"BIONICS"
SHOW 401

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EPISODE OPEN

ALAN ALDA (ON CAMERA) Hi, I'm Alan Alda, about to launch what promises to be a challenging new adventure as host of Scientific American Frontiers. This is just one of the strange machines we'll be meeting in a show that's all about making humans, in a way, superhuman.

ALAN ALDA (NARRATION) We'll also meet some super humans, like Eric - a machine helps him walk again... We'll see machines that sustain a failing heart, and restore damaged sight... And we'll meet the people who can control machines - just by thinking.

ALAN ALDA (ON CAMERA) I'm Alan Alda, join me for the season premiere of Scientific American Frontiers.

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NERVES OF STEEL

ALAN ALDA (ON CAMERA) That's Dan Kemp on the table in there: Army veteran, quadriplegic and as I think you'll see, a remarkable person. Dan is one of the people we'll be meeting in our first story, which is about something that scientists have been trying to do for at least two hundred years - to control and manipulate the human body, using electricity. Of course, the dream has always been to somehow heal the paralyzed, to make the lame walk. Well, this is one of the very few places in the world where we can begin to glimpse the reality behind that dream.

ALAN ALDA (NARRATION) Today, Dan Kemp lives with his family in a suburb of Detroit, Michigan. Six years ago, he was in a jeep rollover accident - and this is the result. Dan's spinal cord was permanently injured, leaving him with no control over his legs and only limited strength in his upper body. The doctors said he'd never work, never have children, never be mobile - but he's steadily been proving

them wrong. With a partner, he's developed a successful lawn-mowing and snow plowing business; his daughter's now five...

ICE CREAM MAN Seventy five, sweetie.

ALAN ALDA (NARRATION) ... and he's working on the mobility, with support from his wife and biggest fan, Brenda.

DAN KEMP We got married after the accident, so that can tell you a lot about her moral character. She bought the whole package, not just the outside wrapping. The first thing that I'd like to do when I finally do stand, would be to stand up, look my wife in the eyes, and give her a big hug.

DR. MARSOLAIS What I'm trying to get is his gluteus maximus muscle.

ALAN ALDA (NARRATION) For his next goal, Dan's going to need the help of Dr. Byron Marsolais.

ALAN ALDA (ON CAMERA) Now, what you're inserting into the muscle, that's not the electrode itself?

DR. MARSOLAIS No, no, this is just a little probe.

ALAN ALDA Right

DR. MARSOLAIS A very tiny probe.

ALAN ALDA And the reason you're doing this is to see if you can get the muscle to react, to give its greatest response?

DR. MARSOLAIS Exactly, and I want just the right muscle, that's the muscle we want, it goes right down here into the femur.

ALAN ALDA Yeah

DR. MARSOLAIS Which is the big leg bone, and you see how it's beginning to jump there, it's beginning to do what we want. I think I can do better, and in order to do better I have to get it right beside the nerve.

ALAN ALDA (NARRATION) There's nothing wrong with Dan's muscles - it's the nerve-brain connection that's the problem. That's why he feels no pain during the procedure. Normally fifty muscles are involved in leg movement. In Dan's case, sixteen will be controlled by eight implanted electrodes. If ail goes well he'll get back limited use of his legs.

DAN KEMP If you don't use it, you lose it and you know, it stands to reason the more I can use, the healthier I'll stay, and longer I'll stay healthy.

ALAN ALDA (ON CAMERA) Now, I think Dr, Marsolais looks like he's found the spot here.

DR. MARSOLAIS That looks pretty good. Yeah. We're getting a pretty, good, tight...

ALAN ALDA Yeah, I can see it.

DR. MARSOLAIS See how that jerks things together?

ALAN ALDA That looks about an inch and a half from where you were first searching for it.

DR. MARSOLAIS Yes, that's right, we're, although we're angled a bit down, we started about here, and now we're about here, but, so we were a good inch away.

ALAN ALDA (NARRATION) Now the permanent electrode, with a wire as thin as a hair attached, can be implanted. The electrode's not much bigger than a pin, and it's at the tip of this tube, which will be removed once the electrode has been placed right at the point of maximum muscle stimulation.

DR. MARSOLAIS Measure. Now we bring this down to exactly the position that we were before.

ALAN ALDA (NARRATION) This is an experimental program - so a question occurred to me...

ALAN ALDA (ON CAMERA) How do you feel when you're going through this? Do you feet a little bit like a guinea pig?

DAN KEMP Yeah, I do, but it's well worth it. You know, and down the road, people will be able to look back, and say if it wasn't for people like me, that they wouldn't have gotten as far as the, I've gotten in the new procedures. So it goes down the line.

ALAN ALDA Yeah

DAN KEMP Everybody helps everybody else, whether they realize it or not.

DR. MARSOLAIS These patients want to see the paralysis licked. There is no question about that. And they want to see it not only for themselves, they want to see it for everybody else. And they're willing to give their time and their bodies toward that goal. Because it is a big sacrifice, but it's the only way that this war can be won.

DAN KEMP Okay.

KENDRA Now Dad?

DAN KEMP O.K. Hit the "G" button.

ALAN ALDA (NARRATION) Back home, Dan and Kendra begin his daily routine, using a computerized box to control the impulses which stimulate his leg muscles.

DAN KEMP O.K., you ready?

KENDRA Go!

DAN KEMP Go! Here they go.

KENDRA Here they go.

DAN KEMP Thank you very much.

ALAN ALDA (NARRATION) An essential part of the system being developed by Dr. Marsolais and his team is exercise - and that's what's happening here. Right now the control box is automatically working Dan's quad muscle group, at the front of the thigh. It's good they've been able to turn it into a game, because Dan has to do this for a minimum of an hour every day. Once a week, Dan returns to the Cleveland VA Hospital, where the research is based, for a session with the team's physical therapist, Paul Miller. Within a year, the control box will transmit its signals directly through the skin. So these external connectors - difficult to maintain and keep clean - won't be necessary. The joystick controller is designed to be used by patients with very limited strength. Here Paul selects an exercise program, then records the muscle power and endurance. Five months ago, Dan could do this for just seconds at a time - now he can keep going for an hour or more. He's about to the point where he can attempt a real task, like standing up.

PAUL MILLER When you're stimulating a muscle or contracting a muscle that hasn't been used in five, ten years, it's like starting ail over again, like a little baby. So, we have to build the strength so that they have enough strength to do a functional task.

DAN KEMP Sitting around after six years of not doing anything and seeing your legs start moving, and feeling the fatigue after a while, it gets you back into a normal pattern of life. It's a great feeling, it really is.

ALAN ALDA (NARRATION) We'll come back to Dan in a minute. First, meet Eric Bellamy. A motorcycle accident five years ago left him paralyzed from the waist down. He's one of six people currently using the largest implant system, with over 50 electrodes now in place. Eric's a kind of pioneer.

ERIC BELLAMY You can't count life out until you go out there and try it. And swimming is something to try, all sports is something to try, anything that gels you in better shape physically and mentally. Life's still out there.

ALAN ALDA (NARRATION) Life is still out there - but the problem is getting at it. Access has improved in recent years, but for Eric a small increase in mobility would make all the difference.

ERIC BELLAMY I see being in a chair always, but I see being able to go up steps, and knock on the front door, and say, hey, you know, I'm down here. Instead of running around the house, and screaming you know telling the guy, hey I'm here, I'm here. I see, even convenience stores, one step you know. So being able to get up and go through this narrow door to get into the bathroom. Just for them answers. If they can come up with that right there, just, your life's in a chair, but being able to overcome difficulties would be a tremendous step. And that's what we're working on right now.

ALAN ALDA (NARRATION) On the outside, Eric's system looks like Dan's. But on the inside it's much more complicated - both within the control box, which right now is programmed to handle 41 of the fifty implanted electrodes, and within Eric's body, where a network of wires runs under the skin from above the waist to below the knees. Why so complicated? Because Eric's system is designed for walking. The first thing to do: Eric selects "stand" and "walk" from the controller's menu of programs. Then he'll hit the "go" button.

PAUL MILLER Okay. Go ahead and stand up.

ALAN ALDA (NARRATION) The controller goes into its pre-programmed walking cycle, putting out about a hundred muscle commands for every pair of steps. Remember, Eric has no natural lower body control at all. This is completely synthetic movement. But he is using his upper body strength to balance - and as with all these research patients, his muscles have to work immensely hard.

PAUL MILLER They’re using tremendous amounts of muscle mass. Their quadriceps are on 100%, their gluteus muscles are on 100%, their hamstring muscles are on 100%, their back muscles, everything is just blasted.

ERIC BELLAMY Whenever they do something, they’re using 100% of all their strength. Whether it's one step, two steps, they’re using everything they got. Like when you stand, everything goes right into it. 100% barn! Total exertion, you know. Everything it has.

ALAN ALDA (NARRATION) Now for the other key function - stairs. Today will be the first time Eric has faced a commonly found design. Eric can maneuver past the lips on the steps only by using his tremendous upper body strength. It’s an example of the biggest challenge facing the research team - the control system has to be able to adapt to a changing world. The aim is to add sensors to the feet and legs which can feed information back to the control box. Then part of the enormous burden of concentration and effort, which so far falls on the user, can be transferred to the computer control.

BUS DRIVER You guys ready to go?

ALAN ALDA (NARRATION) Eric has a personal challenge: to reach these seats unaided. Today, he's going to try, for this simple goal - for the first time. Success will bring the world at large a few crucial steps closer - to Eric and the others who'll eventually benefit from this research. Things don't look good. For some reason, Eric's left knee is not locking up. Eric and Rudi Kovetic, who programs the computer controllers, run through the muscle stimulation sequence.

ERIC BELLAMY Up left?

RUDI KOVETIC Looks like he's got enough power in that left leg, but it doesn't seem to bring him up.

ERIC BELLAMY Could be fatigue.

RUDI KOVETIC Yeah, but it looks like you have a lot of strength in that left leg.

ALAN ALDA (NARRATION) They deride to try again. This time it works. They don't know why, but artificially stimulated muscles often seem to change in strength. Now, it's back to the "walk" program.

PAUL MILLER You have to pivot bad< a little bit more.

ERIC BELLAMY I said I'm going to sit down Rudi.

PAUL MILLER Good job Eric.

ERIC BELLAMY Onward!

ALAN ALDA (NARRATION) We're back with Dan Kemp, and today's the day he'll face his personal challenge - to stand.., and to hug his wife.

PAUL MILLER You ready?

DAN KEMP I'm ready

PAUL MILLER O.K. One...Two...Three... All right! Howls it feet Dan?

DAN KEMP Oh, it feels vertical

RUDI KOVETIC You getting dizzy?

DAN KEMP C'mere. No I'm fine.

WIFE Are you sure?

DAN KEMP Yeah.

WIFE You're fine?

DAN KEMP C'mere. Gimme a hug. It's great.

WIFE Long time since I've seen you that tall.

ALAN ALDA (NARRATION) The simpler systems - like Dan's - will be the first to become widely available - fruits of this extraordinary research.

DAN That's the best feeling I've had in a long time.

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THE BODY MAGNIFIED

ALAN ALDA Machines that magnify the powers of the human body, make it faster, stronger, more agile, have been favorites of science fiction for years, and that's where they've stayed, in fiction. But recently they've been showing up in the most unlikely places.

ALAN ALDA (NARRATION) This is the Springwalker, out for a bound through a Los Angeles suburb - a long way from one of its sources of inspiration. The 1988 20th Century Fox movie Aliens starred both Sigourney Weaver and a power suit battling - and eventually beating - the Alien. The film sums up decades of pop culture images of human amplifiers - even though this suit was made of plastic and worked with the help of a strongman just out of the camera's view.

ALAN ALDA Well I can see why you call it the springwalker, but how did you get ....

ALAN ALDA (NARRATION) I recently visited John Dick and Bruce Crapuchettes, whose Springwalker was inspired by Aliens-like fantasies.

JOHN DICK I realized that I had lost faith in my childhood dreams of the idea of amplified man. I'd been following the research in the field, and it just wasn't happening.

ALAN ALDA What were your childhood dreams, what do you mean by that?

JOHN DICK I remember some books, a book I was reading as a child, it was a picture book, and it had this kid getting inside this large machine which made him powerful and strong, and able to vanquish over his childish enemies. And that was always a very powerful idea with me, and I think its a powerful idea in a lot of people. I thought of trying to do spring shoes, a kind of powerful spring shoe, but then you say how could I possibly leap tail buildings with a single bound. And the idea then came of spring shoes with levers...

ALAN ALDA (NARRATION) The Springwalker is the latest in over a century of mostly unsuccessful inventions employing springs to fun faster.

JOHN DICK Bruce could you bounce just a little bit so we can see a little bit of that action. Thank you that's good. 5o as the legs compress, they pull on the cables, pull down the spring, and then throws him back in the air for another step.

ALAN ALDA When we walk, the gait that we use, what do you think, about 20% or less goes into moving forward?

JOHN DICK Oh it would be 5% or less.

ALAN ALDA Into moving forward

JOHN DICK Yeah

ALAN ALDA 95% of our energy...

JOHN DICK 95%

ALAN ALDA goes into moving up and down

JOHN DICK That's correct.

ALAN ALDA (NARRATION) The Springwalker is designed to capture most of this wasted energy, store it in the bungee-cord spring, then release it to push the Springwalker forward as it lopes along.

JOHN DICK Well Alan I think its time for you to have a go on the springwalker, are you game?

ALAN ALDA Oh, this has been my dream ever since I heard about this. Either a dream or a nightmare, I'm not sure which. You have to strap me in I guess.

JOHN DICK Yes, we'll have to strap you in

ALAN ALDA Would you mind unbuttoning yourself?

BRUCE CRAPUCHETTES Okay.

ALAN ALDA (NARRATION) Now, the inventors know only too well that their current model isn't exactly practical. Just getting onto it - or is it into it? - is a challenge in itself.

ALAN ALDA Ah, but I found a new way for my ankle to bend. I've always relied on the courtesy of strangers.

ALAN ALDA (NARRATION) And that was the easy part

ALAN ALDA I think for a second I'm going to need Bruce's hand here. Where are you? Oh, O.K. Its funny as soon as you put this on, you go blind and you can't hear.

ALAN ALDA (NARRATION) John and Bruce liken this prototype to the first bicycles ever built - slow, cumbersome.., and dangerous.

BRUCE CRAPUCHETTES Turn sharper towards me here.

ALAN ALDA Turning is not that easy, I tend to, I tend to start hopping when I Urn. From now on it's just sort of a normal walk, just drag it along, is that it?

ALAN ALDA (NARRATION) I began to get the hang of it after a while. John and Bruce's plans include a lightweight version for jogging, and a powered machine that could carry heavy loads at up to 25 miles per hour into rough terrain. But John Dick, its chief designer, has a terrible secret...

ALAN ALDA Can I, mind if I hold onto you for a second?

JOHN DICK No, no go ahead.

ALAN ALDA Have you ever been on this?

JOHN DICK Well, I actually haven't been on as much as you have, I've stood at the wall, and pressed and felt the leg.

ALAN ALDA Why didn't you get on it?

JOHN DICK Well, my feeling is the physical insecurities that I feel on the thing get all mixed up with my actual insecurities about the viability of the whole venture, and so instead I'd rather have Bruce do it, who is a professional psychologist and a very secure person.

ALAN ALDA In other words it frightens you.

JOHN DICK Oh yes, I'm a frightened person anyway.

ALAN ALDA Because I wanted to give you a membership card to the club.

ALAN ALDA What makes the Springwalker so much fun, is how simple it is. No wires, no motors, no computers. Without wires, motors, and computers, this would just be 400 pounds of metal. But with them ....

ALAN ALDA (NARRATION) This massive arm, built by students at the University of California, Berkeley, is powered by a huge compressor hidden behind the curtain. Even on my first try, I could move it as easily as if it weighed 10 or 20 pounds. My own arm movements are picked up by sensors in the ring around my forearm, then translated via a computer into movements of the mechanical arm. A simple gripper opens and doses the hand. The arm is just one limb of a complete Aliens-like power suit the Berkeley team hopes to build that will enable people to pick up and move around heavy objects including the family sofa.

H. KAZAROONI We will not have a gigantic machine, we will not have any big, humongous machine. We want a light working machine for civilians, and that's our focus.

ALAN ALDA The reason for making it small is what? In order to, if you want to go into a house and pick up a couch to carry it upstairs, you have to be able to get up the stairs with the machine.

H. KAZAROONI That's right, not only do you have to get through the door, right, you have to get into the elevator. We are working on this problem

ALAN ALDA Do you have like a little program, a little voice box that says, where do you want it lady?

H. KAZAROONI No we don't have that, but we will actually.

ALAN ALDA The person has to come up with that on his own.

H. KAZAROONI That's the whole thing, the human intelligence is with the machine.

ALAN ALDA (NARRATION) The students are designing the whole suit piece by piece. Tanya Snyder designed the legs which - because the suit will be heavy and hard for its wearers to balance - need to be able to balance themselves.

H. KAZAROONI These are here for safety...

ALAN ALDA (NARRATION) The day I visited the lab, a test leg was balancing on its own for the first time.

H. KAZAROONI It's pretty stable and it recovers itself pretty nicely.

ALAN ALDA (NARRATION) The leg balances by bending at the knee, a computer constantly sensing its position and adjusting the angle of the thigh.

ALAN ALDA And this is balancing just on a, on a pivot, there's no artificial foot there or anything, there's no platform for it.

ALAN ALDA (NARRATION) I was pretty impressed - but the team was ecstatic.

ALAN ALDA When did you finally solve it, when did you finally get it to balance?

ZACH Satur..., Sunday, three days ago.

ALAN ALDA So a couple of days ago.

ZACH Yeah

TANYA Yeah

ALAN ALDA Were you here? You had designed the leg, right?

TANYA That's right. Yeah. I've actually been on vacation, and when I left, it was just like Zach said, it was just bouncing all over the place. And I almost, I wondered if there was any hope for it. But, I just got back today, and I saw it, and I just couldn't believe it, its so peaceful, and ifs really working, and I'm really happy about it.

ALAN ALDA (NARRATION) But like all good engineers, they couldn't resist that extra push...

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HEART OF METAL

ALAN ALDA (NARRATION) It's July 23rd, 1993. The players in this volleyball game are doctors, nurses, and patients at Fairfax Hospital in Fairfax, Virginia. Seven months earlier, one of these patients was desperately sick, with a rapidly failing heart. He'd been waiting for a transplant for over 6 months - but no matching donor could be found. For Mike Dorsey, time was running out.

MIKE DORSEY I was very sick. I'd walk from here to you, and I'd been out of breath for that time. I couldn't do nothing. It gets a little frustrating when your wife comes and takes things from you, you know, and you can't carry them, you know, she would take them and carry them in for me. I wanted to do it, but just wasn't able to do it.

ALAN ALDA (NARRATION) The sound Mike now lives with is his new heart breathing - an electric pump planted deep in his chest. It was almost 12 years ago that the artificial heart first hit the world's headlines. But Barney Clarke's brave struggle to live, and his death after 4 months, cooled the early enthusiasm for his artificial heart - the Jarvick 7. After a few more unsuccessful implants, the device was abandoned. But research on mechanical hearts continued. The most promising were pumps that wouldn't replace the heart, but boost it. One of them is called the Heartmate. The designers of the Heartmate took a novel approach to a major problem of the Jarrick 7 - blood clots that form inside, and that can kill when they break off and travel to the lungs or brain. The Heartmate's interior is roughened so that a thin layer of blood clots over its entire surface, and sticks there firmly. Mike Dorsey's problem - one he shares with thousands of others each year - is a weakening of his heart muscle so that the main pumping chamber - the left ventricle - can no longer pump blood around his body. Installing the Heartmate begins with cutting a hole in the left ventricle and sewing

in a short tube. Then the electric pump itself is implanted in the upper abdomen. Blood flows from the heart, through the pump, then back to the patient's aorta. On February 21st, 1993, Mike Dorsey's heart was near total failure. His doctors estimated he had just hours to live. Only weeks before, the Heartmate had been approved by the Food and Drug Administration for use at Fairfax Hospital in just these circumstances - to keep a dying patient alive until a donor heart could be found. The operation began with sewing into Mike's left ventricle the tube that will connect with the pump. Then the Heartmate itself is slid into place. The connection is made between the pump and the heart it will assist. Finally, the pump's outflow tube is plumbed into Mike's aorta. The pump is switched on. to keep pumping. And at this point, no-one knows for how long it will need

LEFRAK Right now this device is approved by the Federal Drug Administration as a bridging device, that is as a temporary bridge to help a otherwise dying patient to make it to heart transplantation. We're hoping that its long term role will be much greater than that, and that actually serve as a substitute for heart transplantation.

ALAN ALDA (NARRATION) Powered by batteries and controlled by a small computer at Mike's waist, the Heartmate clearly has the potential to be an alternative to heart transplantation. Seven months after the operation, it's still working fine - and Mike is still waiting for a transplant. The hospital exercise room has become only too familiar.

MIKE DORSEY It's not really me, I'd rather be moving where I have a destination to go to, instead of standing in one spot, looking at the same old scenery. This is the battery charger here, in order to be more mobile, take two batteries, these, just connect the power source from here.

ALAN ALDA (NARRATION) That's the alarm that goes off if ever there's a problem.

MIKE DORSEY There's only one way they fit in. You just drop them into the pouch like this, fold the flap down. Now I'm ready for travelling.

ALAN ALDA (NARRATION) Mike's travelling so far has been confined to the hospital - where he's become a familiar figure.

NURSE Hello Michael.

MIKE DORSEY Transplant Center

ALAN ALDA (NARRATION) To pass the time and make himself useful, Mike helps out in the transplant center. He is now an invaluable source of knowledge,

advice and reassurance for other heart patients - especially those who might also need transplants.

MIKE DORSEY I've been here since January 27th.

MAN Six months, seven months, already.

MIKE DORSEY Yeah

MAN Have you been out yet, been outside the hospital?

MIKE DORSEY Haven't left the grounds

MAN Oh

MIKE DORSEY I've threatened to, but I haven't left yet. The staff, the nurses and everything have been great, but it's almost like being in prison. I mean you gotta ask permission to do this and do that. You know. I can't just go outside my room, outside and get a breath of fresh air, without asking first, and stuff like that. It's the little things you miss in life.

LEFRAK He was desperately ill, and dying when we put the device in. The unit has allowed him to recover, so that he feels well, perfectly well now, completely different then when he entered the hospital. And of course, he feels that he shouldn't be in the hospital.

ALAN ALDA (NARRATION) But the care and maintenance of the systems that keep Mike alive mean leaving the hospital, even for a short trip - is a very big deal. A lot of things can go wrong.

MIKE DORSEY This tube down here is for the vent line so the, allows the pump to breath, in and out. It circles around, up here, and this little sock on here filters it. And you can feel the air coming in and out.

ALAN ALDA (NARRATION) The pump sucks air in and out with every beat. And if the air tube gets blocked the pump will slow and eventually stop.

MIKE DORSEY So one night I had rolled over on this side, and it had got kicked over like that, and I'm looking at the screen up here, and the numbers start dropping down, and I'm wondering what's going on, and all of a sudden the alarm went off. And you know as soon as I sat up the alarm stopped.

ALAN ALDA (NARRATION) But the air tube can also be a lifeline - one that may give Mike at least a brief break from the hospital. This hand pump can be

connected to Mike's air tube, and will keep the Heartmate pumping blood even if its power supply or computer control fails - which is what happened unexpectedly during a routine check.

DOCTOR How are you feeling Mike?

MIKE DORSEY O.K.

ALAN ALDA (NARRATION) During the 5 or 6 minutes it took to figure out the problem - a loose connection Mike's artificial heart was kept beating with the hand pump.

MIKE DORSEY Oh, just another day here to me, I guess

ALAN ALDA (NARRATION) As long as the hand pump goes everywhere he goes, Mike's given at least partial freedom, able to stroll the hospital grounds. One day, his experience with the Heartmate may help lead to permanent artificial hearts - but for Mike it's intended only as a bridge to a new human heart. And that means his waiting for a donor continues.

MIKE DORSEY You gotta look at it both ways, unfortunately somebody's gotta pass away in order for you to have a donor. You know, and, I'm not gonna wish that on anyone, but at the same time I would like to be transplanted and released too.

ALAN ALDA (NARRATION) In late July, Mike got his first real taste of freedom - a short trip out of the hospital with his wife and family - and plenty of medical back-up. Just 3 weeks later, Mike's Heartmate was relieved of its duties. On Friday, the 13th of August, Mike Dorsey finally got the new human heart he'd been waiting for. Two weeks later, he went home.

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SMART GLASSES

LEONARD PERRA This the kind you wanted?

LEONARD PERRA Yeah, those are fine.

ALAN ALDA (NARRATION) We're in Valparaiso, Indiana and this is Leonard and Leonard Perra. Leonard is legally blind. That doesn't mean he can't see at all, but his sight is seriously degraded. This video effect gives a rough idea of what he sees. The sharp central vision is missing, leaving only the less distinct peripheral vision. Leonard has seen the world this way for ten years.

LEONARD PERRA One of the greatest disappointments with my lack of vision is not being able to see my grandson. And, I can't even see my children anymore, but I've seen them. I hadn't seen my grandson who's seven years old, and I haven't been able to see him with this lack of vision. I don't know what he really looks like.

ALAN ALDA (NARRATION) Like many victims of macular degeneration, as it's called, Leonard uses a series of simple devices to help him cope. For long distance, a small telescope magnifies signs enough for the letters to be legible just using his peripheral vision. He has to scan along the letters to read the word. For close up, he has to choose a magnifying glass. The result is similar. Simple low vision aids like these have been around for years - but just around the comer there are big changes.

JOAN STELMACK We call it ELVIS...

ALAN ALDA (NARRATION) This is a prototype system that will use advanced computer and video technology to help people like Leonard.

JOAN STELMACK ...and it has a number of attributes, but the first one we're going to evaluate is just the magnification that it can provide at distance.

ALAN ALDA (NARRATION) Joan Stelmack is an optometrist at the Hynes VA Hospital, near Chicago. Leonard is trying the helmet for the first time. The system uses a TV camera to view the world, then processes the scene electronically. In the simplest mode, Leonard sees images that are like conventional magnification aids - only wider. It's convenient - and it works.

LEONARD PERRA R-R-D-F-U-V-U-R-Z-V-H. I can see, I can see! And, it's just wonderful.

ALAN ALDA (NARRATION) The system was designed in Baltimore by the VA and the Wilmer Eye Institute's Bob Massoff. The ultimate goal is to tackle even the most difficult problems for low vision patients, like reduced contrast.

BOB MASSOFF To give you an idea of what the patients might experience, we've reduced the contrast of my image, and it, amazing as it is, it's at least this bad, sometimes worse for many of these patients. They complain of not being able to recognize family members, their own spouses, and children. But these same patients will tell you they can recognize caricatures. For example, we can all see right here, this caricature of Bill Clinton comes through just fine. And that's because the details that define the face are heavy contrast. They're dark lines that outline the important features that make the face recognizable.

ALAN ALDA (NARRATION) So Bob is developing a computer program that can start with a TV picture of a face, then derive a high-contrast, cartoon version. This is just the kind of processing that can be built right into the helmet's electronics. And it will happen in real time, too. The user could scan around the table, say, and instantly recognize everybody there. While the high contrast mode should be incorporated into the helmet within a year, Bob's now working on a much more complex form of image processing. There's one form of damaged central vision where the brain responds like this... The sides of the hole get pulled together. The resulting distortion scans across the scene as the person's eyes move. Obviously the image can become incomprehensible. Bob Massoff's response is ingenious. His computer takes the part of the scene that would have been obscured by the damaged center, and distributes it around the outside. The result is distorted. But then the brain constructs its own distorted view of that.

BOB MASSOFF Those distortions will cancel each other out, and the patient should see a completely seamless image with no missing information, and no distortions.

LAB TECHNICIAN Okay. Want to look up?

ALAN ALDA (NARRATION) To make this work in practice, Bob has become his own experimental subject. He's being fitted with a special contact lens with tiny wires attached to it. The metal cage is generating a magnetic field, which causes very small electric currents to be produced in the wires as the lens moves - enough to keep track of Bob's eye motion. Now what the computer system can do is precisely line up its distorted version of the scene Bob is viewing with the direction he's looking.

BOB MASSOFF Because it's following my eye movements, where ever I go to look on the screen, there's the blob, and you can't get away from it. It's almost like a floater or a speck that just stays where ever your eye is looking.

ALAN ALDA (NARRATION) The next step will be to adapt all this experimental equipment so it's small and reliable enough to work as part of the helmet system. So is this really going to help people, or is Bob Massoff just a well-meaning, high-tech dreamer? This is seven year old Joel - the grandson Leonard Perra has never really seen. Time for a field test.

JOAN STELMACK We're hooking you up to the device.

ALAN ALDA (NARRATION) You can tell it's a prototype, because our camera crew had to provide a homemade lens shade to cut out glare from the sun. Now

this is a very interesting test, because at present the helmet gives a view only marginally better then Leonard's conventional aids.

LEONARD PERRA Doesn't this thing look crazy, Joel?

ALAN ALDA (NARRATION) Crazy or not, it does seem to work. It's easier to use. He doesn't have to think about it, or line it up - he can get on with what really matters.

LEONARD PERRA Real good. I can see what he looks like.

JOAN STELMACK Well, what does he look like?

LEONARD PERRA He's beautiful! Joel come here. You haven't lost you're eyesight, and you don't know what it is to lose it and then not see things, then all of a sudden to see them again. And now I can see, I know what my kids look like, and my grandson, and my wife. And it's been a long time since I saw them. All I've ever seen was shapes and not faces, no features, and now I can see their features again.

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MIND OVER MACHINE

ALAN ALDA (ON CAMERA) I'd like you to meet a new friend of mine. This is Kara. And we've just been having a very entertaining conversation, even though Kara's cerebral palsy prevents her from having control over most of her muscles, including the muscles involved in speaking. But Kara can talk just fine, thanks to a very simple device, and to her mother

PAM. You amaze me how you can talk like this, how long did it take you to learn it?

PAM T - W - O, two, M-O-N, two months.

ALAN ALDA Two months, that's all, that's amazing. The communication is really rapid, how do you do this, how are you doing it?

PAM I - L - O - O - K, I look, A - T, at, I look at, A - L - E, at a letter, A - N - D, and, K, and S - O, and someone, S - A - Y - S, someone says, I - T, someone says it.

ALAN ALDA Could I take your mom's place, and, if you didn't go to fast, I'd be able to follow what you were saying?

PAM Y - E, Yes

ALAN ALDA Let me try it. Okay. Can I just switch with you. Okay. Now if I hold it right in the middle here, should I be able to do it? Okay. I'll ask you a question. Ah, let's see, now I have stage fright. You just did a play that's why you have no stage fright, did you help write that play? Wait a minute, Y - E - S, I guessed that yes was the answer.

ALAN ALDA But at least that gave me a chance to know what you were saying. What was the play about? S - E - W, no X, sex, no, sex, wait. Well that's the letter I saw, I'm sorry. Alright S-E is right, right. I got S-E-V-E, S-E-V-E-N, 'S-E-V.

PAM Seven

ALAN ALDA Seven, Oh, seven, N, N, I can't spell seven, that's my problem, S E V E N, seven, seven .....

ALAN ALDA (NARRATION) With very little practice, anyone who spells as well as Kara can have a lively conversation - even with this very low tech device. And because Kara has some control of her right foot, she can also operate a computer.

WOMEN Ok the black rectangles will light up, and direct your cursor over to those black rectangles ....

ALAN ALDA (NARRATION) Kara and her mother are working with the staff at the Center for Applied Special Technology near Boston, on equipment and software specially adapted for the disabled.

ALAN ALDA (ON CAMERA) Kara is one of many people whose mind occupies a body that limits their ability to express themselves, or control their environment. Technology, especially computer technology, is now beginning to provide them with a way to interact with their world, through devices that can pick up even tiny muscle movements. But what if Kara's mind could be plugged into the computer? What if her brain could directly control a machine?

ALAN ALDA (NARRATION) That was the dream of this man, Andrew Junker, who for more than a decade has been working on ways to tap into the electrical activity of the brain and use it to control a machine.

ANDREW JUNKER I pick up the electrical signals from the head, connect them to a bio-amplifier, which amplifies the signal 20,000 times, it sends it to this blue

box which is a radio transmitter, the transmitter sends a signal to the receiver which is connected to the computer.

ALAN ALDA (NARRATION) The machine Andrew likes to control best is his sailboat - about to take a turn around the harbor of St. Thomas - with neither Andrew nor his wife Patricia having to lift a finger. The computer is linked to a motor driven helm - and the computer is getting its instructions from three electrodes inside Andrew's headband. The electrodes are picking up a sampling of the ongoing electrical activity of Andrew's head. He's taught himself to increase or decrease one particular component of this activity - and has his steering mechanism linked up so that an increase turns the boat to the left...

ANDREW JUNKER I'm turning left now

ALAN ALDA (NARRATION) While a decrease turns the boat to the right.

ANDREW JUNKER Now I'll turn right. That last experience felt fantastic, cause I felt in a groove, right here I felt like I was in this slot and as long as I held that slot I could delicately suppress or intensify the signal and the boat responded. It's a fantastic feeling.

ALAN ALDA (NARRATION) Now - I know what you're thinking ... a man sailing a boat in the Caribbean with his brainwaves is a little hard to take seriously - let alone quite believe. But in fact Andrew Junker's work is taken very seriously indeed - by, of all things, the United States Air Force. Flying a modern fighter plane like the F-16 is a very complicated business - and the pilot has only two hands and two feet to do it. As more and more high tech systems are added, the pilot's in danger of simply having more controls to operate than ways to operate them. Which is where Andrew Junker enters the picture. Ten years ago, as an Air Force researcher, he set up a laboratory to study brain machine communication here at Wright-Patterson Air Force Base in Ohio. Today the lab's star subject is Captain Dave Toomey, and the research is directed by Grant McMillan.

GRANT McMILLAN Everything you look at out in the world produces a measurable response in your brain. In this case, it's the response of Dave's brain to that light in the cabin, that's flickering 13 times a second.

ALAN ALDA (NARRATION) The flickering produces in the back of Dave's brain what's called an evoked potential - an electrical signal that can be picked up by electrodes on his scalp. Here's the signal. Keep your eye on the white dot in the middle. Dave's task is to try to change the intensity of the peak marked by the dot - either increasing it ... and holding it there.., or decreasing it, and keeping it suppressed.

DAVE It feels as if you're doing something on a psychic level. It feels like those things you've seen on TV, with the Russians bending spoons and moving balls on tables. It feels like that, it feels like its purely psychic. But in fact ifs hard science, its pure science. It's just using something that the brain does naturally with some very high tech equipment in order to make the link possible - but the human brain to machine link.

ALAN ALDA (NARRATION) The machine Dave's trying to control with the link is a simple flight simulator. When Dave suppresses the signal and keeps it low, the simulator rolls to the left. And when he increases the signal and keeps it high, he rolls to the right.

GRANT McMILLAN We don't really know in any detail at all how people do this, how they actually exercise this kind of brain actuated control. And what we usually do when people ask us that question, is try to give them an analogy - how does a baby learn how to walk? You can't tell a baby you know well you do this, you do this. They develop that new control.

DAVE It's simply a matter of desiring this thing to go to the right or desiring it to go to the left and then my brain automatically produces the signals necessary in order to make it happen for me.

GRANT McMILLAN Hello Ed, welcome to our lab.

ALAN ALDA (NARRATION) Today it's rookie brainwave pilot Ed Fix's turn to try out the system. The idea of using evoked potentials picked up by electrodes on the back of the head was Andrew Junker's - before he decided sailing boats would be more fun - and before he switched to using electrodes on his forehead picking up different electrical signals. But the basic idea is the same - to bring under deliberate control a signal from the head, and use it to command a machine. After a few hours practice, ED can increase the signal and roll to the right.., but he can't suppress the signal long enough to tilt back to the left - to the point where he's about to do a barrel roil!

ED FIX It's a little frustrating, because I could see that control was possible, but I didn't really have good control. It was fairly erratic. I could get it momentarily, and once in a while I could hold it to where I needed it, but then I would kind of lose it. It's kinda like growing a whole new arm, and I'm trying to learn how to use it now.

ALAN ALDA (NARRATION) But a few more hours practice on the machine and Ed is beginning to get the hang of things.

GRANT You had a number of really great runs there.

ED FIX I feel like I've got a little more control, but like I said, I'm not, I don't know what I'm doing exactly, its just sometimes it just seems to start falling into place.

GRANT Yeah

ED FIX I feel like its coming, its getting to the point where I might actually be able to do this.

ALAN ALDA (NARRATION) Today, the man who invented the technology, Andrew Junker, can - when he's in the groove - steer his boat with his brain. Tomorrow, fighter pilots might be hurling their planes around at twice the speed of sound by thought alone. But meanwhile...

ALAN ALDA (ON CAMERA) As fun and as useful as it would be to steer boats and planes with no hands, this is the vehicle that would really be transformed, if it could be run by brainwaves. Imagine how much fun Kara would have with this wheelchair if it would respond to her mind. Until then, see you next time on Scientific American Frontiers.

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