SHOW 205

Smart Talk
Machines Who Think
Art of Science
Homeless Woodpecker
The World's Scariest Rollercoaster

EPISODE OPEN

NARRATION After recess, it's time for math class. On Scientific American Frontiers ... find out how smart animals really are. Also... People -- and computers. Can you always tell them apart? An endangered woodpecker gets a new lease... on life. And engineers put a new twist into the rollercoaster. Come along for the ride, on Scientific American Frontiers.

WOODIE FLOWERS Hi. I'm Woodie Flowers, and welcome to Scientific American Frontiers. Daisy, come. Now most people teach their dogs to bark on command - you know, I say "Speak" and Daisy says "Woof". But we like it quiet - so we tried another tack. Daisy -- whisper. Cute, huh? And it didn't take her long to learn that. In fact, I think Daisy learns faster than we do. Watch this. She figured out, before we did, that returning the toy just out of reach would get her some extra attention. I guess everyone who has a pet must sometimes wonder just what's going on inside that animal's head. The problem is, how would you ever find out? After all, you can't very well just ask an animal. Actually, it turns out you can, if you're clever enough. And our first story is about two people who've come up with some ingenious ways of getting animals to reveal just how smart they can be.

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SMART TALK

IRENE PEPPERBERG I've got to go eat dinner. Gonna put you in, okay? You be good.

ALEX You be good.

IRENE PEPPERBERG Okay. I'll see you tomorrow. I'll see you then.

ALEX Bye.

IRENE PEPPERBERG Bye.

NARRATION Irene Pepperberg is a professor at the University of Arizona. ALEX I love you.

IRENE PEPPERBERG I love you, too. Bye.

NARRATION And one of her top students is an African gray parrot named Alex. Like many parrots, Alex is a virtuoso mimic.

ALEX I'm sorry. You're a good boy. I love you.

NARRATION He doesn't understand what he's saying, he's just parroting. Or is he?

MAN Come on, what is it?

ALEX Keychain.

IRENE PEPPERBERG Good birdie. Good parrot.

NARRATION The extraordinary thing about Alex is that very often, he does understand what he's saying.

IRENE PEPPERBERG What is it?

ALEX Rock.

MAN Good boy.

IRENE PEPPERBERG Yeah, good birdie. Alex, what toy?

ALEX Nail.

IRENE PEPPERBERG Nail, that's right. You're a good birdie. You're a very good boy.

MAN What toy?

ALEX Truck.

IRENE PEPPERBERG That's right.

MAN You're a very good birdie.

IRENE PEPPERBERG Tell me what color. What color?

ALEX Yellow.

IRENE PEPPERBERG Yellow, that's right.

MAN What matter?

ALEX Wood.

MAN Good. That's right. Very good.

IRENE PEPPERBERG How many? Good boy. How many?

ALEX Two.

IRENE PEPPERBERG Good parrot. Good boy. One. Two.

NARRATION Alex is even smart enough to answer different questions about the same objects.

IRENE PEPPERBERG Can you tell me what's different? What's different?

ALEX Color.

IRENE PEPPERBERG Good boy. All right. What same? What same?

ALEX Shape.

IRENE PEPPERBERG Good boy, good birdie. What color bigger? You know. What color bigger?

ALEX Yellow.

IRENE PEPPERBERG Good boy. Good birdie.

NARRATION If you still think Alex is just parroting, watch this.

IRENE PEPPERBERG Look. What matter four-corner blue?

NARRATION Alex has never been asked this question before. To answer it, he examines all the objects on the tray. There are several 4-cornered objects, and several blue objects, but only one that's both 4-cornered and blue. Alex's job is to say what that one object is made of.

DENISE What matter four-corner blue?

ALEX Wood.

DENISE That's a good boy. You're right.

WOODIE FLOWERS (NARRATION) It makes sense that animals in the wild know something about colors and shapes. But who would have suspected that they're capable of this kind of original, logical thinking? Irene Pepperberg's achievement is teaching Alex a way to show us how smart he is. And she's starting the whole process again with this baby parrot, Alo.

IRENE PEPPERBERG Can you tell us what's here? ALO Cork.

IRENE PEPPERBERG Yeah. Good girl. Good girl.

WOODIE FLOWERS (NARRATION) Alo has just learned her first word. But for her, cork means, give me something that I want.

IRENE PEPPERBERG What's here - what's this? ALO Cork.

IRENE PEPPERBERG No. This is cork. What's this?

WOODIE FLOWERS (NARRATION) So teaching her a second word is much more difficult.

DENISE Irene, what is this?

IRENE PEPPERBERG Ay--er.

DENISE Say better.

IRENE PEPPERBERG Paper.

DENISE Paper that's right. Say better.

NARRATION Irene and her student model the answer while Alo looks on. This is very similar to the way a baby parrot would naturally learn how to sing.

IRENE PEPPERBERG In the wild these birds probably learn by observing interactions between the other birds in the flock. They learn their vocalizations by watching two adults duet with one another, and that is what we're trying to replicate in the laboratory. No. Denise, what's here? ALO Ay-er.

IRENE PEPPERBERG No. Say better. What's here?

NARRATION It's only through this painstaking word by word process that Irene will teach a new generation of parrots to tell us how they think. Halfway across the country, at Ohio State University, Sally Boysen is trying to find out how chimpanzees think.

SALLY One. Two. See that. One, two. Where's the two? That's it.

NARRATION She is especially interested in whether or not they can do arithmetic.

SALLY One. Two. Good work, that was good. We're not done yet. Try a cookie.

NARRATION Bob is only 4 years old. And like a small child, he's beginning his education with the basics.

SALLY He's learning just those first two numbers and once - I knew he was going to do that. His attention span is a lot shorter than a child's, and we end up investing a lot more time in playing and social interaction than in actual learning. That's kind of the opposite of what we see in children. Where they spend a couple hours at school and 15 minutes in recess, we spend 15 minutes in school and two hours of recess. You hear that vocal laughter. Oh, boy. Tickle you good, aren't I?

WOODIE FLOWERS (NARRATION) If Bob is in counting kindergarten, then 10 year old Sheba is a graduate student. She is learning her numbers from 1 through 7.

SALLY How many is that? How many is it? Five. It's the right answer. So you can eat them all. Okay. Good work.

NARRATION Sheba also understands zero.

SALLY Okay. Look, Sheba. How many things do we have here? None. There are no candies.

NARRATION She helps herself to a reward.

SALLY She knows zero. Yeah. Oh, you think you should get reinforced anyway. How many is that? You can do your own trials. It was one. That was good. Well, gee, I don't even have to be here. That's right.

NARRATION Now that Sheba's mastered her numbers, Sally has come up with a new challenge. She puts 3 peaches in one box, and 3 peaches in another. For the first time ever, a chimp will try to solve an addition problem.

SALLY Okay. How many peaches? How many? Show me. Yes! Six is the right answer. Good girl, there's six peaches out there.

NARRATION The test involves counting the first set of peaches, holding that number in her head, and then continuing the counting with the second set.

SALLY Get the right answer. Five. Good.

NARRATION Without ever being trained to add, Sheba gets it right the first time. But what happens when Sally makes the task even harder, by substituting numbers for the peaches?

SALLY Do you see that one. Hey. There we go. Okay. How many was that. Can you pick? Show me. Four. Perfect, four. It was once thought that only humans could work on this level of abstraction.

SALLY To find capabilities in the range that we have with numerical concepts is not surprising to me. It means we have to rethink our ideas about what humanness is all about, and also what champanzeeness is all about.

NARRATION To test Sheba's number skills in a new way, Sally has devised an unusual game. One of the players is Sarah. Her job is to eat candies. Sheba's job is to choose how many candies Sarah gets.

SALLY One, two, three, four down here. Are you watching? Miss Priss.

NARRATION Here's how the game works: whichever set of candies that Sheba points to first goes to Sarah. Sheba gets what's left.

SALLY We're going to put two in here. Give those to Sarah. Sheba gets two. Sara gets four and Sheba only gets two. Oh, too bad.

NARRATION So if Sheba understands the game, she should pick the smaller amount first.

SALLY Put five in that one and we'll put one in there. Now which one do you want Sarah to have? Oh, you want Sarah to have these. It's okay.

NARRATION But no matter how many times they try it, Sheba always points to the largest amount first. She just can't figure out how to win this game. Sally has a hunch that making the task more abstract might help.

SALLY Let me ask you a question. Which one do you want to give - you want to give two to Sarah.

NARRATION And remarkably, Sheba now picks the smaller number first.

SALLY And you get six. Oh, you lucky girl. One, two, three, four, five, six.

NARRATION Sarah's not that happy about this new turn of events.

SALLY We have four - now wait, wait until I show you what else we've got. Now what shall we give to Sarah?

NARRATION Sally's theory is that actual candies trigger an instinctive greedy response, but number symbols engage Sheba's mind and help her play the game intelligently. Unlike Sheba, the males in Sally's group are too big and too aggressive to let out of their cages. Still Sally has found a way to play with them...and work with them.

SALLY How much of a peach is this? It's a half of a peach. Right.

NARRATION Darrell is working on fractions.

SALLY It's a half of a peach. That's right. What's that in your mouth, a peach pit? Thank you. Yummy, yummy. How many of these do I have? Two bananas. Right. There's two bananas here. Now watch what I'm going to do. This. And one more time, and now I have this little weensy piece. It's a fourth of a banana.

NARRATION When Sally cuts the fruit in front of him, Darrell has no problem choosing the correct fraction.

SALLY I've got some left, too. I have another fourth. That's right. There it is. Darrell has to understand that there are whole things and there are parts of things; and that we can assign a name for different parts of an apple, for example. So that there's a special name for a half of an apple, a special name for a fourth of an apple.

NARRATION When Sally cuts the fruit in front of him, Darrell has no problem choosing the correct fraction. The chimps don't like it very much when Sally turns her attention to the camera. But they figure out a way to get revenge. Soon,

they're calm enough to start work again. Darrell's next challenge is to determine what fraction of a pear this represents, without actually seeing the fruit cut up.

SALLY Guessing all of them, guessing all of them. I want to show you something. Look what if I took a whole pear like this. Oops. This is one pear, isn't it? And I'm going to cut it up for you. Darrell's still not able to reliably pick the correct fraction. It really helps him still at this phase of the understanding of the concept to see a whole fruit divided into portions. But we're working towards that. Darrell, look how many pieces I cut this into - one, two, three, four. That's right, this is only a fourth. That's good, a fourth. Good, do you want it? You don't want it? Okay. Would you rather have a piece of candy? Alright. There you go. You can stay here. We're still working. Are you going to be afraid of dogs your whole life?

NARRATION Like Alex the parrot, the chimps are actually teaching us.

SALLY Look at - he's a little goofy guy. Oh, he got you. It's two miles an hour.

NARRATION We're learning how animals think, and that's a lesson that never fails to surprise us.

SALLY Uh-oh. Don't hurt him. Don't hurt Skylar.

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MACHINES WHO THINK

WOODIE FLOWERS (NARRATION) Our next story is about absolutely cutting-edge technology - but its roots go back more than fifty years. That's when this man - a brilliant British mathematician named Alan Turing - began thinking seriously about a thinking machine. And just a few years later - in the bleakest days of World War II - he found a way to put some of his ideas to the test. This is the famous Enigma encoding machine. The German military used it to protect their most secret messages. At least, that's what they thought! But Turing and his colleagues built this - the world's first electronic computer - and used it to crack the Enigma codes. Along the way, Alan Turing asked a profound question about computers: Can a machine be intelligent? He even devised a practical test to answer this question. How does this "Turing Test" work? That's what we're about to find out.

JUDGE What is your favorite Shakespearean play?

SCREEN King Lear. I also like many of the comedies. How about you?

JUDGE Sonnets. Also the comedies, but the tragedies are my favorites. Are you familiar with Hamlet? **

SCREEN The college kid who came home and found his mom had married the guy who murdered his dad just a little month before? You might say so.

JUDGE Do you think William was a sexist?

SCREEN Of course he was. At that time everyone was. Even the Queen. Haven't you read The Taming of the Shrew?

WOODIE FLOWERS (NARRATION) We're eavesdropping on a conversation that's actually taking place on the screen of a computer

TERMINAL Emy Gugsa is at one end of this lively exchange, asking lots of questions about Shakespeare. But Emy is really trying to find the answer to an entirely different question. You see, Emy doesn't know whether she's talking to another person or to a computer program. Her conversation is being tapped...not by the KGB or the CIA but by an audience of experts and enthusiasts gathered at Boston's Computer Museum. These people are hot on the trail of the question ..."Can a machine think?"...When Alan Turing tackled that question, he came up with a test to answer it. Today we're witnessing the first attempt to apply this test. If a computer program can pass the Turing Test, these experts will consider it a thinking machine.

PHILOSOPHER Rarely in philosophy, certainly, is there a clear, decisive event like this, where things that have been ideas for years and years actually enter the real world and so it's an exciting moment for all of us.

WOODIE FLOWERS (NARRATION) The Turing Test is set up like this...In one part of the museum are ordinary folks who, like Emy, have no particular computer expertise. They are the judges-- and it's up to them and not the experts to interview all the contestants and decide which are human and which are computer programs. Every 18 minutes the judges rotate and begin another interview. There are two groups of contestants. The first group, the human contestants, are hidden away in the bowels of the museum. Their job is to conduct normal conversation with the judges over the computer

TERMINALs. The other group of contestants are computer programs. They're also talking to the judges over computer

TERMINALs. This is the Turing Test. There are eight contestants. The judges have to figure out which ones are human and which ones are computer programs. If one of the programs fools the judges into thinking it's a human, we call it "intelligent" and it passes the Turing Test. The experts and enthusiasts, watching from the sidelines, will have their own ideas about who is human and what is not. Now open-ended conversation is far beyond the capacity of even the most sophisticated programs. (Graphic) So, to give the computer program contestants a fair chance, this will be a restricted Turing Test. Each contestant has chosen a conversational specialty. And the judges' questions have to stick to these narrow topics. Let's look at this topic, "Problems with Romantic Relationships." We're going to give away the contestant's identity in this one...to get you warmed up.

JUDGE Where's the best place to meet men?

TERMINAL Perhaps you're not getting enough respect in the relationship.

JUDGE But I don't have a relationship.

TERMINAL You're not getting enough security in the relationship.

JUDGE But I don't have a relationship.

TERMINAL Perhaps you're not being appreciated enough.

NARRATION No one is fooled by this contestant. STUDENT That's obviously a computer program.

ENTHUSIAST There's just no interaction going on there at all. They're just about three miles apart all the time.

NARRATION So the Romantic Relationships program fails the Turing Test.

TERMINAL I'm an eight year old girl, a gymnast and a Baptist.

JUDGE Do you go to a Baptist school?

TERMINAL Be careful with non-metals, they're often brittle.

JUDGE Do you work with metals in second grade?

TERMINAL Machines can only do what we have the skill to tell them to do.

STUDENT Well I'm in fourth grade and I don't think that's a human at all. Second graders just don't talk like that.

PSYCHOLOGIST/ROBERT If I interact with you, and all of a sudden you make a remark that's sort of off the wall, I forgive you that remark. I can forgive you several remarks. If you keep doing too many of those, I'll say "uh oh we've got a little problem here."

NARRATION Making too many off-the-wall remarks, missing the point, giving short patterned responses, these are the giveaways that distinguish the computer programs from the humans. But some of the other conversations are proving much harder to judge. Shakespeare's Plays is driven by a human contestant. This is Cynthia Clay...She's a real Shakespeare buff. Now remember... Cynthia is hidden away...you know she's human...but the judges don't. Let's see what they're making of her conversation.

JUDGE Do you know much about the authorship to Two Noble Kinsmen?

CYNTHIA That is not among the 37 plays, unless that is some subtitle.

JUDGE Supposedly it was written by Fletcher and Shakespeare.

CYNTHIA BITE Oh. That's interesting.

TERMINAL But I'm required to only talk about Shakespeare. Why don't we just stick to the Bard himself?

NARRATION Well, unlike the computer programs we've seen so far, Cynthia's on the ball. She understands the questions and her answers are to the point. So...all the judges recognize that the Shakespeare contestant is human...or do they?

EMY Which of his plays is your favorite?

CYNTHIA BITE Let's see I'll give 'em a bizarre answer. Let's see...Pericles. I'll bet they've never even heard of that one.

TERMINAL Let's see Pericles.

EMY Why is it your favorite?

CYNTHIA Because he was obviously called in to play Dr. Somebody's awful script. It was one of the few maybe only two plays written with somebody else.

EMY BITE It was just specific information that sounds like something that would be programmable. So I just thought it was a little more on the machine-like side than human-like.

NARRATION Wow...one judge actually thinks Shakespeare is a computer program...and the audience is split right down the middle.

SCIENTISTS Some of the answers seem too studied. As if they were somehow canned opinions that came from a large data base.

PHILOSOPHER I think the Shakespeare one's human because of the way it answers questions. It can understand the larger meaning of the question. It's not just responding to one key word.

ENTHUSIAST It seems overly intellectual. The responses are too perfect. So it makes me worried that they might just be big canned responses.

ENTHUSIAST I thought I identified one human and I think it's the Shakespeare one.

NARRATION Ironically, Shakespeare is hard to judge because Cynthia knows too much. Her command of Shakespeare is encyclopedic. Having vast amounts of information instantly available is something people usually attribute to computers.

CYNTHIA They thought I was a computer because someone couldn't know that much. It's like...people go to school! People learn things! Think how much Doctors have to know!

NARRATION There's one more conversation that's a real puzzler and by the end of the day quite a crowd gathers around the "Whimsical Conservation" contestant. GRAPHIC It's judge Roseann San Martino's turn to put this one to the test.

TERMINAL Do you have a pet?

ROSEANN Yes, I have a cat. Her name is Bon Ami. Do you have a pet?

TERMINAL Honeybunch the cat has been our pet for about eight years now. She's a regular little kitten factory.

ROSEANN BITE It was personal in a certain sense. I mean we talked about our pets and it seemed to have a life.

TERMINAL I used to live in Connecticut before all the riff-raff moved in. But now I call this little townhouse home.

ROSEANN So you live alone?

TERMINAL Everything's been figured out except how to live. How ya' doin' judge?

ROSEANN BITE I'd like to have gotten to know this person, if it was in fact a person. For some reason I assumed that it was a guy. It just seemed guy like. You know, I would have liked to have met his cat, and seen his little townhouse, or whatever. And just chatted with him a little bit more.

NARRATION Roseann clearly hit it off with the Whimsical contestant. What do you think? Is this a human or a computer program? The last round is over. No more conversation. Every judge has interviewed every contestant. Now the judges have to decide. For each conversation, were they talking to a human or to a computer program? It's these ratings that will determine whether any program passes the Turing Test. Dr. Daniel Dennet, one of the philosophers who organized this contest, will announce the results.

DR. DENNET The winner of the 1991 competition is Whimsical Conversation, computer contestant Joseph Weintraub. Whimsical Conversation didn't just win, it was judged to be a human being by five out of the ten judges. Speaking on the topic of Shakespeare, Ms. Clay was judged to be a computer by two judges. But perhaps it will soften the blow for her if she realizes as well that she was judged the most human on the mean. So she wins both most human and most easily confused with a computer.

NARRATION So what has this first ever Turing Test revealed about computers and intelligence?

COMPUTER CONTESTANT I think we're learning more about the question of what it means to think than we're learning about what the capabilities of a computer are.

PHILOSOPHER It raises questions about what it is to be human, what's special about being human.

PSYCHOLOGIST You learn about the limits of intelligence, not just the limits of artificial intelligence.

JUDGE I think computers can obviously engage in dialogue and they can draw on a data base. But I don't think they can originate a thought. That certainly wasn't demonstrated today.

NARRATION The results of today's restricted Turing Test are not so important. What matters is the proof that the test itself actually works. We now have a meaningful way to ask and to answer the question, "Can a machine think?"

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ART OF SCIENCE

WOODIE FLOWERS (NARRATION) Usually on the "Art of Science" we bring you some of the hottest animation produced on today's supercomputers. But this time we've got a real classic - a film called "Powers of 10," made by Charles and Ray Eames way back in 1977. Its age shows a little, but "Powers of 10" is still a great movie. In fact, for me it's the best illustration ever of a very abstract idea - the relative size of everything in the universe, from galaxies to subatomic particles. In our clip, we start at a picnic beside Lake Michigan. Then, every ten seconds, we'll zoom ten times farther away - until we fly back in like greased lightning.

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HOMELESS WOODPECKERS

NARRATION In the summer of 1989, the Francis Marion National Forest in South Carolina was a haven for one of America's rarest birds, the red-cockade woodpecker. The woodpecker is an endangered species because old growth pine forests like this, once common in the south, are themselves disappearing. The Francis Marion National Forest was special because here the population of the red-cockade woodpecker was actually on the increase. Then came the night of September 21st. 1989's killer Hurricane Hugo struck South Carolina with almost unparalleled fury -record high seas and one hundred fifty mile-an-hour winds. Watching the news reports with mounting horror was ornithologist Jerry Jackson.

JERRY JACKSON I was keeping a very close eye on where it was headed. I had been on the Francis Marion National Forest only about two weeks before the hurricane hit and I knew what was in store and it was disaster, I mean absolute disaster.

NARRATION In just a few hours, most of the Francis Marion was leveled. Of the forest's seventeen hundred red-cockade woodpeckers, one thousand were dead or missing. Many trees snapped where the woodpeckers had drilled their holes,

crushing the birds sheltering inside. It's this destruction of the woodpecker's homes - even more than the loss of the birds themselves - that was the most devastating of Hugo's blows to the species. Because the red-cockade woodpecker's home is definitely not just a hole in a tree. To find out why the red-cockade woodpecker's nest is so special, Frontiers came here, to Mississippi's Noxubee Wildlife Refuge. It's early in the morning - the best time to catch a woodpecker. Noxubee - another of the few scattered old growth pine forests of the south - currently is home to just forty-one woodpeckers. White bands mark trees with woodpecker holes. The question for Jerry is whether the bird in this tree is sleeping late.

JERRY JACKSON Hey! We got one!

NARRATION If this is a female, then she's the only one at home. That's because males and females keep separate living quarters - and it's the father who nests with the babies, while the mother sleeps off by herself.

JERRY JACKSON Oh, this is a bird that has bands on it, so we've got us a recapture. We'll be able to tell how old this bird is and when it was banded.

NARRATION And its sex - because only the males have the red cockade.

JERRY JACKSON They only show these red-cockades when the birds are aggressive or courting. This bird's a little aggressive right now because he doesn't really like being caught.

NARRATION Because it's a male, there are probably babies in the tree - and their hungry cheeps give them away. Both male and female share the feeding chores during the day.

JERRY JACKSON Well, get back to your nest, fella.

NARRATION So here's the first reason the holes are valuable - each family needs two. The second reason is visible around the hole itself - sticky sap, looking like candle wax. The sap is there because, unlike other woodpeckers, red-cockade woodpeckers choose to make their holes in live trees, not dead ones. And making a hole in a living tree is hard - very hard.

JERRY JACKSON The average length of time that it takes for a red-cockade woodpecker to excavate a cavity is four point seven years. As a result, those cavities are extremely valuable pieces of property, and they're passed down from generation to generation, and the males inherit them.

NARRATION Four point seven years' work per cavity is quite a mortgage to pay off - and it raises the question: Why? Why do red-cockade woodpeckers drill through live sapwood, while other woodpeckers just peck their way through dead wood? And here's the answer - the gray rat snake. It's a superb tree climber, its scales giving it an excellent grip on the bark. But around the nest hole, the woodpecker has pecked the bark to keep the sap flowing. As the snake approaches its goal - a succulent meal of eggs or nestling - the waxy sap gets thicker and thicker. The sap works its way between the snake's scales, sticking them together. But if the sap protects against snakes, it doesn't keep biologists away. Fortunately, Jerry's motives for climbing the tree are more benevolent. While the parents are away gathering food, Jerry plans to check on the nestling. This is a three-week old female. She's banded, then weighed -- during which she gets her first real look at the world she'll soon be joining. Jerry's work is part of a detailed monitoring of the birds here in Noxubee from birth to death.

JERRY JACKSON That about does it - forty-five point three grams. This bird is very close to fledging. You can see it has very well-developed wing feathers, but that the wing feathers are still growing. And those feathers will be completely grown probably within the next week, and this bird will be out of the nest by then.

NARRATION Out of the nest - and needing one of her own. Her home nest will be inherited by a brother. Fortunately, in Noxubee, there are still a few trees to be drilled, a few homes to be had. But back in the Francis Marion National Forest, Hurricane Hugo crushed hundreds of woodpecker homes. With so many trees destroyed - ironically, snapped in two often because they contained woodpecker holes - the shortage of homes is acute. And because it takes so long to make new cavities, wildlife managers here feared that the seven hundred birds surviving the hurricane would die homeless. So in the spring of 1990, they went into the construction business. Biologist Carolyn Bachler first drills a horizontal hole, just as the bird does. Then she drills a second hole at an angle from above, to create a vertical cavity down through the middle of the tree. The idea is to reproduce in a few hours what it takes a bird over four and a half years to make.

BOB HOOPER Here's the entrance, here, and it's about nine or ten inches deep. The light-colored wood here is sap wood, and it is living wood and the resin actively flows through it. The reddish-colored wood here is heartwood and it is essentially dead - there's no resin movement through it. The bird needs the heartwood into which to put its cavity so that it doesn't have to contend with resin within its cavity. Carolyn Bachler scrapes off some bark to set the sap flowing. The tree is in move-in condition - but it took half a day's work. Here's a pre-fab option. This time, the tree is excavated by chain saw. A little putty - and a bird house is slipped into place. Even sap holes are started for the hoped-for tenants. A little paint gives the impression that the sap is already flowing. In all, over six hundred artificial cavities were built in the Francis Marion Forest over the winter.

With spring - and nesting season - came the chance to find out if they worked. Eddie Taylor checks one of the bird house implants with a light and a dentist's mirror.

TAYLOR Bob, we've got some eggs.

HOOPER Is that right? How many?

TAYLOR Got two.

HOOPER That's the very first nest. The same nest, three weeks later - and hungry chirping signals that the eggs have hatched.

TAYLOR What I'm gonna do is fixing to pull the nestling out of the nest so we can band them. What I'm gonna use is this little instrument right here. It makes little nooses, and then I'll pull it tight and it'll grab them and I'll pull them out gently. It doesn't hurt the young because their bones have not calcified at this age, and so they're still malleable. And we can handle them gently without hurting them.

NARRATION The chicks' eyes aren't open yet - but they can tell the difference between light and dark. And dark means their hole is covered by Mom or Dad arriving with food. At least that's usually how it is. A nest-by-nest inspection of the trees that remain in the Francis Marion National Forest this spring showed that sixty-five percent of all the new birds were born in the artificial cavities. A band on the bird will help keep track of it in the future. The man-made nests appear to have given the woodpeckers here a new lease on life. But even as this most important population of red-cockade woodpeckers has been rescued from a rare natural disaster, the erosion of their habitat all over the south continues. The real threat to the species' survival remains man, not nature.

JERRY JACKSON There's a lesson to be learned form Hurricane Hugo, and we're very fortunate we have the opportunity to learn that lesson. And that lesson is that every population is important. And that we can't count on having a few large populations. This is probably the best-known woodpecker in the world. We know what it requires - we know what it needs. We've just got to make up our minds to do what it needs to protect the remaining populations.

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THE WORLD'S SCARIEST ROLLERCOASTER

WOODIE FLOWERS (NARRATION) I've always wondered what it would be like to jump out of a plane - so I'm going to find out.

DIVE INSTRUCTOR Head up nice and high - hard arch.

FLOWERS This is fantastic - I hope you guys can hear me.

INSTRUCTOR All right give me a left turn, Woodie.

FLOWERS Okay.

INSTRUCTOR Stop - turn left.

FLOWERS Those are nice, swift turns. This is a 3-D sports car. Here I come!

INSTRUCTOR 3, 2, 1, flare. All right, good job, Woodie. Wow, I'm sure the guys with the cameras did a great job, but there's no way pictures can do justice to what I just experienced. I knew this was going to be a fun job.

NARRATION Actually, I spent a whole day training for this, and it cost several hundred dollars. And even though the risk associated with the jump was probably less than that of driving out here this morning, it's pretty clear that sky diving's not for everyone. But a lot of people would like to get the kind of thrill that I've just experienced without spending the time, and the money, and the nerve. And that's the reason that amusement parks are big business - and that's the reason that the designers of rides are always trying to outdo one another. We wondered how you would design a ride that was both thrilling and safe - so we've spent over a year tracking the designing and testing of what is - at least for now - the world's ultimate rollercoaster. Three or four major rollercoasters open up every year. And in a never-ending competition to be the best, each is bigger than the one before it. Today, coasters can be twenty stories tall and reach speeds of seventy miles an hour. The coasters are designed to be safe. But their intimidating looks are beginning to scare off less adventurous riders -- according to the designer of this coaster, Ron Toomer.

TOOMER I really think a lot of people are going to walk up to that thing, look up there and say, "My gosh, that's too big for me -- I'm not going to get on it."

WOODIE FLOWERS (NARRATION) So five years ago, Ron began toying with a brand new concept in coasters. Here's how all existing coasters work. The twists and turns and ups and downs in the track create forces pushing and pulling on the rider. That's what makes them fun. But always the greatest force is pushing car and rider against the track -- even when you're upside down in a loop --and that's what keeps you from falling out. To demonstrate, we joined a high school physics class as they rode a coaster with their own home-made force meters.

TEACHER That's going to register on this. When we're standing here still, this is our one unit of force. This would mean that on your rear end, when you're in that car, you'd feel your normal weight. But as we go around the bottom of that curve, you're going to see this thing pull down to two, three, or three and a half times your normal body weight.

WOODIE FLOWERS (NARRATION) For the experiment, each student was supposed to look at and remember the force holding them into the car at different points in the ride. But it proved easier said than done.

STUDENTS Too scared to look at it. We didn't look at it - we forgot. Gonna do it again.

WOODIE FLOWERS (NARRATION) We made it easier for us to see by slowing down the action. Entering a loop, there's a force three and a half times greater than normal gravity pushing them into their seats. Even when upside down at the top of the loop, they're being held into their seats by a force two times gravity. So at no point do they really feel as though they're upside down.

STUDENTS You felt like you were on Earth rather than on a rollercoaster upside down. Didn't have a sensation of being upside down. Except for the visual sensation of looking upside down, it felt like you were sitting right-side up. In all existing coasters, that's just as well - otherwise car and riders would fall off the track. Only briefly, at the crest of a hill, does a rider feel like he's coming out of his seat. But what if a coaster could be designed that did a barrel roll -- like an aerobatics plane?

TOOMER We're looking for an advancement of rollercoaster technology here that would allow us to feel more like that kind of a sensation where you're able to roll over, fly along upside down, and you really are upside down. You're hanging upside down, you look down and there's nothing below you but the ground - and there's no tracks -there's nothing there to hold you up.

WOODIE FLOWERS (NARRATION) It was this new twist in rollercoaster design that Ron and his company, Arrow Dynamics, decided to explore. This is an early run of a quarter-scale model. To create the barrel roll effect, the car sits down in the tracks rather than on them, as in existing coasters - and to hold it up when it's upside down, it hangs from a second set of wheels. These are big innovations for a rollercoaster, and when we joined Arrow in the early stages of development, there were still plenty of questions to answer - like just how much initial energy the car would need to avoid the discomfort - and embarrassment - of a problem like this! The main task though, was to stop people from falling out - the job of engineer Dahl Freeman.

FREEMAN Would you like to pull the restraint down now?

WOODIE FLOWERS (NARRATION) The challenge is to come up with a restraint system that holds people comfortably and securely, no matter what their shape or size.

PASSENGER Feels great. Really secure.

FREEMAN So you feel more secure hanging onto the handles?

PASSENGER If we're going upside down.

FREEMAN We're going upside down.

PASSENGER I'll hold on.

WOODIE FLOWERS (NARRATION) Ideally, the restraining system would be adjustable to fit each rider - but the time that would take between rides would make the rollercoaster unprofitable. This system works well for Cindy, an average sized woman. But Bill, who's a little larger, would clearly have some problems. The lap bar is meant to fit snugly across his legs.

FREEMAN Obviously, this is not going to restrain his body and offer the support that he needs when this vehicle turns on its side or goes upside down.

WOODIE FLOWERS (NARRATION) Bill can be accommodated only by shortening the lap bar so it can reach his lap. Now the system works fine for Bill.

FREEMAN Okay, how do you feel?

BILL I really feel secure. There's no place to go.

WOODIE FLOWERS (NARRATION) But can it still do a good job on someone Dusty's size? Arrow's goal is to fit children four feet and taller. Dusty's four feet four.

FREEMAN Pull that down so it's tight. Feel good? Feel locked in? Okay.

WOODIE FLOWERS (NARRATION) The shoulder restraint only keeps him from falling forward. So it's up to the lap bar to hold him in.

FREEMAN Okay. Dusty, how ya doing?

DUSTY Fine.

FREEMAN Good. Things feel OK here.

DUSTY Yeah.

FREEMAN Okay, your legs are tight, look like they're good and tight, your arms - you're holding on a little bit here, your head's clear, OK, and you're off the seat just a few inches. Let's turn him back up.

WOODIE FLOWERS (NARRATION) Freeman is increasingly confident his system will hold riders as different in size as Bill and Dusty, comfortably and securely.

FREEMAN There's a partial compromise here. If I were setting it just for him, I'd probably move this lap bar another 1 or 2 inches. But the way the seat is designed in the lap bar, we got a range here, where we can lock him in securely, and as well deal with someone that probably weighs 4 or 5 times as much as he does.

WOODIE FLOWERS (NARRATION) Devising an effective restraint system was a problem they'd anticipated. But the first time they put a mock-up of an entire car on the track, there was a nasty surprise in store. Because the car sits down between the rails, when it goes through its barrel roll, the rear passengers are brought within a dangerous few inches of the track.

FREEMAN Boy, look at that.

ASSISTANT That looks pretty close.

FREEMAN You know, we haven't had to deal with this before, in that the tracks have always been pretty well under the vehicle. But this track's coming right up around as we go through the spiral. We're going to have to do some shielding here, some more shielding than we normally do. One thing I don't want to do is close this in with a canopy. We've got to keep the vehicle open to maintain the thrill of the ride.

WOODIE FLOWERS (NARRATION) But in the end, a small rear canopy is the only solution to making sure hair and hands don't get caught between wheels and track. At last, it's time to erect the test track -- one quarter of the finished ride. The joins must be precise to avoid dangerous lurches. But even the greatest care doesn't mean the coaster will run as predicted. While expected speeds and forces were all carefully calculated, they were based on assumptions about wheel friction. And this is the first time a coaster has alternated riding on top and bottom wheels. If the friction is less than expected, the coaster will run faster than

planned -- maybe dangerously so. Which is why the first passenger won't be a person, but a machine -- an accelerometer. It's much like the students' home-made force meters, but it records front-and-back and side-to-side forces, as well as up-and-down. Three years after work began, the coaster is hoisted into position for its maiden voyage. The starting height is still something of a guess. If it's too low, the car may not pick up enough speed to make it around the track.

FREEMAN There's always that feeling inside - you know - what can happen that we don't know about yet? And maybe it'll end up just going back and forth right here in the dip and not make it all around or something like that.

WOODIE FLOWERS (NARRATION) The moment of truth. It looks like a perfect run - but were the forces recorded by the accelerometer in line with predictions? All seems to be well -- even in the critical region under the line when the coaster is hanging upside down. So it's safe for a human rider. Who will it be?

TOOMER I don't ride them anymore. I get sick, for one thing; and I don't like to go upside down for another; it's just not my thing.

WOODIE FLOWERS (NARRATION) It's the engineers who'll take the first spin. After all, they built it!

ENGINEERS Bring lap bars down first. Tug on them a little bit. Okay? Have a nice ride.

WOODIE FLOWERS (NARRATION) From the sound of it, Arrow's created the new thrill it was seeking.

FREEMAN This ride concept opens up a whole new dimension to us. And we can see, instead of the horizontal spirals, we can actually see a drop, rolling. We think that'd be wonderful. We see a high speed spiral - just exciting things in our minds and they've got to be developed and tested, but I can tell you right now they're going to work.

WOODIE FLOWERS That's it 'til next time on Scientific American Frontiers. Please come on back and watch.

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