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EPISODE OPEN

NARRATION A chemical in this tree may cure cancer - but there's not enough for every patient. Search for new sources on Scientific American Frontiers. Also: Hot wheels designed by users take the lead in the Boston Marathon. Ants battle for life and death on the forest floor. In the air -- a contest of flying robots. And setting fires is the secret to saving the prairie. All next, on Scientific American Frontiers.

WOODIE FLOWERS Hi, I'm

WOODIE FLOWERS and welcome to Scientific American Frontiers. You know, a modern pharmacy like this is full of miracle drugs. Here's a whole row of stuff for people with colds and allergies. And this one is used to treat some forms of high blood pressure .... modern miracles? Well, it turns out that people in India were making this one out of snake root at least 300 years ago and healing with the afredra plant which is the raw material for these decongestants began with the Babylonians more than 5,000 years ago. Now, it may come as a surprise, but in out own hi-tech era, nature is still the most important source of new medications and you just couldn't ask for a more dramatic example than our first story.

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ENDANGERED WONDER DRUG

NARRATION The Cascade Mountains of Oregon -- home to some of America's very own rain forest. Phil Hassrick and Jerry Kordan are out to find a very special inhabitant of these old growth woods. This is their quarry - the Pacific yew. It grows only 30 feet high, and has no commercial value compared to the big stands of cedar and fir. So why are they cutting it down? 3000 miles away, Elaine Hess is entering the Johns Hopkins Hospital. Elaine has ovarian cancer. She needs what's inside that yew tree -- an experimental drug called taxol. It's her best hope for stopping the deadly disease.

ELAINE HESS I am young and stronger and better able to fight. I know the statistics for ovarian cancer aren't that great but I've never been a person to go with statistics that much myself anyway. I'm going to fight as hard as I can and just go day by day. And I feel that with the taxol I have a much better chance.

NARRATION Elaine may have reason to be optimistic. She's part of a clinical trial that's being run by Dr. William McGuire. The Johns Hopkins trial has produced encouraging results.

DR. WILLIAM MCGUIRE Some 30 to 40% of ovarian cancer patients who don't respond, or have stopped responding to other drugs, respond to this drug. Often times their responses are dramatic responses. The tumors went away.

NARRATION Elaine's tumor is shrinking -- she and her husband may soon be on their way home.

DR. WILLIAM MCGUIRE .... this afternoon. Hopefully, we'll have you out of here by Wednesday morning and then you'll see me in 3 weeks. At that point we'll repeat the cat-scan and hope to see that the disease is small or possibly even gone.

ELAINE HESS Okay, that sounds good.

NARRATION Taxol was discovered by the National Cancer Institute in a random sampling of plants in the forest. Yew tree bark is rich in taxol, so Phil Hassrick is collecting it for the clinical trials. Peeling off the bark kills the tree, but right now this is the only way to provide the drug to cancer patients. And this is the distilled essence of that yew bark: 200 milligrams of the refined drug taxol, today's prescribed dose for Elaine Hess's chemotherapy.

NURSE Okay Elaine, you have your taxol. We're ready to start. You ready?

ELAINE HESS Yes.

NURSE How does your arm feel?

NARRATION The taxol is given intravenously -- six doses like this one over a four-month period.

NURSE Your heart rate is pretty much baseline, but remember when we start I want you to let me know if there's any pain in that site. If you have any chest discomfort at all or any breathing.

NARRATION So far, Elaine is one of the lucky ones. She's not cured yet, but for her and the 20,000 American women diagnosed each year with ovarian cancer, taxol is the one promising medicine on the horizon. But behind this exciting potential looms a serious problem. If taxol succeeds here, there may not be enough of it to treat more women like Elaine. The problem lies in the old growth forests scattered throughout the Pacific Northwest. For the past 80 years these virgin stands have been cut for their timber. The efficient modern method is clear cutting. These areas will be replanted, but only with one or two commercially valuable species. The rich diversity of plant life that was here, including the yew, is gone.

PHIL HASSRICK Prior to the finding of taxol the yew tree was considered a nuisance species to the point where no one had any idea how many trees were in the forest. They were regarded as a menace, they would cut them down or they would try and lay the big trees down on top of them and use them for a cushion so that the big trees didn't get broken as they fell.

NARRATION In just two years, all that has changed completely. The Pacific yew is now a very valuable tree. So Phil Hassrick's company, Hauser Northwest, hustles into the forests before they are clear-cut to remove the bark. But even this is no real solution. As the yew is removed, no one is replacing what is taken. The wild supply of the drug is being diminished. Even if all the yew trees are harvested, there will not be enough taxol to meet future demand. That's because it takes a lot of bark to make a little taxol. At Hauser Northwest's collection center, thousands of yew trees are stripped and reduced to handfuls of bark chips. It takes about 30 trees to fill this box with chips -- and that's only enough to treat ten women with ovarian cancer. If taxol also proves to be effective against lung and breast cancer, 10 times more bark will be needed.

PHIL HASSRICK If this drug is a success, we're going to have a problem. The demand for the drug and the demand on harvesting it from the forest will increase as much as possible. I don't think there's a limit to how much that they can take. And for that reason I think that we have to find alternatives as soon as possible so that we can be out of here and that we can not damage the speeds irreparably.

NARRATION One alternative is to grow the yew. Here in Corvallis, Oregon, a U.S. Forest Service project is planting cuttings from wild trees under controlled conditions. Researcher Nan Vance's goal is to find out how to cultivate the trees for maximum taxol production. But growing these cuttings into mature trees will take 80 years. That's when the bark will be ready for harvest. One new idea is to tap the young needles instead. Taxol is present in these needles, but at much lower levels than in the bark. New work suggests that this approach could lead to a renewable source of the drug, if researchers can grow high-yielding yew

needles. But getting to that point takes lots of basic research. To gather information Nan Vance is stalking wild samples of yew to find genetically superior taxol producers. She's also looking for how growing conditions influence taxol concentration. For example, she takes samples from this shady understory where the trees get very little light. Then Nan and her colleague Rick Kelsy visit another area, where yews are growing in sunnier conditions. Comparing the effects of different light levels takes painstaking analysis in the laboratory. The samples are evaluated and plotted, to pinpoint the most important influences on taxol production.

RICK KELSY Okay, there's our sun sample. Now we've got an overlay. This is your shade taxol and this is the sun sample, its taxol.

NAN VANCE No ambiguity about it. That's very good.

NARRATION If these preliminary results hold up, and shade stimulates higher taxol yields, then Nan will have to mimic the natural shady condition of an old growth forest to raise the most productive yew trees. Meanwhile...far from the forest, a dramatically different approach to the supply problem: making taxol without the yew tree. Bob Holton, a chemist at Florida State University, is using a computer to model the problem of building a synthetic taxol molecule. It's quite a problem --taxol is one of the hardest natural chemicals to copy.

ROBERT HOLTON This is a model of taxol which shows its complexity and its shape. There are essentially two parts, one is this part which looks much more complicated and the second is this part down here which has been know as the taxol side-chain.

NARRATION The simpler side chain is what Bob Holton's team tackled first. After years of effort, running thousands of chemical reactions, they succeeded in synthesizing an exact replica of the chain. But the more complex main ring remains out of reach. So Holton has gone back to nature to get some help.

ROBERT HOLTON There's another naturally occurring molecule known as baccotin III which is identical to taxol except that it has no side-chain. It is obtained from the leaves of the English yew and perhaps many other varieties of yew, and is a much more readily available material than taxol itself. So what we have done is gone ahead and develop a procedure to attach the side-chain here to baccotin III to make taxol.

NARRATION Thanks to Bob Holton's insight, a whole new source can now be tapped to make taxol. And it lies as close as our own backyards. The English yew and other ornamental varieties have Baccotin III in their needle. Each spring at nurseries around the country, these young yew bushes are pruned. The

clippings are left to rot. Here at the Zelenka Nurseries in western Michigan, the world's largest grower of ornamental yew, this spring's pruning is being done differently. For the first time, they're using combines to prune the yew bushes, so they can collect the potentially valuable clippings. It's the world's first ornamental yew harvest. The objective is to produce baccotin III and taxol for testing by the National Cancer Institute. We still don't know if making synthetic taxol on a large scale is viable, or if this hybrid chemical is as effective a cancer treatment as the natural variety. If it is, then these needles ... combined with the chemical side chain from the test-tube.., may one day produce this needed drug in commercial quantities. But remember, these alternatives are still only fledgling developments. For now, the old growth forest is the only place to go for taxol -- and for other discoveries that may be just as priceless.

PHIL HASSRICK More than 70% of the drugs that are available on the market come from natural sources and are extracted from natural products. We don't know at this time what's in this forest. We have no idea how many more taxols there are out there to be found, and what sorts of diseases and what sorts of benefits they can render to man.

WOODIE FLOWERS In the time it took to watch that story, more than a thousand acres of the world's tropical rainforest were destroyed. That's more than 50 million acres a year which is why so many people worry that some day greenhouses like this may be the only place to find many tropical plants and trees. One reason environmental groups argue we have to save the rainforest is that we may be throwing away valuable medicines ... maybe even a cure for cancer. Now, along comes taxol, a real example of a treatment for cancer that comes from rainforests right here in the United States. When you consider that half the plants in the world live in tropical rainforests and that only one in a hundred have been screened for their medicinal value you wind up with one solid practical reason for worrying about the fate of the forest. Those trees that seem so far away may one day save your life.

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DESIGNER WHEELS

NARRATION The starting gun of the Boston Marathon - one of the world's premier sporting events. Just to make this field, you need legs of steel. But some competitors can't use their legs at all. Paralyzed by injury or disease, these racers will pull themselves through 26 miles in wheelchairs. Like every runner here, they have to be in top physical form. But to win in this division, they also need hot wheels. Fast chairs are part of a design revolution -- a profound change that's been engineered by wheelchair users themselves. One of these user-

designers is Rainer Kueschall. He didn't set out to be an engineer - but life left him no alternative.

RAINER KUESCHALL When you are very limited you only have 2 choice to go forward or stay where you are and suddenly one day comes and you say 'I have to do something with my life'. Which way shall I go? And I went a positive thinking way.

NARRATION Watching Rainer work out in his native Switzerland today, it's hard to believe that a diving accident 26 years ago left him virtually paralyzed. His long recovery was made even more difficult by the wheelchair he was given. It's tough to push that conventional wheelchair, even up a ramp, as Rainer's associate demonstrates. As for climbing over curbs -forget it - at fifty pounds, the chair's too heavy. And the main wheels are so far back that steering and maneuvering are really tricky. For Frontiers, Rainer reluctantly agreed to get back into the old standard wheelchair. All the discomfort and dissatisfaction he experienced years ago came back as forcefully as ever.

RAINER KUESCHALL My seat position is not good enough. My legs are much forward. The mobility is absolutely eliminated so I feel real disabled.

NARRATION Rainer refused to endure these limitations. Ten years ago, he decided there was only one thing to do … design his own wheelchair.

RAINER KUESCHALL (V.O.)/SYNC I feel free.., maneuverable.., only like that am I able to be active. I think as you saw me before I never have a chance to survive outside.

NARRATION The standard wheelchair is heavy and high off the ground. Rainer's chair is lighter, lower to the ground, and most important - the back wheels are directly beneath the seat. That makes it easier to maneuver the chair and to get more power into each push. Today Rainer is a world leader in wheelchair design, and he operates a factory in Basel. The engineering changes he made are simple enough - but they make a big difference because they come from a personal understanding of wheelchair riders' needs.

RAINER KUESCHALL We are wheelchair users and it is in our interest to squeeze the maximum out of it. That's why I think we found all these technical improvements in a short period of time that nobody saw before.

NARRATION Thanks to Rainer, and a handful of other user-designers, wheelchair riders can now tackle just about any sport they choose. One athlete who's made the most of the new mobility is Bob Hall. Like Rainer, Bob rejected the limitations of the standard wheelchair.

BOB HALL I found that the wheelchair was the most disabling aspect of my being and that really held me back. It was made for not really any other purpose than to sit there and I wanted to move and move fast.

NARRATION In 1975 Bob became the first athlete to complete the Boston Marathon in a wheelchair. That first ride was in this conventional chair. But he too became a user-designer - and built this racing chair. The back wheels are angled -- that puts the tops within reach for a power push, while providing maximum stability at the bottom. Bob's latest is this three-wheeler. A mere 17 pounds, it's been clocked at 40 miles per hour. Three weeks before the Marathon, Bob is struggling to come up with the extra edge of speed that could make him the winner. To give the chair sleeker lines, he's considering an idea from auto raring: taper the squared off back, so the whole flame becomes a streamlined diamond. And to reduce the weight, Bob's got another trick. For the first time ever, he's fashioning a wheelchair frame from titanium. It's an idea he got from raring bikes, which use titanium because it's light but extremely strong. With some delicate finishing work, the diamond frame is completed. And to get the most out of the new design, Bob's bringing in a top young racer. He's Craig Blancherte - featured in this Nike commercial. Craig is a genuine sports star who's making it big. Three days before the Marathon, Craig flies in from Oregon to take on Bob's new machine.

CRAIG BLANCHETTE How light is it?

BOB HALL What do you think?

CRAIG BLANCHETTE It's awesome. It's awesome.

BOB HALL I think it's about 12 1/2 pounds.

CRAIG BLANCHETTE Really...pretty amazing.

NARRATION Craig's usual event is sprinting - and he discovers he can really fly in this chair. Now he wants to check out a key racing strategy - drafting. With the old three-wheeler up front, Craig gets close in - then he can ride the draft of reduced air resistance, and work less hard. Bob's design is shaping up as a real contender. Back in Switzerland, Rainer is also making final preparations for the coming race. As a quadriplegic, he won't compete directly with Craig, or with paraplegics who have full upper body strength. But just being in the same race is a personal victory.

RAINER KUESCHALL I think it's natural when you are slow you want to be fast. And when you see the big boys, the paraplegics, and so on you saw the

possibility they could move and so ... I think it always a little dream of a quad, 'Wow, if I could just do that',

NARRATION Race day in Boston ... the preparations are over ... time to warm up ... for runners ... and for wheelchair racers. Craig's new chair is ready to roll. Now the pressure's squarely on him: Can a sprint racer really cut it over the marathon distance?

CRAIG BLANCHETTE I'm feeling anxious and nervous actually. I'm ....I really don't know what I'm feeling actually.

NARRATION Fifteen minutes before the foot racers, the wheelchair racers take off on a rolling start. That's Craig in the blue helmet. The official whistle, and they're off. After just a few minutes, the field thins out, with Craig up front. Two miles later ... this trio makes a break from the pack ... with Craig hanging onto third. Jim Knaub, the 1982 and '83 winner, pulls ahead. Craig - already a little winded - remains behind to ride the draft. Then, with a sprinter's spurt, Craig makes his bid for first place. Soon it's just a two-man race, with Jim and Craig trading first place. But behind the leaders ...the infamous Heartbreak Hill takes its toll. And for Rainer it's especially grueling. He's completely exhausted - he can't push anymore - but the crowd keeps cheering him on, and he pulls himself up the hill. Meanwhile, at the front, Jim Knaub begins to pull away from Craig. In a distance event, you've got to know how to pace yourself... Craig's fast chair can't make up for his inexperience. And the veteran wins his third race. hour, thirty minutes. He's wheeled 26 miles in one. Four minutes later, Craig comes in second ... an outstanding finish for his first shot at a major marathon.

CRAIG BLANCHETTE Basically, all I did was try to hold onto second. I tried to dial 911.

NARRATION Rainer finishes in a respectable three hours - his bravery and persistence paid off.

RAINER KUESCHALL It's the hardest race I ever did. These hills take everything out of you. It was unbelievable ... the crowds. These people are absolutely crazy so I never could allow me to give up.

NARRATION The new mobility has progressed so far that a hundred-year-old foot race now has two winners. And as user-designed technology becomes available to all disabled people, everybody wins.

WOODIE FLOWERS Scientists today are in danger. Danger of being buried under all the numbers pouring our computers, but there's hope. We're learning to use these computers in a new way to create pictures to help make sense out of

numbers. And sometimes pictures produced in this process of scientific visualization turn out to be real works of art. As a regular feature of Frontiers we're going to look at some extraordinary images. They may come from microscopes, sensors, TV cameras, or computer animation. What they have in common is enabling us to see something marvelous that we couldn't see any other way. This time we travel inside a severe thunderstorm. Courtesy of the National Center for Computing Applications at the University of Illinois we get kind of an x-ray view of how a storm builds up.

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RESTORING THE PRAIRIE

STEVE PACKARD I'm standing on what was the prairie, the tall grass prairie, now one of the rarest ecosystems in the world. This is why it's so rare. This place, the buffalo pawed here. The rain fell on the prairie flowers and prairie grasses. It says, "Prairie View Plaza" over there. I don't see it. What I would like to see, if I saw the prairie, I would see a mass of blue flowers here, then a mass of green over there, tall grasses waving back and forth, the buffalo comes wandering through over there, big masses of them.

NARRATION Steve wants to see more of this - original prairie. Once it covered 150 million acres, but after European settlers arrived in America, almost all was turned into farms and cities. We need farms and cities, Steve's the first to agree, but now the prairie's nearly a dead ecosystem. Just a few isolated patches like this remain, hemmed in by trees. It's time to do something about it. And a lot of people agree. Today, they meet on public land near Chicago.

STEVE PACKARD What our goal here is, on this little piece, this little six hundred acres, is to put it back the way it was when the buffalo walked across this ground, 200 years ago, 2000 years ago, 8000 years ago.

NARRATION They won't be tearing down farms and cities, but they will attack something else that replaced the prairie - forests. Every tree in sight comes from Europe or Asia, brought in by settlers. Foreign trees have choked out much of the original prairie, stealing sunlight and water. So before prairie seeds can be re-sown, the land must be cleared of everything but the few natives - giant burr oaks. Hundreds of years ago these trees stood alone, amid the grasses.

STEVE PACKARD And we will take these wonderful little rakes that sound like Hare Krishna bells, don't they? You know it helps the seed, we go "Ah, yeah..." really helps them. We'll do some strips, through there.

NARRATION Steve scatters rare prairie seeds on an already cleared area. Foreign grasses are established here. But the rakes drill the seeds into the soil, where the chance to sprout and compete is best. The prairie grasses won't win back this turf for decades. But to those that labor, it's worth the time and effort.

WOMAN SYNC The work out here is what makes me feel my life is counting. This is the important part. I feel like I'm not only doing a nine to five job in an office, that I do all the time, but I'm doing things that make me feel like I'm helping the Earth a little bit more.

MAN SYNC My ancestors came over in about the 1870's from Ireland, so I can imagine what they saw, none of my family has seen for possibly about 50, 60, 70 years. So I'm going to relive somewhat what they saw previous.

STEVE PACKARD People think of frogs as creatures of ponds, but this guy lives in the prairie ... a leopard frog. Making a little squeak.

NARRATION All sorts of prairie creatures are now showing up in a patch of land they've been working on for the past 7 years.

STEVE PACKARD This is a katydid, and they only grow in the prairie and while we're saving 50 species of plants, we may save 500 species of guys like this.

NARRATION And even fire has a place in bringing the land back to life. Winter's over, and underneath the carpet of dead grass, there's a prairie waiting to get out.

STEVE PACKARD These are the weed grasses. These are the ones that we don't want. This one, I see the little cup shaped end, this is Kentucky Bluegrass. And the fire's going to kill it. Unlike the imported bluegrass, native prairie plants do well in fire. The inner kernels of their seeds can survive intense heat. And not only are they safe from fire, they depend on it. The flames will help burn off the thick outer coats of the seeds, so plants can sprout. Started by lightning, fires were once a frequent, natural event here. But as the prairie was broken up by farms and cities, fire could no longer spread and do its job. Now it's up to people.

STEVE PACKARD This is probably as much white prairie clover as there has ever been in one place, and I'm, .. it's just awesome to me, and .... This is a very rare plant.

NARRATION Again, people must lend nature a hand.

STEVE PACKARD What you'll be doing is simulating a cow's stomach, a buffalo's stomach, rather!

NARRATION The buffalo and its stomach juices are gone. They, like fire, used to help eat away at the tough outer seed coat of prairie plants. Now, sandpaper does the job. The best time to plant is when the ground is still warm from the fire. To restore the prairie is a long-term battle -- Every year the seeds of foreign species will blow in and try to take root. But so far ... the prairie shows signs of winning.

STEVE PACKARD This is wild quinine, wonderful little rare prairie species. This is early goldenrod. Not the weedy goldenrod you might find down the street, but a nice prairie one. This Indian Grass is in bloom -- all the little yellow stamens hanging out. This is a patch here. There's a patch over there. There's a patch over the other side of this hill. It's going to make seeds like crazy. They're going to blow all over the place. Pretty soon, the prairie is on the way back.

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SCI-FLY

NARRATION At the University of Texas in Arlington, an aircraft with a strange mission is revving up. Today pilot Steve Spence plans to fly the vehicle using a radio controlled joy stick. But it's just a test -- because eventually this vehicle will have to lift off and hover on its own -- as a flying robot. It will compete with robots from other schools, in the first ever aerial robotics contest. To qualify, computers not man, will have to control the machine. For the contest, a sand volleyball court will be covered by a rubber mat and the net replaced by a 3 foot tall barrier. On one end will be a source ring, containing 6 neon orange disks. The object -- a flying robot must pick up one disk at a time and bring it over to a target ring on the other side of the barrier. The contest is the brainchild of Georgia Tech Professor Rob Michelson.

ROB MICHELSON One of the tasks that has to be performed is to locate these disks. The vehicles will have to fly over the ring in which these disks are contained and then look down or feel around to find the disks.

NARRATION Back in Texas, they're testing a small search camera, attached to the bottom of the robot.

ANDREW CILIA OK David, bring it in.

NARRATION The camera sends its picture to a computer.

ANDREW OK, slowly now. OK, track one. When the faint white lines cross, the computer has recognized a disk. Now the robot has to pick it up.

ROB MICHELSON These disks have been designed so that they can be picked up with a suction device, some sort of tactile grabbing device, or, they can be picked up magnetically.

NARRATION A pulley draws the magnet and disk up to the base of the vehicle -- where they sit until the robot navigates its way to the target ring.

ROB MICHELSON Navigating may be one of the easier tasks that has to be done, because the teams are allowed to set up navigation devices around the arena.

NARRATION Texas is sending sonar signals to a receiver that will eventually go on the robot. Signals are sent out by six sonar beacons. As the vehicle moves, the distance each signal travels will change. An on-board computer calculates position, based on the changing distances, and tells the robot where to go next.

JEFF SMITH (VOICE UNDER) OK stop, now do the rotate.

NARRATION Sonar is nothing new -- the hard part is programming the robot's onboard computer. It has to interpret the navigation data .... and control everything else the robot does. And because it's a contest, the work goes on in secret.

JEFF SMITH Some of the schools are probably doing things that are totally different than what we're thinking about, and it gets your adrenaline going. In San Luis Obispo, Cal Poly is building a hovercraft.

BRIAN SUFFREDINI OK, well as you can see here, we're running on a Briggs and Stratton 3 amp/horsepower motor. It's just turning this plastic fan blade, much like a standard lawn mower would do.

NARRATION It even starts like a lawn mower. It qualifies as a flying machine because it's not touching the ground. Two more fans give the hovercraft a surprising amount of thrust. The hovercraft is speedy and stable -- but it can't fly over a ring. The team plans to throw in a claw to pluck out the disks. The claw is part of a five foot tall arm they're attaching to the top of the robot. The disks won't have to be located by a complicated camera system. The arm will just feel them. As it sweeps around the ring, it catches all the disks. But that's a problem.

ROB MICHELSON The rules state clearly that you can only carry one of these disks at a time.

NARRATION So, a flap will close when the first disk gets caught. Since the other disks won't be locked in place, they should fall out when the arm lifts up. But it's not easy to teach the computer.

ROB MICHELSON I didn't want to design something that everybody would finish with an A+. I wanted it to be a challenge. Therefore it's a very difficult contest, I don't believe it's impossible. I don't know that everybody will be able to move all six disks, in fact I doubt that any of the teams will move all six disks.

NARRATION And now, the day of reckoning.

ROB MICHELSON Ladies and Gentlemen, welcome to the First International Aerial Robotics competition…

NARRATION Four teams have entered. The judge briefs the first team up, the University of Dayton from Ohio. JUDGE ...and you tell me when you're ready and that's when we'll start the clock...

NARRATION They entered late, and haven't had time for a test flight. Their passenger sits in on the maiden voyage. The vehicle is a helicopter ... run on gasoline.., and controlled by computer... or not controlled, as it turns out. At least the passenger survives.

STUDENT We're still intact!

ORVILLE BAKER Mechanical problems will happen. The world's not perfect, and we didn't have it balanced out quite well enough, and the computer couldn't control it.

NARRATION Next, the hometown team, Georgia Tech, has a sad announcement.

STEVE INGALLS We've been working almost night and day for the last three or four months, and as of 4:30 this morning we had an engine failure that we just couldn't recover from. So we're sorry to say that we won't be able to show you anything, at least in the arena. But feel free please to come back and ask us questions about our aircraft, cause we're terribly proud of it.

NARRATION The unwieldy hovercraft is brought in by Cal Poly team members. The judge looks on as the craft makes its way right to the ring ....and keeps going. The navigation system is out of order, so the team's out of the contest. But to demonstrate what it can do...they push the craft back. Some changes are made - with laptop computer in hand - and the claw descends into the ring by

itself. It sweeps over the bottom - feeling all six disks. And only one disk is lifted out. The robot's arm works perfectly.

MARC PETERS You know, we did pretty well. The control system works, and, uh, the arm works, and there's just a little bit more fiddling with it and we'll probably have a working system.

NARRATION Next up, Texas.

STEVE SPENCE When you have to let your baby go, you know, it's like parents kicking their kids out of the house, you know. It's gone, you know, it's all on its own now, you know.

NARRATION Sonar beacons - on the fence. The receiver -- on board. Now, it's all up to the computer. Steve carries the remote control joy stick box out of the arena. He's only allowed to use it as a safety - to stop the robot if it accidentally flies outside the contest area. In its rather short flight, the Texas robot actually accomplished a lot.

JEFF SMITH It went directly toward the ring, didn't it? And it got off the ground, which is a great accomplishment.

NARRATION As soon as the robot took off, it headed directly to the ring. The navigation computer calculated the correct position. But, as the aircraft moved in to hover and search for the disks, the landing gear, enlarged at the last minute, hit the edge of the ring. The computer couldn't correct the balance in time. Still, at an almost impossible task, it was an impressive attempt.

JUDGE I think it's evident, that University of Texas at Austin, uh, Arlington, was the defined winner.

NARRATION The Texas team has taken a first small step in aerial robotics. There's high hope for the future. But as for the present, one team insists they hold the best current technology for the job.

STEVE SMITH I guess they just can't take the man out of the machine!

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INVASION OF THE PUPAE SNATCHERS

NARRATION It's a sunny Tuesday afternoon in the Chiricahua Mountains of Arizona. And there's a strange group of people who are looking for something.

DR. HOWARD TOPOFF We've got a colony-with the queen and brood! And, but she got away. But she certainly was onto the rock.

NARRATION Yes, believe it or not, this is a hunting trip for ants. Howard Topoff and his students at the Southwest Research Center know exactly where to find them--which is about everywhere. But they are after just one particular kind.

DR.HOWARD TOPOFF The vast majority of ants can take care of themselves. But a small group have lost all those abilities. They become parasites. They can't get any food for themselves, they can't clean their nests, they can't feed their young, they can't feed their queen. The only adaptation they seem to have left is the unique ability to get other ants to do all these jobs for them.

NARRATION And these are the crafty parasite ants. They are called Polyergus, red in color, about a quarter inch long--and ruthless. The Polyergus parasites are good at just one thing: making war.

WOMAN Howard, they're raiding.

DR.HOWARD TOPOFF There they go. Up here.

NARRATION Practically every afternoon, not just Tuesdays, the parasite ants send out their armies. As the marauding hordes stream over any obstacle, other ants in the forest are cowering in their nests. Who is going to get hit today? The parasites have found their target. The first innocent victim is slaughtered. And it's always these peaceful Formica ants that are attacked. Now the raid is in full swing. Quick as a flash the parasite ants climb down into the nests and haul out the living white pupae of unborn Formica ants. The red parasite rush their booty back across the obstacles into their own nests. And inside is the most amazing sight. It's full--not of red ants, but of their victims, peacefully looking after red-ant pupae, as well as their own. Today's raid has brought more victim pupae, ants that will be born into slavery. In his lab Howard studies this strange relationship. The victims are well armed. They give off poisonous formic acid. So do the red Polyergus parasites. But look at what happens when the two types meet. In this test they will be kept apart with a wire mesh, but they can still use their chemicals on each other. The result is always the same: even though they both have the same weapons, it's clear that the Formica victims are not doing well out of the exchange.

DR.HOWARD TOPOFF After just a few minutes, all the Formica workers are dead and all the Polyergus workers are still running around. This suggests to us that the Formica workers are indeed sensitive to this noxious chemical formic acid. The couldn't care less. They seem to be virtually immune to it.

NARRATION The parasites are unbeatable. And they're superbly organized too.

DR. HOWARD TOPOFF This scout has just begun scouting. It's kept a relatively straight line from the nest, moving in a southwest direction. It hasn't even started to lock for nests yet.

NARRATION Every day parasite scouts move out in different directions to look for victims. Now this one is about a hundred feet out.

DR.HOWARD TOPOFF She starts circling around, making loopity loops, running in a kind of a tortuous path. Now she's actually looking for Formica nests. And as she moves she sticks her head, sort of pokes her head underneath rocks and leaf litter, and underneath fallen logs.

NARRATION There's a quick fight when a nest is located. The inevitable outcome. And then back runs the scout to call out the troops for a raid. But not so fast. bigger than you. If you're an ant, there's always something There'll be no raid today. It occurred to Howard that it was not just spiders that could stop the raiding. He's mixing up some honey water. And he'll place it where some Formica victims will find it.

DR.HOWARD TOPOFF I'm putting the honey water down on the ground where there's a trunk trail of Formica workers. They are going back and forth, looking for food. And it will take but a minute for them to find the honey water and they'll probably start to recruit nest mates within a couple of seconds.

NARRATION Remember: these are victim ants. They work for the parasites, and feeding their masters is one of their tasks. Very quickly they clean out the dish of honey water and then they will head back to the parasite ants' nests, their adopted home. Inside the nest they regurgitate the honey water and feed their masters. Table manners aren't a big thing in the ant world. There was one striking result of Howard's feeding program.

DR.HOWARD TOPOFF We find that if we keep feeding the Formica workers over a period of several days, slowly but surely the number of raids starts to decrease in frequency. And it remains low throughout the entire summer. So what we have learned from this experiment is that the Polyergus raids are at least in part motivated by hunger.

NARRATION So when the parasites steal pupae, they get new workers--and food. But for parasite ants, perhaps the biggest challenge is starting a new nest.

DR.HOWARD TOPOFF In most of this species of ants, the queen, after mating, digs a little hole, lays a few eggs, and when those eggs hatch into larvae, she

feeds them. But a Polyergus queen is kind of in a unique situation because she is, after all, a parasite. She can't take care of her own eggs. She can't even take care of herself.

NARRATION This is a Polyergus parasite queen. She is being released near a Formica colony, so far undisturbed by any parasites. The Polyergus queen is peacefully laying eggs surrounded by her attendants. Almost immediately, Formica guards rush to attack the parasite queen--but it's no use. Then the parasite queen pulls an astonishing trick. She plays dead, and allows herself to be dragged into the nest, as if she were a piece of food. By now the threatened o~ queen has retired to the corner, but her attendants don't seem to realize the mortal danger. Suddenly the Polyergus parasite queen reveals her true identity. There's panic in the nest. She rushes to attack her target--the hapless Formica victim queen.

HOWARD TOPOFF The fight between the Polyergus queen and the Formica queen is very, very prolonged, very, very brutal, and very, very intense. We think that the Polyergus queen, by continuously biting the Formica queen, is perhaps getting some of the chemicals that identify the Formica queen as a queen. She covers herself with them. That may be why the workers of the Polyergus queen eventually treat the Polyergus queen as their own.

NARRATION The battle royal took over fifteen minutes--but the Formica queen was doomed from the start. She's dragged away by her own offspring, who have become a peaceful new nest of victims, ruled over by the parasite queen.

WOODIE FLOWERS They are tropical carpenter ants, like the kind that will chew up your house if you are not careful. Now listen. Know what they're doing? They are actually banging their tails on the floor. And like the killer whales in our first story, they are communicating. That's what Norm Carling at this lab here at Harvard has figured out. He thinks they are saying, "Trouble. The nest has been disturbed." He thinks that because right after the alarm is sounded, every single ant starts putting the nest back together. Ants don't just use sound for communication. It's more common as the ants and other insects use chemical messages. Like the parasite queen in our story. She fooled her new victims with a chemical lie that announced that they should now serve her. Actually, that's a good example of the kind of odor trickery that's beginning to serve a very useful purpose. It can provide new ways to control pests without using large doses of environmentally-sensitive pesticides. That's it for this edition of Scientific American Frontiers. Next time we'll hold a kayak race off Alaska, track down some wily spiders in Panama, and find out why babies babble -- everywhere. So please, come on back and watch.

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