

"LIFE'S BIG QUESTIONS"
SHOW 501

Episode Open
How Did the Universe Begin?
Where Did Life Come From?
How Did the Earth Get Animals?
Are We Alone?
Will the Robots Take Over?

EPISODE OPEN

ALAN ALDA Hi, I'm Alan Alda. This boiling, sulfurous Yellowstone hot spring is absolutely teeming with life. That recent discovery may help us answer the question, Where did life come from?

ALAN ALDA (NARRATION) New pictures from deep space might help explain, How did the universe begin? Faint signals from the stars -- are they messages, or are we alone? Slivers of rock from China may reveal, How did the earth get animals? And with robots this smart, How much longer will we need people?

ALAN ALDA Join me now for Life's Big Questions, on Scientific American Frontiers.

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HOW DID THE UNIVERSE BEGIN?

ALAN ALDA For our season premier of Scientific American Frontiers, we will be going on a fantastic journey that will take us from the depths of a boiling volcanic hot spring, to the farthest reaches of outer space. We are going to find out what science has to say about those big questions that occur to all of us from time to time, but that come from? Are we alone in the universe? Or will robots ever take over from people? Our first big question, though, is about what you see through this. The view through an astronomical telescope is a truly fantastic sight. Everywhere you look the sky is covered with what we non-scientists call stars. Actually, in the 1920s the great American astronomer, Edwin Hubble, shocked the world when he proved that most of these points of light that we see through a telescope aren't stars at all -- they are other galaxies, each one made up of billions of stars. And that's where we are going first -- to the most distant galaxies, to ask, How did the universe begin?

ALAN ALDA (NARRATION) At 13,000 feet on Hawaii's Mauna Kea volcano, you can look down on the clouds. But from here you can also look far out into the universe.

ALAN DRESSLER So Sandy, this is a pretty steep road.

SANDY FABER It's considered very dangerous because it is steep. It has a lot of ...

ALAN ALDA (NARRATION) Tonight, Sandy Faber and Alan Dressler, two of America's leading astronomers, will be making their first observations with the Keck telescope -- the newest, largest, most sensitive on earth.

SANDY FABER ...O.K. Let's go up and see about those...

ALAN ALDA (NARRATION) It takes a six-floor elevator ride, just to get to the middle.

SANDY FABER Let's go, this is your first big look.

ALAN DRESSLER This is my first big look.

SANDY FABER Here we go.

ALAN DRESSLER Wow. Huge!

SANDY FABER Really something, huh? Beautifully..

ALAN DRESSLER So far down.

ALAN ALDA (NARRATION) Cradled in a white steel lattice is a thirty-foot wide mirror, while the front end of the telescope hangs sixty feet above. Sandy was one of the driving forces behind the Keck, and now it's ready to help astronomers become cosmic historians.

SANDY FABER We are all very interested in our history. Is it useful to me to know that my ancestors came from Scotland and were a certain kind of people? Sure it is. That helps me understand myself. I don't stop there though. I go back to the formation of the earth, the formation of the solar system, the formation of the galaxy. I want to know where the universe came from. I want to know if there are other universes--maybe ours isn't the only one. This to me is one grand cosmic history. I don't know where to draw the line and say it is interesting here,

it is uninteresting here. The whole thing, the whole grand river of time, is a piece. And I love it.

ALAN ALDA (NARRATION) Sandy and Alan are going to look back in time, to see what the ancient universe was like. They're going to observe faint distant galaxies, whose light took billions of years to get here. If you look up at the Big Dipper, you can see stars, but no galaxies --they're too faint. But with a good telescope, right beside the bright nearby star you can pick out a distant galaxy. And a more powerful telescope reveals thousands of even more distant galaxies.

ALAN ALDA What is a galaxy?.

SANDY FABER Why don't we show you a picture?

ALAN ALDA O.K. That's all right.

SANDY FABER This is a pretty nearby galaxy, not too far away from us, and it's a classic example of a spiral.

ALAN ALDA When you say it is pretty near, what do you mean?

SANDY FABER I'd say this one is maybe 8 million, 10 million light years away.

ALAN ALDA That's a, that's a near? That's near?

SANDY FABER That's very near.

ALAN DRESSLER The very nearest Andromeda is about 2 million light years away. So it will take 2 million years for the light to reach us.

ALAN ALDA What is this? This is...

SANDY FABER O.K. Well let's explain what is in the picture.

ALAN ALDA O.K. Yeah.

SANDY FABER First of all, all these white dots that you see all around the edges are the foreground stars in our galaxy. So you have to forget about them. And the thing we are talking about is this beautiful spiral thing in the middle. Now what this really is, is, it's a city of stars. If we stood outside the Milky Way and looked at our galaxy, it would look something like this.

ALAN ALDA We are in a spiral galaxy?

SANDY FABER We are in a spiral galaxy. That's, the Milky Way is a spiral. Now what this is, is, first of all there may be a hundred billion stars in this object. You can see some of the individually brightest ones like this. But mainly they are just crowded together so closely that from a ground-based distant photograph they seem to blend together and make a continuous sea.

ALAN ALDA Wow, so they are gigantic things?

SANDY FABER They are big compared to Minneapolis.

ALAN DRESSLER Both of the Twin Cities.

ALAN ALDA (NARRATION) With the Keck, Sandy and Alan will be taking pictures of galaxies that are much farther away, and therefore much older, than the one they showed me. Their goal is ambitious -- to test the Big Bang theory of how the universe began. According to this theory, the universe started out at time zero unimaginably small and dense. Then came a violent expansion. This computer simulation shows how, over billions of years, gravity can pull matter into clumps, which form into galaxies, stars and planets. To test this whole idea, Sandy and Alan will be looking back in time, to see if real images of the universe match up with the theory.

ALAN DRESSLER The Big Bang model says that in the early days of the universe, it look completely different than it does now. It was hot, seething gas particles, very little structure, incredibly smooth. The best way to understand it would be like being in a fog today. Maybe actually being inside a cloud. You couldn't see much around you, just sort of a white blur every place. So what we are trying to understand is how the universe went from being very smooth, almost cloud-like, to this very clumpy structure where we have stars and galaxies and planets.

ASTRONOMER Focus has changed

ALAN ALDA (NARRATION) Tonight at the Keck, Sandy and Alan are picking up a cluster of galaxies several billion light years away -- so they're looking at the universe several billion years ago.

SANDY FABER It's right here. But why don't we zoom in on here. Are we finished reading out?

ALAN ALDA (NARRATION) Sandy can already see the galaxies are a lot smaller than they are today. But the picture is too blurred to see much more than that. The blurriness comes from having to see through the earth's atmosphere -- and there's only one good way to get around that.

ANNOUNCER And we have a go from main engine start...five, four, three, two, one. And we have lift off. Lift off of the space shuttle Endeavor on an ambitious mission to service the Hubble space telescope.

ALAN ALDA (NARRATION) Excitement at the Hubble's launch in 1990 had quickly turned to disappointment when it was discovered that tiny flaws in the space telescope's mirror made it nearsighted. So in December 1993, astronauts were sent to correct the problem, in spectacular style. Within days of the repair, the Hubble telescope began showing astronomers the universe as they'd never seen it before. After the images are beamed back to earth, the first place they're seen is here at the Space Telescope Science Institute in Baltimore, Maryland. Sandy and Alan waited years to use the Hubble, and now one of their first pictures is about to come in.

ALAN DRESSLER O.K. Great. You are going to bring up some of the pictures for us? O.K.

ALAN DRESSLER This is a single exposure that went on for about 2000 seconds.

SANDY FABER Wow. That's interesting.

MAN We had a couple of satellite trails on this.

SANDY FABER This is unusual, isn't it?

ALAN DRESSLER This is not what you normally see.

ALAN ALDA Why does it show up as a line?

ALAN DRESSLER Well there's sunlight bouncing off of those objects. Trails.

ALAN ALDA Is it because this is a long-time exposure, you mean that it is just lighting up all the way across there.

ALAN DRESSLER There are many things that are distracting us here in addition to these two satellite trails. All the little dots.

ALAN ALDA (NARRATION) The dots are cosmic rays which are flying around everywhere in space -- and which inevitably hit the telescope's camera.

ALAN DRESSLER Debbie, can you put up the next picture from the same chip?

ALAN ALDA (NARRATION) The solution is to take several pictures in the same direction, let a computer compare them, then eliminate the parts that don't stay constant. What remains will be nearby stars -- and distant galaxies.

ALAN ALDA Is this galaxy something you have seen before or are you looking it again better... closer...?

ALAN DRESSLER We have seen it from the earth but only as a fuzzy blob. And now we are seeing these spiral arms coming out of it. So we are seeing detail we have never seen before.

ALAN ALDA Does this have a name?

ALAN DRESSLER Well it's just one of maybe a few hundred galaxies in this one cluster. It's like a city full of galaxies.

ALAN ALDA How, how old is that, do you suppose?

ALAN DRESSLER This cluster is about a distance of 4 billion light years. So we are seeing an image of this galaxy as it was 4 billion years ago. Which is a fair way back toward the Big Bang.

ALAN ALDA (NARRATION) Next we went to the computer room, to see the pictures after they'd been cleaned up. Now we had a clear view, that went back four billion years in time.

ALAN ALDA So everything I am looking at now is either a star or a galaxy or...

ALAN DRESSLER Right.

SANDY FABER It's real.

ALAN ALDA (NARRATION) Sandy and Alan now challenged me with a question, that went to the heart of their test of the Big Bang.

ALAN DRESSLER The question is, what do you see about this picture of a cluster of galaxies seen 4 billion years ago that is different, say, from this picture of a cluster of galaxies seen today?

ALAN ALDA So I should be able to look at these two and see a difference because the universe has changed in that time. Is that right?

ALAN DRESSLER That's the question there.

SANDY FABER That's the idea.

ALAN ALDA Well, am I right that this is a spiral galaxy?

ALAN DRESSLER Right.

ALAN ALDA And am I right that this is a spiral galaxy on its side, so I am looking at the side of the dish, right?

SANDY FABER Right.

ALAN DRESSLER Exactly.

ALAN ALDA I don't see...

SANDY FABER How many slivers do you see here?

ALAN ALDA I don't, right off the bat, I don't see any slivers.

ALAN ALDA (NARRATION) In fact, the galaxies in this modern cluster are all egg-shaped -- what astronomers call elliptical. There are no spirals to be seen.

ALAN DRESSLER And so the question is, what happened to them?

ALAN ALDA Well what did happen? That's the question.

ALAN DRESSLER That's the question?

ALAN ALDA What's the answer?

SANDY FABER Well what's...

ALAN DRESSLER There's some evidence

SANDY FABER I think maybe there's a clue right there.

ALAN ALDA (NARRATION) In the four billion year old cluster, Sandy pointed out two spiral galaxies that were colliding. Galaxies start out as spirals, she says, then, as gravity pulls them into groups, they blend into one another to form elliptically. So Sandy and Alan's big discovery is there are fewer spirals today than in the past.

ALAN ALDA Does this changing universe, this evolving universe, throw any light on, on the Big Bang?

ALAN DRESSLER Well, in the simplest terms, it is a resounding confirmation of the idea of the Big Bang. The Big Bang, you expect to see the universe looking different in the past than it does today. And it's clearly the case. I think there is no question. We don't understand all the details, but there is no question that when you look back 4 billion years you see differences and from all indications, when you look further back, you see huge differences.

ALAN ALDA (NARRATION) So now we're a little closer to understanding how the universe began -- thanks to telescopes that let us see farther back in time than ever before.

SANDY FABER I often think as I look through a telescope whether somebody is looking back at me.

ALAN ALDA Do you really?

SANDY FABER Yeah, I do. Almost every time I observe.

ALAN ALDA No kidding. What do you think then? What do you think, if somebody is looking back at you, it gives you like some feeling of, of fellowship with that person?

SANDY FABER I think we should make an astronomer's union.

ALAN ALDA I am wondering if you think, "I wonder how they are getting their funding?"

ALAN DRESSLER How did he get that telescope?

SANDY FABER Right, is their telescope bigger than mine?

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WHERE DID LIFE COME FROM?

ALAN ALDA (NARRATION) Yellowstone National Park, world famous for its extraordinary hot springs. I'm hiking into the back country with biologists, Norman Pace and Sue Barns. For years, they have been looking for life in the bubbling pools. And recently they discovered something totally unexpected -- new clues about where life came from. Their story begins with a simple idea -- that hot springs are like an echo of the earth's earliest days.

ALAN ALDA How does this look like early earth? I don't, it's hard to believe that it was once like this.

NORMAN PACE Well anything that you would call an earth was formed about four and a half billion years ago. And the early earth was basically a molten ball. There was a lot of water--high-pressure water, steam in the atmosphere, and eventually the earth would have cooled, slowly cooled, and eventually it would have been cool enough that the water could condense. And so by about say 4 billion years ago or so, maybe 4.1 billion years ago, the earth was basically a molten ball with a layer of about say a couple of miles of water all around its surface.

ALAN ALDA (NARRATION) It was always assumed life couldn't get started until that water cooled down -- to the kinds of temperatures that life seems to like today.

ALAN ALDA Would you like a hand, Sue?

SUE BARNES I guess so.

ALAN ALDA (NARRATION) Sue and Norman's research, though, is now challenging the common wisdom. Their big discoveries are coming from an uninviting place called Jim's Black Pool. Whenever they visit here, the first order of business is to measure the water temperatures.

NORMAN PACE Let's map it from, from the lower end up towards the source. So this is going to be all water temps now, Sue.

SUE BARNES O.K. That's fine.

NORMAN PACE O.K. Read them off.

ALAN ALDA O.K. 109, 157, 158, 158...seems like 158.

SUE BARNES We'll call it 158, that's good.

NORMAN PACE 158.

ALAN ALDA That was very exciting. I really liked that.

ALAN ALDA (NARRATION) While 150 degrees could rapidly kill a person, closer to the underground source it was even hotter

ALAN ALDA 169, 182, 183. I'm ignoring the decimals, right?

SUE BARNES Yeah, yeah. I don't think...Whoa.

NORMAN PACE Let's map around out here.

ALAN ALDA I'm story.

NORMAN PACE No, it's o.k.

SUE BARNES It's not fatal.

ALAN ALDA Have you lost many microbiologists?

SUE BARNES Nope.

ALAN ALDA I saw a bleached bone up there.

ALAN ALDA (NARRATION) Actually, bleached bones are no joke -- every now and again an unfortunate bison falls into one of these pools and succumbs in minutes.

ALAN ALDA 165, 166, 166....Is this whole park on a crater, a volcanic crater?

SUE BARNES That's right, that's what Yellowstone is, is the remnants of a massive volcano that occurred on the order of 800,000 years ago. Blew ash all over the western United States and this is what is left of it. It is still pretty active.

ALAN ALDA Pretty...This is as active as it is ever going to get now?

SUE BARNES Ever, no.

ALAN ALDA It is going to blow again, you are telling me.

SUE BARNES We are very...there is a very thin crust area. It could well..

ALAN ALDA Are we standing on one of the places that ...

SUE BARNES It is going to come up here first.

ALAN ALDA It's bubbling already.

SUE BARNES That's right.

ALAN ALDA (NARRATION) It seems like an impossible place for life, yet part of Norman and Sue's big discovery is that even where it's boiling, this place is teeming with microscopic creatures.

ALAN ALDA All my life I have been taught that if you boil the water you will kill anything nasty in it. And if you boil the medical instruments, you will make them sterile.

NORMAN PACE That is certainly true for the sorts of organisms that would infect us. They would not survive the boiling. But if you evolved, if you were capable of, if you are in fat city if you are in such a hot environment, then it doesn't matter.

ALAN ALDA (NARRATION) We had brought along a microscope, to take a look at these heat-loving creatures.

SUE BARNES Should be in focus.

ALAN ALDA (NARRATION) They didn't look like much, but the biologists assured me all these blue lines were alive.

ALAN ALDA I don't see their little faces.

SUE BARNES They are actually sticking their little tongues out at you and you just can't tell.

NORMAN PACE Let's pull up a sample from the boiling floor...

ALAN ALDA (NARRATION) After every trip to Yellowstone, Norman and Sue bring back samples to the lab, to find out what makes these organisms tick. Like all other living things, they have DNA -- the genetic code of life. When Sue analyzed this DNA, she discovered that codes from the Jim's Black Pool organisms were strikingly similar to those found in every plant and animal on earth. The only explanation could be that the hot springs creatures were the ancestors of us all.

ALAN ALDA It's very exciting to look through that microscope, even though I can't, I can't make out their features, I can hardly make out the...

NORMAN PACE That's the way that it was.

ALAN ALDA That was the way, that was -- that's like looking through a time machine in a way...

NORMAN PACE In a very real way...

ALAN ALDA To the earliest days.

NORMAN PACE In a very real way. I think that, that these organisms, the general properties of these organisms will be not at all too dissimilar from the nature of the earliest organisms.

ALAN ALDA (NARRATION) Of course, life didn't stay in boiling mud forever -- but that's the subject of our next story.

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HOW DID THE EARTH GET ANIMALS?

ALAN ALDA (NARRATION) We are in southwestern China, investigating one of the great mysteries of biology: How did animals evolve on our planet? It's a question people have been arguing about since the theory of evolution was proposed more than a century ago. Now, here in the Chinese countryside, we may finally be getting a good answer. Our journey begins with a train ride on a rainy summer morning, traveling through the rice paddies and jagged mountains of Yunan Province. In the sleeper car we meet the scientific sleuths of our story -- Harvard biologist Andy Knoll and his Chinese colleague, Yin Leiming.

ANDY KNOLL This rain is going to keep on through the day?

YIN LEIMING Yeah. This is the rainy season.

ANDY KNOLL The rainy season.

YIN LEIMING Yeah. Usually it is the rainy season.

ANDY KNOLL I hope it stops long enough that we can get to work.

YIN LEIMING I also hope so.

ALAN ALDA (NARRATION) In the coming days, Andy and Leiming hope to collect information that will explain the extraordinary moment in history when microscopic creatures evolved into animals.

ANDY KNOLL We've all heard of the Big Bang through which the universe is thought to have begun. But in biology, there's another kind of big bang--a big bang of animal evolution. Life began at least three and a half billion years ago, but it wasn't until 580 to 570 million years ago that we see any kind of animal life--and then, in just a few million years, we have a tremendous diversification of

different types of large and complicated animals. And here in China, we see one of the best available records of that biological big bang.

ALAN ALDA (NARRATION) It's in the Chun Jiang Hills of Yunan where you can see spectacular fossils of those first animals, in rocks that formed out of mud on the bottom of an ancient ocean, 550 million years ago. In rocks just a little older than these, all fossils are microscopic -- so this place marks the very beginning of animal life. There's been an excavation here for almost five years, and today Andy and Leiming are meeting the man behind it, paleontologist Chen Jun Yuan.

ANDY KNOLL It's in there that the event that really captured the

CHEN JUN YUAN Yeah, yeah.

ALAN ALDA (NARRATION) The real fossil hunting here takes place across the road, where 30 local women split the newly-excavated rocks into thin slices. They get paid about 50 cents per fossil found -- plus a bonus for unusual discoveries. The rocks are loaded with fossils.

ANDY KNOLL Have these people been finding a lot of specimens?

CHEN JUN YUAN Oh yes, the average every day, you can find five or six specimens.

ANDY KNOLL Each person can find five specimens.

CHEN JUN YUAN Yeah.

ANDY KNOLL So with 30 people, you could find ...

CHEN JUN YUAN Would be hundreds

ANDY KNOLL ...hundreds of specimens every day. I could use that kind of help in my work.

CHEN JUN YUAN Oh that's a kind of ...

ALAN ALDA (NARRATION) While the fossils come pouring in, Professor Chen tries to figure out what they were.

ANDY KNOLL ...and then the animal inside is a little bit shrimp-like.

CHEN JUN YUAN Yes.

ALAN ALDA (NARRATION) This seems to have been a kind of combined clam and shrimp.

ANDY KNOLL It has almost like a fin on it which would help it to move through the water.

CHEN JUN YUAN Yes.

ANDY KNOLL Interesting. How about this, these look like big pincers.

ALAN ALDA (NARRATION) And this fossil has the familiar look of a lobster claw. Chen's never found a whole one, but he's got enough parts to know these animals could get huge.

CHEN JUN YUAN The largest one can be two meters long.

ANDY KNOLL Two meters long, that's...

CHEN JUN YUAN Very large, a large mouth.

ANDY KNOLL And so this could eat everything else in the whole fauna.

CHEN JUN YUAN Right.

ALAN ALDA (NARRATION) Some of the fossils don't look like anything alive today. They're species that became extinct. The most puzzling thing about all these animals is why they evolved from their microscopic ancestors at exactly the same moment in time, in what amounts to a giant explosion of life.

ANDY KNOLL People have argued about the causes of the explosion for years. And for years one of the most popular explanations has been that until the eve of animal evolution there simply wasn't enough oxygen available to support the biology of large animals.

ALAN ALDA (NARRATION) The early atmosphere had almost no oxygen but was rich in carbon dioxide, from volcanoes. The carbon dioxide dissolved in the oceans where algae used it to grow -- keeping the carbon, and releasing the oxygen. But oxygen could never accumulate, because when the algae died, the process of decay used it up, making carbon dioxide again -- bringing the whole process around full circle. Of course, today there's plenty of oxygen, so at some point it must have begun building up. Did this happen right before the big bang of animals? That's what Andy Knoll wants to find out.

ANDY KNOLL I think we are going to find just what we came to find.

CHEN JUN YUAN O.K.

ANDY KNOLL Maybe we will get a thesis out of it, so we will all be happy.

ALAN ALDA (NARRATION) Accompanied by Yin Leiming, Andy is setting out on the second leg of his journey, this time in Guise Province. The region is famous for its rice farming, but not so much for this quarry. The limestone being excavated here dates back exactly 580 million years, right before the explosion of animal life. These rocks should contain a record of how much oxygen was around back when they formed.

ANDY KNOLL Great.

ALAN ALDA (NARRATION) The only hitch is, rocks can't be tested directly for oxygen. So Andy and his colleagues will have to work indirectly. For oxygen levels to go up, something must have interrupted the cycle of growth and decay in ocean algae -- but what? In the end, laboratory analysis found just what he was looking for. The rocks here contain telltale minerals, that show the whole world was being hit by dramatic geological changes just before the animal big bang. New mountains were pushed up over much of the globe. Then cascades of water carried parts of those new mountains down to the oceans. So as Andy Knoll sees it, the critical new factor was sediments, in huge quantities.

ANDY KNOLL Sediments are formed as mountains rise and are eroded. And rivers carry these sediments down to newly opening ocean basins and as the sediments come into the shallow seas, they form a seal between the algae remains that are accumulating on the sea floor, and the atmosphere. And when that seal was formed, oxygen accumulated in the atmosphere. And that seems to be what made large animals possible.

ALAN ALDA (NARRATION) Not only did it make these ancient animals possible, but it led to all the animal life we see around us today. And that even includes us humans.

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ARE WE ALONE?

ALAN ALDA (NARRATION) In the movies, there has never been any doubt about the existence of extraterrestrial, or that someday we will meet them -- perhaps in a bar, like the one George Lucas dreamed up for "Star Wars." But is life on other planets just science fiction? I discussed this with Carl Sagan, a scientist who has devoted much of his career to the search for real extraterrestrial.

ALAN ALDA The question is, if there are planets that could possibly support life, are we alone here? I imagine you feel passionately about the answer to that?

CARL SAGAN I don't know the answer, but I do feel passionately about it.

ALAN ALDA That's a great combination. Explain that.

CARL SAGAN We'll we've not found extraterrestrial life. We're just at the very earliest stages of beginning. We haven't found it yet. So it would be foolish for anyone to say that he or she is absolutely certain there's life elsewhere. At the same time, we have a fairly good idea of the stars in the Milky Way galaxy. It's about 400 billion.

ALAN ALDA 400 billion?

CARL SAGAN Right. So that's roughly speaking 100 times more than the number of people on earth. Imagine if every person had a hundred stars...

ALAN ALDA And every one of those stars has an unknown number of planets.

CARL SAGAN And that's just in this galaxy, and there are tens or hundreds of billions of galaxies. Put that all together and it seems laughable arrogance for humans to pretend they're the only life and the only intelligence.

ALAN ALDA (NARRATION) Harvard University's Paul Horowitz couldn't agree more. He's been collaborating with Carl Sagan for many years to search the sky for alien messages. His radio-telescope is large enough to pull in signals from clear across our galaxy. If aliens are trying to make contact, Paul is determined to get their message.

PAUL HOROWITZ We're the first generation on earth that could realistically communicate across galactic distances. Contact would be the end of the earth's isolation in a very deep sense. It would be the greatest event in human history. Why am I doing it? How can you not do this experiment?

ALAN ALDA (NARRATION) Listening for alien signals is a tricky business, because there are millions of possible radio channels to scan, all full of interference caused by everything from garage door openers to spy satellites. So Paul Horowitz had to design a special computer to recognize this interference and filter it out. Even the stars themselves produce a loud radio signal.

PAUL HOROWITZ This is god's own signal. Radio astronomers love this stuff and it's what they use to map out the galactic structure. We are not interested in this at all because it is not intelligent life.

ALAN ALDA (NARRATION) As for intelligent signals from earth, these usually have a recognizable pattern. So as the telescope systematically sweeps the skies, the computer knows what to ignore on the hundreds of millions of radio channels it's monitoring simultaneously. Since Paul began in 1989, six unexplained signals have gotten through the filters. All of them came from the middle of our galaxy, where most stars are. And all of them looked like this -- a tall, thin spike.

PAUL HOROWITZ This is the kind of signal that gets our heart pumping. This signal came in on May 10th, 1990. It is narrow, it is strong. Everything is perfect about it except it has to come back a second time or we can't trust it.

ALAN ALDA (NARRATION) Paul is now spending much of his time trying to pick up those six signals again. But if aliens really exist, they might already be receiving signals from us.

CARL SAGAN Television stations are sending signals.

ALAN ALDA How far out does that go?

CARL SAGAN MASH is being broadcast to the stars.

ALAN ALDA I, I haven't gotten the check for that yet.

CARL SAGAN No, the residuals are going to be hard to come by, but...

ALAN ALDA I hope that they are getting "Mr. Ed." Is that, is that, is that really, I mean, receivable?

CARL SAGAN It gets out. It gets out.

ALAN ALDA Don't you need like big rabbit ears for that up on Venus?

CARL SAGAN You have a big enough antenna and you have a sensitive enough detector, you can pick it up.

ALAN ALDA (NARRATION) Even if there's nobody out there watching our TV, there still might be simple forms of life beyond the earth. When we sent the Viking spacecraft to Mars in 1974, that's what we were looking for. But nothing crawled in front of the lander's camera. And dirt samples collected by the robotic

arm didn't show even microscopic life. The mission did discover deep canyons, as seen in this animation constructed from orbital photos. It was proof that Mars used to have running water -- so maybe there was life here, that's now extinct. The possibility of returning to Mars to search for fossils, brings us back to Yellowstone and a boat ride on a scalding hot spring. As NASA's Jack Farmer sees it, Mars, like the early earth, probably had lots of hot springs. If it's possible to go back to Mars and find remains of ancient springs, and if there was ever life around them, Jack believes we'll discover many fossils -- because of the strange way hot springs work.

JACK FARMER Here along the edge of this spring, we have a place where organisms are being turned into fossils before our very eyes. These orange areas are communities of microorganisms or mats which grow upwards towards the light creating all kinds of interesting patterns and surface textures.

ALAN ALDA (NARRATION) Something very unusual begins to happen in the shallow edges. It's a little cooler here, causing minerals to settle out of the water, coating the microorganisms. The communities die, but their patterns remain.

JACK FARMER If you move down in this direction a little bit, you see whitish-colored gray areas where the structures have been completely preserved -- essentially turned to stone. And a result of that process, the biological information that was in the original community can be preserved for literally billions of years.

ALAN ALDA (NARRATION) Hoping to find similar fossils on Mars, Jack has been studying satellite pictures of the planet, looking for places that could have had hot springs. So far, his favorite is this giant volcano. You can tell it's a volcano and not a meteor crater by the water channels running down the side. Jack's picked out one in particular.

JACK FARMER On this southern flank of the volcano, there's a large channel formed that seems to originate out of nowhere. It, it just comes right out of the side of the volcano. It's 20 miles wide and hundreds of miles long. And it seems to have formed where water flowed out from underneath the surface and eroded its way out this direction.

ALAN ALDA (NARRATION) If Jack has his way, some day this channel will be explored. And this is the rover that might do the exploring. Built by the Russians, it's being tested in California's Mojave desert, where the terrain is similar to Jack's Martian channel.

MAN Are we there yet?

ALAN ALDA (NARRATION) Future missions to Mars will most likely be joint US-Russian efforts, so scientists from both countries are participating in this dry run.

RUSSIAN WOMAN (Speaks)

ALAN ALDA (NARRATION) Footprints are erased, so there are no extra clues for the people who will try to figure out where the rover landed, from the vantage point of mission control some 200 miles away.

RUSSIAN MAN 33-right.

ALAN ALDA (NARRATION) A "rotate" command is sent by radio to the rover. At each of 6 stops, its cameras take pictures of the terrain, collecting a panorama of the landing site.

WOMAN O.K. Next package.

ALAN ALDA (NARRATION) The pictures are beamed back to mission control and passed on to a team of geologists, who've not seen the landing site. Among them is NASA's Jack Farmer, and a counterpart from the Russian space program, Sasha Basilavsky. First they assemble the full panorama, then start trying to locate the rover, relative to a satellite picture of the area.

JACK FARMER Well, if we position ourselves here, this feature right here, it's sort of a pressure ridge, would be correlated to this one here.

SASHA BASILAVSKY It means that we should be like here. We have an old saying among Russian geologists that eight geologists have ten opinions. So, now we're four, so at least five opinions we have.

ALAN ALDA (NARRATION) They did, eventually, reach agreement.

JACK FARMER Okay let's spot it from here. So we're standing on this...

ALAN ALDA (NARRATION) The day after the exercise, a visit to the desert will reveal whether or not they were right. Being able to figure out where you've landed -- and knowing which way to turn to get to your target -- are crucial if a Mars mission is going have a chance of finding signs of ancient life.

MAN This face right here is this one.

SASHA BASILAVSKY This is that, and this is supposedly this.

MAN Right.

ALAN ALDA (NARRATION) When they stand on the spot they chose, the rover's panorama matches up perfectly.

JACK FARMER What I am wondering is ...

SASHA BASILAVSKY Ah...yeah, yeah, yeah.

JACK FARMER And we were looking through the bushes. And if this, you know, provides an indication, I would say that we stand a chance of doing pretty well. There are only a few places, I think, where one would focus to look for evidence of past life and certainly if we can find them here in the desert, we can probably find them on Mars too.

ALAN ALDA (NARRATION) As for intelligent life, the search continues at the Harvard radio telescope 24 hours a day, seven days a week. Paul is still trying to confirm those six promising signals. But so far -- nothing.

PAUL HOROWITZ What you think when you look at this is, if it's really real, it's going to come back. Please come back. And it never, never obliges us. Never has. Some day it will. Some one's gonna get the thrill.

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WILL THE ROBOTS TAKE OVER?

ALAN ALDA Flakey, follow me.

FLAKEY Um. Following. I don't see you.

ALAN ALDA There he goes... What does he say, "I do see you?"

KURT KONOLIGE No, he says "I don't see you," but it's wrong.

ALAN ALDA He's obviously lying.

KURT KONOLIGE Yeah, I know. It's going to be a little hard ...

ALAN ALDA Well, I don't know, he doesn't.... Flakey, stop.

FLAKEY Um. Duh.

ALAN ALDA Duh, that's a great thing to say after you nearly killed me.

KURT KONOLIGE Tell him to turn right and we'll follow him out.

ALAN ALDA Yeah. Flakey, turn right.

FLAKEY Um, turning, boss.

ALAN ALDA Turning boss. I love that boss stuff, and then he steps all over my feet.

ALAN ALDA (NARRATION) Meet Flakey, the smartest robot around. He inhabits the corridors of the Stanford Research Institute.

ALAN ALDA Does anybody object to treating it like a person?

KURT KONOLIGE You mean...

ALAN ALDA I mean, it's a box, you know.

KURT KONOLIGE Curiously enough, only the researchers.

ALAN ALDA Really? Why?

KURT KONOLIGE Because they that think it cheating in some ways. They know what goes on inside and they know it's not yet like, really like a person. We'll see a lot of that.

ALAN ALDA Does anybody think it eventually will be like a person?

KURT KONOLIGE Oh sure.

ALAN ALDA Oh sure?

KURT KONOLIGE Oh yeah. Oh, it's clear. I mean, there's a lot of stuff going on in intelligence, there are a lot of different facets to intelligence. And we are only starting to pick in at the edges.

ALAN ALDA Flakey, Look at me.

FLAKEY Um. O.K. Thanks. O.K. I gotcha

ALAN ALDA I gotcha.. Yeah. Watch me, I'm going here.

ALAN ALDA (NARRATION) Flakey is a bundle of computers, watching through TV camera eyes, listening by radio.

ALAN ALDA Now if I move too fast, what...

KURT KONOLIGE Yeah. It is going to lose you.

ALAN ALDA Yeah, it loses me. But now it...

KURT KONOLIGE But it will re-acquire, you, yeah.

ALAN ALDA (NARRATION) You can talk to Flakey in a human way -- but as with people, communication can break down.

ALAN ALDA Flakey, walk this way.

FLAKEY Um, O.K. Thanks. I am looking, dude.

KURT KONOLIGE Just a little slow in getting commands. Try again.

ALAN ALDA Flakey, come here.

ALAN ALDA (NARRATION) Flakey's black box can't fit all the brain power he needs. So he's connected to computers all over the building.

KURT KONOLIGE We're a little slow. I mean, let me check the computers and see what is going on.

FLAKEY Um, duh. Um, duh.

ALAN ALDA Maybe there's something wrong with the battery on this.

FLAKEY Um, duh. Um, duh.

ALAN ALDA Flakey, come here.

FLAKEY Um. Coming boss.

ALAN ALDA Ah, look at this. Look at this. Coming boss, that's what I like to hear.

ALAN ALDA (NARRATION) Imagine Flakey's my new assistant, and today's his first day on the job.

ALAN ALDA Follow me over here ... and make it snappy.

ALAN ALDA (NARRATION) So first, I'm showing him around the office.

ALAN ALDA Watch out for the wall.

ALAN ALDA (NARRATION) Flakey's sonar sensors keep him from crashing into things.

ALAN ALDA Oh, good, good, he got around that corner O.K.

ALAN ALDA (NARRATION) Kurt Konolige, head of Flakey's design team, has caught up with us. Flakey's brain seems to be in good shape.

ALAN ALDA Flakey stop.

FLAKEY Um, sure thing boss.

ALAN ALDA O.K. Flakey, look right.

FLAKEY Um.

ALAN ALDA Flakey, this is Karen Meyer's office.

FLAKEY Um, an office, O.K.

ALAN ALDA (NARRATION) Flakey's reply meant he'd now memorized Karen's office.

ALAN ALDA He's, like he's watching out for this wall.

KURT KONOLIGE He's watching out for wall.

ALAN ALDA (NARRATION) As well as helping him avoid obstacles, Flakey's sonar is hooked up to a map-making program, which creates and stores the positions of walls and doorways.

ALAN ALDA Flakey, look left.

FLAKEY Um.

ALAN ALDA I love that nod, that is really funny. Flakey, this is John Bear's office.

ALAN ALDA (NARRATION) Flakey now understands this doorway is John Bear's. But there's more he needs to know.

ALAN ALDA O.K., now pay attention, I'm only going to tell you this once. Flakey, John Bear knows where Karen is.

FLAKEY Um, duh.

KURT KONOLIGE It's not, I don't know if it really understands that. Let's see.

ALAN ALDA (NARRATION) Kurt's suggestion is to tell Flakey the same thing, but in a very precise way.

KURT KONOLIGE Flakey, Karen is seldom in her office, but John usually knows where she is.

ALAN ALDA Oh, that he'll understand, right? Flakey, Karen is seldom in her office but John usually knows where she is.

FLAKEY Um, O.K., thanks.

ALAN ALDA No problem, glad to help.

ALAN ALDA (NARRATION) In fact, Flakey can understand some pretty abstract ideas, but at this point, Kurt's team had not yet given Flakey the full vocabulary he needed. His navigating ability is not yet perfect, either.

ALAN ALDA He's shredding the documents on the shelf here. All the documents are getting pushed up. Did you ever think of working for the White House? It's not going to work, it's costing too much.

ALAN ALDA (NARRATION) Now it's time to see if Flakey can put what we've taught him to use.

ALAN ALDA Look Marty, listen to me. The picture is costing too much. We haven't started shooting yet, all right?

ALAN ALDA (NARRATION) To give Flakey a realistic situation to work in, I'm acting out a typical conversation from the world of show business.

ALAN ALDA I know he's got a family. I...look, we have to make a movie at a certain price. O.K. Fire him, fire his family. That doesn't bother me. Look, I have a... I have the budget in the other room. It's in Karen's room. Wait a minute, I'll get it for you. Wait one second, one second. Flakey, come here.

FLAKEY Um. Coming boss.

ALAN ALDA Hold on, I'll get it for you in a second. Flakey, get the budget from Karen.

FLAKEY Um. That's a big job, boss. Here I go. Heading for Karen's office.

ALAN ALDA Good, just go do it, don't talk so much, O.K.?

ALAN ALDA (NARRATION) The first challenge is -- can he find Karen's office? Looks like he's making the correct turn. And by the way, this is for real -- we really did send Flakey out on his own like this.

FLAKEY Hi, Karen. Please give me budget file. Hi, Karen. Please give me budget file. Nobody is here. Heading to ... heading to John's office.

ALAN ALDA (NARRATION) Looks like he remembers John usually knows where Karen is.

FLAKEY Where is Karen?

JOHN Flakey, she's in the front office.

FLAKEY O.K. Thanks. Heading to front office. Um, duh. Please clear the hallway for me.

MAN O.K.

FLAKEY Thank you. Hi, Karen, please give me budget file. Hi, Karen, please give me budget file.

KAREN Flakey, here is the file.

FLAKEY Duh. Would you please repeat that, um.

ALAN ALDA(NARRATION) A little rough on the communication, but Flakey gets it.

KAREN Flakey, here is the file.

FLAKEY Um, duh. Could you please repeat that? Um, duh. O.K. Thanks. Heading to Alan door, um, O.K. Thanks.

ALAN ALDA We don't have to fire everybody, all right? No. We'll make other cuts. We just, we'll go over the budget, the budget is on its way in. We'll go over other cuts. We can, no. No. Not my hotel suite, no, we don't have to cut that.

FLAKEY Alan. Are you there?

ALAN ALDA Yeah. I'm here, wait a minute.

FLAKEY Please take this budget file.

ALAN ALDA O.K. But why don't we...

FLAKEY Alan, are you there?

ALAN ALDA Yeah. I'm here. I'm here. Let's, let's cut the scenery, why do we need all that scenery? We can keep my hotel suite and we will keep the scenery. Thank you very much. Thanks. Rest.

FLAKEY Alan, are you there? Please take...

ALAN ALDA I'm here, I took it, thanks, take a break.

FLAKEY Please take the file.

ALAN ALDA Thank you, I got the budget here. Look, people we'll keep...

FLAKEY Nobody is here. Heading to Alan door.

ALAN ALDA Go take a break will you. Get go have a can of motor oil or something, relax. I hate it when he stares at me like this, it drives me crazy. All right. O.K. What can we cut? You know, we don't need you Marty. What about this fear of robots becoming so intelligent that they'll outsmart us, they'll take over the earth, that they'll run everything?

KURT KONOLIGE Well, you saw, you saw how hard intelligence is to get. Currently I'd say a robot like this is kind of close to the dog level.

ALAN ALDA (NARRATION) But these creatures are the result of an astounding new idea that may soon take us from the dog-level to super-intelligence. Robots like Flakey must be programmed, feature by feature. But not these strange things. They created themselves through a process called artificial evolution.

KARL SIMS Evolution by itself has led to the creation of incredible complexity. Ourselves, all the organisms in the world. This process happened on its own. At least in my opinion. There was nobody that assembled all of these wonderful things in the world. On computers, we can simulate the same process and we

can get these very complicated, very interesting things without having to understand them and assemble them.

ALAN ALDA (NARRATION) When he first dreamed up this evolution idea, Karl Sims couldn't predict what would happen. He just gave his computers some basic parts, and let his creatures go from there.

KARL SIMS The bodies of these creatures are fairly simple. They're just made of some number of blocks. The blocks are connected by joints which can bend or twist. The creatures also have a nervous system. They have sensors which can sense the angle of the joints or sense contact. And the nervous system processes the signals from the sensors and tells the muscles when to move, which generates some kind of behavior. I've given it the capabilities to include all these elements but the computer actually decides how they're assembled and used in specific creatures.

ALAN ALDA (NARRATION) Numbers chosen randomly by the computer -- a synthetic genetic code -- described how the first simple creature would look, and how its nervous system would be wired. Then it was put into a simulated lake and told to swim. It twitched but didn't get anywhere, so now the computer went to work. Using the original numbers as its base, the computer made a few random changes -- the equivalent of mutations. It did this again and again, creating a new generation of 300 different offspring. Then all the offspring got a swimming test, with the best swimmers selected as the basis for the next generation.

KARL SIMS When the computer makes mutations in the genes of these creatures, it has no idea what these mutations are going to do. Sometimes the mutations might knock out pieces of the nervous system and perhaps cause the muscles not, not to move any more. But other mutations might actually improve the motion.

ALAN ALDA (NARRATION) So from the original creature, increasingly better swimmers evolved over generations, all without any human intervention. In the end, this was the best swimmer of all. But when Karl Sims put it on simulated land... it was like a fish out of water. So over subsequent generations, the mutation and selection process had a new goal -- to walk. After 15 generations, this was the champion. Other computer runs have produced even better walkers

KARL SIMS Sometimes these evolving creatures would think of solutions to their goal which were completely different than I expected. In this one example, the creatures got taller and taller and taller, and would simply fall over. Instead of figuring out some clever way of walking, they would fall to generate horizontal velocity. What I was telling them to do was to just move, and falling was a perfectly good solution as far as they were concerned. So this creature

specialized in falling for as long as it possibly could, including doing a complete somersault.

ALAN ALDA (NARRATION) The strength of artificial evolution is that it comes up with solutions that computer programmers could never imagine. So if the process could be applied to making robots, we might see a really smart Flakey, sooner than we think.

KURT KONOLIGE It would be nice to have something that, you know, would learn like a little kid does. I have a little kid and it's great to watch him learn all these things. But that's a very complicated self-evolving system. And our robots are not like that.

ALAN ALDA Okay, now look. You're a scientist and your curious and you're inventive.

KURT KONOLIGE And I want to do it.

ALAN ALDA You want to make it better and better. Is there a point beyond which you don't want to go? That you're afraid this will then gallop ahead out of control.

KURT KONOLIGE Will I win a Nobel Prize for it?

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