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Bart De Moor

World views, science and technology

What is the role of science and technology in constructing world views? That is the question explored in this article. The first step will be to attempt an analysis, in which we examine how science and technology have resulted in the present-day post-modern technotope. The second step will be synthesis, in which we shall attempt to distil those elements and characteristics from science and technology that are useful and relevant for constructing world views. It may already be evident that this can only be regarded as a tentative start to a broader research programme, the various aspects of which will have to be explored in more detail in the relatively near future.

To clarify our understanding, it may be useful to briefly remind ourselves of the seven components of a world view, as described in the first book on *World Views*[1]. Every world view *describes* the world: what is the world we are living in, how is the world structured and how does it function? A world view also tries to *explain*: why is the world as it is? Furthermore, a world view contains elements that relate to *assessment* and *appreciation*. All this should enable the *future* of the individual and of mankind to be evaluated (rational futurology). World views have both a *cognitive* and a *practical* aspect. The cognitive aspect concerns the way in which we go about acquiring knowledge and the way in which we deal with knowledge. The practical aspect describes what actions we can take and how an integrated action model is part of a world view. Since each world view is in itself fragmentary, there is a need for confrontation with other world views. In other words, an *atlas* of world views is required.

This article is organised as follows: paragraph 1.1 is a concise description of how a rift occurred in recent times, the result of which was that science and technology came to exist autonomously. This, in our view, is the origin of the post-modern technotope in which we live today and which is described in paragraph 1.2. The central idea we wish to put forward in paragraph 1.3 is that science and technology, in particular, act as a catalyst in the creation and development of our present-day world and world views. Technology has become *the* driving force behind cultural, social, political and economic changes. Technology creates two opposing forces: increasing globalisation and, diametrically opposed to this, increasing individualisation. There is no turning back, however, and this aspect, i.e. the totalitarian, compelling nature of science and technology, is still underestimated today. In paragraph 1.4 we reflect on post-modernism in science.

In the second half of this article we try to show that, although science and technology *in se* have irrevocable consequences, nevertheless we have to be smart enough to turn certain elements into tools that can be used to construct world views. This situates technology within the traditional dialectic of good and evil. On the one hand, technology traps us in a regrettable uniformity. On the other hand, technology spreads power and knowledge, so that technology itself becomes more accessible for everyone, thus encouraging fresh debate. It is this form of persistent excitation that can lead to a 'better' world. This will be discussed in more detail later.

It is not our intention here to advocate a method of constructing world views based purely on scientific research. This kind of scientism produces an inadequate world view, as substantiated in paragraph 2.4. We would argue, though, that most types of world view construction are not scientific enough. Often the opportunities that science and technology offer us are insufficiently exploited, out of ignorance. Without wishing to go into the subject too deeply, we describe various views and concepts that are substantially based on mathematical system theory.

In paragraph 2.1 we first of all invalidate the sometimes exaggerated assessment of the impact of post-modernism and all things associated with it. Paragraph 2.2 examines the principles of induction and deduction as the driving force behind the development of new models and theories. The conclusion that constructing world views is a way of building models of the world is developed in paragraph 2.3. The world view project will be discussed from this point of view.

The concepts used here are neither new nor original. What is new is the fact that we attempt to apply these insights to the construction of world views by *scaling them up*. Not everyone agrees with this inductive method of working. Nevertheless, this kind of approach is particularly inspiring and produces interesting insights.

1 The post-modern technotope

This section describes how science and technology came to exist autonomously and how a post-modern technotope developed out of them. We discuss the totalitarian characteristics of the technical and scientific bulwark and describe some post-modern features of science.

1.1 The ontotheological schism

> Dieu? Je n'ai pas besoin de cette hypothèse!
> LAPLACE (?)

Two important rifts resulted in what we might call the ontotheological schism. The roots of science and technology as we know them today can be found in this dual rift. It is our conviction that the rift cannot be mended and that we should make no attempt to do so. The *World Views* project should in no way be interpreted as such an attempt. On the contrary, we shall demonstrate that science and technology can play a vital role in the construction and conception of world views.

In ancient times the world formed an all-encompassing whole. The *physis* of the Ionian philosophers, the *kosmos* of the classical Greeks and the *natura* of the Romans had physical, human and divine aspects. A new element was introduced, however, with the Christian God. He was placed outside creation as a Creator, which gave rise to a divine sphere clearly separated from nature. This caused the first rift in the all-encompassing whole. Fifteen hundred years later the second rift occurred: the individual as an interpreting being becomes separated from what henceforth would be called objective physical nature. Man as an individual henceforth places himself at the top of a scale of values and from there determines values and meanings. This so-called objective reality was described and explained by science, which came to regard itself as being more and more independent of other ways of describing reality such as theology, for example. Henceforth, science was synonymous with objectivity. This increasing autonomy created much tension. One only has to think of Galileo and his problems with the Church, or the witticism by Laplace (?) in reply to Napoleon: 'Dieu? Je n'ai pas besoin de cette hypothèse!' (God? I have no need for such a hypothesis!).

Every attempt by neo-Aristotelians, neo-Platonists, neo-Thomists, baroque (to heal the culture-religion rift once again), humanists, and so on to make the ontotheological schism whole again ultimately failed. At the end of the sixteenth century theology finally conceded and yielded its grip on science forever. Culture followed in its wake. At the end of the eighteenth century the dream of a synthesis between art and knowledge also vanished.

The tide could no longer be turned because science and technology had also gained a real hold on society. James Watt invented the steam engine and Adam Smith's 'invisible hand' shed a different light on economic relations. The political world followed and a new phase was heralded in with the concepts of Liberty, Equality and Fraternity, inherited from the French Revolution.

It was now impossible ever to return to a single world view.

1.2 Post-modern fragmentation

> All concepts fail...
> PAUL VAN OSTAIJEN

Basically we all agree that we live in turbulent times. Our prosperity, or at least the pursuit of it, is based on *big money, big labour* and *big economic expansion* but nevertheless has shaky foundations. It is sometimes said that we live in a post-modern age. Herman De Dijn speaks of 'the post-modern man who tries to live and survive in a world without ideals, without a grand future, thrown upon his own resources in the midst of a culture descending into confusion, and striving for whatever the market extols as a must or the 'in' look'.[2]

It is difficult to put into words exactly what post-modernism is. There are no generally accepted concise definitions. The following elements recur, however: there is an uncontrolled pluralisation of cultures and of culture fragments, the time of great stories is over, ideologies have become inflationary, there are increasingly differentiating trends and divergences in the sciences, people's sense of values and ethics is declining, commitment in the visual arts, music and literature is waning, and so on. Now that communism has collapsed, the emptiness of former capitalist societies provokes a variety of reactions ranging from a superior sense of relativity, to cool cynicism, to a fanatical wish to hold onto 'old values'. The result is a narcissistic attitude to life, the youth culture of MTV, amorality and ambiguity where extolled 'virtues' such as tolerance and pure indifference can co-exist. Post-modernism is characterised by a tendency towards globalisation and individualisation. Rock music as a mass culture allows individual perception ('I'm dancing with myself').

Software is commercially available and exchangeable but allows you to create your own (virtual) world where cyberpunks live in cyberspace. In all these areas people are frantically pursuing instant pleasure.

Within the socio-economic framework, we are witnessing the transition from man as producer (from labour to goods) to man as consumer (from goods to services). This leads to problems precisely because work has until now been one of the guiding principles of our society. 'We now know that we no longer live to work, but our society is far from being organised around the idea that we work to live.'[3] The crisis we are now going through is not therefore one of means but one of ends. This is also the theme of Hans Achterhuis' book *Het Rijk van de schaarste*, in which the Dutch philosopher describes how in modern times certain relationships have been reversed.[4] In a traditional society man was a creature with finite needs and infinite means to fulfil those needs. Now there seem to be finite means available to satisfy seemingly insatiable needs.

Science and technology have undoubtedly contributed to the various elements that we have classified under the category post-modernism. Our world is no longer a biotope, but a *technotope*, where science and technology encroach on our daily lives. Technology creates two opposite trends, summed up in the commercial slogan: Think Globally, Act Locally (known as glocal).

In the first place there is globalisation, in which technology is the catalyst for a unified world culture. Hence the *Global Village Concept* of CNN is the modern version of 'The world is our village': the media as a window on the world. This global information is available to all and leads to uniformisation: take for example the worldwide trends in fashion, film and architectural styles and music, particularly rock music. The result of globalisation is that the individual citizen lives on a patchwork quilt of different worlds (the village or town, the region, the country, the linguistic, cultural or religious community, the continent, the world), each of which claims a bit of his identity.

On the other hand, technology increases the freedom of the individual. Examples include democracy, increased mobility ('my car means freedom'), telecommunications, the opportunities for leisure activities to fill free time that is largely created as a result of technology, and so on. Technology not only enables us to explore the earth and the universe, it even opens the door to virtual worlds, limited only by our own imagination (virtual reality and engineering, multimedia, etc.).

1.3 *The tyranny of technology*

Alas, however hard we struggle against this raging monster,
resistance is futile.
LEONARDO DA VINCI

Science and technology have something compelling about them. We are not sufficiently aware that the technotope is the only possible world for us, that there is no other choice. In this sense technology has totalitarian characteristics. We shall briefly describe these.[5]

1. In what we might describe as classical metaphysics, a thing is perfect when it stands alone or refers exclusively to God. This is not so in the case of technological developments. Here, the more complex an invention or a technical object is and the more tasks it can do, thereby referring to as many other technical objects as possible, the more perfect it is. The more references to other technical objects that are possible, the more perfect the technical invention is. A multidisc CD Dolby stereo system with twenty four controls, each with five functions, on a trendy operating panel is much more sophisticated and perfect than a record player where only the volume can be adjusted. An ultramodern digital telephone exchange is more perfect than the manually operated switchboard of eighty years ago because its capacity (i.e. the number of connections possible with this kind of communication equipment) is several orders of magnitude higher. This aspect of technology is extremely important if we are to begin to understand its totalitarian nature.

This kind of interdependence is also inherent in science too. What makes a good scientific article? One where the impact factor, i.e. the average number of quotations from the work in publications by other scientists, is high. The more fundamental a scientific discovery is within its own discipline, and preferably in other disciplines as well, the better it is.

Networks are spreading in society too: power and hierarchy have been greatly weakened. Instead a network of contacts, information and relationships has formed. This, too, is a symptom of technologisation. The most influential figures are no longer the 'rulers of the earth', the traditional world leaders and politicians, but rather the *lobbyists*, an activity that has developed into a respectable profession (the modern version of a mercenary). Power no longer resides in knowledge, but in the hands of those who can find their way through the barter trade of vested interests.

2. A second characteristic originating from science and technology, which characterises our social world more and more, is the highly rationalised practice of cool economic efficiency. The tendency to list, systematise and organise is inherent in science as we know it today. Ptolemy's 48 star systems, Mendeleev's periodic table, the multiplicity of elementary quantum particles, the Human Genome Project: all of these strengthen our belief that nature and the world are highly structured and are based on principles of efficiency and effectiveness. This is the economic rationality of Leibniz: we live in the best of all possible worlds, created by God at minimum cost...

This process of objectivation results in what some call the flaying of society and what others call control. It results in bureaucracy in the civil social order. The French philosopher Michel Foucault pointed out that the compelling power of rationality, efficiency and technology results in *the homo docilis:* someone whose papers are in order is a good citizen. It results in quality being defined in terms of mathematics. Count the world, ban the stories! A good scientist is one who has many publications to his name (who ever reads them...?). From a social point of view, society is degenerating into a meritocracy, in which every fact and every action is examined for its merit, economic or otherwise. In medicine this leads to biocracy. The objectivation of the human body deteriorates into a therapeutic determination, where patients' lives are senselessly made dependent on machines or where 'scientific' experiments (such as artificial insemination of sixty-year-old women) conflict with 'ethical' objections, which become increasingly eroded and vague in the face of advancing science and technology. In almost all social functions the philosophers, visionaries, prophets and utopians have been replaced by lobbyists, technocrats, marketing experts and PR men.

The increasing hold that technology has on our daily lives has also drastically altered how we deal with time and how we perceive time. In the technical world, time is 'won', people are into time management and speed is idolised. The annoying thing is that speed 'implodes': speed only has meaning when the others, the competitors (literally, those who strive with you — or at least try to), are slower. So ever faster, ever more efficient is the message. As Lewis Mumford once said: 'The clock, not the steam engine is the key machine of the modern industrial age'. Punctuality has become an imperative virtue. Transgression can have serious consequences. not only from an organisational point of view but also socially and emotionally.

3. A third characteristic ensues directly from the first two: following on from ontological interdependence and the tendency towards efficiency comes uniformity and the increasing uniformisation of the world around us. For example, the globe is organised into time zones, there are only a limited number of types of power points worldwide and computer compatibility is a must. Conformism is essential. The way in which multinational companies operate is a good example of this. Solidarity and uniformity of personnel is the aim while standard behaviour is called for in order to perform well and efficiently. Independent thinking is taboo and, above all, ideas must be kept simple ('Keep it simple!'). There is also increasing evidence of this trend in society where large and inspiring projects are now outdated. Successful political parties are those with a simple message that can be expressed in slogans and one-liners.

4. A fourth characteristic is the conclusion that science and technology sustain each other. Science gives rise to new science, technology gives rise to new technology, science stimulates new technology and vice versa. We should at once scotch a persistent misconception that assumes there is a causal link extending from science to technology but not the other way round. Many scientific discoveries (for example in cosmology or high-energy physics) would simply be impossible without technology. The reverse is also true: many technical achievements are impossible without scientific insight. The forces that drive, draw and compel people to achieve more, better and more radical results in the 'positive' sciences and in technology are unknown in the fields of philosophy, ethics, morality, literature... or at any rate they are not in evidence to the same exponential degree. Every scientific breakthrough immediately raises a number of questions. Every answer to these questions raises still more questions and so it continues. The same is true of technology. An interesting technical achievement (such as the transistor) is immediately used in dozens of other applications (telephones, TVs etc.), which in turn... and so on. Science and technology have no external objectives; their only aim is their own perfection. There is opposition to this. Ecologists are resisting morbid ecologically[6] destructive tendencies and the further development of a society that is being forced structurally and economically into unbridled dynamism (for example the belief in an economic growth model).

5. A fifth — and somewhat unexpected — characteristic of the growing technologisation is the increasing tendency to believe in and have faith in what others do and in what we are told. After all, it has become impossible — even for scientists, and even for scientists within their own discipline — to examine every claim that is made by others. Are you sure the earth revolves around the sun? Probably. But have you proved it yourself?

In our daily lives we are also — perhaps unconsciously — confronted with a wholesale faith in both technology and the people who control technology, in other words 'resting easy' about things without understanding why. In our daily dealings, are we not entirely at the mercy of the kindness of others (a trust that is sometimes betrayed and then relatively quickly forgotten...)? Do we not rely on the train arriving on time? Or that our plane will land safe and sound? Do we not drink the water that comes out of the tap without giving it a second thought?

Anyone who with the best will in the world still cannot adopt this belief and faith in science and technology will end up suffering from technophobia. But even if we do not suffer from such an extreme form of a-technologitis, science and technology do give rise to a feeling of individual helplessness, which used to be much less common among ordinary people. We are dependent on power producers for electrical power, we have long since been dependent on others for our food supply and even where leisure activities are concerned, we think that we are dependent on television. The individual has become powerless and realises this himself to a greater or lesser extent, especially when he sees TV pictures (and not just in the evening, but every hour of the day) that vividly show harrowing famine, increasing environmental pollution, street crime, the civil war in former Yugoslavia, and so on. A kind of tyranny of current affairs develops, which dulls long-term thinking or even completely eliminates it and ensures that we cannot see the wood for the trees.

Moreover, technology can create potential global differences. Differences in environment, living conditions, food shortages and food supplies, water, comfort, wealth and poverty are well known and create tensions that encourage migration. The three cultural revolutions (rural, industrial and information) now rule the world. While in some parts of the world farmers are still ploughing the land, elsewhere unskilled labourers, sometimes even children, are chained to the production line while here teleworkers sit at home and map out their future on a computer screen.[7]

1.4 Post-modernism in and as a result of science and technology

The conclusion to the previous paragraph is that science and technology behave like a runaway train that cannot be stopped. The vast inertia of the scientific and technological complex creates various effects, even within science itself, which could be labelled post-modern. In the first place there is scientific research for the sake of research. Under the influence of the various self-fuelling mechanisms described above, there is a risk that scientists will indulge themselves in no-strings-attached activities that swallow up millions[8], with research being conducted purely for the sake of it. The saying *publish or perish* is not just a witticism; it is a serious fact. The result is an increasing divergence within science itself, a tremendous specialisation that certainly poses an enormous intellectual challenge but is not bound by any need for human or social relevance. Many scientists devote themselves to seeking solutions to problems that they think are of enormous importance (and that they themselves have formulated in many cases). Science is full of examples of trivial subjects that have been the object of intensive study. The perception of the importance of a problem is a predominantly subjective matter.

The philosophy of science follows the same trend. Feyerabend's subtle 'Anything goes!' opens the way for a defeatist *laissez-passer* mentality, where anything goes 'in the name of science'. The subtlety lies in the fact that Feyerabend advocates keeping an open mind as regards types of knowledge other than the purely scientific (see also paragraph 2.4) and that there are actually no 'objective' standards against which the 'truth' can be measured. Not everyone understands the concept in this way, however.

Research as an independent activity where social relevance is of secondary importance also carries risks. Science is often used as a forceful argument but in an *à la carte* fashion: selective use is made of arguments that suit a particular purpose. Is there, for example, conclusive proof that there is a link between chlorofluorocarbons and the hole in the ozone layer? Or are we accepting a suspicion as a fact? It might perhaps be a good idea to allow CO_2 levels to rise via the greenhouse effect because plant growth in the Third World would thrive better as a result.[9] One of the greatest challenges facing us in the future is that of 'science sharing' to prevent a new kind of illiteracy arising.

2 World views as models of the world

In the second half of this article we shall attempt to demonstrate that the construction of world views is analogous with the way in which models are constructed in science. We shall therefore try to make the most of this analogy between scientific models and theories about world views.

First of all we shall invalidate the impact of post-modernism somewhat. We shall then take a concise look at the inductive-deductive pump that is a feature of scientific research. The main characteristics of models are transferred to world views in paragraph 2.3. Paragraph 2.4 examines a Gödelian trait in science, from which, among other things, an ethical deficit arises.

2.1 Is post-modernism a thing of the past?

Post-modernism is an elusive label that is eagerly used to classify certain present-day cultural phenomena. It is a disjointed collection of symptoms and characterisations, which are employed just a bit too readily. We can therefore ask ourselves whether we do not show post-modernism too much respect and whether we do not overestimate its impact. Is post-modernism not an aversion to what is called modernism, rather than the dawning of a new age? Gerard Bodifée calls post-modernism a trap for Western philosophical uncertainties.[10]

'The modern programme is not so much outdated as incomplete,' according to Louis Dupré.[11] The great philosophical ideas and schools of philosophy of the past have a permanent meaning because they not only reveal the various facets of reality but also change them. It is true that the time of the great stories is over, in the sense that history has clearly taught us that blind faith in just one great story is totally inadequate and can sometimes have an unhappy ending. Communism has collapsed, yet it has taught us enduring lessons about our own socio-economic system; certain aspects of communism have become integral to the way we act and think. The Enlightenment is not a thing of the past either. Yet we recognise that there is more than Reason and Progress.

The *Worldviews* project wants to be characterised within this context. Some people object to such an ambitious utopian venture. They maintain that *Worldviews* would be an outstanding exponent of post-modernism because we want to construct not one but several world views, for example. Nothing could be further from the truth and this interpretation is somewhat gratuitous. *Worldviews* is not a club where you can make free and arbitrary use of all kinds of ideologies and schools of philosophy. The plurality, the interdisciplinary nature and the versatility of the world views we want to construct have everything to do with the power and robustness required. We shall return to this point later. Each of the world views is essential in terms of how it complements (and at times overlaps) each of the other world views.

2.2 Models

Models are a matter of inspiration,
Not deduction.

Scientific research amounts to nothing more than constantly constructing models, which are inspired, confirmed or invalidated by experiment and/or observation. Models can be verbal, mental or intuitive; in modern science, however, mathematics is the ideal language. The ancient Greeks were interested in numbers, ratios, geometric figures and the like with models preferably based on aesthetics (ratios) and geometry. The Renaissance brought us the mechanistic determinism of Newton, Leibniz and so many others, in which man acts as observer of the great mechanical clock of the universe. Mathematics became part of scientific research once and for all: Newton and Leibniz invented differential and integral calculus in order to make mechanical mathematical models. With the advent of quantum mechanics, chance and the theory of probability also found their way once and for all into the bastion of mathematics. One of the conclusions is that science is not about nature but about the interaction between man and nature. Man is not an external observer; the experimenter is always involved in and even determines what is being observed. And in the light of the most recent insights in physics, concepts such as entropy, dissipative systems and deterministic chaos have secured a place amongst the latest scientific theories.

What is remarkable is that all these theories and insights can be expressed in the language of mathematics with the same relative ease. Hence chemical reactions are preferably expressed in reaction formulae, physical laws are described using mathematical expressions such as Newton's second law of motion, $F = ma$, or Einstein's mass-energy equation, $E = mc^2$.

An important insight gained since Newton's time is the fact that systems and models are dynamic. This means that their behaviour changes as a function of time. A key point here is the notion of the *state of a system*. The state is the minimum information that is needed, given the inputs of the system, to clearly determine the outputs. In other words, in addition to input and output variables, a system also has so-called 'internal' variables, known as states. Knowing the inputs does not provide sufficient information to calculate the output. The internal variables also have to be known, for example the initial state or the state at a time chosen as reference. One object that may serve as an example is the car. When the engine is cold, the car reacts differently when the accelerator pedal is

pressed than when the engine is warm and the accelerator pedal is pressed by the same amount. The system is the same (the engine), the input is the same (the amount by which the accelerator pedal is pressed), but the output (for example the acceleration the car undergoes as a result of pressing the accelerator pedal) is different in both cases because the state of the engine is different in both experiments. We actually come very close to what mathematicians and physicists mean by the concept of state in the everyday language we use. When we inquire about the condition (state) of a patient or the situation (state) in Angola, we are trying to assess, on the basis of this information, how things will develop in the next few hours. This concept of state was only fully developed in the mathematical system theory devised after 1960, although it has played a more or less explicit part in physics since Newton in the seventeenth century and the development of thermodynamics in the nineteenth century.

The conclusion is that in order to fully characterise a system, not only do we need a model and the inputs that will be applied, we also need to know the state (initial or otherwise) of the system. It would take us too far to examine the mathematical formulation here.

Systems without inputs also exist, so-called autonomous systems. Even if we have a good mathematical model of such a system, we still need to know the initial state in order to simulate the output of the system reliably. Here, however, we come up against the first fundamental limitation of mathematics (or of nature?). Relatively simple autonomous systems exist — so-called non-linear mathematical equations — which require infinitely accurate knowledge of the initial state to enable the behaviour of the system to be calculated accurately over an infinitely long period of time. In other words, if we only have limited accurate knowledge of the initial state of such a system (which is always the case in practice), then the behaviour of that system can only be calculated over a limited (finite) period of time, even if the model equations are known exactly and an ideal computer is used that makes no calculation or rounding-off errors. A system that displays this kind of behaviour (among others) is called chaotic. It should be stressed here that systems like these are completely deterministic, in other words no chance factors are involved. Only our limited knowledge of the initial state throws a spanner in the works and means that the accuracy of the predicted behaviour of these systems decreases over the period of time to which the prediction applies. We do not have to look far in nature to find examples of chaotic systems. A sun with two orbiting planets that move in its gravitational field is an example of a chaotic system (the famous 'three-body problem'). This view, which began with the work of Poincaré at the beginning of this century, seriously discourages the belief in the power of mathematical models. It deals a severe blow to the mechanistic determinism of the mathematical rationalists, who thought that everything could ultimately be explained by means of mathematical models. As we shall see later, it also implies a limitation of the rational futurology for which we wish to use world views.

Making models is constructive work. A model is made, based on every possible source of information, including experimental data.[12] An attempt is made to find qualitative links between the different variables and, if possible, to translate these into quantitative terms. Within the field of science, this modelling process often follows a fixed pattern[13], the basic elements of which are: the hypothesis, the assumptions postulated, the observations, in other words the information gathered as a result of the hypothesis, and the idea of falsification, which Popper introduced into philosophy. We can represent this principle in the form of a high-level computer program as follows:

Repeat an infinite number of times

1 Formulate-refine the hypothesis as long as it stands up
2 Repeat until the hypothesis is falsified:
   a Refine the experiment.
   b Check whether the information obtained invalidates (falsifies) the conclusions that can be deduced from the hypothesis.

Scientific research proceeds in exactly the same way. First, a given hypothesis is formulated, which is true as long as it is not invalidated by counter-arguments that can be verified experimentally. The hypothesis can be refined an infinite number of times; the experiments can also be continually improved, made more accurate, and so on.

This process, in which a theory comes under attack, proceeds in an extremely fair manner, in the sense that the scientific theories themselves have to supply the arguments that could invalidate them. Let us take as an example Newton's findings that the planets move in an elliptical orbit in a plane with the sun at one of the foci. This consequence of Newton's theory of gravitation can be invalidated if an example is found of a planet that, for example, does not move in a closed orbit in a plane. Just such a planet was found in our solar system: Mercury. The 'rosette'-shaped orbit that Mercury describes (in other words it does not move in a closed orbit since the planet does not return to the same place after a period of time) is, incidentally, accepted as one of the

'proofs' (experimental verifications) of Einstein's general theory of relativity.

Consequently we can never know for sure whether a scientific theory is 'right'. Every theory is 'true' and 'valid' until it is demonstrated by means of scientific arguments, preferably supplied by science itself, that it is 'wrong'. It is a bit like the legal principle, which states that the accused is innocent until proven guilty (the difference being that the accused is not expected to put forward arguments to prove his potential guilt). This scientific game is therefore not so much aimed at proving that theories are right (although every 'confirmation' is of course gladly accepted), but that hypotheses (theories) are wrong! According to Popper: 'Irrefutability is not a virtue of a theory, but a vice!'

The process outlined above contains two kinds of logic: firstly deductive logic, which involves reasoning from the general (the hypothesis) to the particular (the conclusions and verifiable consequences...). Secondly inductive logic, which involves formulating a new or refined hypothesis from particular observations. There is a great deal of philosophical (and emotional) debate about this last step in particular ('scaling up'), which dismisses induction as a principle.[14] Often deduction prevails for some time before any inductive steps are taken. A good example of this is found in modern physics, where scientists have such great faith in mathematics that research is mainly conducted with a pen and paper (and computer), based on axiomatic deduction, before any conclusions are verified (or rather falsified) experimentally.[15] Mathematics is of course an important tool and for those who can handle the subject it can be particularly inspiring because the deductive manipulation of formulae and laws, where the rules and principles of calculation are strictly observed, results in new laws and insights, which can then be verified again experimentally. Whereas deduction is mechanistic (research is even conducted on 'automatic proofs' by computers), induction calls for more creativity and is the real driving force behind scientific progress. For example, the formulation of 'theorems' does not require any formal logic (although it helps of course), but is a seemingly inexhaustible source of new findings (take for example the Riemann hypothesis or Fermat's Theorem in number theory).

In a certain sense the dynamic nature of science and technology is embodied in the aforementioned computer program. The mechanism of deduction-induction is like a pump that drives scientific effort, sometimes to unprecedented heights (and sometimes to horrendous depths). In particular, the fact that elements have to be found that invalidate a given hypothesis livens things up quite a bit. You can never rest on your laurels for long. This 'restlessness' that characterises science and technology is fundamentally a good thing. It guarantees perpetual mistrust, which ensures that scientific pronouncements are of a high quality. It also ensures that questions, theorems and hypotheses are constantly formulated, examined, validated or invalidated. (This aspect can also be taken amiss, however, and become associated with the totalitarian nature of science and technology, which we have already described.)

What we have just described as the agitation within science and technology can also be associated with the concept of *persistent excitation* in mathematical engineering.[16] We described earlier how dynamics and the concept of state are essential elements of mathematical models. It can happen that not all states are excited in a dynamic system and that, consequently, they cannot be observed in the outputs. It is a bit like seven sleeping dogs that are there in the dark, but you notice nothing unless they wake up and start barking. Careful analysis of the noise will then reveal that there are seven of them. In engineering practice this is called the condition of persistent excitation or of sufficient stimulation. The dynamics of a system can only be modelled if the dynamics can be observed sufficiently.

Let us look at an example in engineering practice. Suppose that we want to create a model of the suspension of a car by carrying out measurements — using accelerometers — of the acceleration of the car. If a flat, straight stretch of road is used and the car is driven at a constant speed, not much acceleration will be measured (the suspension is not activated) and, consequently, nothing can be discovered about the characteristics of the suspension. The car needs to be driven relatively 'wildly', in other words speeding up and slowing down (pressing the accelerator pedal more or less and braking) and, for example, zigzagging about (only a thought experiment is involved here of course). Only then will the car's suspension be sufficiently activated and we will be able to find out more about the stiffness of the suspension and such like from the acceleration measured. It is evident that the inputs of the system (in this case the accelerator pedal, the brake and the steering wheel) must create sufficient stimulation for the dynamics of the system to be apparent in the outputs.

By scaling up we come to the same conclusion for the success of scientific research. Important discoveries are sometimes made by accident because the experimental conditions (the 'inputs') are not right for stimulating the phenomena one is seeking (as a result of errors in reasoning or because one fails to realise how the experiment should be excited). Sometimes, however, effects are seen that were not expected immediately, precisely because the experiment has excited 'modes' other than those planned. In other words, in science the right experimental conditions have to prevail in order to arrive at particular conclusions. The experiment must have sufficient persistent excitation.

2.3 A model is not the system

Ceci n'est pas une pipe.
RENÉ MAGRITTE

The relevance of the insights just described, in terms of constructing world views, is embodied in our conviction that world views are models of the world. Herein lies their strength, but also their weakness. If the concepts and characteristics of models, which we discussed earlier, are scaled up to the level of world views, an interesting characterisation of world views emerges, which sometimes goes further than anything previously found.[17]

World views can be constructed using a technique based on the principle outlined above, in which hypotheses are formulated, possibly experiments are carried out or available data is analysed, and then world views or elements of world views are eliminated (falsified) because they are inconsistent with practical experience. This is almost an ideological attitude of course. But what a challenge!

A model of a system or of a physical phenomenon is not the system itself, just as Magritte's painting of a pipe is not a real pipe. Modelling a system or phenomenon always involves *a priori* choices. The colour of a rocket is not important in the description of its trajectory, but it may well be relevant to its identification. A model is therefore always made with a specific purpose in mind, which is implicitly or explicitly expressed in the choice of model.

The same applies to world views. A world view is always constructed with a specific purpose in mind. As a model, it reduces reality to those aspects that are important for the purpose of the model. World views are not constructed at random to explain 'everything'. Each world view in itself can, however, describe and possibly explain a relatively large or small chunk of reality.

The same is true of world views that people want to use to assess the future of mankind and the world. Not only is there an inherent mathematical limitation on our ability to do so (think of the deterministic chaos described earlier); the world view that we use for our rational futurology will also depend on what we actually want to predict.

Engineers are very familiar with the reducing character of the model concept. When a model is defined, the inputs and outputs are carefully specified beforehand, and possibly also the states that are to be included in the model. Every dynamic element not included in the model is regarded as uncertain and an attempt is made to have an indicator for this uncertainty (for example, a worst case scenario of what can go wrong). Of course this is partly based on *a priori* assumptions (and a great deal of experience), which can, however, be subsequently falsified! In addition to deterministic inputs, which can be freely manipulated, other inputs are also possible, which are not under control. These are called disturbances. When an engineer defines a model, all he does is divide up a given system into desirable dynamics and undesirable elements (uncertainties), and the input signals into manipulatable (deterministic) inputs and disturbances. This division is fairly arbitrary and in many cases proceeds by trial and error. Furthermore, the way in which it is carried out depends on what one intends to do with the model. Engineers know this only too well because they realise that models that are used for accurate simulation (models based on physical laws for instance) can be completely different from models that are used to make predictions, which in turn can be quite unlike models that are used to devise a specific regulating measure.

This reducing character of models is therefore the reason why one single model is never enough. In order to cover the full 'work range' of a system using relatively simple models, several models have to be used, which preferably overlap one another partially. This is sometimes called overlapping parameterisation. Scaled up to world views, we come up against the fact that not one, but several world views are required (an *atlas* of world views).

There are other rules of thumb in engineering pragmatics that are useful in constructing world views. With most models, accuracy (of the prediction for example) has a price, namely that the model is very sensitive to minor variations. In engineering terms, there is a 'trade-off' between performance on the one hand and robustness on the other. Unlike pure scientists, whose prime consideration is consistency in the model, the engineer's is objective, is more pragmatic: the model, the solution, the technical discovery has to work in a real situation. This means that people will be more inclined to sacrifice some accuracy if the system or model designed is sufficiently robust (for example so that small changes in certain parameters do not result in sudden, abrupt discontinuities).[18]

This kind of qualification also applies to world views. World views should not be constructed to describe, explain or predict with complete

accuracy. World views should consequently be devised with a due sense of engineering pragmatics. A world view should not be 100% accurate (impossible in any case), but it should be good enough for the purpose for which it is constructed.

The part played by science in all of this is obvious. Science acts first and foremost as the sensor through which the world makes itself known to us. The measurements provided by science — the scientific theories — serve as experiments for constructing world views. Science provides the material from which theorems and hypotheses concerning world views can — inductively — be formulated. Science not only serves as our window on reality, it can also be the means of invalidating certain world views or elements thereof. The world views to be constructed should not only be true to science. They must be such that they do not come into conflict with it as this would result in them being falsified.

It is perhaps less obvious to argue that world views should, of necessity, be dynamic. If the language of mathematics cannot be used, it is not obvious how dynamics can be described (in other words the way in which the state of a system changes). Yet dynamics is one of the fundamental characteristics of the modern world. And we are increasingly aware of this fact. Much of what we say and do nowadays takes future generations into account, for example when we talk about environmental issues or solidarity with future generations as regards social security. These are dynamic elements that people take into account more than they used to.

In the first part we explored in detail the interconnective nature of our technotope and the driving (= dynamic) character of science and technology. We also implied that this inherent restlessness was fundamentally a good thing. Certainly as regards the construction of world views, science provides permanent persistent excitation. The 'pumping' action of constant questioning, the formulation of hypotheses and theories and the constant search for falsifying elements, with the accompanying scientific debates, ensure spontaneous stimulation. In principle this simplifies the construction of world views because the dynamic relations that make up a world view are to a large extent made explicit in the scientific research (just as the suspension of a car is indicated by measuring the acceleration, if there is sufficient excitation). For example, we can argue that what science says about mankind now is particularly relevant to the responsibility of mankind. It makes us realise that we should use all the knowledge and resources we have to prevent us from sawing off the branch on which we are sitting.

It is important therefore to ensure that there are always sufficient sources of persistent excitation, otherwise the world views we construct will be extremely unreliable. If there is no persistent excitation, dynamic models turn into static models, which are unable to cope with sudden changes in an effective and robust manner. Galbraith describes a particular lack of persistent excitation as 'the culture of contentment'.[19] A large number of people have become relatively well-to-do and have come to regard this as a personal merit (the aforementioned meritocracy). This predominantly middle-class group comprises contented individuals and is large enough to ensure that a poorer underclass continues to be invisible. This contentment results in a lack of persistent excitation, which continues to corroborate existing wrongs (as long as they are not *too* visible or annoying...). As a result, the culture of contentment is not able to seek long-term solutions.

Science itself is not immune to this danger either. In Thomas Kuhn's view, science evolves in accordance with social patterns, with originality threatening to become sidelined.[20] Most scientists adapt their behaviour to prevailing fashions, publish in scientific journals that are 'in' and settle down to a cosy existence that is far from being persistently exciting and eventually gives rise to erroneous world views. Researchers who gnaw away at the edges of the current paradigms are censured by their colleagues. Only when the growing pressure becomes too great because of the number of scientists who 'rebel', or — as more frequently happens — because of a scientist who blows the top off the scientific world with one brilliant insight, only then is the current paradigm replaced by a new one.

2.4 *Science is not a world view*

> J'ai cherché la vie.
> Je n'ai trouvé que la Science.
> ANONYMOUS, UCL CAMPUS

Relying on the seven components of a world view, we can immediately get rid of some candidate world views. Religions, for example, can contain elements of a world view (such as value judgements and giving meaning to life) but because they are less descriptive and explanation is not their immediate aim, they do not satisfy all of the criteria that a complete world view has to meet.

For similar reasons science and technology of themselves are insufficient to construct just one world view. Science is limited. Of all the things that affect us, it can only satisfy one need and that is our curiosity.

Science also raises questions and problems, which it cannot solve on the basis of its own dynamics. In other words, science and technology have a Gödelian trait.[21] One illustration of this is the so-called ethical deficit that coincides with the current developments in science. Never has there been so much social debate about ethical and moral issues such as abortion, capital punishment, biogenetics, etc. There are ethical commissions not only for biomedicine but also for economics and engineering. Science creates certainties, increases freedom, but ironically it is then that doubt creeps in. If I *can* do that, what should I do? The price of scientific certainties, of the ability to determine the future ourselves, the price of purposefulness is doubt: what should we choose? Our freedom is a terrible burden to bear, says Bodifée. Much-needed moral reflections cannot keep up with the driving rhythm of technical and scientific developments. We can ask ourselves whether we — as scientists — should not consider building in voluntary rest periods — moratoria. Ethical reflection is based on something other than pure verification/falsification as is the case in research. Even a proper precedent can offer little consolation here. It is evident, therefore, that science and technology are not in themselves able to fill the ethical deficit, the meaning of human existence and human progress.

We should not run the risk of a new schism developing, with science and technology splitting off from the rest (something which has happened several times already: for example, the development of the atomic bomb, where the moral implications were left to non-scientists, or some imposed biogenetic experiments). Science split in this way would be inhuman in its triumph. The rift would be at least as great as the onto-theological schism.

Notes

1 Apostel & Van der Veken, 1991: 29.
2 De Dijn, 1993: 15.
3 Rosseel, 1993.
4 Achterhuis, 1988.
5 Taken from IJsseling, 1993, among others.
6 From the Greek *oikos* (home, surroundings) and *logos* (word, discourse).
7 Toffler, 1993.
8 Also encountered in the cultural world incidentally.
9 Sombroek, 1993.

10 Bodifée, 1993.
11 Dupré, 1993.
12 Only artists seem to turn the definition the other way around: in their case the model is the thing that is modelled, i.e. reality.
13 Bohlin, 1991.
14 The arguments use this very principle, however. It is stated that inductive inference sometimes results in failure. It is concluded from this that as a principle it is not valid, which in itself is a form of induction!
15 It was once a different story. In the seventeenth and eighteenth centuries, for example, experiments were carried out and then a mathematical description/explanation was sought.
16 Engineers who work in system theory sometimes get frustrated because they are not always taken seriously mathematically speaking. On the one hand they are reproached by mathematicians for not being rigorous enough while other engineers accuse them of being too mathematical and hence too theoretical. That is why they themselves describe their discipline as *mathematical engineering* or *engineering mathematics* depending on whom they are talking to.
17 Apostel & Van der Veken, 1991.
18 The branch of mathematics that studies such questions of structural stability is René Thom's catastrophe theory.
19 Galbraith, 1992.
20 Kuhn, 1962.
21 In Kurt Gödel's work published in the thirties, Hilbert's idyllic dream of basing mathematics on logical deduction alone was killed off instantaneously. Gödel demonstrated that in a consistent logical system, there are always well-formed propositions whose truth cannot be decided within the same system. This implies that the possibilities of formal logical deduction are limited. In other words, the price of consistency is incompleteness. This is good news and bad news at the same time. The bad news is that we will never be able to prove everything. The good news is that scientific research and our creativity in this field need never come to an end.