Challenging Prometheus : a history of technology for an age of grand challenges

Inaugural lecture
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Where innovation starts

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at Eindhoven University of Technology

Introduction

Ladies and gentlemen,

About ten years ago – on the evening of Saturday November 4, 2006 to be precise – the lights went out.

I remember that evening. At our house we did what people do in such circumstances: check the fuse box, and check the neighbors – had their lights gone out too? They had. Our little square was covered in darkness. People lit candles and came out of their houses.

Most likely, you've all experienced blackouts before. What made this particular blackout truly remarkable, we only found out later.[1] It turned out that the sequence of events leading to our domestic blackout started with a ship. The Norwegian Pearl to be precise. And the Pearl was not sailing on the Eindhoven canal, close to my home. No, this liner was sailing down the River Ems, hundreds of kilometers to the North-East, from a North German shipyard to the North Sea. For that passage, the high voltage line across the river had been shut down. This is standard procedure. But on this particular evening, some transformer stations were closed for routine maintenance. High wind power production in Denmark and Northern Germany caused large electricity flows from Northern Europe to South Western Europe. The power grid was operating near maximum capacity. The Control Room staff made certain decisions. And like in any system, you sometimes have unexpected fluctuations that nobody understands. That evening, in a perfect illustration of Charles Perrow's Normal Accident Theory (which studies how interacting contingencies in complex, tightly-coupled technological systems can cause unpredictable faults[2]), human and technical contingencies combined in an overload of a second power line that switched off. Then it happened: As the electricity sought other pathways, one line after the other overloaded. Within 15 seconds, a cascade of failures traveled from Northern Germany to the Czech Republic. Within another 5 seconds, people got trapped in dark elevators and train

1 UCTE, *Final report*. Van der Vleuten and Lagendijk, "Historical shaping of the European Blackout."

2 Perrow, *Normal accidents*.

cars in Mediterranean countries like Croatia and Italy. The blackout affected over twenty countries, from Portugal to Romania, and from Denmark to Spain, and beyond: Via the Spain-Morocco cable, the blackout rolled into Northern Africa, ultimately reaching Tunisia. Imagine this: a power line overloads in Northern Germany, and lights go out in Tunisia. The event became known as the Great European Blackout of 2006.

As a historian of technology, I was thrilled – because the blackout speaks to major research questions in my field. Old questions as well as new questions. That is why I have chosen to start with this event today. Let me mention a few of these research questions.

Making Technology – and History

Complex innovation dynamics

A first, classic question for the History of Technology is how technological change and innovation work – in the real world. This is one reason why engineers once founded the field. We have many stylized innovation models, but when we study the engineers who actually built technological systems in historical reality, innovation always turns out to be much more complex. Let me give you just a hint of this complexity.

The European Blackout revealed to the public eye what engineers already knew: an enormous technical system that normally supplies energy to users reliably and cheaply. The blackout illustrates that this system stretches right across the continent. It is also extremely fine-grained, connecting nearly every house and industry. I find that rather amazing – knowing, as a historian, how before the age of electricity, it was a daily struggle for most people to get energy for light, heat, and power. So, how did that impressive system come about?

For a long time, engineers and historians studying its development believed that state-of-the-art engineering went hand in hand with economic advantages in a historical trajectory of ever larger electricity systems. Larger power plants generated cheaper electricity per kWh. Higher voltage transmission lines enabled economic energy transport over larger distances, reaping the economic benefits of more diverse supply areas. The synchronous interconnection of numerous power plants in one power pool allowed power companies to save on back-up capacity, and to activate the power plants that produced the cheapest energy at any given moment.

But does that really explain the development of our European electricity system? Later historical studies of electrification, especially inspired by Thomas P. Hughes, reveal a more complex picture.[3] It turns out that many different engineers worked on very different types of electricity systems. They disagreed about the optimal

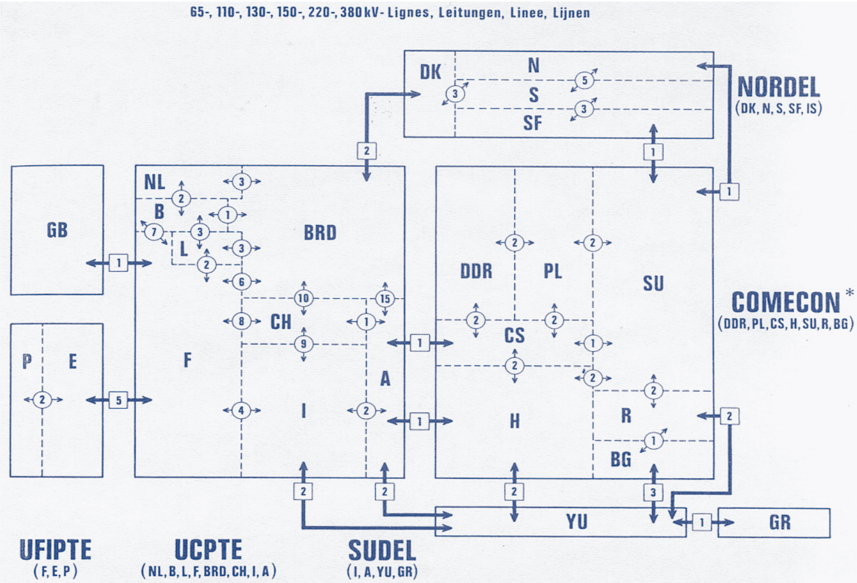
3 Hughes, *Networks of power*. For a review and state of the art: Lagendijk, *Electrifying Europe*; Lagendijk and van der Vleuten, “Inventing electrical Europe.”

scale of electricity supply. Our own studies show that by 1930, some engineers were indeed planning a large scale, European power pool. But that would fail completely for the time being. Others planned and sometimes built national power pools, as in Britain and the Soviet Union. However, most engineers were working on regional and even local power systems. Thousands of villages, even very small ones, owned isolated local systems. Many cities had urban power systems. Many industries, large and small, preferred in-house power plants. In the Netherlands, as Geert Verbong has shown, the provinces became the preferred units for electrification.

Why did they all resist further increase in scale? Their engineers had sound technical, economic, and social arguments. For example: they avoided Very High Voltage lines because these were extremely expensive, sometimes making up half of the kWh price. And they profited from innovations of their own: Wind-electric turbines and small-scale hydel (that cut fuel costs) were developed for village systems. Combined Heat and Power (CHP) production was developed by municipal power companies, selling the waste heat from electricity production as 'town heating' through underground steam pipe networks – you cannot do this in a centralized system where your mighty power plant is far from the city, as the steam will cool down. In many countries, national and international connections only came later, and were comparatively weak add-ons. So: different power companies worked on different scales. Jointly they engineered a complex 'multi-layered system' that stretches across the continent, but has strong local, regional, and national dynamics – in its technological make-up, in its patterns of electricity flows, and in its governance structures.

This brings us to two History of Technology contributions to understanding complex innovation processes. First: real-life historical case studies show how engineers and other innovators weave together social, economic, and technological considerations when making innovation choices, and do this in parallel yet very different ways.

Second: Historical legacies shape future innovation options. The electricity system has strong 'path dependencies', as economists call them. As the EU discovered when trying to forge one electric 'common market' – it proved extremely difficult to dismiss local, regional, and national dynamics. And sustainable energy innovators found out while attempting to 'green the grid', which is making slow progress – encouraging successes notwithstanding. Historical legacies can provide



Europe's electricity systems in 1976. The numbers indicate (very few!) interconnections between countries – sufficient for system synchronization, but not for substantial energy trade. Source: UCPTE 1977, 199.

opportunities for change, not just barriers: The Danish global wind turbine success, built on local traditions, is a good example.

History, my predecessor as TU/e history chair Johan Schot often said, helps us understand innovation because it is the ultimate complexity science – following engineers in historical reality through the nonlinear dynamics of innovation. So the History of Technology has become a prominent approach for studying innovation, also in fields such as the Economics of Innovation, Science and Technology Studies (STS), and Sustainability Transition Studies.[4] [Local note: When we discuss making technology more sustainable today, we are fortunate to have a multidisciplinary research group – the Technology Innovation Society group, chaired by Rudi Bekkers – where historians of technology work side by side with economists and transition scholars, chaired by Floor Alkemade and Geert Verbong].

4 Canonical works include: Bijker, Hughes, Pinch, *Social construction of technological system*; Grin, Rotmans, Schot, *Transitions to sustainable development*.

Making History

The Great European Blackout also illustrates a second classic research question in the History of Technology. A moment ago I explained an historical innovation process; I brought history to engineering. Now I will talk about how my field brings engineering to history.

The problem: Most agree that we live in a technological age. But most histories hardly consider technology beyond the trivial. This is why social historians, who shifted the research focus from elite political events to people's everyday lives, have persistently called for studies of technology. For example: Historian Marc Bloch (citing Paul Valéry) famously wrote that electricity was wrongfully ignored by historians – it should be studied, because it had more influence on our lives and futures than all the political events combined.[5] He wrote this during the Second World War, a political event of sorts, making this statement even more compelling. Historians of technology have answered the call.[6] [Local note: Harry Lintsen and others contributed to this mission too in their huge program to study the role of technology in creating Dutch society, culminating in a wide research network and a 13-volume landmark publication that defined our field in the Netherlands.[7] And this is why our group works with the NW Posthumus Institute, the interuniversity research school for social and economic history].

Back to electricity. Our group studied the making of the European electricity system (e.g. in a highly praised dissertation by Vincent Lagendijk[8]) as part of a broader contribution to history: to rewrite European (integration) history – through the lens of technology. The argument: European integration histories mostly focus on 'formal integration': politicians making treaties, institutions, and rules. By contrast, our history of Europe's "hidden integration" through technology follows technology makers and users as they connected (or fragmented) peoples and places through, for example, common research and standards; common transport, communication and energy networks; or the circulation of food and resources, soldiers and tourists, information and entertainment, social housing models and urban mobility practices, and much more. Technology makers and users made European everyday life – how we came to eat, live, work, play, but also wage war

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5 Bloch, *The historian's craft*, 55.

6 Canonical: Roe Smith, Marx, *Does technology drive history?* Still impressive by a former TU/e professor: van Houten, "Techniek-geschiedenis."

7 Lintsen et al., *Geschiedenis van de Techniek in Nederland*; Schot et al., *Techniek in Nederland*.

8 Lagendijk, *Electrifying Europe*; Lagendijk and van der Vleuten, "Inventing electrical Europe."

and pollute. And this happened largely before and outside the formal EU integration process.[9]

In the case of electricity, the engineers, architects, and others were working on European integration via a common energy system. Consider this image (see figure) and quote from the 1930s: “only interconnection through a power network will create European Union.” The idea: nationalist politicians were withdrawing behind national borders. Since some had plenty of energy resources, and others very few, they saw each other as prey – let’s conquer those coal mines – or threats. A pan-European grid would allow for sharing scarce energy resources, making countries interdependent, thereby preventing war and stimulating economic growth.

Source: Herman Sörgel, Die drei grossen “A”, 91.

9 Misa and Schot, “Inventing Europe.”

As we saw when discussing innovation dynamics, the original plan came to nothing. But later engineers often mentioned European integration when they – for a variety of reasons – built Europe's multi-layered electricity system. At its heart is the so-called *continental synchronous area*, a phase-locked 50 Hz grid covering over 20 countries and 400 million customers. That system was said to beat with a "European electrical heartbeat" of 50 Hertz.[10] Europe's electrical integration was created before and outside EU institutions, by engineers, and had a very different geography from political Europe. Just one example: The political integration of Morocco and Turkey into the EU is, well, rather contested. But both countries have been electrically integrated in the continental synchronous grid, and both find that collaboration mutually beneficial. Incidentally, this is also why the 2006 blackout affected Morocco (Turkey was only connected later).

We conducted similar studies for researching, building, and using all kinds of technologies and technological practices.[11] Writing this European history through the lens of technology helped us to better understand technology (e.g. incorporating its European dimension) and to better understand history (structural changes as well as changes in everyday live). Writing that novel history took 15 years and involved an international network of some 300 researchers. [Local note: It was conceived and coordinated in Eindhoven. Johan Schot and Ruth Oldenziel (and later myself) chaired that international network, and our in-house Foundation for the History of Technology SHT coordinated the network. It still does today, while we turn our attention to a new history – a history of technology for an age of global challenges].

Engineers and Crises

Ladies and Gentlemen, I'm approaching the main theme of this lecture. To get there, let me add one more layer of complexity about our blackout – as a crisis.

In the days after the blackout, newspapers cited European Union politicians (or former politicians like Romano Prodi) stating that the 'European Blackout' was a major crisis; the European power system was vulnerable; and that this was because it was "insufficiently European", being managed by regional and national power companies. A stronger European network and a new EU agency were

10 UCPTE, *Rapport annuel*, 103.

11 E.g. Oldenziel and Hård, *Consumers, Users, Rebels*; Kohlrausch and Trischler, *Building Europe on Expertise*; Högselius, Kaijser, van der Vleuten, *Europe's Infrastructure Transition*; Schot and Kaijser, *Writing the Rules for Europe*; Diogo and Van Laak, *Europeans Globalizing*; Fickers and Griset, *Communicating Europe*.

needed, they said. But when I discussed this with Wil Kling, professor of electrical power systems at this university, who sadly passed away a few years ago, he laughed out loud. He squarely called the blackout political hype. There had been no crisis.

What is going on here? We followed this up.[12] The power sector had a radically different view from the EU, and that view had a history. When the sector built the transcontinental system from the 1950s onwards, it did so to *increase* the reliability of national and regional systems – providing backup and system stabilization through the synchronized grid. Already then, the sector discussed that daily reliability gains came with a new risk of an occasional rolling blackout. They got prepared. Transmission lines were equipped with overload protection gear, so when overloaded they would switch off, not burn through. As for crisis management, individual power companies would disconnect, restore the balance between production and consumption in their own supply area (which they knew best), and go back online. During the 2006 blackout that approach worked according to plan: Within 2 hours max, the entire system was back online. The downtime was minimal, and on an annual basis hardly significant. From this perspective, the blackout confirmed the reliability, not the vulnerability, of the system. Indeed, the sector warned: European centralization of vulnerability management is the true danger to system stability.

How could power sector and EU perspectives diverge so radically? We found that EU policy directly followed sector policy – until 9/11 and other transnational crises (BSE, avian flu, the Madrid and London attacks, and climate change). The EU redefined its role to being the ultimate transnational problem solver – solving problems that transcend individual nations.[13] The blackout triggered this new sense of purpose. Sector and EU interpretations of system vulnerability began to diverge – with very concrete consequences, for subsequent clashes and negotiations shaped European power grid innovation and policies such as the EU's Third Energy Package (including that new Agency).

We have similar historical analyses for the Chernobyl nuclear disaster or financial crises (the financial system is an ICT system). Once again, the radically diverging perspectives clashed, then shaped innovation and policy.[14] This raises important

12 Van der Vleuten and Lagendijk, "Interpreting transnational infrastructure vulnerability."
13 Boin, Ekengren, Rhinard, *European Union as crisis manager*.
14 Kalmbach, "Radiation and borders"; Högselius et al, *Europe's infrastructure transition*, 159-181.

questions when we discuss the engineers' role in solving social and environmental challenges, a core debate in engineering today. How do engineering perspectives relate to political perspectives on such challenges? Or more provocatively: how can engineers work on social challenges, without reducing engineering to merely executing political agendas – which can be rather opportunistic, as recent political changes in certain countries illustrate? This leads me from a single case – the blackout – to the generic topic of engineers and grand challenges.

Engineers and Grand Challenges – What we know

You all know the huge crises we are facing: refugees and security (from terrorism to internet security); climate change; and the looming breakdown of unsustainable energy, mobility, health and financial systems, to mention but a few. The engineering community seeks to solve these crises by finding technical solutions. For example, speaking on behalf of that community, the presidents of the US, UK, and Chinese Academies of Engineering published a joint statement. They argued that engineers need to address the challenges threatening humankind and the world around us. So engineers translated social and environmental challenges into an engineering research agenda: the so-called Grand Challenges for Engineering.[15] Our own engineering visionaries have a similar message: Rutger van Santen, former rector of this university; Dhan Khoe, emeritus professor of electrotechnical engineering; and science journalist Bram Vermeer interviewed over 60 prominent scientists and engineers on their future research agenda. The conclusion: today's challenges are of a deeply technological nature, so technology also holds the key to solutions. Scientists and engineers have some serious work to do – on sustainable energy, smarter mobility, securer data, livable cities, and so on.[16] Prometheus – the titan in Greek mythology who brought fire to humankind and became the symbol for humanity's technological development – today faces a new challenge: find innovative solutions to current crises.

History, as the science of change in time, helps to make sense of ongoing developments. In that case we can ask: why and how have engineers engaged with social challenges in the past? What insights can their experience contribute to present-day debates? Let me start with some of the very basic insights that we discuss with our students.

Ladies and Gentlemen, this university – like other universities of technology – focuses its research agenda on grand challenges. It also prepares tomorrow's engineers (our students!) for their future work environment as well as the vast

15 Mote, Dowling, Zhou. "The Power of an Idea."
16 van Santen, Khoe, Vermeer, *The thinking pill*; van Santen, Khoe, Vermeer, *2030*.

challenges that lie ahead. As we can read in the TU/e educational vision written by Anthonie Meijers and Perry van den Brok, this means students have to learn to integrate the human and technical dimensions of engineering.[17] The staff in my department – Industrial Engineering and Innovation Sciences – therefore teach a university-wide program on the human dimensions of engineering, called the User-Society-Enterprise (USE) program. The TU/e history group, together with the ethics group, delivers the opening course of that program. In fact, coming Monday 2000 students(!) will arrive for the first lecture of this year's course. They will discuss today's Grand Challenges for Engineering, and address the questions: How did engineers engage with such challenges in the past? And how can engineers navigate the ethical choices that such engagement entails? Let me give you a glimpse of these issues (for a systematic review, I refer to our recent book[18]).

Solving and Causing Challenges

The first observation is that engineers have engaged with social challenges for centuries. Indeed, modern engineering as we know it today emerged roughly 200 years ago in response to such challenges. Before that time, engineers were usually military engineers. They developed weaponry and fortifications for elite rulers. But in the 19th century this changed. For instance, governments started to build national infrastructure, creating welfare and security for their citizens. So they established Public Works agencies (in the Netherlands: Rijkswaterstaat) that trained and employed the first civil engineers. And to educate civil engineers, schools soon followed – these became our technical universities. Other social challenges were in enterprise: Entrepreneurs seized the technologies of the industrial revolution – steam engines and factory machinery – to establish technology-based companies, or to scale up and create more efficient production processes. They needed mechanical engineers, and this profession institutionalized, too. With the new electrical and chemical industries came electrotechnical and chemical engineering, and with the management challenges of large companies came industrial engineering. More engineering branches followed. Conclusion: it was in response to societal and business challenges that engineering as a civil profession emerged. Ever since, the engineering profession has progressed by interacting closely with such challenges.

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[17] Meijers and van den Brok, *Engineers for the Future*.
[18] Van der Vleuten, Oldenziel, Davids, *Engineering the Future*.

A second observation: While engaging with social challenges for over two centuries, engineers have of course had their fair share of the more thorny issues. Engineering a better future was never straightforward. Engineers have seen some well-intended innovations turn into nightmares. For example: generations of engineers have worked on building an energy system that could get energy cheaply and reliably to our businesses and households; they democratized energy access. Challenge solved. But they built this system to a large extent on fossil fuel inputs, which in time caused new challenges – geopolitical energy dependencies, resource depletion, and climate change.

Chemist Fritz Haber embodies the clash of beneficial and harmful technology – in one person. In 1918, he received the Nobel Prize in Chemistry for the Haber process, used to make artificial fertilizer that greatly reduced world hunger. A technical solution to a tremendous social challenge. But during the First World War, the German military hired Haber to develop poison gas. Haber's team used their chemical knowledge to develop chemical warfare. (He was not alone: the American Chemical Society pledged the aid of its 15,000 members to US gas warfare capabilities, for example). Haber's standpoint, to "serve mankind in peace, and the fatherland in war" is still food for ethical discussions today.[19]

Two approaches to engineering better futures – and avoiding nightmares

A third observation: Confronted with such dilemmas, engineers developed ways to engineer better futures – while avoiding new nightmares. They realized that even engineers cannot predict the future, much less control it – there are too many stakeholders and complexities. They have, however, tried to navigate this situation. For our students, we summarize these experiences in two idealtypical approaches.

The first is what we call the technocratic approach. It rose to prominence in the postwar decades, from the late 1940s to the 1960s (the groundwork was laid earlier). Putting it bluntly, the thinking was: warring politicians and profit-seeking business people had steered technology towards two world wars, worker exploitation, and the Great Depression. So were these the right people to make key innovative decisions for tackling social challenges? Engineers and other experts should do that – basing their decisions *not* on political ideology or profit, but on scientific reasoning: analyzing every aspect of the problem, and making the best choices with the resources available.

[19] Fritz Haber, "Chemical Warfare," *Nature* 109 (1922): 40.

How? Experts translated the complex issues into engineering challenges using systems theory. This meant identifying the many technical and social components of a problem and the relationships between these components. They then modeled the problem as a 'system' with interacting elements (this interdisciplinary capability, by the way, was said to distinguish engineers from natural scientists). By manipulating the individual components in their model, they could simulate the effects on future system behavior – and thus detect any harmful scenarios and search optimal solutions.

The development of computer modeling greatly helped these efforts. For instance, computer engineer Jay Forrester and his MIT digital computer lab had developed the Whirlwind computer for the military as part of an air defense system. They were at the forefront of computer engineering – developing real time control, parallel processing, and magnetic core memory. Forrester and his team also developed *system dynamics*, and used their computer to simulate complex technological, urban, industrial challenges as dynamic interactive man-machine systems. Forrester studied the industrial conglomerate General Electric, which had become too complex to manage, as "a system in which the flows of information, materials, manpower, capital equipment, and money [determine] growth, fluctuation, and decline".[20] This led him to find solutions for very complex production and labor problems – solutions that felt counter-intuitive to managers, who according to Forrester lacked a systemic view, and tended to mistake the symptom for the cause.

The technocratic approach gave engineers responsibility for solving social challenges; it required scientifically and ethically trustworthy engineers who were up to the task. So technical universities stepped up their science & theory teaching (only now the term 'engineering *science*' became hegemonic, even in countries where engineering had predominantly been an 'art'). Curricula now featured social science and humanities courses, since engineers had to integrate technical and social concerns in their systemic approaches to complex problems – and besides, they would become societal and business leaders. Engineering associations changed their professional code of ethics: In their old-style codes, employers came first: "the engineer should consider the protection of a client's or employer's interests his first professional obligation", read the American Institute of Electrical Engineers' code in 1912.[21] New codes stressed autonomous

[20] As quoted in: Edwards, "The world in a machine", 236.

[21] As quoted in: Mitcham, "A historico-ethical perspective," 39. On ethical codes: van de Poel and Royakkers, *Ethics, technology, and engineering*, 31-66.

Jay Forrester in front of the Whirlwind computer in 1957. Forrester developed system dynamics to simulate complex technological, urban and industrial problems. Later he would simulate world resource problems for the Club of Rome. Source: MIT Museum.

engineering values, serving the public first. For example, the Verein Deutscher Ingenieure stated that the German engineer should work "with respect for the dignity of human life so as to fulfil his service to his fellow men without regard for distinctions of origin, social rank, and worldview".[22] Our ethics colleagues cover this subject in depth in their lectures.

A second approach to engineering the future without creating new nightmares is what we call the participative approach. It emerged in Western countries from the late 1960s (in China and some other places, technocracy endures today – most *politburo* members are engineers). It stemmed from critique on the technocratic

[22] As quoted in: Downey et al., "Engineering ethics", 471.

approach. A vocal group of engineers shared the critique and worked on a new approach.[23] The critique was that expert decision-making deliberately bypassed politicians (because they were not trusted), so escaped democratic control. Moreover, systems approaches tended to optimize systems for efficiency, not for human experience or environmental values. The solution: The system needed to be opened up to other people and values. And since stakeholders and citizens knew their own wants and values best, they should *participate* in technological decision-making and engineering better futures – instead of experts planning the future on their behalf.

So engineering associations and universities worked to make technology more 'applied' and 'humane' as they called it. They massively reintroduced design courses (at our TU/e: OGO) and set up Technology & Society programs (which I had the fortune to study at TU/e). University professors and students also let stakeholders participate in setting their agenda – working with industry as well as citizens, in the science shop movement. Also outside university, many engineers and scientists developed citizen science, working with volunteer citizens on

User-innovation: Volunteers at Tvind School in Denmark carrying a rotor blade for their modern self-made wind electric turbine in 1976. Other users would develop back-garden turbines. These initiatives inspired the later Danish wind turbine success story. Source: Collection Tvindkraft, Denmark.

[23] Wisnioski, *Engineers for Change*.

human-scale technology: renewable energy, recycling technology, appropriate technology for developing countries, technologies of everyday life, and so on. Other examples of the participative approach are user-centered innovation and participative design. Participative Technology Assessment mobilized stakeholders and citizens to identify the potential negative consequences of technological solutions *for them*, in order to feed these insights back into the technological decision-making and design process.

In sum: engineers developed two different approaches to engineer a better future and avoid new nightmares. Both had pros and cons (also the participative approach: sometimes it triggered open conflicts, proved very expensive, and was hijacked by certain parties). These two approaches existed side by side. At times they clashed, but today both belong in the engineering community's toolbox – an experience to draw on when addressing complex challenges.

This leads me to the Grand Challenges of Engineering today. One: clearly, engineers have engaged with social challenges for centuries. Two: it is equally clear that engineering a better future is not straightforward. Well-intended technological solutions can induce new challenges. The engineering community should not be naïve about this today. Nobody likes to hear it, but past experience suggests that today's solutions *can* be tomorrow's problems. Three: earlier engineers thought a lot about this, and devised ways to engineer better futures without creating new problems. These did not turn out to be perfect, with their own set of pros and cons. So the challenge today, it seems to me, is to develop new approaches that combine the best of earlier methods and avoid their shortcomings. There are many ongoing (and often conflicting!) initiatives by political, engineer, business, and user communities to address the great challenges of our times through innovation. We can study these initiatives as experiments with successes, setbacks, and conflicts. Which experiments will succeed and fail, only the future can tell. But we can monitor these experiments and systematize the learning process, just like we do in sustainability transition studies.

Challenging Clio: Towards a Research Agenda

Ladies and Gentlemen, we have seen that Prometheus – symbolic for engineering – is challenged to develop technologies that solve today's challenges. And we know this is not a straightforward task: innovation, challenges, and history relate in complex ways. Historians of technology, knowledgeable of technological *and* social change, are in a position to rethink history from a grand-challenges-for-engineering perspective. So, how do we connect the challenge for Prometheus with a challenge for Clio, the Greek muse and inspirational goddess who became the patron of history?

Prominent historians of technology like Wiebe Bijker, Arne Kaijser and others have already called for systematic historical investigation of global challenges.[24] We have taken up that challenge. The Foundation for the History of Technology SHT and our international research network are currently building a new research agenda – a successor program to our Technology & European History program.

In an explorative phase, thematic networks explore specific challenges. Examples: mobility & migration; health challenges; ICT and security challenges, and so on. [Local note: Eindhoven historians coordinate the program and are involved in several themes. Ruth Oldenziel and Frank Schipper in Sustainable Urban Mobility; Frank Veraart, Jan Pieter Smits and Harry Lintsen in Global Resource Chains; and Karena Kalmbach co-organizes Cultures of Crisis]. These teams of scholars ask: what are the crucial research questions and how will we investigate them?

At the same time, we formulate relevant research questions across themes, the 'big questions' for history. To conclude this lecture, let me mention seven such 'grand challenges' in my field.

Challenge 1: How to study crises in time? One challenge is to overcome our current chronocentrism: a mental lock-in on present-day obsessions as the only ones that matter, and an inability to see beyond these. How to overcome such temporal

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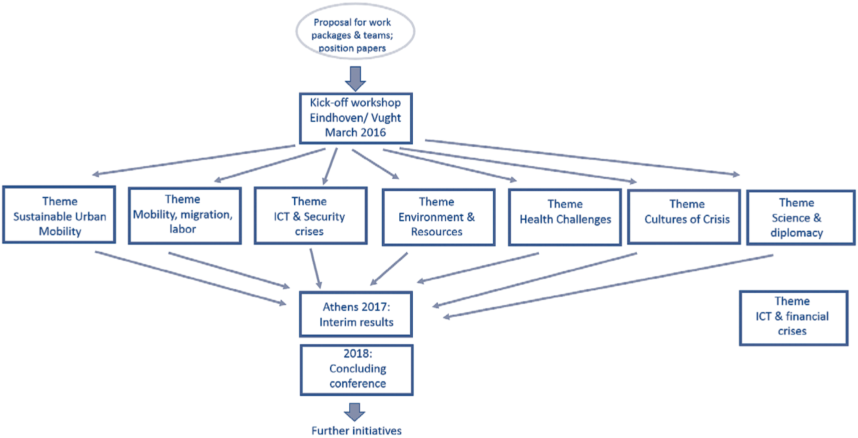
[24] Bijker, "Globalization and Vulnerability"; Kaijser, "New Challenges"; Schot, "Confronting the second deep transition."



Research program 'Technology and Societal Challenges 1815-today', explorative phase.

short-sightedness? Should we compare present-day crises with past ones? For example, do we actually have more refugees today than in past refugee crises (we do not); are our security crises greater (they are not); and are our challenges similar in the first place (probably not)? More questions: What historical challenges existed, who invented and prioritized the solutions and why, and how do these past solutions affect today's crises and challenges? Besides, how does crisis time work anyway? Some crises are incidents (like natural disasters), others are long in the making (soil subsidence or climate change), still others are cyclical (financial crises).

Challenge 2: How to study crises in space? Can we overcome eurocentrism – a similar mental lock-in on our geographically-based world view? For example, Frank Veraart, Jan-Pieter Smits and Harry Lintsen are working on the history of global resource chains: biofuels might be sustainable for German users, but not for Malaysians burning rain forests to make way for palm oil plantations. How to study such global connections? Besides, how does the spatiality of crisis work? Many Grand Challenges are global – the 1987 financial crisis hit the New Zealand stock exchange hard. Others are geographically contained – the 2010 flash crash did not cross borders. Why? Can we advance the transnational analysis developed for our European history project, to investigate why spatial categories emerge and disappear, compete and co-evolve, transfer and contain crises?[25]

[25] van der Vleuten, "Toward a transnational history."

Challenge 3: How to study crises across domains? The challenge here is to transcend 'domain-centrism.' Most political and research programs – including our own – are domain-specific: migration, health, or security challenges etc. However, in real life these are not isolated domains: multiple crises interact.[26] Political and academic think tanks acknowledge this in multi-domain programs such as Inclusive Green Growth or the Water, Energy and Food Security Nexus. Can historians show why and by whom domains become historically entangled, and how specific historical choices in these entanglements shape later cross-domain crisis dynamics? And just like some crises do not cross geographic boundaries (see our previous challenge), most actually do not cross domain boundaries and are contained – why?[27]

Challenge 4: How to study crisis as simultaneously imagined and real? For the 2006 blackout, we have vastly diverging interpretations (was it even a crisis?). The same goes for today's grand challenges: these are partly political and media events, hyped to get readers, votes, research funding etc. – also by scientists and engineers, as Harro van Lente, Arie Rip and others remind us.[28] Yet we cannot belittle this phenomenon as hype. For example, my group has worked closely with the Greek history of technology community for many years. When we hear firsthand about people losing jobs, suffering in the streets, and dying on their shores, calling financial and refugee crises 'hypes' seems a bit of an insult. So how do we study the simultaneously real, social, and imagined notion of grand challenges, to paraphrase Bruno Latour?[29] I hope that our Cultures of Crisis team can help us out here.

Challenge 5: How do crises relate to radical historical change? Today's multiple crises call for radical change in the direction of a sustainable society. How does such change work? How well do we understand *historical* radical changes? Johan Schot and others have developed a promising approach in the sustainability transitions field. I find it promising because it combines time, space, cross-domain dynamics, and what is real and imagined. They call it "deep transitions": radical historical change happens when developments in many different domains interact, on interacting spatial scales, in reality and in our imagination (e.g. as expectations). The infrastructure transition of the past 150 years that we recently

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[26] Beck, *World at Risk*.
[27] Luijf et al. "Empirical findings."
[28] Beck, *World at Risk;* Cottle, "Global crises in the news"; Bos and van Lente. "Unpacking the grand challenges"; Rip,"Science institutions and grand challenges."
[29] Latour, *We have never been modern*, 7.

studied is one example: Infrastructure industries, economic sector developments, warfare, urban developments, and changes in nature became entangled on a local, national and transcontinental scale, in imagined and lived reality; these mutually reinforcing entanglements produced unprecedented historical changes that have altered society and nature beyond recognition. These interactions along multiple dimensions are complex and unpredictable, but can be historically disentangled – history as complexity science indeed.[30] So historians and transition scholars should continue working together to develop an understanding of radical historical change.

Challenge 6: How to better understand engineering challenges *as well as* history? How do we make history relevant as well as good?[31] Making history relevant means engaging with the big questions of our time, and with the scholars and stakeholders working on these challenges today. [Local note: On the theme of Sustainable Urban Mobility, Ruth Oldenziel, Hans Jeekel and Frank Schipper collaborate with various university departments, Rijkswaterstaat, and Pon Holdings.[32] Rijkswaterstaat's Bert Toussaint has also developed a "usable past" approach, informing better engineering today.[33] Our history group can work with experts on different challenges at this university and the TU/e Center for Humans & Technology].

On the other hand: to make good history, historians need to keep some distance from the political agendas: the 20th century has seen the severe abuse of historians for political purposes. Professional historical standards require professional autonomy (just like engineering, as we saw when discussing technocracy). Scholarship can be compromised when present-day questions lead to the historical fallacy of "presentism" or "anachronism" – misreading history because of present-day bias. Can we save *anachronic* history – asking questions relevant today – from *anachronism* as a fallacy, as historian of science Helge Kragh argued?[34] Can we make a history that is both relevant *and* better, as our Technology and European History program did – uncovering crucial historical experiences that existing histories had overlooked?

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[30] Schot,"Confronting"; Högselius at al, *Europe's Infrastructure Transition*.
[31] For an intelligent discussion: Lundin, "Making History Matter."
[32] http://www.cyclingcities.info/ (consulted April 16, 2017).
[33] Toussaint,"Using the Usable Past."
[34] Kragh, *Introduction to the historiography of science.*

Challenge 7: Finally, how to connect to ethics? Dealing with the world's great challenges leads us to descriptive and analytic, but also normative questions. As a historian of technology greatly influenced by Max Weber's philosophy of science, I have always found it difficult to cross the divide between "what is" and "what should be". Social historian Marc Bloch, who I cited earlier, put it much more strongly: he called the "mania" for making normative judgments a "satanic enemy of true history".[35] However, working with the Philosophy and Ethics group has convinced me that there is still a world to win here. Andreas Spahn, with his usual humor, sometimes lectures me about what ethics can do nowadays, and I want more of that. Our new research program is already benefiting from a novel joint history-ethics project – I can hardly wait for the insights it will bring.

These were my grand challenges for the history of technology. The conclusion: Historians of Technology, too, have some serious work to do!

35 Bloch, *The historian's craft*, 26.

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References

Beck, Ulrich. *World at Risk*. Cambridge: Polity Press, 2009.

Bijker, Wiebe "Globalization and Vulnerability: Challenges and Opportunities for SHOT around Its Fiftieth Anniversary," *Technology and Culture* 50.3 (2009): 600-61.

Bijker, Wiebe, Thomas Hughes, Trevor Pinch, *The social construction of technological systems: New directions in the sociology and history of technology*. Cambridge, MA: MIT Press, 1987.

Bloch, Marc. *The historian's craft*. Manchester: Manchester University Press, 1954: 55.

Boin, Arjen, Magnus Ekengren, Mark Rhinard. *The European Union as crisis manager*. Cambridge University Press, 2013.

Bos, Colette, Harro van Lente. "Unpacking the grand challenges of nanotechnology." In: *Innovation and Responsibility*, edited by C. Coenen et al. Akademische Verlagsgesellschaft, 2014: 165-71.

Cottle, Simon. "Taking global crises in the news seriously." *Global Media and Communication* 7, 2 (2011): 77-95.

Diogo, Maria Paula, Dirk van Laak. *Europeans Globalizing*. Palgrave, 2016.

Downey, Gary Lee, Juan C. Lucena, Carl Mitcham. "Engineering ethics and identity: Emerging initiatives in comparative perspective." *Science and Engineering Ethics* 13, 4 (2007): 463-87.

Edwards, Paul N. "The world in a machine: Origins and impacts of early computerized global systems models." In: *Systems, experts, and computers: The systems approach in management and engineering*, eds. Agatha and Thomas Hughes. Cambridge, MA: MIT Press, 2000: 221-54.

Fickers, Andreas, Pascal Griset. *Communicating Europe*. Palgrave, in press.

Grin, John, Jan Rotmans, Johan Schot, *Transitions to sustainable development: new directions in the study of long term transformative change*. London: Routledge, 2010.

Haber, Fritz. "Chemical Warfare," *Nature* 109 (1922): 40.

Hughes, Thomas P. *Networks of power: Electrification in Western society, 1880-1930*. Baltimore: JHU Press, 1983.

Högselius, Per, Arne Kaijser, Erik van der Vleuten. *Europe's Infrastructure Transition: Economy, War, Nature*. Houndmills: Palgrave, 2015.

Kaijser, Arne. “The Trail from Trail: New Challenges for Historians of Technology,” *Technology and Culture* 52.1 (2011): 131-142.

Kalmbach, Karena. “Radiation and borders: Chernobyl as a national and transnational site of memory,” *Global Environment* 11 (2013): 130-59.

Kohlrausch, Martin, Helmuth Trischler. *Building Europe on Expertise. Innovators, Organizors, Networkers*. Palgrave, 2014.

Kragh, Helge. *An introduction to the historiography of science*. Cambridge University Press, 1987.

Lagendijk, Vincent. *Electrifying Europe*. Amsterdam: Amsterdam University Press, 2008.

Lagendijk, Vincent, Erik van der Vleuten. “Inventing electrical Europe: interdependencies, borders, vulnerabilities.” In: *The Making of Europe’s Critical Infrastructure*, eds. Per Högselius et al. Houndmills: Palgrave, 2013: 62-101.

Lintsen, Harry et al. (eds). *Geschiedenis van de Techniek in Nederland. De wording van een moderne samenleving 1800-1890*. 6 Volumes. Zutphen: Walburg Pers, 1992-1995.

Latour, Bruno. *We have never been modern*. Harvard University Press, 1993.

Luijf, Eric et al. “Empirical findings on critical infrastructure dependencies in Europe,” *International Workshop on Critical Information Infrastructures Security*. Springer Berlin Heidelberg, 2008.

Lundin, Per. “Making History Matter: The Historian as Expert.” *Mobility in History* 7, 1 (2016): 7-16.

Meijers, Anthonie, Perry van den Brok. *Engineers for the Future. An essay on education at TU/e in 2030*. Eindhoven: 2013.

Misa, Thomas J., Johan Schot, “Inventing Europe: Technology and the hidden integration of Europe,” *History and Technology* 21.1 (2005): 1-19.

Mitcham, Carl, “A historico-ethical perspective on engineering education,” *Engineering Studies* 1, 1 (2009): 35-53.

Mote, C.D., Ann Dowling, Ji Zhou. “The Power of an Idea: The International Impacts of the Grand Challenges for Engineering,” *Engineering* 2.1 (2016): 4-7.

Oldenziel, Ruth, Mikael Hård. *Consumers, Users, Rebels. The People who Shaped Europe*. Houndmills: Palgrave, 2013.

Perrow, Charles. *Normal accidents: Living with high risk technologies*. New York: Basic Books, 1984.

Rip, Arie. “Science institutions and grand challenges of society.” *Asian Research Policy* 2,1 (2011): 1-9.

Roe Smith, Merritt, Leo Marx (eds). *Does technology drive history? The dilemma of technological determinism*. Cambridge, MA: MIT Press, 1994.

Schot, Johan et al. (eds). *Techniek in Nederland in de twintigste eeuw*. 7 Volumes. Zutphen: Walburg Pers: 1998-2003.

Schot, Johan. "Confronting the second deep transition through the historical imagination," *Technology and Culture* 57.2 (2016): 445-456.

Schot, Johan, Wolfram Kaijser. *Writing the Rules for Europe. Experts, Cartels, International Organizations*. Houndmills: Palgrave, 2014.

Sörgel, Herman. *Die drei grossen "A". Grossdeutschland und Italienischen Imperium, die Pfeiler Atlantropas.* Munich: Piloty & Loehle, 1938.

Toussaint, Bert. "Using the Usable Past: Reflections and Practices in the Netherlands." In: *Transport Policy: Learning Lessons from History*, edited by Colin Divall et al. Farnham: Ashgate, 2015.

UCPTE. *Rapport annuel 1976-1977*. Arnhem: UCPTE, 1977.

UCTE. *Final report. System Disturbance on 4 November 2006.* Brussels: 2007.

van der Vleuten, Erik. "Toward a transnational history of technology: meanings, promises, pitfalls," *Technology and Culture* 49.4 (2008): 974-994.

van der Vleuten, Erik, Vincent Lagendijk. "Transnational infrastructure vulnerability: The historical shaping of the 2006 European ''Blackout''", *Energy Policy* 38 (2010): 2042–2052.

van der Vleuten, Erik, Vincent Lagendijk. "Interpreting transnational infrastructure vulnerability: European blackout and the historical dynamics of transnational electricity governance," *Energy Policy* 38 (2010): 2053–2062.

van der Vleuten, Erik, Ruth Oldenziel, Mila Davids. *Engineering the Future, Understanding the Past. A Social History of Technology.* Amsterdam: Amsterdam University Press, 2017.

van Houten, B.C. "Techniek-geschiedenis: een historiografische beschouwing", *JbGBT* 3 (1986): 15-42.

van Santen, Rutger, Djan Khoe, Bram Vermeer. *The thinking pill and other technology that will change our lives.* Amsterdam: Neuwe Uitgevers, 2007.

van Santen, Rutger, Djan Khoe, Bram Vermeer. *2030: Technology that will change our world.* Oxford: Oxford University Press, 2010.

van de Poel, Ibo, Lambèr Royakkers. *Ethics, technology, and engineering*. Malden, MA: John Wiley, 2011.

Wisnioski, Matthew. *Engineers for Change: Competing visions of technology in 1960s America*. Cambridge, MA: MIT Press, 2012.

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