In Dialogue with Michelle Oeser

iGEM CONCORDIA

ASTROYEAST 2020

Michelle Oeser
R&D Manager at Lallemand
October 2020
Interviewed by iGEM Concordia Montreal

SUMMARY KEYWORDS

culturing, microgravity, yeast, cells, biomass, strain, experiments, selecting, media, population, growth, reactor, culture, stress, feeding, conditions, fermentation

iGEM Concordia 00:01
We're doing microgravity studies. We want to take yeast, perform adaptive evolution, put it in our microgravity simulator for multiple generations. And then select for ones that have desirable traits that aren't influenced by microgravity-induced stress. That's our plan. We're building these microgravity simulators. The one we're building is quite simple. It's actually like a pretty basic bioreactor design, it's just a cylinder, and then it rotates.It's the same way that the International Space Station orbits. It's always accelerating, but then because of free fall it experiences microgravity. We need nutrient exchange so that we can keep these cells alive and somehow keeping the experiment consistent. So we're not affecting gene expression with an influx of nutrients, and to maintain reliable measurable values for two to three weeks. That's the basics of it. I'll just run through some questions if that's okay. Is YPD what is commonly used in bioreactors?

Michelle Oeser 01:42
Whatever you use a medium, you want to be able to make a lot of it and be able to autoclave or otherwise sterilize large volumes. In your case, well, just to make sure I understand. You're asking, is this choice of media appropriate?

iGEM Concordia
Yeah. Or, like, well, for us, it seems like the easiest choice because it's what we use in the lab regularly. Are there options, better options?

Michelle Oeser
For us, it would depend on, like, when we do strain adaptation work, we just want to make sure that the media recipes that we're using reflect what the organism will experience ultimately in the application. So if you anticipate having some sort of like a cultivation system in space that is YPD based, then that's your media to use. If the goal ultimately would be to produce as much biomass as possible. Would that be the goal for you? Is it something that survives microgravity?

iGEM Concordia
For the initial experiments, the goal would just be to be able to culture this yeast for multiple generations, because we're selecting for genetic traits. And then we would take the good ones, do more directed evolution with them to get them to be fully resistant, then those would go to space and we'd want to culture more mass.We are interested in both for now, I'm talking about just the experimental part.

Michelle Oeser
The reason I was jumping to like your final application, is that usually what's going to be ultimately applied? We try to incorporate into the adaptation design, but I think for your purposes, I think YPD would be a fine choice. Do you know right now if your strain survives in microgravity conditions?

iGEM Concordia 04:49
We are using classic lab strings such as BY4741 or S288c and have cultured quite a while ago, early 2000s they have cultured for eight days, it was viable. The thing that happens is there are unpredictable changes. There is random budding, the cytoskeleton moves, some genes are upregulated, others are downregulated. There are these unpredictable effects that are happening for which we would like to make strains that were predictable. So we could take bio engineering applications here on Earth, and send them up to space.

Michelle Oeser
It sounds like you have some instability of the phenotype that you need to have whatever changes are happening, does that make the cells less viable? after a certain point?

iGEM Concordia 06:04
For viability there are some papers, it's mixed. Some papers are like saying that it's okay. For colony growth, I think I forget, I read this one a while ago, the viability in space isn't a huge issue. I would say from what I've read, I don't think they've done a ton of full cultures in space. They're mostly doing transcript transcriptomic studies. It’s more about these pathways. So the HOG pathways, the cell wall integrity pathway, the Heat Shock pathway- they're not sure actually why it is affected, they think maybe radiation and the osmoregularity, those are the ones we're looking at. And one, like a yeast researcher, he sent up his gene deletion collections, he and other researchers, they think a lot of it just has to do with the fact that there's no gravity, so that the convection in the cell is changing everything. I find it quite easy to imagine how things can be affected without these external pressures.

Michelle Oeser 07:25
The reason I asked about viability is if you're trying to use a continuous culturing adaptation strategy, you will want to have some kind of condition, that's a challenge to strain, not just in terms of like transcriptomics. You want the conditions to be challenging enough that the cells have difficulty growing, because it's like going through additional generations, if like the parental strain has some difficulty, then you can enrich for improvements. But like, over time, if your starting point, say you had like a mutagenized population, or you're over expressing things with like a plasmid library or something like that you need to be selecting for something.

There needs to be some sort of challenge for improved isolates to overcome such that they become enriched enough that then your population after multiple generations, or however many looks different than your starting population. It's easiest to enrich for something. If there's at least a challenge, parental strains such that it has some difficulty growing. The easiest things to select for is actually when your parental strains can't grow at all, then you don't necessarily even have to do a gentle continuous stream improvement culturing strategy. You'd need to create some genetic diversity and then send that population through your selection and then whatever lives in that living pool, and so send it through again, it's more considered like a classical screen improvement strategy. Whereas adaptive laboratory evolution is this gradually changing of your population.

If your starting point is more like there are these transcriptomic changes that are observed in space, but that it isn't apparent yet what the phenotypic problem if any, what that is, that might be trickier. It's a little harder to anticipate what you might get from culturing and microgravity.

iGEM Concordia
Our selection pressure is microgravity. Then let's say the Heat Shock Protein, HSP30, which is the most upregulated. Our idea was that we would run it in the microgravity simulator, and then you run a control experiment as well. So the same thing, but you rotate it perpendicular. And then when the expression matches, that's what we're looking for. In microgravity conditions bringing it back to the control expression levels.

Michelle Oeser
To put it in very lay terms, I guess, to get your ultimate improved strain to look like it has no stress? iGEM Concordia 11:45Yeah, and then adaptive evolution seemed like the best option because everything's so integrated, that the cell kind of gets to decide what's good for it. Then from there, we can sequence and do the next phase of experiments.

Michelle Oeser 12:08
So through the transcriptome, it looks like the cells are experiencing a certain degree of stress. Is there any observable phenotype?

iGEM Concordia 12:31
Well, random budding, the nucleus moves. cytoskeleton… there are quite a few things that happen. I have the list here somewhere, too. So you're saying we need something more specific? Is that correct? That's what I'm understanding?

Michelle Oeser 12:57
An approach like adaptive laboratory evolution usually works best when you're kind of at a starting point, that's at least a bit challenging in terms of allowing for growth, or accumulation of biomass. That's kind of the evidence of selective pressure, because then with culturing over a certain number of generations, there should be that opportunity for something better to come along, and then that kind of starts to sweep the population.If you don't have a selective pressure that's really putting pressure on the ability to grow. You might have a lot of different things that kind of change over time, but I don't know that you would necessarily get an enrichment of the strains that look like they're super cool and aren't stressed at all. You kind of need some growth challenge to enrich for what you want.

iGEM Concordia
Are you talking about pressures such as microgravity?

Michelle Oeser 14:42
Possibly, although I hesitate to propose other stresses, because if you kind of start combining a lot of stresses, they may not ultimately be relevant for what you guys need. The phenotypes that you're seeing, are they a problem? For the types of, like for the different ways that people would like to use yeast in space?I realized in asking that question like, I don't want to like up in the project. Yeah. Usually for our stream improvement projects that we do, at Lallemand, we try to get the business unit that we're working with to really clarify what the current problem is. And I'd like it to be something that we can measure, like, our wine strain does not perform well under low pH conditions. And we know that it doesn't perform well, because we can measure that it doesn't grow as well, or once it grows, it dies off very quickly.

And then that allows us to set up a strain improvement scheme, where usually we'll start with wanting to introduce some amount of genetic diversity, whether that's by random mating, if it's yeast, or random mutagenesis or something like that we could also transform in a library of whatever it is that we're interested in, have some sort of

genetic diversity, and just juggling a diverse population through some sort of challenging environmental condition where only a best subset of that population will survive, or will grow enough that, if we were doing rounds of adaptive laboratory evolution, where we're sending our wine strains through like grape juice, fermentation mimicking wine production, in such a way that it was really challenging for the parental stream, we could do rounds of that. Hopefully, over time, we were able to measure things like increased, viable cell counts.

That's our measure of performance. And that's our indication that the population is changing. And that we're seeing an improvement in that specific area where the parental stream suffers, if our measurable opportunity for strain improvement at the beginning was 'cells are dying too early in wine fermentation', then we'll want to be measuring, during our culturing, to see we're observing better survival, as measured by viable cell counts.The key things are defining that measurable opportunity for strain improvement, generating some degree of genetic diversity, passing that diverse population through some sort of challenge or selective pressure, and then measuring it in a way that's relevant for actually detecting that strain improvement that we want. I think in the case of yeast for tolerating microgravity conditions, the challenge might be to know what the measurable opportunity for strain improvement is like.

iGEM Concordia 19:33
This year, we're looking at nutrient production. Next year, we were thinking of maybe adding something insulin, which is something that we could easily do in space as well. What I'm understanding is we probably want to look at -if that's our end application, we'd want to see how much protein production is being affected? Or if there's a phenotype that interferes with that?

Michelle Oeser 20:07
You could also, do you know if in the microgravity simulating reactor, what cell growth looks like there compared to just a more typical reactor on the bench? Because if they look different, that is your opportunity for strain improvement, if you get a lower OD after a certain number of hours of growth, then something's going on and your yeast are not doing as well under the microgravity conditions.If it was something like OD, that would be awesome. Because that's really easy to measure. And as you're doing your culturing over generations, you can just look at...I guess it would depend on the setup of your experiment. But you basically would look for indications that your strain is growing better than it did in the beginning. So that might be a good first thing to try. And then later, if it was something like cell growth just doesn't look as good under microgravity conditions, then sort of implied in that is getting more protein out of your yeast culture kind of goes along with improving the biomass. You could get fancier than OD if you wanted to, by measuring like total protein or that sort of thing. Yeah.

iGEM Concordia
I'll drop the, it's in the chat. It's a Rotary Cell Culture System (RCCS) which, from what I understand, they actually are used as bioreactors as well. But it was designed by NASA for microgravity studies. It's a perfusion system. This is what we're kind of imagining right now. We're still doing research.

[Shares the Synthecon website]

Michelle Oeser
I've not seen any like this. And I will admit, I'm much more like I'm a molecular biologist by training. For things like process development and bioreactor work, I've mainly become familiar with that, since moving into industry, so I'm not really a process person. I can also, if I don't have a good answer for particular questions that you've got for me, I can find the right person. But yeah, I haven't I have not seen reactors that look like this one. It looks good.

iGEM Concordia
The cells basically rotate in there. And then they have these membranes for gas exchange, waste exchange. I'm sure there are a ton of publications, but that's the stuff we're kind of troubleshooting right now. The tricky part is not disturbing the cells too much. You don't want air bubbles in there, because the air bubbles can hit the cells and then they mess up the simulated microgravity.I guess a question. So for most papers, um, for microgravity, bioreactors listed operating at 30 Celsius. But then we saw for other bioreactors it is at 37C, which I assume is for biomass instead of research purposes?

Michelle Oeser 24:28
I think most of our culturing for yeast biomass is 32 degrees. 37C. Seems a bit high. That's definitely survivable for yeast. But that's getting sort of in the range of heat stress. I would say it's not that stressful. When you're in an environment, when the yeast in an environment like YPD. And 30 is a pretty typical, yeast, experimental temperature. I just know for yeast production, like large scale production, often we're at about like 30-32C. Sometimes for experiments in the lab, we'll speed them up and make things happen a little bit faster without stressing the yeast very much. We'll go to 35C.

iGEM Concordia
Do you ever go lower for any reason?are you familiar with bioreactors which are similar to this?

Michelle Oeser 25:58
Not that I know of for Saccharomyces cerevisiae production, where the goal is to make a lot of biomass. But if we're trying to mimic some process that we know,

that typically happens at a lower temperature. For example wine yeast fermentation, people aren't fermenting grape juice at 32 degrees, it is way too hot, and then probably makes gross wine at the end. We're adjusting our experimental parameters to match what the yeast are going to experience in their application. Space is going to be chillier. And in their capsule they are going to be colder than that. Maybe you want to incorporate that. But for now, if your focus is just the microgravity I think 30-32C.

iGEM Concordia 27:28
Cool. For cellular waste, what cellular waste do we need to eliminate as we're culturing?

Michelle Oeser 27:43
If you're providing oxygen, you might have ethanol. If you got fancier and fed your carbon at a lower rate, then you might be below the threshold where yeast will switch from respiration to fermentation. If you stay below that threshold, you won't get ethanol production. But if you were just using YPD, in batch, and you've got your large amount of sugar available upfront to these they will ferment. So you'll be making ethanol. You'll be making carbon dioxide. And it's not like a waste product, you will generate some heat. And so not sure if that cultivation system has any temperature control with it, or if you'd have to kind of put it in an incubator.

iGEM Concordia
What about ammonia, does that happen when they are stressed?

Michelle Oeser 29:59
In YPD I don't know if that would happen. It might happen if they are stressed. And this can happen- I don't know if it happened in YPD- often you'll get like fusel alcohol production if there's nitrogen starvation that's going on. And I think sometimes that can also come in combination with heat stress.But that might not be a concern growing in YPD, that's lots of nitrogen, you'll have relatively happy yeast, with that recipe.I would think CO2, and ethanol are your main things. I think YPD is like decently buffered, so that you wouldn't necessarily have pH fluctuations, but that might be something to check.

iGEM Concordia
From what I've found, pH for yeast is 4.5?

Michelle Oeser
4.5 they can tolerate it. They're pretty tough yeast can handle a pretty wide range, they can go a bit lower in pH, then quite a bit lower in pH than that. And they can also go higher. In mentioning pH, if you don't want pH to be a factor, you might just want to

take some measurements over time and see that it's not fluctuating. Like if you started at 4.5, perfectly fine, you just want to see is it changing very much as you're cultivating? If it is, then you may want to increase the buffering capacity of your media or get fancier in terms of pH controller, it's way easier to increase the buffering capacity, the recipe, but again, that said, I think YPD is generally better for that, then a more minimal media would be. There's a decent amount of buffering capacity already.

iGEM Concordia 32:43
I'm not sure how we are going to do this yet, we have to do some calculations, but we are feeding fresh media which would be the buffer?

Michelle Oeser 32:58
Yep that's true. Do you know what you're going to use to trigger feeding, your dilution rates?

iGEM Concordia
We have a team working on it right now. And we're hoping to go off with some of the other designs that people have done. There's pumping systems. And then we have to look at these membranes and again, like the gas exchange, and somehow that it doesn't disturb the cells. Or that there's enough media present, enough of a reservoir that depletes over time, but there's always enough. For two to three weeks, I'm not too sure how much media yeast needs.

Michelle Oeser 34:00
It would depend. You'd want to get an idea from those preliminary experiments. What sort of dilution rate you're going for and then you can calculate how much you need to have on hand. What is the volume of these?

iGEM Concordia 34:24
The other part we have to decide is how big the compartment would be. And then we were looking at while doing multiple tubes so we can have more samples in there as well. And then how much space do the cells need to be in simulated microgravity? The volume of cells would have changed.

Michelle Oeser 34:58
It's cool that this exists.

iGEM Concordia 35:00
NASA built the first rotating wall vessel for my simulated microgravity on Earth. And this company (Synthecon) came out of that. And they do custom design. It's used for 3D cell culturing as well. The next question I have is do we need to flush out some of \th
Or can we just leave it all in there?

Michelle Oeser 37:17
It might be useful to have a measure of that periodically, do a check for cell viability. Whatever tools you have for that could be really simple like using a viability dye, counting with a hemocytometer under a scope, or maybe you have a flowcytometer available for easy viability measurements. Whatever that is, you may want to periodically check just to have an idea of, well, I only have 20% viable cells in the bioreactor right now. It's not looking good. That may be an indication that you'd want to, pause, take your samples out, give them a chance to recover and start again.You had a membrane, right? Are Some of your cultures going to be coming out? Live and dead cells?

iGEM Concordia 39:03
We are looking into it, because most experiments aren't running this long. They're shorter experiments, that people do in a couple days or something. I don't think it's an issue for them as much, or they're culturing for biomass. Like you were saying, whereas we're culturing for microgravity.

Michelle Oeser 39:29
So that's interesting. You could reach a pretty high cell density I would imagine if you're not getting rid of any of that culture and then if you're feeding new media, you're mainly going to get fermentation happening rather than biomass growth. I guess another question is, do you want the cells to be able to grow under microgravity? Well yes, you want to be able to culture and have them grow, because at some point in your experiment, I think you're going to be selecting more for survival than growth. So if you want to continue to select for growth, and you'd want to be diluting your culture, like some of your culture needs to be coming out of your system. And if that's happening, you're going to be removing your live portion and your dead portion.

Hopefully, over time, if there's an opportunity to grow or survive better in microgravity, then you might expect that over time, your proportion of your population that's alive might increase and your dead might decrease.But you'd want to see in your microgravity setup, compared to a Earth gravity setup, normal setup if you're observing poor growth under microgravity. Hopefully, there's some issue with growth under microgravity, so that then you have that opportunity to select for something that grows better.

But yeah, I think there's going to be other stresses that come into play like the density of your cells, if you weren't getting rid of some of your culture you might have a lot of starvation going on. Your biomass would be increasing... in order for your feeding to actually meet the demand that increased biomass you'd have to feed more and more and more and then you'd need to dilute even more. I think it becomes a very complex, process wise, a very complex setup.Having something like a more typical chemostat setup, where your some of your culture is going out probably makes sense.

iGEM Concordia 43:37
Could we assure that our volume was large enough that this wouldn't be a stressful environment? Would that work?

Michelle Oeser 43:55
I think at some point there's going to be…. I'm not sure what limit you reach first but if you're wanting to give your yeast oxygen you might start to be limited by oxygen transfer or gas transfer, you might start to be limited by that. You might be limited by the volume or amount of media you can even put into your system within a short period of time. Is it because the reactor is designed a certain way that you want to keep all your biomass in there?

iGEM Concordia
No, just considering our options. What you had mentioned, a chemostat is new and something to look at. Removing and diluting is also something I'm personally not too familiar with. And if we remove some cells as well, we have to test them… the idea of experimenting in simulated microgravity is ideally we don't take them out and then put them back in later because then we're exposing them to gravity.

Michelle Oeser 45:49
You can only really measure the performance of your strain when it's in that microgravity context. So it's hard to sample your populations over time. If you've got your one setup that can do microgravity, and you've got your culture going, you can't at the same time evaluate that population. I think for evaluating performance, if performance is measured by something like OD over time, like how your cells grow, then you're having that set up where you'd want a Batch Setup, meaning all of your nutrients, everything that's the yeast are going to have access to, during their culturing time, is available from the beginning, then you probably wouldn't even need to like to feed anything if you just inoculate your yeast and watch them grow over time and accumulate biomass under microgravity conditions.

In that case, you don't really have to worry about feeding anything in or taking anything out. That's for measuring performance.But then back to the culturing, it's possible in doing the adaptation approaches, it's possible to do batch culturing, even in your microgravity system. Similar to if you're doing this in a flask or test tube or whatever scale, you inoculate your yeast and put them in there, and then they grow to a certain density and they're running out of some nutrient and they kind of plateau, that would be considered one cycle, and take a sample of that out. And then whatever you've chosen as your inoculation rate, then you do the same thing again, and then run another cycle, and over and over and over.

And that would be a different setup. And oh, and you can calculate your number of generations, like you can still reach whatever generation number you're aiming for. A reason to do batch would be if you have some reason to think that going through a cycle of growth and then plateau and then some degree of survival is more relevant for you then controlling every possible condition and it's just your microgravity that is the stress that points more to a continuous adaptation system. But in doing that, you will really want to have some of your culture being diluted, because when you have that really increased biomass, there's going to be a lot of things that are very different in that environment than at the beginning of your culturing experiments.

iGEM Concordia
So if we found this phenotypic thing that was affecting the growth of the cells. And then if we did something more continuous, it would be like selecting for microgravity specific improvements,

Michelle Oeser
I think so or at least microgravity specific changes. And doing continuous culturing would give you an opportunity if you wanted to sample at different points over time and then do, I don't know if transcriptomics is part of the budget or the plan for this, but doing a more continuous adaptation, controlling all of these different variables, then could give you that opportunity to kind of sample and see if the transcriptional state of your cells at one time point is different from another.

iGEM Concordia
We are hoping to measure it with GFP, like fluorescence is what we're looking at. And then if we get successful strains, then we'll get them sequenced.

Michelle Oeser
Ok, so it's GFP. Is it a fusion with some protein of interest? Or is just expression of GFP?

iGEM Concordia
Fusion with our promoters so we get a fluorescent reporter.

Michelle Oeser 52:11
Ok so you get a fluorescence reporter for expression. In that case, that's really nice, too, it depends what you're planning, like, if you can sample periodically and fix your cells so that whatever is happening in terms of level of fluorescence, at that moment in time, that you sampled, and however, you're measuring GFP, you have that snapshot? Cool. Yeah. I think the continuous approach makes a lot of sense, then. You want to be running it like a Chemostat. If you want I can pose some questions to my more process-educated colleagues?

iGEM Concordia
I know, we'll have some questions next week, because we were actually building one machine. And then we have two engineering teams building machines as well. First off, we just aren't sure that we'll be successful. And the conditions are very different in different machines. So we'll be able to compare the results. We have a lot of people with a lot of questions coming up.

Michelle Oeser 53:51
I have a question about the GFP reporter, or whatever fluorescence reporter you would use. Do you have control genes that are known to not change in microgravity?

iGEM Concordia 54:10
We chose a couple. And we are hoping that it'll be a control strain that we can contribute to the community. And then also having histone and ribosomal controls which we were suggested to do.

Michelle Oeser
Another question is, do you have access to cell sorting? A lot of universities have a core facility for this. If you did, then you're looking for a certain fluorescence signature, that's your indication that something transcriptionally has changed. And we might want these cells more than others. That might get around the challenge of...Okay, if you're doing adaptive laboratory evolution, it really helps to have conditions where you're selecting for something that can grow better, because that becomes enriched in your population over time. It's still nice if you can achieve that. But if instead, you're just kind of culturing under these conditions that you know are relevant because it imposes the relevant stress, but you're looking for cells within your population that have a different transcriptional response.

Even if they didn't sweep and take over your culture, if you had a way to periodically sample and you knew what level fluorescence you wanted to get, you could do something like FACS (Fluorescence Activated Cell Sorting) and sort for the cells that have that signature that you want. And then you can take those, and maybe use that like the sub population that you've selected to inoculate a new round of culturing that that might be a way to pull out hose ones you're more interested in?

iGEM Concordia
This is a later application question.We were talking about when you're culturing on the spaceship. For example, Scott Bryson is with Orbital Farm and they use closed loop systems. So he's mentioning if you could somehow create media, like recycle it from something else, for example maybe human waste or plant waste. I was just wondering if you knew anything about recycled media or other sources of media?

Michelle Oeser 57:42
I don't know a whole lot about that. I think there are some different groups currently that are interested in doing microbial fermentations using, dairy waste, that might have a lot of lactose as a carbon source.But I've heard that a particular challenge with that is that the lactose concentrations are pretty low, the waste is pretty dilute. So the lactose isn't concentrated enough for what you might need for culturing, this is for some non *Saccharomyces* yeast, and maybe some bacteria also. A way to deal with that might be to concentrate that waste stream. But I guess the challenge that comes with that is that certain salt concentrations increase to a degree, that it's not a very nice media anymore for your microbes, so then there's a need to do dialysis and remove some of the salts.

That is all to say that, if you're thinking about waste streams, having in mind what concentrations of carbon, nitrogen, like the basic nutrients that you're trying to provide, having an idea of what levels those might be at and if there are certain levels of compounds that you wouldn't really want to concentrate further. Those are things to think about. I just posted a bunch of challenges to you rather than offering any like ideas or solutions, but I think it's a wonderful idea. And I would love to see more feeding waste streams into microbial cultivation. Just generally, and I guess spaces have a wonderful opportunity to do that.

[End]

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

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

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