An INTERVIEW with ASTRONAUT MICHAEL BARRATT

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NANOOZE

THE SPACE ISSUE

RIDING AN ELEVATOR INTO SPACE

SMALLER AND SMALLER: NANOSATELLITES AND NANOGELLANTS

NEW WAYS TO SEARCH FOR LIFE

CHECK IT OUT! THE BIOSUIT™

NANOOZE

ALL ABOUT THE THINGS TOO SMALL TO SEE

Welcome to Nanooze!

What is a Nanooze? (Sounds like nah-news.) Nanooze is not a thing, Nanooze is a place to hear about the latest exciting stuff in science and technology. What kind of stuff? Mostly discoveries about the part of our world that is too small to see and making tiny things using nanotechnology. Things like computer chips, the latest trends in fashion, and even important stuff like bicycles and tennis rackets. Nanooze was created for kids, so inside you'll find interesting articles about what nanotechnology is and what it might mean to your future. Nanooze is on the Web at ***www.nanooze.org****, or just Google "Nanooze"—you'll find interviews with real scientists, the latest in science news, games and more!*

HOW CAN I GET NANOOZE IN MY CLASSROOM?

Copies of Nanooze are free for classroom teachers. Please visit ***www.nanooze.org*** *for more information or email a request for copies to* ***info@nanooze.org****.*

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NANOTECHNOLOGY AND OUTER SPACE

SPACE, THE FINAL FRONTIER. It's kind of an interesting place. Really huge, but also lots of open space. A big vacuum, which means not a lot of molecules. Maybe about a few hundred molecules in a cubic meter. Compare that with 10^{25} in the air at sea level on Earth.

We Earthlings have always been interested in space, since our beginning. The night sky, the stars, constellations, all that stuff up there. After sending up a few monkeys and dogs to make sure it was safe, man first went into space over 60 years ago. Then, we sent people to the moon, and now, space travel is a relatively routine thing.

Nanotechnology can make visiting space a bit easier. It's pretty expensive to launch things into space—it costs $10,000 a pound to get things up there! So nanotechnology can help by making things **smaller and lighter**.

Nanotechnology is also being used by scientists to develop better **rocket fuels** that have more energy. But the big idea is to build a **space elevator** that will lift things into orbit, including people. To do that we are going to need a really strong, lightweight cable and that's where nanotechnology will also help. **Carbon nanotubes**, which are stronger than steel and pretty lightweight, may help solve some of the problems.

This issue of Nanooze is devoted to nanotechnology in space. Not just the science itself, but some of the really neat people who are involved in the science.

We even got to interview an astronaut, Michael Barratt, who not only went into space but is a medical doctor as well. So get ready to take off and spend some time learning about nanotechnology and space.

NANO KNOW-HOW

Learning about nano stuff is fun but it can be complex, so it helps to keep these four important facts in mind:

1. All things are made of atoms.

It's true! Most stuff, like you, your dog, your toothbrush, your computer, is made entirely of atoms. Things like light, sound and electricity aren't made of atoms, but the sun, the earth and the moon are all made of atoms. That's a lot of atoms! And they're incredibly small. In fact, you could lay one million atoms across the head of a pin.

2. At the nanometer scale, atoms are in constant motion.

Even when water is frozen into ice, the water molecules are still moving. So how come we can't see them move? It's hard to imagine that each atom vibrates, but they are so tiny that it's impossible to see them move with our eyes.

3. Molecules have size and shape.

Atoms bond together to form molecules that have different sizes and shapes. For instance, water is a small molecule made up of two hydrogen atoms and one oxygen atom, so it is called H_2O. All water molecules have the same shape because the bonds between the hydrogen atoms and the oxygen atom are more or less the same angle.

Single molecules can be made up of thousands and thousands of atoms. Insulin is a molecule in our bodies that helps to control the amount of sugar in our blood. It is made up of more than one thousand atoms! Scientists can map out the shapes of different molecules and can even build most types of molecules in the lab.

4. Molecules in their nanometer-scale environment have unexpected properties.

The rules at the nanometer scale are different than what we usually encounter in our human-sized environment. For instance, gravity doesn't count because other forces are more powerful at the molecular level. Static and surface tension become really important. What is cool about nanotechnology is that we can make things that don't behave like we expect. **Things are really different down there!!**

Q&A

with Astronaut Michael Barratt

Michael Barratt and crewmates aboard the ISS in 2009

You have a background in medicine and zoology? Yes, I have a degree in marine zoology from the University of Washington, and then I went the medical route. Now I'm a space medical doctor.

Did you like to do experiments when you were young? Oh yeah. Once when I was about 9, I made a small gondola for a mouse, attached to a kite. I flew him up for about a half hour to see how he did. The gondola was made out of plastic bags with holes in it. I wanted to make sure there were enough holes so he could breathe. In retrospect, he could have wriggled through them, he didn't.

Did he come back? Oh yeah, he did fine!

Have you always been interested in science? Yes. We lived on a farm, but my dad was a chemical engineer. We had a big old barn where we rode horses, where I also had a small chemistry lab. We were breaking a few flammability codes there!

What kind of chemistry experiments did you like to do? I liked to throw lumps of sodium into water and watch them explode. I used to have tremendous fun with that!

You have five kids. Are any of your kids going into science? They are all over the map. One of them wants to be a librarian, she loves being around books and information and stories. One is at university doing computer science and minoring in music. One wants to be a lawyer, and the other two are undecided. My youngest has expressed interest in flying into space.

If you weren't an astronaut, what do you imagine you would be doing instead? The beauty of being an astronaut is it combines many things. I love oceanography, biology and medicine, so probably some kind of wilderness medicine or diving medicine, something like that.

Are you a SCUBA diver? I am! Aside from the mouse in the kite, I also built an underwater habitat for mice. I made a cylindrical container out of plexiglas and would dive them down to 15 feet, and bring them up again. I couldn't keep them down there very long though, because I couldn't get the CO^2 out, I didn't get the whole idea of applying pressure from the surface.

What first comes to mind when you think of nanotechnology? What I envision is the ability to have a really, really smart little machine that can get to a place of disease or a tumor or a blood clot and take it out slowly, early, carefully in a really controlled fashion so you don't do a big surgery and cause more damage in the process of curing the person. If a micro machine can destroy a tumor or impair its growth, that is going to be incredible medicine.

Will we all get to ride in space elevator some day? I hope so! If we do have a space elevator, I will be near the front of the line to get on it.

Probably be less stressful than going up in a rocket? Well, yes, rocket rides are very exciting, there's no question about that, but we need a more reliable and routine way to get people and things to orbit. I think the technology is definitely possible, and it is going to take materials science advances way beyond what we have now. But they are within our grasp. And do we need it? Absolutely!

We heard about Koichi Wakata's nanotechnology-infused underwear that he wore for an entire month. Oh yeah, I get a lot of questions about that.

Is it really true that it didn't smell? In space, we are always mindful of our hygiene. You get kind of used to the smells around you, and you can't necessarily smell yourself. But things don't get that dirty up there either because you don't have that heavy contact with your clothing like you do here, it's just kind of loosely around you. At the same time, you are exercising, you're sweating, and periodically we would ask each other, "Hey, do I stink?", "Am I OK to be around?" And I can tell you that Koichi didn't stink.

What was the coolest thing about being up at the International Space Station? It's really hard to say. I rank three things as almost equal. One of them is looking at the Earth, which is just astounding. Second, floating, flying from place to place. And the third thing is being at the galley table with my shipmates. We just had a blast sitting around the table, playing with our food, which you can't *not* do at zero gravity.

You guys work pretty hard up there. We do. You definitely do, but you have to have some together time. We'd eat for an hour and a half and then we'd all go back to work. But that time was just incredible.

AN ELEVATOR TO SPACE?

Space, the final frontier. But space is really not that far away. Space begins only about 70 miles from the surface of the Earth. If you could drive a car straight up into the air, you could cover that in a little more than an hour. Just this year a group of people flew a plane to the closest reaches of space and won a $20 million prize. Some day that sort of trip might be common. But is there another way to get to space?

How about an elevator? Some scientists are currently thinking about a space elevator. One end of the elevator would be attached to a satellite and the other end would be anchored someplace on Earth. Then when you wanted to go up into space or put something into orbit, all you would have to do is press a button.

Sound impossible? What would it take? It would take a very, very *long* cable, probably about 100 miles long. It would also take a very, very *strong* cable, so strong that it could lift thousands of pounds. Scientists can already build very strong cables and one way to do that is by using carbon nanotubes.

Carbon nanotubes were discovered about 15 years ago by Japanese scientist Sumio Iijima, who looked inside of a furnace and found some black crud. When he looked at the crud with a very powerful microscope, he saw long, skinny strings that were a thousand times thinner than a hair.

Carbon nanotubes are just carbon atoms linked together to form a tube only a few nanometers wide. Back when Iijima first saw them, carbon nanotubes were only a few hundred nanometers long. Now we can make carbon nanotubes that are thousands, if not millions, of times longer than they are wide. And they are really strong, about 100 times stronger than steel.

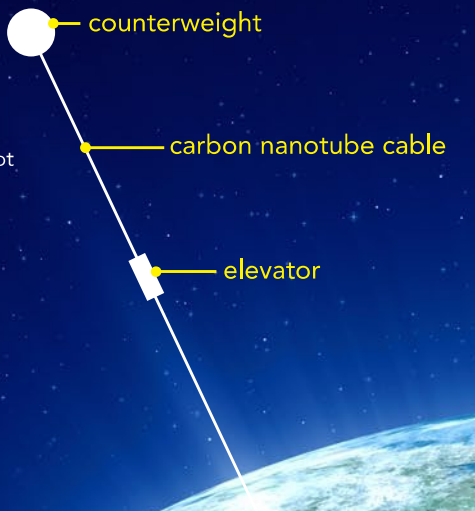
So the first step in making a space elevator is to make a cable with carbon nanotubes that is 100 miles long and hook one end to a satellite and the other end to the Earth. Sound impossible? Maybe not… The next question is, could you drive your car up the space elevator?

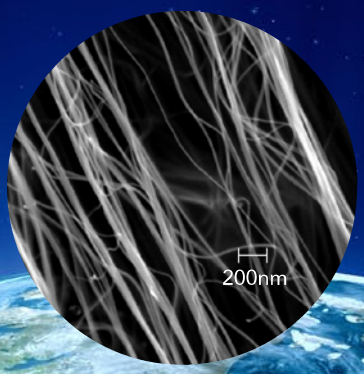
A very long carbon nanotube

Could carbon nanotubes make a space elevator possible? Theoretically, a carbon nanotube cable to space would need to be at least 100 miles long.

A space elevator

A space elevator could help make the trip into space a lot easier and less expensive.





A scanning electron microscope picture of carbon nanotubes.

Carbon nanotube SEM image courtesy of M. Zhang, University of Texas at Dallas

Bumblebee
WEIGHT: .01oz
COST TO LAUNCH: $6.25

You
WEIGHT: 100lbs
COST TO LAUNCH: $1,000,000

Clown
WEIGHT: 180lbs
COST TO LAUNCH: $1,800,000

GPS Satellite
WEIGHT: 2000lbs
COST TO LAUNCH: $20,000,000

CanX-2
WEIGHT: 8lbs
COST TO LAUNCH: $80,000

Your dog
WEIGHT: 60lbs
COST TO LAUNCH: $600,000

BLAST OFF!
LAUNCHING NANOSATELLITES

Just recently, the guy who started Cirque de Soleil (that way cool circus show) paid about $35,000,000 to ride on a rocket and visit space. He got to hang out in the International Space Station and the Russian Soyuz spacecraft. Twelve days in space, $35,000,000, and he said he would go again.

There are lots of reasons why some things cost a lot of money. Getting things into space isn't cheap—it costs around $10,000 a pound (that's $22,000 per kilogram). Send 10 pounds into space and it costs you $100,000.

The smaller the thing, the less it costs to send it into space. So why not make really small things?

That is exactly what some scientists are trying to do. For example, a GPS satellite, the ones that are used to tell you where you are, weigh about 2,000 lbs. Why? Because most of the machinery and materials used to build it weigh a lot.

There have been lots of "nanosatellites" built and shot into space. While they really aren't technically "nano"—as in one-billionth of a meter or about 1/100,000 the width of your hair—they are pretty small.

A group of students from the University of Toronto in Canada built a nanosatellite they named CanX-2 that weighed only 3.5 kg (about 8 pounds). It carried instruments to measure pollution in the upper atmosphere, including greenhouse gases.

So where is the "nano"? Parts of the computers, and a lot of the electronics, have nanometer-sized parts, and the instruments to measure greenhouse gases also have some nanometer-sized parts.

There are a lot of other nanosatellites that are going to be sent up into space and one idea is to have them fly in formation acting like one big satellite. With lots of them up there, if one doesn't work there are a lot more to back it up.

Getting things into space isn't cheap—it costs around $10,000 a pound.

SLIMMING DOWN

Getting into space is expensive, and it all depends on weight. The heavier something is, the more it costs to get it up there. One of the heaviest things on a rocket is the fuel, and that gets burned up just getting to space.

Sometimes the fuel is 98% of the total weight of the rocket!

The amount of energy that you get out of each particular fuel is different. Think about it, if you had to power a train from wood, that would be a lot different than using maybe coal or diesel fuel. Wood has about one-quarter of the energy per pound compared with coal, and diesel is about the same as coal. So if you had a rocket that was powered by wood (crazy...) it would take four times the amount of fuel.

Rockets aren't powered by wood (or coal or diesel fuel), but nanotechnology can help make rocket fuel more powerful. Materials at the nanoscale have unexpected properties. As you make things smaller they sometimes behave differently. Fuels (like gasoline or something called hydrazine) burn a lot faster and generate a lot more energy when they are made into small particles. Rockets also use liquid oxygen to help make these fuels burn.

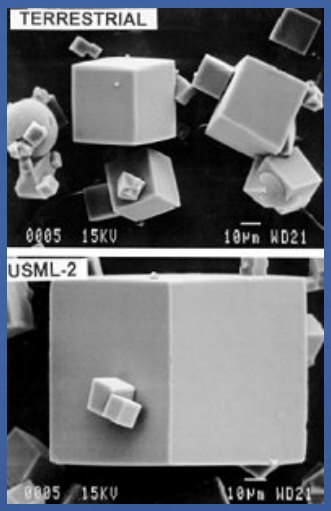
Scientists are experimenting with nanoparticles and things called nanogellants. Nanogellants are fuels that are cooled down to very low temperatures, so low that fuels that are gases at normal temperatures are liquids at these very low temperatures.

Nanogellant fuels have very large surface areas (the amount of surface for a certain weight), about 1000 square meters per gram. A piece of wood has a surface area of around 0.001 square meters per gram. That means that these nanogellants have about a million times greater surface area than wood!

More surface area means more energy generated.

More energy from a fuel means you can shoot more stuff into space.

Scanning electron microscope pictures of nanometer-sized nanogellants, a new kind of rocket fuel.



FUEL PROPORTION BY WEIGHT

Will nanogellant fuels help us send heavy things into space more easily?

LOOKING FOR LIFE

We are not alone. There are billions of stars and lots of planets that are orbiting those stars, so there is some probability that there is life somewhere else besides Earth. And we aren't even talking about people, like your friends or family, just something that might be living.

Scientists looking for evidence of life aren't even going that far, maybe just to Mars, a mere 36 million miles away. They are searching for different kinds of molecules—like water and organic molecules—that are found in living things. And that is exactly what they did on Mars using the rovers Spirit and Opportunity.

Looking for more complicated molecules like DNA is a lot harder.

One way to look for DNA is to use the polymerase chain reaction (PCR), a cool technique invented in the 1980s to duplicate DNA. PCR has been used for a lot of different things, from detecting diseases to recovering dinosaur DNA from ancient samples of amber. So why not use it to find life on another planet?

The big problem is that most PCR involves a whole lot of complicated steps and pipetting tiny amounts of solutions. That's fine if you're on Earth, but now we are on Mars. Nanotechnology to the rescue!

Scientists working on the Search for Extraterrestrial Genomes (SETG) project are using nanotechnology to build an instrument that will look for life on Mars. So how do they do it? Well, they are using nanotechnology to create tiny chambers for conducting PCR that are so small that they hold only a nanoliter. There are a billion nanoliters in a liter and a drop from your faucet is like 50,000 nanoliters. Since the chambers are so small, you can fit a few thousand on a "chip" that's less than the size of a postage stamp.

So what kind of life might we find on Mars? Well, about 4 billion years ago, a lot of meteors passed between Mars and the Earth. Ancient microbes may have hitched a ride on one of them and smacked onto Mars. Anything on the surface of the meteorite would have been singed to a crisp on the way through space, but a large enough meteorite could still have had some "bugs" living inside of it.

Scientists are using nanotechnology to build an instrument that will look for life on Mars.

courtesy of NASA

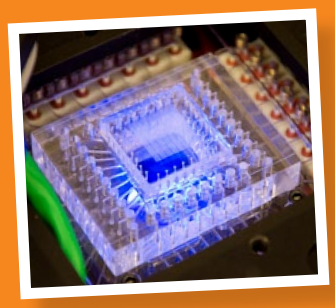
A Scanning Electron Microscope image of the Allen Hills Meteorite, which came from Mars, shows possible signs of fossilized microbial activity.

To test their prototype PCR device, the SETG team traveled to the volcanic, Mars-like terrain of South America.

At the foot of the volcano Copahue, on the border between Argentina and Chile. *Left to right: Clarissa Lui; Nicolas, our local guide; and Cyrus Vafadari.*

Field testing in the lower Rio Agrio Valley, Argentina, against a backdrop of giant araucaria trees, a species that has been relatively unchanged since the Jurassic era.

Regular PCR tubes are about an inch tall. The SETG team is making them much, much smaller.



This 0.8 inch by 0.8 inch microfluidic chip is part of the SETG instrument that performs PCR. The blue light illuminates the fluorescent dyes that help identify and analyze DNA.

Building a Better Space Suit

THE BIOSUIT™

Dava Newman, professor and aerospace engineer at MIT (Massachusetts Institute of Technology) has invented a new space suit, called the BioSuit™, that could revolutionize human space travel. How does it work, and why are giraffes important? Read on to find out!

Professor Dava Newman testing out her invention.

What kind of properties are important for BioSuits?
The BioSuit design relies on mechanical counter pressure (MCP) to "squeeze" the astronaut and apply sufficient pressure to keep him/her alive. The material properties of the spacesuit need to be quite elastic, robust and easy to put on and take off. The fabric suit provides tension in order to apply constant pressure over your body and keep you alive.

Are there special types of materials that you see in nature that might be useful for this kind of application?
The materials that we incorporate into the BioSuit include passive elastics, kind of like a nylon-spandex suit for athletes, and then we use active materials to provide additional pressure. Active materials are not found in nature, but need to be produced in our research laboratories. One of my favorite active materials is "muscle wire" or shape memory alloys. A typical muscle wire is made from a combination of nickel and titanium, which are each natural elements, but we need to combine them into an active material, sometimes called NiTi, to use them in our designs.

You mentioned about being interested in giraffes? What kind of things interest you?
As an aerospace engineer, I'm always inspired by nature and nature's design. For example, I studied giraffes and especially their neck muscles when I was formulating my early BioSuit designs. Have you ever thought to yourself, "Why don't giraffes pass out when they raise their heads almost four meters, from eating off the ground to stretching as high as they can reach to the tops of the trees?" If we jump out of bed in the morning, sometimes we feel faint. This is because when we jump out of bed quickly our hearts have to pump blood up to our heads instantaneously. How do giraffes do that when they have such long, skinny necks? I believe the answer lies in giraffes' strong neck muscles that squeeze blood, a lot of blood, up their necks to their heads almost instantaneously as the giraffes are raising their heads. This natural design is like the giraffes having their own G-suit.

How do you test your suits?
I test our prototype suits on human subjects and on a robotic spacesuit tester. We measure the actual pressure that we can create on the person's skin with paper-thin pressure sensors. Then we also test our prototypes on a life-sized robot that I have in the lab.

Graduate student Kristen Bethke, working on a BioSuit prototype.

Tiny bundles of spandex fibers make clothing stretchy. The passive elastic material used to make the BioSuit is a spandex-like material.