TECHNOCULTURE

Computers and ecosystems

Episode 3

Full transcript

Guest: Angelo Vermeulen [Angelo]
Host: Federica Bressan [Federica]

[Federica]: Welcome to a new episode of Technoculture. I'm your host, Federica Bressan, and my guest today is Angelo Vermeulen. I will ask him to introduce himself. First of all, welcome, Angelo.

[Angelo]: Hi, good morning.

[Federica]: I will ask him to introduce himself, because he does so many different things that I will also ask him to kind of put all of these things together in one profile. You know, I'm a researcher, and when I wake up in the morning normally, I do research, which is really a bunch of different things, but it's recognized as one thing. Now, it says here that you're a researcher in space systems, biologist, an artist, and community organizer, and keynote speaker, so you travel a lot, so please tell me, when you wake up in the morning, what do you do? Who are you?

[Angelo]: Well, it's not that complicated, actually. I live in a few worlds, and I build bridges between all those worlds. I'm a scientist. Originally... My original training is in biology. I'm a developmental biologist and an ecologist but over the years actually moved over to space exploration, and now I'm actually a space systems researcher and also a space biologist, so that's how my scientific career evolved. But apart from that, I'm also an artist and a design thinker. I studied... Originally, I studied photography, but I very quickly moved on to different types of art, and installation art is pretty much the medium that I'm active in most, and in my art and in my science, I work with lots of people. I'm embracing in particular methodology both in research and in artistic creation, which is co-creation and bottom-up design. So I work with large groups of multidisciplinary people to explore concepts both in science and

art. Now, the thing is, I'm not living separately in those two worlds. I'm actually blending those two worlds. So whenever I'm doing scientific research, there's always a lot of inspiration, ideas coming from culture that are really impacting the scientific research that I'm conducting, and on the other hand, when I'm making art, there is always a lot of technology and kind of scientific ideas that are seeping into the artworks, so it's really a very transdisciplinary practice.

[Federica]: With the guests on this podcast, sometimes we go down the road, we explore more the territory of the arts, sometimes more of science, and seldom we also have guests that embody both worlds together. So you just explained it a little bit, but I would like to elaborate on that a bit more. I want to ask, is it a cliché, is it true or not, and how not, that the mindset of the scientific researcher is different than that of the creative artists? Is there really like a diametrical opposition in the approach to what to do, or there is a sort of Hegelian synthesis and you are in the same mindset as you do both, you just, your end product is different?

[Angelo]: Well, the thing is, it's interesting when you engage in the discourse on art and science in the cultural field and in the artistic world. There is really a big interest in trying somehow to prove that art and science are the same. I hear that a lot. I find it very problematic because I think art and science are different, even though, of course, there is overlap. There is definitely things that are very similar. One of the things - and it's actually already... You kind of indicated one of the aspects in your question. It's funny how many people, when they talk about art, they talk about creativity, and when they talk about science, it seems not to be related to creativity, which is absolutely not true, of course. You need the same amount of creativity both in art and in science. So creativity is definitely one of those elements that makes them similar. There's always, there's also the location of experimentation and of discovery, which for a scientist is the lab and for the artist is the studio. There's a lot of correspondence there. So there are definitely quite a few elements that are very, you know, that are similar in both practices, but there are very crucial differences, and I think those crucial differences are the reason that I'm embracing both, because for me, working in such a transdisciplinary way basically gives me, offers me a bigger toolset to engage with the world, and to inquire, and to make... I'm essentially an explorer, and I always thought that just exploring the world through science would not be enough, and that's where the arts come in for me. So for me, exploration is really at the core of my entire practice. Now, to go to a bit more specific, some of the things that I think are very different is the underlying worldviews of artists and of scientists. Within science, and especially within science that is very, very practical, it's very related to very tangible, physical reality - so I'm not talking about physicists that are working on the nature of matter or cosmologists, because they tend to be a bit more philosophical - but scientists that are really engaging with cause and effect on a daily basis (I've been there; when I was a biologist, I was living like that; I was working like this), it's difficult not to start absorbing this idea that truly the world is nothing more than math, that somehow at a certain point, we will understand all causality, and everything will be turned into equations and algorithms, and

we can understand the reality, and we can reduce reality to some mathematical model. It's just this underlying dream of a lot of scientists that they're build - they're collectively working on this giant model of the world. When you're outside of science and you're outside of this daily practice of investigating things and looking for cause-and-effect relationships, it's hard to imagine how you can be so naïve. It seems to be like, of course it's... When you talk with philosophers and artists, they're like, "Of course the world is more than just mathematical equations and molecules interacting." There is a depth that maybe is beyond the mathematical scientific approach. And I must say I've experienced both positions, so I understand very well where they come from, but I think that's a beautiful difference there. And the idea of... I've always explained it like this. The underlying idea of the scientific mind is that reality is like this disc, and the scientific model is a superimposed disc that is actually getting bigger and bigger with the hope that the scientific model, the disc of the scientific model, will in the end overlap with the disc of reality. That's like this idea, you know, we're just continuously expanding our insights. The interesting thing is that from a more philosophical perspective is that as soon as you expand this inner disk of knowledge and of model building, the edges of the disc of reality are receding even further, so it's a never-ending process. It's a moving target. You never get there. I think that's really at the core of a more philosophical and artistic view of reality, and I think for me, art is very much related to the unspeakable, what is beyond discourse, what is beyond rational explanation. I mean, you can always talk about art in a kind of rational academic way, but I never think it fully covers the experience of a good strong artwork. So I think that's really a key difference. It's this worldview. The second thing that I want to elaborate upon which I also find interesting is the self-reflection. Art has evolved, of course, during the course of humanity. The art that we're embracing now or the art paradigm that we're embracing now, especially in the West, is a very particular paradigm. It's the avant-garde idea. It's a modernist idea of self-reflection, reflection on itself, on how it operates, which politics are embedded in its mediums. And I think this level of self-reflection is kind of - how to put it - it's questioning its own methodologies and then turning them inside out or offering alternatives that are sometimes even the opposite. That's a very typical artistic approach, and that's what is expected from an artist. In science, this is not... This is very different. Yes, you will question a scientific paradigm and you will investigate it and see if you can tweak it or even change it into a different paradigm, but questioning science itself is very difficult for many scientists. Once again, I think people that are more on the edge of more fundamental research, like physicists for example, they might be more open to a more philosophical approach to science, but many scientists that are doing, once again, that day-to-day, the day-to-day [grind 9:50] of dealing with reality, they find it very difficult if you start questioning the actual underlying assumptions of, for example, science - for example, the underlying politics of science and the biases that are embedded in science. They find it very difficult. It makes them very restless very often. So this element of self-reflection is... I'm not saying it's impossible in science, but it's not really part of scientific practice. In scientific practice, you, more or less, you step into a tradition of good scientific practice, while in art you're supposed to turn the existing practice upside down.

[Federica]: So you are invited on many platforms as a speaker, not only then a scientific communicator, but also as a explorer, like you said. What are some of these platforms that you've spoken from, and what is your favorite topic to talk about to audiences at large, like non-specialist audiences?

[Angelo]: I'm a professional speaker, and I'm also a very passionate speaker. It's something I've been doing for a very long time, actually basically since I was a teenager. I love to be on stage and to do storytelling. The platforms are very diverse. I talk on, for example, I'm a Senior TED Fellow, so I've been speaking at TED conferences - those are really big platforms - but also love to speak for small community organizations or grassroots organizations. And I actively keep that breadth of platforms where I'm sharing my stories. I don't want to start, you know, how to put it, getting sucked into just one specific direction of big platforms and lose touch with the smaller initiatives. As I said before, community is very crucial for me. It's part of my practice, and I really find it important to stay connected also with grassroots movements and smaller-scale platforms. Now, the topics that I talk about, there's a bit of a diversity of topics. On one hand, I do talk about specific research, for example the current research that I'm doing on interstellar exploration, new concepts for interstellar exploration, and then I talk about this particular research. Of course, I also talk about my art projects. Sometimes I just combine the different projects into one talk, but also talk from a more methodological perspective, and I've been working... I've been embracing over the past few years this methodology of co-creation and bottom-up design, and I've learned a lot of lessons. So sometimes people invite me to talk and to talk about this, and about this experience and which, what lessons learned I can share, I can share with them. And this ranges from cultural organizations that are interested in how to connect with communities, a museum or a cultural institution that wants to connect with a local community where they're situated, but also sometimes I get a question from a company, you know, who wants to change, they want to change their governance, their internal governance, and they want to change internal structure, and then I get invited to talk about bottom-up design and a more horizontal kind of collaborative practice. So it's either I talk about the actual specific projects, or I talk about those methodological approaches that I've been developing over the past two years. And another topic I got invited to talk about is how to think about the future, because that's really at the core of my practice. Like I said, I'm an explorer, but I'm really an explorer with an eye on the future. All the projects that we're doing is, it's all about somehow always related to the future. We are... I'm operating from within a collective which is called Space Ecologies Art and Design, and this multidisciplinary collective with engineers, scientists, artists, hackers, gamers - all kinds of different people - and our common thread in what we do is prototyping the future. We're all interested in the future, passionate about it. Many of us are science-fiction fans, but we're impatient. We don't want to wait.

[Federica]: Mm-hmm.

[Angelo]: And so we're embracing a hacking ethos, and we're basically hacking things and building prototypes that could be potential concepts for the future. And so this whole idea of actively engaging with the future and trying to shape the future and trying to prototype the future is also a topic that I talk about, a lot about.

[Federica]: Let's go down this rabbit hole. So it may seem banal, but what do you mean by 'future'? Is it 5, 10 years? Is it 100 or 500?

[Angelo]: It's open. There is really no... I mean, my current research on interstellar exploration is really deep future thinking. That's like research that might happen, research that might be useful for a very specific concrete application like a starship in maybe 500 years, because there is no... At this point, we don't have any possibility to build anything to go to a different star, but nevertheless it's interesting to already explore some of the underlying concepts, how to travel to a different star. So that's really deep future research. Some of our other projects are much more near-term futures, like the Biomodd project, for example, is a project, and it's an art project, an arts and technology project in which we bring together computers, recycled computers, e-waste, and living biology, and we bring them together in very imaginary and imaginative systems that actually operate in which biology and electronics are feeding off each other in different kinds of ways. And this is actually, this is... They look very futuristic in a way, because you see computers that are containing internal ecosystems that are living together with all the electronics and their sensors and robotics, so it's somehow futuristic, but it's not like... It's very near-term futuristic, let's put it this way. It's something that we're building that ties in with ideas from science fiction, how biology and technology are merging, but at the same time, these are the things that are happening right now. So that's... Like, I said we're working in a broad scale of future thinking.

[Federica]: In Biomodd, ecosystems and technology, do they just coexist or... You use the word they merge, and if so, is biohacking involved? How does that happen?

[Angelo]: Yeah, that's, it's, you know, that's... It's a bit of a conceptual discussion, of course, when you can talk about merging, or when they're just coexisting. I think in the beginning, the very first concepts of Biomodd were basically to recycle e-waste, to build functioning computer networks with the e-waste, like in a sculptural setup, and then to build living ecosystems inside of the computers that use the waste heat of the electronics to grow and develop around all the electronics. We get this kind of, indeed, a kind of coexistence of electronics and plants, which generates an interesting image, because you're not used to having sensitive, all kinds of sensitive electronics like motherboards and graphics cards and hard drives and then all kinds of plants growing around it. We even added, right from the start, we added algae,

single-celled algae, so we were cooling, water cooling, some of the processors using single-celled algae, so the algae were actually physically in touch with the hot surface of the processor. After some time, we started elaborating on the concept, and we started deepening the concept, and we started adding a level of intelligence to the whole system. We've been exploring how to use sensors and robotics within that system so the computer could not only, was not only taking care of the plants in a passive way through thermodynamics, through waste heat, but was also, could also kind of consciously start this side through the robotics, how and when to take care of plants. So then things became, started to merge, and you get a kind of hybrid world, especially since we created a virtual world running on the network of all the computers in which all this information came together and was kind of a mixed reality in which the sensors that were picking up the dynamics of the ecosystem were actually feeding in to the virtual world and changing the virtual world, and at the same time, the virtual world was physically changing the ecosystem through the robotics, and then you get this kind of entanglement between a virtual world running on the network and the ecosystem living around all the hardware. And then I think, yeah, that's more of a merged or mixed reality that you generate.

[Federica]: You said that you were first interested in photography, but then you found installation art as being like the best means to practice your art. What attracts you to installation art, as opposed to, you know, other art forms?

[Angelo]: Well, I'm still very passionate about photography. It's not like I feel I've really left it, and I'm still thinking that after all the quite complex installation works and community work that I've been doing, it would be interesting to go back to photography and do a photo project and publish a book, which will probably happen, but installation art is, I'm a systems thinker. I look at the world through the lens of systems thinking. I think that's also why I became an ecologist. Ecologists are per definition of systems thinkers. And what I'm doing now, the advanced concepts research for interstellar travel, is also from a systems perspective. I'm not focusing on one particular technology that I'm trying to refine within the world of aerospace engineering. I'm taking a step back and I'm looking at the larger picture of, "Okay, what is the challenge of going, travelling to a different star, and how could we possibly reimagine this, so from a systems level?" So, and I think the systems thinking also matches really well with installation art, because the installations that we built with our collective, SEAD, are usually quite complex, complex artworks. Biomodd is one example. We have also have other projects like Seeker in which we build prototypes of starships, but like large-scale architectural sculptural constructions that we built with the whole community, and the structure is actually the resulting, is actually the result of a conversation, of a dialogue, and of experimentation with a whole community about the future of humanity in space. And these systems also are quite relatively complex, of course, as you can imagine. First of all, because the topic is relatively complex. Building an environment that at least addresses some of the challenges of mankind and aerospace leads to quite layered, a layered structure, but at the same time, because we're

working with these communities with many different people, multicultural, multidisciplinary, multi-generational. You get input from all these different angles, and then that also results in a very layered artwork. So I think it's the... I'm really interested in systems, in complexity, and in emergence, systems that emerge from a bottom-up perspective. And in this way, I think I ended up being very active in using installation art.

[Federica]: Is the presence of living organisms in these installations a problem in their exhibition and set up, and if it needs to be there for three months, you know, these things grow, so how do you manage that?

[Angelo]: Yeah, a lot of our artworks do indeed contain living biology as part of an ecosystem that is... Like in Biomodd, an ecosystem that's actually integrated into the electronic system, or in the case of Seeker, an ecosystem that is actually kind of a life-supporting ecosystem where food is being grown. And yes, this needs maintenance, and it all... You know, like I said, the art projects that we're building are very dynamic art projects. They do contain ecology, but they're also social experiments, and they do contain technology, so all these three different levels, they're kind of unpredictable in their creation, and once they're there, yeah, they need to be maintained on these different levels. They keep on evolving during the exhibition. So either you work with the institution that is actually exhibiting the artwork and they take over maintenance or part - and this is what usually happens - part of the local community is engaged to keep taking care of the artwork and just keep on even, sometimes even keep on evolving it during the exhibition. So it's more like you have to tend to these artworks. That's basically what you have to do. So they're not collectible in a traditional way. They're much more temporary setups, temporary living experiments.

[Federica]: Is the presence of living organisms in your installations an obstacle in their exhibition, and most of all in their preservation? Is it correct that they can be easy, it's easier to document them than to preserve them as they are?

[Angelo]: Honestly, it could perfectly be preserved. You would need a good technical team to figure out, to create a manual on how to put it together again. That's definitely from a structural perspective, but that's definitely feasible. But the thing is, because of the emergent nature of the artwork, there is no plan. So the artwork really emerges out of the group dynamics and every single day, people add and remove components. So the end result is very, how to put it, there's a lot of serendipity involved in the creation of the artwork. So if you take it apart again, yeah, you need to document it very well in order to be able to reconstruct it. The biology is, these are basic things. You know, these are things like algae and specific plants that can be acquired easily, again, if you want to resurrect the artwork and you can just plant them again. I mean, there is no point in trying to preserve the original biological components. I've seen artworks, for example, by Joseph Beuys in which he used oranges, and then the museum

desperately tries to preserve the original orange, which I find completely ridiculous. I mean, that was never the point of Beuys to preserve that particular orange. It's just, if you set up the work again, you go to the supermarket, you get some oranges and you put them in there; that's what needs to be done. So sometimes I think there's a bit of, too much, a bit of a fetish perspective on living biology as part of a preservation strategy.

[Federica]: So technology and the living organisms are two main elements in your work, but I've heard you mention also that there's a social aspect to these installations. How so? What do you mean by that?

[Angelo]: So the social experiment is basically the idea that... I mean, I'm not an instructor. I'm not an educator. I'm not... I have no idea. The only thing I have is when, for example, we start a Biomodd project, is, we have a core concept which is all about bringing together recycled e-waste and living biology, but then the question is up to the group to shape that idea. And so depending on the group dynamics and on the cultural dynamics, because in every single culture we have, of course, different ideas on how art could and should look like on different ideas about the relationship between nature and technology, and those ideas and those underlying ideologies that are present in the group will shape the new iteration of the artwork. So in this way, it is always a bit of a social experiment. It's also a social experiment because we try to radically embrace this idea of bottom-up design, not working with a specific plan, not giving people detailed instructions, and allowing, giving people a lot of agency to add and even sometimes remove parts of the artwork. And that is really a very, is a big challenge from a design perspective, to create a system without central planning and just see how the group deals with that and what comes out of it. So on those two levels, it is really, so the bottom-up design perspective on one hand, and on the co-creation on the other hand, it is really always a very challenging social experiment.

[Federica]: There are ways in which you've been talking about your work that made me think that it could qualify as conceptual art, because it's so fascinating to just hear you talk about it that it already evokes emotions and thoughts and images. But say we're one of those lucky people who are there and can actually experience it in person. Are some of these installations interactive in that the audience can touch, move, take, do something with it, or just, you look at these works, you walk around them, you contemplate?

[Angelo]: Well, the thing, the way... That's my personal vision on art is, I think when people are confronted with an artwork, and it's a successful artwork, it somehow is a good, a strong piece, I mean not successful like on a financial level or anything, but when it's a good art... a strong piece, a strong artwork, and that's what we strive for every single time, the main idea is that when people are for the first time exposed to the artwork, they are immediately... You know, it speaks to them. They're immediately engaged with the artwork. Even though they

might not know and they probably will not know all the different layers that are embedded in the artworks that we create, because once again, we create complex systems. What is important for me is really that when the spectator walks in, that it immediately speaks, it immediately grasps the spectator. And I'm not talking strictly about a sort of, from a visual perspective. There should be some... People should be deeply intrigued, and should feel - and this is what I really believe - that the different layers that we've been putting in there, and also the social layer, that the fact that what you're seeing is the result of a dialogue of many people over quite some time, that it emanates this, even without literally giving any indications for this, but that somehow there is an energy emanating from the artwork that emanates this. And then, so when you already have this, this is a really good starting point, and then you can engage with the spectator in different ways. Sometimes we are hosting our artworks, and we walk up to a spectator, we engage in a conversation, and we start to disentangle the artwork in conversation with them, and then they really... The experience is even more, is deepened even more when they realize this has been done with this group of people over this amount of time, and that's the underlying idea, so I really... I think it's definitely both. I don't expect the spectator to see these artworks and to fully grasp everything in detail. On the other hand, I don't want to create artworks that are a total mystery, you don't feel anything, but after you've been reading an academic treatise, then you're like, "Okay, this is what it's about," and then you start appreciating more what's being shown. I have a little bit of issues with that as well. I mean, that's a tradition of conceptual art, but I really love to combine strategies.

[Federica]: You've been doing this for many years, so you have a lot of experience. I'd like to know if you've ever been surprised by one of your works, by the outcome, but how it went, the turn it took. You basically prepare a setup, but then because of the living organisms, this thing is meant to grow and evolve of its own accord, so... And there's an element of serendipity, like you said. So have you ever been surprised by the outcome?

[Angelo]: Yes, and yeah, of... There are a few things, I mean, I think a few examples that I could give. For example, one of the things that in the beginning of the Biomodd project we were very concerned about was this whole idea of combining wetware with electronics. That seems like a really dangerous combination. We were also concerned the electronics would kind of oxidize or there would be shorts, shorted, or any other kind of bad thing would happen within the system. But that never... Actually, it was the other way around, it was more like battling heat, battling drought, battling the fact that the electronics are constantly drying out the ecosystem. So that was actually the opposite, so it wasn't a problem with humidity at all. So when you bring worlds together and you have no idea what's going to happen, it's true, it might, you know, it might result in a very different situation. Also, an older work that I did quite some time ago was a kind of a vertical panel on which I wanted to grow algae, and then instead, instead of algae growing on there, because I tried to infect the surface of the panel with algae, it seemed that somehow the panel had been treated with some chemicals so the

algae were not growing there, but on the back of the panel, there was an incredibly beautiful ecosystem of different fungi growing and developing, which I did not anticipate and it was not the goal, and on the floor where the water was splashing, there were all kinds of al... There was a whole range of, how to put it - there were algae growing on the floor, basically. So the whole work was just completely acting differently than what I expected. So of course, when you're working with biology, this is what typically happens, yes, but I must say in Biomodd, for example, we've been developing the project for I think 11 years now, with close to 30 versions all over the world, and so we've seen quite a few different things on a biological level, and now we're ready to move on to push the boundaries again. For example, it would be interesting to start working with insects instead of just plants and algae and fish, the main organisms that we've been using now - so just expanding the kind of non-human agents that we want to incorporate in the work. And then once again, we'll be... Yeah. We have no idea what's going to happen. There's going to be... There might be very surprising outcomes.

[Federica]: How did you first transition from the study of biology to outer space?

[Angelo]: Well, first of all, I've always been interested in many different scientific fields and in in arts. I have never transitioned from one thing to another, so all these interests have always been there. I've been basically... Basically, I've been nurturing these different interests. That's what I've been doing. So it was never a transition or a move. When I was very young, I was already... I had my own little science lab, and I was observing the stars at night, and I was making photos of stars, etc., etc., but I never really thought I would - and I never consciously planned - a career in space exploration, mostly because I looked at myself first and foremost as a biologist and not so much as an engineer. And it's only later in life that the world of space exploration came knocking at my door based on projects like Biomodd in which technology and ecology are integrated in these kind of futuristic setups, and that kind of seemed interesting for a particular research group at European Space Agency called MELiSSA. And that research group, MELiSSA, is developing an ecosystem concept for future space colonization. It's basically biological life support. It's an artificial ecosystem that keeps humans alive and provides oxygen and food on a continuous basis for astronauts. And in the beginning, I was working with them as an artist that created a few art pieces inspired by their work, but very quickly I felt like I wanted to actually contribute to the world of space exploration. My original need to be a researcher came up again, and that's how I ended up in the situation where I find myself now, in which I'm actually parallel... I'm doing research, I'm doing scientific research, I'm doing engineering research, and I'm having an arts practice, but they're also bleeding into each other, so it's not like they're very separate lives. So, honestly, there has been a bit of serendipity by meeting those people from the European Space Agency and them inviting me to start working with them, but once I started engaging with the world of space exploration, things went very fast, and I very quickly found myself in the middle of different, yeah, different space-related activities.

[Federica]: Can you tell us a little bit about the ongoing research, the experiments that are currently being done to find solutions, strategies, to support life in outer space, life in all of its forms, not just humans, but also growing food, for example, in outer space?

[Angelo]: Yeah. Yeah. In terms of space, human spaceflight, because there's a very big difference between space exploration and space colonization. Colonization is a bit of a difficult word. I prefer the word 'space settlement,' which is a bit more neutral. But those are two very different things, and honestly, the whole idea of space colonies on Mars or on the moon is still very far off, even though it's in the news all the time, with people like Elon Musk talking about setting up colonies on Mars. I think he's probably the most famous example of people bringing out very specific visions on how humanity could establish itself outside of Earth, but honestly, there is... For many different reasons, there is no... It's not very realistic that any time soon we'll actually start colonizing outer space. The challenges are, of course, technical. There's still so much technical issues that need to be tackled before we can do that. Just living for extended periods of time in deep space is something that we don't know, we don't know anything about. We have lived at the, on the International Space Station. Several, many astronauts have lived there, but the International Space Station is still very close to Earth. It's still very protected, for example, by Earth's magnetosphere. Once you go into deep space, there is much less protection and you're basically, are exposed to much more radiation, for example. So we really have very little understanding of what happens to humans when you send them in deep space for extended periods of time. And also, just landing on the surface of Mars, creating habitats on the surface of Mars, there's a lot of concepts there, but nothing has been built or tested properly, so all of that still needs to be developed, so that's a lot of work, a lot of money, a lot of technical challenges. But the thing is, what the differen... I mean, I could imagine a mission to Mars in the next few decades just visiting as scientists, but colonizing requires a whole different mindset, of course. With colonizing, you also need to take into account an economic model, and at this point, there is really no viable economic model that could sustain a colony on Mars, for example. That's just not going to happen. Also, we haven't properly colonized Earth. I mean, there are so many harsh spaces on earth that we're not living, and those harsh spaces are easy in comparison to a place like the Moon or Mars. So I think we're still a long way off. But we're moving ahead. I think the next step is probably going to be a new, a smaller space station close to the moon. That seems to be the next step, which means that we'll get more understanding of what happens to the human body and human minds when we're living more in deeper space more removed from Earth. So that's what can happen on a short term. Long-term, I'm actually more interested myself in the next step, which is to, for humanity to move beyond the solar system, which is interstellar travel, travel... The nearest stars are between four and six light-years, which if you would travel 10% of the speed of light, would take you 40 to 60 years to get there. We don't have the adequate propulsion systems yet to realize this, but nevertheless, it's going to be part

of the next step of human exploration. There is already one particular interstellar mission that is currently under development. It's not a manned mission. It's actually using very miniature probes. It's called Breakthrough Starshot, and that's actually the first interstellar mission that is under development. It's still a long way off - once again, they still have a lot of technical challenges to solve - but they're very specifically focusing on reaching the nearest stars, which is the Alpha Centauri system. It's basically a combination of three different stars, and they want to send a mission there to make photos and send those photos back to Earth. And what I'm interested in, what I'm personally interested in, is sending humans to those different stars. It's called, we're building concepts for generation starships. These are spaceships in which multiple generations of people are living and surviving, so basically the starship becomes a world of its own. It's a very interesting challenge because a starship is not relying on Earth any longer. Like the International Space Station, for example, it constantly gets resupplies from Earth. That's how people survive there; that's how the whole system survives. But when you're talking about interstellar travel and a generation starship, the ship has to be self-sustaining, and that's where it becomes very interesting. That's where working on this concept also becomes very meaningful for Earth, because the lessons learned when you're developing these kind of systems, these kind of very sustainable self-sustaining systems, those lessons learned can also be applied on Earth, of course, to maximize sustainability, to maximize resilience. And very specifically, what we're working on is spaceships that actually are dynamic, spaceships that are, evolve over time. One of the crucial challenges of interstellar travel is that you cannot predict what's going to happen. You have to design a system for uncertain futures, which is a bit of a paradox for an engineer. How can you design a system for a future you cannot possibly predict? Nobody knows what's going to happen during interstellar journey because it's way too long, way too far, so how do you design a system for that? For example, if you compare it to the Apollo program where the Americans were sending people to the moon, they would go gradually closer and closer, they would get closer and closer to the moon, each time coming back to Earth, optimizing the system with the lessons learned and the risks that they observed, and then gradually after multiple missions they would actually touch down on the surface of the moon. But with interstellar travel, this is not something you can do. You can't just go a little bit interstellar and then come all the way back to Earth and fix things. So you need to disconnect from Earth, and you need to build a system that can handle unexpected situations. And that's where my biology background comes back, and we're actually building concepts for spaceships that grow and evolve during the journey, and the technologies we are using to enable this are asteroid mining and 3D printing. Basically, we're using an asteroid as a resource. A small proto-starship is connected to the asteroid, and then during the journey, the asteroid is being hollowed out, it's being mined, and the materials are being used to 3D print an emergent spaceship structure at the back of the asteroid. And then through reconfiguration of the model or architecture, the structure can actually adapt itself for upcoming challenges.

[Federica]: Wow. I certainly wanted to hear something that would surprise me during this

interview, but this is mind-blowing.

[Angelo]: There is actually a few more layers to it, but this is the kind of the basic idea. Maybe the second component that I need to add to complete the picture of what we're doing here at Delft University of Technology is that in the computer models that we're developing - because we're developing computer models to test these ideas - we're not just focusing on a autonomous adaptive architecture that is using asteroid mining and 3D printing. We're also including an ecosystem, a self. . . a closed-loop ecosystem. Because there is no point in having a spaceship that arrives at the destination fully structurally intact with everything inside dead. That would just not be a successful mission. So we're also including in our computer model a regenerative ecosystem, a closed-loop ecosystem that is constantly cycling all the different molecules that are necessary to keep people alive, so it's an ecosystem that combines people, plants, and bacteria in a constant material dialogue with each other, they're exchanging all kinds of molecules with each other, and actually the concept we're using for that regenerative ecosystem, for that closed-loop ecosystem, is an existing concept from ESA. It's the MELiSSA concept that I talked about before. So we're actually using existing technology from the European Space Agency and embedding that in our starship concepts. And so this is really what we try to do. I mean, we are using ideas from science fiction to build these new concepts, but at the same time we're building an engineering foundation using chemical engineering, ecosystem engineering, and, like I said, ideas that are actually, have already been developed by actual space agencies.

[Federica]: So this sounds like sci-fi, but at present it's science.

[Angelo]: Well, the thing is, it's conceptual design. We're not building an actual spacecraft. We're not building actual hardware, even though in the future we might start building robotic small prototypes that might definitely be a future part of our research, but right now it is conceptual design, it is conceptual research. And the type of engineering is called morphogenetic engineering, and morphogenetic engineering is really a crossbreed between biology and engineering. It's basically an engineering approach in which instead of using a blueprint, a top-down blueprint, to design or to build a system, you're basically designing individual agents, individual components, that have specific attributes and specific behaviors, and by putting them together, they build the emergent system. It's a bit like termites, how termites build a termite mound. A termite mound is a very sophisticated structure, but there is no central planning when these termite mounds are built. It's basically through the interactions of the different termites that the structure gradually emerges, and this is a really interesting paradigm for engineering. I'm not saying that all engineering could be done like this, but it's definitely a really very powerful approach to building systems that are well adapted, adapted to a specific situation, and that can retain some adaptability.

[Federica]: So humans are not ready yet to just go to space and settle down, but what about other forms of life? I mean, stuff that grows. For example, some of our food - vegetables, for example.

[Angelo]: Growing food near Earth and then bringing it back to Earth would be very, would not be very cost-effective. I think there are much better ways to either change crops so they can handle the changing climates on Earth better, or to develop environments, controlled environments on Earth, in which you can grow your crops in a very controlled way. I think that would be way more cost-effective. Now, the idea of space farming is definitely a big idea that is gaining more and more momentum because for long-term space missions, either exploration or actual colonization, you will need a system in which at least part of your food is locally grown in space. You just can't ship all the different food items that you need, because it would be just way too much. It would just a huge bulky situation, and your spaceship would have to be way too big. And so there is a lot of... There's more and more research that is being done in this field, and also because by developing systems in which we can grow food in a very controlled way in quite difficult circumstances in space might actually teach us lessons on how to improve growing food on Earth. So there's really a dialogue between those two worlds, between agriculture on Earth and space farming.

[Federica]: There's something that emerged quite clearly from your answers, I think, and I like that we got a chance to clarify it, because the debate about space exploration sometimes is controversial in the media. What emerged, I think, is that the only motivation to keep exploring, to keep learning, is definitely not just that we are exploiting our planet to the point that one day we'll just need another - because this won't be available - but no, there's so much more we can learn and we can do that already benefits us without the aim of leaving Earth.

[Angelo]: Yes. One of the typical critiques that I'm hearing a lot is, "Shouldn't we fix Earth before we go into space?" Of course we should fix Earth. Nobody in the world of space exploration will disagree with not fixing Earth. The thing is, why would you see space exploration as being opposed to this? You know, some people think there's too much funding going to space exploration. There's a few answers to this. First of all, space exploration is already deeply embedded in the way we do care of Earth. If you would pull out space exploration, we would have a hard time taking care of Earth, really, because, for example, the whole study of climate change, weather patterns, all these things are done because of space exploration. Our whole communication networks. I mean, everything is connected to space exploration nowadays. Technology is strongly connected to space exploration. So it's really at the heart right now of the way we already try to take care of Earth and study Earth. So it's already part of it. Of course, some people are more, when they're critiquing space exploration, they're more thinking about human space exploration like, "Maybe we should just stick to satellites, you know, and forget about all the expensive human exploration things, because that doesn't really

seem to contribute." Once again, I disagree with that. I think it's very clear, and a famous example is, of course, Earthrise is this famous photo that was shot where you can see Earth rising above the surface of the moon. It's actually a bit of a... It was originally a vertical photo, and then they tilted it so it looked horizontal. That's an interesting detail. But that Earthrise photo gave birth to the whole green movement, or that's, you know, it's definitely part of why the green movement started, because suddenly mankind viewed Earth as a very fragile sphere in a vast space. So, and I mean, this is well known and well documented, the impact of that image, but that's just one of the examples. Also, you hear it from every single astronaut who comes back to earth that observing Earth from out there, it just gives you a whole different perspective. It's called the overview effect, but just seeing that a very thin atmosphere as a very thin veil around the surface of the Earth makes you really realize how fragile the whole thing is. So I think human spaceflight brings a lot to cultural sensitivity of taking care of Earth, but it's also through specific technologies that are being developed like, like I said, this whole area that is now emerging, a kind of combination between improving agriculture on Earth and at the same time developing agriculture in space, and the connections between those two are also very tangible advantages of having space exploration. And last but not least, moving away from Earth, exploring deep space, I think, generates this, once again, this cultural sensitivity of how precious Earth is. So I think on a more philosophical level, it's definitely crucial to keep exploring, but also these are all different types of arguments that that make a case for the importance of space exploration in terms of taking care of Earth, but also, even if you would disagree with all of that, and you would love, you would want to stop, it's going to be impossible to stop the momentum now. There is a huge momentum in space exploration, especially since there is now an economic drive, there is a sort of new space economy that has emerged and is starting to emerge, which is a combination of different potential new economic fields. Of course, just simply launching satellites is a huge market, but it has been a huge market for quite some time, but it's now opened up to many more companies also because satellites have gone smaller and smaller, it's basically the, humanity can participate much more in experimenting and building satellites. But it's way more than just satellites. So one of the fields that is developing is space tourism. It's something that will emerge, and there is still a lot of development needed, and it's still a little unclear in which direction it will go, but it's going to be part of the future, and then asteroid mining is another field that is under investigation because there's a lot of money to be made in asteroid mining. So there are different types of sectors, potential economic sectors, and what you can see is that humanity has moved into deep, into outer space, as a new economic zone. And you can see that throughout history of humanity that humanity has been seeking out new areas for economic development and economic growth all the time. And very often, it happens in the context of colonization with all its horrible consequences, of course, and wars and all that, but you can really see how the layer around Earth will become a very active new economic field driving global economy, and there is no way you're going to stop it. And my contention is, my position is, if it's, or if it's happening and if the momentum is so strong, you might as well join it and help to shape it to avoid

some of the problems that we did in the past instead of just trying to ignore it and wish it away.

[Federica]: Thank you so much for this explanation. Indeed, how power will be managed and shared is a crucial point. Let me ask you, do you see space tourism happen in our lifespan?

[Angelo]: Yes, of course. Yes. It's, they're well underway for launching the first space tourists. There's companies like, of course, Virgin Galactic, Blue Origin. They're well ahead in launching the first space tourists. It might still take a couple of years, but it's going to happen. This is very basic space exploration, or is a very basic space experience. It's basically launching a space vehicle to a high altitude so you can have a view on the curvature of the Earth. Some people think you will see Earth as a globe, which is not the case at all. You're still way too close to Earth. Even in a space station, you do not see Earth as a globe. You just see the surface of Earth, as a curved surface and then because the spacecraft will then fall in free fall back to Earth, you experience a few minutes of weightlessness. And that's pretty much the experience, so it's a very basic approach to space tourism, but one of the next steps could be that they will develop space hotels, and that's something where Bigelow, for example, an American entrepreneur is working on. He developed a concept of inflatable space modules. There is one inflatable space module right now from Bigelow attached to the International Space Station. It's the first time they're using it, and the idea would be to launch an entire inflatable space station that actually operates as a space hotel, and then tourists could be shuttled to the space hotel and experience space for an extended period of time instead of just a few minutes of weightlessness.

[Federica]: Well, thank you so much for talking to me. In the launch of this podcast show, I said I'm going to be talking to the top players who work at the forefront of art and science, and you're right up there. Thank you so much for your time.

[Angelo]: You're welcome.

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