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Living with a physical disability isn't easy anywhere in the world, but if you live in a country like the United States, there's certain appurtenances available to you that do make life easier. So if you're in a building, you can take an elevator. If you're crossing the street, you have sidewalk cutouts. And if you have to travel some distance farther than you can do under your own power, there's accessible vehicles, and if you can't afford one of those, there's accessible public transportation. But in the developing world, things are quite different. There's 40 million people who need a wheelchair but don't have one, and the majority of these people live in rural areas, where the only connections to community, to employment, to education, are by traveling long distances on rough terrain often under their own power. And the devices usually available to these people are not made for that context, break down quickly, and are hard to repair. I started looking at wheelchairs in developing countries in 2005, when I spent the summer assessing the state of technology in Tanzania, and I talked to wheelchair users, wheelchair manufacturers, disability groups, and what stood out to me is that there wasn't a device available that was designed for rural areas, that could go fast and efficiently on many types of terrain. So being a mechanical engineer, being at MIT and having lots of resources available to me, I thought I'd try to do something about it. Now when you're talking about trying to travel long distances on rough terrain, I immediately thought of a mountain bike, and a mountain bike's good at doing this because it has a gear train, and you can shift to a low gear if you have to climb a hill or go through mud or sand and you get a lot of torque but a low speed. And if you want to go faster, say on pavement, you can shift to a high gear, and you get less torque, but higher speeds. So the logical evolution here is to just make a wheelchair with mountain bike components, which many people have done. But these are two products available in the U.S. that would be difficult to transfer into developing countries because they're much, much too expensive. And the context I'm talking about is where you need to have a product that is less than 200 dollars. And this ideal product would also be able to go about five kilometers a day so you could get to your job, get to school, and do it on many, many different types of terrain. But when you get home or want to go indoors at your work, it's got to be small enough and maneuverable enough to use inside. And furthermore, if you want it to last a long time out in rural areas, it has to be repairable using the local tools, materials and knowledge in those contexts. So the real crux of the problem here is, how do you make a system that's a simple device but gives you a large mechanical advantage? How do you make a mountain bike for your arms that doesn't have the mountain bike cost and complexity? So as is the case with simple solutions, oftentimes the answer is right in front of your face, and for us it was levers. We use levers all the time, in tools, doorknobs, bicycle parts. And that moment of inspiration, that key invention moment, was when I was sitting in front of my design notebook and I started thinking about somebody grabbing a lever, and if they grab near the end of the lever, they can get an effectively long lever and produce a lot of torque as they push back and forth, and effectively get a low gear. And as they slide their hand down the lever, they can push with a smaller effective lever length, but push through a bigger angle every stroke, which makes a faster rotational speed, and gives you an effective high gear. So what's exciting about this system is that it's really, really mechanically simple, and you could make it using technology that's been around for hundreds of years. So seeing this in practice, this is the Leveraged Freedom Chair that, after a few years of development, we're now going into production with, and this is a full-time wheelchair user -- he's paralyzed -- in Guatemala, and you see he's able to traverse pretty rough terrain. Again, the key innovation of this technology is that when he wants to go fast, he just grabs the levers near the pivots and goes through a big angle every stroke, and as the going gets tougher, he just slides his hands up the levers, creates more torque, and kind of bench-presses his way out of trouble through the rough terrain. Now the big, important point here is that the person is the complex machine in this system. It's the person that's sliding his hands up and down the levers, so the mechanism itself can be very simple and composed of bicycle parts you can get anywhere in the world. Because those bicycle parts are so ubiquitously available, they're super-cheap. They're made by the gazillions in China and India, and we can source them anywhere in the world, build the chair anywhere, and most importantly repair it, even out in a village with a local bicycle mechanic who has local tools, knowledge and parts available. Now, when you want to use the LFC indoors, all you have to do is pull the levers out of the drivetrain, stow them in the frame, and it converts into a normal wheelchair that you can use just like any other normal wheelchair, and we sized it like a normal wheelchair, so it's narrow enough to fit through a standard doorway, it's low enough to fit under a table, and it's small and maneuverable enough to fit in a bathroom and this is important so the user can get up close to a toilet, and be able to transfer off just like he could in a normal wheelchair. Now, there's three important points that I want to stress that I think really hit home in this project. The first is that this product works well because we were effectively able to combine rigorous engineering science and analysis with user-centered design focused on the social and usage and economic factors important to wheelchair users in the developing countries. So I'm an academic at MIT, and I'm a mechanical engineer, so I can do things like look at the type of terrain you want to travel on, and figure out how much resistance it should impose, look at the parts we have available and mix and match them to figure out what sort of gear trains we can use, and then look at the power and force you can get out of your upper body to analyze how fast you should be able to go in this chair as you put your arms up and down the levers. So as a wet-behind-the-ears student, excited, our team made a prototype, brought that prototype to Tanzania, Kenya and Vietnam in 2008, and found it was terrible because we didn't get enough input from users. So because we tested it with wheelchair users, with wheelchair manufacturers, we got that feedback from them, not just articulating their problems, but articulating their solutions, and worked together to go back to the drawing board and make a new design, which we brought back to East Africa in '09 that worked a lot better than a normal wheelchair on rough terrain, but it still didn't work well indoors because it was too big, it was heavy, it was hard to move around, so again with that user feedback, we went back to the drawing board, came up with a better design, 20 pounds lighter, as narrow as a regular wheelchair, tested that in a field trial in Guatemala, and that advanced the product to the point where we have now that it's going into production. Now also being engineering scientists, we were able to quantify the performance benefits of the Leveraged Freedom Chair, so here are some shots of our trial in Guatemala where we tested the LFC on village terrain, and tested people's biomechanical outputs, their oxygen consumption, how fast they go, how much power they're putting out, both in their regular wheelchairs and using the LFC, and we found that the LFC is about 80 percent faster going on these terrains than a normal wheelchair. It's also about 40 percent more efficient than a regular wheelchair, and because of the mechanical advantage you get from the levers, you can produce 50 percent higher torque and really muscle your way through the really, really rough terrain. Now the second lesson that we learned in this is that the constraints on this design really push the innovation, because we had to hit such a low price point, because we had to make a device that could travel on many, many types of terrain but still be usable indoors, and be simple enough to repair, we ended up with a fundamentally new product, a new product that is an innovation in a space that really hasn't changed in a hundred years. And these are all merits that are not just good in the developing world. Why not in countries like the U.S. too? So we teamed up with Continuum, a local product design firm here in Boston to make the high-end version, the developed world version, that we'll probably sell primarily in the U.S. and Europe, but to higher-income buyers. And the final point I want to make is that I think this project worked well because we engaged all the stakeholders that buy into this project and are important to consider in bringing the technology from inception of an idea through innovation, validation, commercialization and dissemination, and that cycle has to start and end with end users. These are the people that define the requirements of the technology, and these are the people that have to give the thumbs-up at the end, and say, "Yeah, it actually works. It meets our needs." So people like me in the academic space, we can do things like innovate and analyze and test, create data and make bench-level prototypes, but how do you get that bench-level prototype to commercialization? So we need gap-fillers like Continuum that can work on commercializing, and we started a whole NGO to bring our chair to market -- Global Research Innovation Technology -- and then we also teamed up with a big manufacturer in India, Pinnacle Industries, that's tooled up now to make 500 chairs a month and will make the first batch of 200 next month, which will be delivered in India. And then finally, to get this out to the people in scale, we teamed up with the largest disability organization in the world, Jaipur Foot. Now what's powerful about this model is when you bring together all these stakeholders that represent each link in the chain from inception of an idea all the way to implementation in the field, that's where the magic happens. That's where you can take a guy like me, an academic, but analyze and test and create a new technology and quantitatively determine how much better the performance is. You can connect with stakeholders like the manufacturers and talk with them face-to-face and leverage their local knowledge of manufacturing practices and their clients and combine that knowledge with our engineering knowledge to create something greater than either of us could have done alone. And then you can also engage the end user in the design process, and not just ask him what he needs, but ask him how he thinks it can be achieved. And this picture was taken in India in our last field trial, where we had a 90-percent adoption rate where people switched to using our Leveraged Freedom Chair over their normal wheelchair, and this picture specifically is of Ashok, and Ashok had a spinal injury when he fell out of a tree, and he had been working at a tailor, but once he was injured he wasn't able to transport himself from his house over a kilometer to his shop in his normal wheelchair. The road was too rough. But the day after he got an LFC, he hopped in it, rode that kilometer, opened up his shop and soon after landed a contract to make school uniforms and started making money, started providing for his family again. Ashok: You also encouraged me to work. I rested for a day at home. The next day I went to my shop. Now everything is back to normal. Amos Winter: And thank you very much for having me today. (Applause)