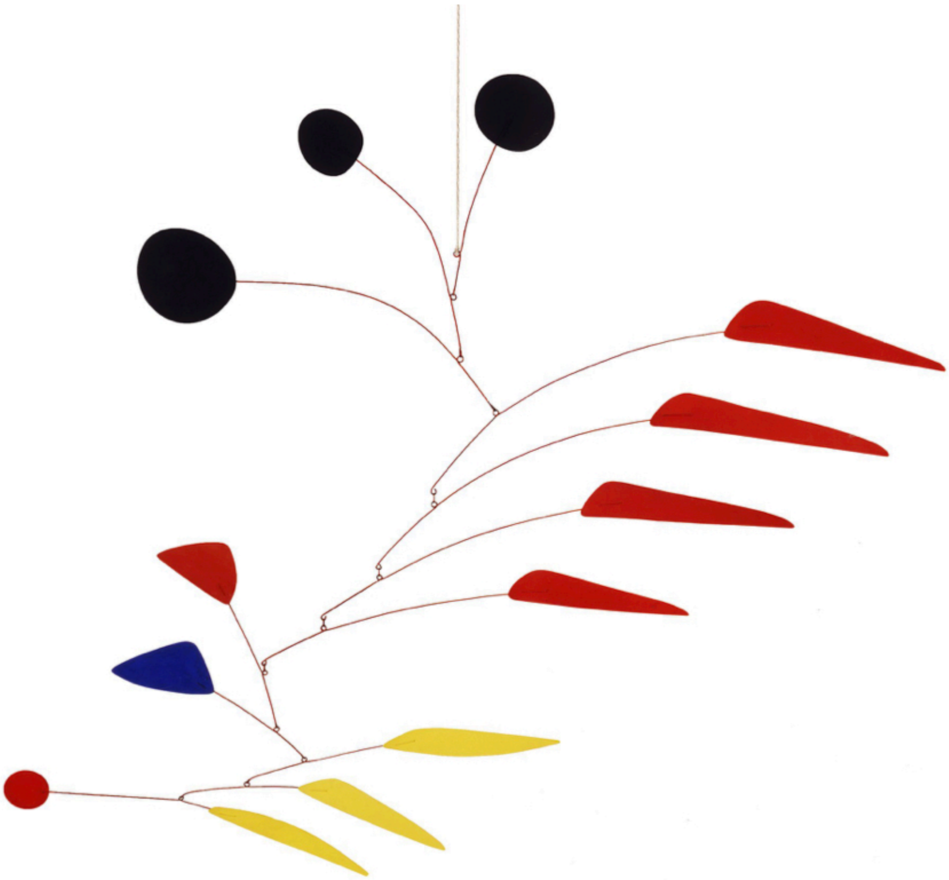
From Calculative Thinking towards Thoughtfulness
A phenomenological inquiry into Applied Physics

Charlie van Dijl



Abstract: In his famous essay *The Question Concerning Technology* Martin Heidegger investigates what the essence of technology is. He finds that it is not something technological, but a way of revealing which he calls *Enframing*. In the mode of *Enframing* we are challenged to understand nature as a calculable structure comprised of functional units that can be exploited at any time, at any rate. As such we have lost sight of ourselves and of all other ways of being. In this thesis the implications of *The Question Concerning Technology* for the applied physicist, whose habitat it is to approach life and nature as a mathematical construct, are studied. Through a thorough analysis of *The Question Concerning Technology*, this thesis aims to be a starting point for a shift from merely calculative engineering towards thoughtful engineering.

Bachelor Thesis Philosophy of a Specific Discipline
Erasmus School of Philosophy
Number of Words: 9068
Student number: 473046
Thesis Supervisor: dr. A.W. Prins
Thesis Advisor: Prof. dr. P. Arora
Tutor: C. Foole, MA
Main Study: Applied Physics, TU Delft
Date of Completion: July 2022

Erasmus Universiteit Rotterdam

For my younger self,
and the older me.

“Les grandes personnes aiment les chiffres. Quand vous leur parlez d’un nouvel ami, elles ne vous questionnent jamais sur l’essentiel. Elles ne vous disent jamais: ‘Quel est le son de sa voix? Quels sont les jeux qu’il préfère? Est-ce-qu’il collectionne les papillons?’ Elles vous demandent: ‘Quel âge a-t-il? Combien a-t-il de frères? Combien pèse-t-il? Combien gagne son père?’ Alors seulement elles croient le connaître.”

— Le Petit Prince, Antoine de Saint-Exupéry

Contents

Preface

I remember well the lecture in which I first heard about the text *The Question Concerning Technology* by Martin Heidegger, it was during the course *Quest for Man II* given by dr. A.W. Prins. When the lecture was finished I walked out of the hall a different person. This might sound a bit dramatic, but it is true. When I was still in primary school and the first years of high school I was good at the language and humanities courses, while mathematics and the natural sciences were very difficult. It took me many insufficient marks and one wonderful tutor to find out that mathematics and physics are actually beautiful and also quite fun. So, slowly I got better grades and near the end of high school I decided to take on the challenge of studying Applied Physics. The first two years were rough. All the romantic and exciting talk about world changing inventions had been replaced by a desert of mathematical derivations. I worked hard and got through it, I learned a great deal. Still, I always felt that something had been missing. Meaning, life, creativity in language, thinking critically and perhaps even humor.

My dear friend Stephan, who also studies Applied Physics, introduced me to the Double Degree program of philosophy and I decided that this might be what I needed. And I was more than right. Philosophy has broadened my perspectives on the world in ways that I did not think were possible. But most importantly, philosophy has taught me — and will teach me, as I am not done yet — to think, really think. Not thinking in terms of rules, of what should and should not. No, not a cold type of thinking. Philosophy has taught me a thinking in terms of life. This thinking is often uncomfortable as it presents us with our fears, our permanent inabilities and deadly blind spots. Yet, at the same time it leads to a kind of freedom because in the wide field of perspectives on life that philosophy offers, it becomes clear that we are not simply stuck with one.

For this reason, I walked out the lecture hall that day a different person. What exactly had been bothering me about Applied Physics did not occur to me before and now I was able to grasp it. All I had been taught to do was calculative thinking, but that had meant that no other type of thinking was important. When analyzing a rose, no physicist is interested in its colour except for the matching wavelength. It was not about leaving the description of the colour of the rose to the artists, and for us engineers to do the calculations. In my study of Applied Physics it seemed as if we had totally forgotten about all other possible descriptions of the rose.

So, in this thesis I take you with me on my search to understand in what respect to calculative thinking the engineer exists. All the questions that I pose and try to answer are questions that I have myself as engineer-to-be. Writing this thesis has therefore been incredibly interesting to me and a great deal of fun. I have literally written parts with a smile on my face. I hope that you will share a bit of that excitement when reading your way through my thesis.

But before heading to the real work, I would like to thank dr. A.W. Prins for his guidance, advice, and his unique way of teaching which has opened my eyes. I want to thank Prof. P. Arora for her role as advisor. Thank you to Cleo Foole, for her continuous support — also content-wise, even though this was not part of her job. Special thanks also to Stephan, who is one of a kind and always willing to spend hours philosophizing. I am so glad for our encounter at the most boring course of physics ever. And finally, thanks to all my family and friends. You make me feel alive.

Charlie van Dijl

Rotterdam — July 2022

Introduction

When I graduated from high school I decided to study Applied Physics because I believed that it could offer me a deep understanding of the fundamental layers of nature and life. I hoped that, after a tough trajectory of study, I would be able to understand how the world works and that I could apply the gained insights to all types of fields. I imagined myself working for the United Nations as policy maker “for the people”. I dreamed of becoming a journalist, unveiling the structures making and breaking societies. I thought about making a career in a big corporate firm, where I could contribute to change their course in the world. I was naive, perhaps even romantic. Although physics has taught me all about the beautiful laws of nature on earth and in space, it has taught me little about life. Because, even though we are bound to this one earth we seem to live in two different worlds. On the one hand, in the world in which we feel, fall in love, fight, care, grieve, kill and regret. On the other hand, in the world where we articulate everything in numbers, where we choose for mathematical descriptions of processes, for optimization and efficiency. I realised that the world represented by mathematical laws might be about the world we live in, but that the mathematical world itself is emptied of life. Yet, in today’s society we seem all too eager to incorporate the mathematical world in our lives everywhere.

There exist many interesting perspectives that shed light on this duality between technology and life. In particular the text *The Question concerning Technology* by Martin Heidegger gave me more insight into what had troubled me so. In this text from 1953 Heidegger investigates what is the actual essence of modern technology and what this implies for the way in which we understand the world. He comes to find that the essence of technology pulls us into a calculative mode of thinking which makes it incredibly difficult to perceive the world in all its different shapes and colours.

Although I believe that Heidegger points out an important problem of modern day society, his contemplation of calculative thinking puts the engineer in a rather complicated position, because analytical, mathematical thinking is precisely the natural habitat of the engineer. It is the necessary way of thinking to accomplish his or her tasks, which are to understand nature in terms of mathematics and to use this knowledge to invent technology or to think of ways to improve it. Then, should we read Heidegger’s text also as a criticism of the engineer? Can the engineer continue her job as before, or is she called upon to broaden her views on technology? And what other ways of thinking are possible that the engineer can make her own?

Every day technology becomes more ingrained in all aspects of life. Accordingly, the engineer increases her influence and slings calculative thinking into the world. Therefore, it is important to investigate the engineer’s position with respect to technology and to the way we understand the world. Only then we can decide who we want the engineer to be: calculative or a thoughtful engineer? In this thesis I will investigate how Heidegger’s *The Question concerning Technology* can guide us in questioning the engineer’s position and analyse if the text offers us new possible ways of thinking that can broaden the perspective of the engineer on the world.

In the first chapter of this thesis I set out what is meant with the science of Applied Physics. Next, I discuss Heidegger's *The Question concerning Technology* and highlight his most important thoughts. Chapters 1 and 2 provide us with the basis to start our analysis of the engineer's position in the world, which is the subject of chapter 3. In this chapter I analyse in what way Heidegger's text problematizes the current position of the engineer, and study if and how *The Question concerning Technology* is a possible starting point for defining the tasks of a thoughtful instead of calculative engineer. In the last chapter I conclude my thesis and ponder on ideas and new questions that have come up during my research that will help us in our search for the thoughtful engineer.

1 What is Applied Physics?

1.1 The search for a general understanding of nature — physics

The scientific domain of Applied Physics finds its basis, as the name suggests, in physics. Ever since human beings have walked around the earth, they have tried to find explanations for the phenomena of nature. From the 16th century onwards natural philosophers such as René Descartes (1596-1650), Johannes Kepler (1571-1630) and Galileo Galilei (1564-1642) laid the path for mechanistic descriptions as general principles of physical processes in nature. But it was Isaac Newton (1642-1727) in the 17th century who invented the classical mechanics which formed the basis for the physics we still use today. Newton created the mathematics of calculus and from it mathematical principles that describe natural phenomena, such as gravity, acceleration and the interplay of forces, could be derived. His theory showed that a mathematical description of nature could help us to predict the unfolding of a physical action. If an object with a certain mass m is moved with a force F, then the object will experience an acceleration a of magnitude F/m. Then, from the acceleration we can determine its velocity v and the spatial trajectory of the object. Thanks to Newton, only a few elements of a situation are needed to calculate and thus predict the detailed course of the entire mechanic event.

Over the course of the 18th and 19th century Newtonian mechanics was extended to explain planetary motion, the movement of bodies, the flow of liquids and acoustic sound waves in media (Brandt 2009, 1). The developments that followed from these scientific findings in combination with the industrial revolution requiring deeper knowledge of physical laws, have led to the science of modern physics. Near the end of the 19th century physics was believed to be almost completed. Yet, several important findings opened a new barrel of fundamental questions about nature that physicists are still working on today, and are nowhere near a final conclusion (Brandt 2009, 1).

The extension of Newtonian mechanics formed the basis for the possibility of the industrial revolution. However, to further develop technology a deeper knowledge of why certain phenomena take place and what constitutes a material's properties was demanded. Ludwig Boltzmann (1844-1906) developed a theory of statistical mechanics, introducing probability to thermodynamics and accordingly allowing the application of mechanics to the large numbers of particles that form gasses (Brandt 2009, 2). In the same century it was James Clerk Maxwell (1831-1879) who combined the knowledge of electricity and magnetism into his theory of electrodynamics which predicts the existence of electromagnetic waves. Also, a deeper dive into the hypothesis of atoms as the indivisible building blocks of matter gave rise to particle physics. The formation of the periodic table by Dimitry Iwanowich Mendeleyev (1834-1907) helped with understanding the differences between types of matter (Brandt 2009, 3).

The subjects of 20th century physics that followed from the discoveries mentioned above at the end of the 19th century moved away step-by-step from classical mechanics and daily observations to the more fundamental structures underlying the observable. In general, modern physics revolves around two larger themes: getting grip on the microscopic structure of matter and understanding space and time (Brandt 2009, vii). It is widely agreed upon that the birth of modern physics started with Max Planck's (1858-1947) quantization of energy in 1900, breaking with classical physics (Brandt 2009, 28-33). Albert Einstein (1879-1955) translated Planck's findings to electromagnetic energy and explained the photo-electric effect (which got Einstein the Nobel Prize). Electromagnetic energy, or light, had always been described either in terms of waves, or in terms of particles. But now light was attributed both descriptions (Brandt 2009, 40-43). The concept of this wave-particle duality meant the start of quantum physics. Over the past century quantum physics has given us insight into the structure of the smallest particles, but it has confused us even more. The foundation of nature appears to be probabilistic and has little to do with the deterministic classical mechanics that so practically describes the world we see around us.

Modern physics has also shown that nature plays according to different rules on a cosmic scale. In 1905 Einstein developed his theory of special relativity which describes what happens when two reference frames of different observers move relative to each other at high speeds. In each frame the same classical laws of motion hold, but because the speed of light c has to be the same in each frame, time and length are subject to relativistic effects, which are noticeable when frames have a velocity near c. In the frame at rest, which depends on your perspective (are you in the train looking at a moving landscape, or are you on the platform looking at a moving train?), time seems contracted and length dilated when looking at the moving frame (Brandt 2009, 44-49). Later, Einstein finalized his theory of general relativity which deals with the bending of spacetime as a consequence of the matter that is in it. Space moves matter and matter bends space and therefore the path of light. General relativity gave an entirely new perspective on the workings of gravity, and consequently of time and space, compared to the description Newton had given — which had been the general conception for more than 200 years (Brandt 2009, 105-109).

Today, physics is far from being finalized. Physicists from all over the world are trying to find answers to the complicated questions that quantum physics and general relativity and the findings following from them, have given to us. Although modern physics could not have been possible without classical physics, the main difference is that modern physics goes far beyond what is observable to the human eye. It is about the smallest structures and the greatest distances and the effects that are at play at these unimaginable scales. Modern physics zooms in to what nature is made of and zooms out to what it is part of. In such a way it reveals the secrets of nature. The question, to which we will get back in Chapter 3 and the Epilogue, is what this way of revealing implies for our perspective on the world.

1.2 What is Applied Physics?

As we now have a basic understanding of which questions belong to the science of physics, we can discuss the field of Applied Physics. Similar to the physicist, the applied physicist is concerned with the fundamental mathematical laws that constitute nature. However, the applied physicist's focus is on the ways these laws can be applied to create or optimize technology. Before understanding to what extent the laws of physics can be applied to technology, a thorough understanding of these laws is necessary. Part of the Applied Physics field is therefore focussed at studying the characteristics of matter, in all its phases, that give them e.g. magnetic, electrical or optical properties which are practical for certain applications. Another part of the Applied Physics field concerns the development of instruments for the measurements that are needed for modern physics to progress, such as the electron microscope, the radiowave telescope or particle accelerators. Not seldom does the research necessary for the development of these instruments lead to technology that can be used for industrial or practical purposes. One can think of the laser, the nuclear reactor and transistors (Brandt 2009, 485). Another type of application of physics is the invention of technology that facilitates solving problems. For example, the improvement of radiotherapy that helps cure cancer without killing healthy tissue, of solar cells which harvest solar energy, the development of safe and sustainable nuclear reactors, or the attempts to build an incredibly fast quantum computer that is difficult to hack.

1.3 Thinking as an applied physicist

The applied physicist has a kind of double role. She is a physicist, interested in the why, and at the same time an engineer, interested in the how. As a physicist, she studies the fundamental layers of nature and from that point of view she creates technology as an engineer. This double role gives the technology she invents a different position in the world than for example the mechanical or civil engineer (although there is some overlap in the digital age). Interested in the underlying structures of nature the applied physicist applies modern physics to technology instead of merely mechanics, statics and thermodynamics. And in this sense modern technology, as it is based on modern physics, moves away from us. While the phenomena modern physics describes concern the same atoms that form our bodies, we do not encounter these phenomena ourselves. We do not recognize ourselves or our daily observations in the mathematical rules that modern physics presents. The applied physicist is an abstract thinker. Modern technology resulting from Applied Physics is then a concrete form of the abstract, both in this world in the shape of apparatuses and out of this world as we cannot relate to its founding phenomena from our concrete worldly experiences. But for the applied physicist this is not a problem, as she can relate to these founding phenomena via her natural language of mathematics. She *thinks* the world in terms of mathematics and can accordingly accomplish her tasks by applying it to technology. Yet, for the end-user of modern technology the same cannot be said. As modern technology represents the applied physicists' mathematical thinking, it pins down what lays below the surface and it leaves the user forced to accept nature as a mathematical structure.

This is where we need to start thinking about the position of the engineer with respect to technology and our understanding of the world. Because, this distance between our experience and modern physics that technology represents, in what ways does it affect us? And, does the engineer play a part in creating and overcoming this distance? Should she? Before being able to reflect on the position of the engineer in the world, we should focus on what she is concerned with. Therefore, we must investigate what technology is, how it comes to be and what its' character implies. In the next chapter we will commence this investigation by studying Heidegger's *The Question concerning Technology*.

2 Heidegger’s Question Concerning Technology

> Most philosophers of technology would probably agree, for good or ill, Martin Heidegger’s interpretation of technology, its meaning in Western history and its role in contemporary human affairs is probably the single most influential position in the field. (Sharff & Dusak 2003, 247)

In 1953 Heidegger gave his influential speech *Die Frage nach der Technik* in which he searches for what technology is and how it has come to define our thinking and being. In this chapter I explain his most important thoughts from *The Question Concerning Technology* following three main questions: What is for Heidegger the essence of technology? What does the essence of technology imply? How to move on? In answering these questions we find the ingredients to reflect on the position of the engineer in the next chapter.

2.1 What is for Heidegger the essence of technology?

Heidegger begins his speech with the remark that the question concerning the essence of technology has so far neither been posed nor answered. Often we presume that the essence of technology is itself technological and therefore a neutral, harmless tool. As a result, the question concerning the essence of technology did not appear urgent. Yet, Heidegger points out that the essence of technology is not technological at all. Therefore, we must question the essence of technology or else we will blindly live our lives chained by the technological. The goal of questioning technology is to find a free relationship with it, such that the essence of technology can reveal itself to us (Heidegger 2013, 4).

Heidegger’s questioning starts with the two definitions that are usually given of technology. The first is the instrumental definition: technology is a means-to-an-end. The second is the anthropological definition: it is a human activity (Heidegger 2013, 4). For Heidegger both of these definitions are correct but not true, because the essence of technology is not revealed through these definitions. However, Heidegger does believe we can come closer to the truth by way of investigating what is meant with these correct definitions (Heidegger 2013, 6). Heidegger finds:

> Technology is a mode of revealing. Technology comes to presence in the realm where revealing and unconcealment take place, where alētheia, truth, happens.
> (Heidegger 2013, 13)

Let us unpack this passage. When we regard technology as a means-to-an-end we actually understand technology in terms of a cause resulting in an effect, i.e. causality. Through causality something is brought forward that had so far been hidden (Heidegger 2013, 9). Thus, in causality something is revealed, brought into appearance. This bringing-forth is what Plato named *poiēsis,* the unconcealment of the concealed (Heidegger 2013, 10-11). At the same time, the Greek word for revealing is *alētheia*, which translates as 'truth' but literally means 'unconcealment'. This means that bringing-forth is a revealing in the realm of truth (Heidegger 2013, 12). *Phùsis* is the type of *poiēsis* that carries bringing-forth in itself. It is the caterpillar unfolding into a butterfly. The other type of *poiēsis* is *technē*, the revealing that carries its bringing-forth not in itself, but in the artist, craftsman or engineer (Heidegger 2013, 13). Accordingly, technology as *technē* is a mode of revealing, it brings forward what cannot bring itself forward. Technology is a gathering of materials, know-how, purpose and form and through this gathering the hidden comes to presence (Heidegger 2013, 13).

The problem is that this idea of technology as *poiēsis* is hard to align with modern technology, because the latter is based on modern physics (Heidegger 2013, 14). Hence, Heidegger dives deeper into the question of what the essence of modern technology is. He writes that modern technology is also revealing, yet not in the form of *poiēsis*. Modern machine-powered technology differs from 'old' mechanical technology because it unlocks, transforms, stores and distributes what is hidden in nature instead of merely unlocking it (Heidegger 2013, 16). Like 'old' technology modern technology reveals what is hidden in nature, but in modern technology that which is revealed is always used for the purpose of something else (Heidegger 2013, 15). This means that the revealed needs to be stored such that it can be distributed in its tailor-made shape whenever needed in some other technological process. According to Heidegger the essence of modern technology is that it challenges nature to reveal itself as part of the *standing-reserve.* The *standing-reserve* is the big storage space that we once called earth, from which we can extract infinite amounts of anything at any time (Heidegger 2013, 17). Yet, the *standing-reserve* is not merely a storage space, something happens to the character of the objects when they are revealed as part of it. Objects no longer stand on their own as objects, they exist only in the service of an ordering process. They are always on standby to be ordered for the use of something else (Heidegger 2013, 17). The essence of modern technology thus reveals itself as a commanding mode of thinking, which effects how the world appears to us.

But how is this essence of modern technology brought about? Is it, for example, in the materials, the maker, or in the final product? For Heidegger, man does play an active role in the revealing of nature as standing-reserve. In the end, we are the ones that invent technology and drive its development (Heidegger 2013, 18). However, man has no control over the unfolding of ordering which is revealed through modern technology. There exists a disposition that pulls man into that ordering mode of revealing. Such a disposition is what Heidegger calls a *destining*, it pushes us in a certain direction of understanding the world (Heidegger 2013, 24). *Poiēsis* is in that sense also a form of *destining* (Heidegger 2013, 25). The *destining* that holds sway in the essence of modern technology and that demands us to reveal the real as *standing-reserve* is named *Enframing*

(Heidegger 2013, 20). We must understand *Enframing* as the disposition that calls upon us to view nature as consisting of functional units of an ordering process. The essence of modern technology is the type of unconcealment that *Enframing* asks for. Modern technology is thus only a response to the challenge that *Enframing* sets upon us (Heidegger 2013, 21).

In this way, the essence of modern technology is an ordering mode of revealing that coincides with the challenge of *Enframing*. The essence of modern technology is thus, perhaps against our intuition, not technological at all. But is modern technology not simply applied modern physics? Then, does the essence of modern technology not lie within the essence of modern physics? Heidegger argues no. It is true that, for modern technology to be a response to the challenge of *Enframing*, it needs modern physics. Still, modern technology is not just applied modern physics. Because for modern physics to exist, the essence of technology must already have called upon us to reveal nature as *standing-reserve*, as a calculable structure comprised of functional units (Heidegger 2013, 23). Modern physics paves the way for the essence of modern technology to reveal itself expressed in the form of modern technology, yet it is shortsighted to think of modern technology as merely Applied Physics. If we understand modern technology only in this way we become blind to the consequences of its essence, hindering us to arrive at a free relationship with technology. Our inquiry into the essence of technology is thus not yet finished.

So far, Heidegger's layered investigation to the essence of technology leads him to something that is not technological. In summary, we are called upon by *Enframing*, which challenges us to understand the world as an infinite resource for exploitation. Modern technology is our response by virtue of its very essence, the ordering mode of revealing, because that is the type of revealing that *Enframing* demands. The essence of modern technology is thus a mode of revealing in which the real is revealed as part of the *standing-reserve*, it is a commanding mode of revealing. To understand what the essence of modern technology entails and what it implies, we must continue our inquiry in order to arrive at a free relationship with technology.

2.2 What does the essence of technology imply?

When reading *The Question Concerning Technology* one notices the pessimistic wind that blows through its pages. There is reason for this pessimism, since the essence of technology is not neutral. It has implications not only for the way we understand the world, but also for the world itself. The essence of modern technology reveals itself in a calculative mode of thinking. This means that we no longer understand the objects and beings of nature for what they are by themselves, but only in terms of their use as part of a larger ordering process. To clarify this, Heidegger gives the example of the Rhine in which a power plant is placed. The Rhine is no longer a river as river, it is an energy source. Its water flows in service of the power plant. Even if we regard the Rhine as part of a landscape, it is in service of tourism (Heidegger 2013, 16). In fact, Heidegger argues that we as human beings have also become part of the *standing-reserve* (Heidegger 2013, 18). We do not consider students as young human beings that are searching for what their passions are, who study to make sense of the world and to decide how we should move on as society. We regard them as Human Capital which will pay itself off once the graduates enter the job market. Here they become the focus of Human Resource Managers, who decide where in the ordering process they can contribute most happily - read efficiently - to innovations which drive profits to infinite heights. Because of the essence of modern technology everything becomes an object of calculation. Each being, each object, each energy is placed wherever in the ordering process it is of most use at minimum cost or else it is simply discarded as useless (Heidegger 2013, 15).

The ordering mode of revealing is endless, according to Heidegger (Heidegger 2013, 16). So, it is easy to think of many more examples of the commanding mode of revealing. We could even think about the relation between calculative thinking and, for example, climate change. But Heidegger points out that there is another and more pressing consequence that should be addressed and that is what lies in the character of *Enframing* itself. Heidegger calls *Enframing* the *supreme danger* for two reasons (Heidegger 2013, 26). First, when every object reveals itself to us as part of the *standing-reserve* and we do nothing but order, we become part of the *standing-reserve* ourselves. At the same time, as orderers we praise ourselves for our resourcefulness and start believing that whatever we encounter has come to be due to our intelligent design (Heidegger 2013, 27). As a result, we do not see that we are called upon by the challenging claim of *Enframing.* We consider ourselves as free and autonomous but in fact we act and live with respect to this claim (Heidegger 2013, 27). So, *Enframing* puts our relationship with ourselves in danger. Moreover, because *Enframing* conceals itself as revealing, the ordering mode of revealing seems to be all that we can do. We can no longer reveal the real in other ways than as *standing-reserve*. It is thus in the character of *Enframing* that it conceals itself and accordingly blocks other modes of revealing (Heidegger 2013, 27). As such, also truth remains hidden (Heidegger 2013, 28).

It is not a cheerful message that Heidegger conveys. We are trapped in a calculative mode of thinking and we are not even aware of it. Yet, it is exactly in this becoming aware in which Heidegger finds a way forward.

2.3 How to move on?

First, it is important to note that Heidegger is not against technology (Heidegger 2013, 28). The danger lies in the essence of it. The essence of technology pulls us into the ordering mode of revealing, unknowingly. We do not know in which mechanism we are caught up and we do not know what other ways of revealing are possible either. Thus, Heidegger's purpose is to question the essence of technology once again to find a free relationship with it. That is, a relationship in

which we are not constrained to obey, but in which we can observe and understand our interplay with the essence of technology (Heidegger 2013, 25).
Heidegger quotes from a poem of Friedrich Hölderlin:

> But where danger is, grows
> The saving power also. (Heidegger 2013, 28)

His interpretation of the poem is that if the essence of technology is the *supreme danger*, then it must carry in itself also “the growth of the saving power” (Heidegger 2013, 28). Through questioning *Enframing* as essence of technology we can find out how this saving power is carried in it and how it can come to growth. Heidegger begins with our usual understanding of essence: it is the ‘whatness’ of what is (Heidegger 2013, 29). For example, what unites all chairs is their ‘chairness’. This would mean that the essence of technology is the technological. However, as we have seen, the essence of technology, *Enframing*, is precisely not technological but a mode of revealing. The ‘whatness’ thus does not suffice to understand how the saving power is carried in the essence of technology. Heidegger, who turns to the Ancient Greeks again, writes that essence is that which endures (Heidegger 2013, 30). Yet, whatever endures must also have been granted (Heidegger 2013, 31). The essence must have been let to last. It is in this granting where Heidegger finds the saving power of the essence of modern technology. The essence of modern technology is the ordering mode of revealing, meaning that this way of revealing too has to be granted. Because we are the ones who are called upon to grant, we are the ones who keep watch over the unconcealment of the concealed as well. This means that it is also through us that truth can come to light, if only we are conscious of the revealing of technology (Heidegger 2013, 32). If we pay attention to how we are called upon by the essence of technology, we can also decide to answer the challenge differently. Then, we are no longer obeying what puts itself forward most dominantly, but free to reflect on and reply to the challenge that *Enframing* presents.

Heidegger concludes that the essence of technology is ambiguous (Heidegger 2013, 33). *Enframing* conceals itself and every other type of revealing. Yet, at the same time *Enframing* carries inside itself the saving power, and can with our awareness of its mechanism truth appear (Heidegger 2013, 33). Heidegger underlines that a free relationship with modern technology is not found through action, it is found through thinking. Because when we reflect on the question concerning technology we can understand the essence that lies within the metal frames of machinery. Only through reflection we can find out that we are claimed by the essence of technology and in what way. Through thinking we come to understand that technological thinking is not all there is, but merely a response to the challenge of *Enframing*. As such, we learn that the world can reveal itself in many ways and that we are not restricted to calculative thinking.

The main question one is left with is: what other ways of revealing are possible if we find that the commandeering mode of revealing is not always desirable? Heidegger writes that we have not yet experienced the revealing of modern technology in its true sense (Heidegger 2013, 35). However, he points out that we can find guidance in art, since it belonged to the realm of *poiēsis* as *technē* in the time of Ancient Greece. Art brought to presence what remained hidden (Heidegger 2013, 34). Therefore, art and technology share a mutual ground even though they are fundamentally different as well. For this reason Heidegger considers the realm of art to be the appointed realm in which to reflect on technology (Heidegger 2013, 35). That is, in art we can experience the tension between concealing and revealing. Through this experience we might be able to grasp and appreciate the entities of this earth as more than mere stock (Thomson 2019).

After a complicated investigation to the essence of technology we have realized that our relationship with technology is anything but straightforward. *Enframing* has got a tight grip on us and as a consequence we continuously lose ourselves. Still, we are not lost forever. In fact, through human reflection we are on our way to find in what respect to *Enframing* we exist. It is through questioning, and through questioning alone that we can move forward. As Heidegger concludes, we learn: We must be thinkingly on our way and then perhaps in the future technology will show itself in its true form, as will we, then (Heidegger 2013, 35).

3 Reflection: From Calculative Thinking towards Thoughtfulness

Up until now we have studied who the applied physicist is and have gone through a thorough analysis of Heidegger's *The Question Concerning Technology.* So far, we have also mostly asked questions. In this chapter we will use the ingredients from our investigation to reflect on the questions that we posed at the beginning of and during the course of our study.

3.1 A Call for the Engineer's Attention

We want to reflect on the position of the engineer with respect to technology and to the way in which we understand the world. According to Heidegger the essence of technology, *Enframing*, has molded our understanding of the world in such a way that we no longer view beings and objects for what they are but only in terms of what they can be used for. This calculative thinking is always pointed at efficiency: how can we make use of these beings and objects with minimum effort and maximum yield? Heidegger writes that as a consequence we lose sight of other perspectives and unconcealments. Yet, the engineer's natural language is calculative thinking. It is what she is educated to do and expected to enforce in her job. The question that comes up then is: does Heidegger's contemplation on the essence of technology address the engineer specifically? If we stay close to Heidegger then our response would be both yes and no. To understand why, we need to remember what Heidegger wrote on what brings the essence of technology about. He argues that we are challenged by the *destining* of *Enframing* to reveal nature as a calculable structure. Our technological activity is then merely a response to this challenge (Heidegger 2013, 21). The essence of technology reveals itself through us, but it is not because of us that the ordering mode of revealing is the essence of technology. The same holds for the engineer. Although she is the one who invents technology, and makes it possible for the essence of technology to reveal itself, she is merely responding to the challenge of *Enframing*. So, the engineer is not called upon differently by the challenge of *Enframing* than any other. However, Heidegger's contemplation on the essence of technology does concern the applied physicist too. And precisely because the engineer is at home in calculative thinking, it is important to pay attention to what *The Question Concerning Technology* implies for her.

3.2 No Technology can Save Us

After reading *The Question Concerning Technology* the engineer would, as she is used to, immediately ask: 'Then what am I to do?' We have learned that we need to question the essence of technology in order to become aware of how we are tied to the challenge of *Enframing*, only to find out how we can respond to this challenge differently than with the ordering mode of revealing.

But what this different response must be, is hard to grasp. Therefore, it can be argued that Heidegger gives us little, or even too little, on how to move on.

Andrew Feenberg finds that Heidegger's belief in the freedom that arises from human reflection on the essence of technology is too passive and nostalgic (Thomson 2000, 208). According to Feenberg, Heidegger forgets that technology is created in a process which consists of many parts and involves many people and their decisions. As a consequence, we have power over what technology becomes. We can decide on its shape, its material and, more importantly, its purpose. Feenberg thus calls for "strategic interventions in the design process" , i.e. a democratization of technology (Thomson 2000, 212). Even though I agree that the shape technology takes is molded through time by our own wishes, experiences, questions and choices, I do not think a democratization of technology will help us to address the problem raised by Heidegger, namely that we are stuck in a calculative mode of thinking because of the essence of technology. A democratization of technology does not alter the essence of technology specifically because this essence is not technological, it cannot be invented. The essence of technology lies neither within the metal frame, nor in the engineers who design the machine. Moreover, a democratization of technology based on complex modern physics would not be able to take away the presupposition that nature is a calculable structure. While later in the design process one could debate about the shape, material and aim of the interface, where the apparatus and the user meet, the machine would still need to presuppose nature as a mathematical construction or else the machine would not function. The distance between technology based on modern physics and the user, which we discussed in Chapter 1, is therefore not dissolved by a democratization of technology. The user is still forced to accept nature as a calculable structure, since he cannot relate to the phenomena on which modern technology is based from our concrete worldly experiences.

Although I do not think that Feenberg's democratization of technology solves the problem Heidegger poses, I do want to underline that as engineer it is increasingly important and necessary to take into account the politics of technology and also its negative side-effects for e.g. the environment, and that through a more open and democratic design process we can steer the development of technology in a direction where its design is more caring for life and earth. A good example is the project *Marker Wadden* in the Netherlands. Because of the construction of dams and embankments the Markermeer was left with few natural shores. As a result, thick layers of sludge formed at the bottom of the Markermeer and the water became turbid, both having a negative effect on the flora and fauna in and around the lake. The solution to this problem is the *Marker Wadden*. The sludge was used to construct small islands, forming natural shores where plants can grow and birds can nest. Also mussel banks were grown to filter the water, which helps to restore the food chain. Accordingly, nature in the Markermeer is now blooming (van Dijl 2022). The construction of the *Marker Wadden* is executed by dredging firm Boskalis in cooperation with the government, Natuurmonumenten and other funds and organizations. The project also offers researchers the possibility to gain knowledge on *building with nature*, which is one of the project's goals, and the development of new ecosystems. What is beautiful about the example of the

Marker Wadden is that it shows that technology does not have to do much harm to the world. On the contrary, when designed properly in cooperation with people with a wide variety of specializations, technology can ameliorate the environment for plants, animals and human beings. Still, Heidegger would argue that even here we have not escaped from calculative thinking. We have merely solved a technological problem with technology. We must recognize that technology, even in its best design, has effects beyond intentions which cannot be solved by intelligent (re-)design (Mitcham 2001, 35). So, again the engineer will ask: "Then what am I to do?"

3.3 A World Full of Life through Thought

At this point the engineer must start to think that Heidegger is against technology. If this type of caring technology is not good enough to answer Heidegger's claims, then what is? But right here we have to think again. If we read Heidegger's text closely it becomes clear that it is not another type of technological activity for which Heidegger is looking. He argues for a different relation with technology, where we come to learn that "although a technological understanding of being is our destiny, it is not our fate" (Dreyfus 2009, 57). And how to get to this relation with technology is not through action, but through thinking. So, for once the engineer is asked not to set up a plan with logical steps leading to a definite answer, she is asked to think and reflect on what it *is* she is concerned with. 'What is technology?' is the question the engineer should dive into. Because only through reflecting on this question she can find out that the disposition which has come to characterize our being is *Enframing*, and more importantly that it is "nothing more or less than our current cultural clearing" (Dreyfus 2009, 57), our current cultural disposition. Our understanding of being has been different in the past and can become different in the future. Through reflection she realizes that technological thinking is not all there is and not all she can do, she is merely responding to a challenge that she is confronted with continuously.

And this realization already makes all the difference. Why? Because then she is no longer forced to always think like a machine. She is no longer summoned into almost becoming a machine herself. This does not mean that she has to abstain from calculative thinking. To convert solar energy into electric energy still requires a mathematical analysis of nature's phenomena and a technological design of the solar panel. In fact, Heidegger writes in *What Calls for Thinking?* that the scientist — in our case the applied physicist — needs to understand the world as a calculable structure to guarantee its own course (Heidegger 2011, 264). But now the engineer can decide when and where it is necessary to think in terms of efficiency and when to let things and people be as they are, and appreciate them accordingly. Now she knows that nature can be revealed as a mathematical structure but that this is not the only way of revealing. She has become aware that calculative thinking cannot account for all aspects of life and nature. A free relationship with technology is thus both a yes and a no to technology (Heidegger 1979, 40). A yes in the sense that we can design and use technology and apply technological thinking to solve problems, wherever we deem it necessary. And simultaneously a no, meaning that we leave technological devices for what they are and do not let calculative thinking overtake all of life.

It will take practice in thinking to give shape to this free relationship with technology, as the engineer is taught to say yes to technology always. If we follow Heidegger this practice can best take place in the realm of art, because in art we can discover ways of revealing different from the ordering mode of revealing. This is best shown via an example. When we look at Vincent van Gogh's painting *Starry Night Over the Rhône* we discover that this painting does not portray a scene as an object of calculation, but reveals how nature can affect us. These stars are not simply giant gas bulbs, making Helium atoms out of Hydrogen and emitting photons with wavelengths accordingly. These stars, in the way they are depicted here, they make us feel at home. We feel warmth, rest and perhaps even a hint of love when we look at this painting. Van Gogh portrays the same experience we can have when we look above at night ourselves. In art we are thus able to grasp what in technological thinking would forever remain hidden. As such we step out of the ordering mode of revealing and we learn that nature is not only an object of calculation, nature also moves and humbles us. A yes and no to technology is then the ability to acknowledge this spectrum of modes of revealing, and the sensitivity to know when to say yes and when no.

Starry Night Over the Rhône, Vincent van Gogh (1988)

Some may find it disappointing that Heidegger's way forward is not guided by any concrete actions and is therefore a rather open, unknown path. Yet, Heidegger's message actually means something quite wonderful: that life and nature have so much more to offer, are so much richer and more full of colour than we allow ourselves to think. Through questioning technology the engineer becomes attentive to this richness. No longer is she restricted to cutting of the edges of squares until they fit in the description of a circle. In this attitude of attentiveness the calculative engineer ceases to exist and the thoughtful engineer comes to life, and so does everything else.

Epilogue

We have arrived at the final part of this thesis. We have investigated the position of the engineer with respect to technology and to the way in which we understand the world. In our analysis of Heidegger's *The Question Concerning Technology* we found that through thinking a different relation with technology can emerge, one in which we say both yes and no to technology. This free relation with technology allows the engineer to think calculatively whenever needed, but also to appreciate other ways in which life and nature reveal themselves. As such, the world becomes more than a mathematical structure, more than an infinite storage space from which we can extract anything at any time. In this way, life is no longer lived along the lines of mathematics, it is free to take on any shape or colour.

The question now is whether we are happy with this outcome. Is it sufficient to change the engineer's approach to technology and life? And have our findings lead to the necessity of this change? I must admit that when I started writing this thesis I had hoped to find a way of thinking for the engineer that unites both calculative thinking and a sensitivity for life and nature. Yet, throughout my research I had to conclude that this is not possible, because in order to invent technology, the engineer must always approach nature as a calculable structure, there is no other way around it. And this calculable structure is by definition emptied of life. Physics itself pays no attention to the width and depth of being, for what we feel, think and experience, and nor can it have this attention if it wants to guarantee its own course. A sensitivity for life and nature will thus always be next to calculative thinking and cannot be ingrained in it. Although it is not what I hoped for, it is no reason for disappointment. It is like what Heidegger argued: a free relation with technology is both a yes and a no to technology. Apparently, we cannot change calculative thinking but we can change our attitude towards it. The thoughtful engineer differs from the calculative engineer in this sense that she has a different attitude towards the world and life. I do think that Heidegger could have expanded more on how such an attitude is lived from day to day. Iain Thomson suggests that we must look at the Amish, who decide as a community which technologies to let in and which to leave out of their lives (Thomson 2000, 208). But this cannot be a realistic approach as we are overwhelmed by technology everywhere. Hubert Dreyfuss argues we should draw inspiration from Japanese culture where "the TV set and the household gods share same shelf" (Dreyfus 2009, 57), implying that there a technological understanding of being exists next to a non-technological one (Dreyfus 2009, 57). Still, it is not entirely clear how such a free relation with technology must take shape for those who so far have been under the spell of calculative thinking. Therefore, Heidegger's *The Question Concerning Technology* is not sufficient to grasp completely who the thoughtful engineer must be, but it is in any case a good and important starting point.

And as a starting point, I think that our findings already prove the necessity of a different attitude of the applied physicist towards life and earth. Recently, an engineer who works in the energy sector asked me if a thoughtful engineer is better at her job than a calculative one. A good question, to which I respond with yes wholeheartedly. A thoughtful engineer is as good as the calculative engineer in applying a mathematical approach to a problem that needs to be solved. Yet, the thoughtful engineer, who in her attitude is attentive to the different ways in which life and nature can reveal themselves to us, is able to understand and address the limits of her own thinking. This attitude of attentiveness gives her the ability to listen to perspectives that are fundamentally different than hers and to cooperate with other disciplines when a problem asks for more than mathematics and metal machines. It allows her to be humble, and not to rumble forth in the belief that an analytical approach is all it takes and always right. A thoughtful engineer is also more willing to take into account the politics of technology and its negative side-effects when designing a machine. As such, perhaps an opening appears for a democratization of the design process of technology, to the satisfaction of Feenberg. In this way the thoughtful engineer adds something truly different to the world than a calculative engineer, who merely extracts.

In conclusion it becomes clear that, although we have started our way towards thoughtful engineering, we have not yet arrived at who the thoughtful applied physicist is precisely. We have stepped out of calculative thinking — the world has come to life — but we still have work to do concerning the free relation of an engineer with technology. We must therefore proceed with thinking to give form to the attitude of attentiveness of a thoughtful engineer. What does thoughtful engineering come down to when the applied physicist is faced with concrete technological problems? At which moments can she decide that calculative thinking is not the way? And what other ways emerge at such a moment that can counter the force of calculative thinking? It is yet to be found out.

Therefore, the only way to end this thesis is with a call. A call for all engineers and engineers-to-be to think, really think on what thoughtful engineering is. I ask them not to leave this thinking simply to philosophers, ethicists, writers and artists but to work together with them. Together we should look into technology and its practice to find out where thoughtfulness can appear. We have found our starting point in Heidegger, it is now up to us to unravel our way. And with the challenge of climate change ahead, which demands from us so much more than a number of technological fixes, this unraveling of the mystery of technology is more pressing than ever. Thus, let us not disappear in our laws of physics and hide behind the machines that represent them. Let us be no mere robots and let us take on the challenge of thoughtful engineering. We have everything to lose and all of life to gain. So here we are.

Bibliography

Brandt, Siegmund. 2009. *The Harvest of a Century : Discoveries of Modern Physics in 100 Episodes*. Oxford: Oxford University Press. *https://ebookcentral-proquest-com.tudelft.idm.oclc.org/lib/delft/detail.action?docID=430692*

van Dijl, Charlie. 2022. “Changing perspectives: how ecophilosophy can teach us to think about the sustainable energy transition.” In commission of Energy Investment Management B.V. (To be published: July 2022).

Dreyfus, Hubert. 2009. “Heidegger on Gaining a Free Relation to Technology” in *Readings in the Philosophy of Technology*, edited by David M. Kaplan. Lanham: Rowman & Littlefield Publishers Inc. pp. 53-61.

Heidegger, Martin. 1979. *Gelatenheid*. Translated by: E. van Doosselaere. Tielt: Lannoo. p. 40.

Heidegger, Martin. 2004. “What Calls for Thinking” in *Basic Writings,* edited by D. Farell Krell. Translated by J. Glenn Gray. London: Routledge. p. 264.

Heidegger, Martin. 2013. “The Question Concerning Technology.” In *The Question Concerning Technology and Other Essays.* Translated by William Lovitt. New York: Harper Perennial Modern Thought, Inc.

Mitcham, Carl. 2001. “Dasein versus Design.” *International Journal of Technology and Design Education* 11 (January): 27-36. https://doi.org/10.1023/A:1011282121513

Sharff, Robert C. and Val Dusak. 2003. Introduction to “Heidegger on Technology”. In *Philosophy of Technology: the Technological Condition: An Anthology.* Malden/Oxford: Blackwell Publishing. p. 247.

Thomson, Iain. "Heidegger’s Aesthetics”. *The Stanford Encyclopedia of Philosophy* (Fall 2019). Edited by Edward N. Zalta. https://plato.stanford.edu/archives/fall2019/entries/heidegger-aesthetics/.

Thomson, Iain. 2000. “From the Question Concerning Technology to the Quest for a Democratic Technology: Heidegger, Marcuse, Feenberg”. In *Inquiry: An Interdisciplinary Journal of Philosophy,* 43 (2): 203-16.