WELCOME TO THE NANOWORLD
EPISODE 1
... FROM MICRO TO NANO ...
ENGLISH SCRIPT

TC IN : 00 00
<u>OPENING TITLES - NANOWORLD</u>

LA COMPAGNIE DES TAXI BROUSSE
PRESENTS

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00 00
COMM
All around us, around you, and me… the worlds of media, science and economy are resounding with the prefix « nano ». All I hear is references to this invisible scale, a billionth of a metre, just a few atoms wide…

The frenzy is global. Thanks to nanos, science and technology foresee a fascinating new world, infinite new research fields, and miraculous new possibilities.

From materials to energy, the environment to medicine, via electronics and agriculture… nanos should make everything more efficient, more resistant, cheaper and less polluting…

Nothing in our world will be free from nanos… a prospect which sometimes appears quite alarming…

Welcome to the Nanoworld.. to the Nanoworlds…

01 08
TITLE :

WELCOME TO THE NANOWORLD
... FROM MICRO TO NANO ...

01 06
COMM
Welcome aboard for a journey to meet the initiators, the pioneers who opened the doors to the infinitely small.

01 15
SUMIO IIJIMA
PHYSICIEN
The meter, about this. Then one thousandth of a meter is one millimetre. Ok ? Then one thousandth of one millimetre is one micron, one micron. Then one thousandth of one micron, micron is one nano-meter.
Welcome to nano-world !

01 43
COMM
Nano ? Did you say nano ? Being a novice, and despite hearing the term left, right and centre, I'm a little bewildered. It's time to look a little closer. Very, very close, in fact… firstly, because nanos represent a scale of 10 to the minus 9 metres. A billionth of a metre, just a few atoms wide. A nanometre is 4 silicon atoms, side by side. On that scale, a speck of dust is as big as a planet. Between the macro world, our world, and the nano world (from the Greek, meaning very small) there is the same relation as between the thickness of a finger and the diameter of planet Earth.

02 15
COMM
During the 20th century, the quest for the infinitely small inspired many scientists, and revolutionised our world, from computers and nuclear physics, to biology and the search for new materials. Today, a new adventure is under way. Featuring Nanoscience and Nanotechnology, which include a wide range of disciplines all seeking to study and exploit the potential of nanometric matter.

02 54
COMM
On this minuscule scale, will we be able to penetrate the secrets of the natural world, and of matter itself ? To realise, perhaps, the same feats as flies, and walk on the ceiling ? Or to see our limbs re-grow, like the tail on a lizard ? To make surfaces where everything slides, like on a lotus leaf ? Or manufacture batteries as thin as a sheet of paper, yet as powerful as a nuclear power station, cables stretching from the Earth to the moon, and molecular computers ?

To find answers to these questions, I first of all head for Japan, to the Nagano province, to attend a lecture given by the British scientist Sir Harold Kroto, a nanoworld pioneer, and one of its best-known popularizers. Here, like everywhere else, he's given a star's welcome. And for openers, he gives me his vision of nanotechnology…

SYNTHE :
SUZAKA

03 42
HAROLD KROTO
CHEMIST
Nanotechnology has many definitions and the one I mentioned was, that I like and prefer, em is atom by atom, molecule by molecule assembly em to create a a complex structure.

04 00
COMM
How does Harold, the chemist, get mixed up in this story ? As a professor at the University of Sussex in the United Kingdom, he is intrigued by the long chains of carbon thrown out into space by dying stars.

On planet Earth, we know the purest forms of this same carbon, as diamonds, for rings, and graphite, for pencils. But in space, the carbon atoms appear to come together to form rather different structures.

In order to understand them, Harold decides to reproduce, in a laboratory, the conditions in which this stellar dust is created. In 1984, in Houston, Texas, he joins up with Bob Curl and Richard Smalley, who dispose of the latest equipment and a highly qualified team.

04 41
HAROLD KROTO
I went to Rice University to do the experiment and within about three days of doing the experiment we came up with an incredibly exciting result.
We came out with a fantastically strong signal which indicated that you could put 60 carbon atoms together to make a very stable structure, which was a big surprise.
We thought that maybe somehow a round object could explain this.

So suddenly from an assumption that all the carbon people eh had that graphite wants to be flat, suddenly we realised that on a small scale and by small I mean sixty, a hundred, a thousand and maybe ten thousand atoms, it actually doesn't wanna be flat, it wants to be closed.

We were just ecstatic

05 35
COMM
The results are beyond all expectations. 60 carbon atoms come together to form an object, that according to the calculations, could only be spherical. Round, like a football. This is C60, the first member of a new family of carbon molecules, called Fullerene, by Kroto himself, after the visionary architect Buckminster Fuller, who built a dome with a premonitory silhouette for the 1967 world fair in Montreal..

05 58
IN HAROLD KROTO
Hello, how are you ?
JOURNALIST

How much do I have ? 1, 2, 3, 4...

06 04

COMM

Through the discovery of this new molecule, in showing how it can form itself from carbon atoms, and in studying the specific characteristics and properties linked to its size, scientists are, objectively speaking, working for the first time in the nano science and technology field. And that's how Kroto and his Fullerenes kick-start the nanoworld…

06 24

HAROLD KROTO

It didn't have that big impact initially nineteen eighty five because it hadn't been proven to be correct, in fact the first five papers said we were wrong, they were very stupid papers.

06 35

COMM

Stupid. Completely stupid.

They find proof of the existence of this form of spherical carbon… and Kroto, Curl and Smalley are awarded the Nobel Prize for Chemistry in 1996.

06 54

COMM

The adventure is truly under way. My journey continues…

In order to delve deeper, I have to make a quick visit to California.

SYNTHE :

PASADENA

07 08

COMM

It is here that I find James Heath, one of the students working with Kroto at Rice when he discovered the C60. The student has progressed since then… He now runs the nanotechnology platform at the California Institute of Technology, CALTECH.

07 24

JAMES HEATH
CHEMIST
CALTECH

C60 was the first totally unexpected and novel thing and um, you know it really made people completely rethink what was the best understood element on the you know carbon, carbon is the basis of all organic chemistry and no one had thought about curved carbon before.

And so before the Nano world, if we wanted to modify some material what we would do is modify it's chemical composition, the different elements that are in it, we had the periodic table was basically our flexibility. Now, we got size and shape, that's like a whole different level of control and that's what really has emerged as a you know the really exciting physics and chemistry that's come out is by being able to

really control to a great level, the size and shape of materials and therefore their properties.
IN
How's that ?

08 17
JOURNALIST
Who was the first one had the idea of Nanotechnology?

08 20
JAMES HEATH
CHIMISTE
CALTECH
Well Fineman, here at you know my university Kaltech was the first guy who ever gave a talk where he really sort of laid out the potential of Nanotechnology you know nineteen fifty nine or something, it was um, and largely missed until twenty years later.

08 39
ARCHIVE
RICHARD FEYNMAN
What's happened, is over the past ten or twenty years chemists have learned how to control and build molecules which are a few Nanometers in size with true precision.
At the same time, engineers have been coming uh uh from say the immigrated circuit point of view and beginning to make structures that are very very small, as these two things meet there's a natural meeting of link skills and that's sort of where
Nanotechnology emerges.

09 00
COMM
Feynman, also a Nobel Prize winner, had an intuition back in the 1950s.
« Let's stop trying to miniaturise, let's build up from the infinitely small, from the atom. »
If nature conceives elements based on an astute assembly of atoms and molecules, then according to Feynman, man will one day be able to do the same.

If we can control the organisation of such Lilliputian elements, on a vast scale, it should be possible to construct absolutely any object ; a pebble or a toaster. An in addition, the good news is that on an atomic scale, the world is infinitely big.
There's a lot of room down below. Between the atoms that make up matter. In the thickness of a sheet of paper, it would be possible to pile up some 400,000 metal atoms. With space left over…
But what should we build ? And above all, how ? It will take time to begin to find the answers to these questions…

09 49
JAMES HEATH
CHIMISTE
CALTECH
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10 15
COMM
Back to Japan… Kroto continues his visits and meetings. And I continue to learn a little… That size counts, for example… Contrary to common belief…
On the nano scale, the scale of the infinitely small, the properties of matter change. The rules that define the everyday world around us, and determine the potential and behaviour of things, do not apply here.

10 43
HAROLD KROTO
CHEMIST
As you get smaller and closer to eh an atom there are changes in properties and eh probably one good example, the best example I can think of at the present moment is water, if I if you pour water into a tray, it's more or less flat because it's controlled by, by gravity which pulls the seed out flat, if you have a small drop of water it's round, it's it's spheroidal because the controlling factors are the is the surface tension which now overcomes all the gravity, it's much stronger on that small scale.

When you get down to atoms and molecules you're starting to discuss things like what sticks, how are we stuck together, how are our atoms stuck together and that's a quantum effect, and we're the result of it.

11 36
COMM
A quantum effect… what is it exactly ? A behavioural change in matter, according to quantum physics. And what is quantum physics, exactly ?
Physical laws different to those that rule the world that we know.
For example… if I take a ball, and throw it against a wall. In our world, it bounces. But if I'm very small, and the ball is of nanometric size, when it hits the wall, it bounces back, (of course)… but also goes through it. It's here, there, elsewhere, and nowhere.
If you're a bit lost, don't worry. So am I. And even the great scientists are still wondering about it…

12 13
JAMES HEATH
CHEMIST
Um, so quantum mechanics has this bizarre phenomena, that if you try and learn really accurately say where this object is then you don't really know where it's going, and if you try to learn really accurately where it's going you don't really know where it is. It's called the Eisenberg Uncertainty principle. It's just the weirdness of Quantum Mechanics.

12 35
HAROLD KROTO
In fact, at it's very simple level the fact that you can see colour is a quantum effect, people don't

realise it, you're so used to it, one cannot explain the colour of things.
And as you get down to smaller and smaller components these quantum effects become more important.

12 57
COMM
New properties means new applications. But let's not get ahead of ourselves… First of all, we have to identify these new properties, and catalogue them…
It wouldn't be until 1981, and the invention of the scanning tunnelling microscope, that another breakthrough would be made… seeing matter at an atomic level – a crucial step in the history of nano-science and technology.
And once again, I'm back in Europe. I head for Bavaria, in southern Germany. To see Gerd Binnig, a Nobel winner, naturally.

SYNTHE :
MUNICH

13 31
JOURNALIST
We where wondorering where to meet you….
It's the easier way….

13 40
GERD BINNIG
we looked into what exists uh in in science as technology that you can have that you can study those fine details and there was nothing; so we thought if there's nothing we have to invent something that we can look into these fine structures and after thinking a few months not much more than we came to a conclusion and thought yeh we build a new microscope that's more powerful than everything else that exists today.

14 10
COMM
And so the scanning tunnelling microscope was born…

14 17
JAMES HEATH
What they did was they imaged as if it was this um floor here and each one of these squares was an atom, they imaged the atoms on the surface of the silicon waiver and for the very first time they could see these atoms one by one and they had a map of this of this atomic structure.

14 36
GERD BINNIG
In principle you have two components, you have in the here and you want to look at so it's maybe a little piece of something maybe this table for instance, if you look into the finest details there are atoms sitting, so they are usually something like round objects and they sit here kinda in a certain way, yeh, and underneath are certainly also atoms, everywhere are atoms. So now you want to see all these atoms where they sit and how they are arranged, you bring in em extremely fine tip, it ah could be uh a

needle from steel although the needle is built up by atoms so it looks more or less the same thing but it has a different shape, it has this sharp tip and it uh forms this tip yeh and everywhere are the atoms.

Yeh, far away, the approach come closer, you apply a voltage so that the current could flow then you know there is an atom. Then you can move sideways, you come to this point here if you do this in a continuous fashion you can move this way and you see the atoms by the structure and you do it line by line, that's then called scanning yeh, and if you add all the lights you have an image of the of the surface.

16 01
GERD BINNIG
For the first time you look at the surface and uh and you see structures and suddenly you get a high resolution and you see all the atoms sitting there and forming a beautiful nice structure.
It then was certainly a very uh emotional moment.

16 30
HAROLD KROTO
You do need physical feel rather than mathematics to do something, I mean remember when I was studying molecules I had eh a signal on the chart paper but now you can actually see them, and it there's no doubt that human beings need a physical picture, the they it helps them even though that physical picture might not be quite perfect, because we know from quantum mechanics that physical pictures are misleading at the quantum scale but they are helpful to develop new ideas and new experiments but not take them too literally.

17 09
COMM
Thanks to Gerd Binnig and Heinrich Rohrer's invention, we can now see atoms, one by one, and a whole amazing new world opens up…
And the point that scans matter enables us to go even further…

17 29
GERD BINNIG
for the first time uh we got in touch with atoms yeh, no other method can touch atoms, when you're in touch with an atom you understand an atom much better, I I think, yeh, you can play with it you can kick it around?

17 51
and you can maybe build artificial structures atom by atom, and some of this was already done, so it's not, it's not just fantasy, it exists already.

18 05
COMM
The possibilities of the tunnelling microscope have barely been revealed, but already some people start moving atoms, one by one, to create constructions both serious and quirky.
The subject doesn't matter… what's important is showing that one can design and manufacture on an atomic scale…. Even if there are limits, of course.

Assembling a sheet of paper by adding a million atoms a second would take more than a billion years…

18 30
GERD BINNIG
if you want to build atom by atom with an STM that would take much long, if you want to build a complex structure that would take years yeh? So you can't do this with an STM atom by atom, but you might do it in combination with uh self organisation, where you just go to a few places and you place something an atom there and there and there and the rest is done by uh self organisation

18 56
COMM
Self-organisation, is simply the ability of matter to organise itself, on its own. Similar to living cells.

19 14
HAROLD KROTO
The best example of bottom up, self assembly, atom by atom, molecule by molecule is a human being, because we've been assembled and constructed from molecules;

What living systems as we understand them better have told us that is that there's a way of assembling very complex systems, machines if you wish, machines that like a bricklayer puts these things together and that's really what a what the ribosome does in the cell, it takes these gets all these bricks, these proteins which are flying around and puts them together according to this incredible recipe of DNA

19 14
COMM
The perhaps far-fetched idea that whatever nature can do, man will also one day be capable of doing – basically applying the mechanisms of living organisms to technological problems – leads, during the 90s, to the idea of building « bottom up »… of constructing from atoms, thanks to the self-assembly notion. You no longer need a tree to make a tooth-pick. No more Top-Down miniaturisation, going from the very big to the very small, but simply using Bottom-Up techniques : assembling the very atoms which constitute the tooth-pick.

10 29
Visionaries, prophets and madmen are already dreaming of a time when molecular machines will carry out such operations.

20 35
ARCHIVE
ERIC DREXLER
When you consider what technology is about is making things by rearranging the building blocks of matter. And when you consider that today we can't grab those pieces and put them where we want them, that we sort of push them around in big piles, it's I think clear that this going to be a fundamental revolution with pretty broad implications that will change the way we make essentially everything.

20 58
COMM
Eric Drexler, for example, in his book « Engines of Creation », imagines installations, composed of robot-like entities capable of assembling other robots, copies of themselves, which would work simultaneously, at high speed, to create, atom by atom, whatever objects we want.
No more processes requiring vast amounts of raw materials and energy. We could create objects using the very building-blocks of matter itself, the atoms, and create them without any waste, defects or impurities. The fantasy is decried by the scientific community, but inspires further dreaming.

21 51
COMM
Today, this is all strictly science fiction. And yet…

SYNTHE :
HOUSTON

21 57
COMM
And yet, in Texas, at the same Rice University where Harold Kroto revealed his Fullerene, I discover that another scientist is making molecules capable of transporting atoms. Nano-cars, or nano-trucks. A concept many would find unbelievable.
His name is Jim Tour, and his ideas and work may appear a little cranky…
And yet…

22 16
JAMES M. TOUR
Put those glasses on...

22 17
JAMES M. TOUR
So a lot of the research that we do up here is is ah, working on the the Nano cars, it's a unit that has four axels four wheels and can actually roll across a surface, they look very much like a standard car in that in that realm.
We take take ah a piece that will be a chassis then we take other pieces that will be the axels from the bottom up then we take other pieces that will be the wheels that attach on all from the bottom up.
Um, we have ones that have motors, and they're very small so we fit about twenty to thirty thousand of them depending on which model we use across the diameter of a human hair, so they're really quite small.
It gets it's power from light, so when you shine light on it, it starts to rotate.

23 20
COMM
In a single operation, Jim Tour is able to produce several billion nanocars. A 1 with 18 zeros… More than the automobile industry has produced in its entire history.

23 40

JAMES M. TOUR
We're nowhere close yet to the point of being able to actually build higher or the structure, we're just learning now how to pick up single atoms and bring them into place, but then in a hundred years to think of these small entities these Nano cars bringing in objects objects and assembling structures as big as buildings, because what we've been doing is we've been building buildings the same way for the last five thousand years, we bring in bricks and sticks and mortar and we build, but is there a way to build it from the bottom up? Many people say well you can't build rapidly that way, actually you can, there are some strains of grass that can grow almost a meter tall in a single day and all we have to do is is is learn how to do this, there's nothing magical about nature, it's just complex and so the idea behind the Nano cars was to first understand Motion then understand how to pick up an object and move it and then to controllably do this in unison to build up higher level structure.

24 39
JOURNALIST
You will be able with your car to build this kind of cars?

JAMES M. TOUR
Absolutely

25 00
COMM
After the discovery of Fullerene, the invention of the scanning tunnelling microscope, studies into the self-assembly phenomenon, and the idea of constructing from atomic building-blocks, the nineties are marked by a new discovery that will, for the first time, drag nano-technology out of the research lab and into the real world of industrial applications.
Carbon nano-tubes…

In order to meet the historical actor whom they discovered, I go to Japan, a 100 km from Tokyo, where I meet the dashing Sumio Iijima.

SYNTHE :
TSUKUBA

25 38
SUMIO IIJIMA
PHYSICIEN
NEC
« Carbon », « Nano », « Tubes ». Three words.
Carbon Nano Tubes made out of carbon atoms in tube structures. They are very small, nanoscale. The carbon nano-tube is part of graphite but the properties are very much different. Doesn't exist in nature. So it's very artificial. Synthetic material. You create them. Actually, this is carbon nano-tube. Million times enlarged.

26 38
JOURNALIST
Can I see what you're seing here ?

SUMIO IIJIMA
Yeh sure, sure

26 42
JOURNALIST
Ah you're already have a good ….

SUMIO IIJIMA
This is not individual carbon nano-tubes but it's a bundle of many tubes so… so that typical image of carbon nano-tube…

27 06
JOURNALIST
What is the size of what we're seeing here ?

SUMIO IIJIMA
This one is probably one to three nano-meter.

27 18
COMM
A brief flashback… to review the circumstances in which Sumio Iijima discovered the nano-tubes.

27 26
SUMIO IIJIMA
In the nineteen eighties, eighty five, the carbon …the fullrene molecule was discovered. But still the people were not interested by this material. And my friend Harry Kroto, one time I met him and he said « Sumio »- that's my name – « you should work on this material because you have some background on this material. So I got involved in this area. This was at the beginning of 1991. And accidentally, behind the … next to this structure was…this elongated material was there. So that's the beginning of carbon nano tubes.

28 24
JOURNALIST
Was is a surprise to find this kind of material?

28 28
SUMIO IIJIMA
Yeah, that's a very serendipity, at that age people has a lot of interest studying Carbon Fibre and I want to produce much stronger and the high quality Carbon fibre by special process and then I found finally the special process.
And some day I clean up the substrate by emery paper, the next day under the microscope we found a very small and a tiny tube.
Emery paper mainly consists of the iron oxide and the small particle leaved from the emery paper dispersed on the substrate and accidently grow the tube..

28 49

COMM
In just a few years, nano-tubes become the iconic emblem of the nano-world and nano-technology, apparently thanks to Sumio Iijima. That's the official version…
But I also discover the unofficial version… Another Japanese scientist, Morinobu Endo, is said to have identified these structures in the 1970s, but was unable to analyse them, or give them a name. And the story also goes that even further back, in the 1950s, the Russians (obviously) had observed them in their laboratories…

29 18
JOURNALIST
What happened in the 70s?

29 20
MORINUBO ENDO
CHEMIST
Emery paper mainly consists of the iron oxide and the small particle leaved from the emery paper dispersed on the substrate and accidentally grow the tube..
And people say, Endo this is so beautiful science but still too young for mass production practical application, so they're difficult to promote worldwide big community working on this material

29 48
COMM
Morinobu Endo has made up for lost time… and he's in a hurry.

29 51
MORINUBO ENDO
Thank you very much…

29 52
COMM
He invites me to accompany him to a carbon congress he's organising in Nagano…
The world's carbon elite comes together to discuss the properties and applications of carbon… and he's also invited his old accomplice… his friend, Harry Kroto… the superstar guest of honour.

30 20
MORINUBO ENDO
And this Carbon Nana Tube related with all fundamental technology of the 21st century, so we are very active to upgrade this advanced or innovative material to the field of the 21st century's fundamental technology.

For example a big aircraft they have about one ton of the conductive wire, but if you make Carbon nanotube conductor, perhaps the weight of the conductor deduce one tenth. But not yet we haven't from the such a long conductive wire.
Scientifically it could be possible to grow continuous wire as long as one kilometre, two kilometre from Japan to Hawaii but still we should break through some technical point,

31 17

HAROLD KROTO
Remember, you know we're dealing with something quite incredible, we're dealing with something that the diameter of this nanotube has a ratio of a hundred million times smaller than a soccer ball right. In fact the ration of the earth to the soccer ball is the same ratio as the soccer ball is to the diameter of these nanotubes. At the same time the length we want to be in meters
31 45
COMM
As well as their electrical and thermal conductivity, nano-tubes also display mechanical resistance far beyond today's best materials, such as steel or Kevlar. They should enable much lighter materials to be made. Nano-tubes also have excellent chemical resistance faced with oxidising products, and possess a potential for storing energy. For example, carbon nano-tubes should enable batteries to be made that can store and render, for an equivalent volume, ten times more energy.
The possible applications appear to cover every field, from electronics to health-care… And the production of nano-tubes is already under way…

32 25
SUMIO IIJIMA
This is the the device where we produice carbon nano horns. Nano horn is similar to Carbon nanotube, Nanotube is a pipe it's in diameters. Nano horn is um like a cow horns, that's why we named it;
So this part is where we load the material the uh the Carbon load.

32 49
JOURNALIST
So th'at's carbon ?

SUMIO IIJIMA
Yes this is carbon
so uh this is rotating and we shine the laser ligh and the these are sort of the trace the uh the uh laser beam.

33 01
JOURNALIST
And what is it for?

33 02
SUMIO IIJIMA
I don't know HA HA HA...

This is where we evaporate the carbon and make the Carbon Nano horns. Carbon Nano horns is very light like a soot so flying then then we introduce to this big chamber the Carbon Nano horns are come down to this uh lit little box there and where we collect and then then we have the Carbon Nano horn like that.

33 45
JOURNALIST
And how much how many Nano can you produce?

SUMIO IIJIMA
three hundred gram per day, so it’s good, it’s quite uh

34 02
SUMIO IIJIMA
So it’s quite efficient.

34 02
SUMIO IIJIMA
You can buy them but it’s still five hundred US dollars per gram, so it’s still very very expensive material more than platinium gold

34 19
COMM
To see the nano-world, to touch it, to discover new forms of matter, to imagine atom-by-atom constructions, to build the first nano-tubes… Such concepts could well have been confined to the laboratory, and remained the crazy dream of a marginal scientist obsessed by the infinitely small, if it wasn’t for this man. A rather unique character, an American, whose strong Romanian accent conceals the eloquence of a prophet… Mihail Roco, the pope of nano-technologies. He would provide the ultimate boost that would propel nano-science and technology into the spotlight.

SYNTHE :
GRENOBLE

COMM
He is welcomed to France as a dignitary by the director of the brand new Minatech, a centre devoted to nano-technologies inaugurated in 2006, bringing together 2,400 researchers over 50 acres.

35 03
IN
This is Vercors…

35 25
MIHAIL C. ROCO
I had the chance in eh March, eleven I recall ninety nine, I was called to the meeting
of the science, science and technology policy in the White House, I was given ten minutes to
explain what Nanotechnology can do for society.
And we convinced people that this is an important topic and they put on their long
term strategic planning Nanotechnology which was very unusual for the moment
because no one this agency has this topic one year before.

35 59
IN
Nanotechnology…

MIHAIL C. ROCO
And in eh December eh ninety nine I think December eh eighteen I was told no longer to speak to the Media about this topic because the President is considering to speak himself.

36 15
SYNTHE :
ARCHIVE BILL CLINTON - 2001
Soon researchers will bring us devices that can translate foreign languages as fast as you can talk. Materials ten times stronger than steel at a fraction of the weight. And, this is unbelievable to me, molecular computers the size of a tear drop with the power of today's fastest super computers. To accelerate the march of discovery across all these disciplines in science and technology I ask you to support my recommendation of an unprecedented three billion dollars in the 21st century research fund. The largest increase in civilian research in a generation. We owe it to our future.

37 07
MIHAIL C. ROCO
The impact was tremendous in business and political arena, what is happening. And in fact something immediate effect was Japan immediately reacted, when Japan learned United States will put eh half a close to half a billion dollar and they decided almost immediately in a few months to put the same amount without having any preparation planned.

37 35
COMM
A presidential speech, a political decision… and the world goes wild.
The United States sets up the National Nanotechnology Initiative in 2001.
Europe reacts very quickly, as Renzo Tomellini tells me in Belgium. He was head of the European nano-technology initiative between 2003 and 2008.

SYNTHE :
BRUXELLES

37 59
RENZO TOMELLINI
There is fierce competition, we're all at the same point in history, there isn't one economy which is particularly in advance. In a structural sense, there are sectors where Europe has been very active and earlier than individual countries in the European Union. With European research since the 1980s, Europe is active in nano-technology.

38 22
JOURNALIST
Compared to the rest of the world in the nano-technology field, what does European investment represent ?

38 28
RENZO TOMELLINI
The European research programmes began to provide funding for nano-technology research with

the fourth and fifth Framework Programmes… The seventh Framework Programme, covering the period 2007 to 2013, has already, in its first year, given something like 600 million euros to support nano-technology.
In 2007, the European Union member states provided more than one billion euros in backing.

38 54
COMM
Investments, economic returns… The figures are mind-boggling… For a clearer picture, I go to the United States to see the author of one of the most thorough studies on the subject. Mark Bunger is a consultant with Lux Research, a firm specialising in strategic advice for emerging technologies.

39 10
MARK BÜNGER
Hi !…

39 18
COMM
He begins by suggesting a little nano shopping trip to a sporting goods store in town.

39 34
MARK BÜNGER
Yes it's a nano shopping adventure in a sport store

39 36
JOURNALIST
what do we have?

39 37
MARK BÜNGER
Ok, so ,a lot of these products are using carbon nano tubes. So this is a tennis racquet for example it's a racquet ball racquet same company same basic idea. So Nano materials being smaller can then make this a stronger piece of equipment, so if you hit the ball, more of the energy from your hit should go to the ball as opposed to bending the racquet.

And then this is a completely different Nanotechnology, so swimmers want to swim really fast of course, and the friction of the water can slow you down so a lot of wet suits now are saying they have a a Nano hydrophobic coating, so a Nano coating that repels water, which is gonna lower the friction and allow you to swim just a little bit faster. This is Carbon Nanotubes um in bike parts from a company that puts them into the materials again to make them stronger and lighter weight. Some people always want to have the latest greatest technology in their sports equipment even if they don't know for sure that they can get a benefit from it, and ah so I think there's a psychological aspect to it more than an at least as much as an actual performance benefit, but I think you have to be a really good athlete to actually to get that much performance out of your equipment.

40 56
COMM

We're still talking about nanotubes, but the applications go way beyond sporting items.

41 05
MARK BÜNGER
The big areas ah of investment in Nanotechnology are in healthcare and live sciences, electronics and IT, materials and manufacturing, energy and environment and then tools and instruments so electron microscopes and things like that. Were just under fourteen billion dollars, worldwide, so about five percent of that is venture capital money, so that's the private investors who want to make big bets on *their technologies, the rest is pretty evenly split between government spending and corporate spending.*
North America, Asia and Europe invest about four billion dollars each in Nanotechnology, the rates of growth are slightly different, it's a uh double digits in in each area, but Asia for example is growing very rapidly.

41 49
COMM
It's a planetary movement. Globalisation is immediate. And Europe joins in the dance too. As in many fields, China, India and even Russia have seen the most significant growth in recent years.
China is today in third place in terms of public investment, and fourth concerning private investment and the number of specialised nano-technology centres. The United States and Europe could soon be left behind.
They're making nano-objects in China, and giant Napoleons in San Francisco. In a French baker's, Mark outlines the rules of the game, on an international scale.
42 20
MARK BÜNGER
I'm gonna try this anyway ; You're sure you don't want any ?

42 20
JOURNALIST
It's great, it's a millefeuille…

MARK BÜNGER
We call it a Napoléon

JOURNALIST
Napoléon ?

42 33
MARK BÜNGER
So we've done a study where we've looked at a number of different countries and rated them on two different types of factors ah one on their academic strength and investment in Nanotechnology specifically and then the other access is their ability to commercialise scientific discoveries and so a lot of European countries, France being one of them, have very very strong academic programs and are doing a lot of work in terms of science but they are not as good at turn as as say India or China at turning those into commercial products.

43 04
JOURNALIST

If we think about ah ah advantage and ah witness of um different continent...

43 14
MARK BÜNGER
Well, I think that the Nanotechnology today is going from science to it's first commercial applications and the continents, the countries that ah do best will be the ones that are already good at making those things, so if you're good at medicine, Nanotechnology will help you be better, if you're good at agriculture you know Nanotechnology will give you some advantages.

43 36
COMM
60,000 publications concerning nanotechnology around the world. Patents in their thousands, and the numbers are increasing annually, by almost 30%.
We talk about France, the opportunity is too good to miss… And we return to Europe to consult Françoise Roure, an economist specialising in the field…

SYNTHE :
PARIS

43 57
FRANCOISE ROURE
The quantity of patents, as well as the quantity of publications referring to nanometric concepts is exploding, so we're not at all just following a trend… the nanometric scale is really the pertinent scale being researched for its specific properties.

44 14
COMM
Françoise Roure is also one of the experts consulted by the European Union, and represents France in international discussions pertaining to nanotechnologies.
And nanotechnology is not only about scientific progress and technological advances, but also an essential factor in numerous countries' development policies and international relations.
Every country wants to be involved, and launches its own research programmes…

44 40
FRANCOISE ROURE
Scientific and technical roadmaps are emerging in many countries at the same time, and so we could mention Brazil, for example, which is very interested in food industry applications… China is very, very interested in all applications relating to nano-materials, as is Japan. South Africa is interested, for example, because of its significant mining heritage, in applications concerning the use of gold, and so in nano gold particles… which means that initiatives in favour of nano science and technology – public initiatives – are emerging practically simultaneously in many new places.

45 18
COMM
Research tools and production are expensive, but the theory is available to anyone who's interested. This is the challenge that a number of emerging countries are raising : to reach to the same level of competence that France, Scandinavia, Japan or the US have enjoyed for several years.

I decide to take a trip to South Africa. Every country may have different priorities, but nanotechnologies have the advantage of responding to every sort of problem.

SYNTHE :
PRETORIA
COMM
I meet Thembela Hillie, he is one of the directors at the department responsible for nano-structured materials at South Africa's national research centre.

45 58
THEMBELA HILLIE
In South Africa we need to put eh value into our em resources like eh minerals for example, so instead of just sending them overseas we can put value before sell them we need science to ah solve some of the societal problems like in health like eh energy issues ah purification of water. So Nano becomes a good weapon in that sense for South Africa as well.
46 33
JOURNALIST
When you say eh you would have different priorities what are the priorities?

46 38
THEMBELLA HILLIE
Look doing science doesn't have to have a specific region as far as I'm concerned, I think it's people who teach science, they can teach it anywhere so em, but it is also imperative to have this happening in South Africa because we are closer to the problems of the society in South Africa and will be able to see them if we do some of those things here, we can do some of those things especially synthesis, in very efficient and cheaper ways, in these developing countries.

47 11
COMM
The nanoworld inspires dreams of technological innovations, huge economic returns, new relations between countries, social upheaval, and even a new way of approaching science, way beyond the limits of our traditional disciplines…

47 24
JAMES HEATH
You know we have, we're in a university here and it has what's called a Germanic structure to it, meaning that there's chemistry and there's physics and there's biology and you know, even within chemistry there's organic chemistry and physics, whatever, so this structure was set up to solve my father's and grandfather's problems, it was not to set to solve the problems we have today, I mean we've got problems they're like energy and global health care you know
I think if you wanna effectively operate at the level that we do right now in um modern science you have to ignore the fact you've got this Germanic infrastructure imposed upon you and you just pull the pieces together that allows you to solve a problem. Nanotechnology has catalysed that kind of interaction probably more than any other field has.

48 08
JAMES M. TOUR
Because it's Nanotechnology we're able to work together in a way that we never did before and this is part of the joy of Nanotechnology and because you're getting this concerted movement together then we are seeing these larger leaps than we normally would in science.

48 26
MIHAIL C. ROCO
Nanotechnology offers a revolutionary way to change the existing eh productive methods, to change the revolutionary the medical field, to change revolutionary our understanding of the world

48 40
RENZO TOMELLINI
We're in a situation where we will be increasingly moving towards an economy based on knowledge, adding intelligence, using our brain as a primary resource, and so we'll increasingly invest our knowledge in materials, products and processes.

48 59
GERD BINNIG
I think the final aim, the final goal of Nanotechnology is to build complex structures machines will come closer to life forms in the in the future and Nanotechnology I think will be will be a big part of that so they will go in this direction that sometimes maybe you can't say was this reaction by a person or was it by a machine, that means you you're you have some kind of life form in in front of you, even if it's artificial.

49 30
HAROLD KROTO
I would only hope that our human attitudes develop in pace with that so that when we get these fantastically em useful em new devices based on this we don't misuse them.

49 47
JOURNALIST
Do you think there could be a em a misuse?

HAROLD KROTO
Oh absolutely, we know that any technology that's useful can be misused, and we see that everyday

50 00
COMM
It's not surprising, then, that nano-science and nano-technology, though barely at the teething stage, provoke as much anxiety as they do expectations. Especially in a context where knowledge must occupy a more predominant place in our economy, to resolve the problems of energy and the environment.

My adventure in the land of nanos is therefore far from over. What are the risks, the benefits, the rules we should apply ? Is this an evolution, or a revolution ? Answering these questions will require further exploration, to discover the first real applications reaching the market-place. Materials, foodstuffs, electronics or textiles… Or in the health-care field. Not forgetting ethical and toxicological questions.

And so the journey continues…

TC OUT : 50'48'14
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