# In Dialogue with Dr. Scot Bryson

iGEM CONCORDIA

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## Scot Bryson
## Founder of Orbital Farm Circular Project, Space Farmer and Vaccine Manufacturer
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Interviewed by iGEM Concordia Montreal
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## *Part 1*
*organisms, develop, technology, system, astronauts, protein, produce, closed loop systems, bioreactor, projects, capability, growing, microgravity, product, plants, people, human, ammonia, utilize*

**Scot Bryson 00:17**
I started Orbital Farms two years ago. But I've been working on this since early 2016. Orbital Farms is a project development firm that is setting out to build closed loop systems to produce food medicines all around Earth and pilot the technologies required so that we can develop closed loop systems for life support systems in lunar or Mars situations in the future. Our intention is to build a large number of projects and assets that will give us a testbed and a platform to test in different environments, test growing different types of foods, dealing with different waste streams. Develop a deep understanding of the interconnection of these closed systems and be able to pilot and develop smaller technologies in that pathway.

By developing a commercial entity, with this purpose in mind, this will give us the capability and a robust data set that we're going to have confidence in developing life support systems that can withstand you know, significant lengths of time and we can have confidence that systems can operate for six years on a Mars base in the future. We obviously can't simulate the gravity's in situ, but certainly, you know, the closed system itself is difficult enough. And that's the key focus and challenge. And at the same time, the side benefit of what we're doing is that we can feed hundreds of thousands of millions of people with each facility. The side benefit being, we can address food insecurity in these places where they don't have significant sums of water. They don't have significant access to fertilizers and nutrients or, they're located in areas where the soil isn't great, or it's in northern climates where they don't have enough sunlight to sustainably develop crops.

And additionally, when you're developing large closed loop systems, you become climate independent and the variability in the agriculture system based on the weather is what drives, you know, a 400% volatility price in food prices. As the climate changes and warms, this is going to get worse and you know, the frosts are, are going to come earlier, the rains come harder, the hail storms become more frequent, that wind storms and tornadoes, and hurricanes and flooding events, these all majorly disrupt our agriculture system. This is a huge risk globally as a human species, let alone individual communities and space.

**Scot Bryson...**
The development of large closed loop systems, I think is fundamental. And so what I've set out to build within Orbital Farm is understanding that these technologies that currently exist in many different places and we have had greenhouses for a very long time, we've had bioreactor technology and capabilities for, you know, well over 100 years.

We have the capability of capturing carbon dioxide for that length of time, we have developed the capability of producing hydrogen and, and agriculture systems. What we've gone through and done is selected a number of technologies and an architecture that lets us build a closed loop system that starts from that endpoint desire, which is, a human in space. How do you build an ecosystem from the waste streams that are available from that situation itself. And so, NASA developed technology in 1968, to capture the carbon dioxide that astronauts were breathing out and develop a protein source for the astronauts and they came across a single celled organism called us hygenotroph and this is part of the knallgas microclass... So knallgas microbes or bacteria. And this is part of what's called the dark ecosystem. And so these exist in the soils, in the bottom of the lakes and the bottom of the oceans.

These organisms consume $CO_2$, oxygen, hydrogen, and ammonia. There's mineral salts in the water, and they grow incredibly rapidly. They're prevalent, you know, everywhere, their waste product is $H_2O$, they bind the hydrogen and oxygen molecules together. They're difficult to grow because they grow on hydrogen, oxygen and $CO_2$. So that's been a physical challenge to this organism. But in 1960 they publish papers on developing a system where utilizing these microbes, they can convert the carbon dioxide onboard the space station we breathe about a kilogram of $CO_2$ for as an adult each day, and so they can consume that kilogram and produce around 500 grams of protein for each kilogram that they're consuming. That is enough to sustain a human to live and we need about 50g if you're an astronaut, you need maybe about 100g because you're exercising two hours a day.

But you know, you've gotten a capability now of being able to produce enough protein for an astronaut from the $CO_2$ that you know, they're breathing out every day…an excess amount to actually beyond that. They published traditional papers in 1970/71, I think, on this, and then they didn't, because we haven't gone on missions longer than a year. And the NASA budget got cut, and money moved and shifted over to funding the Shuttle Program, which was great and fantastic. We got astronauts into space. But this technology died almost completely. The teams and the engineers and the biologists that worked on this moved on to other things and the companies that they worked with to develop the prototypes and everything also moved on to other things. I contacted them and they don't have that knowledge and capability any longer.

**Scot Bryson...**
In 2008, there are a couple companies that came across this during the biofuels boom. And they started to look at this microbe and realized that they can also produce oils. It can produce polymers and that they could utilize this organism to be able to, to create a biofuel product. And then when the biofuel market sort of fizzled out, they pivoted back and started producing protein.

Since 2008, there are now five major commercial companies that are working on scaling up this, the capability of growing these organisms to combat climate change, and to provide a protein product as an aquaculture feed. The amino acid profile of these organisms, they look like fish meal product, because that's the basis of the amino acid building process in the ocean ecosystem. You're taking the core elements and creating the beginning of that food chain. And so, they have ones that steer towards aquaculture, feed that can also be used in pet foods or in food for chickens or for pigs. It can be used as a biostimulant in soils to increase the productivity of plants both, on the plant biomass itself, as well as in the root structure and the microbiome within the soil.

They've also got a strain that is equivalent to a whey protein powder, amino acid profile they've selectively bred a number of these. It was a very long way of describing all this, but that is the base organism, that we're trying to develop projects around this technology at large commercial scale and setting up large fermentation systems utilizing that microbe, the challenges that it's not at full commercial scale yet. Everything has been proven lab scale and at demonstration size. They've transferred the protocols to different labs that have been able to replicate and grow and develop this in larger fermenters. But there are large fermenters that can take hydrogen and oxygen in the same bioreactor. And that becomes the critical element it literally becomes a rocket if you do it wrong.

So it's dangerous, but it's not any more dangerous than oil refineries or natural gas power plants or, you know, we have many more dangerous elements with many more dangerous materials. This just needs to be done carefully, slowly and properly. That's the key limitation to scaling it up. The basis of our technology stack begins with that ideal system that utilizes the carbon dioxide because that's what's going to make a huge impact globally. We think these systems can be catalysts to implementing carbon capture systems, because they require significant sums of $CO_2$ to operate.

And the scales that we want to build these facilities is somewhere in the 10,000 tons per year to 100,000 tonnes per year. So large scale facilities, which is a typical fermentation facility size, you know, if you look at large breweries and things like producing 100,000 tons of biomass is not out of the realm of possibility and it's quite normal.

In the pharmaceutical space, 10, 15, 20,000 tons per year is certainly achievable as well. That's typically the range that we're looking to develop these projects.

**Scot Bryson....**
That's going to consume pretty much double that in carbon dioxide. So 200,000 tonnes of $CO_2$ in years, that's a significant amount. And the amount of protein that that actually produces. The protein content is somewhere between 70% and just above 80% protein content for these organisms, so it's extremely concentrated. Well, if you take 100,000 tons and you take 83% protein content, what you come out with is that that hundred thousand tons is able to support over four and a half million people's daily protein requirement of 50 grams per person per day.

That means you can have country level impacts with a single facility. Take a country like Namibia, which has to import 75 to 95% of their food. And you can create enough protein that you can support twice the number of people that our country currently has with a single facility. How many of these facilities do we need to end world hunger? That number is 180. So 180 facilities we build at 100,000 tons per year, what we need to achieve to end the 821 million people that were starving last year, at least their protein requirement, which is the most difficult and expensive and difficult thing for people to consume, and access. Well, that's an achievable number.

And that gives us a driving motivation to build the hundreds and hundreds of facilities that we're going to need and different places around the world that can be our testbed platform to develop these larger closed loop systems. So that's the trajectory that we're on. The other really important piece here is, you know, it's not just these bioreactor systems. And it's not just a single technology, because this is not at full commercial scale yet, there's still another few couple of years it's going to take to get through FDA approvals. There's work that needs to be done. There are two other types of organisms that we're currently targeting and, you know, happy to add a third in and so, beyond.

Beyond the hydrogenotrophs, there's a cousin organism called methanotroph, which consumes methane, oxygen, ammonia, synthesis, same knall gas microbe type of organism. Their waste product is $CO_2$. And this is again a technology that's been around since the early 80s. They were developed and commercial entities were created to develop this technology. This is already at commercial scale…They've selectively bred these things and they have a doubling time of a few hours. Selectively breeding them is not as difficult and their purpose in nature is as a food source. Similar to the hydrogenotrophs, these organisms also really thrive around hydrogen vents at the bottom of the oceans, which support large numbers of bacteria, but large communities of bacteria and then even larger communities of shrimp and crustaceans that thrive off of these bacteria that are growing around these thermal vents. They have that key benefit already, so you don't have to steer them in any direction that they're not used to being.

That's a technology that we look to develop projects alongside. We try to identify locations where we could implement both.

**Scot Bryson...**
Theoretically, we should be able to build a methanotrophic bioreactor system and capture the $CO_2$ coming off of that and feed that to a hydrogenotrophic bioreactor system. And, be able to utilize that waste product with a very pure $CO_2$ stream already. And because we're not using sugar to provide nutrients, the cross contamination- methanotrophs will not live without methane and hydrogenotrophs will not live without hydrogen. So you know, you do have that added key added benefit of sterility, it isn't really sterility, but, whatever you know what I'm talking about. So that's another system.

We've also come across another technology that is another bacteria which consumes leftover, I might be misquoting maybe it's a yeast, anyway it takes over leftover sugars within wastewater streams. And so this can come from wastewater treatment plants alongside sugar processing facilities and alongside abattoirs, with the blood water, alongside pulp and paper mills as well, and utilizing some of the leftover remaining sugars in the wastewater streams. And again, same process, these aren't knallgas microbes, but they consume the leftover sugars and they produce an amino acid profile similar to fish meal. And out of all three of these types of processes we get a powder product and that powdered team product can go as an ingredient to other feed companies. We intend to build our own feed mills themselves and produce an aquaculture feed product. From that we think aquaculture feed products, and it's not going to be the same for every different project location because that's not an asset and universally available, but we do intend to try to spur additional aquaponic systems in different places around, do you know aquaponics?

**iGEM Concordia 24:07**
Is it like recycling hydroponics?

**Scot Bryson  24:10**
Yeah. So let me let me briefly explain it. This is a 4000 year old technology that the Mayans figured out that when they grew their corn base, they would take the water coming from a stream, and they would divert that stream into these pathways where they would run the water and they plant their corn in between these. What they realized is when they started growing some fish upstream, in a more enclosed area. That water started flowing through their cornfields, that they would get a significant more yield of corn in their crops.

This is how they built their agriculture system, growing fish just upstream and then flowing the water through the cornfields and this was also developed in Asia. They developed this at the same time and their society continued. It’s been prevalent there for a very, very, very long time. But what they realized is that the symbiotic relationship between these fish and their plants was extremely beneficial. They obviously didn't understand how to function with the waste stream product of fishes, ammonia, if you put fish in a fish

**Scot Bryson...**
tank, and you don't filter that water, you're going to die because they get too much exposure to ammonia at the end. What happens in where if you take that water and you flow that through a filter system that has a large amount of surface area, naturally existing bacteria, two different strains will convert that ammonia into nitrates and the one strain converts ammonia to nitrates and then the other one converts the nitrates and nitrites and that then creates the nice fertilizer required for plants.

You now have this very naturally existing and very rudimentary system where you can even just put bird netting into a big barrel and throw the water through it. And after a certain period of time that builds up enough cell growth to actually convert that. What happens is they figured if you grow the right number of fish and the right number of plants and flow the water at the right speed, well, those plants are going to uptake your nitrogen clean enough that you can just take that water and put it right back in your fish tank and create a closed loop system between your fish tank and your greenhouse system and your hydroponic growing system.

You can grow your plants and really your fish can become your fertilizer vessels. You're not in the business of growing fish. You harvest the fish once they get older, but you're really in the business of growing plants and those fish are providing fertilizer for you. All you need to do is keep your fish alive. How do you keep fish alive? You feed them and what does a fish eat? Well, if you're growing salmonid-type fish those consume 45 to 55% protein content in their food. And if you're deriving your protein coming from CO2, oxygen and hydrogen and even waste streams, you can now build a system combining bio reactors, aquaculture and hydroponics in a single system.

You can essentially build near closed loop systems to be able to sustain people anywhere. And the inputs being carbon dioxide, electricity and water and human waste and you can build up an ecosystem and this is sort of the framework, the architecture, that we're trying to build.This flexible architecture allows us to go into different places, partner with other industrial waste stream partners, and develop projects alongside them and deal with the current linear economy and take advantage of that linear economy and develop profitable agriculture systems alongside these industrial partners. Having this flexible input, similar structure, bioreactor, aquaculture greenhouse, we can disrupt that. And you can go directly there, there are ways of accessing ammonia directly where you could cut out the aquaculture system if the local population doesn't eat fish and you're not able to export it to different markets. We can grow both plants but also create vaccines within our greenhouses. There's plant-based vaccine companies that were licensing their technology to be able to use plants to actually be the bioreactors themselves for creating vaccines.

**Scot Bryson...**
So, yeah, that was that was a longer explanation of what we're doing, but hopefully gives you a sense of structure and pieces of the puzzle. And, yeah, what we're focused on. I guess, just to clarify, what we're focused on doing is understanding these technologies, and developing the capability to develop those projects, as I described, and built the partnerships with those waste stream partners, understand the technologies enough that we can we can facilitate the development of a commercial project, you know, make suggestions to make improvements, but we're not the technology owners of those.

The core part of our understanding and technology really is focused around the integration of these systems, and how we integrate and I think that that gives us that flexibility and the capability for new technologies to emerge and develop, like exactly what we're describing here today. Where a different strain of different bioreactors, they're still within the same infrastructure that will be required- centrifuges, spray dryers, a powdered product at the end that could be made into different products. But that type of structure gives us that flexibility to work and develop many of these different projects. And the truth is the hydrogenotrophic example and those organisms, they're great, but maybe at the end of the day, once we were at a really large scale, it makes more sense to utilize an algae or maybe it makes more sense to utilize a yeast.

That ends up being the technology that proliferates. My sense is that the hydrogenotrophs are the answer, but since it's not scientific, and I'm not a scientist, I can appreciate that we definitely could be wrong, and I want that flexibility. When you guys reached out it was great. I hadn't worked out exactly, a yeast based approach, and I absolutely see the key benefits and the ease for scaling up the availability of bioreactors and the speed at which we could work with specific strains that are either engineered or evolved to produce the right types of products. And yeast is obviously extremely well understood, very trusted from people, you know, regulatory approvals and acceptance globally is great. So, looking forward to hearing more about what you guys are doing and how we can work together or help.

**iGEM Concordia 31:47**
That's a really great background of all your work you're doing. It's pretty amazing. I will say, we have some questions, since you're in industry, and we want to ask you before we talk more about our project.It seems like with all the research we have done so far that there is this great amount of looking for sustainable technologies in space. So, I want to ask what would you say are the more important things we need to keep in mind when doing bio production space?

**Scot Bryson 32:33**
The more important things well, definitely waste streams, I think you've got to start with that. We already have poop on the moon. Let's start there. There are bags of

**Scot Bryson...**
poop right now on the Moon. And while that may be fine for a couple astronauts, a handful of astronauts, as we start to be there more prevalent... I mean, the moon, we're not really contaminating an environment, from what we currently understand of life, there's no life on the moon and I don't anticipate that there is.

But when we get to Mars, this is not the situation and the efforts and the lengths that we need to go to, for even just biosecurity of other organisms, preservation of past organisms. The moment we send humans there, we are going to contaminate Mars significantly, but if we start dumping waste, we've got a massive problem. And beyond Mars, the richest man in the world has an interest in building O'Neil cylinders. We're going to need to utilize waste and you're going to need to start with the waste streams, because you're not going to have access to other resources and we're certainly not going to send carbon dioxide from Earth to these communities on a continual basis. Understanding the full waste stream systems from humans is a critical piece.

**Scot Bryson 34:29**
You're going to need to understand energy mass balance, and what I've come to understand is also really important is understanding the thermal components of this, temperature, pressure, what needs cooling, what doesn't need cooling in space. Cooling is a really difficult thing that ends up being a really major challenge eventually. You're going to need to understand how they operate in microgravity. That's an important component. Although my work is really focused in gravity situations. Growing plants in microgravity is very different from growing plants with gravity situations. Same thing with aquaculture systems, bioreactors are not as bad, they work, microbes don't really care.

And in fact, the gas to liquid transfer actually ends up being better in some instances and the ability for those organisms to thrive in microgravity, we think that that's actually going to be better in microgravity for microorganisms that you trust, but certainly something that needs to be better understood and to be totally transparent. I have not done enough research into that. Again, my key focus has been starting here and with planning in mind for what we what the architecture needs to be, for achieving space.

What else is really critical is productivity, so it's the efficiency of the organism, how it's using energy and how it's using inputs and feedstocks. That's also really important because, its resources are so constrained and limited; having access to that, and the waste stream products that this also produces and how those are dealt with and either reutilized or used in other systems and how they can be it can be done digestibility.

Deeply understanding the human, as well as animal component of how it's digested and absorbability, I think you guys probably have a good sense of that, and most universities tend to have a good handle on that.

I would definitely encourage more understanding work on how the protein is absorbed within the human? How does it become a more of a product beyond just a powder? A big piece to the space puzzle is people don't want to just have to eat a protein powder. People need to have variety. People need to have different flavors and textures and tastes. And while you can make smoothies it also needs the capability of being able to blend with flour. So you can make a protein enriched bread or you can make protein rich pastas. Smoothies are fine, three times a week, four times a week. But if you have smoothies seven days a week for three meals a day, you're gonna kill the other astronaut.

Having a flexible platform, having it work together with high moisture extrusion technologies that allows Beyond Beef and Impossible Burgers to have that similar mouthfeel. They take a powdered product, they add water, you have an extruder system and you heat and apply pressure to those products and in a very specific manner, and it molds the proteins and the structures into specific fibrous types of forms. That’s what gives you that sort of mouthfeel and bite of what a meat analog actually is. Knowing that the organism can withstand those pressures and temperatures and, an algae, for example, it can, but when you cook algae, the chlorophyll turns black. So, you know, black food is not palatable. That's a big challenge. You might be able to convince astronauts, they're not gonna like it, and you're definitely not going to get mass market acceptance globally.

Anything that we're going to use has to have been tested for very long periods of time. And, if it is black, and you have the option of something that's beige, colorless and tasteless, that technology is going to win out over algae and that's why my key focus isn't algae for one of those reasons, the other is also the efficiency of the metabolic process from my understanding is nowhere near as efficient as within bacteria and hydrogenic frozen organisms and their efficiency of actually converting the energy at the metabolic pathway level is much more efficient. You get more product for in a smaller space which, at the end of the day, what we're launching into space is so expensive, that's going to make a really big difference in the ability to sustain a population. Safety and security are really big components.

Developing a very automated system that doesn't take significant human labor to manage and operate and maintain is going to be critical, if we are redeveloping a food production system, they require 70% of the astronauts to be working and maintaining and operating. It's never going to work. This is how our society was originally built, 70% of humans were growing the food for everybody and that’s in North America, that sounds like

**Scot Bryson...**
3% or 1% or something like that, incredibly lower, it's not going to be that low for a small crew. If you're planning for 100 people, you're still gonna be maybe in the 10 to 15% range. They're going to manage food or some part process of that food production system. Automation is critical. In the earlier stages.You guys have utilized yeast, yeast is great for the scale up process because you don't have to go and invent a new bioreactor. And that's a huge technology risk, that's a huge length of time to develop that. Huge amounts of engineering and money and capital to make that happen.

That has huge benefits. Beyond protein, there's other important vitamins and minerals. Developing a deep understanding of all of the different vitamins and minerals that are possible in the organism. Where you can steer it with a little bit of effort.That’s really great to understand vitamin B12, for example, we're going to need sources of that. That's a difficult thing that can't come from other plant material. A deep understanding of the biomass and the nutritional qualities that come from it is critical.

The other good thing about the hydrogenotrophs is that with similar organisms, just different strains, some are able to produce, more polymers like PHAs and PHBs that can be made into plastics and some are able to excrete more oil, or produce more oil itself either excluded or retained within the cell bodies themselves. As we were describing proteins as well, that flexibility with the same physical infrastructure gives you the capability of producing multiple different types of products. And different uses either direct consumption are used as a biostimulant or used as human food or animal feed. That flexibility gives a huge amount of strength to it. That’s a critical component.

## *Part 2*

*project, bioreactor, waste stream, system, greenhouse, build, people, space, food, CO2, technologies, microgravity, plastics, piping, elements, life support systems, started, year, assets, facility*

**Scot Bryson**
Part of furthering that business model part of the business involves working with NGOs and with international organizations like the World Food Program, like the FAO like USAID to help procure and large offtake agreements for produce and product that we can actually produce and use those agreements to be able to finance the development of new physical projects. There are different elements within this, you know, we've also theorized that in terms of the business model of how you actually get to financing a project.

**Scot Bryson...**
The premise can come from two different ways. One, you can have a nonprofit that's willing to put money into providing free food for people that can't afford it or extremely low cost food for people that can't afford it. Or two, there's a commercial business model that that you can pursue utilizing the 80/20 rule, where you have 80% of the of the income supports giving away 20% of the food product or vice versa and 20% of the product then becomes the financial support to continue the operations and being able to provide a percentage, very low cost production quantities. That framework it's utilized in many other industries, the software industry and a number of others. And I need some help modeling this within a large-scale context within large bioreactor systems.

So maybe a follow up part of some of your work within the iGEM project, at least, is understanding the economics of the projects, and how those projects scale up to large scale and then how that can operate within this model as I'm describing. The essential framework being you begin operations with a facility for a certain period of time under the 80% of the project, paying for the capital cost, and paying down the debt for building the facility. Once that debt has been paid off, then flipping the business model the other direction, because you don't have to carry the financial burden of your mortgage payments essentially, on the asset, and flipping the business model the other direction and allowing food to be produced for free. Understanding the economics of developing a large-scale version of growing organisms would be fantastic to help with something that we could plug in different organisms into and different strains and different feedstocks. Some formalities around that would be great.I don't know what else but let's start there.

There are tons of different ways it really comes down to, who's available and who's actually interested. What departments is it? Is it the whole school, is it just the more efficient strain, is it the development of this work; if we can utilize additional waste stream products that we're not currently accounting for with these organisms. That opens up different possibilities. The other important piece to the universal food project is that a key element is that we're accessing low cost or free or even getting paid to deal with waste streams from some producers. And that ability for extremely low cost inputs gives us the capability to be able to provide very low cost food to the people who can't afford it.

Accessing or having a strain that is able to grow on universally accessible feedstocks. It is an extreme help to furthering that cause and furthering that business model.

**iGEM Concordia 05:16**
I'm curious, who do you have involved in the project, on the program so far?

**Scot Bryson 05:23**
So we've got a CFO down in Florida, who's been a CFO under mining companies that I specifically chose for that, because what we're trying to set these projects up as large mining operations, but we're mining CO2 and our waste streams and producing food. These projects are incredibly capital intensive, in the hundreds of millions of dollars to build and construct. He's taken companies from 20 people all the way up to over 2000 and raised billions of dollars to build massive operations. He was also the CFO for a company called DSM (Dutch State Mines), which you may or may or may not know, but definitely worth knowing in your industry.

The European company, I think they started in the Netherlands, I believe. They do tons of fermentation, tons of bioreactor technologies produce organic chemicals and, you know, many, many, many, many different great products. So, we've got him, we've got a VP from one of the companies that from the bioreactor companies who also was a CEO of a global organic chemicals company, as well as a polymer company as well, and built manufacturing facilities and many more countries around the world. We've got an advisor, he used to be the CTO of a project called a company called Sundrop Farms and Sundrop Farms they capture, they drew in water from the ocean.

They use that cool water to provide cooling for the greenhouse and then they took that water, after cooling down the air for the greenhouse. They then ran that through a concentrated solar system, to concentrate sunlight and turn that water into steam. Then they use that steam to turn a turbine, to generate power, to power the greenhouse operation. And then they took that steam that was from the saltwater, which almost completely desalinated that water. Then they use that desalinated water to provide the water for the greenhouse. And then they use the waste heat from that process and store that in large tanks, and then use that to heat the greenhouse during the evenings.

They were able to build and construct projects in Portugal, Oman, Qatar, Australia and the United States. And build 150 million projects that now, the one in Australia now provides 15% of the tomatoes for the country. He's combined technologies that have existed before but just hadn't been combined in that manner for that purpose. Not that that's easy, I'm not trying to say that that's easy. But that’s an analogue for what we're trying to do here as well. Agriculture bioreactors, aquaponics, hydro, greenhouses, these have all been built and constructed just not for fit for purposes I’ve described.

I've got some aerospace consultants. I've got a consultant in Europe who has studied. He currently works at a large seed company, a multinational seed company. He did his PhD on understanding how seeds respond to gravity. He's used microgravity simulators, as well as putting that microgravity simulator into a centrifuge to simulate lunar gravity and then simulate Mars gravity. The microgravity simulator was actually in a centrifuge itself. It was quite brilliant. A number of people in the US and Canada, in some of the other industries, such as some others in mining, and others energy, and yeah, I'm the one working on it full time, and everywhere else are consultants at the moment.

**iGEM Concordia 10:34**
I've been like with all this project development I started to realize that like, a long time I go, people used to just create stuff and it’s like green is a technology ticket, do something with it. But then they don't realize with the time we're coming to account the huge harm this new technology could have been great, but at the same time, they didn't count into all the things. Like plastics was created, a cool idea. And now we're floating in plastics. We've been seeing this a lot with space because people are trying to not make the same mistakes, right?

**Scot Bryson 11:15**
It's pretty neat in terms of plastics, just briefly and this is a good way to think about the waste stream elements. If you're familiar with a process called gasification, you heard of that before. Gasification is where you heat up products with the presence of oxygen. What happens is the molecular bonds begin to break down. You get what's called a syngas, which is carbon dioxide, carbon monoxide, hydrogen. Then trace materials of whatever else is built within the actual molecular bonds of the product. But the syngas is really valuable and in the energy world, it's used for heating and you can burn it to be able to then create more energy or electricity or heating things up very hot. But syngas is also essentially what the hydrogenotrophs actually consume.

You can go from non-recyclable plastic, you can gasify it. You can run that syngas then through a bioreactor and grow organisms that could then make a bunch of PHA and PHP polymers. And you could go back to making an organic plastic from that. It's very possible to develop a closed loop system of plastic recycling. You could take a whole bunch of black plastics and white plastics and whatever, doesn't matter the color or the contamination, because you're heating it up to like 900 degrees Celsius. That is something that we're thinking about. It's not the key focus right now. But you know that it's a possibility and that flexibility is important. Where that ties in with your program is some of the waste stream products if yeast doesn’t really have that, but if there are other additional food packaging, waste streams, this is where we are thinking, because that is going to be a critical component. Producing fresh food is great, but there's going to be leftovers and there's going to be stuff that there's lots of plastic wrapping, wrapping that will take place.
So how do you how do you build that closed system?

**iGEM Concordia 13:54**
For our project, we're really taking a focus on diversity and inclusion? What role does inclusion play at Orbital Farms?

**Scot Bryson 14:16**
It's a good question. We need more.We need a more diverse group of teams working, I think is the beginning statement. I'm a white guy, coming from a privileged country in Canada. We're definitely on the lookout for how we can improve our diversity. Always. I don't have a lot of women on my advisory teams, there's a few but that has really only been because there's not a ton of them. I would welcome a much more diverse group of advisors let me put it that way.

**iGEM Concordia 15:18**
Okay, so we have more few questions that came up in the discussions. So this one is actually from my colleague, she wants to know if the worst happens and an explosion blows up an Orbital Farm that has been established and supports hundreds of thousand people. What is the amount of time to establish it? How would the community support itself in the meantime?

**Scot Bryson 15:44**
That's a very good question.How long would it take to develop and redevelop a project, if it's destroyed, if an explosion happens I would say a year and a bit, I guess it all depends on how large the facility is. If we're talking about 100,000 tons per year facility, these projects typically take guaranteed 18 months to contract and construct and build. We're talking about off the shelf fermenters. It is possible to accelerate that within you probably a six month, maybe eight, eight month window, that a facility could be constructed. But really, we tend to plan for two years to build and construct a project and from that length of time. Yeah, we're obviously going to try to avoid catastrophic failure because you know, that it will create so many other repercussions. We're involved in law and space law around protecting life support systems. What we're undertaking is an effort to re-establish and reaffirm the country's commitments to human rights to food and access to protection of those assets as critical infrastructure assets.

**Scot Bryson 17:24**
The same protections that a country offers to an oil refinery, or a mining operation as critical infrastructure or power plants and as critical infrastructure to a country. What we're looking to do is to have countries reaffirm those values and treat these assets as those life support systems and take that affirmation and beyond their borders, extend that to all countries. And beyond all countries extend that into outer space, and the recognition that these are life support systems. That we do want to end world hunger within the next 10 years, and that the critical elements of food, clean water, fresh air are all critical elements

to the survival of humans, and whether that's on Mars or the Moon or whether that's locally within their county or country, that those assets should be protected from from terrorism.

We are taking proactive steps in doing the best we possibly can to ensure that doesn't actually happen. If we can even get protection from United Nations groups that would see that protection and the other piece to this, I think, through food, and through human rights, we sort of break down the political issues that come from a lot of conflict. And there certainly are catastrophic failures, from accidents that happen at facilities all around the world all the time. But good engineering makes that happen pretty infrequently. And, you know, we aren't launching rockets, which do explode a lot more often.

**Scot Bryson 19:30**
Oil refineries don't just blow up. There are catastrophic cascading failures that do happen. But, you know, again, this is why we're going slow. We don't currently have a facility for this purpose, so that we are making sure that the proper steps are taking place, and that we're not going to build something unless we are 100% sure that it is safe. It's a very long way of saying that it's okay. It's great.

**iGEM Concordia 20:08**
Who are your main partners for manufacturing bionutrients with cellular agriculture and which one of projects they are most excited about.

**Scot Bryson 20:19**
The bioreactor technologies that we're discussing with some of these companies so Kiverdi is one company. Another company, there's a company called Novanutrients and these are all in the hydrogenotrophic space. Solar Foods is another entity. Deep Branch is another entity that is growing these similar types of organisms, just different strains. These end up being key partners for us.

**Scot Bryson 21:10**
We don't have a local fermentation partner as of yet within Canada. Although to be transparent right now we're trying to develop projects in the United States, as well as in the UK. And so, you know that ends up being a key focus at the moment. Those projects at the moment we're currently focused on vaccine production within them. So as the first stage before Coronavirus. The priority was the bioreactor systems, and then Coronavirus hit and we flip the priority to the greenhouses and to begin increasing the production and manufacturing of vaccines, but selecting the right locations where we can ultimately

add in two second stages, the bioreactor systems so co-locating alongside a large $CO_2$ emitter, co-locating in areas where captured $CO_2$ is already accessible locating where it's feasible for an aquaculture system to be put into place. It's with the foresight of planning but right now the key focus has been on the vaccines because that's the biggest need globally.

**iGEM Concordia 22:29**
If we wanted to produce bionutrients in space, what do current concepts of bioreactors look like?

**Scot Bryson 22:42**
Good question. I have not gone through the efforts of designing, again, microgravity bioreactors, I have not done any of that work. My short answer is I think it's going to be cylinders. I have not gone through that energy and effort. Part of the thinking has been, this is a challenge for a later time. And right now, we need capital and we need commercial projects to be able to finance the research and development that is going to undertake the efforts for that. And I also think that we should be doing some computational modeling in terms of how these plants grow. And, you know, understanding what the optimal design really is, and I think we can model that in computer models and understand gas to liquid transfer, nutrient transfer and pressure and temperatures through a bioreactor system. That would be my approach to how to answer, instead of the short statement of, “I think it should be a cylinder.”

**Scot Bryson 24:07**
The cylinder is not even the right answer always, anyways because you look at another fermentation technology company called UniBio. They’re one of the methanotrophic technology companies and their bioreactor is what's called a U Loop bioreactor, and it literally is a lot of really wide pipe essentially, that the material is flowing through the system. And that ends up being an ideal form and shape to continue to rapidly grow and have evenly distributed nutrients through the bioreactor itself. That may be a more ideal shape. I know in gravity, and again with knallgas microbes, your ideal shape and design is a large vertical tall cylinder. This is because instead of a stirred tank reactor which is a typical system, which takes significant amount of energy to be able to stir the continue stirring the tank with knallgas microbes in gravity situations, you can utilize the air bubbles to actually provide the turbulence and distribute the nutrients through the bioreactor itself. So that an air lift type of system enables a more efficient reduced energy type of design.

That doesn't work in microgravity. It’s highly dependent on the location that you're in. You also need to understand the form factor and where you're operating as a lunar base. We’re going to be dealing with tunnels, tubes, retrofitting rockets, fuel tanks, reutilizing assets that are currently available. How do you convert an oxygen fuel tank from a starship

**Scot Bryson...**
into a bioreactor? How do you convert some of those other assets and piping components that are part of those ships into a bioreactor? That's the better question that you should be asking. How do we reutilize assets that are already there and existing, that were for the purpose of, other components? And how do we repurpose those into what we're trying to do? That's the right answer to be asking in a space situation again, back to the waste stream approach of looking at a system and understanding what assets that you have available to you.

**iGEM Concordia 27:04**
Going back to these closed systems, do you have any concerns with diversity in your systems like working with a lot of these organisms at the same time?

**Scot Bryson 27:15**
Yeah, I do have a concern with that, to be honest. The rigor of actually fully developing a closed system is incredibly difficult. So, Biosphere 2, are you aware of that? Hmm? Okay, so definitely look at biosphere two. biosphere two was 150 125, over 100 million dollar project that was built in the 90s. And this was built in finance for similar purposes of developing a closed environment habitat that humans can live in. And that can sustain people for long periods of time.This is owned by Arizona State University. It is a massive greenhouse. I think they had asked 10 scientists that were part of it, and for the program and they were trying to be in there for two years.

The project ultimately failed, because of social reasons. The scientists divided into two groups. So we don't have an even group, number of people. They divided into two groups, they had a differentiating opinion in terms of what the purpose of the project was going to be and for what elements and they got into fights. And one of the scientists ended up breaking the glass to end the project because of the frustration that happened. They also didn't have enough protein. They had too much carbon dioxide in the atmosphere, and the high elevated levels of $CO_2$. And the lack of protein led to you know, people making bad decisions.

**Scot Bryson 29:12**
Anyway, all that being said, they tried to go fully closed from the beginning. And that didn't work. Because there's so many elements that we don't understand and don't know. These systems are massively complex.Our approach with what Orbital Farm projects has been to have an open system to create a waterfall type of approach and begin slowly into closing that loop.
We produce much more protein powder than our aquaculture systems actually need. We produce more fertilizer than our greenhouses need, and the net output of greenhouses watering plants. We don't really have a waste stream that we need to deal with. There are certainly some waste streams in greenhouses but, not of significant form and

**Scot Bryson...**
fashion. In that open model, that waterfall type of approach allows us to slowly develop that closed loop system. We don't have to develop it at every single project, we can build this over time. And again, with the foresight of aiming to build hundreds of these facilities, we can spread this out over time and gain learnings and understanding as we go through that process. Then additionally, pilot new technologies in each of the different phases in different locations to begin to close that further at a later point. But to get back to a space situation, the bioaccumulation of elements, that's a serious concern, where elements end up within the system. What systems are going to fail, what systems are going to off gas that then will bioaccumulate. My fears end up being elements that we're not looking for.

One of the best examples that I heard was that in the life support system on the International Space Station, don't quote me on all these details, because it's a bit foggy, but I can get the general premise out. The atmosphere in the ISS was I think 3000 ppm of $CO_2$ and the atmospheric controls, they draw in the air, they remove the carbon dioxide, $CO_2$ scrubbers onboard, and then they vent the $CO_2$ on the International Space Station, but they also extract the moisture from the air so the water was cycling onboard, ISS is fantastic. I think it's something like 98% of all water is recycled, it's a significant sum. And so much that they extract the moisture from the amount of water droplets that we breathe out. What happens when you have significant sums of $CO_2$ in water is that water actually becomes acidic. The acidity of that water started to corrode the pipes inside the piping, where they extracted the water from the moisture in the air, and it degraded the pipes so that there ended up being a burst, or leak, or contamination and this is the part where it's, don't quote me on this part, but it's a major issue, a critical issue that needed to be repaired with speed and, it wasn't emergency situation.

But the determination was that because of the excess amount of carbon dioxide and because of the acidification of the water and over time and a long period of time, that failure of piping inside the walls of the system. That was completely not foreseen. They ended up changing the pipes out into a different material that doesn't actually corrode with that, and then they reduce the amount of $CO_2$ in the atmosphere is how they solved the challenge. But that example, you know, it could have very easily leached material, leached an element into the water system and then that could bioaccumulate and if you're not watching for cadmium, I don't know, whatever that element is, you're not watching for it and you're not screening the materials that are coming in and knowing all the different properties that are part of the piping system. Every piping system, then you may not look for that, and you may not test for it, and it may appear at a later point. There’s so many unknown elements, that there are possibilities of contamination and bioaccumulation within a closed system. This is the reason why I think we were

**Scot Bryson...**
developing a system over a 20 year period. And why we need to develop these systems over long periods because we get to know where they fail. And we've got to measure in places that we're not thinking about measuring that part.Aquaculture systems also are incredibly challenging for completely closed, zero discharge systems. And currently, we don't have that right now. These are all things to think about. The way that I go about solving it is maintaining an open system. Slowly closing that over time testing and trialing it, that's my approach.

**iGEM Concordia 34:59**
You spoke of how privatization of the space industry was beneficial and also how commercial partners are beneficial to your process, that it offers you the opportunity to integrate these tech, do you see the private industry as beneficial for achieving your dreams at Orbital Farms?

**Scot Bryson 35:26**
Yes, because we have to, we're licensing their technologies. Without their involvement, I would have to build everything myself. And that would be an impossible challenge. It would take crazy amounts of money.Let me reverse this back again, to design that system that we want to operate on Mars for six years where we know it's not going to fail. We know strong enough that we're not going to bring food with us that you're willing to go to Mars without provisions that are going to last you for that period of time. For you to have that level of confidence, that system has to not only operate for six years, but you've got to be damn sure that it's gone through all the rigorous controls that it's not going to fail because you're going to die if it does. And so how do you build and design a system that's going to operate for six years, at a large enough scale to support? You can't just send four people. I mean, you technically can, but that's not going to create any sort of civilization. We want to be building for at least 100 people. That's what Musk is planning on as well.

And how do you sustain a 100 person community? That's a significant sum. It also has to operate at that scale. You can't scale up the process for the first time, and then expect that that's going to operate for six years or minimum three years to operate. In order to facilitate a design that's going to operate for that six year period, you're not going to get it right the first time. It's going to take a number of different iterations to make that happen. That timeline really is 15 to 20 years out before we're going to get to that ideal system design. If you're going to write grants for 20 years, to operate a system that can produce food for 100 people every single day, you're never going to write grants for that, there's never going to be a granting operation that's going to be able to provide the support for that. It has to be a commercial entity that develops those technologies and capabilities. Just operating that facility alone, let alone designing all the components that are part of it is again an impossibility for a single organization to do so. It's required that we have these commercial partnerships. The motivations that

**Scot Bryson...**
we have with the commercial companies, and the reason that they want to work with us, is because of the humanitarian work that we were able to do, because we're able to help commercialize their technology and help prove them, because we become a revenue stream for them. We literally will be paying them money for every product that we sell. We are designing what an Orbital Farm really is, and how we build these partnerships, that was a critical element to this even getting going. If that piece wasn't in place, I think there would be no point in doing what I'm doing.

Now, on the flip side of all of that, it's hard as hell because I'm like David Goliath and I'm talking with some of the biggest multinational companies in the world. Utilizing their technologies and, who am I, what is Orbital Farms, aside from this vision, this motivation to tackle these problems and challenges, we have to provide a key value and benefit to them spending time and money and energy with us. That's been an important piece to the puzzle.

*[…conversation edited out…]*

**Scot Bryson 47:50**
In terms of, of researchers and researching past work that's been done. The discovery of the hydrogenotrophic pathway, in 1968. The amount of work that's happened and been developed already, within NASA and within the life support systems community, is very extensive. One of the things that I would make sure to counsel you on is having teams because it's going to take teams of people to dig through and sort through and discuss and it's not easy to find all this information.

There's so much knowledge that has been built within NASA already with a lot of this work and tests and experiments that they've already done and I have not spent time looking into yeast and what they've tested and experimented with already, but it has to have been done. It definitely has been done. I do know that yeast has been flown in the ISS and that there have been some experiments. There's even an oven now up there. The ability to make cookies and bread is now potentially possible or is possible with the cookies. And certainly within breads and things. This is already happening and taking place. What I would counsel is ensuring that there's a significant amount of time that is spent like months of time spent on digging through past work.

***[End]***

*Thank you Scot!*