Q&A Session Transcript

After the speakers' presentations, the audience had the opportunity to ask questions, moderated by Dr. Nicola De Blasio. The revised transcript is included below.

De Blasio: Dr. Bextine, can you please describe how the process of going from plastic waste to food works in a little more detail?

Bextine: The way we approach DARPA projects is, I would say that we give guardrails. We have a concept that we want to execute on, and we realize that we have a lot of talented, smart, ingenious people out there that have good ideas. We go in with an idea of how we would like to do it. In my case, I really wanted something that would use synthetic biology through the entire process. That way, you have a way to really conserve energy and put yourself in a good position to be successful. But then as proposals come in, we make evaluations and determine different ways. And like I said at the end, we want to mitigate some of those risks, so you want to take multiple shots on goal, not to use too many cliches here.

What we've been really looking at is different approaches for breakdown. There are catalytic approaches that we have some of our researchers doing things that are activated by very low energy targeted heat approaches. We actually had an interesting outcome on one of them. The program's been up and running for about a year, and I have a colleague, Eric Van Gieson, who's running a program called PPB. He's rethinking personal protective equipment in sort of a new biology focused way, and as part of that they are producing some new materials that looking at it are going to produce new problems for us because these materials are going to be even more difficult to break down. And he gave a talk, and had somebody from the WHO that brought up the fact that during COVID we've been producing 42 million tons more plastic trash just from medical waste, and I think that was on a weekly basis. Whatever it was, it's way too much. And turned it to us and said, "Hey, can you start to break down your stuff?" And it turns out all the plastics we're working with are the medical waste plastics.

And so using that sort of physics based approach, I think we have a low energy good outcome approach that breaks some of those materials down. It also happens to decontaminate, which is a nice piece to it. But we have a lot of different ways. We've also been looking at microbes. So because now we're at a point where we've had dumps in place with plastic there for about 50 to 70 years, we've started to see evolution come up with approaches for breaking these materials down. We have opportunities to harvest microbes that break down the materials. We can also take the enzymes out of those microbes and utilize them. We have insects that have eaten some of these plastic materials, developed gut microbiomes. So we have some sort of microbiome consortium type concepts. So there's different ways to handle the problem.

On the buildup, as long as we can get down to sort of a center of the wheel sort of molecule, we can take that a lot of different directions for use. So we can start to use cellular outcomes from microbes or even higher organisms like fungi or insects potentially and make 3D printing material that Alessio can put into what he does.

De Blasio: You mentioned that you go down to change the plastics' eight to fourteen carbon structure. You then feed these to the enzymes, so you don't use them directly to create food, correct?

Bextine: No. There's a middle man in that which is the microbes. And we have individual microbes. We can do synthetic biology to make them more efficient in their use. We could also use directed evolution. So basically growing them over and over on a new source so that they learn to utilize it more efficiently. But essentially what we're doing is sort of tailoring a carbon source to a microbe or a microbial community, and then the utilization and harvesting of that carbon and the energy contained within those carbon bonds can be utilized for upcycling into other carbonic structures like other carbohydrates, fats, or protein structures if we have nitrogen available and things like that. Just using microbes to ultimately produce what you need.

De Blasio: And then Alessio, could you add to that and explain how and if one could actually 3D print an apple that you could actually eat?

Lorusso: Well, Nicola, not yet. No, I'm joking. Our 3D printers today work, of course, with our super polymers and composite materials, which of course comes from oil. This is not a problem today, but it will become a problem tomorrow if we don't act to let our technology be prepared to be sustainable, because of course 3D printing is more sustainable compared to massive production because we don't need to produce millions of parts and we don't need to store those parts for years in warehouses. 3D printing uses just the resources it needs to create the products, first of all.

And talking about metals, and especially CLC machine metal, of course we don't need to create waste of materials because we use just the material needed for the part. So 3D printing is more sustainable compared to mass production, manufacturing matters like CNC machining, injection molding and the other stuff. But the technology is becoming more and more adopted in the world. So a moment will arrive where 3D printing will become part of the problem if we don't create a supply chain behind the recycling of the printed parts and if we don't create today the right conditions for this technology to be adopted to become a real sustainable manufacture for the long-term.

So our goal today is to create a supply chain method and a business model which allows our customers to send back the parts at the end of the life cycle and to send back all the scraps, little scrap but still scrap, like super structures, and all other things involved in the 3D printing process. Because it's not true that 3D printing is a zero-waste process of manufacturing. That's not true. Even 3D printing creates some waste. So, we need to care about that.

Our model behind the recycling allows our customers to be sure that all the scraps and all the 3D printed parts at the end of the life cycle will be recycled into new materials. We want to incentivize them to care about this by offering the new recycled material to them, the circular economy material, at a fraction of the cost of the initial one. Of course, we all know that after recycling polymers lose some mechanical properties, but there are still an enormous amount of applications where thermal properties, chemical resistant properties are required, and you don't need that level of mechanical performance, even within the same customers. The goal is to democratize more and more the usage of high temperature and high performance technopolymers and incentivize the circular economy program we put in place. While we do this, we need to invest today to create the biopolymers and the biocomposites in two, three, four years from now. It's not easy. It's not easy, because super polymers and composite materials like carbon fibers, PEEK materials, et cetera are the result of years, decades of inventions around the world. So today we all need to be concentrated in developing the future generation of biopolymers and biocomposite polymers that come from nature, because I firmly believe that nature has all the answers. We just need people to replicate what nature did in the last thousands of years in a laboratory into industrial scale. This will require time and will require huge investment, but if we don't act today, we'll still be victims of oil for the next 50 years. We cannot do that. We need to invest today.

De Blasio: How quick are these processes? Blake, how quickly can you break the plastic down and then feed it to the enzyme? And then we have a question for both of you about how you could combine both programs in the value chain, where you go in maybe not for a war but just for the fettuccine Alfredo and you start to break down all the plastic and you 3D print everything you need.

Bextine: A big problem that we have in utilizing biology for most approaches ends up being the time that it takes, because biology when compared to chemical approaches like pyrolysis is going to be much slower. And then the other problem is always consistency and replication. Biotic organisms can be finicky, constrained by physics. So where you have temperature issues, things like that, humidity, pH, are are pieces of that that we have to get consider.

But the speed, largely on the front end of the system, of breaking down the plastic where we've used the catalytic based approaches with a small amount of energy, we're able to almost instantly break down the materials in a matter of minutes. And then on the biological part of the process it's much slower but we're looking at approaches to potentially increase that time either through genetic manipulation or the directed evolution approach. It's early stage research so we have ways to go, but what we're trying to do is sort of lower that bar of entry so that some of these other approaches can be de-risked a bit.

On the back end, looking at the growth of the microbes, one touch point that we have in thinking about the microbial system that we use for making biological cement that ultimately leads to a cement alternative, that usually grows on the order of four hours for large amounts of material. So we do have some ways that we can accelerate the production. And the goal in the program... And most of the time in a DARPA program when you put the broad agency announcement out, if people don't think you're a little crazy, then you're probably pitching at the wrong level of what you want to do. But we are really looking at having a continuous system that can in the smaller footprint device support 10 individuals over like 10 days, and so something that continually puts that in. Now, a lot of that's dependent on the amount of material that you have to put in on the front end.

In the larger format we're looking at something that could sustain a large group of people in the order of a hundred for a 30-day period of continual production. Those are hard metrics to hit, honestly. We're looking good, I think we'll get there, but we've got to set the bar high so that we can really push the researchers to do something incredible.

De Blasio: Alessio, how fast can you 3D print?

Lorusso: Well, I don't want to give numbers because without the world context they are not useful, but what I can say is that we can print in hours what today is produced after three, four weeks. This is because today, to produce some parts by sensor machine or by injection molding you need to put in place the entire process. You need to create the molds, you need to do the first, the second, the third, the fourth interaction, and at the end of those interactions probably you discover that the way you designed the part is not the best and you need to start again. So we do today in hours what, until yesterday, has been done in weeks.

But what we can do more and what we do more every day is to have hundreds of printers today in the world that can print simultaneously hundreds of parts. So in my opinion, 3D printing will never be as fast as traditional manufacturing because the concept behind 3D printing was different from the beginning. So if we pursue the goal of realizing the 3D printing technology capable of printing or producing and they have the same productivity of an injection molding, that's not the right direction in my opinion. 3D printing must ensure us the same level of performance, reputability, and consistency of traditional manufacturing methods, and in my opinion, the business model needs to ensure us the scalability of the production. In our business model we have hundreds of microfactories in the world that we can control, and with one click 50 machines start to produce the same parts in different locations in the world. In my opinion, the business model is the real key to scale the productivity of the technology. The technology must be reliable, must be consistent, must create reputable result and performing parts while the business model should create the right scalability.

De Blasio: Could each of you say a few words about the cost of the processes that you're suggesting?

Bextine: The ReSource project is still in its super early stage so there is currently no cost other than the research funding that we're providing.

Lorusso: It's still expensive in my opinion. And we really need to be careful about this. 3D printing is not cheaper. Probably it's not more expensive than traditional manufacturing methods, if of course we compare apples with apples. So if we talk about the same parts numbers, it's not more expensive but it's still expensive. The way to create a more affordable technology and to democratize the technology more and more, in my opinion, is the sustainability. I firmly believe that sustainability is the key to democratize the technology, because in our business model, the more parts are printed by our 3D printers by our customers, the more recycling we can do and the more materials we can offer to our customers at cheaper price.

This, in my opinion, is the key to democratizing the technology, because all base polymers are expensive, because there are expensive processes to create them. PEEK material is one of the most expensive polymers in the world, but it's one of the best performing polymers in the world. So, we need to find a balance. We need to democratize the use of these super polymers while exercising care about the recycling of those super polymers and create a mechanism where we can offer these materials as circular materials to the same customers, and to other customers, to new customers in order to democratize more and more the technology.

And at the same time we need to develop high performance biopolymers which replicate the same mechanical performance, thermal and chemical performance, maybe one day of these all base polymers. It's not easy. It's not easy, of course. But in my opinion, today, we start to have the right tools and there is a huge commitment today even from customers in adopting these super polymers. They are more open mind today than ever before. So this is the perfect moment to invest massive resources in this because I firmly believe that biopolymers and biocomposite will be the future, will be way more cheaper than all base polymers.

Fallon: Nicola, could you also speak to maybe the relative costs of mechanical versus chemical recycling to the best of your knowledge?

De Blasio: Well, in a way it's an easy answer. The fact that chemical recycling is not being done today shows that it's definitely more expensive, but it also relates to the fact that if you compare virgin plastic to recycled plastic, sometimes the virgin plastic is still cheaper, especially when all prices are low. But I think to the point that Blake and Alessio made, it's important to keep in mind that we do this cost analyses without considering a lot of the externalities that we don't factor into fossil fuel use. So it's like comparing apple with pears sometimes.

Bextine: I was also going to mention... One of the questions that came up was about breaking some of these molecules down. Currently pyrolysis breaks us down into the single carbon or ethanol space and so what you end up with is a large energetic cost there. And if you sort of use the logic that we're approaching ReSource with, you have to develop those molecules back up two carbons at a time, and every time you reassemble, you utilize energy. So in the pyrolysis example, you're using a lot of energy and then building something up is going to utilize more energy. And so our approach was really to break things down into, I guess what in the business world would be like the minimal viable product that we could get out of that breakdown process and try to conserve as much energy as possible.

I think to Nicola's point, some of these alternative approaches haven't scaled yet because we don't know sort of where the bounds are. And so with projects like ReSource, we're looking into that and looking at the risks that come from it and seeing where they go. When I think about some of these technologies and how they're going to scale, DARPA, the agency that I work for, has always been very thoughtful about how do you produce something, that's one thing, how do we make the impossible possible? And then on the other side of it, at what point do you start getting it into the market so that it can be useful.

Concrete is a good example where traditional methods of concrete are known throughout the world. We've been doing it for a long time. I think the Romans made some pretty good concrete back a few generations ago and it still stands. So it's a well-known, well-tried, very true process. So when you come in with something new, and in this case, I guess that we're on the right side of the carbon equation, people want to be on that but they don't want to spend 50 times, a 100 times the cost to do something on a large project.

So what we have to do is try to push towards scale, where the scale of our biological approaches or our alternative approaches, like Alessio was talking about, can actually meet the market demand while also being cost effective. And then, I think, if you're within the same order of magnitude, then people would want to use the more bio-friendly approach. But for all of these types of things, we have to get there, we have to get it to scale, and that takes a lot of work and a lot of time. So whatever we can do to push that will make the world a whole lot better place.

De Blasio: Alessio, what is the optimal batch size for 3D printing per unit cost?

Lorusso: Very, very, very nice question, and the answer is, it depends. It can be 100, can be 1,000, can be 10,000. The real question is, when do you need these parts? Do you need them Monday morning at 8:00 AM or you do you need them on a monthly basis. The real thing is how many parts do I need in this specific moment, because you can have the need to have probably 10,000 parts per year but you don't need the 10,000 parts Monday morning at 8:00 AM, you need 1,000 parts per month.

So the real question is, how can I produce these parts in a smarter way? How can I produce my parts on monthly basis instead of producing all these parts in just one shot with traditional manufacturing methods and wait one year to use my parts? This is the real question. The timing is the most important thing, because if you need parts and you need these parts split in a year, the most sensible thing could be probably, even if the number seems to be high, produce this part with 3D printing so you can produce just in time on monthly basis avoiding warehousing costs, production costs set up costs and all the things involved.

De Blasio: Blake, have you tried the food coming out of the ReSource process?

Bextine: Technically, on a presentation to the public, no, because it hasn't been through FDA approval, so no. What we do is we break that plastic material down into those smaller carbons. That's sort of a slurry of DCAs that are the middle part of that process. And then what we ultimately do is grow that into what looks like a granola bar that is made of cellular material. But this is just one approach.

We also have been able to take the cellular material at the end and we can actually separate out parts of that so we can pull oils out specifically. So we've been looking at lubrication needs, machines, and things like that as one of our endpoints. We even have some pretty cool ways that we can get the microbes to excrete that fatty acid material and we can collect that. And if we use molecular biology, we can tailor that to specific chain lengths in fatty acids so you get different capabilities there. We haven't used any of it in practice officially. It smells good, I can tell you that.

If you think about yogurt production that's made by a microbe, that's sort of the end product that we can hope for. I don't know how old everybody there is but it's also how beer is made, so we might be able to make some additional products out of the system.