chapter 1

Countdown

My spaceship was painted a brilliant white and sported sleek red and black stripes. The small hatch windows appeared black in color, designed as they were to block the hazardous ultraviolet light emanating from the suns. Take-off and landing were executed vertically. Once on the ground, the spacecraft rested on its small stabilizing fins, to which its three or four engines were attached. You could tell the spaceship had already traveled a great deal; its hull was dented quite a bit. My spaceship had brought me to loads of planets and moons in faraway star systems. The elliptical orbits I chose to navigate around the planets no longer held any secrets for me. I had also learned why it is necessary to protect yourself against the blistering and tempestuous solar winds.

How old was I? Nine or ten perhaps. The spaceship was my own design and it was glued together from paper. The engines were small and needed little fuel because they worked on anti-gravity, a principle I had invented especially for that purpose. Sketches of the planets that I had visited along the way could be admired in my drawing book.

Naturally, an important aspiration during my interstellar expeditions was to stay ahead of all other space travelers. Now this was far from easy. I discovered I had competitors, indeed, many

of them. They were the writers of science fiction novels, whose creations were far more imaginative than mine: they invented spacecraft that traveled hundreds of times faster than the speed of light; they met extraterrestrials who nourished themselves with pure thought; and they described aliens who traveled in the comfort of their own home planet, by hopping right into superspace with just a snap of their tentacles. Against such adversaries I would never be able to win.

But I had one consolation, which kept me going. The others were cheating! They modified the laws of nature way beyond credibility. Forcing a wormhole through space and time or paranormal communication — those weren't possible in my wildest dreams. If you don't impose any of the constraints dictated by science, science fiction really isn't that much fun anymore. No, if you want to undertake interplanetary travel, you must comply with the laws of nature — and find the loopholes within. Now *that*'s what's important, because the laws of nature are forbidding; disobedience will never be tolerated. No, you have to be cleverer than that.

Trust me, I know. Because I now know a lot about the laws of nature. I studied physics and have made it my profession. This awesome field is my life's passion. As a physicist, you realize that the laws of nature are not to be messed with. With an amazing mathematical precision, a certain Isaac Newton formulated laws explaining that the gravity of planets, stars and moons is generated solely by their masses, and that this force cannot be influenced by any other external source. One of the conclusions to be drawn is that anti-gravity is impossible, even if you take into account the adjustments one Albert Einstein made to Newton's laws 200 years later. Creating anti-gravity, or whatever else others might conjure up to neutralize the gravitational force, is simply out of the question.

But that's only for starters. There is a lot more that is incompatible with the laws of nature. Indeed, the laws of nature precisely specify what you *cannot* do, even more so than defining what *is* within the realm of possibilities. This has grave consequences. Brace yourself for what comes next:

- It will never be possible to travel faster than the speed of light. Ever.

"*Dear Mr. 't Hooft. Surely you have heard of the new Tachyon theory, developed by Gerald Feinberg, and you must be aware of the recently published articles of Luis Gonzalez-Mestres. I am currently developing a brand new design for a faster-than-light machine, and am inviting other like-minded pioneers to invest in my invention. Presently it only exists on paper and hasn't actually been built yet, but ...*"

I receive such letters all the time. Gullible investors are guaranteed to lose their money. While velocities greater than the speed of light do exist in physics, spacecraft will never be able to make use of them. Consider a beam of light emanating from a lighthouse. The torch within spins around, and if you stand sufficiently far away from the lighthouse, you can see a spot of light swiveling around with superluminal speed. But it is immaterial; it is impossible to transport any people on that blob of light.

- For every transfer of information a medium is required, such as sound, light or even a piece of paper. Whichever medium is chosen, no message can go faster than the speed of light.

So you cannot even transport a letter with the fast-traveling bundles of light coming from the lighthouse. This feature is shared by all known laws of nature. It is a basic principle that explains a lot about the rules that govern our existence.

- Energy can be transformed into heat, but conversely, only *differences* in temperature can be transformed into usable energy.

Another one of those things: a Perpetuum Mobile, a machine that magically generates kinetic energy out of nothing, is a fabrication. You can't get energy back from heat, but differences in temperature, such as those produced in a steam engine, can be used to generate a lot of energy. This is also the subject of many letters, which end up without much ado at the bottom of the filing cabinet under my desk.

- It is not possible to accurately determine both position and velocity of a tiny particle at the same time. It's either position or velocity!

The mathematical formulation of this law is a bit too complicated for the purpose of this book, but the so-called Heisenberg Uncertainty Principle is of such importance that it must at least be mentioned. The principle poses many limitations to what can be done to atoms and particles.

And so on.

But now what? While science fiction writers might be developing their stories on a load of hogwash, my own paper spaceships didn't work so well either. Is there really no way to travel to the Moon other than in NASA style, with monstrous money-gobbling machines, filled to the brim with fuel — and without my beloved hatch windows?

Well, that might be a bit too hasty a conclusion, as I will explain in Chapter 15: nature's laws allow for another way to lift up into space. But how? That will remain a secret for just a little while longer.

And what about those paranormal phenomena? Aren't the tabloids always full of them? I will take an even more contentious stand: the reason they are called *para*normal is because they are not compatible with the laws of nature. That there are still people out there who attribute any credibility to these phenomena is because they are not taking the laws of nature very seriously. That is odd, considering they owe all their everyday conveniences to these laws, such as their car, television, central heating and what not.

"*Mr. 't Hooft, why are you being so cold and harsh? Can't you soften up these laws a bit? Why not allow an exception or two — that wouldn't hurt anyone?.*"

I also get a lot of those letters. "*Scientists should be more modest*," I read one day in a letter submitted to a newspaper, "*there are truths other than scientific ones*." That may be, depending on how you look at it. However, in no way will those alternative truths allow for circumventing or diluting the laws of nature.

Authors of science fiction completely disregard the limitations imposed by those laws. That's why we end up reading about powerful laser beams used for teleportation from spacecraft to the surface of fantastic imaginary planets — marvelous nonsense that lets you escape reality for a while. But while authors certainly create wonderful dreams, even the most outrageous absurdity isn't crazy enough for some writers.

Do you want to enjoy this sort of reading? By all means, go right ahead, read your science fiction and dream on. But remember it is fiction and has little to do with science; not even with the science of the future or with any science known to faraway aliens on distant planets. Most science fiction writers convert the wonderful field of physics into an unrecognizable blur of who knows what, just so that their storyline has at least the appearance of respectability. "*Beam me up, Scotty,*" a man recently sentenced to death exclaimed when he was allowed to say his last words. To no avail; apparently Scotty could not find the button in time.

A negligible minority of science fiction writers attempt to portray a somewhat more realistic version of what the future might hold for mankind. In his 'Mars Trilogy', Kim Stanley Robinson describes how he believes the colonization of Mars will be accomplished. First, robots will be sent to build living quarters for the planet's first colonists. Then, a selection will be made of 50 men and 50 women, representing all continents on planet Earth. Of these, 35 will be American and 35 will be Russian, and each will have a particular specialty or strength. They are 'The First 100', who will undertake the nine-month journey to Mars in an impressively sizable spaceship.

The Mars Colony expands quickly through migration and indigenous population growth. Humanity spreads across the entire planet, which increasingly resembles a suburb of Los Angeles. After only a few generations, the new inhabitants succeed in warming up the atmosphere of the planet and maintain a minimum level of oxygen required to support life, until there is no longer a need to wear space suits. This concept is called 'terraforming', a treasured notion among science fiction visionaries.

Robinson believed that terraforming could begin with building a few windmills, which would generate the necessary rise in temperature. This is rather naïve, to put it mildly. However, his scientific ideas are not nearly as far-fetched as those of other science fiction writers. If terraforming is at all possible, it will take many generations before a change in temperature will be noticeable on a planet such as Mars. Just consider how long it has taken humanity to generate any noticeable changes in our atmosphere on Earth! And it won't be accomplished by building windmills, but with greenhouse gases (I will tell you more about this later).

The speed with which Robinson believes Mars can be colonized — he mentions several waves of immigrants — seems unrealistic to me. The air on the surface of Mars will remain too cold, too thin and too toxic for a long time to come. Robinson paints a pretty picture. However, as I will argue further later on, future inhabitants will have to live either in large glass domes or underground.

And then there are these so-called 'serious researchers', or futurologists, who attempt to base their ideas for the future on scientific findings. But their arguments are equally unconvincing. Because what is their scientific support based on?

Their argument is usually straightforward. "*Let's go back in time, just a few centuries*", I read recently in a quasi-scientific text "*and ask the scientists from way back then, whether they would have been able to envision our life as it is now, with its cars, airplanes, television, skyscrapers, Internet and numerous medical wonders. They would have been flabbergasted. Is it really too far-fetched to think that the science of the 21st century will astound us in a similar fashion? Like the progression from horse-drawn carriage to airplane, wouldn't the vehicle of the future be similarly advanced compared with our current modes of transport? It would, wouldn't it?*".

This is as far as this futurologist's argument went. Of course, he could have consulted physicists, engineers and other professionals who understand the laws of nature and technology, and who might have been able to tell him which improvements could be envisioned

for the future and what its limits are. But then again, they have been utterly wrong in the past, haven't they: wasn't it Max Planck's physics teacher who said that physics was "*finished*"? Didn't a Lord Kelvin, at the turn of 20th century, admire the "*beauty and clearness of theory [of physics in his days], overshadowed by just two clouds*"? Those two small clouds would develop into major storms: Quantum Mechanics and Relativity Theory, the two pillars of modern physics.

Such isolated and unfortunate remarks continue to haunt current scientists and as a consequence, futurologists continue along the same path as those other storytellers who dominate the world of science fiction. And how on earth can that path be reversed if even celebrities such as Stephen Hawking and Carl Sagan romance producers of science fiction movies with their tales of space warps? Laurence Krauss as well, in his book 'Physics of Star Trek'; how is a level-headed physicist who respects only the true laws of physics going to make it clear to the greater public that much of the so-called 'physics' used in science fiction, or at least the vast majority of it, is only an illusion? Mankind will never be able to travel faster than light — even the speed of light itself is far greater than the velocities that we will ever achieve ourselves. Communication will not go faster than light either, and paranormal communication is out of the question altogether.

You shouldn't compare the current level of modern science to what it was in the late 1800s. During the 20th century, science and technology advanced to such a degree that extrapolation can be made much more accurately now than even a reputable scientist such as Lord Kelvin was able to do more than a century ago; it is perhaps even more unfair to make a comparison with a 19th century physics teacher. "*Why do you say these things,*" I asked one such author, "*surely you realize this goes against everything we know?*" "*Well, yes, I do,*" was his response, "*but if I write that, my books will never sell!*" And so it is. My book will undoubtedly sell fewer copies than his.

But please don't misunderstand; the physics of the future will continue to surprise us and it is possible, even likely, that the

future will reveal remarkable technological developments. This potential will be the focus of my book. But we will assume that all the laws of nature presently known to us are accurate, or at least close enough to the truth that we should not expect any major deviations. Contrary to popular belief, the laws of nature known to man a century ago have not proven to be incorrect since. There have been subtle corrections, such as to Newton's laws. However, most of his laws hold up without any amendments. Most modifications concerned phenomena that Newton had not studied, such as extremely high velocities. No, only new phenomena for which no laws have yet been identified might lead to the discovery of new regularities. Only those might bare the promise of new applications. Such unexplored territory was much more commonplace in the 19th century.

However, the above discourse is likely to end up in the same place as the prophecies of the 19th century scientists; the bin. So be it. You've read my book this far. But why shouldn't I, as a physicist, be allowed to fantasize about what *is* possible, about avenues that have not yet been explored and about technological developments whose limits are not yet in sight? What day dreams can we allow, if we wish to abide to the rules, and obey the laws of nature? Physics hasn't 'finished' quite yet; nanotechnology is only just taking off, there are lots of potential space projects to be imagined and communication via computers is only a few decades old. There is lots of room for expansion here. Let's see how far we can take it.

In the next chapters I will tell you what you may and may not expect of space travel, what the information technology revolution still has to offer, which serious changes to our society are to be expected, and which ones aren't. Every now and then the dry language of physics might put you off, but most of what I have to tell you can easily be followed with a bit of common sense. I hope to surprise you. Even within the boundaries of real physics, we can make dream worlds come true; worlds where the laws of physics continue to keep everything under control.

Not everything I will tell you about are true prophesies. There will often be reasons having little to do with technology or physics that will prevent the use of certain inventions. Can magnificent constructions of the future be sufficiently safeguarded against terrorist attacks, for example? I will not take these aspects into consideration, when I talk about future possibilities. Sometimes there will be economic, political or ethical objections against certain developments, such as the transfer of biological life from Earth to another planet, or against some of the more fantastic and fascinating possibilities that I will disclose later on.

There will be small details that will disappoint you. Such as my conviction that the exploration of extra-solar planetary systems will take tens of thousands of years to accomplish. This means that neither you nor I will be there to admire the results of such expeditions. Nevertheless, there are many other fun things to look forward to in our own time.

Exploring new developments and new ideas, and also repudiating those that are incompatible with our understanding of the laws of physics, that's what this book is about. Actually, I should have molded what follows into a juicy and romantic science fiction story, with good guys and bad guys, with a plot and lots of sex — after an unbelievably narrow escape, the good guy forges a miraculous happy ending — or something to that effect. But this type of creative writing is not my forte and it would distract too much from what I really want to talk about. You'll have to use your own imagination as to how the would-be heroines of these stories boldly go where no man has gone before....