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EPISODE OPEN

WOODIE FLOWERS (RUNNING IN, GRABBING MIC) Live -- from MIT -- it's Scientific American Frontiers! (Machines start...Crowd roars...Find Woodie in aisle seat in audience)

WOODIE FLOWERS Engineering students in a battle of crazy machines -- no wonder this is always one of my favorite segments on FRONTIERS. Now we're back for a brand new contest to kick off our new season. But there's more to the excitement here than the thrills and spills of competition -- there's a behind-the-scenes story of creativity and experimenting and learning.

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MIT DESIGN CONTEST

NARRATION It all starts with this kit of parts...an exam in a box. Students enrolled in MIT's Engineering Design course must create a machine solely from the materials provided. In six weeks their machines will compete in a contest, and they'll be graded on how well their machines perform. It's a scary proposition since most of the students have never built anything before. These science wizards are discovering that an idea is good only if it can be built. That means rolling up their sleeves and handling a drill as well as a calculator. And as 200 students compete for tools, life in the shop becomes frantic. This is the contest playing field: two tables, separated by horizontal pipes about 6 feet long. In the center is the goal -a plexiglass cylinder with a partition running down the middle. In just 30 seconds, the machines have to deliver ping pong balls to their side of the goal. Each machine can carry as many balls as you want...but everything must fit into a one foot cube. The machine that delivers the most balls wins. The biggest challenge is a good idea...and students look for inspiration anywhere they can. For example, Rob Graham plays football for MIT. The competitive strategy he uses in the field sparked Rob's plan: drive straight down the line.

ROB GRAHAM My idea is to drive out on both cylinders and then once I get to the goal, dump my box of balls into the goal. So I'll start in a position about like

this, and these will be my struts. And they'll start like this. And then I'll have pneumatic pistons that will force the struts down and drive out to the goal. As soon as Rob finishes building each element of his vehicle, he tests the whole design. Testing is the only way to avoid nasty surprises. And there are always surprises.

ROB GRAHAM The problem is that it's too heavy and it falls through the middle of the pipes. So hopefully the box of ping pong balls will weigh less than the masonite. This is Heather Klaubert. Heather is an engineering major -- and a member of MIT's fencing team. For her, competition means speed, aggression and marksmanship.

HEATHER KLAUBERT My basic concept is a frog. I want to leap, carrying all the balls with me, land on the target and dump them. To do this I have a frog, using the constant force springs, and it's going to launch off of a lily pad, or a weighted pad that won't move and will provide enough friction. Speed and aggression are there, but the marksmanship needs work. Heather's frog design almost croaked. According to contest rules, ping pong balls can be launched but machines can't. She got around this by combining her launcher -these coiled springs-with her ball carrier. So the frog takes its power source with it -- and that makes it legal. The students are scrambling -- and that warms the heart of their instructor, Professor Harry West.

PROFESSOR HARRY WEST At this stage, when the student's machines don't work very well, they become very teachable. It's the machines themselves that are teaching. When the students has made a mistake the machine lets the student know because it doesn't work.

NARRATION Ping pong balls are flying -- and so are rumors. I've heard rumors of a machine that can dump 40 ping pong balls in two seconds. Well, I heard about one that supposedly shoots 40 balls in 20, uh in two seconds. Yeah, I've heard about people who can get like 400 balls in, in like two seconds.

NARRATION The mystery machine is the brainchild of Kris Pfister.

KRIS PFISTER I have 48 balls here inside the box which is attached to a string to the machine.

NARRATION The box is placed on a spring-loaded catapult. When released, the catapult launches the box through the air. It's a great design -- but it has one big problem: it's not legal. Unlike Heather's frog, Kris' launcher doesn't travel to the goal. He'll have to redesign it.

Contest day. The students may not be in such good shape...but their machines are ready for action. And they're off! You can shoot balls...you can reach out... you can fight head to head...you can even drive off the road... as long as you get the most balls in your side -- you win. Rob's vehicle on the white side of the table is competing against a pop gun design on the orange side. It's a slow start -- his wheels hardly hit the ground before the pop gun machine begins to fire. It's down the tubes for Rob.

ROB GRAHAM I had too much friction on the bottom of my machine. And these little knobs that I put on weren't, didn't lessen it enough so that I could drive off. So it didn't work nearly as well as I had hoped.

NARRATION For her first round, Heather is as jumpy as her frog. She's up against a Model "T". The leap is just short of the goal.

HEATHER KLAUBERT I just added too many ping pong balls and it was too much weight. And the frog didn't jump as far as I thought it would. But I learned a lot and it was really enjoyable.

NARRATION This is the former mystery machine, now completely redesigned. Kris has built an extending arm with a blocker attached to the front...an aggressive defense. He's up against a vehicle -- and it's over quickly for Kris. Here's what happened. His arm shoots too low, so his blocker hits the center divider. Kris defeats himself.

KRIS PFISTER The practice attempt that we made just before that was perfect so I don't know what happened. A little bit of luck is involved I guess.

WOODIE FLOWERS (NARRRRATION) After three elimination rounds, every machine left can do the job. What matters now is how many balls you can deliver and how fast. For example, on this side 200 balls...over here, maybe 50. They're both vehicles, and after a rough start on the left, it's a pretty even match. They both get there, they both work -- but 50 has no chance against 200. The Volume Vehicle scores a solid win. In this next match intense concentration takes over...as a light weight extender goes up against a vehicle. The Extender Contender is fast and fully loaded. It delivers all its balls before the vehicle even arrives. In round after round the Extender Contender sprints ahead of the competition. It's got speed and volume on its side. But there's another strategy showing a lot of promise: blocking. This Blocker is really fast. It delivers just two balls. But it wins because the opponent can't get by the defense. But what happens when blocker meets blocker? This round is a test of brute strength. Both machines are quick -- they collide head-on. But Tom's Brute Blocker on the right gets there just fast enough to prevent the opposing blocker from deploying...he then delivers a full load.

TOM MASSIE I was really worried about his machine. I was scared that I went up against him. But I thought I might be able to plow him out of the way, even if he got there before me.

NARRATION As we move into the semi-finals, it's Dokyun Kim and his Volume Vehicle, Tom Massie and the Brute Blocker, Paul Hsaio with the Extender Contender, and Chad Clizzer, also running an extender. Dokyun's Volume Vehicle is up first against Chad's elegantly simple extender. The Vehicle's stabilizing arm deploys slowly so the extender gets a head start. It may be slow, but the Volume Vehicle relentlessly delivers... and delivers... and delivers. It's a delicious victory. In the second semi-final, the Extender Contender faces the Brute Blocker. At this level of play, strategy can make all the difference. Tom packs his machine in hopes of gaining a volume advantage. The Extender is intimidating, and Tom's got the jitters. At the last minute crafty Tom makes a reconnaissance foray...sees how many balls the Extender is carrying...and decides to lighten his own load. The Brute blocks out the Extender altogether. No judges' decision necessary -- the blocker is the clear heavyweight here. The final round: it's Tom's Brute Blocker against Dokyun's Volume Vehicle. Dokyun gets a final scouting report on the Blocker....The news is not encouraging. And sure enough Tom's off to a fast start. Dokyun's only hope now is to knock the block off -- otherwise volume won't make any difference. But the Blocker won't budge -- Dokyun is just shadow boxing. It's a total knock out. Tom's a real champ. His Brute machine floats like a butterfly and stings like a bee... a real crowd-pleaser. The Engineering Title is a long coveted prize.

TOM MASSIE Awesome! This has been a dream of mine since I was like in the eighth grade. It's incredible. I still can't believe this happened.

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PRESCRIPTION POSION

WOODIE FLOWERS (on roller blades, wearing suit.) When I've got classes and meetings all over campus, these things are the only to get around. And when you've got a break -- they're even better.

SFX: CRASH!

WOODIE FLOWERS Okay, so there is one draw-back: That's why these are an important part of the outfit. Hey, look -- if you go cruising for thrills, you're taking some risk of getting hurt. But our next story is about a mysterious kind of injury that can happen to anyone --and about an even stranger remedy. Eight years ago this man was a professional violinist. But then his career was tragically cut

short by a mysterious muscle injury. Now his fingers cramp and spasm uncontrollably. For Gordon Baughman, playing is nearly impossible.

GORDON BAUGHMAN These three fingers involuntarily contracted. I don't want them there, I want them over the fingerboard. And what will happen is that if I continue to force them, they will just lock up.

NARRATION (MUSIC AND PHOTOS) This is a recording Gordon made ten years ago. He was on the ladder to success, performing in prestigious orchestras and chamber groups. Then the finger spasms began. No treatment could be found. Gordon to abandon music all together.

GORDON BAUGHMAN All these years I would have loved to have played even if not in a professional sense... the sheer joy of playing this instrument, is something, if it could be restored would be wonderful.

SINGING GROUP Morrell Roper, manager of this R and B band, also found her life radically changed by an incurable disorder. Ten years ago her voice was normal. Today she struggles to be heard. The effect on her life has been devastating.

MORRELL ROPER Since my voice problem, the most difficult thing for me to do is to meet people. And to have a conversation, a general normal conversation, I cannot do, that's been very hard for me to do. Which has been bad for me because most people think I'm shy, I'm being cold, I'm elusive-- it's not that.

NARRATION Gordon Baughman at NIH After years without music, Gordon is once again looking for treatment. The search brings him to Barbara Karp at the National Institutes of Health. Prodded and poked, Gordon's hands check out fine -- except when he plays the violin. So Dr. Karp moves on to the muscles that control the fingers. They're located not in the hand, but in the forearm. Her diagnosis: Gordon's fingers are constantly flexing against his will because the muscles that control them are overactive. Morrell's disorder has also brought her to the National Institutes of Health. She's here to visit their voice specialists. Kay Rhew is inserting an endoscope -- a fiberoptic cable attached to a videocamera. The camera is threading through Morrell's throat. Coming into view is the tongue, and behind that the white lines of the vocal cords. Christy Ludlow will keep a close eye on the vocal cords as Morrell performs speech exercises. Sound is produced when air from the lungs pushes through the cords, making them vibrate.

NORMAL Here, in this normal example, muscles hold the vocal cords slightly apart, like this, allowing a smooth flow of air. But when Morrell speaks, these same muscles overcontract and the vocal cords clamp shut. Viewed side by side,

the difference is dramatic. In fact, both Morrell's problem and Gordon's are caused by the same thing -- overactive muscles. It's a surprisingly common condition called dystonia that can strike practically any muscle. Here's the problem:

GRAPHIC

Movement begins in the brain, which sends commands speeding through the nervous system toward the muscles. At the nerve endings, the brain's commands are passed to the muscles through a pulse of messengers.

NARRATION But Morrell Roper and Gordon's problem is this. It's not known why, but the brain sends a flood of messengers that overstimulate the muscles. There is no cure -- but now for the first time, there is a treatment. The signals can be blocked -- with poison.

OLD FILM

There's a new poison. One ounce can kill the entire U.S... Germ warfare can wipe out an entire city.

BIOWARFARE SHOTS

They're talking about the botulinum toxin, the poison that causes botulism. In World War II, the US army began investigating it as a biological weapon.

CANNING

But the toxin is more familiar as a source of food poisoning. It's produced when common bacteria are denied air, like in a sealed can. IMPROPER CANNING
Outbreaks of botulism were all too common in the early days of canning.

HEADLINES

And over the years, it's taken a deadly toll. Because the toxin blocks the signals for movement, the body's muscles are paralyzed. When it hits the muscles that control the lungs, the victim suffocates.

INJECTION SCENE

Today, the toxin's paralyzing ability will be used for treatment. This deadly poison offers Morrell Roper new hope.

DR. LUDLOW We find most of our patients who come to see us now really are not even listening to the words botulinum toxin, but rather listening to the words treatment. That's what's important to them.

EMG PREPARATION For Morrell Roper, getting the poison won't be the worst part. First Dr. Ludlow must figure out where to put it -- which requires programming her vocal system with electrodes.

DR. LUDLOW How are you feeling? They must check a lot of muscles. Most are normal, showing only a small amount of activity. But when the needle is inserted into a key speech muscle, there's tremendous activity. This is the muscle responsible for Morrell Roper's problem.

NARRATION Now Dr. Rhew is going to inject the toxin directly in to it. It's this precision, combined with an incredibly small dose --about a billionth of a gram -- that makes treatment possible. There is no risk of poisoning -- just the targeted muscles will be weakened.

GRAPHIC

The toxin works its way to the nerve ending where it sets up a sort of barrier, blocking the brain's messengers and eventually paralyzing the muscle. The effect lasts six months. Then Morrell will need another injection to keep the muscle weakened.

Gordon's problem will also be treated with toxin. Again the most painful part is finding the right muscle. They're going to inject the fourth and fifth fingers, beginning with the fourth. The needle part of the syringe is going to play a crucial role. What we need you to do is listen carefully... Do the 5th finger, do the 4th finger... we're going to need to move the needle over... When the needle moves in sync with the fourth finger, they've found the right muscle. They haven't found it yet. The injection itself takes just a minute. Then the entire process will have to be repeated to find the other problem muscle. But will the treatment work? To document their progress FRONTIERS gave home video cameras to Gordon Baughman and Morrell Roper

MORRELL ROPER HOME VIDEO

The tapes tell an extraordinary story. At first, as the toxin weakens her vocal muscles,

Morrell Roper's voice gets even worse. But soon... Party I'd like to thank all of you for coming out to celebrate my new voice, it is a new voice you know... It's two months after

MORRELL ROPER'S INJECTION

She's having a party to celebrate the end of ten years of silence. Of course, the band is here, along with her friends and family. Sarah/Eric/Leo She is sounding more like a human being... From 1 to 100, it's 110. She's much more outgoing.

MORRELL ROPER This cook out -- I wouldn't do it before because I didn't want to interact with my friends because I thought the way I sounded was awful. This is a start for me.

MORRELL ROPER DANCING

Meanwhile, Gordon's also charting his progress on home video. For the first week, there's no effect -- his fingers still cramp and spasm. Then ... a good sign: his pinkie loosens up. A few days later ... so does his fourth finger. Just weeks later... for the first time in 10 years...

Baughman is performing with another musician. Gordon I never thought I'd be able to play again. I never wanted to think about playing again. It's wonderful to feel like an artist. It's an incomparable joy to play music.

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ART OF SCIENCE: "LIQUID SELVES"

One of our most popular "Art of Science" features was a piece called "Panspermia," produced by Karl Sims and Thinking Machines Corporation. So we're delighted to present the TV premiere of Karl's newest work. What you're going to see is quite different from the standard video effects in commercials or on MTV. Karl has managed something new -- an amazingly fluid style of animation on a modern supercomputer. So sit back and enjoy "Liquid Selves".

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THE POWER OF PERSUASION

In any group, some children have more influence than others. They get what they want more often. They are the leaders. Colgate University student Lily Cabezon is trying to figure out who the leaders are in this group of 5 year olds.

LILY We're trying to get an objective view and a measurement of which children are dominant and which children are submissive and it's done through observation while the children are at free play. Lily doesn't just watch and decide who seems dominant and who seems submissive. She has a much more precise method. What she does is count. She keeps track of a range of behaviors that indicate dominance. Some are obvious, like telling someone what to do.

JESSICA And ah, Citlin you go but I have a next door neighbor that does.

CAITLIN But I have a next door neighbor that does. Jessica on the left commands and Caitlin obeys. Here Sean, on the right, tells his friend what to do.

SEAN You pick those up. Lily also counts physical dominance -- who initiates it, who's the target. Here, Caitlin is on the receiving end of a bite. Gestures are also important, like hands on hips, and chin thrusts -- both mean dominance. Facial expressions count too, like this submissive smile. When it's all tallied, the results are clear. Sean has an extremely high dominance score. He is a leader in the group. So is Jessica. Caitlin has one of the lowest dominance scores. What makes certain kids dominant? What's their secret? Psychologist Carrie Keating

believes it's gestures and expressions that matter most. What we say is less important than how we say it. To test this, Carrie has designed a fascinating experiment.

CARRIE In real world dominance situations, in real world leadership situations it is frequently not the words that people say that distinguish them as leaders -- they don't often have the best words and they don't often have the best ideas, necessarily, but what they have is a way to move us. What we are really studying here is a little chunk of what you might consider that charisma that defines leaders.

EXPERIMENTER What we're going to do is I'm first going to tell you a secret, ok, alright, so we're going to ask Carrie to leave.

CARRIE OH-OK We're going to tell secrets and I don't get to hear.

EXPERIMENTER No

CARRIE I'll be back later

EXPERIMENTER OK As a test of charisma, the children will be put in a psychological hothouse. They'll be asked to lie. This juice has been heavily laced with salt and baking soda.

EXPERIMENTER Take a real tiny sip Do you like it? You don't like it? Does it taste icky? OK, it tastes yucky! So when Carrie comes back, ok, you're gonna tell her, we're gonna pretend, that we like it, ok?

CARRIE Oh -- I heard a knock -- look at all that nice juice over there. Did you have a drink? Was it a good drink?

CAITLIN yup

CARRIE Yup -- Why, what did you like about it?

CAITLIN Um

CARRIE How'd it taste?

CAITLIN Good

CARRIE Good -- Ya? Caitlin's non-verbal persuasion skills are not proving to be very persuasive.

CAITLIN Good, it tastes good

CARRIE It tastes good -- huh?

CARRIE What makes a bad liar, is that they leak, they leak nonverbally with gestures and facial expressions--very subtle body movements, scratching themselves and picking at their clothing. Those kinds of activities which are basically nervous activities, tend to leak out when people are deceptive. Here's an instant replay. Watch for the lip licking, the nervous smile, the downward glance.

CARRIE Does it taste good?

CAITLIN Uh huh

CARRIE What does it taste like? Sean's deception, on the other hand, barely leaks out at all. It's hard to spot any of those non-verbal giveaways.

CARRIE Ya, what would they like about it?

SEAN The taste

CARRIE They'll like the taste? What did you like about it?

GIRL Because it tastes more sweet Now you decide. Would these children fool you?

CARRIE What did you like about it?

GIRL Because it tastes a little bit sweet Here's the best way to judge non-verbal behavior. Get rid of the distracting words. Just focus on the faces. This is exactly what this panel of judges does as the final step of the experiment. They decide who is telling the truth and who is being deceptive. And here are the results: Sean was the best at fooling the judges. Jessica was a close second. And Caitlin was the worst. And look at how that compares to the leadership ratings from the classroom: Remember -- Sean was the most dominant child. Followed closely by Jessica. And the least dominant -- Caitlin. Carrie finds this connection again and again: the girls and boys best at the deception task are the most dominant in their social group. Their non-verbal behavior is the most persuasive, even when they're not telling the truth. What happens when kids grow up? Does the essential connection between non-verbal persuasion and leadership remain? If it does, then we should be able to predict which of these adults will be dominant, simply by watching them lie.

CHRIS It just tastes really good.

CARRIE Do you think the other children will like it?

CHRIS Oh-Sure Chris is probably not going to be dominant. He's a terrible liar. Ty's not very convincing either. Michael's pretty good. Not too much in his expression. Jeff is a real poker face. It's impossible to tell whether he's lying or telling the truth. So he should be the dominant type. In this next part of Carrie's experiment, we'll be able to see if the prediction is correct. This group has to work together to figure out how to survive a plane crash.

CARRIE You have just crash landed in the woods of Northern Minnesota and southern Manitoba. The last weather report indicated that the temperature would be minus 25 degrees in the day-time and minus 40 at night. While escaping from the plane your group salvaged 10 items.... But it's not the group's ideas that matter to Carrie; it's who emerges as a leader.

CARRIE Ok, you can begin Alright

JEFF Ok Um, I don't think we really need this cigarette lighter - it has no fluid - it would serve absolutely no purpose so therefore should go relatively last.

JEFF Wait, Wait, Wait

OTHERS Ya, you can use the spark The knife I think is absolutely essential, but... The discussion meanders for a while, and then Jeff takes control.

JEFF Ok guys, what I think we need to do first is, to decide I mean I know like in a wilderness type survival situation you have priorities, and that you should set your priorities first and then rank your materials to kinda correspond with your priorities.

CHRIS Well what about um food? I mean if you can't necessarily assume that your gonna be rescued, alright, you can provide yourself shelter, but you have to come up with possibly some sustenance. Chris, who remember was a terrible liar, has some good ideas, but according to Carrie, that's not what it takes to be a group leader.

CARRIE That person may not be the person with the most information, or the best ideas, but that's the person who is best at maneuvering and manipulating the group members, helping them along with their ideas, and making members feel that they have moved towards some consensus.

JEFF OK, does everybody agree with that? Jeff, who is proving to be an expert at consensus building, is also a student leader on campus.

JEFF The next thing you want to do is be rescued, OK. What about adult women? Would you predict that Paula would be a leader?

PAULA It was cold and refreshing and it..... How about Cathy? Maria? Whatever you guessed, you're probably wrong. Remarkably, for women Carrie has found no relationship between deception and leadership. A leader will still emerge from this group, but Carrie does not yet know how to predict who that leader will be. All she can say is that women who are good at deception are not necessarily good at leading their peers. But with adult males, as with children, Carrie has found an unmistakable connection.

CARRIE Our laboratory research has shown, that, males who are best at the deception task emerge as leaders among their peers. It's not necessarily the case though that leaders disguise the truth any more than the rest of us do. But the implications of our research are that if they choose to do so, they would be very, very good at it.

WOODIE:CONCLUSION TO "THE POWER OF PERSUASION" The past 20 years of American politics haven't left us very enthusiastic about the idea of leadership. But Carrie Keating's research is not just another knock on politicians. What she's telling us is something more troubling -- the skill that makes people persuasive can also make us trust them even when they're lying. That's why elections are hard work for us voters as well as for the candidates: we have to check things out for ourselves, and make choices based on facts, not on images.

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LIGHTS, CAMERA... MAGIC

NARRATOR A motion picture sound stage in northern California. Filming is about to start on a national TV commercial for Nice shoes. And to pull it off, their ad agency has lined up an all-star cast. As the heavy, they've signed Japanese film legend Godzilla. He's defeated Mothra. He's defeated Angillus, and Mecha-Godzilla. But he's never faced an adversary like this. Godzilla's new screen rival is going to be basketball superstar Charles Barkley. And here are the other star players -- the production team from Industrial Light & Magic. They don't breathe fire. They don't jump through hoops. But they are magicians -- when it comes to creating special effects.

PRODUCER CLINT GOLDMAN "So is there some way of framing this so that you can get the shoe, Barkley's head, and Godzilla and the Tokyo sign all sharp in the shot?"

DIRECTOR MICHAEL OWENS "It will be a finessed thing and it will take a lot of time if we can't put him in. But it's just going to get down to physics: does it work or not?"

NARRATOR With this killer cast, the ad agency has whipped up some ambitious ideas. They look great on paper. Now it's up to director Michael Owens and his team to make them come alive on screen.

MICHAEL OWENS "As director I have to rely heavily on all the artist and technicians that pull this project together. The good thing about Industrial Light& Magic is that I'm close with all these people and I trust them immensely. So right off the bat I have a good start. But I have to, because that's the only way it's going to work."

NARRATOR If anyone can make a TV commercial cook, it's the folks who brought you such special effects blockbusters as The Empire Strikes Back. For the commercial, Godzilla will get his wardrobe and make-up in the Creatures and Models Shop, where an army of artists and model makers is hard at work. Painter Richard Miller is prepping Godzilla's teeth to look their meanest.

RICHARD MILLER "We're going to try to make them a little nasty looking in that they're a little tartar, dirty from all the flame that comes out of his mouth. Plus a little shiny and white at the ends from chewing up a lot of people."

NARRATOR This twelve foot long foam tail is Godzilla's trademark. Covered in latex rubber skin -- he'll be suitably reptilian. Godzilla's unusual anatomy demands a lot of last minute alterations. The suit may fit like a glove, but will it work? As we'll see, there's more behind this monster than meets the eye. The lighting is set -- Tokyo is nearly in position. It's time to shoot. Charles Barkley is ready for his first scene -- and it's a big one! Barkley is supposed to be one hundred and sixty feet tall. In real life he's six foot six. To make him appear taller, a miniature city has been built. But this set is only half the illusion. With his height scaled up twenty-four times, Barkley's movement has got to look just as big. The movie camera is placed at street level, looking up at Barkley. The angle helps ... but it's not convincing on video playback.

MICHAEL OWENS I think that looks like he's walking too fast, he's in a hurry. I think we can shoot it at 32 perhaps.

NARRATOR So, Michael tries an old trick -- playing the tape in slow motion. It's beginning to feel right. Now, it's simply a matter of arithmetic ... Michael calculates a new film speed to capture this look. The result? A lumbering walk that fits with his giant dimensions. Next, it's Godzilla's turn to make a grand entrance. It's going to be so dramatic that they can't shoot it all at once. So they position the camera, then lock it down. From here they can film layers of effects one at a time. First -- the actor rampages through the set. What's next? Godzilla's infamous breath of fire. The layer is created by drawing right on top of the actual film frame -- with pencil and tracing paper. This traditional animation ... simple ... and tedious, since it requires seventy-two different drawings, one for each frame of the three-second shot. Now the breath will set the city aflame. And that means a layer of smoke, produced with a vat of boiling mineral oil. Remember, they're shooting this from the same locked down position. And they keep going, adding layer after layer that will all come together in a single shot. Flames...falling billboards... fireworks! Now, take a look. Catch them all? Well, even more details have been added ... like helicopters ... and fleeing people. Take a closer look, in slow motion. It's time for Godzilla and Barkley to meet up. This shot could be a director's nightmare! Michael's problem here is that the frame is going to be very tight. First, he has to position Barkley low and hunched. Then he wants a graceful lunge. The two don't go together. And the takes are piling up. Everyone is getting tired. And the director's nerves are getting frayed. But when they finally get it ...

MICHAEL Action!

NARRATOR ...it all looks easy.

MICHAEL OWENS We knew that it was a challenge to get this shot right, but I feel really good. It's like squishing Charles into this little space and I think we finally got that.

NARRATOR Meanwhile, more surprises are waiting in the wings. The tail is taking on a life of its own.

MARK SIEGAL I'm going like this. I'm giving it a little backward curve and then an upward curve so that it is doing a whip thing.

JEFF MANN TO GODZILLA So you're doing your destruction, destruction. And then I'll say 'now' and you'll turn and give your look. Okay?

NARRATOR Looks like great acting ... but it's really great hardware. Godzilla's expressions are created with a skull full of devices, like these radio controlled eye-balls. With a working jaw, twitching eyebrows, and a sneer, they have a truly emotional monster ... as long as there are four puppeteers working together behind the scenes. J

EFF MANN Give us a bit of an eyebrows going up, just real quick.

NARRATOR This remote control choreography leads to a lively on-screen character.

MICHAEL Is he hooked up for the eyebrows?

NARRATOR And expression is at the heart of their next shot. Fine-tuning Godzilla takes some minor brain surgery.

MODEL MAKER What are we doing walleyed?

NARRATOR Why walleyed? Because Barkley is going to foul him on the chin. But neither star is getting the right expression. There are two problems. This is a complex move for the puppeteers.

CHARLES BARKLEY But you told me to miss him!

NARRATOR And it's asking a lot of non-actor Charles Barkley. Then Michael has a brainstorm.

MICHAEL OWENS Puppeteers, can we do this in reverse?

NARRATOR He can solve both problems by setting their final expressions first. Even with lots of high tech tools, sometimes the right solution is simply a clever idea. The camera films this. But played in reverse ...

MICHAEL OWENS Now that's the look! In his peripheral he knows he's there, but he's going there.

NARRATOR For the commercial's grand finale, Barkley is filmed in front of what's called "blue screen". This technique allows another shot to be added later. Why? Because they want to marry two great moves -- but -- each one needs different lighting and focus. This is what's going on behind Barkley. It produces a sharp-edged mask. So in the editing process, when Barkley is superimposed over Godzilla, the combined image is so seamless you really believe they're on the same street corner. With all the shots "in the can", Michael is liking what he sees.

MICHAEL OWENS I think it looks great, which is a relief. I mean it really is. It's just a joy when you plan it like this and it actually comes out like this without any obstacles. We've changed along the way and modified, but it's really neat that this stuff comes out the way we want it to look.

NARRATOR After eight days of filming and four weeks of editing, this thirty seconds of wizardry is ready for prime-time!

BARKLEY VS. GODZILLA: NICE 30-SECOND COMMERCIAL

WOODIE:CONCLUSION As they say on a movie set, that's a "wrap" for this edition of Scientific American FRONTIERS. Next time we'll rescue a trapped whale off Newfoundland, track howler monkeys in Cost Rica, and examine the tuberculosis epidemic right here in the U.S. Please come on back and watch.

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