going to be very, very difficult to get them back. So if we can understand how difficult it is to build an ecological system in space that can only tell you how difficult it's going to be to build an ecological system from the degraded landscape that we ourselves induced here on Earth.

Some cornerstones of Deep Space Ecology is pretty much understanding everything that is involved with food security, because food security, no matter where you are here on Earth, or in space, has these dimensions that if you solve this dimension in space, you're going to have a way to solve it here on Earth and vice versa. And these dimensions include accessibility. How are the people who are living in your particular system in your community, able to access the resources and the food that they need? When we're talking about that here on Earth, we're talking about does a community have an agricultural system in their community? Or are they having to rely on the supply chain to bring their food resources in? Which, of course, you get into the politics and finances of that. That can become messy very quickly. Splitting that into space, we have a similar issue here, where, when we talk about accessibility, are the people who are living on, i.e. Mars, do they have their agricultural system there or are they relying

on this resupply chain? Or are they relying on prepackaged foods? That, again, doesn't allow you to be long term sustainable, away from Earth. We have these commonalities that are between areas on Earth, other food insecure places, and space, which is also food insecure. Having this conversation and bringing food security and its dimensions and the research behind it into the space industry is something that Deep Space Ecology has been working on. It's not simply just oh, we need to have an agricultural system. It's actually understanding that it needs to be accessible. It needs to be able to support the economy and bootstraps a local economy, it needs to provide safe food that meets the needs of each member of that community, each member of that crew, whether they have food restrictions, whether they have health problems, whether they come from different food cultures, and the medical and as well as the psychological benefit from being able to eat something that brings you comfort as well. Not simply just eating the same thing and eventually succumbing to food fatigue, menu fatigue.

A pillar of Deep Space Ecology is bringing food security into the conversation and having that is a cornerstone of what we're trying to achieve here. Like I've said before, adaptability, providing people in systems with the ability to adapt, no matter where they're living, Whether it's in different extreme environments on Earth, because we see that in the Middle East, we see that in the Arctic. We see people who have been living in these environments and people who are living in environments that are now changing due to climate change, and are becoming harsher and are leading to agricultural systems that are failing. We need to understand what makes the system adaptable and what would allow us as people and parts of that system, what would allow us to be adaptable in that system. That goes into understanding the ecological services that ecosystems provide as a whole, whether it's provisional services, which is the food and the medicinal and the fabrics, cooking oil, stuff like that, to the cultural elements to the regulating services, which can be the biogeochemical cycles happening in the soil, or the formation of soil over time from just bare rock and sand.

Understanding all the ecological services either involved in the system and making sure that we're meeting all of those, instead of just focusing on “Oh, humans need food. We’re building a system that just provides food.” And that's not sustainable. That’s getting rid of these other services that we survive off on a daily basis. And that's something that I like to put people through. I like to bring this up as a practice. For people it's to actually go about your day, and start thinking about the ecological services that you're relying on within that 24 hour period. And you'll be surprised how much we rely on our natural environment. And I think it helps give people a different perspective about their own local ecosystem and how they themselves are living in it and affecting it and how other people around them are affecting it.

Morgan Irons...
Food security, understanding ecological services and how that brings adaptability to us, and then human well being, and no matter where humans are living, they should be able to live healthy, uplifting lives. That's something that Deep Space Ecology is working towards as well. We want for people to be able to celebrate their local ecological cultures and their food culture and live in an environment that is able to support them, and that they're able to support, and that allows them to be healthy and have just overall good wellbeing.

And so that's something else that we really focus on as well is understanding each individual situation, you can have a base cookie cutter model, which is my quasi closed agricultural system, that's the base for what everything is based off of. When we're talking about going into a location in Africa, or location in the Middle East, or in Indonesia, or on Mars or on the Moon, those are all situations that are going to be very unique to those local cultures and the people who have lived there for generations and have certain practices and traditions. When you're thinking about how to help them with their food security, how to help them with being able to adapt when climate change affects their region when they're in a situation where they need to adapt. How can they do that while being able to maintain their health and their well-being and the survivability of their community? So those are like three pillars that Deep Space Ecology has been developing and building , our mission and our actions around.

iGEM Concordia 17:58
I was just reading yesterday. The FAO actually is estimating that by 2050, we're gonna need 70% more food production. How are we going to respond to this? How is it going to tax our environment? I think these are conversations that we should definitely be having right now. And your ecosystem is definitely part of it. As you're saying, it has to be adapted to local communities. Do you have a framework for assessing that, let's say when you are thinking of a community, I don't know, in Kenya, or somewhere in Africa, how would you, what are the things that you think about when you're designing that ecosystem versus when you're looking at somebody who's in a remote area in Alaska?

Morgan Irons 18:46
Part of this gets into understanding how to do ecological and human health risk assessments where you have to understand the situation that you're going into. That involves the environmental side, as well as the human health side of things. These risk assessments are commonly used by the Environmental Protection Agency and other agencies to assess environments, or assess changes that will be made in practices, or if we use this fertilizer over this fertilizer, how will this affect the local environment? Applying this to each of these very specific locations and situations so that you understand what's happening

there and understand what a local community actually means. How the local ecology has changed over time. Starting off with doing that assessment, and understanding the situation, and then of course, going in and talking with the local community, which can be difficult, of course. It can always be good to reach out to the local university and the local community organizations and connect with people that way.

Morgan Irons 20:40 Talk with people and get their thoughts. What they've seen happening on the ground because they're the ones who are there everyday experiencing this. As well as, especially when we're talking about food security, talking with the farmers. Because the farmers themselves are experimenting. They've been experimenting for years. And they've been adapting their systems as their local environments have changed. Understanding what they've been doing, and seeing if that's working in the current environment, or not working, because that's something else to consider. When you do this overall risk assessment, it may seem like things aren't working. When you actually get there on the ground, you can find people who are doing things that are working. It's just not as widespread knowledge to the rest of the community sometimes. Opening conversations and understanding if there are already practices there that are working, hoping that can be communicated to the wider community to help them, as well using science. To help explain why these practices have been working or why these aren't. It can be very complicated but I would say the major things are just going in and making that connection with the people.

And maybe this is kind of harsh but I always warn people who want to do work like this. Don't go in thinking you're going to be a saviour to the people there. I don't like that and I'm sure the people there don't like that either. You need to go in there and understand what the people need and assist them with having them lead the charge and change, helping themselves and giving them the knowledge and the tools or helping provide additional knowledge to help them understand, why what they've been doing has been working or why this method would probably be better and it could help save them money or things like that.

Going in making that connection and making sure that everyone understands it's for the community and it's for them leading the charge. Then doing that risk assessment, understanding the local environment and the situation from the ecological system perspective and the human health perspective. And then, based off of that risk assessment, I'm coming up with potential solutions or integrating what's already being done into a potential solution. It's initial stages, kind of like what consulting firms do, where someone comes to the consulting firm with a question or an issue. And so the consulting firm assesses the situation and comes up with different solutions based off of what the situation is and what's being asked of them. Ultimately, it's the customer that makes the decision of what fits best with

what they need moving forward. I guess that would be a perfect analogy is that initial stages, doing that consulting and figuring out what's working, what's not working, potential solutions, things like that. Once those potential solutions are brought forward decisions are made.

Morgan Irons 25:48 That's when it's important to make sure you have certain collaborators in place to help make all this happen. Involving nonprofit organizations, involving local universities, involving local leadership and figuring out how best to implement these solutions, so that you're bootstrapping the local economy, instead of setting up a supply chain for the community where money is going to be going out of the system, and it's not going to really do anything for the local economy. When you're thinking of these solutions, there might be an initial investment where you have to bring some resources in.

Especially when we're talking about more extreme environments, where you don't necessarily have the resources to help stabilize that system within the system.There might be that initial investment. But ultimately what you want to do is create a local economy surrounding those solutions. That allows the community to keep money in the local economy, not have to rely on a politically financially charged supply chain that takes money out of the system. Allows them to become food secure and create their own jobs and create a system that supports their well-being and their needs. I don't know if that made sense. I kind of get off on tangents sometimes.

iGEM Concordia 27:45
Yes it did. If we think of your system and Mars, at which stage would you say that it is now because I've seen your TedEx video, for example, the system would be transported from Earth to Mars. Then it would actually rely on the survivability of those living organisms that would inhabit it. Our project is about how microgravity is affecting living organisms and so we're wondering how do you think microgravity will impact the organisms that inhabit the system and the whole system itself?

Morgan Irons 28:28
Yeah, so a lot has happened since my TEDx talk.If you don't know already, there's this movement in the agricultural industry here on Earth, called Digital Agriculture. And it's this movement to bring more robotics and other devices into the agricultural industry to help reduce on labor to help. Just overall, especially with smaller farmers who are competing against these big conglomerate farms, having something like this digital agriculture movement can help them be on par with these larger farms. We see this event that's been happening relatively recently. And this is something that Deep Space Ecology has to lean into, because this is definitely an opportunity for the agricultural industry and the space industry to collaborate. Where technology that's being developed, for example, being able to have a robotic system code for a field and pinpoint which plants are ready for harvest, which ones aren't

and be able to pick it itself. Having something like that on Mars where you don't have limited labor resources, because you have a limited number of people in that community. And they have to do other things because of their job there. I think something new, that has been incorporated since my TEDx talk, is understanding that initial mission where, before even human stuff, well, Mars, you're going to have to start developing the system and that can be involved with sending robots, sending other mechanized systems to start setting up this agro ecological system on Mars.

There's definitely opportunity here for Digital Agriculture to be involved in this initial stage, which I think we all need to talk about a bit more in the space industry. It'd be a bit difficult to have people go there and then set up the agricultural system because that can take months; to get your initial crop. Then you're risking potential failure if your crop doesn't develop. There's that and then with the biodiversity that you would be bringing. That includes the microorganisms, the plants, any other organisms that are needed.

Morgan Irons 31:45 What we have to think about is when we look here on Earth, and we're thinking about what organisms we would need to be bringing with us, something that I think is important is to look initially at systems that have similar characteristics to what we would find on Mars. Harsher soil environments, lower atmospheric pressure environments, things like that. When we look at some places that come to mind are the Andes, in South America where they tend to have harsher soil conditions and are higher up on these huge mountains where the atmospheric pressure is going to be different. What's growing there? What crops, what plants are growing there? And would those be adaptable to the Mars environment because of the similarities?

I think it's important to look at the similarities that we already have across systems because that would allow for hopefully, easier adaptability, with these plants, but you definitely need to bring a biodiversity of these species because once you go to Mars, not all of these species are going to survive. But some of them might be able to adapt and evolve over time to the Martian environment and become a unique Martian ecology, where they are able to lend into that long-term sustainability of that system. The microorganisms you bring are going to be very important as well. Especially if you're having a soil-based system. What I think with these systems is that it's probably what you're going to have is a hybrid system of a field system with a hydroponic system. And with hydroponic systems, they try to keep those as sterile as possible, currently here on Earth, because once microorganisms are introduced into the system, it can lead to system failure because they're trying to keep it sterile, really a major issue.

Initially, bringing the system there, I think, as you develop your field based system, you're also going to have a hydroponic system to lend itself to producing certain crops

and having that faster turnaround of crops that you need while your ecological system is developing. I know there are some researchers here on Earth that are trying to solve the microorganism question with hydroponic systems with the field-based system in mind. We have to think about what microorganisms are in symbiotic relationships with these plants as well. If we were to have an unknown viral vector come into the system, do we have microorganisms that could defend the rhizosphere in the soil and around the root system. So you need enough biodiversity to be able to defend against disease and the like.

When it comes to microorganisms, it just gets really complicated because there's so many recorded organisms and the research is still very much ongoing here on Earth. With the experiments that have been done on the International Space Station, there definitely has not been enough when it comes to the organism side. That's because of the focus on the sterilization of the International Space Station, because we've seen these situations where certain microorganisms that didn't start out viral and became viral. That's a major concern. Of the microorganism experiments that have been done on the International Space Station, most of them are, swab the surface, swab the human microbiome and see what you find or see how things have changed. That's something that definitely needs more research to be done and something that I'm working on, as well.

iGEM Concordia 36:32
If we took these microorganisms that are surviving here on Earth in similar conditions to Mars, like you said, and we bring them over there and maybe some survived, or maybe don't, it could be a long process to wait for adaptive evolution to happen. One of the things we're doing in our project is we're taking our yeast and we're subjecting them to microgravity conditions or performing directed evolution. Do you think, in that sense, synthetic biology can contribute to accelerating this process, let's say, directed evolution, and then after these organisms have adapted more quickly, and then you bring them on Mars?

Morgan Irons 37:22
Yes, I can completely agree with that. I think having that directed evolution will be very helpful. A technique that I've seen other microbiologists do, especially when they're doing something that's looking at finding that moment when that change happened, where they are now adaptable, where that gene was switched on, switched off or changed is where, over time; they collect a sample and freeze it and keep it frozen, then over time collect another sample. They do the DNA tests on the samples to see if there's any changes in the genes that they're looking at specifically. I know that there have been microbiologists who have had success in actually pinpointing the generation where that gene changed, because they've sampled over time from their experiment. That it can be a directional evolution that they're working on...

it’s mostly directional because exposing them to certain elements and seeing what happens. I really think having directional evolutionary studies, especially exposing it to a microgravity environment and seeing over time if there's any changes, and those indicator genes will be very helpful for this. If we can come up with strains that have this adaptability before we go to space. I think that will put us in a better position for the survivability of the system.

iGEM Concordia 39:29
You mention that, looking at when it changes, is important. One of the things we're trying to do is look at these changes in real time. And hopefully, we can succeed but this is our main goal. And in terms of looking at the genetic changes that happen, how do you think, let's see, if we find out it changes over X number of generations? How can this information be incorporated when we're trying to go out in space and use certain microorganisms?

Morgan Irons 40:00
Yeah, so this gets into genetic modification and genetic engineering. If you're able to pinpoint a gene that allows for this particular adoptable ability of the microorganism, and you experiment by doing this gene swap or whatever you need to do with another mark organism and testing that to see if it leads to the same adaptation that could lead to being able to more quickly bring a larger population of microorganisms into your system. Of course, we got to make sure we test all of this.

Starting in the lab is definitely a good place to start. Having that simulated microgravity for directional adaptation and if possible, if that adaptation were to happen in the lab, isolating that community that has that adaptable adaptation and then go back one generation before that adaptation was developed and send both of those to the international space station and see if that adaptation continues forward, and see if that previous population gains that adaptation, or if it goes in a completely different direction, because the microgravity in space is different from the simulated microgravity we are experiencing in the lab. That’s something to always keep in mind, to freeze each generation as it develops. It gives you the ability to go back in time. Will they lead to the same evolutionary path or have a split. And will the split be better, or not make a difference?

iGEM Concordia 42:37
In your system, here on Earth, but also in space, do you use genetically engineered crops?

Morgan Irons 42:55
I haven’t been as involved with that element, currently. I can’t speak as much to that. I think it’s important to understand, especially since there’s a lot of stigma with genetically engineered crops, to understand that genetics engineering is a new name that we have for this. Especially since now we are going into DNA chains and changing things. The

breeding programs that we've had for hundreds of years with these crops are technically genetic engineering. You're just breeding them to get those different characteristics that are favourable to what you need in that time. I don't necessarily have anything against genetic engineering and I think it will be necessary especially when we are talking about changing an extreme environment. Especially if you want to have an increase in biodiversity in your system beyond what would typically survive in that environmental condition. I think more research needs to be done on this in the context of extreme and changing environments whether it's here on Earth or in space. I am currently with my PhD research. I do have some natural soil microbiomes that I am launching into space soon. I'm going to be looking at how that microgravity environment affects certain behaviours of these microorganisms when it comes to soil, organic matter and resistance and carbon dynamics in soils.

iGEM Concordia 45:15
That comes to my next question, what are you researching?

Morgan Irons 45:20
My PhD research right now, mostly focuses on microbial and organo-mineral stabilization mechanisms in soil aggregates and their contribution to the persistence and long term sequestration of soil matter and carbon. With Deep Space Ecology we're developing some cool things, I can't go into all of the details, but I feel good about where Deep Space Ecology is going with it's next steps and how it will continue, with food security here on Earth and in space. Then with my research at Cornell, which focuses more on that fundamental knowledge, I'm hoping that fundamental knowledge can lead to understanding better soil practice and management here on Earth which will feed into understanding how we can manage degraded soil regolith on other planets, such as Mars.

These experiments that I'm doing in space will definitely help to understand whether gravity is part of the mechanism for these certain behaviours that we see with microorganisms or if gravity is kind of just shadowing what is actually happening. When we take that out of the equation and finally see what has a bigger influence on these behaviours and these dynamics, then we'll be more informed and better able to make these decisions- what will we focus on- when we are talking about the microbiome in this particular soil environment?

iGEM Concordia 47:35
It's been said that colonizing space is of interest, because colonization has always been very negative in the past. What is different or the same with respect to colonizing extraterrestrial bodies versus here on Earth?

Morgan Irons 47:50
That's something at my most recent talk, I always make mention that we need to make sure we don't repeat the same mistakes that we've done. We need to understand that traditional agricultural systems, it doesn't mean they're inferior. The Chinampas of Mexico City are a traditional agricultural system, but they're highly sustainable and at the peak of the Aztec empire, they were supporting thousands and thousands of people. This is something that I'm very passionate about when it comes to understanding traditional ecological knowledge and understanding the practices in the agricultural systems of indigenous and people of different areas have been doing for thousands and thousands of years.

How we can preserve that knowledge and bring it forward in a respectful way to the people and the culture that it comes from. We're starting to see that in the agricultural industry here on Earth with understanding that the western way of tilling the soil isn't actually sustainable. Doing a no tillage system where you use crops in place, and i.e. crimp them down, is actually highly sustainable for your microorganisms and your carbon dynamics and helps increase the organic matter in the area. This is knowledge that comes from traditional ecological knowledge, because people were living in these environments and they may have not understood the science behind it, but they themselves were experimenting with this knowledge that worked. You can use science to explain why it worked.

When it comes to how we approach going into space, it's very very important to keep in mind that we need to increase this conversation about sustainability in space and how we need to keep in mind these more sustainable practices and really understand ecological systems and dynamics, because this understanding can allow us to create these more sustainable, adaptable systems without doing what we did in the dust bowl, in the US midwest in the 30s. Where they just stripped everything and it became this desert. We don't want to repeat that. I think as we move forward with going into space, we need to look back on our own history and understand what isn't sustainable, what is sustainable, who contributed that knowledge. To treat the people with respect, of where that knowledge comes from as well as looking back at traditional agricultural knowledge and ecological systems and we can find solutions for how we approach things going into space.

I guess the second part of my answer to this question is that there are certainly agricultural system here on Earth, that we can learn some very valuable lessons from. My favorite example to use, especially when it comes to talking about Mars and more desolate civilizations, is the Nabataean civilization of the Negev hinterlands, which is in the middle east near Jordan and that area. The Nabataeans lived in the middle of this huge desert and the Romans couldn't conquer them because of this huge desert. They couldn't figure out where the water was or where the resources were. The Nabataeans were able to support a

population of 30,000 people in the middle of this desert, because they were able to navigate the contours of their local environment and understand the water resources, and understand how the ecosystem works and then kinda built around that and modeled around how the system worked. In that way they were able to produce this flourishing oasis in the middle of the Negev Hinterlands that supported this huge population of people.

Looking at examples like that and understanding what they did and how they did it can provide solutions in a modern day context as to how we would approach a situation like this on Mars.

iGEM Concordia 54:12
What do you think are the biggest challenges or areas of achieving sustainable food futures and do you think synthetic biology could help in that sense?

Morgan Irons 55:10
When it comes to space, it is, of course, always funding and accessibility. I'm sure you understand that completely, it's very difficult to get anything in space you need the right people and have the money to do it. I feel that is a barrier to students and smaller businesses that are trying to gain that knowledge by sending samples to space. As well as, going a bit more into the business side of things, another barrier for a lot of businesses in the space industry is finding that initial investment or a continued investment. Because when we're talking about investors, a lot of them are looking for that short term return on investment, where within a couple months, they want to start seeing some money come back to them a lot, in the space industry. A lot of this is more long term investment, because we're not going to Mars tomorrow. This is a couple of years out. To find investors that are willing to put that forward, and a lot of these investors are angel investors who are more willing to take that risk.

Morgan Irons 55:59
With the business side of the space industry, the finances are definitely something that can be a huge barrier and are huge barriers for a lot of smaller companies and people trying to get their experiments into space. But a way to help mitigate that is this new emerging industry called New Space where you not only have that space side of your business, but you have the Earth side of your business and they both feed into each other. And with the Earth side of your business, you can have those shorter returns on investment. Those goals that help lead to achieving that longer term goal for your space side of your business. So that's something that Deep Space Ecology does. And that's how we work to mitigate some of these barriers Synthetic Biology, I really think that this is an important movement and an important area of research that needs to continuously be moved forward. I don't think we've truly unlocked the potential with it yet. What your team is doing, it does have that potential to contribute to not just one, one goal or one track of industry, but it can actually influence food production,

medicine, biofuel. People are even doing fashion with biosynthetic engineering.There's all this potential here. And I definitely think working in this field that we call bio synthetic engineering and technology needs to be brought forward more and incorporated into plans that we have for how we approach not only habitation in space, but common problems and challenges that we have here on Earth. I think that they can also help with the food security challenges, especially what we're going to be seeing in the coming decades with, as you said, the FAO saying that by 2050 we're going to be in some issues here.Yeah, barriers, a lot of it is financial. When it comes to money, moving things forward.

Morgan Irons 65:29 Then we've talked about the fact that Elon Musk wants to send his crew to Mars in 2024. It's important to get ready for that. I personally don't feel that we are but it's a good starting stuff. Also, if we're not ready, what that means is that we're going to be shipping food to the International Space Station through supply chains, which is costly, it's very time consuming, it taxes our environment even more. There's an urgent need for these sustainable solutions for us to produce food. You think that maybe we're not ready and we're being overly optimistic and we should wait a little bit more before we get there and learn a little bit more about the environment today. There's definitely research being done about food supplementing.For example, the food team down at NASA Kennedy Space Center in Florida, a lot of their research has focused on these growing systems on the International Space Station like veggies, where they're able to grow these highly nutritious microgreens and more dwarf-kind of species that astronauts can supplement their diets with.

Astronauts, cosmonauts mostly live off of those pre-packaged foods. But with a growing system like veggie, they can add some burst of flavor and some more nutritious value to their diets. And that can give them a bit more leeway in developing a menu so that they don't suffer from any fatigue. I feel how quickly SpaceX wants to go with this; and it's hard to say because maybe people have been working on this and just haven't said anything.Yeah. Maybe SpaceX will surprise us, we did this and we solved this issue. But if that isn't the case, and we do have this mission to Mars coming very soon, and we don't see this push towards developing these systems. Most likely what will happen is that a lot of it will probably be prepackaged foods. I don't know if it would necessarily be, maybe SpaceX will pull off a resupply chain. But unless we can get an agricultural system set up on Mars, it would definitely be a lot of turnover. You would need resupply or you would be there for a stretch of time and then come back and then that base would be empty for a time. And that's something that's happening with The Lunar Gateway.

What they have planned is that humans would be on there for a time to set up experiments and stuff like that, but most of the time it would be uncrewed. Again, that

it's so expensive. Then the politics involving just the United States and company politics can put a block on that if they're not seeing any real investment.I think what we may initially see if we're like really gung ho to going into space this soon, is a lot of pre-packaged foods. We'll probably have some hydroponic based system to do a supplementation for the crew diet. And maybe we'll be surprised and we'll see them start to try to develop an agricultural system on Mars.I'm definitely going to continue doing the research that I'm doing. I'm hoping that the research that I do will contribute to the eventual development of the sustainable long term adoptable, quasi closed agro ecological system. I'm on another planet. So well, we'll have to see how this goes. But there are definitely researchers working on this question of diet supplementation.

iGEM Concordia 87:24
I was looking heavily into those packets, and issues over time. If you think of a trip to Mars, it takes six months to go, which is a very long time and you can just imagine, having to supply if they build a space station over there and you're gonna have to do a year to go and come back. It must be extremely costly. It's completely unsustainable to even go that down that road. I didn't know about the hydroponics. I had watched a few videos, really cool ones. They grow these greens on the space station and then they can refuel themselves continuously or how does that work?

Morgan Irons 97:47
These systems that we see, there's definitely been different iterations of these hydroponic based influence systems. We've seen plants grown via seed pillows, which are grown in an artificial substrate that's similar to soil but not really soil.You've seen people developing solid, 3D printed blocks that have all these holes through them. Allow the roots to grow and find themselves to this block. And then these hydroponic systems. There has been a system that has ponds, where pretty much you fill up this pond, this closed bowl with water and at the top, you have this seed that's between these two wicks.Then the water travels up the wicks and to the seed and then the plant grows via this pond. Then there's also been the more traditional kind of systems on a smaller scale, where you have the plants growing out of these tubes and their roots are in the tubes and water is pushed through these tubes. We've seen these different iterations of growing plants on the International Space Station and there's been success with it.

Morgan Irons 109:54
There's been a lot of astrobiology research done on understanding plant physiology and development and effects of microgravity and the like, but we've also seen a lot of challenges with these systems just because of the general physics involved in being in a microgravity environment, whether it's not going to move the way it's supposed to. You're going to get these pockets of water or pockets of air that can lead to asphyxiation of the roots. Or the roots aren't getting the oxygen that they need. There's this buildup of

volatile organic compounds that can be dangerous for the plants as well as for the crew.There's definitely been movement at NASA to try to figure out how this works. They've had their life science RFPs (request for proposals) announced where they're asking researchers to try to help develop new growing systems for the International Space Station, because of these common water delivery program problems and trying to increase overall yield because you're so limited in the space that you can actually grow these things.

That's a general overview of what's been happening with that. With the work that I'm doing, since a lot of my work is focused on soil science, I'm very much intrigued to see if there's a way for us to better understand soil science in a space gravity context. See if that could be incorporated somehow into growing systems for long duration spaceflight, but also, when we get to the surface of a planet, we're able to understand... okay, we know how these organisms interact in zero gravity, we know how they interact with this percentage of gravity and doing these different studies. Then when we get to Mars with its particular percentage of gravity, we have a better idea of, if we introduce these organisms into this environment, how will they react, at least to the gravity side of things? A lot of the focus has been on more hydroponic systems, especially since hydroponic systems don't need microorganisms because the water isn't fused with nutrient solutions to support the plant.

iGEM Concordia 138:16
What we're doing before we get to doing the genetics work is establishing a software and web application. As if you would go on NCBI and it was specialized for microgravity. We're looking at what we started with yeast, because that's what we're interested in. We wanted to do a comprehensive review of the literature about the different genetic changes that are happening, but then we figured, why not help the microgravity research community and just add more model organisms. Now we're looking at bacteria. We're looking at different microorganisms, we want to move to plants and humans, and it would be specialized and open source. Researchers can just go in, type like the gene name and get all the information- the studies by how much it was regulated, what kind of type, what type of study, was it on Earth or in spaceflight? If you're studying in microgravity and how these microorganisms respond to that, do you feel that that would be a useful tool to have and how do you think it would impact your research process?

Morgan Irons 154:37
I think that would be very useful. I am very much for open source open access, because that helps just increase overall knowledge and helps people understand where the gaps are, and where we need to go next and what questions aren't being asked and what needs to be asked.I completely agree and I love that idea of having an open access database, and it's something that I would contribute my work to as well just to, I hope, help

people further develop their own research and help the next generation of researchers who are coming up through the ranks. Know where they themselves can, like, help push the research off. Because especially something that I've noticed, is there are researchers working on these questions of microorganisms and plants and space and ecosystems in space.

Morgan Irons 156:14 But there's really nothing that has allowed us to connect with each other. So a lot of this research, it's like, 'Oh, I found this paper. I didn't know that they were doing that. I wish I had known about this sooner.' And there's no conference really, I mean, there's an agricultural conference, but you don't really see conferences focused on the environmental science, the food security side of space. You see a lot of rocketry and astronomy and all this other stuff. But we still haven't developed this network to connect scientists with the similar interests together. That's something that I've been working on with going to these conferences and giving these talks and everything. It's not only to start these conversations but to connect myself with researchers who have been doing similar research for years now or are new students who are interested in starting this research and it's the first time they're really hearing about this again, because there's really nothing there that connects everything together.

So I think a database like this, not only would allow open access to this research, but also could be used as a way to connect these scientists together and see, okay, these people have done this research. I should contact them to learn more about what they did and see how I can bounce off of their research and continue their research moving forward. I think this is a wonderful idea for data access, as well as the networking opportunity.

iGEM Concordia 175:56
We are really proud of it. We have a working example right now, but we definitely have to add more, more studies and more models, but we have time, it's a two year project we embarked on. I wanted to talk about a little bit of a different topic, because it's very important to us. Inclusion has become a really central part of everything we're doing with our team, iGEM and we're incorporating that into our project. We've added a few inclusion questions that I would love to ask you if that's okay, and the first one is, what role does inclusion play in your industry and also at Deep Space Ecology?

Morgan Irons 196:38
Everything that I do and that my company does we do with a thought of inclusion in mind. Realizing that, just like an ecosystem is more stable and more resilient and just more amazing when you have biodiversity, having a biodiversity of people and opinions and, experiences just can enrich the environment and help you come up with solutions and things that you just never thought of. That's the example that I like to use.

You would think with environmental scientists understanding that biodiversity is so important that we would understand that diversity, in the workplace as well, is super important and can lead to better solutions and better conversations and the like.

At Deep Space Ecology we always make sure that we have as much diversity as we can, with people having different experiences, bringing in people from different food cultures and different cultures from around the world, agricultural systems, talking with people at all levels from from the farmers, to the land owners, to students, government officials, everyone's thoughts and ideas leads to a better understanding of situations and potential solutions that can come from these things. I'm happy to say that our company throughout its history has had people from around the world from different ethnicities, different races, different sexual orientations, who have come to work with us and help contribute to bringing the mission and goals of Deep Space Ecology forward.

I myself, I'm a white female, but I'm also part of the LGBTQIA plus community. I've always tried to understand how to raise up other people and be an ally and a comrade to people within my own communities, because being part of a community doesn't mean there's allyship, even within the community. You have to understand that you need to be an ally to people in your community, but also outside of your community as well.

Deep Space Ecology has definitely worked to make sure that we're always thinking about inclusion and diversity and applying that to these unique situations and unique environments that we find ourselves in, because we're experiencing different cultures we're experiencing different languages. We're experiencing systems and communities that have been plagued by systemic racism and are in food deserts because of it. You can't ignore something like this because you have to understand why and how some of these situations happened. Especially when we're talking about urban spaces that are food deserts and have food insecurity. A lot of the time it's because of systematic racism in the history of slavery and segregation, especially in the United States. You have to keep all of this in mind.

Then with my own personal work as a PhD student, I get involved in being an ally for organizations such as SACNAS, which is the Society for American Latina, Latina, Latin x, Hispanic, and Indigenous Native peoples as well as the LGBT communities, as well as getting involved in the leadership with Organizations at Cornell, participating in these conversations about racism in academia and how Cornell and how our own department needs to do better, need to do better. And as well as I'm a co leader for diversity preview weekend where we bring students from low income, diverse backgrounds to come and experience Cornell.And then I work also with different organizations for outreach. I work with the Mars Generation, I work

with Skype a Scientist being able to actually go out and talk with students. Be able to reach students from diverse backgrounds. has been very, very enlightening, as well as something that has brought me a lot of joy. Because being able to talk with you, the students who didn't know that something was possible just because nobody told them or they've never been exposed to something or when I showed them pictures of my team and they see somebody who looks like them, for the first time doing something like this and they're like, I wish I could be that. Representation, exposure, those are so important. you don't know until you've been exposed to something and then seeing somebody who looks like you in that environment gives you that hope that if they can do it, I can do it. Even though there may be people around me saying,' Oh, you can't do this because of the color of your skin, you can't do this because you're a woman. You can't do this because you're trans, but they did it. That person who's just like me did it.

Morgan Irons...
Inclusion and diversity are something that I've always worked towards and something that I asked on a daily basis, working with these different organizations, working with my company, even working with my research. How can I include more people? How can I, who can I ask to do these things? Who can I recommend? If somebody reaches out to me about something? Can I recommend somebody else who isn't being represented, but has the same knowledge that I do? Who would do great in that situation? I have a lot more to learn. I'm not saying that I'm perfect at this whatsoever. I still have a lot to learn. It's something that I'm working on a daily basis. A lot of it it's something that you should do, you shouldn't expect a pat on the back. You shouldn't expect praises for doing something that you should already be doing. I'm glad that we're seeing much more movement in this area than sadly what we've been seeing in the past. I wish this had happened sooner.

But it seems like just 2020 may suck, but we may see some good things come out of it just because people are being forced to slow down and being forced to listen and to pay attention because they're stuck at home or they can't go out and distract themselves by doing other things. So the movement that I've been seeing with my own organizations and circles of people has been promising. And I hope that we keep this forward momentum and it doesn't turn into another situation where we had a few months and then nothing changes. As a student as a business owner, I'm doing what I can to try to keep the momentum going, and to keep these conversations open and going, and increase the exposure and the visibility of underrepresented people in these fields that I'm working in.

iGEM Concordia
I absolutely love that we built an inclusion framework and those are the two things we chose as well- representation & exposure and then safe space.

Morgan Irons
That safe space is so important because you can talk about diversity and invite people, but if it's not a safe space for them, they're not going to want to stay. That's very important to keep in mind as well.

iGEM Concordia
Just as I'm sure now you're inspiring the people that you're talking to, there has to be somebody that inspired you when you were younger. We were wondering who is that, and also, whether growing up you felt that there was enough representation of women as scientists and entrepreneurs?

Morgan Irons
Two people that come to mind immediately is Dr. Jane Goodall. Just hearing her story being a woman in that male dominated time. It was odd and strange for a woman to want to learn her story and how even when she didn't have opportunities, she made her own opportunities. And how she, in her own way, integrated herself into, her research and the local communities where her research was taking place. Working with local people and not letting other people dictate what she should be doing because she's a woman. That was just very inspiring and she continues to be an inspiring person and I always look forward to when she gives talks and hearing what she has to say.

She is a black writer and she's considered the great Dame of science fiction. She is fabulous and if you have not read her books, please read them because she incorporates, not only raised race, the questions of race and racism into her work, but also in the 70s and 80s had LGBT characters. And her main characters are underrepresented, tend to be disenfranchised characters. They're fabulous stories and they're so creative and she's won so many awards for her writing. I know there's a scholarship now that her foundation puts on for underrepresented people who want to attend this one writing conference that she went to. Her writing and her stories created an opportunity to learn about these topics that can be uncomfortable for a lot of people in an exciting and creative way, but also in a way where we need to make sure that that doesn't happen again, or we need to make sure that doesn't become our future.

Because even though it's science fiction, there's elements to it that are reality. It's kind of like the handbook, it's fiction technically, but everything that happens in it has happened somewhere on Earth. It's that kind of dynamic. So her work, Dr. Jane Goodall, and I guess one more person I can add, who inspired me to think outside the box and be creative was actually a fictional character. MacGyver. I am a diehard. I have all of the series for the old 80s, 90s MacGyver. Being able to think outside the box and come up with these different

solutions and just overall help people. Another thing with MacGyver is he just helped anyone who needed help. That was a big inspiration as well. I guess this would be like the three people growing up that influenced a lot of how I viewed the world and how I have approached the way I problem solve and handle different situations.

iGEM Concordia
Beautiful, so awesome. We had two last questions. I'm going back to our conversation earlier. Do you have an agroecological system in your home or anything like that, fully developed or not?

Morgan Irons
I do have a garden in my yard where we're growing different herbs and tomatoes and things like that. We also have compost bins like vermicompost, things like that, where we try to reduce food waste through composting. Being in Ithaca, New York as well, this community has a lot of hippies and so it's just natural that you would have a garden as your front yard. I tend to garden, have composting, I suppose support local farmers by going to the farmers market or going to the local farms nearby to pick directly from the field for when different fruits and vegetables and things are in season. And with some of the work that my company is doing, I will definitely be developing some things and testing some things out here as well. Some of these things may see some changes over the next couple of months with different things that we're testing out.

iGEM Concordia
Here in Montreal, I changed my whole perception of life and I started to want to shop local. I discovered this really cool network. They connect you with farmers all over and they'll just ship back for people who don't have transportation or whatnot. The farmers have an understanding with some local stores and they'll just ship there once a week. And you get to eat directly from the farm. You choose which one you want. And I thought it's pretty cool. I wonder if you have that over in New York?

Morgan Irons
Yep, different food exchange networks where you get connected directly with a farmer or you have a middle person that you go through to receive produce directly from the farm. I think that's something that needs to happen more and having that network, that connection, because that's the thing, building that initial connection between farmers directly to consumers and community members is something that can help develop these networks. I think also having these food exchange networks would also reduce food waste as well. Because pretty much you get what you get. With a lot of products you buy in the store, they have like these perfect shapes and you don't really see anything that people who work on farms see, which is sometimes you get a carrot or you sometimes get a gourd that's

this weird shape and they can't sell it because there's quality issue with it. It just doesn't look like your standard carrot or your standard, whatever. The exchange networks helps to bypass this well, where you're less worried about the aesthetics of your produce. And you're able to actually sell that produce to local consumers who don't have an issue with it. It looks interesting. It's still edible, it still has nutritional value. So yeah, I think increasing food exchange networks is very important. And that's something that deep space ecology is also looking into.

iGEM Concordia
My last question, what inspired the creation of refugee cities or agricultural units and have they been implemented?

Morgan Irons
The refugee units. What inspired that was, I've known people who have been refugees, my family has helped people who've been refugees. Ever since I was little my grandparents helped them help people and even people who wouldn't be considered refugees, but people who are just homeless. That's something that has been a founding principle that my parents taught me growing up was if you have the resources and the ability to help you need help, it doesn't matter what that person does with your help after you're no longer there, but if they need help, and you're able to do so you should do so.

The refugee units are kind of based off of this. These morals and principles that I grew up with and seeing the horrible conditions that a lot of these refugees are in. And these areas are very highly food insecure areas. You have to think about the limited resources that they're going to have. How can you solve the question of food security in these kinds of environments, and this is where the refugee growing units idea came about.

Having something like a shipping container that is actually relatively cheap to get. My family lives, right next to this huge port and we've looked at the prices of shipping containers and they're actually cheaper than what you think. Having something that's looking at the resources that are already there, like a shipping container, and then thinking about what other local resources are available that you don't have to spend a lot of money on. Like having a soil based system instead of a hydroponic system. Hydroponic systems work in a more financially stable, closer to a consumer area, so having a hydroponic system supporting a restaurant.

iGEM Concordia
Or water.

Morgan Irons
Yeah, exactly. You're not necessarily going to have these resources to have something like a hydraulic system in the refugee camp. So building a protected, movable agricultural system that uses local resources, that allows for people to grow their own food hopefully year round can help improve the well-being of the refugee camps until they're able to, hopefully, get into a better situation. It's solutions like these that we're looking at implementing and seeing where we can help and this involves getting involved with nonprofit organizations and organizations like the World Health Organization. So that we can gain access and to talk with people and see how we can take this initial idea and adapt it to the needs of particular people in these different camps.

We're working on making this a reality. It can be very difficult to do with, like I said, some financial restrictions, COVID-19. But even if we can't send out or build a system tomorrow, we are constantly working to figure out how to better fine tune our solutions and actually looking at different case studies of, if we were to gain access and are able to help people in this particular camp in Yemen or in other areas, what would we need to do? A lot of it is developing procedures and learning about the local situation, the politics of it, the finances of it, the local ecology, and creating these case studies, so that when we do have the opportunity and the means to implement it, we are able to do it as simply as possible.

iGEM Concordia
I think it's a really amazing project. That concludes my questions.

Morgan Irons
You are doing amazing work. I'm very excited to see where all of this goes. I definitely would be interested and happy to answer questions if you need a subject matter expert or somebody to bounce ideas off of. I'm completely fine with that. Maybe even when COVID-19 is no longer a thing in the US Canada Border reopens, I'm in upstate New York and we could have a meetup or something awesome.

[End]