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"Games Machines Play "

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WORLD CUP FOR ROBOTS

SUPERHUMAN SUBS

TEETERING TO VICTORY

WORLD CUP FOR ROBOTS

ALAN ALDA This is a show about contests -- contests between machines and the people, mostly students, who built them. Contests are fun, they're exciting and they're a great way to learn. But as we'll see, the creative edge generated by the very human desire to win is also pushing the development of these machines. And some of them are able to do surprisingly human things. Welcome to the world of robot soccer.

MANUELA VELOSO Go, go, go, go, go, go, go, go!

ALAN ALDA There he goes. There he goes.

ALAN ALDA (NARRATION) We're in Seattle for the finals of RoboCup 2001.

ALAN ALDA Pushed it in with his chest. Pass, pass, pass! Pass it!

MANUELA VELOSO Ah, there you go, yeah.

ALAN ALDA (NARRATION) But we first met the players and their makers a couple of years ago, on a visit to Carnegie Mellon University in Pittsburgh. There the CM United team was being put through its paces by one of the founders of the RoboCup contest, Manuela Veloso.

MANUELA VELOSO Shoot again, shoot!

ALAN ALDA (NARRATION) One of the stars of CM United was their goalie. Trying to beat it gave me the chance to find out how the robots know what to do.

ALAN ALDA How is this working? Does that little guy have eyes in its head somehow?

MANUELA VELOSO No, actually the robot does not have any eyes. There is a camera that is overhead and sees the whole field.

ALAN ALDA (NARRATION) From the video image, a computer figures out the position of the ball and any robots on the field. Then it predicts the ball's current direction and speed -- indicated by the length of the line. The computer does this 30 times a second -- fast enough to cope with all but the speediest shots.

MANUELA VELOSO There you go.

ALAN ALDA I went too fast.

PETER STONE Vision's fine.

ALAN ALDA (NARRATION) Behind the scene, Peter Stone's running the vision system, while Mike Bowling's laptop is sending wireless instructions to the robots on the field. But during competition, it's hands off.

ALAN ALDA You're not allowed, by the terms of the competition, to give it any directions from a human during the game?

MANUELA VELOSO Yes, we can not give it any directions.

ALAN ALDA It all has to be done beforehand, as you design the software.

MANUELA VELOSO Right. And the challenge is that the domain, the task, is very uncertain. So we have to up front program or make the robots think about a very large number of situations.

ALAN ALDA (NARRATION) So success at robot soccer depends not only on the speed and quick reactions of the robots, but on the central computer's ability to read the game and direct the players.

MANUELA VELOSO There's a pass, perfect....ah.

ALAN ALDA (NARRATION) RoboCup 1999 was held in Stockholm. Referee Three, two, one...

ALAN ALDA (NARRATION) It's the quarter finals between two of the top teams in robot soccer. Watched by an audience of computer scientists from around the world, the match pits robots from Cornell University against a team from Singapore -- and Cornell strikes first.

RAFAELLO D'ANDREA Oh, yeah! REFEREE Three, two, one...

ALAN ALDA (NARRATION) Cornell's robots are fast and strong, and they convincingly beat the Singapore team, called the Field Rangers. Manuela's CMU United has also made it to the quarter finals. But in this match they are literally getting pushed around by the fast and aggressive robots of another team from Singapore, Lucky Star. This play sums up the match. A penalty attempt by CMU turns into a beautiful goal for Lucky Star... who go on to crush CM United 8 - 0. Now it's Cornell's turn to face Lucky Star in the first semi-final.

RAFAELLO D'ANDREA This is the fastest team that we've played against, so that we have to be sure we can cope with their speed.

ALAN ALDA (NARRATION) Both teams have similar robots -- fast, maneuverable two-wheelers that kick the ball mainly by ramming into it. After two 10-minute halves of play, Cornell prevails.

RAFAELLO D'ANDREA Excellent game, guys. Referee Three, two, one...

ALAN ALDA (NARRATION) In the final, Cornell is up against a team from Berlin, called the FU Fighters. The German team has made it this far thanks largely to a dramatic innovation, a spinning bar that delivers a devastating kick. In the end, Cornell's superior strategy wins out over the FU Fighter's kick, and Cornell takes the championship.

MANUELA VELOSO And the first prize is for Big Red from Cornell University who only suffered two goals during the whole tournament.

ALAN ALDA (NARRATION) Also making an appearance at Stockholm were RoboCup's first four-legged contestants. The robot dogs were very obviously beginners. Unlike the wheeled robots, each dog is on its own. It has to figure out where it is with the help of a camera in its nose and colored beacons around the field.

MANUELA VELOSO Go blue! Go CMU!

ALAN ALDA (NARRATION) Goals were scored mostly by walking the ball into the net... And the dog's walk was slow and ungainly. But this was 1999. And as we said at the outset, nothing pushes innovation like competition. Jump ahead two years to RoboCup 2001 in Seattle. The dogs themselves have undergone a makeover. But much more importantly, most teams -- including Manuela Veloso's Carnegie Mellon team -- have written new software programs for their dogs that make them walk much faster.

ALAN ALDA It sort of crowds the ball into the goal.

ALAN ALDA (NARRATION) The CMU dogs' new and faster walk can pose new dangers for the opposition.

ALAN ALDA Oh, it fell over.

MANUELA VELOSO Right there it fell.

ALAN ALDA Did your guy knock him over do you think?

MANUELA VELOSO I think so. Not on purpose, but it just happened.

ALAN ALDA (NARRATION) But as the blue team rallies, CMU's goalie -- down here at our end of the field -- seems to have lost interest in the game.

MANUELA VELOSO This is actually our goalie.

ALAN ALDA He's out to lunch.

MANUELA VELOSO We have a big problem with the goalie so for the finals we have to...

ALAN ALDA Uh oh, here it comes, here it comes.

MANUELA VELOSO Oh but now I think that when it sees the ball it does the right thing.

ALAN ALDA (NARRATION) Another innovation CMU introduced last year is this elegant head swipe to move the ball up the field. The coolest new move this year is a two legged kick -- which starts as the dog drops to its haunches

ALAN ALDA There he goes, there he goes. Oh, he's moving nicely.

MANUELA VELOSO That was a nice goal, huh?

ALAN ALDA That was beautiful.

ALAN ALDA (NARRATION) Not only has competition sharpened the dogs' skills - - so has cooperation. Every year, each team shares its software secrets -- even the computer code itself -- with all the rival teams. The result is that everyone is building on everyone else's breakthroughs.

MANUELA VELOSO Years ago they could hardly see the ball. They spent all the time just looking around, "where am I, where am I." But now we take it for granted...

ALAN ALDA Everybody's improved because you've shared your information, your knowledge. Of course, you wait until after you win the game.

MANUELA VELOSO That's true.

ALAN ALDA (NARRATION) The team at the forefront of much of this innovation is from Australia's University of New South Wales, here playing in the other semi-final. This year they've introduced another new kick. CLAUDE SAMMUT When the ball is between the front legs of the robot, if it does a quick turn, that will give you a flick sideways, which is quite effective because it gets the ball away from the opposition. There's a short range kick, which is a push forward on the chest. And there's another one which is two legs forward. You'll see other teams doing that because they copied it from us last year.

ALAN ALDA (NARRATION) There's another new trick in the Australian's play-book this year -- one that uses the dogs' sense of hearing as well as sight. To avoid teammates scrapping with each other, one robot will back off if it sees a same-color dog with the ball. As it backs away it whistles, letting the lead robot know where it is. It's a tactic likely to be widely imitated next year -- and this year has helped the Australians get to the finals -- where CMU's goalie still hasn't quite figured out its head from its tail. Final score, UNSW 9, CMU 2.

MANUELA VELOSO I'm very proud, very proud. Of course, silver is not gold, but again, gold is just for one.

ALAN ALDA (NARRATION) It's not just the robot dogs whose skills have improved for RoboCup 2001.

RAFAELLO D'ANDREA Excellent.

ALAN ALDA (NARRATION) Cornell's wheeled robots, the current world champions in their league, can now move in any direction while facing in any direction.

RAFAELLO D'ANDREA Okay, now this is going to be our ball control. This is the hard test.

ALAN ALDA (NARRATION) The Cornell robots have also developed a sophisticated passing game, aided by a spinning bar to put backspin on the ball, holding it against the robot while it maneuvers. In their quarter final match,

Cornell is up against a team from Portugal. The backspinner comes into play at once as a Cornell robot tugs the ball from a corner, turns and passes.

RAFAELLO D'ANDREA Nice pass.

ALAN ALDA Yeah, wow! They're really good at passing.

RAFAELLO D'ANDREA Yup. Oh, nice save.

ALAN ALDA (NARRATION) Portugal is countering with aggressive tackling.

ALAN ALDA This other guy. He seems to be hitting your shins.

RAFAELLO D'ANDREA It is.

ALAN ALDA (NARRATION) Cornell has already played four games in the tournament, winning them all handily. They seem to have this game under control too, until after this hard hit in the corner... CROWD Whoa! Whoa! Hey! (Clapping)

ALAN ALDA You've never had a goal scored on you?

RAFAELLO D'ANDREA No.

ALAN ALDA Until now.

RAFAELLO D'ANDREA Until now.

ALAN ALDA (NARRATION) As play resumes, the Cornell robots remain in firm control of the mid-field, thanks to their positioning and passing.

RAFAELLO D'ANDREA Whoa!

ALAN ALDA Jeez, what a pass. They can pass like, at an angle.

RAFAELLO D'ANDREA Oh yeah.

ALAN ALDA (NARRATION) But despite Cornell's passing, the Portuguese defense holds them scoreless through the first 10-minute half.

ALAN ALDA Why is this such a tense game?

RAFAELLO D'ANDREA They're a really good team. They're playing our defense perfectly. They had a great opportunity. Our defender was caught out of the zone. The other player came in and very quickly was able to put the ball in.

ARMONDO SOUSA What we play is an aggressive system that attacks the player with the ball soon, and that prevents Cornell from making deadly passes. So, that's the strong point of Cornell; that's the point we eliminated.

ALAN ALDA Can you make adjustments right now? Or do you have to wait until next year?

RAFAELLO D'ANDREA No, we could. In fact, that's what we're doing right now. We're analyzing what happened when they scored. And we're making some changes to the gains of the system to change how fast they're moving, accelerating, their thresholds for passing, for shooting, etc.

ALAN ALDA Your passing is kind of a dangerous tactic because you're putting the ball out in the open. What's the percentage of successful passes? Have you checked that out?

RAFAELLO D'ANDREA Roughly about 80 to 85%. It's pretty high. And it's also fun for us to develop that, too. Part of it is winning. We want to win and we also want to play very well.

ALAN ALDA You want to look cool, too.

RAFAELLO D'ANDREA Yeah. That's very important. Seriously.

ALAN ALDA Really? Wh does that add to it?

RAFAELLO D'ANDREA Part of what motivates us is trying to come up with a system that is really fun to watch.

ALAN ALDA That was great! Oh!

ALAN ALDA (NARRATION) Cornell's mid-field play continues to sparkle. But like many real-life soccer teams, once in the goalmouth, they seem to falter. Then an over-aggressive Portuguese robot shoves a Cornell player into the corner, giving up a free kick.

STUDENT Yeah! Whoa!

RAFAELLO D'ANDREA Make a pass, make a pass.

ALAN ALDA (NARRATION) A few minutes later, the same thing happens.

REFEREE There will be a yellow card for potentially damaging a robot.

ALAN ALDA I love the lining it up like that.

ALAN ALDA (NARRATION) Final score, Cornell 2, Portugal 1.

ARMONDO SOUSA We put up a good fight. And I think Cornell also has a bit of learning to do.

RAFAELLO D'ANDREA We didn't think they could score on us. So they really surprised us by getting that goal. But in a sense, I'm glad that it happened. Now we know we have a weakness in our defense and we'll fix it for our next game.

ALAN ALDA (NARRATION) As Raff and his students plan their changes, another quarter -final is underway.

REFEREE That's a goal for the FU Fighters.

ALAN ALDA (NARRATION) This one is between a Spanish team and the Berlin FU Fighters -- the robots with the faces. This year the German team, like Cornell, have omnidirectional robots on offense, but on defense they're relying on their older hard- kicking machines. Like Cornell, the FU Fighters' forwards maneuver more skillfully than the Spanish robots -- and their defense is solid. But also like Cornell, the Germans seem nervous in front of the goalmouth. It turns out this is by design. One of the rules of the game is that any contact with the goalkeeper is penalized.

ALAN ALDA I saw one of your players there looking very nervous. Backing up, moving forward, backing up. It looked like he didn't know what to do. Had you changed his behavior about the goalie at that point?

RAUL ROJAS No. Yeah. We did. We agreed....

ALAN ALDA You told him not to get too close.

RAUL ROJAS Yeah.

ALAN ALDA (NARRATION) As the match progressed, the German team tweaked their forward's behavior to make them a little less concerned about hitting the goalie -- and were rewarded with a convincing win. Cornell meanwhile is in a tense semi-final confrontation with the Field Rangers from Singapore -- the team they beat two years ago in Stockholm. Once again, Cornell's dribbling mechanism is setting up promising plays in the opponent's goalmouth.

ALAN ALDA Pass pass pass pass! Pass it!



ALAN ALDA (NARRATION) But the Field Rangers' reflexes are lightning fast. At the half, Raff isn't happy

RAFAELLO D'ANDREA Okay. I have to see if I can figure out what's going on.

ALAN ALDA Were you able to make a strategic change here?

RAFAELLO D'ANDREA Yeah. What we did is, hopefully the change that we made will allow us have this player go into the box so that he could receive a pass and put it into the net.

ALAN ALDA (NARRATION) The second half features a superb attacking move down the field, setting up the shot Raff is hoping for.

RAFAELLO D'ANDREA Here we go. Here we go. Here we go.

ALAN ALDA Pass pass pass pass.

RAFAELLO D'ANDREA He will.

ALAN ALDA (NARRATION) But again, the Field Rangers are faster to the ball -- and then the goalie simply steals it away.

ALAN ALDA Whoa, he stole it! Look at that!

ALAN ALDA (NARRATION) Seconds later, a Field Ranger robot makes a brilliant attacking play.

ALAN ALDA Time out.

ANNOUNCER Three and a half minutes remaining in this match, Singapore now having the lead.

ALAN ALDA (NARRATION) Cornell again sets up what seems like a certain score -- and again is thwarted. After a three-year undefeated run, Cornell is dethroned. In the other semi-final, Berlin's FU Fighters get off to a spectacular start against the second Singapore team to be defeated by Cornell two years ago in Stockholm, Lucky Star.

ANNOUNCER How fast is this game going? Artificial intelligence at 100 miles per hour. Look at these guys go. There's no way a human can keep up with this kind of playing. They're going far too fast.

ALAN ALDA (NARRATION) A free kick for Lucky Star...

ANNOUNCER Goal!

ALAN ALDA (NARRATION) And it's the beginning of the end for the FU Fighters. In the all-Singapore final, it's Lucky Star who'll go on to become the new RoboCup champions.

ALAN ALDA What do you think are the next couple of steps that we'll get to with game-playing robots?

MANUELA VELOSO So, we actually are trying to get to a point where we can play with humans.

ALAN ALDA Play against a human?

MANUELA VELOSO With or against, yes. So we'll go all the way until we play on a real soccer field with humans. All the way.

ALAN ALDA (NARRATION) On display in Seattle is a little two-legged robot called Pino, from the same company that manufactures the robot dogs.

MANUELA VELOSO We are going to have a competition, probably next year with these little guys playing. They will be able to follow the ball again, go to the ball and kind of kick it.

ALAN ALDA You do a very funny impersonation of a robot.

MANUELA VELOSO That's what they will be like.

ALAN ALDA You spend a lot of time with them; you get to be able to do them.

MANUELA VELOSO That's how they look, right? So far.

ALAN ALDA So far. Right.

## SUPERHUMAN SUBS

ALAN ALDA (NARRATION) Neptune is a submarine, built by students at the University of Michigan. It will soon be filled with water -- and propelled by human pedal power.

ALAN ALDA How many people will be in this boat?

MATT OLSOFSKY There are two people in this boat. And they both pedal.

ALAN ALDA Is it the biggest boat here?

MATT OLSOFSKY Oh yes.

ALAN ALDA Yeah?

MATT OLSOFSKY Oh yes. It gets moving.

ALAN ALDA (NARRATION) Neptune is one of some 15 boats entered in the 2001 human-powered submarine race.

JERRY ROVNER Are we ready to race? Okay, we're gonna do a race right now, so..."

ALAN ALDA Okay.

ANNOUNCER Michigan. Michigan. Michigan. Michigan.

ALAN ALDA (NARRATION) We've strapped a camera on Neptune to get a sense of what it's like to lunge at a fast walking pace through the nearly ink-black water of an immensely long indoor tank. Just outside Washington DC, the tank is more usually employed testing new ship designs for the US Navy. Ten years ago, the human-powered sub races were held in the sunny waters off a Florida beach. Pairs of submarines raced each other around a circular course.

ANNOUNCER Okay, I see the first boat coming. It's the Benthos boat. Holy smokes, is it pulling. Whoa, wee.

ALAN ALDA (NARRATION) Beating most of the opposition was a boat from the Benthos Corporation of Cape Cod -- one of the few boats built by people who construct submarines for a living.

BENTHOS One more race, that's all we got, one more race left. If they can get us off the starting block clean tomorrow we should have a damn good chance at it.

ALAN ALDA (NARRATION) Most of the other competitors in 1991 failed to complete the course, because of bad luck... bad driving... or bad design. But a boat built by students from Florida Atlantic University put on a flawless performance. As in the Benthos sub, one person steered while a second pedaled

in the rear. One of the secrets of their success was plenty of practice in ocean conditions

ROB COULSON Up until now we've kinda held back a bit, make sure we've got round the cords to not get tangled in any buoys. Today we're gonna take a few chances.

ALAN ALDA (NARRATION) So into the starting gate for the final go the students of Florida Atlantic University -- and the professionals of the Benthos Corporation. The race is twice around the track -- a total of one half mile.

ANNOUNCER They're going into the second turn right now and starting towards the back straightaway. They're still not more than five feet apart, They're really moving now. There's the FAU boat passing the finish line and the other boat's right behind them. They're about eight feet apart.

ALAN ALDA (NARRATION) It ended in an upset win for Florida Atlantic -- and an opportunity to remember what contests like this are really all about.

FLORIDA ATLANTIC We took this baby from the just basic conception to actually building it, and testing it and getting it to run. And that's what engineering's all about. So basically they're just training us to be engineers. This is the result.

ALAN ALDA (NARRATION) With the human powered submarine race now in the calmer waters of the Navy's testing tank, that 1991 race remains vividly in the mind of one of today's contestants.

JUSTIN HLAVIN Back when I was younger, about nine or ten years old, I watched the program, Scientific American Frontiers, on the initial races and just being a scuba diver then and seeing what they were doing, I became highly interested. It really played into which colleges I chose and I actually went and interviewed with those teams to see how organized the teams were and to see which one I would want to join.

ALAN ALDA You picked the school according to their chances for the race.

JUSTIN HLAVIN I wanted to be with a good team.

ALAN ALDA Isn't that great?

ALAN ALDA (NARRATION) The team that Justin eventually joined -- and now leads -- is from Virginia Tech University. Their boat, the Phantom, is very different from the subs of a decade ago. Most significantly, it's both powered and steered

by only one person, making it much smaller, sleeker -- and faster -- than the subs of old.

ANNOUNCER V-Tech, V-Tech, V-Tech, V-Tech.

ALAN ALDA (NARRATION) The race is different too -- it's now a pure time trial, the subs sprinting one at a time along a straight 100-metre course. The emphasis is on raw speed. In the early races it was rare for a sub to go faster than three knots. Justin is hoping to take the Phantom up to as much as 6 knots. The critical part of the course is the speed trap in the middle... a 10-metre section marked with illuminated white poles.

TIME-KEEPER Number two. Got him.

ALAN ALDA (NARRATION) At the end of the 100-metres, a team of Navy divers helps slow the subs to a halt. Justin's time on this run is still well short of the 6 knots he's hoping for.

JERRY ROVNER One-sixtieth of a second we can time it down to. So we're giving very accurate, you know, very accurate races.

ALAN ALDA So someone could win by one-sixtieth of a second? JERRY ROVNER Yes.

ALAN ALDA (NARRATION) During the five days of the meet, everyone gets to take as many runs down the course as they can. While many of the subs here are single -person like the Phantom -- and this on, the Bull Dog, built by a high school team -- there are still a few 2-person boats. Most of them are steered by one diver and pedaled by another in the rear, making them not much faster than the subs of a decade ago. An exception is the University of Michigan's Neptune, in which both divers pedal. This makes the Neptune quicker than the other 2-person subs -- but also harder to control. This isn't the first time that Neptune has ended a run by ramming into the side or bottom of the tank.

ALAN ALDA How'd you do?

MATT OLSOFSKY Well, looks like we lost control.

ALAN ALDA What happens to you when you see you're gonna crash?

PAT FINN I prepare to crash. I feel the bottom's coming, I dump my regulator, kinda get out of the way. I watch the nose coning plod into my face.

ALAN ALDA You know, I've been asking people all day, why they do this? But I think you're the best one to ask because you have your face up in the nose and you're liable to crash at any moment. Why do you do it?

PAT FINN Crash helmet. These guys thought I would need a crash helmet for all the crashing I've been doing this week. I guess for the competition of it. And just - I'm one of the naval architects on the team and this is what we do, so...

ALAN ALDA (NARRATION) Not everyone here is an engineering student pushing for raw speed. Bob Golobic, for instance...

ALAN ALDA Hi. Can we talk to you for a second? Are you getting ready to go now?

ROBERT GOLOBIC No, I'm in the queue.

ALAN ALDA Oh, you're in the--. When do you go?

ROBERT GOLOBIC Like about last.

ALAN ALDA How long have you been in training with this group?

ROBERT GOLOBIC I've been in training for 30 years.

ALAN ALDA Did you build it?

ROBERT GOLOBIC Yes, I constructed it in my garage.

ALAN ALDA Do you have anything special about this that you think is a design feature that may put me ahead of other people? ROBERT GOLOBIC Ah, no. If I had an electric motor, perhaps.

ALAN ALDA (NARRATION) Bob's sub is called the Reef Cruiser, an elegant twin-propeller design built more for comfort than speed.

ALAN ALDA There he is. There he is.

CHEERER Come on, reef cruiser.

ALAN ALDA (NARRATION) Bob's goal is simply to complete the course.

ALAN ALDA Everybody's cheering him on. "Come on, you're almost there."

CHEERER Come on, reef cruiser. I think I can. I think I can.

ALAN ALDA He's just got a few feet to go. He's twisting and turning.

CHEERER Give him a push.

ALAN ALDA Go straight.

ALAN ALDA (NARRATION) After six starts, Bob finally finishes. EVERYBODY Hooray!

ALAN ALDA Do you have your breath?

ROBERT GOLOBIC Oh, absolutely.

ALAN ALDA Do you want to hold on?

ROBERT GOLOBIC Yeah, I would like that.

ALAN ALDA Good for you. That was fantastic. Did you go past the finish line backwards? Is that what you did?

ROBERT GOLOBIC No, no. Sideways.

ALAN ALDA Sideways.

ROBERT GOLOBIC Yeah. Sideways.

ALAN ALDA (NARRATION) At the other end of the spectrum from Reef Cruiser is this slender, torpedo-like submarine from the Montreal School of Technology.

ANNOUNCER Omer, Omer, Omer, Omer.

ALAN ALDA (NARRATION) Omer-4 seems scarcely big enough even to contain its driver, let alone allow him to pedal. It leaps out of the starting gate and streaks down the course a good two knots faster than any other team here is even dreaming of. On this run it sets a new world record.

TEAMMATE Whoa! Wo-hoo!

ANNOUNCER 7.019 knots.

TEAMMATE Wo-hoo! Bring it home, baby. Bring it home.

ALAN ALDA (NARRATION) As well as its sleek hull, minimizing the drag of the water, Omer-4 has a unique design breakthrough in its tail -- a computer that can change the pitch of the propeller. As the sub's speed picks up, the bite the propeller takes of the water is gradually increased. In effect, the computer matches the pitch of the propeller to the speed of the sub, producing the maximum thrust no matter how fast the sub is moving.

ALAN ALDA Is the main thing that's helping you get that fast is the ability to control the propellers?

SIMON JONCAS With a variable pitch, what it does is enables us to generate thrust even at speed zero. So it still can move forward. So as the pitch varies, we increase our speed more rapidly than other teams.

ALAN ALDA (NARRATION) The Montreal team came with two pilots for their sub. This run is being taken by the junior of the pair, Jeremy Lebel.

ALAN ALDA Wow, that's fast. Where are you? What is your speed?

JEREMY LEBEL That race it was 7.119.

ALAN ALDA That's now the top speed for a human-powered sub?

JEREMY LEBEL Exactly.

ALAN ALDA (NARRATION) While Omer-4 has been steadily breaking records, another one-person sub has been surprising everyone. It's manned by 18-year old Logan Rainard

ALAN ALDA Did you build this yourself?

LOGAN RAINARD Yeah. I designed it last summer and my neighbor and my friend Ed Liebolt who's an ocean engineer here at David Taylor and is right behind me. Ed, stop eating and come here.

ALAN ALDA Congratulations.

LOGAN RAINARD He helped me build it. Probably built about... I built half and he built half.

ALAN ALDA How long did it take you?

LOGAN RAINARD Oh, we started in January and we were finished and in the water and running in April, so--.



ALAN ALDA That was really fast, huh?

LOGAN RAINARD We built it really fast. Like any ship, you design it around the power plant of the boat. And the power plant is me in this case.

ANNOUNCER Scuba-doo. Scuba-doo.

ALAN ALDA (NARRATION) Over the five days of racing, Logan's Scooba-Doo has completed every run it's taken -- and on one run has posted a speed of 5.088 knots -- second only to Omer-4. The other boat competing for second place is Virginia Tech's Phantom -- Justin Hlavin's boat. This run is being taken by the crew's female pilot, Dotty McDowell. A few runs before this one, Dotty broke the woman-powered submarine record with a speed of 4.348 knots.

ALAN ALDA How'd you do?

DOTTY MCDOWELL Pretty good. A little faster this time.

ALAN ALDA Are you worn out after that?

DOTTY MCDOWELL Yeah. I tried to catch my breath.

ALAN ALDA When did you start to give it everything you got?

DOTTY MCDOWELL Usually when I start to see any kind of light in front of me. Because they light the ten meter section.

ALAN ALDA Yeah.

DOTTY MCDOWELL Ah--. Let me catch my breath for a minute.

ALAN ALDA (NARRATION) Justin Hlavin has been hoping to push Phantom as fast as 6 knots. But he's hampered by a makeshift propeller -- actually the tail rotor of a helicopter -- because the planned propeller didn't get made in time. So Justin's team has asked to borrow a propeller from Logan's Scuba-Doo

JUSTIN There is a propeller. Let's see if it'll work.

ALAN ALDA You're using a propeller that you borrowed from the high school team?

JUSTIN HLAVIN Yes. They are going faster than us. We asked them to borrow it. We just want to see what we can do. The hull shape itself is a very fast hull

shape. It was specifically designed to go above six knots. And we just need to find the power to do it now.

ALAN ALDA (NARRATION) With Logan's propeller providing the power, Justin's run was just 7 one hundredths of a knot slower than Logan's.

ALAN ALDA Justin, you look like you were flying.

JUSTIN HLAVIN It's the prop that made the difference. I was very conservative on that run just trying to figure out what it could do. And now that I know how to control the boat, and how that prop feels, I'm prepared to let her loose, to see what she can do.

ALAN ALDA (NARRATION) But Justin never did attempt another run, not wanting to use Logan's propeller to snatch away his second place.

LOGAN RAINARD So we're still second place as it is right now by very very very close. And um, Michigan is in the process of going right now and they're looking pretty fast, too. So, I'm a little worried but there isn't anything I can do about anything right now except sit here and watch the times come up.

ALAN ALDA (NARRATION) With time left for one last run, the huge Michigan sub -- containing one-and a half tons of water as well as its two-man crew -- slowly accelerated away. Unlike most of the other subs, Neptune takes much of the 100-metre course to reach its top speed. But when it did...

MATT OLSOFKY That was a great run.

ALAN ALDA 4.9. Wow.

MATT OLSOFKY Great. Best one ever.

ALAN ALDA (NARRATION) Best one ever at 4.905 knots -- but still not quite enough to overtake Justin Hlavin's Phantom in third place or Logan Rainard's Scuba-Doo in second. Omer-4 -- over two knots faster than the rest of the field -- remains the boat to beat: in the next human powered submarine races set for the year 2003.

TEETERING TO VICTORY

ALEX SLOCUM 3-2-1-go.

ALAN ALDA (NARRATION) It's time again for the grand-daddy of all the student engineering contests -- the annual battle of machines built by sophomores at MIT.

ERIC VARADY Now comes the fun part. Calling my mom.

CROWD Double win! Yeah!

ALAN ALDA (NARRATION) This year's contest -- hatched six-months earlier -- involves a teeter-totter beam and a swinging 8lb ball. The challenge is to build a machine that starts out sitting on the beam and that after exactly 45 seconds has managed to tilt it in its favor -- against an opponent trying to do the same thing. There's a 10lb weight limit for each machine... and a box of parts to make it from. Each of the hundred plus students in the contest -- which is actually a course in mechanical engineering -- gets an identical kit of stuff -- including several electric motors from home power tools as well as things which seem like mechanical leftovers.

ALAN ALDA What would you do with this?

ERIC VARADY Nobody in the class knows what that is. We had a...

ALAN ALDA Is that true? No one knows what it is?

ERIC VARADY No one knows how they're gonna use it.

TEACHING ASSISTANT Usually people just do this: pop it in, take the motor and do something with the motor and then toss that back in there. What it is good for is--.

ALAN ALDA It is a mistake to toss that away?

ALAN ALDA (NARRATION) After several weeks of brainstorming and designing their machines on paper and computer, the class sets to work manufacturing them. And it's now that some of the strategies the students have come up with begin being tested. Grinding sharp spikes is Jessica Baker, one of several with a plan to have their machines reach down and grab the carpet underneath the beam. Alex Slocum is the professor running the course, and one of a dozen MIT staff helping the students translate their designs into reality.

ALEX SLOCUM Oh! So that's about ten or fifteen pounds up. From one tooth. Imagine if you had twenty teeth.

ALEX SLOCUM When they build a machine and they do the calculations right, the machine works, and you get this intense "er", just like a geek gasp from knowing that what you created in your mind and on the computer is actually doing what you told it to do.

JESSICA BAKER It's gonna be dropped from up above there by the strings. And these things grab into the carpet, theoretically. If I can grip the carpet well enough, I can harness the full power of the motors.

ALAN ALDA (NARRATION) Here's another plan to pull the beam down.

WILL LARK This locks on to prevent the whole mechanism from falling off the beam once it drives to the end. It takes about 15 seconds.

ALAN ALDA (NARRATION) This is Will Lark.

WILL LARK Once it's flipped open, this rock represents the car, which will drive over here, attach with magnets and reel the beam in.

ALAN ALDA (NARRATION) In contrast to Jessica and Will's plan to tug the beam downwards, Nick Martin intends to jack it up.

NICK MARTIN It will drop off the beam, drive over to the opponent's side, and then raise the jack to raise the beam, thus changing the angle.

ALAN ALDA (NARRATION) Ernesto Blanco has been helping students in this course for over 20 years. The contest changes, but not its intent.

ERNESTO BLANCO Practically everything in mechanical design is involved here. And we're happy to be able to give the students that kind of an experience. And at the same time, a little bit of frustration.

TULIKA KHEMANI It's an awesome class. It's very very productive and I've learned so much in this course. It's amazing. But it's also very stressful.

ALAN ALDA (NARRATION) It's now just a few days before the contest and a hundred machines are taking shape.

ALEX SLOCUM About mid year there were some worries that maybe the contest was a little too complicated. And, oh my goodness, the students were having a really tough time. But in reality, what they were doing is they were hidden in their warrens, working away on solutions that, when they surfaced, just "whoa!"-blew our minds with how elaborate and cool they were.

TEACHER Folks, it's two days before delivery time, so let's see what you got.

ERIC VARADY So the plan is, this guy, all he does is he goes from here to here and then these syringes apply 500lbs of force...

ALAN ALDA (NARRATION) Eric Varady has a plan similar to Will Lark's.

ERIC VARADY And it clamps down so it can't be moved.

ALAN ALDA (NARRATION) He drops a car off the beam and uses it to place magnets on a metal strip, then winches his side of the beam down. The car is then free to roam...

ERIC VARADY If there are any robots on the ground, which is what I'm really afraid of, it can take them out.

ALAN ALDA (NARRATION) Nick Martin, meanwhile, has almost finished his mobile jack.

NICK MARTIN The goal is to drop the robot off the beam, onto the ground, drive to the other side of this beam, and then raise this jack, and then push their side of the beam up. This strategy of winching to the magnets will produce a lot of force. I'm worried about robots like his.

ERIC VARADY I'm worried about him, so hey!

ALAN ALDA (NARRATION) Jessica Baker's carpet grabber is also almost done - - and testing well.

JESSICA BAKER I think I need to perfect that carpet driver so it digs in more. But I'm happy with how the rest of it works.

ALAN ALDA (NARRATION) Sarah Mendelowitz's machine is designed to give her opponent a jolt -- then, like Jessica's, drop a carpet grabber to the floor. A winch then hauls the beam down.

STUDENT Nice. That's sweet.

TEACHER Okay ready? We're gonna have a run.

ALAN ALDA (NARRATION) Will Lark, meanwhile, has built his car but dropped the idea of using it to place magnets. Now he plans to simply drive away, pulling out telescoping rods to maximize his leverage.

TEACHER We have a winner against the brick.

ALAN ALDA (NARRATION) After 14 weeks of design, construction and testing, the machines face one last hurdle.

LAB ASSISTANT Fit it in the box, however you can get it in.

ALAN ALDA (NARRATION) To qualify for the contest, every machine must fit within the box its parts came in.

LAB ASSISTANT Is it in straight?

TULIKA Yeah.

LAB ASSISTANT Put the lid on please.

TULIKA Wo-hoo!

ALAN ALDA (NARRATION) The machines must also weigh no more than the 10lb limit.

ERIC VARADY Oy!

LAB ASSISTANT What can you get rid of?

ERIC VARADY I can drop one of these clamps.

LAB ASSISTANT Do whatever you have to. You have less than two hours.

ERIC VARADY Heh.

ALAN ALDA (NARRATION) Kateri Garcia machine just slips in under the weight limit -- as does, eventually, Eric's.

ERIC VARADY Yes! Yes!

KATERI GARCIA Everybody has to put their machines away with the lock placed backwards, so they know you've been impounded. And you're not allowed to touch your machine until Tuesday morning, the morning of the competition. At that point you can decorate or do whatever you want. As long as you don't change any of the mechanics of your machine. So I'm glad it's out of my hands and I'm really excited for the competition.

ALAN ALDA (NARRATION) It's now the first of two days of head to head competition -- with no second chances. One loss, and your machine is eliminated.

ERIC VARADY I'm nervous and I'm a little stressed out by that because, I mean, it's all fun. But I spent so much time on this, so much time that, ah, I want my money's worth.

ALAN ALDA (NARRATION) Before an expectant crowd in MIT's ice hockey arena...

ALEX SLOCUM 3-2-1-go!

ALAN ALDA (NARRATION) ... Nick Martin's machine, flawless in tests, doesn't give him his money's worth.

NICK It fell over, and that's kind of depressing. I've never seen that before. I tested it, I ran it, but, you know, I guess that's what engineering's all about.

ALEX SLOCUM Go!

ALAN ALDA (NARRATION) Nick's isn't the only machine to dash weeks of hard work in a few seconds of competition. Kateri Garcia's machine, designed to bulldoze her opponent off the beam, this round simply has to cling on. Sarah Mendelowitz's jolting mechanism fails to flip open. But her carpet grabber takes a firm grip and pulls her to an easy victory. Will Lark's already made it through a couple of easy wins. And again his machine works as advertised -- almost. His car never really finds its feet, but still pulls the telescoping rods out far enough to get the leverage to win. Here's the view from above the beam -- featuring a robot that's using the bulldozer technique: shove the opponent off the beam -- then drive back to your end to tilt the beam down. The bulldozing robot was built by Malima Wolf.

MALIMA WOLF It's a pretty powerful robot, and, it's pretty simple, but, like, it doesn't have a problem falling off the beam which a lot of the robots do. So, it works. It's simple.

ALAN ALDA (NARRATION) Here's another mobile jack. Dropped off the beam, it's driven over to the opponent's side and smoothly lifts it into the air. Will DelHagen is the piston's designer and builder, and it's obviously a machine to be reckoned with. Now watch carefully. See that projectile flying over the yellow ball? It's attached to a string from a robot that's just been bulldozed off the beam.

ALISON WONG Oh my god!

ALAN ALDA (NARRATION) But Alison Wong's not out of it yet. By grabbing the pendulum, Alison manages to keep most of the weight of the whole system on her side of the fulcrum -- and pulls off a win that seems to surprise her more than anyone. Eric Varady's already breezed through several early rounds. The magnets and the winch have provided all the power he's needed. So far his car has had no opponents needing to be harassed.

ERIC VARADY It worked perfectly. So, if it keeps up, I got a really good chance.

ALAN ALDA (NARRATION) Jessica Baker's also been doing well with her carpet grabber. But this time it's up against another of those mobile jacks. And before Jessica has a chance to do any serious winching...

JESSICA BAKER He has a really nice machine. I was hoping to get down there really fast and lift up the carpet so he wouldn't be able to drive over there, but he drove over there too fast.

ALAN ALDA (NARRATION) While Jessica had the bad luck to face a jack, Sarah's carpet grabber's been having a fairly easy time. This round her opponent's magnets fail to get a grip.

SARAH MENDELOWITZ Nice job. I seemed to have gotten lucky a lot of times. I haven't had to go against a jack yet. So I think it's a lot of luck, who I picked. But I'm glad things are working well. And so far so good. I'm excited that I got this far.

ALAN ALDA (NARRATION) Malima and her bulldozer are up again -- this time against another pendulum grabber.

ALEX SLOCUM She got to winch and hope that she doesn't get off the beam.

ALAN ALDA (NARRATION) But Malima simply goes into reverse, dragging everything with her.

ALEX SLOCUM Oh! Amazing! Absolutely amazing!

MALIMA WOLF It works pretty well right now. And it seems to be making it. It hasn't broken yet, so--.

ALAN ALDA (NARRATION) Now here's a confrontation we've been waiting for -- Sarah's carpet grabber against Eric's magnets and car. Sarah gets a grip -- and yanks so hard she makes Eric's magnets lose theirs, leaving them dangling helplessly. Now Eric's only hope is his car. But Sarah hangs on -- and Eric's streak is over.



ERIC VARADY She deserved to win. That was awesome.

SARAH MENDELOWITZ That was my toughest match so far, so, I'm looking good. I'm really excited.

ALEX SLOCUM 3-2-1-go!

ALAN ALDA (NARRATION) This is the first match-up we've seen between mobile jacks. One jack maneuvers into position more quickly than the other...

ALEX SLOCUM He may have it. Don't get greedy.

ALAN ALDA (NARRATION) The faster jack is driven by Alex Jacobson. Jack's that work well, like Alex's, are beginning to look unbeatable. Here's another face-off that promises to be fun -- Will's drive-away car against Malima's bulldozer.

WILL LARK As long as the front part stays on its hooks, it should be fine.

MALIMA WOLF I think I can do it. I don't know. Who knows, we'll see.

ALAN ALDA (NARRATION) Malima's bulldozer attacks -- but it's stopped short by Will's lock-on clamp. Will's heavyweight car does its thing -- and its extra leverage keeps Malima's bulldozer hanging high.

ALEX SLOCUM That was good. Excellent!

WILL LARK Oh man!

ALAN ALDA (NARRATION) Only a few machines now remain in the running. One is the mobile jack built by Will DeHagen. Alex Jacobson has the other almost identical jack -- here literally ripping a carpet grabber out of the contest. Kateri Garcia's bulldozer has been steadily plowing its way through the opposition. It does it again. But as time is about to expire... With both machines off the beam, it ends up a tie.

KATERI The controls are really touchy and this thing likes to take off and I shouldn't have touched it, I should've left it alone.

ALAN ALDA (NARRATION) So there's a rerun. This time Kateri's bulldozer fails to dislodge her opponent ... whose carpet grabber clings on

ALEX SLOCUM Look at the climb on that! Amazing angle! There she goes, up up up and away!

ALAN ALDA (NARRATION) But Kateri's heroic climb isn't enough to dislodge the carpet grabber.

ALEX SLOCUM I've never seen, literally in seven years of teaching, a student design a machine set to go up a 45 degree angle almost.

ALAN ALDA (NARRATION) Will Lark's car is still going strong -- this time pulling the telescoping arm as far as it will go. With this win, he's in the semifinals.

WILL LARK Whoa! I've got to take a breather for a second.

ALAN ALDA (NARRATION) Sarah's luck, meanwhile, looks to have run out, as she finally confronts Will DelHagen's all-powerful jack.

SARAH MENDELOWITZ I did a lot better than I thought I was gonna do. I came up against a really tough opponent. I don't know if there was much I could do, so I did my best. Having it done on time and having the opportunity to practice really helped a lot. I think that was a big part of how well I did.

ALAN ALDA (NARRATION) But then -- an unexpected reprieve from the judges.

SARAH MENDELOWITZ So now I guess I'm rerunning since my control system stopped working again. So they're gonna let me rerun.

ALAN ALDA (NARRATION) Remember Jessica Baker's plan to try to pull up the carpet before the mobile jack could get into position? It looks like Will DelHagen's jack has finally met its match -- until Sarah give one last tweak on the controls. She tries to recover -- but it's too late.

SARAH MENDELOWITZ I got too greedy I think. I didn't want him to get underneath and I popped off. I think if I didn't get so greedy I might have been able to beat him, but it was really close. It was good.

ALAN ALDA (NARRATION) The first semifinal. And now it's Will Lark's turn to face Will DelHagen's jack. Almost before the car has even jumped off the beam, the jack is hoisting it up. All Will DelHagen has to do is stand and watch as Will Lark's car desperately tries to hook around the jack and yank it away.

WILL LARK Winch it, winch it!

ALAN ALDA (NARRATION) For Will Lark, it's the end of a great run.

WILL LARK The only way to get him was to mess him up.

ALAN ALDA (NARRATION) The second semifinal. It's Alex Jacobson's mobile jack against a simple extender that has quietly made it through round after round. For a moment it looks like Alex has gotten trapped by the corner. But then... So for the finals, it's mobile jack against mobile jack. ALEX JACOBSON A lot of things I wanted to get done I didn't get done, but everything I needed I guess I finished, so...

ALAN ALDA (NARRATION) We tracked Alex down behind the scenes... ALEX JACOBSON I gotta go.

ALAN ALDA (NARRATION) Where, it turned out, he'd been conspiring with Will. Good friends, who've been comparing notes ever since the class began, Will and Alex now plan a final collaboration.

WILL DELHAGEN Alex, come on!

ALEX SLOCUM Up and away...

ALAN ALDA (NARRATION) Carefully choreographed, the two robots jack the whole apparatus an inch off the ground -- with the beam dead level. The result is a tie...

ALEX SLOCUM Double win?

ALAN ALDA (NARRATION) ... or in MIT-speak, a double win.

ALEX SLOCUM This has never, never happened before. And I so glad it did, because we like to be different. CROWD Double win! Double win!

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