Michael Lye

Industrial Designer, and Senior critic and NASA Coordinator at RISD

Lee Anderson (LA) *I want to start with a background question, but frame it in the question, why spacesuits?*

Michael Lye (ML) It actually started as a kid. My parents were both scientists and my dad worked for a company called Martin Marietta, which later merged with Lockheed and he was involved with NASA as part of his job. When I first went to college, I was at Johns Hopkins to study physics and decided that wasn't for me. I dropped out and then went to work for about 15 years. After that point, I decided to go back to school in design.

I took a roundabout way of even getting into design. And then most of the work I've done at RISD and as a professional has been looking at universal design issues and design for the human. That started out by doing a lot of accessible design and, eventually, a possibility opened up to take over what the ID (Industrial Design) department at RISD was doing with NASA.

From there, a I learned more about spacesuits through a happenstance encounter and then started to try to design one. So it's a long story, but really came from the shared background that I have of the love of sciences, as well as design.

Design is often thought of as on the art side of things and science and engineering on a completely different side, but it's really a continuum and I fall somewhere in the middle there. I do more of one at some times and more of the other head other times.

LA *How did human centered design and universal design become a central part of that practice?*

ML I really started for two reasons. Do you know The Aeron chair design? It's a very famous ergonomic chair. I listened to Bill Stumpf, one of the designers of the chair, speak once about accessible design and universal design. He said, basically everybody who does this kind of work usually has a story where someone they know had an issue. In his case, one of his relatives had some issues that made him very sensitive and aware of universal design. The same thing is true of the whole line of OXO products. The whole company was

Michael Lye in Mars Suit 1

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founded based on the fact that Sam Farber's wife had trouble with a potato peeler.

In my case, it was the fact that my mother had rheumatoid arthritis, for most of my life. It really had a big impact on what she was able to do. And as a kid, it was always really frustrating for me to see her struggling with things because they weren't designed very well. At the time I didn't recognize what that was or *why* it was; but as I progressed through my career into design, that became a big factor.

I think most people who design things want to make the world better in some way. In my case, it was that recognition that it's really hard for a lot of different people in a lot of different ways, just to exist in the world. And that's what I really wanted to focus on.

Now, let me backup a little bit. As an undergrad at RISD I worked with Mark Harrison in the Industrial Design department. He was one of the people who, even though he didn't refer to it that way, who really started either Human Centered Design or universal design, depending on how you want to look at it. He was one of my professors and I got involved with him on a project called the Universal Kitchen Project. It was based on these ideas of making the kitchen much more accessible for the people who are really using the kitchen, as opposed to glossy Shelter Magazines.

After I graduated from RISD, I was hired to work on that project for several years afterwards. That really sealed my direction in terms of universal design and accessible design because I learned so much through that project. I realized how essential universal design was, if I didn't already know it.

And then to take that a little bit further into the NASA work. That NASA connection is interesting to me because it's an incredibly extreme environment, obviously, being in space. And what I learned through all these different experiences up till then was that extreme environments are really defined by the people who are in them, what they're trying to do in them and how hard it is for them to do it. So for a ski jumper going down, jumping off the end of a ramp and flying however many meters seems perfectly normal. To me, that seems insane and it seems incredibly extreme and I wouldn't be able to function at all in that circumstance. But the same thing is true for some of the people we looked at on the Universal Kitchen Project.

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We were looking at, for example, 80 to 90 year old women who wanted to do things in a kitchen but were really limited by the built environment that existed there.

My correlation there is that we don't think of astronauts as being disabled, but they're disabled by the environment that they're in, in the same way that maybe an 80 year old woman is disabled by her kitchen environment. She might not have the strength in her hands to pick things up or the dexterity to do things that she might once have had. But the same thing is true of an astronaut. He can't do the things in space during a spacewalk that he could do, or she could do on Earth. By just moving a few hundred miles, suddenly, they're disabled by their environment.

I started to see these parallels, and realizing that these sorts of extreme environments are useful for trying to understand what people really need. So if I looked at you in your kitchen, it might be hard to see the problems because you've accommodated those problems and adapted to them in a way that not everybody else could. For students trying to learn about design and learn how to do this sort of thing, it's sometimes easier to find answers, or find questions at least, by looking at somebody who's having trouble.

LA *The MS1 suit went through different phases of testing, getting more and more complex. Can you speak to that process, how you decided where to start and what to test first, and then getting to the point where you're in Iceland, and you have someone scaling a glacier to see how the suit would work?*

ML Just one funny aside about that: NASA, a few years ago, put out a series of touristy themed posters about exploring other planets. One of them has an astronaut rappelling down the face of the cliff in his suit on Mars. So when we had this opportunity to test in Iceland I said, "we've got to do that." It wasn't necessarily the most valuable test, but it was actually a lot of fun. And it did highlight some useful things.

The MS1 was originally intended to work in Hawaii at the HI-SEAS project. We didn't quite get it done in time for mission V So it was going for HI-SEAS mission VI. I took the suit to Hawaii for HI-SEAS VI to train the astronauts on how to use it.

After I returned from Hawaii, the mission was about four days in and they were having problems with their electrical equipment. One of the astronauts got zapped pretty badly and they had to end the mission.

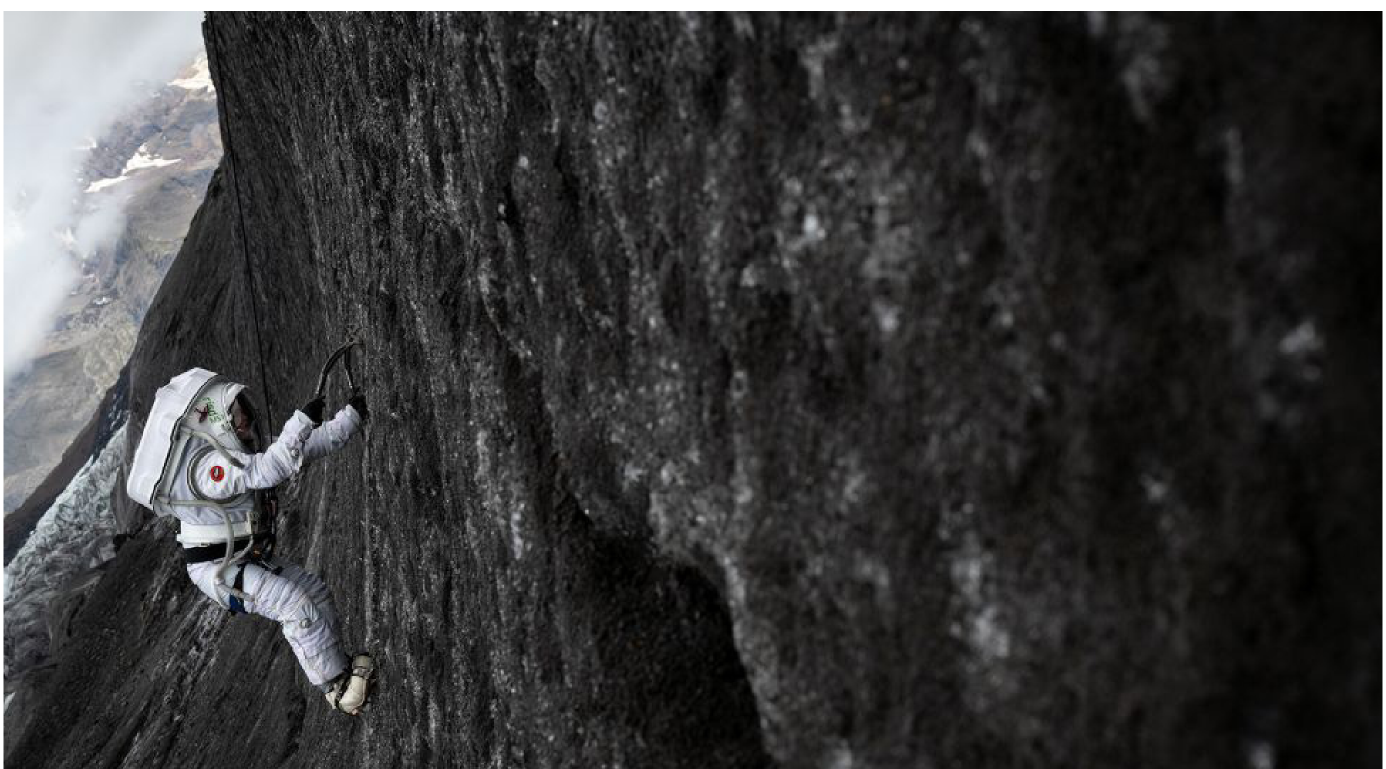
So it didn't get as much testing there as I wanted because they only wore it a few times. After that we made a few changes to it, and I started looking for a new opportunity to do some more realistic testing. And that's where Iceland came in.

Most of what I'm trying to do right now for the testing is, essentially, make sure stuff works the way that we hoped it would work, and make sure it actually fits as widely as we wanted it to fit, and as many different people as we wanted it to fit. We're doing lots of fit testing, getting people in and out, and then seeing what's wearing out, what's breaking, what would have to be dealt with in terms of durability or lifespan for a suit like that. So those are the two big missions that we're doing that testing.

We were in Iceland for about a week, and between eight people over the week we had it being worn every day. Asking, how does it feel? How does it work? Does it break down? Do zippers bust? And that part of the test worked really well.

We did find one problem with the suit through this testing that needs to be addressed in that it was designed for Hawaii, so high temperatures, and we were in Iceland where it was extremely cold. So I didn't need any of the cooling equipment that we had built into the suit. The suit's bulky and you can wear clothes or under layers under it, so cold wasn't an issue except for the fact that when we were working with NASA on the design of the visor area. We were able to figure out through them

"I want to make it so that if you go out and do a field study for geology in Iceland wearing our spacesuit— If you did this in Iceland, you could do it on Mars."



Helga Kristín climbs up the face of a glacier wearing the MS1 Mars prototype spacesuit. Credit: © Dave Hodge/Unexplored Media exactly how much air flow we wanted to have through the visor area. If you don't have enough, you build up CO_2 and you just start re-breathing your exhaled breath.

So we knew, as a margin of error, or safety margin, we needed two to three times as much airflow as might technically be needed. And in Iceland, we realized that in really cold weather that might actually be a problem—that we need to get it more specific and more exact—because people's noses were getting really cold. And it wasn't that cold and Iceland, even though it was quite a dramatic place, it was only between zero and 20° Fahrenheit. So, if it were ever to be used in really cold conditions, frostbite on your nose would be a big issue.

One of the plans I'd had all along was that I would start to integrate a lot more biometric sensors into the suit, including measuring that CO_2, and that got pushed up to a higher priority as a result of the Iceland mission. That's one of the things I'll be working on this coming year.

LA *Is it the shape of the visor or the curvature of the visor or the circumference of that joint? What types of design considerations come into play when you start to address those things?*

ML It's all of those things really. Specifically in case of the airflow around the face and nose and mouth. It's the shape of the visor, the volume that exists there, and also includes the area where the air exhaust back into the suit and how you know how the airflow actually moves.

It becomes an interesting design problem in that, if you're in the suit,

Credit: NASA/KSC

that visor becomes a really important part of how you see the world both literally and figuratively. So, the shape of it, how big it is, and how the air moves through it becomes really important.

If you try to wear it without the airflow going on it's really uncomfortable within about five to 10 minutes because you can just feel that you're re-breathing your own exhaled air. Trying to make it so that, with that visor on, people are comfortable, required good airflow for the CO_2. But I think it also requires a certain amount of airflow just to make people feel like they're not going to suffocate inside. And it's those sorts of overlaps, between the really technical CO_2 concentrations, and, the "we don't want people to get claustrophobic or feeling sick as a result of just wearing this." Those things were an interesting challenge to balance there.

"We need to do longer duration testing to the point where people start to become frustrated by the limitations of the suit rather than just be excited about wearing it."

LA *Having sensors built in like this again bridges a lot of the healthcare, the universal design, having a broad range of wearability for different types of people. What are some of the other things that you might try to measure?*

ML One of the things that's very difficult about wearing a real spacesuit and would have big impacts in terms of analog missions on Earth, trying to do testing of various things, would be how difficult it is to move. Spacesuits pressurize, and as you flex your arms or your fingers or move your legs, it requires force just to do those things that you don't normally feel.

Doing a pressurized suit here on earth is difficult because it's complicated, and there are health risks associated with it. If you suddenly depressurize it, and it's pressurized at the level that an astronaut would have it relative to the outside, they could get decompression sickness. And so if you were in a NASA spacesuit, or something similar to it, on Earth when they do testing, they'll have a crew of five people. And that doesn't work for this kind of environment, for these analog missions.

Nobody, other than one example that I know of, has really tried to deal with how you simulate those joint forces, and how you design something that is going to make that feel like a spacesuit.

Dava Newman at MIT wrote a paper a few years back where she worked with a company to try and simulate those joint forces from a very high tech perspective. Computers and motion sensors, force sensors were used to simulate and apply feedback to require the correct amount of force.

From my perspective, the problem with that was it really avoided one of the big difficult issues, which is that for these analog missions on Earth, they don't have billions of dollars of budget to spend on stuff like this. And they can't have a crew there supporting it. So what she was suggesting would probably work perfectly, but it would be too expensive to roll out in any sort of large scale where you could put six people in HI-SEAS in suits like these.

So, even at the beginning of the project, we started thinking about this although we didn't address it yet. But how do you simulate a pressurized suit where it requires force to bend your elbow without pressurizing it? That's one of the design challenges where we know it can be done if we had a few hundred thousand dollars per suit. But can we do it for a couple thousand, or five thousand, in addition to what we're already spending on the suit, and make it really quite realistic.

I want to make it so that if you go out and do a field study for geology in Iceland wearing our spacesuit—If you did this in Iceland, you could do it on Mars. And right now, we don't have that. We had Helga [Kristín] in Iceland chipping rocks with a hammer. But that would be very different in a real space because she can't freely swing in the same way.

If people want to start testing those ideas so that we can explore this way on Mars, we need equipment that will mimic that. And to my knowledge, nothing like that really exists at this point. And that's where I'm hoping to take this.

LA *You also have the benefit of a human wearing the suit to then describe that experience. Things like the fatigue that you would feel with that stress on your muscles could then help figure out how long an outdoor activity or task could last before someone really needed to come back in and rest. That seems like very valuable types of data.*

ML That speaks to the kind of sensors that we would be incorporating. I don't have a full suite of sensors yet that I'm planning on but we have heart rate, respiration and blood oxygen; a standard set of sensors to judge how people are doing. So that we can say, “Okay, you've had enough, you need to go back inside now before you have a heart attack,” or “you're overheating,” or “do you need to adjust this or that?” And that's ultimately what NASA has on real suits. They can actively monitor what's going on with the astronauts. And if they get a reading from something in a spacewalk, they can respond to it. And there's nothing like that right now in the MS1 suit. And that's where I want to push it.

LA *In addition to NASA, we also have a lot of private, non-government companies and organizations getting involved in what is becoming a real economy for space. What opportunities do you see there?*

ML There are actually a lot of opportunities there. I've worked mostly with NASA, but some of the people I worked with in Iceland were connected with the ESA. And so Benjamin Pothier for one was somebody who had done many of these simulated missions in the past, so he was a good person to be on that trip and test the suit. So there's certainly a lot of possibility of collaboration with the European Space Agency, and now potentially the Iceland space agency, even though it's not a governmental organization, it is a company there.

All the private space companies, right now, they've certainly got their hands full getting people into space and doing everything else that they want to do. But SpaceX flying two NASA astronauts in SpaceX spacesuits up to the ISS, they had to do a lot of design work to make those things happen.

I think, even outside of the sphere of private spaceflight, these kinds of suits, and the research I'm doing with this suit also has applications in other areas, including things like hazmat suits, or firefighters suits. It's not a direct connection, but it's just a step or two away from, “okay, now you're in a hazardous environment, and it's full of COVID-19 patients. What do you wear?” And how can we make this so that it works better? So there are ways that it could flow into these other areas.

LA *With the eight people that you had in the suit in Iceland, were you also able to get data somehow from their experiences and talking to them about how it felt, in terms of the psychological experience and also the physical experience that they had?*

ML We were debriefing them when they got out as well as tracking what they were saying while they were wearing the suit. Also looking at how hard or easy it was to don the suit or doff the suit at the end of it and what sort of problems they ran into there.

One of the problems with that experience in Iceland, although it was really helpful, is that it wasn't very long. The MS1 suit is pretty good at putting people in a frame of mind like they're wearing a spacesuit. Put somebody in it who's not an astronaut, for example, and they are automatically excited. It feels to them like they're in space.

Some wore the suit for a couple of hours and were so excited to wear

NASA/Jet Propulsion Laboratory-Caltech, Creative Strategy: Dan Goods, David Delgado the suit that they didn't want to tell me anything was wrong with it. And it's like, "No, no, no, I want to hear these problems."

Even in Iceland, they were so excited about the experience that they were not aware yet of the real problems that they would encounter with something like that. So we need to do longer duration testing to the point where people start to become frustrated by the limitations of the suit rather than just be excited about wearing it.

We tracked as much of that as we could to really get an understanding of where people were having problems. The verbal feedback we got from them, in some cases, was way too positive for us. But it was still helpful because even just observing the donning procedures we refined those a little bit, got them a little bit easier to do, identified some weak points in how the donning worked, and the design of the suit as a result.

We were able to put it on a really wide range of people, in terms of body types. And that was helpful because it might show the range of sizes that we can fit comfortably, and anybody with a bigger waist than that, or bigger hips than that may well be a problem. Would I change the suit design to accommodate that? Maybe. At some point, obviously, there's going to be an upper limit for everything. So where is that limit? That hasn't been determined yet.

LA *Are there pieces of the suit that are easy to replace, so something that might get a lot of use but if you're on the moon or on the space station, you could 3D print the new part pretty quickly?*

ML Two answers: on both the MS1 suit and on real spacesuits. Yes, they're somewhat modular. In NASA suits currently you have the three sizes of the hard upper torso and then to that you can attach sleeves, and the different lower torso. You mix and match and that's how they accommodate sizing now.

The MS1 is that idea taken to an extreme in that the arms can be replaced, but in the arm you can replace three segments of it. So the lower arm, elbow and the upper arm are all separate and can be replaced.

For the moon, I think the problem there is that these things are so complicated, and they have such high levels of quality and so many requirements to meet that really, at least in the near future, we'll have to have a stock of replacement parts. And when we're done with those, or we start to run out of things, we'll send up more to the astronauts there. I don't think they'll be making their own anytime soon. Not for the moon. For Mars that might start to change a little bit. But even there, until people start living on Mars for multiple years, really long durations, I think the suits will last and they'll have enough spare parts to just swap things.

But at some point, we're going to have to start making stuff there. And 3D printing or something analogous to that might actually be good. I've been looking at companies like Shima Seiki, making 3D computerized knitting machines. Sending something like that, and fiber, to Mars actually seems fairly doable. So that you could make new outer layers for something. If your outer layer was getting damaged, you might essentially have a space suit with a sort of protective coverall over it. And when the protective coverall is worn out, then you replace that. And you could knit those or use something like that on Mars. The size of the machine isn't so big. And if it's all completely programmed, it's theoretically not too hard to make it work.

LA *Especially when you put it on that timeline, because there's time to develop these things and do the research. And that's a really cool use case that I hadn't thought about, particularly the potential damage to the suits that that would solve for.*

ML It's a stretch, I'll admit, but that's kind of where Iceland comes in, and climbing up the ice face. What do we expect astronauts to do on Mars? And right now NASA would say, "No, they're not going to do that. We won't let them do that." But if they're on Mars, and they're six or nine months away from rescue, they may have to do that under some circumstance. So being aware of—ok, it's not the same thing, but—how did the MS1 suit perform doing that? And where does it break? Where are the difficult points? What sort of problems do you run into? Could start to be a useful tool to learn about requirements for our suits in the future.

LINKS

Michael Lye RISD