Nobel Voices Video History Project, 2000-2001

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HOLLANDER:

Doctor, would you please tell us who you are and what it is you do.

t'HOOFT:

Okay. My name is Gerardus 't Hooft, and my subject is theoretical physics. I'm studying the laws of physics, in particular those laws of physics that are developing for the very tiniest structures of matter, the atoms, the molecules, and even smaller things that those are made of. There are experiments being carried out, experiments are in big laboratories, to figure out how these objects are made and how they move, and what happens when two of them collide with as much energy as possible. And there are theories that tell us what happens and how you can predict as well as possible what happens when particles collide. It is these theories that are my profession.

HOLLANDER:

Is it possible to draw a line from your profession to something very practical you use or do or will do in the future?

t'HOOFT:

Well, those lines are there, but they are quite long, because right now the main focus of interest of what we're doing is structures so tiny that enormous amounts of energy are needed to get anything moving there, to get anything to see, and these amount of energies are so tremendous that you can't think of very simple day life applications like an engine in your car or a new refrigerator or something like that, because those are properties of atoms and molecules at much more mundane distance scales where the laws of chemistry are valid or perhaps the laws of nuclear energy. But even that, we have gone long, we have passed for a long time, and so we are now in a domain of physics where direct applications are difficult to imagine. It could be in very, very large contraptions, perhaps, such as a very fancy energy generator that some people have in mind. Even that is already applications of a branch of our field that has already been passed.

So what remains is understanding, and what remains is that we really want to know how the laws of physics work, how they make sense. So our problem is that the behavior of these very tiny units of matter seem to elude all our understanding, and we consider it as a tremendous challenge to us, to humanity as a whole, to figure out how these particles work, what they do. It is exactly the fact that it seems so strange to us, these laws, we can't make them tick the way we would like to.

So here we see nature pose a tremendous intelligence test to humanity. They even ask, "What's the use of an intelligence test?" This is, I think, where the line to application begins. We are being tested. If we pass this test, we may say that we are intelligent and that we can probably use this intelligence everywhere in life, including practical applications of all sorts, perhaps other branches of physics, other branches of physics which also produces Nobel laureates—many of them are here—branches of physics which have direct applications.

But they sometimes require fancy analytical methods, mathematical methods that also are very difficult to understand and explain, but I like to see ours as perhaps the most difficult ones because there is so little that we actually know and so much that we have to guess. If we pass this test, I think we'll be smarter as human beings.

HOLLANDER:

But we haven't passed it yet?

t'HOOFT:

No, certainly not. Well, we have passed a lot. We have, say, passed the entry test to nursery school, that is called Standard Model of elementary particles. It, to me, is a tremendous achievement that was reached in the past, roughly, thirty years. About thirty years ago, new developments took place in our field that gave rise to what we call the Standard Model. It's a very dull name. It's actually something extremely interesting, because it's the first coherent, fairly complete description of the subatomic particles that before that were one great mystery. With this Standard Model, we can explain nearly everything. So we should be happy.

But of course, we are now focusing on those questions not answered by the Standard Model, and there are plenty of them. Now we're trying to answer those questions and define. They are test number two, the elementary examination for primary school, and that's much more difficult.

HOLLANDER:
So we're still in nursery school?

t'HOOFT:

Okay, well, depends on who is asking, of course.

HOLLANDER:

Doctor, how did you develop such an interesting nursery school?

t'HOOFT:

The nursery school of physics. Well, actually, I got interested in physics from a very early age on. I don't know why, whether if it was in my genes or whether my family also inspired. There are scientists in my family, so it was not a new phenomenon in our family to get this little boy being interested in basic science, laws of physics, nature in general, which caught my attention much more than, say, humanities or inter-human relations, which I always found very mysterious. I could not understand. Whereas I thought I could understand very well the laws of nature, the laws of mathematics, which I loved and I liked to excel in.

HOLLANDER:

Was there any particular moment or book or person or event where you could say, "Oh, now I'm going to be a scientist" that influenced you greatly?

t'HOOFT:

Difficult to say, because as I said, it's a very from as long as I remember I wanted to become a scientist. I want to investigate nature. That is as long as I remember. So I remember that when I still was something like a toddler or so, that I was looking at the wheels of bicycles and I note—there are two children's bicycles standing upside down and the wheels happened to touch. I noticed that if you rotate one wheel, the other wheel also rotates. So there's a principle of transmission. I remember being thrilled by that, that here laws of nature are doing something that is a consequence of these laws, and I could understand what was happening, of course. One wheel rotates, the other wheel will rotate. So this I found very curious.

Then I remember looking that at the little insects crawling in the sand in between the pebbles, and I was wondering what life would be like if you were an insect, walking through the pebbles, and then later trying to figure out the laws of numbers and mathematics, the complex numbers. That is, of course, much later, but still going through those stages. I feel like that as a person, I went through same stages that humanity went through during the evolution of science. There are many small instances where I got this great feeling that I learned something new.

HOLLANDER:

[inaudible]. How did you learn to think? I know that's a rather difficult question.

t'HOOFT:

Well, I must say my uncle who was, is, a theoretical physicist, a professor of theoretical physics, is also a bachelor, and he used to visit my family very frequently, once every so many weeks, and I loved to interrogate him, asking questions about physics. I wanted to invest or think about physics, and I was thinking about physics with my mind, but I was doing it wrong, of course. As a kid, you don't understand immediately what you have to do.

So I had these books about Einstein, about Bohr, and I wanted to do something similar great. So I asked him questions, "What about this? Suppose I do that? And now I have this great theory. What do you think of it?"

Of course he said, "This great theory of yours is nonsense." Basically he said, "What do you really want to know?" Very often he would just say, "I want to know what your real question is." Then when he started to ask, he discovered what I really wanted to know, he said, "Well, suppose you ask the question this way. Suppose you ask this question. Suppose you try to calculate that. What do you see?" This way, he kept me on track, as it were, and that was a very important part of the process, to get you thinking about things the right way. Someone has to put you on the right track.

HOLLANDER:

But the thought process, how to think, [inaudible]?

t'HOOFT:

Yes, well, he helped in that, that he would [unclear] his critical mind. As soon as you would come with some argument or a conclusion, he would interrupt and say, you know, "Why? Why did you conclude that from what you said previously, you know? You are jumping. I don't follow you here. What is that?"

Then, you know, I tried to explain more precise and discovered, indeed, that the argument didn't make sense, and you have to say things more precisely.

HOLLANDER:

Doctor, why did you win the Nobel? What exactly was it that gave you the Prize?

t'HOOFT:

Well, it's a curious phenomenon and perhaps the combination of science and sociology, what makes you win the Nobel Prize. It's obvious that one has to be tremendously lucky, one has to be at the right place at the right time and have the right idea. How that works is impossible to reproduce. So I was very lucky in arriving at the particular moment that Veltman was working on a tremendously interesting problem where he had very original ideas shared by very few others, and where it was clear that there was something very deeply true about those ideas, but also something wrong.

I had learned to think very critically, very methodically, and I could see that there would be better ways to handle the problem. So at that moment, then, I realized that you should build up the theory in a way which is not done in usual papers. They always start somewhere in the middle of a theory. They should start at the beginning. That is to say, at the very tiniest distances, the theory should be correctly formulated, and then you should be able to integrate out the equations. It's very hard work, but in principle, it should be possible.

So this was my philosophy, buildup improved models that allow you to understand what's going on, and you have to ask yourself continuously, you know, does this theory really make sense, is it logically coherent, and so on and so forth. If so, I should be able to do the calculations I want to be able to do. Whereas in the theories which existed at that time, such calculations were impossible, so people got stuck and had strange ways of arguing how to get around the problems. I always get—you know, I feel like I don't understand that argument, I don't believe it. I would argue the same way as my uncle would at the time, you know, address my own foolish thoughts, and try to get a sharper picture of what's going on.

HOLLANDER:

How has the Nobel Prize changed your life?

t'HOOFT:

Yes, well, I should have continued on the previous, because there's still—no, that's all right. I'm sure you are going to cut some things and edit it.

So it was one particular aspect of the theory called renormalization, which has to do with the fact that at the very tiny [unclear] scales, you formulate the laws of physics. I should think you know them. But then you apply those in events where the characteristics scale is much larger. Then it turns out that the parameters relevant at that scale are different from the parameters relevant at the very tiny scales. You have to renormalize them. So you have to renormalize the mass of the particle, you have to renormalize the electric charge of particle and so on.

That procedure called renormalization had me very mystified in the past, and basically that procedure has been cleared up by the way that we handled these theories. So we end up with a scheme that suddenly turned out to work and also a scheme that would allow us to identify which models of the particles would correctly allow precise calculations so they would make sense. So the work led to a complete understanding which way one should build a model of elementary particles.

Then it was easy to check. Actually, such models already existed, but have received very little attention before that time.

The first thing that happened was that Weinbach [phonetic], Glashov [phonetic], and Salome [phonetic], who had each independently produced a model, models of subatomic particles, they had already written down such models long before Veltman and I came with our results. So they first got their prize, because their model suddenly became very successful.

Then for a long time, there were prizes given for other or related topics in particle theory or in other topics of physics, and it took a long time for the Nobel committee to recognize that our work has been, well, an essential step in understanding how to put things together, because to my feeling and many others, by the way, it was the early seventies when it became clear how to make models of subatomic particles.

The point was that we could do the mathematical calculations now, so we could analyze as well as very precisely compare them with experiments, very, very precisely, and see that the experiments agreed that these results make sense in terms of these models. So now the story is that first there are people who propose the model, which is Weinbach, Glashov, and Salome. Then there were the experiments which confirmed the model. There were various prizes given for those experiments. Then came theory to allow an accurate analysis. That's how it's now being presented and how you now also often see that the history is being told to people, and then the theorists came and tried and understood things.

So now we are given the Prize, because now the experiments have really confirmed not only the rough structure of the models, but also the mathematical details. So what happened in recent years was that the experiments became so accurate that any calculations, which were very tough and difficult calculations, were done by many of my colleagues, which showed that the experiments agreed with the calculations, but also in the very tiny details, not just in the first decimal place, but many decimal places with the numbers, they agree now with the details of the calculations.

That was for Stockholm the reason to give us the Prize. So you see that's it kind of sociology of science which is rather strange every now and then. So some people think it's strange that we got this prize some twenty-eight years or so, maybe thirty years, after we did our work.

HOLLANDER:

[inaudible]

t'HOOFT:
Yes.

HOLLANDER:

Doctor, how has the Nobel Prize changed your life, or has it?

t'HOOFT:
It certainly has in a considerable way, although, you know, I was known in my field before that time, and so I have been asked every now and then to give a popular lecture about my field, to write a book, to attend conferences, and every now and then to also to be in, say, a television program or so. But all that has intensified by a factor of ten or more after the Prize became known. So what used to be a very small part of my life, every now and then doing something in the public, explaining things to high school children or to interested laymen or other things that I could characterize as being an ambassador of science, now it is taking nearly all of my time. So for this year, I'm just enjoying that. I hope to go back to physics sometime.

HOLLANDER:

What about your personal life? Has that changed, too?

t'HOOFT:

It also, because, you see, your standing has changed. I mean, now the man on the street, as it were, often knows that this is this guy who won this prestigious prize. Whereas I've had other prizes in the past, but they never had this effect.

HOLLANDER:

Relations with your family, have they changed?

t'HOOFT:

They don't change, no, because they know me too well, and so there's no reason for them to change their attitude to me. Of course, they enjoyed as much as I did what was happening. For my wife and my daughters it was a big event, and they enjoyed everything of it. Even their lives have been affected a bit, because their relatives, their acquaintances, their friends, they know about the Prize that their father or their husband or their uncle has won.

HOLLANDER:

Suppose I were to walk up and drop a baby in your lap, and I would ask you, "Please tell the child a story before it went to bed."

t'HOOFT:

A baby? I don't know.

HOLLANDER:

Or a child.

t'HOOFT:

At what age?

HOLLANDER:

Say five to six.

t'HOOFT:

Five or six. I don't know. I would perhaps give it a toy, a little car, you know. At that time, I loved to play with toys. Or perhaps I remember at that age, little toys or things you can take apart and put together again.

HOLLANDER:

What about a story? Is there a story you can tell the child?

t'HOOFT:

Story is—I'm not so good at storytelling. Not at six or seven, but at somewhat later age, I told stories to my daughter which were the Greek myths that I learned at high school, because my kids were always asking to tell stories, and I would often read a little story out of a book or so.

HOLLANDER:

What was your favorite story? The first one that comes to mind.

t'HOOFT:

I'm not a very good storyteller. There's a famous Dutch author who wrote about a little boy who had his first job being a servant in an elevator. People come in the elevator of the department store, and a woman with all shopping bags comes in and says, "Fourth floor," and he presses the button fourth floor. He has a special suit on. It's a very important job. But before he was given the job, he was told, "There's one button you should never push. The red button, don't push that button."

So he goes up and down in the elevator and helps people. Everybody tells, everybody asks, you know, this floor, that floor, I want to go to the basement, I want to go to the sixth floor. But then one day when he sees all these elevators full of people and nobody is look at him, he says, "What happens if I press this one button?" So he presses the button, and the elevator goes up, but it goes up and up and up and up and it doesn't stop anymore. It goes out of the building, it goes into the sky, and it flies like an airplane.

Then he presses the button again, because he gets worried, and then the elevator stops and goes horizontally. Then it flies to America or something, comes down again. Then you have all the adventures in America.

And then what? How do they get home? So they all step into the elevator again, he presses the button again, hoping to go home. Then the elevator goes down, and it goes down through the Earth. It goes down right down through the Earth, and then somehow, I don't know how it turns over, but it goes down through the Earth, and finally it comes out at the other end, back in the department store, and they're back in the basement or somewhere or the first floor and everybody steps off.

That nice story was being—I read it for my own children, and I can remember it from my time as a kid.

HOLLANDER:

You're working with subatomic particles. You're working with the very elements of nature, of life. What is your view on life? Has it changed?

t'HOOFT:

Well, for a long time, I couldn't completely understand life in the sense that I found it was mystifying, and just because I couldn't understand it, I wasn't too much interested in it, although I was interested in very primitive life, which I thought could be understood, like bacteria or sponges or snails. That looked sufficiently simple that you can understand what drives these creatures and so on.

But life as human life I found so complicated. But then, I must say, understanding came slowly, a little bit more, and what changed my view a bit was the books by Dawkins on *The Selfish Gene* and so on, which explain how life can be understood in totally physical terms. So the way life has evolved in this planet is not because the laws of living things are different from the laws of dead things in physics. No, they are the same laws. But I knew that for a long time they are the same laws, but what I did not know was how these laws really functioned to make life look the way it is.

Now biologists such as Dawkins describe in their books how laws of physics really could produce life as we know it, in very rough terms, of course, how the genetic structure of this—well, the things in the cells, the DNA, how this information could be passed on from one creature to its progeny, and how natural selection actually works. This was the first more or less complete description of how the genetic mechanism works and how basic laws of physics are all behind it, and how the basic laws of physics are connected and explain the basic laws of life. This I found very revealing, that life is nothing but an extended way in which the laws of physics appear to work.

HOLLANDER:

But the next question, obviously, is going to be why, the big "why" question.

t'HOOFT:

Yes. Here I think my opinion differs a bit from what I read very often. Many physicists, biologists, and other scientists appear to believe that life was a practically necessary thing to happen to this Earth and that there will be many other planets where life has evolved, even intelligent life. I happen to think that what happened on this Earth, the evolution of life, must have been an extremely special event, enormous combination of coincidences.

I have thought a little bit about how it would be like to make a machine that can reproduce itself. That's what life is. Life is all, everything you see in here, everything that lives is example of a little machine that can copy itself and reproduce itself. Now, if you try to think, how would you design a machine that can reproduce itself, it is tremendously difficult. I don't think any engineer would be able to produce such a machine at present. I think it will be possible in a more distant future to make such a machine. I think it will be interesting to make such machines that can reproduce themselves. But it's tremendously difficult.

And nature just did it by chance. I think the number of coincidences needed for nature to produce cells and more advanced constructions that can reproduce themselves, the number of coincidences needed for that is fantastic. Also coincidences is needed to have these cell-reproducing organisms evolve into something as complicated as us. I think coincidences are needed that are very, very special, which makes me believe that the Earth might well be the only planet in the universe or the only planet in the galaxy, an extreme rare combination of coincidences that made this Earth suitable for life and actually for life to just evolve out of nothing. It's possible.

In other words, as you may have noticed, you may have expected a different answer. My answer to the question why is in physical terms, you know, how could the laws of physics produce life. I'm not even trying to answer the question of why did the laws of physics produce life. I really can't. But I think the question of how is by enormous set of coincidences.

[Taping interruption]

HOLLANDER:

Doctor, I'd like you to come back to this question of life, because I think it's something that preoccupies everybody, and it certainly preoccupies people when they're in their adolescence. You have a period where you're expanding and you're reaching out to the world, and you're wondering why doesn't this world come to me. Has this study of theoretical physics, has it led you to any metaphysical [inaudible]?

t'HOOFT:

Well, it's an interesting question, because in doing physics, you do need a certain amount of philosophy to guide you, as it were, into the kind of questions that you want to ask. So it's practically impossible to function as a theoretical physicist without having some sort of belief, a belief that you can't substantiate, you can't verify, that you just have to believe. Of course, as a human, we need even more such beliefs to function properly.

Many people call it religion. You may call it anything you like. But there's some sort of attitude towards the world around you that you need in order to function. Well, my attitude is a very, I should say, atheistic one. I don't believe in any sort of predetermination or things like that, or other religious thoughts. But we do need a belief that, well, we've been put on this Earth for, well, for some reason, some would say, or by some accident, as I would say. Basically some accident has put us humans on this planet. The accident made it such that we humans, only humans allowed on this planet are humans which function a certain way, that are the laws of physics. If we wouldn't function this way, we would not function at all, and we would not survive as a human.

So the only humans that exist are the humans whose character and organs and everything function according to some basic rules. Those rules are understandable because the rules have been implanted in us by the laws of physics, and we better behave along those rules. If we try to behave differently, first of all, you feel very unhappy if we don't behave according to the rules that have been planted into us.

HOLLANDER:

What I'm trying to get at is do these rules—what are these rules [inaudible]?

t'HOOFT:

Well, it's obvious that humans are social creatures. So we must obey certain social laws to function, and so we must, in particular, safeguard our family and our friends and our whole society. We should have a responsible life. This is how humans, in general, work. We are like cattle. We form a herd of creatures, and the herd takes care of all the members of the herd. That's how humans function. Well, when you try to think logically about these things, it's not entirely possible, because humans are not made to think entirely logical, certainly not when it comes to social behavior.

You are made not but to think logical, but you behave because only those humans who behave according to these rules are the humans that can make up society, and they're [unclear] function. So all one can do is as a human being is to try to obey those laws as well as one can. And one quickly notices that although the law sometimes tells you that you are one of a herd and there's another herd that you have to fight as hard as possible so you have to go and grab your arms and fight the other herd and so on, we realize that that is not a very nice way to behave, so we should try to consider all of humanity as one herd that we should try to protect.

HOLLANDER: [inaudible]

t'HOOFT:

No, not a justification, but an explanation. I like to explain. I like to understand the things I see around me. So I like also to understand human behavior, which for a long time I could not understand.

HOLLANDER:

How do you explain, then, what's happening in the world today, or what do you see happening in the world today? Does it conform to the rules or—

t'HOOFT:

Well, of course, not quite. One learns every day that the world is not what you thought it was. There are always things, unexpected things, happening in this world, and I try to fit that, of course, in the overall picture I have of the world and of humans as a whole. But mind you, of course, that's not my field, and I'm glad I'm not a politician or have to decide about matters that I really don't understand sufficiently well.

HOLLANDER:

One last question. What do you see as the role between science and society, the relationship between the two, and where are we now?

t'HOOFT:

Well, science has done a tremendous lot for society. There wouldn't have been a society like ours without our science. So science has had a tremendously important impact on society. Society is paying us back. Scientists are perhaps even more curious than many other people, and they want to know. People like me, I want to know what the laws of physics are like for the very tiniest particles in the universe. Society pays back the scientists by allowing them to make the big machines to fulfill their curiosity. And I think society owes that to science, because science has made the society, has given them not only the television and the automobile and the computer, but also fire, the way to make clothes, to communicate, and so on and so forth. So society owes it to science to allow them to fulfill their curiosity also in the future, regardless whether or not there will be any practical uses.

So one comes back to the beginning of the interview, which is about practical use. So I think ultimately there will always be some practical uses of the unexpected kind, like S____, which produced the Internet as something very practical, very useful, but S____ wasn't designed to develop Internet for us. Quite to the contrary. It was designed to investigate the subatomic particles.

HOLLANDER:

I notice here there's very few media. I mean, we've been filming the event. Society is not here, in one sense. We've been very shocked by this, to find that we're almost the only crew here doing interviews. How do you explain that? I mean, I would think logically that it should be full.

t'HOOFT:

Logically, I agree with you. There should be more interest. But, well, I'm also used to the situation. It hasn't been different throughout the ages. The majority, say, 99.9 percent of the people, are not interested in science. They see things come and go, and they say, "Well, it's not my life." People are interested in so many different things in this world than science. It has always been like this.

I have in mind the Middle Ages, where science was only carried out by monks who had little else to do than to investigate the laws of creation. They were clearly very religious, but they thought, "God has made this world. What a simple way, let's try to find out how he has made it," and they made their small and big discoveries. And few other people.

Then the Golden Ages came where the western countries became extremely wealthy, and there were more people who had nothing else to do. They were sort of misfits of society. They ran into doing discoveries or measurements or investigations. They made their discoveries and they made science go forward, not because a large community wanted to do science, but only a small number of individuals were interested and were curious to see how the world functions. It has always been like this, and so I simply don't see any change in human attitude or the attitude of the public at large toward science.

HOLLANDER:

Are there any questions I should have asked that I didn't?

t'HOOFT:

No, I can't imagine anything else with this last one. So, no, it's your questions.

HOLLANDER:

Thank you very much.

t'HOOFT:

Okay.

[End of interview]