Bingecast: Thomas Furness on Virtual Reality

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Austin Egbert:

Greetings. I'm Austin Egbert, Director of Mind Matters News. You're listening to another Bingecast where multiple episodes are combined into a single program. This week, we talk with the grandfather of virtual reality, Dr. Thomas Furness about the origins of virtual reality and the many technologies and innovations that arose from its development. Enjoy.

Announcer:

Welcome to Mind Matters News, where artificial and natural intelligence meet head on. Here's your host, Robert J. Marks.

Robert J. Marks:

GPS and the internet were both founded by the United States Military in their think tanks. The military also had a major role in the development of virtual reality. We are fortunate to have with us today the man that pioneered virtual reality during his military service to the United States. Our guest, Dr. Thomas Furness, has been dubbed the grandfather of virtual reality. I first met Dr. Furness at the University of Washington, where with our mutual friend, Dr. Tom Caudell, who was then at Boeing, we put together the first technically serious conference on virtual reality. This was a long time ago, back in 1993. Dr. Furness, of course, was the general chair, but that was over 35 years ago. The conference got great reviews and was standing room only. It really was the launching pad for serious interests outside of science fiction Comic-Con sort of type gatherings for interest in virtual reality and other human interface technology.

Robert J. Marks:

Lots has happened since then and Dr. Furness has been right there in the development. Dr. Thomas Furness is professor at the University of Washington in Seattle, where I used to hang my hat. He is a professor in the Department of Industrial and Systems Engineering and the founder of the Human Interface Technology Lab at the University of Washington. He has sister labs, HIT labs (Human Interface Technology Labs) at the University of Canterbury and the University of Tasmania. His technology has started 27 companies. Two are currently traded on NASDAQ and are worth like $12 billion. We're going to ask him if some of that stuck to him. Hope so. I think very prestigiously, he recently received the IEEE Virtual Reality Career Award for his lifetime contributions to virtual reality and augmented reality. If you don't know, IEEE, it's the largest professional society in the world. It's the Institute of Electrical and Electronic Engineers and it has over gosh, 400,000 members. Dr. Furness is also a fellow of the IEEE. Okay. I'm out of breath, Tom. Welcome. It's good to talk to you.

Thomas Furness:

Oh, Bob, it's so good to hear your voice again after all these years. We've both been on some amazing journeys and I'm just happy that we can get together again after our conference together in 1993.

Robert J. Marks:

It was a long time ago. Hey, let's go back to the beginning. This is way before we met. You were with the Air Force. You were first a commissioned officer with the Air Force and there you had a command from somebody to develop virtual reality in what sense? Walk us through the history of that.

Thomas Furness:

You bet. Well, it's interesting the journey that I've taken. I graduated from Duke University in electrical engineering in 1966. The day of my graduation, I was commissioned as a Second Lieutenant in the Air Force and assigned to Wright-Patterson Air Force base in Ohio. I didn't know what to expect. I knew that I had to spend four years doing the military. This is the Vietnam War period. I felt if I have to go to war, it'd be best to go in the Air Force rather than any of the other services. When I did show up to begin my duty assignment at Wright-Patterson, I was assigned to basically do whatever I wanted to do. This was an amazing program. They call it the LEAP Program, which is the Lieutenant's Education Application Program, which meant that I could go work anywhere I wanted to at Wright-Patterson Air Force Base.

Robert J. Marks:

Such a deal. Wow.

Thomas Furness:

What a deal. Yeah, I mean, this was like the hog heaven for an engineer. There was all of these laboratories. This is where they developed the advanced aircraft, where they did flight testing and all of that. Of course, what I had wanted to do , before joining the Air Force was I wanted to be an astronaut because I wanted to go into space, I wanted to go to the moon, all those kinds of things, but it turns out my eyes kept me out of doing that in the Air Force Academy. I ended up at Wright-Patterson, but then this thing happened. What I decided to do with advice from the personnel office is to pick maybe three jobs I'd work in for three months or four months at a time. Then at the end, pick a job that I wanted to do for the longer term. I picked those jobs, one of which was in flight test, which was really fun because I was flying in a fighter. I was flying in the Phantoms, F4s.

Robert J. Marks:

You were a pilot then?

Thomas Furness:

I was a flight test engineer.

Robert J. Marks:

I see, okay.

Thomas Furness:

I was sitting in a back seat. I had to suit up. I was sitting in an ejection seat, and parachutes and G suits, and all this kind of stuff, just like the pilots, but my job was actually running the test instrumentation while the pilot was flying the airplane. Half the time the pilot said, "You take it." I was flying the airplane while he was eating bananas or something like that. We were boring holes through the sky. We were going near the mock and beyond the mock, and testing this equipment, flying at low altitude, flying at high altitude, going straight up, going straight down. It was really fun.

Robert J. Marks:

I got to ask you, Tom, does anything special happen when you go faster than the speed of sound?

Thomas Furness:

Not really. When you're on the inside, there may be a little bit of buffeting that you feel, but other than that, it's no big deal when you're on the inside. You don't really notice it too much.

Robert J. Marks:

I see. Okay.

Thomas Furness:

What happened? In the process of doing this, I found out that to spend those few hours in the air, you had to spend a lot of time on the ground in preparation, as well as sitting on your hands a lot while the aircraft was being prepared and things like that. I decided, I would really rather be working on building these interfaces, and these cockpits and things like that. Yeah, I'll fly too, that's fun, but still I'm an engineer. I want to build stuff. I decided to go back to one of the jobs I had during this first year period, which was basically developing advanced cockpits. Again, this is during the Vietnam war period. We had some really tough problems. We were trying to decide how we could fly at night without being seen and find the enemy on the ground using sensors. We had low-light level television, forward-looking infrared sensors that let us see at night. There were just a whole bunch of problems in terms of also air-to-air combat and things like that. It sort of boils down to, I guess, into three sets of problems.

Thomas Furness:

One was... And these were all the ones that I was dealing with running the lab that they set me up to do. They actually said, "Build a lab that works on this stuff." I did. Here's a brand new Second Lieutenant as an undergraduate. I started putting together these ways to develop better interfaces for cockpits. One of the problems we were trying to solve is actually aiming things.

Thomas Furness:

As it turns out, the way that these aircraft were built, in order to aim the weapon systems of the aircraft or to aim sensors and things like that, you had to aim the whole airplane. You used these head-up displays to do that, but it meant moving this amazing mass, this high energy mass around to aim doing that. It was difficult to do. When in fact, you could actually see what you wanted to do. You could actually see the targets, but in order to get those into the machine, you had to physically fly the machine to aim it. I decided, "Well, why isn't just looking at it good enough? Because we could probably measure where you're looking." That's what I started working on: the idea of why don't we track the pilot's helmet position, and what we'd do is project a infinity collimated reticle-

Robert J. Marks:

Okay. Okay. You have to back up a second. An infinite something, something. What is that?

Thomas Furness:

Right. Well, what this is, it's like a gunsight pipper, but it appears in the distance. It's not like it's in front of you, it's out in the distance and that's what we call infinity collimation.

Robert J. Marks:

I see. Yes.

Thomas Furness:

That means the light rays, optically, are fixed so they appear to be coming a long way away. What we call optical infinity, which is beyond the 30 feet or 50 feet. That's when the light rays are so far away they appear to be parallel. We had this little mirror system located on the front of the helmet that you'd look through and you'd see this little pipper, what we called a pipper, or gunsight, projected out in space. All you'd do is move it around with your head and put it over the target, or the designate something that you were interested in.

Thomas Furness:

Then what we would do is, aligned with that pipper and the line of sight of the helmet, we had two photodiodes on each side of the helmet. What we'd do is interrogate those photodiodes, they're infrared sensors, with this fanning light that would sweep through the cockpit. Every time the photodiode picked up a signal, we would take the timing of that signal, the timing of the sweeping of the fan, and we would basically triangulate on those four photodiodes on the helmet. Then we would draw vector through those and resolve that vector into azimuth and elevation angles relative to the aircraft. Wherever the line of sight of that pipper was, then the aircraft knew that line of sight. Then we'd use that to aim sensors, infrared trackers, or missiles. We could use it to designate something on the ground to our navigation system and determine the coordinates of that. We could also aim imaging sensors, low-light level television and forward-looking infrared, things like that.

Thomas Furness:

We were able to solve the tracking problem. It was the necessity. Vision comes from necessity. The mother of invention is necessity. It was trying to solve a problem of how do you aim the aircraft that we started doing this head tracking stuff. Then it was clear that, okay, so you've done that, but then you have this problem of how in the world do you communicate the images from the sensor? Let's say an imaging sensor, that's looking into darkness. How do you display that to the pilot, when in fact you had no space in the cockpit to do that? We were trying to figure out how would you cut a hole in this cockpit big enough to make a display that was big enough that you could actually represent those pixels to the pilot so they could see the information? This was very expensive and difficult to do because cockpits, fighter cockpits especially, the most expensive real estate on the earth per square inch.

Robert J. Marks:

Wow.

Thomas Furness:

Because if you start moving things around, it costs a fortune to do that. There just wasn't enough room. Already, we had 300 switches, 75 displays, 11 switches on the control stick, and 9 switches on the throttle in this cockpit, and you're trying to manage all of that. I'll get to that a little bit later. We said, "Well, why don't we, instead of trying to create a real image display where you're actually looking at the face of a cathode ray tube or some kind of display device, why don't we make it a virtual image?" A virtual image is something that you see in space that doesn't really exist there.

Thomas Furness:

For example, the simplest example of this is really on the mirror in your bathroom. You're standing in front of your mirror in the bathroom, you see yourself, but that's not really you. You just appear to be there. You're not really there. That is a virtual image of you. If we could use some mirrors and some what we call beam combiners, we could actually take a really small picture, like from a miniature cathode ray tube. It may be the size of a quarter. We could draw a picture on that, then we can magnify and collimate it, meaning make it appear in the distance and to project it into the eye so you get a huge screen, maybe a 30-inch screen that doesn't take up any cockpit space.

Robert J. Marks:

Well, the first thing that comes to my mind is that's going to block your views of other things.

Thomas Furness:

Well, you see through it. What you do is you see the outside world through this combiner, so that you can see the virtual world, the virtual scene superimposed on top of the real thing, just like we're doing with head-up displays.

Robert J. Marks:

I see. I always think of driving at night and I put something on my dashboard and it reflects in my windshield and it looks like it's just floating there. That's the sort of thing you see?

Thomas Furness:

It is, and you see this all the time. We see these kinds of things, especially at night. Reflections of our dashboard into our windows and things like that. The beauty of this is that it really didn't have to take up any space in the cockpit, so there wasn't a major overhauling of the cockpit instruments and things like that. This was something, it was just attached to the helmet. It had the additional advantage, is it moved around. You had this big picture projected to you that moved wherever you moved your head, of course. Now, the exciting thing happened when we found that we could actually see those pixels that came from the infrared sensors and the low-level television sensors.

Thomas Furness:

We can actually see them now, but then we decided, well, wait a minute now. If we combine this head tracking thing with this head helmet-mounted display thing, now we had basically an aperture, a big screen that we can move around and we always knew where it was. What that meant is that we could take our head position and move those sensors around outside the cockpit, and then display a picture in that same angle. It was just like cutting a hole in the whole airplane and being able to see at night, sort of like having a picture window, being able to see at night. This became, really, the first virtual reality system where we could basically take the place of seeing through the cockpit.

Thomas Furness:

Now, after that, we said, "Well, wait a minute. Why can't we put all the instruments up there? Not only that, we could stabilize them in space." In other words, we can have things that moved with the head, but things that seemed to stay stabilized with the cockpit, therefore we could take the whole cockpit and project that as a virtual image in addition to what we were getting from our sensors. This became evolved over years. I was working on this continuously from 1966. In the process of getting there, we were building better and better head tracking systems, better and better displays. We were using

miniature cathode ray tubes to begin with. Nice thing about cathode Ray tubes is electrons are really small. You can scan a lot of these babies on a faceplate at high illuminance.

Robert J. Marks:

I see.

Thomas Furness:

The only problem is that you have to have an accelerating potential in that, so you have 15 kilovolts sitting on the side of your head in order to get that image. When liquid crystal displays came along and OLEDs and things like that, that changed everything, but we were still using miniature cathode ray tubes at the beginning. We continued to develop the displays, the tracking systems and the computers that would actually generate these cockpit instruments. Finally, I convinced the Air Force to give me enough money to build a so-called VCASS system.

Robert J. Marks:

Say again, a VCASS.

Thomas Furness:

VCASS. It's called VCASS, Visually Coupled Airborne System Simulator. Because what I wanted to do is simulate this idea of a virtual cockpit, the whole cockpit being a three-dimensional virtual image, on the ground before we took it into the air to test it. The VCASS we started building it in 1977, and the whole idea is to create a panoramic display. We had an instantaneous field of view of 120 degrees by 80 degrees. It was stereographic. We had a 16 bit tracking system, a electromagnetic tracking system to measure where that was. We had a speech input. We had eye tracking and even were working on tactile displays.

Thomas Furness:

We switched this on in 1981. We had, I think it was eight VAX computers to run this thing and two Evers and Sutherland picture systems, one to draw the left eye and one to draw the right eye. This is the simulator on the ground. We would generate the outside world. We'd generate other adversaries in the outside world, as well as our virtual cockpit. This was all vector graphic type stuff at the time, which meant there were lines. There wasn't a continuous picture, filled in raster picture, but it worked.

Thomas Furness:

We were working with this and found some amazing things about the power of virtual reality. This launched another project, that was what we called a super cockpit. The super cockpit, I proposed this as part of an exercise we did at the Pentagon called Air Force Forecast Two. This is one of the two projects that got funded out of that. This was to build basically a cockpit the pilot wears. We started working on this in the mid 80s, based upon what I was doing in the earlier work. It was to do all the things I've mentioned before, but also have tactile displays and to have artificial intelligence built into it. You'd have R2D2 in the cockpit to help you with things. They were organizing and storing information. You had a circumambience of information with a panoramic scene and you could see through it in the daytime and at night, it sort of took the place of the outside world.

Robert J. Marks:

Let me ask you a couple of clarifying things. You say tactile display. Usually I associate that with feeling and things of that sort. What sort of tactile display did you use?

Thomas Furness:

Okay, well of course now that we have this virtual image, how do you interact with the virtual image? Now you could look at it. You could look at various symbols and give a verbal command, say "Select." You'd look at a switch and just say "Select", but we also wanted to have a different way of interacting. That was to be able to do this with your hands. We figure out a way to track the hands, the hand position and finger position. Then as you would reach into a particular volume space in the cockpit, a switched panel would window in. It would appear in that location. Then the whole idea is to reach out and touch a switch to activate it, but you need to have feedback. One of the feedbacks was really a sound. You'd hear that switch clicking with binaural sound.

Thomas Furness:

By this time, we're using three-dimensional sound, binaural sound. We're using individual ear prints of the pilot so that you're basically mapping the sounds so it's true 3D sound and not just stereophonic sound. It's 3D sound, so you hear things in 360 degrees around you. You'd hear that switch click in that direction and then in the gloves, you would have tactors that actually would stimulate the fingers. You'd feel a little pressure in your finger when you touch that display, even though it's not really there, but it appears to be there. When you get this tactile feedback, you'd know that you'd activated that switch. You got the sound that it clicked and things like that. You take your hand away, the switch panel disappears because it's just getting in the way otherwise.

Robert J. Marks:

Understood.

Thomas Furness:

This was the notion of this super cockpit and the whole idea was we're going to develop this and test it to be an airborne system. We were using a simulator to engineer it, but it was eventually going to be a real cockpit in the airplane.

Robert J. Marks:

This was this actually a cockpit that was worn by the pilot, you said?

Thomas Furness:

Basically. Yeah. I mean, you're in a real cockpit, but you plug into this and now all what you see... You have standby instruments in the cockpit. What you see is this virtual projection in 3D and surrounds you. We'd take information from the outside, we'll reject it in there in terms of where you're located, the navigation information, where the friendly aircraft are, where the enemy aircraft are, where the ground surface to air missile batteries are. All of this, you'd see in this grand gestalt, this picture that surrounds you.

Robert J. Marks:

Now, I've seen flight simulations, Tom, where from the outside, it actually tumbles as you do things. Are you there yet, or is that coming?

Thomas Furness:

Tumbles meaning physically, it's moving?

Robert J. Marks:

Yes. You're in this little ball and this ball kind of tips and does different things.

Thomas Furness:

Yeah. That's the large amplitude, LAMARs there to fly dynamics lab at Wright-Patterson Air Force Base. That's one of them certainly, but yes, we were actually testing some of these things in real aircraft so it was happening. Let me tell you a little story that goes along with this. Here we were developing this kind of concept, the super cockpit. We're using our Darth Vader simulator. This so-called VCASS. We decided now's the time for us to bring in the test pilots. These are the Air Force finest pilots from Edwards Air Force base and other places. We wanted them to take a look at it and see what they thought. They knew that it was going to be something pretty far out that they'd never seen before, but they didn't realize how far out this was going to be. They came into my lab and over to the cockpit simulator. They saw this huge helmet hanging above the cockpit. This thing weighed about 10 pounds at the time, but it was just the simulator of these things. It had all kinds of bells and whistles built in.

Robert J. Marks:

This was the equivalent of today's virtual reality headset?

Thomas Furness:

Yes, it was. It gave us the wide field of view. It had these miniature cathode ray tubes tubes built in, and all the tracking stuff and things like that. We had this negator spring assembly that would actually support the weight of the helmet. It wouldn't change the angular momentum of the headset when you're moving it around, but nevertheless, it... the first reaction when these pilots came in and they saw this helmet, they pointed at the helmet and they pointed to me and said, "You got to be kidding me." I said, "Wait, guys. Understand that this is just a simulator for us to test out what it should look like and how it should function, but here's what the airborne version is going to look like." I showed them this new helmet that had actually been done. This was with a project we'd had with McDonnell Douglas and Kaiser Aerospace, where the helmet was actually designed by Lucas Films.

Robert J. Marks:

Really?

Thomas Furness:

That we'd hired the industrial design guys from Lucas Films after they did the first Star Wars. We said, "We want you to make us a sexy-looking helmet." Pilots, they have to look good.

Robert J. Marks:

They're known for their big egos.

Thomas Furness:

That's right. They have big watches and things like that. There were some other requirements of this that we had to put into it, so they did. They came back with a bunch of different designs and so some of

them are really pretty cool. We had some of them built. I hand this to this flight pilot. I said, "Okay, this is what your airborne version's going to look like. This is what you're going to wear when you're flying the airplane." It was blue sky and had lightning bolts painting on the side of it. They looked at that and said, "Wow, this is really cool."

Thomas Furness:

Now remember, these guys are engineers too. They're really good flight test people, but they're also engineers. They said, "Oh, this is so cool." I said, "Okay, you're going to see what's inside this helmet when you go into our big helmet so give it a go." They'd get in the cockpit. We'd suit them up. We'd log them into the speech recognition system and boresight the system with a head-up display kind of thing. Then we would switch on the display. This huge picture would open up to them. It's like sitting on the front row of an IMAX theater. They would say, "Wow." I said, "Well, look around a little bit." They'd look around and they said, "Wow, this is really cool."

Thomas Furness:

Then we started explaining how it works. Now, they'd never seen this before in their lives, but they knew how to fly airplanes. We explained some of the things that they're going to see. For example, they could actually see the radar painting the sky. They could see the radar signals actually painting the sky. They'd see where these other guys are located in the world and in 3D. They had a God's eye display where they could look down in their lap and they see this bubble, this hemisphere of the whole world, so to speak. That's their outside-in display. Then their head-mounted display was their inside-out display. All of this was going on. We'd launch them on a mission and they would see this information being portrayed. They'd see their energy management curves in the aircraft and so forth. That's when they said, "Wow, this is really cool." That was our signal to send in the bad guys.

Robert J. Marks:

The bad guys being the guys with the money in the military?

Thomas Furness:

No, no, not those bad guys.

Robert J. Marks:

Oh, other bad guys.

Thomas Furness:

These are the adversaries, the computer-generated adversaries.

Robert J. Marks:

I see.

Thomas Furness:

They're flying along in this world. They see the outside world. They're flying along. They're seeing all this information and now they're in this virtual simulation. Then what would happen is we'd send in the bad guys. The first thing they would do is they'd hear it in 3D sound behind them. They hear this guy radiating them from behind and then rearview mirrors would window into the cockpit. They would see a

representation of the guys coming in from behind. Then there'd be a few swear words that come out of the pilots when that happened. Then they would go into afterburner. They'd go into afterburner and start climbing straight up. Then they were in what we call a furball, where they're working with this adversary in air-to-air combat. They were in and out afterburner, speed breaks, the whole deal. Just watch Top Gun and you'll see what they were doing. They were swearing and all of this kind of stuff going on.

Thomas Furness:

Then about that time, what I did was I shut off the simulation and everything went dark. I said to them over the microphone in their headset, I said, "Okay, guys, we need another quarter."

Robert J. Marks:

Just like for Space Invaders or something, yes.

Thomas Furness:

That's right.

Robert J. Marks:

Okay. Gotcha. Gotcha.

Thomas Furness:

They were so sucked in. They said, "Oh my goodness. I'm able to do things I've never been able to do before." It's the same airplane. The only thing different is the way we're representing information in virtual space. As a result of that, we got the funding for working on this super cockpit. It was a substantial amount of money because there was a lot of going on, including the artificial intelligence people that would be trying to infer the intent of the pilot, what we call a pilot intent inference engine. We were trying to look at what's going on in all of the sensors, what the pilot was trying to do, and basically organizing this virtual world to help them do it.

Robert J. Marks:

Oh my goodness. Okay.

Thomas Furness:

We were also concerned about the pilots blacking out and things like that when they're pulling excessive Gs.

Robert J. Marks:

Of course.

Thomas Furness:

That was another thing that hit. The physiological state of the pilot was important.

Robert J. Marks:

Tom, that's incredible. What year was this, by the way?

Thomas Furness:

Okay, this was about '86.

Robert J. Marks:

My goodness. Okay.

Thomas Furness:

'85, '86, '87 time period. Now, let me tell you what happened after that. This is sort of a transition. This is what changed my life. I got a phone call from a general in the Pentagon. He says, "I know about your virtual cockpit stuff that you're doing. We would like for you to write up a press release and have a news conference, hold a news conference on what you're doing on that virtual cockpit stuff." I told him, "Well, it's classified. Some of the stuff we're doing is classified." He said, "That's okay, just declassify it." I said, "Okay." He said, "We need some positive publicity." It had just come out in the news that the Navy was spending $800 for toilet seats. The Army was spending $500 for hammers. I don't know if you remember this, but this was-

Robert J. Marks:

I do remember that.

Thomas Furness:

This was the military industrial complex that was spending us into oblivion.

Robert J. Marks:

$50 paperclips, stuff like that.

Thomas Furness:

They said, "We need some positive publicity. The Defense Appropriations Bill is coming up and we're going to get hammered and we don't have a black airplane to show this year, but we have your stuff." I said, "Okay, I'll do it." I wrote up this press release and CBS Evening News comes into my lab. This is a Dan Rather's crowd and David Martin, the Pentagon correspondent is there for the film crew. They spend two days typing stuff. I have tape over the top of instruments and things like that in the cockpit but, anyhow, I end up a few days later on the CBS Evening News. Here I am a lab puke from Wright-Patterson Air Force Base and I'm on the evening news talking about virtual cockpits.

Thomas Furness:

Well, that was the event that opened Pandora's box because after that, then ABC had to come, and NBC, and CBC, and CNN, and BBC, and Australian television, New Zealand television. The science editor of the New York Times came in and spent a whole day with me talking about the future of virtual reality. I was contacted by Popular Mechanics to write an article about this. We were on the front cover of US News and World Report. After that, we didn't do any research anymore. We were into show business and I started getting phone calls. You had all these visiting. By the way, when the generals came to visit - they'd heard about this, they wanted to see it - we had what we called the general switch. Whenever the generals sat in the cockpit to operate this, we had the switch that's a general switch. When we switched that on, the generals always hit their targets.

Robert J. Marks:

Tom, that's terrible. That's divisive, but it probably worked right?

Thomas Furness:

They worked.

Thomas Furness:

No, we didn't have to throw the general switch on. They get the idea of it. But nevertheless, what happened, as a result of all this media exposure and all of these policies, test pilots when they got out of the cockpit they said, "Hey, Tom, this is fantastic. We have to have this." And so as it turns out, of course, this was over the period of 23 years. I was an officer for five of those years, a military officer, and then basically did the same job as a civil service scientist.

Robert J. Marks:

I got to ask you a question, with all this hype you got from the generals? Did you get a promotion?

Thomas Furness:

Well, actually I did. And the Air Force was really generous to me. They sent me to England to do my PhD and got some good promotions. And that was equivalent to, from a military standpoint, sort of between a colonel and a general by the time that I finished after the 23 years. So the Air Force was good to me, and it was a marvelous place to work. Because there were a lot of resources, a lot of smart people, we had a problem to solve, we took it seriously of how we solve these problems to help our country and to keep us safe. And I mean, that was always foremost in our mind, that we are doing a service for the country. And of course, as you know, the military pioneers a lot of technology that eventually ends up in the civilian sector, in the consumer marketplace.

Thomas Furness:

And that's sort of what happened here, because as a result of this media exposure that came as a result of my super cockpit and virtual cockpit work, I was exposed to the public and this elicited a number of questions that came my way, including the one question that came. One of the first ones I received was from a mother who had watched a program that apparently I was talking about the virtual cockpit. And she called me and said, "I watch this program and I want you to know my child has cerebral palsy. Is there anything you can do with this technology to help my child?" And then not long after that I received a phone call from a surgeon. He told me he was a thoracic surgeon, he was trying to replace a graft on the aorta in the heart and a vessel, the artery of the heart.

Thomas Furness:

And he said, "I have a real problem because I don't have a navigation system. I'm inside my patient up to my elbow, sort of feeling my way around. And my map that tells me where things are located and what I should be doing is actually a CT scan. It's on a light box on the side of the operating room. And I'm having to look over to that all the time. And what I need is a map that I can look into the patient and see it there. Can I do that?" And then another surgeon said, "Can you put my eyes inside the patient, so that I can look around? Because I want to do this minimally invasive surgical procedure where I'm only inside looking out rather than outside looking in."

Thomas Furness:

And then there was another phone call from a firefighting company. They said, "We have a real problem with firefighters. They walk into these buildings, they're full of smoke. They don't know where the fire is. They don't know if the people are inside. The other firemen are in there. They don't necessarily see them. And the person who's directing all of this, the fire chief is on the outside of the building with a radio. He doesn't know anything. Is there any way that you can give us basically a cockpit to use inside of a building with a fire and smoke building so we can find our way around?" So anyhow, I was getting three or four phone calls a week like this.

Robert J. Marks:

Wow.

Thomas Furness:

And my answers with them, these people, that call well said, "Well, yeah, you could do that. Matter of fact, that'd be the easy to do compared to what I'm trying to do." And that's when I realized, we're onto something really big. This is a paradigm shift. This is a shift in a way we get bandwidth to and from the brain. Because we noticed through all the tests that we did in the military cockpits, the virtual cockpits, how easily the crew members learned this and how well they remembered it. The retention was enormous.

Thomas Furness:

And it was a much higher bandwidth to the brain. And so it awakened spatial memory. So I realized at that time, there are lots of applications beyond the military applications for this technology, and again, this was in 1986, '87 time period. And I convinced the Air Force that we needed to come up with a long-term investment strategy for this virtual reality technology. And what I'd like to do is spend a year building this long-term strategy and sort of take a sabbatical with a travel budget and to sort of investigate.

Thomas Furness:

And they said, "Okay." And so I went everywhere. I went to hospitals, to toy companies, to kindergartens, to aerospace companies, to computer companies. And I remember this was an '87 time period where there wasn't a microprocessor. There was not the internet. There were not these things that really do exist today. But what I was able to see and realize, oh my goodness, we're going to have an explosion not only in computing technology, but in the connections of those computers, with what's happening with telecommunications and fiber optics.

Thomas Furness:

And what was going to eventually happen with these optical systems that we're looking at. But no one was working on the interface. This is we're still sitting in front of a screen and wiggling our fingers on a keyboard that was designed in the late 1800s. And so it was clear that we needed to have a shift in the way that we think about the interface of humans to these advanced computing systems. So I put together a proposal as a result of my sabbatical.

Thomas Furness:

And I said, when I came back home, I said, "Hey guys, the best thing we can do with this technology is to get it out of the military and get it out into the world where we have all of these pulls, like the people that called me in medicine and education in design and so forth. And what I would like to do is establish a lab somewhere in the United States, associated with a university that would concentrate on that side of things, where we can have students who learn about it. And they eventually become our missionaries and our evangelists and actually build the technology because you've invested a lot in my education and a lot in this technology. And we need to get it out in the world where it'll make a difference. And I would like to do it. I'd like to shop this out and find out who bites on the bullet."

Thomas Furness:

So as it turns out, I went to many places, MIT and Caltech and Stanford and Carnegie Mellon, University of Texas, University of Utah, University of North Carolina and the University of Washington. And I sent a cold call to the University of Washington saying, "I have this idea for a lab that would work on virtual reality in advanced computer interfaces. And here's the plan for it. Are you interested?" And I got back a call from the Dean of the College of Engineering, Ray Bowen, whom you know.

Robert J. Marks:

I know Ray. Yes.

Thomas Furness:

And he said, "Why don't you come out and talk to us?" And so I did, flew out to Seattle and I walked into his office and there was another guy in the office with him. And his name was Ed Steer.

Robert J. Marks:

I remember Ed. Yes.

Thomas Furness:

Ed Steer introduced himself and said he was the director of the Washington Technology Center.

Robert J. Marks:

The WTC. Yes.

Thomas Furness:

That's right. And I said, "Well, haven't I met you somewhere before?" He said, "Yeah." He says, "I was the chief scientist in the air force. And I was in your lab at Wright-Patterson Air Force Base and I saw what you were doing and we want it here."

Robert J. Marks:

Okay.

Thomas Furness:

So they made me an offer I couldn't refuse. They brought me in as a full professor with tenure and gave me some space in the flu call and a budget and with a different kind of report card, they said, "Okay, your job is to spin-off companies. Your job is to generate patents and build a bridge between university

and industry. Now you'll do the regular professor stuff. You'll teach and you'll write proposals and mentor students and all that kind of thing."

Thomas Furness:

And I was thinking, "Wow, that's exactly what I want to do. I want to build stuff and get it out there and also be able to tell folks what I've learned over these past 23 years." So in September of 1989, I moved to Seattle to start the Human Interface Technology Lab at the University of Washington. And as a result of what happened in my mandate, started with one person, me, a budget, a mandate and a great university. The fences are really low. What attracted me to UW versus the other universities I went to is that the fences were really low between departments. People work together.

Robert J. Marks:

Oh, okay.

Thomas Furness:

And I mean, I found that that was something that was unique.

Robert J. Marks:

That is true. I don't think a lot of people realize that in universities, many professors live in their own silos, there's no communication. And that wasn't true at UW. That's right.

Thomas Furness:

No. And basically I had the run of the university as all the professors did. And to work with EE and with ME and with bio and material science and civil and computer science, then the medical school, middle school, nursing. As a matter of fact in the end, my lab grew from one person to 120, which included faculty members, with students, with the staff, visiting scholars, things like that. And we had funding from the government, we had funding from industry, have sort of half and half. And this is when we spun-off 27 companies.

Thomas Furness:

And those companies, several of those companies would trade on NASDAQ and a market cap of $12 billion. And this was done with students, this with my students who got turned on fire and took what they were learning in the lab and starting companies from it. And so that was the process story of what happened starting in 1989. And here we are, 30 years later. What has gone on during that time? Well, transformational, because as you know, we went through several ups and downs in virtual reality.

Robert J. Marks:

Oh, I didn't know that.

Thomas Furness:

I mean, it'd be over-hyped and everybody get excited, sort of like artificial intelligence.

Robert J. Marks:

Yes.

Thomas Furness:

It'd get high and low and you've been there.

Robert J. Marks:

Yes, I have.

Thomas Furness:

And the whole neural net stuff, but we survived those times. And in the end the lab actually propagated to New Zealand and Australia.

Robert J. Marks:

Yeah, you have HIT Labs at the University of Canterbury and the University of Tasmania.

Thomas Furness:

Yes.

Robert J. Marks:

That's a fun word to say. Because I usually think of Bugs Bunny and the Tasmanian devil.

Thomas Furness:

That's right. I've seen some real Tasmanian devils.

Robert J. Marks:

Have you? Okay. So what are Tasmanian devils? Are they little-

Thomas Furness:

Well, let me tell the story about that.

Robert J. Marks:

Like doggy things or what?

Thomas Furness:

Yeah, well, so here we have the HIT Lab that has 120 folks in it and spinning-off these companies and it's a ubiquitous lab. I mean, we have students from every department of College of Engineering with exception of chemical engineering. We even had material science and engineering and bio and electrical and mechanical and industrial and so forth. But we also had students from art, drama and music, oceans and fisheries, medical school, dental school, nursing school, geography, the college of the built environment, architecture.

Thomas Furness:

And these were students that actually lived in the HIT Lab. I mean, they were there in terms of that was their where their office was. And what I would do is organize these students into clusters of four members. And they would be in this little sort of a bullpen with four of them. And one would be a psychology major. One would be a EE major, one would be oceans and fisheries and the other, drama,

PhD. And you say, "What?" You say, "Yeah." And so what I do is seed them with a problem to solve. And lo and behold, these kids would generate several patents a week.

Robert J. Marks:

Seriously? A week.

Thomas Furness:

Oh yeah. I mean we had, one year, we had more patents in the HIT Lab than all the rest of the university combined. And the reason for it was because of the different perspectives. You'd have these different ways of looking at problems like the blind men around the elephant, right? That each of them have their own perspective and they think that's what an elephant is like, when in fact when they start comparing notes with the other blind people, they finally figure out it was bigger than that and there are different ways of looking at it.

Thomas Furness:

And so that's what we found happening with these students. They had their own lexicon of the way they talk about things, but they had to learn another lexicon from a different perspective. And so it was amazing to see the product. And these kids were on fire. I couldn't get them to go home. They just loved it and the stimulation that came from that. And then of course what we had fuel the fire was we had a virtual worlds consortium. This was 50 companies that help support the laboratory. They would pledge $50,000 a year or equivalent and in-kind to be a member of this consortium to see what was going on.

Thomas Furness:

They didn't get anything for it other than information. And of course, access to our students, and they showed up and the students would present to these consortium members. And we had, again, the 50 of them, we had Microsoft and Boeing and Sun Microsystems and at the time Digital Equipment Corporation and Broken Hill Proprietary, the largest company in Australia, from all over the world. From Japan we had seven companies from Japan. And these people would show up to see what was going on in this phenomenon of how these students from diverse backgrounds, a transdisciplinary background were working together.

Thomas Furness:

Because they'd never seen it before. And then what we saw happening was these people were starting to talk to each other. They didn't go to conferences where they... They went to conferences with people in the same business, but they'd never been to conferences where you had people from Chevron sitting across the table from a Nike executive. And they started comparing notes and starting projects together. And they loved it. And it was quite an enterprise that was underway. So, that's how all these companies got spun-off, the 27 companies. And because of not only a combination of the kids, but the venture capitalists started hanging out saying, "Do you have something for us to invest in?" And we did. So things got started that way.

Robert J. Marks:

Excellent. Well, I tell you what, Tom I'd like to talk about some of these spin-off companies and some of the new technology and the state-of-the-art of virtual reality. [PART 2 OF 4 ENDS] So Dr. Furness, I'll turn it over to you. I don't know where you want to start. I have some specific questions, but tell us some of the technology which has come out in your startup companies.

Thomas Furness:

You bet. Well, certainly what we are trying to do is embrace this whole idea of the push and the pull of technology. I mean, for many years, virtual reality and augmented reality were in push mode. Basically the whole idea if you build it, they will come. That the technology was developing we knew from the early days, especially in the military days, it was profound in terms of the power it had, but what could we do to get it out of the military, to where it could be used in not only vertical markets on outside consumer markets and industrial markets, but how we could solve real problems with it?

Thomas Furness:

And so you have the push of the technology and you have the pull of the applications. And how do you make these work together? Well, in an earlier segment, actually the first segment, we talked about that actually a VR emerged from at least from my work in it, beginning of 1966, emerged as a result of trying to solve problems in the military aviation. And as a result of the process of solving those problems, we invented what we know today as virtual reality. And we found over the years what a profound impact it has on the way people think. And as I transitioned from the military to a university environment, we started looking across different domains and how this technology might be applied.

Thomas Furness:

Now, one of the beginning things that happened was that when I showed up in 1989, very few people knew what virtual reality was, that it existed or what it was. And so we decided maybe we should try to introduce a device into the consumer marketplace. And working with some of my colleagues even before arriving in Seattle, we came up with what we call a personal eyewear display. And this looked like ski goggles that you would wear and what it would be was basically a virtual display, a head-up type display that would display for over one eye a virtual screen.

Thomas Furness:

It appeared three meters away and about one meter wide. It's loaded like a home theater system that you wear on your head. And it would plug into this little battery pack with a television receiver hooked around your waist. And we started working on this and a patent that was issued in the early '90s. And we started a company called Virtual Vision to make these, and indeed we did, and we raised a bunch of money and started building these devices. And so this was a really simple display in that we just took a liquid crystal screen that was rear-illuminated and then we projected down to a prism that you would look through and you see this virtual image, but you'd also see the outside world around it.

Thomas Furness:

And so it didn't replace the outside world. It was just sort of a small piece that you saw appeared out in the outside world. And so you could sit on Waikiki Beach and watch the NFL playoffs if you wanted to with this device with broadcast television. And so we introduced this. Actually the first opening of this product, we took it to the consumer electronics show and people were lined up for two hours to see this thing. And they'd take a look at it.

Robert J. Marks:

What year was this?

Thomas Furness:

This was in '94, '95 time period.

Robert J. Marks:

Okay.

Thomas Furness:

And they would say, "Oh gosh, this is amazing. This is transformative. You guys are going to make a fortune." And we started saying to ourselves, "We're going to make a fortune." And we started believing our prayers. And so what happened-

Robert J. Marks:

That can be very dangerous.

Thomas Furness:

It can dangerous. That's right.

Robert J. Marks:

Yes, it can.

Thomas Furness:

So we ramped up, we were producing these things and they appeared in the marketplace. We had a big advertisement on the New York Times and all this and indeed people would show up and line up outside of Magnolia Hi-Fi, which was the first place where we introduced it. We had the network television, people were there and the big introduction and people would go in and put it on and say, "Wow, this is really neat. I want one of these things." And they looked at the price tag.

Robert J. Marks:

Oh.

Thomas Furness:

And it was $799. That was back in '95. This was '94. That was a pretty steep bill. And by the way, we weren't making any money at that price point. But the technology was still pretty archaic at that time. So what happened was that people didn't buy them. They wanted to buy them, but it would just cost too much. And so we were disappointed in that, but then we started seeing, there was one market segment that was buying these things like crazy. We said, "Hmm, what's going on here?" We tracked it down and they were dentists.

Thomas Furness:

Dentists were buying this virtual vision display. And we went and visited the dentists and saying, "What's going on?" And they showed us. What they were doing is they were giving these to their patients and the patients would put them on. They would select a movie, plug it into a VCR, play this into the headset. And there they were in the dentist chair and they were watching this video or this movie while the dentists were inflicting pain on them. And the dentist said, "The patients love it. And we love it because they don't complain anymore. They are watching this movie, they're sort of zoned out in their

own space." And then they said, "However, it is creating another problem. Now we can't get them to leave. I can't leave now this is a good part."

Robert J. Marks:

They didn't finish the movie, of course.

Thomas Furness:

That's right. And so, but even more remarkable than that was the children. They would have these small kids in and they'd hook this up to Nintendo. And so here, the kids were playing Nintendo with this headset on with a virtual headset on and sitting in a dentist's chair while the dentists were doing their thing. And usually the kids are terrified and they don't want to be there. And so these kids loved it and they'd go home and talk to their mothers, "Mommy, when can I go back to the dentist again? So I can see this special glasses."

Thomas Furness:

And so when did that ever happen? When did kids ever say they want to go back to the dentist? But the dentists were saying, "It seems like they don't notice the pain when there is some, because they're distracted." And we're saying, "Hm that's interesting." So then we contacted some of our colleagues at the Seattle Children's Hospital to see if this pain thing really was relevant, especially with leukemia patients, these little patients are really sick. And the way that you determine the efficacy of the treatment, which is basically chemotherapy, they would have to extract bone marrow and look at what was going on with a white count in the blood marrow. And this is a really painful procedure.

Thomas Furness:

You put a needle in the hip and extract the bone marrow and the children would just scream. It's so painful. And they're so sick you can't anesthetize them. And so this was what was happening. And we went in to the hospital with our equipment. Again, it was connected with Nintendo and these kids would be going through this procedure, but they're playing Nintendo at the time. And the doctor would put the needle in and the kid would make a little say "mh" or something like that, and just continue to play the game. And the nurses and doctors were looking at each other saying, "What's going on here?" And it's like they didn't even notice it. And that set us on a whole different track of what we're doing with these virtual displays. We said, "Wow. What's happening is, in order to experience pain, you have to be conscious of pain. But if you're doing something else that is engaging, then you don't notice it."

Thomas Furness:

And so we went to the Harborview Burn Center, this is one of the regional burn clinics, where these patients are severely burned and they are doped up with morphine most of the time. So the morphine can control the so-called rest pain when you're just lying in the bed in semi-agony but the morphine controls that, but morphine isn't good. It's toxic, it's addictive, it's pretty bad stuff. And when they went in for wound care to remove scape staples from skin grafts or to do physical therapy or they'd soak the patients in these tubs of water and then slough all the dead skin, anytime that happened, the pain would shoot through the roof. You couldn't dose them with enough morphine, because there's what it's called breakthrough pain.

Thomas Furness:

It would break right through that. So we started introducing VR to the burn clinic and the patients again, would put on the headset, we built a virtual world where they'd be flying basically in snow. They would be in a snow canyon and there would be snowmen, they're throwing snowballs at them when they're flying through this canyon. And they would throw snowballs back at the snowmen. And this was all going on during the time that they were receiving this treatment. And then we'd asked them for a pain index. And what often would happen is the patient will say, "Well, when are you going to start?"

Robert J. Marks:

Really?

Thomas Furness:

When in fact you'd finished the procedure.

Robert J. Marks:

What is a pain index? Is that where they ask you, "Tell me on a scale of one to 10 what the pain's like?"

Thomas Furness:

Yes. Yes.

Robert J. Marks:

I see. Okay.

Thomas Furness:

And this was a well-established pain scale. I mean, and they talk about, what do you feel when you add this particular number? And usually with breakthrough pain is just off the scale. Rest pain is maybe two or three, but then when they were in VR, the pain went from 10 to zero. And then we asked them the unpleasantness of the pain, the feeling of presence in it, all of these kinds of things. And we thought, "Well, this is amazing." But it only worked once. You put them in this world, it would, after they get used to it, it's not going to work. We were wrong, exactly the opposite. It gets better with time as they get it in. And furthermore, they remember being in that world. And we're now finding out that's a big factor in chronic pain.

Thomas Furness:

These other things were acute pain during wound care, but in chronic pain, rheumatoid arthritis, things like that, it even works there because of the model that the people build in their head. So what this did, this early work, is it set us off on an altogether different track of an application for VR. And now VR is being used worldwide in hospitals, not only for treating things like burn pain or acute pain, but also in pediatric clinics.

Thomas Furness:

And we're actually using it - we have a project with the Make-A-Wish Foundation where we're actually making wishes for these kids who are terminally ill to help them with giving them something to do in VR. So the impact on medicine, just from the pain standpoint is huge, not to mention the diagnostics, the simulator training and things like that. So in my HIT Lab we had a major project going on in looking at

medical applications of VR, including the pain work also for surgery simulation, to train surgeons, amazing, what happens there.

Thomas Furness:

In the case of, for example, urology, where there is going to be a procedure called a trans urethral resection of the prostate. That's when you go in and carve away part of the prostate that's restricting urine flow in the urethra. And this is a painful process. It can be a painful process and you don't want to mess it up because that can change your will to live. You know what I mean. And so what happened is the doctors that are learning, the residents, they only have a limited amount of time to practice this procedure. And over a period of three-year residency, they could only maybe do a total of maybe 30 or 40 procedures on real patients. And of course, most of these patients will be normal. Nothing unusual happens.

Thomas Furness:

But with our simulator that we built in conjunction with the UW medical center, University of Washington Medical Center, these residents could do 50 procedures a day. And with all kinds of variations, with things that would happen, with bleeders and things like that, what it is flight simulation, just the pilots train. We're having the surgeons train the same way. And this has been done with sinus surgery simulation, with suturing simulation, training medical students. And so this is a boon for training, especially medical training. So here again, as we have an application pool that's come from this.

Robert J. Marks:

Well, you can see from your illustration, the need for this cross-curricular sort of approach to things, you need the psychology, the medicine, you need the art, you need cultural anthropology, you need all of these different disciplines because they all contribute.

Thomas Furness:

That's right. And no one, no single discipline owns virtual reality because it cuts across. It is basically, it's all aspects of building tools for humans to work in the world. And just like everybody uses wheels. So-

Robert J. Marks:

Yeah.

Thomas Furness:

It's that kind of thing. It's a ubiquitous kind of technology. Now to jump around a little bit, certainly we were working on these applications, but again, we had to get the technology to keep up with the need.

Robert J. Marks:

Mm-hmm (affirmative).

Thomas Furness:

And up to this point in time, we were building displays that started off with some kind of image plane or what we call an object plane, where an image was formed and then we relay that image to the eyes some way, but you had to start off with this object plane. So it was a little screen in case of the, for example, the virtual vision display I just mentioned, a very small screen, and then you magnify and you

project it so it appears to be a big screen. But, the problem is you're really limited in how many picture elements you can put in that small screen and especially high luminance.

Thomas Furness:

So there had to be a change in a way we did it. And so this is where we got into this whole idea, why are we having to start off with an object plane to begin with? Why don't we scan the image directly on the retina of the eye? And so we started working on this concept of a virtual retinal display, where you start off with a coherent beam of light from a micro laser, very low energy laser. And then you can scan it such that the screen is the retina of the eye.

Thomas Furness:

That's the only place where an image exists, is by scanning the photons across the surface of the retina, very low energy. As a matter of fact, it's lower energy than what you get outside when you walk out in daylight. And what you now see is an image that doesn't exist and is very high resolution, very wide field of view, high luminous, matter of fact as high luminous as you want it to be, and you could probably run the thing with a hearing aid battery. So this direct retinal projection was transformative.

Robert J. Marks:

The biggest objection I hear today about virtual reality is the clunky headsets. This is an answer to that, isn't it?

Thomas Furness:

It is. It is indeed. And so what we did with this, this was at the time we patented this and we have several patents and we had a company that wanted to license it, and that company was MicroVision. And MicroVision licensed it from the universe, at the time it was the largest-

PART 1 OF 4 ENDS [00:34:04]

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PART 2 OF 4 ENDS [01:08:04]

Thomas Furness:

- licensed deal the University of Washington had ever done. And it was a huge, licensed thing. I think it was 5.133 million, a 9% equity in the company, two and a half percent royalty stream with a minimum that was promised. And Microvision started making these things. And then they went public and turned the university stock into something that was really worth a lot. And now they still exist, and they're one of the companies traded on NASDAQ.

Robert J. Marks:

I see. Where can I get one of these? I want to get rid of my clunky headset.

Thomas Furness:

Well, that's the thing. Right now, you can't get it because it was being used by the military for awhile, and now that engine is now being used for head-up displays in cars, because it can have such high

luminance. But it is certainly the wave of the future. Now the company Magic Leap started out using this concept, the technology, and actually a variation of it was done by the Google Glass. And so it will come again into the world, because it's got to be the way to go in terms of getting rid of the clunky headset.

Robert J. Marks:

Well, let me ask you about Google Glass. I think that they kind of went away. I don't hear much about them anymore, but they probably had something to do with your ski goggles and your virtual retinal display, or did they?

Thomas Furness:

Well, they were related, and it was very small field of view. And of course the problem with the Google Glass was the technology worked. It worked and it worked pretty well. The problem was the social aspect of it. No one really realized what that was going to do when you're talking to a person and they have this Google Glass on, and you don't know if they're paying attention to you or they're paying attention to what's being displayed in the Google Glass. And people started, "Are you taking pictures of me? Are you taking images of me?" Which you could do by the way. And so this became... That was something they never really did get into at the time.

Thomas Furness:

Now, Google Glass is a resurgence and, again, better designs, but it's now being used in vertical markets. These are where people absolutely have to have this in order to do their job and so that's different. That's what all the different marketplace than where Google originally introduced this.

Robert J. Marks:

I see.

Thomas Furness:

So there is a big deal about now that you have, you're wearing these glasses and these glasses display information, and you're now interacting with another human being and they know that you're wearing these glasses, but they don't know what you're seeing. And are they somehow psychoanalyzing you while they're looking at you? You just don't know. So.

Robert J. Marks:

I feel that way, Tom, when I talk to a psychologist. No, a professor in psychology, I talk to him and I think is he analyzing me?

Thomas Furness:

Yeah.

Robert J. Marks:

Same thing, I guess.

Thomas Furness:

Yep. Well, I get that with my wife anytime I talk to her.

Robert J. Marks:

Yeah. Ditto. Yeah. Ditto. Yep. Yep.

Thomas Furness:

So anyhow, the virtual retina display became one of our mainstream devices that we were working on in the lab, developing the technology. We had this big project funded by Microvision, but here's what happened. We had one of our lab units, our bench top units, optical bench unit, where we were displaying this image on your retina. So we'd have people who'd come in, could see it and see how it works. And so there's one guy that came in, a gentleman who was actually on the board of directors of the Washington Technology Center. He said, "I've been hearing about this virtual retinal display. What I'd like to do is see it operating." We said, "Okay. Come down to the lab and we'll, do that." So at the time we're using acousto-optical modulators in order to do scanning, and there was a monocular display, but the image was painted with high resolution on your retina.

Robert J. Marks:

Uh-huh.

Thomas Furness:

And it was remarkable, but it was just one eye. So we invited him down to the lab. We were just using one eye at the time, this monocular system, an optical bench. And so he came down to the lab and he sat down in front of the optical bench and looked into our objective lens of this and, sure enough, saw this virtual image. And he said, "Wow. This is really amazing. And a really high resolution, high luminance." And we said, "Yeah. Well take off your spectacles." And he took off his spectacles and he said, "Well, I could see it just as clearly without my spectacles." We said, "Yeah. We're not really using the optical power of your glasses or the lens of your eye. It's basically we're writing almost directly on the retina."

Robert J. Marks:

Wow. But wouldn't you still have to take into account whether the person was near-sighted or far-sighted or... that doesn't wow. Okay.

Thomas Furness:

No. No. No. It doesn't matter. It doesn't matter. And so it's clear. I mean, the image is just as clear, because you basically have a beam, a non-diverging beam of light. It's collimated, and it goes right to the retina. So, he was seeing this clearly as we do, I mean, all the other people that'd been working with the virtual retinal display, but then he did something else. He then switched to his left eye and started looking with his left eye into this.

Robert J. Marks:

Mm-hmm.

Thomas Furness:

Just on his own, and his mouth dropped open and he said, "Wait a minute. What are you doing here?" We said, "Well, what do you mean?" He says, "I can see this with my blind eye." We said, "What?" And then he says, "I'm blind in my left eye, and I can see that image." And we said, "What?" And so he said,

"Yeah. I'd been in an automobile accident and it blinded my eye, because there's all this scar tissue in my eye and I'm seeing this image." And we said, "Oh, yeah?"

Thomas Furness:

And so after that, we went to the department of ophthalmology at the university in the medical school and said, "This is what happened." And they started sending us patients and, sure enough, these patients that especially had optical problems in their eyes, were able to see with the virtual retinal display. And then we started finding out that people even with degenerative diseases of the retina were able to see better with age-related macular degeneration. And even when they thought the receptors were dead, we were getting light into those receptors.

Robert J. Marks:

Oh my goodness.

Thomas Furness:

And we found out later is the fact that we're using coherent light, the receptors act like wave guides, and the coupling efficiency of our coherent light, which is much greater than what you could get from broadband light, non-coherent light, and so they were actually seeing. And so what this did, again by accident, just like the dentist, it just took us off in another direction where we started working on low vision and low vision aids. And we wrote up a proposal and got some money from the National Science Foundation to work on this. So it's one of these journeys I've taken, and this has been true all the way through, where you stumble over something that you weren't... You were going in another direction, but you stumbled on something. And that became more interesting than the direction you were taking initially.

Robert J. Marks:

That is amazing and exciting stuff. I can actually see how coherent light could actually go down the wave guides that you mentioned, whereas broadband light wouldn't be able to do that. And so that's kind of what happened. Yeah. How about that? [END OF PART 3] Tell us something about some of your other current projects. Maybe one of them is the RATLAB, and we were talking offline and it kind of reminds me of the Skunk Works and I don't know why engineers use deplorable animals to describe what they're doing, but the RATLAB stands for a Rocking and Thinking, is that right?

Thomas Furness:

That's correct.

Robert J. Marks:

And it's an incubator. Tell us about that.

Thomas Furness:

Yes. Well, I was enjoying my activity at the university, certainly a wonderful place to do research, but it is a bureaucracy. And I found that sometimes having worked for the Air Force for the Department of Defense for 23 years, I got used to the bureaucracy, but it sure does slow you down and reduce your flexibility.

Robert J. Marks:

Yes.

Thomas Furness:

Especially if you want to try out things. And so I decided that what I needed was an outlet to do some pretty far out things that I wouldn't be able to do at the university, because I would be labeled as a flake. Well, I am a flake, but I didn't want to be labeled as a flake. And so in 2005, I was thinking about how can I hire some high school dropouts because these kids are brilliant? But the university would never hire them.

Thomas Furness:

And I had some projects I wanted to do that I wasn't particularly interested in giving away to the university, because those were my own ideas and they were orthogonal of things I was doing at the university. So I was driving home one day, and I just happened to glance over the side of the road. There was a house for sale, not too far where my home is. And I started thinking about that. Hmm. What if I could build a residential business, sort of a lab that would be like a garage shop operation, where I was able to play with technology with a bunch of kids, adults, PhDs, kindergarten, whatever.

Thomas Furness:

And I can hire who I wanted to hire. I could knock holes in the wall if I wanted to. I could pay them what I wanted to pay them and not have to go through the bureaucracy that would prevent that from happening. Generate IP if necessary, spin off companies. So I talked to my wife about this and she thought I was crazy, but I convinced her that we needed to buy this house.

Robert J. Marks:

Okay.

Thomas Furness:

So we bought this house and turned it into a lab. I was kicking it out around with my wife, and she's the one that actually came up with the name. She said, "Well, experiments, rats and things like that." And I said-

Robert J. Marks:

Oh, okay. I get the connection now for rats. Okay.

Thomas Furness:

Yeah. And so, The Rats of NIMH, there was a movie about that, and rats are pretty smart and really industrious. And so we decided the RATLAB would be a good name, but rat doesn't mean what people think it is. It means, we're going to be a rocking group of people and thinking people. And I was thinking of sitting in a rocking chair, just sitting there and thinking, but there's a different connotation to rocking as well. So, I started the RATLAB as a Washington company, an LLC, that would be working on just investigating advanced technology. And I started working with some clients who said, "Could you help me with this problem?" And I said, "Oh, okay." And so I started looking at what they were trying to do in this case. They were trying to use light to characterize matter. And I'm sort of a photonics guy. So I said, "Well, yeah. We could probably look at that." And so I gathered together some of my rats and we

started looking at this and we said, "We wouldn't do it the way you're thinking about doing it. We'd do it entirely-"

Robert J. Marks:

Now by rats, you don't mean literal rats. You mean employees in your lab.

Thomas Furness:

That's right. The kids and the employees that worked at the RATLAB were called rats, including me. I'm the king rat. And so we started looking at this and, lo and behold, we came up with two or three patents. And the company said, "Wow. That's great. Could you develop some prototypes?" And we said, "Well, sure." And what I did was I chocked this house full of all kinds of technology. And we make our own electronic fabrication, printers and milling machines and things like that. And so we started making stuff, and they said, "Wow. This is pretty good. How would you like to take over all of our R&D? And I said, "Really? I mean, I'm here to... I want to play with stuff." And they said, "Well, you can do that too." And I said, "Well, it's really going to cost you." And they said, "Well, how much?" And I said, "A million bucks." I didn't know. I just threw out that. And they said, "Okay."

Robert J. Marks:

Really? You know, of course, you didn't ask for enough.

Thomas Furness:

At that time I said, "Good grief. I should have asked for two or three."

Robert J. Marks:

Absolutely.

Thomas Furness:

So anyhow, we got some money, and we started playing around with technology. And we ended up with, I think it was 20 patents or something like that in this particular area. And then we got approached by a few other companies. One who wanted to work on what was called Heart Rate Games. How do you use games as a means of helping people get healthy, and with exercise machines. So what we did was figure out a way to take a bicycle, just your regular bicycle, plunk it into this machine, and you'd be peddling away on this bicycle. And you put on a headset, virtual reality headset, and you become a dragon and you breathe fire and you start, and you're just flying around in three-dimensional space while you're peddling.

Thomas Furness:

And you're peddling charges up your flame thrower, and you have to keep an energy level up on that flame thrower. And then you're flying around and you have these dragons that are trying to attack you, and you're zapping them with your flame thrower and things like that. And it's back to the pain thing we talked about before. You get completely distracted that you're exercising, and by the time 30 minutes is up the game's over, and they say, "Really? We have to quit now?" When in fact you look at the profile of what you've done. And we came up with a way with doing it adaptively.

Thomas Furness:

So we wanted to keep you in the zone of where you were sufficiently challenged, but it wasn't too much, so that you would stay on this curve of exercising and eventually, over a period of time, you get to the point where you didn't have to have the game anymore. You felt really good exercising. And then it became a social thing. You wanted to compete with other people. And getting people over that hump of where exercising is unpleasant to where it is pleasant, because you're fit, you're more fit, that was our objective. And we worked on that for a while, with a company called HeartRate Games. And then we spun off a few companies along the way. One of the projects I started working on was with XPRIZE. I don't know if you've heard of the XPRIZE Foundation.

Robert J. Marks:

No. Let me back up. HeartRate Games. If I wanted to buy one of these, is it commercially available now?

Thomas Furness:

Nope. It's not. As it turns out, Heart Rate Games went under.

Robert J. Marks:

Oh, no. This is such a great idea, Tom, and I need exercise.

Thomas Furness:

Yeah. Well, it would work and we knew it worked, but the problem is the industry is dominated by a few manufacturers. And we started talking to those manufacturers, and they just were not interested. They thought, nah, it's going to be too big a deal, too expensive. And we have a direct line to all of these fitness centers, and we were trying to convince them that this was a way to go. And so, as it turns out, we couldn't get through that particular roadblock.

Robert J. Marks:

I would think the home market would be really good.

Thomas Furness:

Well, yeah. And, I mean, it could transform this whole situation where people... It makes people uncomfortable to exercise. If you...no pain, no gain kind of thing. But we can make the pain go away and make it fun, make exercising fun, so you get to a point where you're fairly fit.

Robert J. Marks:

Well, keep me up on that, because I want one.

Thomas Furness:

You want one? Okay.

Robert J. Marks:

Yeah. I want one. Okay?

Thomas Furness:

Yeah. So that was one of the projects we worked on. And then another project I started working with the XPRIZE Foundation. And XPRIZE, I don't know if you know about the XPRIZE Foundation, but they award these big prizes for accomplishing something, pressing the technology limit. And SpaceX won the XPRIZE for one stage to orbit. And there's an XPRIZE for mining on the moon and for acid in the oceans and things like that.

Robert J. Marks:

I see.

Thomas Furness:

And anyhow, this XPRIZE was a Tricorder XPRIZE, the medical Tricorder like in Star Trek where the doctor scans the patient noninvasively and tells what's wrong with them. So I was asked by the medical director of the XPRIZE, Tricorder XPRIZE if I would like to be a judge of this. Now it turns out this guy used to work for me at the HIT lab. He's a physician, neurologist. He was actually on the staff of my lab at the University of Washington. And he went on and as a professor at UCSD, but he became the medical director of this project. He said, "I'd like for you to be a judge." And I said, "To heck with that. I want to be a contestant, and I want to build one of these Tricorder deals."

Thomas Furness:

And as it turns out, I got involved. We signed up to be a contestant and started down that road. And then we found out that really this isn't going to take us anything advanced. We're just going to be integrating what's already out there, because of the sponsor of the XPRIZE. That's what they insisted. And I said, "Well, we're not going to do any blue sky work." And I said, "I think I'll just do my own XPRIZE."

Thomas Furness:

And so I've got together with the rats and said, "Okay. We're going to do this." So I said, "Let's go to work and find out what's really killing people." And as we did the research, we found out pretty much it's heart disease. That is a silent killer.

Robert J. Marks:

Yes.

Thomas Furness:

When people have heart disease and don't know it. And the way Western medicine works, they only intervene when you have an event, and that may be too late. You have a heart attack and then you die, or you're injured for the rest of your life. And so there's not a whole lot that goes on in preventative heart disease. If you do have a good physician who does an EKG every year, you may be able to pick up on some of this, but EKG isn't too good, actually. So we started digging down and said, "How can we come up with a warning system for cardiovascular disease?"

Thomas Furness:

And we stumbled upon traditional Chinese medicine.

Robert J. Marks:

Okay.

Thomas Furness:

Because these have been practicing this for 2000 years, of where a traditional Chinese medicine physician will feel the pulse, the pattern of the pulse. They take the pulse with three fingers on the radial artery on your left arm, and on your right arm, too, but mainly the left arm, and they can tell pretty much what's going on in the body by sounding the body. The pulse actually is like sonar. It tells you what's going on throughout the body. And they have-

Robert J. Marks:

My goodness. They must have pretty sensitive touch.

Thomas Furness:

Oh, yeah. And, I mean, it's a human pattern recognition thing. And they can tell by the timing and the shape of the pulse and things like that, what's going. Well, I didn't believe this. I didn't believe that that was really happening until we said, "Okay. Where can we find one of these guys, these traditional Chinese medicine guys?" And, as it turns out, the largest traditional Chinese medicine clinic in the U.S. is over in Poulsbo, Washington.

Robert J. Marks:

Okay.

Thomas Furness:

On the peninsula.

Robert J. Marks:

Yes.

Thomas Furness:

So we went over and talked to this guy. He actually came to us and we said, "We want to talk to him about this." And then what he did, the first thing he did, is he went around the room. There were, I think, eight or 10 of us rats around the room, and he went one at a time and felt our pulse and told us our whole history, medical history. I couldn't believe it. None of us could believe that he was... he told us, and he didn't know us. This was the first time he'd met us. So this was beginning to make a believer out of me.

Robert J. Marks:

Well, you can't argue with success, can you?

Thomas Furness:

That's right. And so we said, "Hey, how would you like to do a project with us? What we'd like to do is instrument you. What we'd like to do is digitize what you're feeling. And you tell us how you interpret what you're feeling, and what we'll do is build some machine learning algorithms, and then we'll take those patterns and build a library and be able to recognize what the diagnosis is based upon the pattern of the pulses." And so this would be sort of a holidoc kind of thing. And so we started a project. We spun

off a company from the RATLab called Pulse Tectonics, and Pulse Tectonics was working on this way to do this measurement. And we raised some money, and in the process we found something else. We noticed that in some of the patients, some of us, we were using our measurement system on ourselves, there was a strange bump that would occur sometimes and not other times in the pulse.

Thomas Furness:

We say, "Hmm. What is that? Sometime it's there, and some of the time it's not there." And we finally figured out, by doing some monitoring over a period of time, that this had to do with we're hungry. When we're hungry, that bump appears, and when we're not hungry, it's not there. And we said, "Well, what this is all about is we're actually measuring the shunting of blood to the stomach, to the digestive system that is being basically shut off when you're hungry, but the demand is there. And then when you eat, you're basically releasing that into the stomach." And we found that that was a correlation. And then we said, "Well, we wonder if we can determine with the pulse what you've eaten."

Robert J. Marks:

This is fascinating. Okay. What you've eaten. Okay.

Thomas Furness:

Yeah. And so we started doing some experiments and we said, "Okay, well, this is all on ourselves. Let's do a diet of protein, let's do carbs and whatever and fat, and let's see if there's any difference in the pulse." Sure enough, there's a difference in the pulse. We could tell by looking at the pulse what you'd eaten. And basically what it was telling us is how the body reacts to what you've eaten in terms of the way it allocates blood supply. So the more we looked into this, we said, "Good grief. This is a bigger market than cardiovascular disease, the nutrition and diet market."

Thomas Furness:

So anyhow, we continued down this line. We, again, have some patents and we're ready to raise our next round of money. We had it identified, and then the Chinese market shut down. Basically the investment resources of China to the U.S.A. started drying up.

Robert J. Marks:

I see.

Thomas Furness:

This was even before the current administration.

Robert J. Marks:

I see.

Thomas Furness:

And so all of our money, this next traunch of funding was going to come from China, because they were the market. They were going to be where we introduced it, because we thought, "Well, why would China want this?" Because they have the traditional Chinese medicine practitioners.

Robert J. Marks:

And it would be more open to Chinese sort of culture.

Thomas Furness:

Yes. Yes. Not only that, the traditional Chinese medicine practitioners, of which there are about 100,000 of them, said, "We want this, and the reason we want it is we have no way of documenting what we've done. It's just one of those things. We go feel the patient and give them some herbal medicine to make them better. And this way we have a record of it, and not only that, we can give them this system to take home so that we see what happens during the day."

Robert J. Marks:

So you could make it that cheaply then?

Thomas Furness:

Yeah. Oh yeah. Yeah. It was going to be... Really, the most important part of it was the database. I mean, that was the most valuable part of it. And so we would make these things for, they'd be 15 bucks kind of thing, and in quantity and then it would communicate with the Cloud and access this database and the machine algorithms and things like that. And it'd spit back to you what was going on and what you needed to take in terms of herbal medicine. Now these are Chinese herbal medicine, which is different than what we get at the drug store here in this country.

Robert J. Marks:

Yes.

Thomas Furness:

Now, the other reason they wanted to do this is because they wanted to be legitimatized in Western medicine.

Robert J. Marks:

Of course.

Thomas Furness:

Because they're looked upon as sort of spooky medicine. And that was another reason for this.

Robert J. Marks:

Well, I even know the chairman of our department has a son that's both a medical doctor and practices acupuncture. And I know acupuncture has had the same sort of pushback.

Thomas Furness:

Yes. Yes. Absolutely.

Robert J. Marks:

Mm-hmm.

Thomas Furness:

And so anyhow, this guy, by the way, also practices acupuncture and we've talked about that too, and how it's relevant in this situation. So anyhow, that started the Pulse Tectonics company with all these different variations. It's sitting there ready to go once we can get the money. We were trying to raise like $5 million to take it to the next step to where we can field a bunch of units and start building our database with that. So that is another spinoff that came out of the RATLab. There is another one that is sort of interesting. A colleague of mine, again, the guy that I worked with on this XPRIZE, who is a physician, MD PhD neurologist, we were really interested again about vision and what's happening with the retina. And here in the RATLab, we took one of the bedrooms and we converted it into a chamber, a light isolation chamber, to measure the light that comes out of the eyes.

Robert J. Marks:

Out of the eyes?

Thomas Furness:

Yes. We know that photons go into the eyes, and, of course, the quanta of energy is released in the retina using the Dobson molecules that send electrical signals eventually to the visual cortex. But we looked at the structure of the optical pathways and we said, "Hmm. There's almost like a U-turn there." And we're wondering if there isn't a feed forward loop. So we built this chamber. We put in some detectors, photon detectors, cooled detectors, and we started measuring photons that come out of the eyes.

Robert J. Marks:

Now clearly there's not enough photons coming out of the eyes where you can see somebody in the dark, is there?

Thomas Furness:

No. No. This is what was called ultra-weak photon emission. And so you have to use photomultipliers in order to count these photons, but it's clear that there are photons that come out of the eyes and these are in the visible spectrum. These are not a byproduct of a normal metabolism, infrared or whatever.

Robert J. Marks:

Yes.

Thomas Furness:

So that is another area that we're continuing to explore, because if there's something there, if this has something to do with what's going on with brain chemistry, then we have a portal, potentially a diagnostic portal, into the brain, especially with people that may have cognitive impairment, mild cognitive impairment, Alzheimer's, things like that. So again, this is one of those stumbled upon kind of deals. But, I could do it in a RATLab, and I could do it cheaply and not have to worry about going through the whole university system.

Thomas Furness:

And so that was another reason for having it. I can tell you some more stories. For example, I was hired by a company, to be unnamed, to actually build a virtual cockpit for them for a new search and rescue helicopter. And so one of the bedrooms, we converted into a helicopter simulator, and this was a virtual

cockpit for helicopters, because the real problem with search and rescue is these pilots are flying in these awful conditions, weather conditions, and they don't see. And we were going to provide a way for them to see and a way to hover, station keep, rescue people, things like that.

Thomas Furness:

So we built a simulator to test some of our ideas like I did at Wright-Patterson Air Force Base and had developed a whole new way of providing a cockpit for helicopters. So in the process of all of this, my rats were getting all kinds of experience.

Robert J. Marks:

Mm-hmm.

Thomas Furness:

And then they went on, the ones that went on from there, well, they loved it, and then they used that as a stepping stone to get the responsible jobs in industry.

Robert J. Marks:

Excellent. Excellent.

Thomas Furness:

And several of them I'd send to Australia and New Zealand to work on their graduate degrees based upon the experience they did here.

Robert J. Marks:

So that's where you got the HIT Labs at the University of Canterbury and the University of Tasmania, right?

Thomas Furness:

Well, yeah. I mean, there is a story about the HIT lab, especially in New Zealand. What happened, of course, when I was working in my office at the university and I got the call from a Dean's office saying, "There's a delegation here from New Zealand who would like to come see your lab."

Robert J. Marks:

Uh-huh.

Thomas Furness:

And I said, "Okay." Apparently they had, I don't know, they'd found something online and they thought it was interesting, and so they came. And I found out that they were members that Seattle and Christchurch, New Zealand are sister cities. And they were up here as part of a sister cities delegation with the mayor and some university folks and the so-called Canterbury Development Corporation, which was basically their government incubator kind of thing to start companies in New Zealand. And so they show up in my lab, and I show them around, tell them what I'm doing, and they spout off all these companies, and we're doing this multi-disciplinary, transdisciplinary activity that where we're generating all the patents, things like that. And they said, "Can we do that?" Now, at that point, I thought, if I play this right, I'm going to get a free trip to New Zealand.

Robert J. Marks:

New Zealand's beautiful, too.

Thomas Furness:

It is.

Robert J. Marks:

Yes.

Thomas Furness:

And so, I'd been there when I was in the Air Force. I actually had worked with the Royal New Zealand Air Force some. And, and as it turns out, one of my PhD students in electrical engineering, actually, Mark Billinghurst, was about to finish and graduate in EE, and I introduced them to him. And I was looking around for a job for this kid. So anyhow, maybe I told them, "Maybe I should go to New Zealand and check it out." And they said, "Oh, would you? Would you come? I mean, we'll fly you down business class. Bring your wife. You can take some time off and get around and things like that." And I said, "Oh, maybe I'll do that."

Robert J. Marks:

Yes. The beaches in New Zealand rival those in Oregon. They're just beautiful.

Thomas Furness:

Yeah. Well, as it turns out, when I got down there and they showed me around and we had a blast just driving around the countryside, and they asked me, "Well, what do you think?" I said, "Well, maybe I should come back. I have a sabbatical coming up and I could spend six months here taking a look and see what we can develop." So they offered me an Erskine fellowship to come back and spend six months. And then they introduced me to the prime minister, the deputy prime minister, all of the ministers. And the government said, "We're going to do this. And we're going to form two entities," the HIT Lab New Zealand Research Center, hosted by the University of Canterbury, and the HIT Lab New Zealand Limited, a company owned by the university and by the University of Washington that would develop the technology once it happens in the research center.

Robert J. Marks:

And let's remind listeners that HIT Lab stands for Human Interface Technology.

Thomas Furness:

Right. So what happened? We started the lab. And, oh, by the way, one of the things that had to happen is I needed to be in New Zealand every year from January to the end of March during the winter quarter.

Robert J. Marks:

Oh, I'm so sorry. That's when it rains in Seattle, right?

Thomas Furness:

Yeah. And other things.

Robert J. Marks:

Our joke used to be it's like living in a carwash during that period.

Thomas Furness:

Pretty much.

Robert J. Marks:

Yes.

Thomas Furness:

And so the New Zealanders gave us a permanent residence visa. We bought a home and we lived in New Zealand every year for three months during that period of time.

Thomas Furness:

And we started a lab, it's booming. My student became the director, he stayed for 12, 13 years. Now we have a new director. They have gobs of money, gobs of students, generating the spinning off companies and it's wonderful.

Thomas Furness:

Now what happens is the Aussie's see this, Aussie looks over the pond and says, "What are these Kiwis doing?" And they came over and said, "Gosh, if the New Zealand people can do this, surely we can do it."

Robert J. Marks:

Of course.

Thomas Furness:

So they wanted to start their own HIT lab that would be a sister to the New Zealand lab and to the HIT lab at University of Washington. And so they did, they started one in Tasmania and it didn't grow as fast, but another one of my PhD students in electrical engineering became involved in that one.

Robert J. Marks:

My goodness.

Thomas Furness:

Yeah, so that's how it happened.

Robert J. Marks:

So Dr. Furness, we have been talking about a number of fascinating things, but there's still some things that I'd like to talk to you about.

Robert J. Marks:

Another one is ARToolworks. Now AR here stands for augmented reality. I believe that augmented reality was actually a term coined by Tom Caudell when he was at Boeing. But what is the ARToolworks? What are you doing there?

Thomas Furness:

Let me stop back a little bit. When we were beginning the work in virtual reality in the Air Force, we really didn't call it that. We called it visual coupling systems. And there was no differentiation between VR and AR.

Thomas Furness:

Now the difference really is between VR is generally where you are completely immersed in a computer generated environment, that's all you see is the computer generation images. AR, on the other hand, is where you see the real world, the physical world, but you're able to superimpose on top of the physical world images generated by the computer.

Thomas Furness:

Now that can be done one of two ways. It can be done as a video based virtual reality or augmented reality. And that's what the Pokemon Go was where indeed you were seeing a video scene of the outside world, but then you had the Pokemon figures on top of that or embedded in it.

Robert J. Marks:

I remember that was a really big thing. And there were pictures of people walking off cliffs and stuff while they were doing their Pokemon Go stuff.

Thomas Furness:

That's right. And then there's another augmented reality where it's basically an optical combining. So you actually see through, you see the outside world through a medium through which it's transparent, but at the same time you see computer generated information. So you're actually not looking at a video of the real world. You're looking at the actual real world.

Thomas Furness:

So that's the difference between the two augmented reality, the video based and the direct view or the see-through of virtual or augmented reality.

Thomas Furness:

So it turns out the easier one to do, I mean, in the early days we were with head-up displays and most of our displays that we're using in the cockpit are head-mounted displays were actually see through. You could see the outside world and then see the virtual information on top of the outside world in daylight. But at night, what we would do is basically all you can see is the virtual world. So to us, it was really a spectrum where we went through complete see-through to complete VR.

Thomas Furness:

And so we never differentiated between the two. But as the technology evolved over a period of time, there was this notion of Tom Caudell, indeed a project that we did with Tom at Boeing, was where we

were looking at the wiring harnesses. How we could use augmented reality to help manufacture wiring harnesses for the large body aircraft.

Robert J. Marks:

So this was the wiring sort of schematics for Boeing aircraft?

Thomas Furness:

Yes, very difficult to do this when you, the traditional way of just putting wires on top of a blueprint, but with augmented reality, you would see a loom that contained these pegs where are you're going to stream the wires. And you see one wire, virtual wire, superimposed over that. And all you had to do is just look at that one wire and string it through this particular set of wiring looms to get there.

Thomas Furness:

It was a breakthrough and that's what we called, we started calling this augmented reality to differentiate it from where you didn't see the outside world, it was all computer generated.

Thomas Furness:

So what happened in the late 1990's, I had a graduate student in conjunction with the HIT lab in New Zealand, Mark Billinghurst, he was a PhD student in electrical engineering, and we were playing around with how do we provide a way to interact with virtual images?

Thomas Furness:

Because what we were doing at the time was we're trying to use these hand controllers to reach out and grab things. But we became interested in how could we use objects as a means, tangible objects, as a means of doing this interaction.

Thomas Furness:

And we could use computer vision technology to actually track these tangible objects and have them interact with the images. And then the idea came to mind, well, why don't we just put the images over the top of these objects? And so this became what we called, what we began to call video based augmented reality.

Thomas Furness:

And so what would happen is let's say that you would have these special glasses that you'd wear, you put on these glasses and they have a television camera in the middle between the two eyes. And then what would happen is we'd display that image to the eyes.

Thomas Furness:

So basically what you have is a video view of the world. And then we take an object, for example, a piece of cardboard or a piece of paper that had a black square in the middle of this. And there would be a symbol in the middle of the black square.

Thomas Furness:

And when the camera that we're wearing on our headset saw the black square, it started tracking it. And by looking at the edges of the black square, it could determine the pose or the orientation and position

of that black square relative to the headset. And then what we said is, okay, there's a symbol inside of that black square. That meant something. And so we would recognize that symbol, a particular character and that meant an object. We would extract that object from a library of three-dimensional objects and we'd superpose it in the black square.

Thomas Furness:

So now it appeared that that three-dimensional object was like super glued to this card. And as you move the card around, it tracked perfectly. It was like it was really there, but it wasn't there. And this became the beginning of what we call the ARToolkit.

Thomas Furness:

And so what you can do is build them. Build these objects, objects can interact with each other. You can build a whole system - it's like Legos - of this, that you see the real world, but you see these virtual objects in the real world, depending upon where you place these tangible markers, these tangible card markers.

Thomas Furness:

So in the late '90's, I think it was actually '98 or '99. We had an exhibit at SIGGRAPH in the emerging technologies section of SIGGRAPH, where we demonstrated this. And we actually had a memory game. We had set out where you'd have two players who would be wearing these glasses and a big table.

Thomas Furness:

And then you'd have these cards that you would turn over. And let's say that you would turn over a card and you would see a spaceship, you see a flying saucer, and then you'd turn over another card and you'd see a broom or something like that. And they didn't match so you turn those back over. And then you go around playing this game and then you turn over a card and there's the flying saucer again, you turn over another card and there's an alien. And then you bring the two cards together and the alien jumps into the flying saucer and it starts flying around the room.

Robert J. Marks:

I see, okay.

Thomas Furness:

So it's the Memory Game only with a difference. And so that's what we demonstrated at SIGGRAPH and everybody just went ape over this. This way of using tangible markers as a means of manipulating computer generated images that appear to be there on those markers.

Thomas Furness:

We built teleconferencing where you could actually flip over the cards and call a person and they appear on top of this card and you put them around your desk. So you're interacting with these people in 3D around your desk, little miniatures of these people.

Thomas Furness:

And we were also, we had one big card that we made in our lab that when you walked in, if you had these glasses on, is the Millennium Falcon. So you see the real room, you see the real lab, but the

Millennium Falcon is sitting there in the middle of it. And you can walk around it, and the Star Wars Millennium Falcon.

Thomas Furness:

Anyhow, that got us started. And so we started this company, we built ARToolkit at the University of Washington, and then we released it open source and we had a hundred thousand downloads.

Robert J. Marks:

So is this still available for open source?

Thomas Furness:

Yeah, it is.

Robert J. Marks:

Do you know the website off the top of your head?

Thomas Furness:

It was through Vuforia for a while. I don't know what it is now, actually what the latest one is. I'll have to let you know.

Robert J. Marks:

Okay, thanks.

Thomas Furness:

And so what happened was we had all those downloads and we're thinking, maybe we ought to start a company. And so what we did was we started a company called ARToolworks, Inc. The idea, we were going to take the open source thing and rewrite it and support it, sort of like Unix and Linux and so forth.

Thomas Furness:

And so we did that and started this company. It was the very first augmented reality company. It started in 2001 and existed until about 2015 when we sold it to DAQRI. And then DAQRI worked on it for a while and then DAQRI went belly up.

Robert J. Marks:

Oh, no.

Thomas Furness:

But you could still get it, I guess, but this has become the foundation for just so many other companies have taken this and built other approaches for doing this kind of thing.

Thomas Furness:

Same kind of thing. Matter of fact, there's one company that split off from my HIT lab in New Zealand called Quiver. And then you can go online, Quiver Vision, go online, Quiver Vision and you download these little, it looks like a coloring book. And what you do is you can print out this coloring book and

then you have your kids color those with crayons, and then you take your phone or a VR device and you look at that page that you've colored and now it pops into life. That's textured mapped, the objects are textured map of what you colored on that two dimensions onto a three-dimensional figure. And they do various things, they play games and things like that. And that's called Quiver Vision.

Robert J. Marks:

That is so interesting. I got to ask you now about your NSF project that we talked about offline. That sounds so incredible.

Thomas Furness:

Well, what happened in the early days, again, when I was working on virtual reality, we found that it was pretty amazing what was happening in a far periphery. That indeed we were taking in lots of information from the peripheral retina that we weren't necessarily seeing. And so when I did finally come to the University, we had a project that was funded by Eastman Kodak and Eastman Kodak was trying to build and based upon basically a plan that I gave them, what was called a world vision system. And a world vision system and I sort of convinced them to do this because you know what Eastman Kodak is I convinced them, I think I was trying to convince them, I gave them a keynote address at their annual award ceremony. And the theme of my talk was that Kodak is really, this is when Kodak still existed, that actually you guys are actually in the transportation business and not in the image business.

Thomas Furness:

Why are you in the transportation business? Okay, let's say, I'm sorry for this story it's going to take a little bit.

Robert J. Marks:

That's fine.

Thomas Furness:

So here we have, let's say that we have this amazing Kodak technology, film technology. And so let's say you're taking your family for a visit to the Grand Canyon. And so you're driving up to the Grand Canyon, you stop in the parking lot and park your car, you go outside and to the rim of the Grand Canyon, you whip out your camera, that has Kodak film in it. And then you take these photographs and then you go back home and turn in your roll of film to your drugstore. This is when camera's still had film. And then you get your prints back. And then you look at the print and you think, it's not the same as being there. And you show it to your friends and you tell them, well, you just sort of need to be there.

Thomas Furness:

And I said, that's the business you're in. What your business is you're taking our eyes to another place in another time. The problem is the vehicle you've built to take our eyes to another place and another time has really small windows.

Robert J. Marks:

Oh, yes.

Thomas Furness:

And what you need to do is build a transportation system that lets you open the door, walk outside and be there and be there again and again and again, and take your friends so they can be there. And what you need is a world vision system.

Thomas Furness:

And then what I did was I outlined a whole program for them to build a world vision. So I was doing this just for fun, just to give a talk. And I had my outline the role of the world acquisition system, the world's synthesis system, the world delivery system, the networking, all of that in this talk.

Thomas Furness:

Well, after I finished this executive vice president from Eastman Kodak comes up to me and says, have you written this down? And I said, not really I mean, I was just doing it for this talk. And he said, would you mind putting together a concept paper for us on this world vision system? And I said, oh, sure, I'll be happy to do that. So I did and sent it to them and they started a $20 million program and they awarded the University of Washington, the HIT Lab, the largest project that was ever done with a university.

Robert J. Marks:

Now, who was this? Who was the sponsoring organization again?

Thomas Furness:

Eastman Kodak.

Robert J. Marks:

Oh, that was Eastman Kodak? I see, okay.

Thomas Furness:

And so we started working with them and the first question they wanted to ask us is, "Well, how good does it have to be, that you feel like you're there?" And so we started doing research on this. Okay, how good does this picture have to be? And we started simulating various devices that would give you wide field of view and high resolution, things like that. But the problem is how do you measure? What is the dependent variable?

Thomas Furness:

Because what we'd used up to this time is all subjective. You say, "Do you feel like you're there on a scale from one to 10? Do you feel present? You feel immersed?" All this. And of course, there's variability all over the place in this subjective assessment. And we realized that we needed an objective assessment for this. So we came up with this scheme of let's measure postural stability. Let's measure how we can affect the balance of a person as a function of how big a picture is and whether it moves and what is the resolution of it, things like that.

Thomas Furness:

Because this is a direct connection to basically the central nervous system through the postural stability mechanism from our eyes. So, that's what we did. We built a posture platform, people would stand on it, they were in a harness because we'd knock them off their feet. And we would display these different fields of view to them up to 180 degrees.

Thomas Furness:

And sure enough, what happened is as we increased field of view, the effect kept increasing. Which meant that we had more and more presence with a wider field of view than we gave them. But our instrumentation was limited to 180 degree picture because we're using a rear projection hemisphere. We're projecting on this for our studies. And I decided we're going to have to eventually go back and extend the field of view because it's still going up. It hadn't asymptoted in terms of the effect.

Thomas Furness:

I thought it would asymptote by that based upon the work I'd done in the Air Force, but it didn't. So here recently I went back to visit this again, I'm really intrigued what's going on with a peripheral retina, especially since recent research shows that the retina extends way beyond that 180 degrees. And indeed at the rim of the retina in an area called the ora serrata, there is a rich ring of cone receptors, which gives us a highly detailed color vision. Just right on the rim of the retina. So why is it there? Because what happens is the limit of detectability is really around 100 degrees, all facets, which is 200 degrees. We were able to only go in our research with 180, but I was interested in what happened beyond that. This NSF grant was to help me explore that.

Thomas Furness:

And so we started doing the research to say, "Okay, what is the limit of detectability?" And so we extended the range out to where we can go all the way out to 240 degrees field of view. And we found that pretty much around 101 degrees is where people stop seeing visual images. So at 100 degrees centricity, which is one axis, you add that together to about 200 degrees is the limited detectability. So if you go beyond that toward the rear, you don't see it anymore, right.

Robert J. Marks:

Yes.

Thomas Furness:

And we start from the rear and go front that's when you start seeing it again. So there's a little band there of the limits of detectability. We said, okay, that's interesting. What if we display something beyond that? The limit of detectability, because the rim of the retina is way beyond that.

Robert J. Marks:

Really? Okay.

Thomas Furness:

Okay. And so what we did, we did these experiments where we display different objects in the far periphery beyond this limit and asked the subjects to identify what object we presented. And they said, but I can't see it. We said, that's okay. Tell us what you think it is. And they get it right.

Robert J. Marks:

Seriously?

Thomas Furness:

Yes.

Robert J. Marks:

That's amazing.

Thomas Furness:

So this is what is called perception without awareness. Now it's obvious that this information is being processed in the brain somehow, but it's not leveled, not in our consciousness. Now it's probably processed in other ways, but we believe, and this is where we're continuing to do our work, that this may be a direct channel to some of the subconscious and to the limbic system and to the emotional state and actually help you establish where you are.

Robert J. Marks:

Now, I'm not familiar with the system that you talked about.

Thomas Furness:

Limbic system, this is sort of the emotional side of people. And this is, we're particularly interested in that because that's where stress comes in and perhaps pain, things like that. So it's conceivable that we can build devices that are inconspicuous, display devices where it's inconspicuous that only display information to the far peripheral retina that you don't realize that are even there that can help heal you.

Robert J. Marks:

That's incredible, Tom.

Thomas Furness:

Yeah. So that's what we're continuing to do. In what we call the Ben Lab, which Benjamin Hall at the University and with an NSF sponsorship.

Robert J. Marks:

That is really amazing stuff. And you're going to be doing experiments in this, I guess, with psychologists.

Thomas Furness:

We are, oh, yes.

Robert J. Marks:

Goodness, that's incredible.

Robert J. Marks:

Well, let me ask you one final question about what do you think the future of VR is going to be like? We see stuff in movies, like in The Matrix where there's total immersion, you have no idea you're in a virtual reality world. I don't see that ever happening, but Elon Musk just came out with something where he sticks wires in your brain. I've decided that he's not going to stick any wires in my brain because I think it's kind of wacko stuff. But what do you see the future of the technical reach of virtual reality in so far as total immersion?

Thomas Furness:

Well, I believe that indeed, we aren't going to stick wires in the brain, but they're already there. We're born with them. It's called the optic nerve.

Thomas Furness:

We have the most amazing optical coupling to the brain that you can imagine. We also have an amazing coupling of a chemical sensor to the brain, which is already there, which is olfactory bulb. We have gazillions of sensors in our skin, the largest organ of the body. It's already there, the interface is there. So what we need to do is just figure out a way to stimulate those sensory end organs that provide us this picture. We don't have to put wires into the brain, it's already there. And so what we need to do is just figure out a way to do the optical coupling. And that's what we're talking about with these virtual visual displays, virtual acoustic displays and virtual olfactory and whatever, the different senses.

Thomas Furness:

So I think that what will happen is we will realize that that is a way to go. Now, let me back off a little bit. It's easy to get intoxicated by all this stuff. It's easy to get intoxicated about virtual reality because you've had the experience, you put the headset on and by the way, that's a sacred moment. The first time you put a headset on a person and they experience VR for the first time, it's sort of, it's a holy moment because they'll never be the same after that.

Robert J. Marks:

It's like remembering where you were when Kennedy was shot, or the space shuttle exploded, all of those other things. Yeah.

Thomas Furness:

And that's what we found over the years. And especially all the educational projects we've done. I've done 10 different projects with kids in education using VR. It's amazing.

Thomas Furness:

What we found is the kids that were failing caught up with the smart kids and we test them a year later and they were better. And it all has to do with the awakening of the spatial memory, and that's what VR does. Once you've been in a virtual world, you never forget it, it's just like you were talking about.

Thomas Furness:

And so it's a very powerful meeting. We're playing with fire and we're unleashing enormous power in terms of the ability to influence people, because we're putting these images in their head that will never go away. And we're doing that by putting them in a place. We're putting places in people by putting people in places.

Thomas Furness:

And so we have to be responsible for that. And that's one of the reasons why I did the Virtual World Society is because we need to not go to the default of building games of violence that people will play in VR. We need to be using VR for education.

Robert J. Marks:

So tell us about this society. It is a society that you founded, right? And this is its mission?

Thomas Furness:

Yes, the Virtual World Society mission is really to do three things. One is unlock intelligence, link minds and lift hearts. And it's all for humanitarian applications of virtual reality in education, in medicine, in design to lift mankind.

Thomas Furness:

Whereas the default of industry is to tear terrorists down by practicing killing people. And if you kill a person in VR, it's different than killing a person on a computer screen because you're up close and personal. And when you blow out their brains, it's different. And what happens as a result of that is you either have nightmares or you get numb.

Thomas Furness:

And so what I'm trying to do in the Virtual World Society is all of these projects that show the positive aspects of what we can do with virtual reality in education, building what we call a learning living room. This is where we have thousands of families around the world who are basically VR laboratories that are using VR for educating their families, as well as coupling with the other families that are doing this.

Robert J. Marks:

You're right. I can see that breaking down social barriers.

Thomas Furness:

Yes. And it's amazing and generating empathy. I mean, when you go, and New York Times has done this. If you're a subscriber of the New York Times, you receive in the mail this Google cardboard. And you basically assemble this and put your phone in it, your smartphone, and then you can download these different experiences. One of them was a food drop in Africa. And here you are standing on this field with all these other people from a village waiting for the C-130 to fly over and drop food.

Thomas Furness:

Wow. That changes your life. You'll always remember it, you'll see the faces of those people. What happened when they rushed to the packages and you're there in the middle of it. And this is transformative in terms of generating empathy in what is going to be the future of news because you're going to be there.

Thomas Furness:

So I think that, again, the Virtual World Society, we're just a fledgling society. We have about 1200 members now. But these people are really keen on doing humanitarian things. They want to build these worlds that educate and lift. And I mean, we're doing work with the Make-A-Wish foundation. We're doing things for helping communities who have a problem of social unrest. With people who are isolated because they have dementia or because they're locked into a nursing home or in a hospital. And so this is the area where there's a huge market for VR. I'm trying to point the way to industry to say, "Hey guys, there's a whole market out here. We don't have to default to games of violence."

Robert J. Marks:

Where would you go to find out more about the Virtual World Society? And can anybody join?

Thomas Furness:

You bet, and you can join for free. So you just go online to www.virtualworldsociety.org and their amazing newsletter about what we're doing and a community where we built a platform called we make reality for kids who want, or people who want to be involved in building these worlds and so forth.

Robert J. Marks:

Excellent. We'll put a link to that on the podcast notes. So I guess virtual reality is like any technical tool. It's not good or bad, it's how you use it.

Thomas Furness:

Absolutely. And that's why we need, as a civilization, to be responsible for these tools. It's not going to replace what's out there now. I mean, it's just going to be just like television didn't replace radio. And so it is just another tool in our arsenal to help us grow and progress and make the world a better place.

Robert J. Marks:

Dr. Thomas Furness, what a wonderful note to end on. You've led a full and rewarding career in virtual reality, being one of the big pioneers and also leading innovations in it. And you got to have a good feeling about living a life like that. Congratulations, sir. It's really, really good stuff.

Thomas Furness:

Thank you. I'm a lucky guy.

Robert J. Marks:

Yes. You know, when you're able to use the gifts that God has given you for the good of mankind, it's a good life.

Robert J. Marks:

And also Dr. Furness and I, we share something in common, our wives won't let us retire.

Thomas Furness:

That's right.

Robert J. Marks:

You were in a trial retirement and your wife said, "Nope, you can't do that." So you got to keep on working. I was talking to a friend of mine at church, and he said, nowhere in the Bible, did they mention that people retire.

Thomas Furness:

That's right.

Robert J. Marks:

And I told my son, of course, I told my son that. He was happy to hear that. But I did say that it does talk about kids taking care of their parents when they get old. So maybe that will kick in somewhere.

Thomas Furness:

It's better to wear out than to rust out, right?

Robert J. Marks:

Exactly. We've been talking to Dr. Tom Furness at the University of Washington. He's a professor there, an innovator in virtual reality and augmented reality, and is sometimes dubbed the grandfather of virtual reality. And Tom, it's been a delight to talk to you.

Thomas Furness:

Same here. Thank you, Bob.

Robert J. Marks:

Okay. So until next time be of good cheer.

Announcer:

This has been Mind Matters News, with your host Robert J. Marks. Explore more at mindmatters.ai. That's mindmatters.ai. Mind Matters News is directed and edited by Austin Egbert. The opinions expressed on this program are solely those of the speakers. Mind Matters News is produced and copyrighted by the Walter Bradley Center for Natural and Artificial Intelligence at Discovery Institute.

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PART 4 OF 4 ENDS [02:13:55]