FORUM: GRAND CHALLENGES

History and Technology in an Age of "Grand Challenges"

Raising Questions

ERIK van der VLEUTEN

ABSTRACT: This essay introduces the forum about history and technology in an age of "grand challenges." First, it sketches present-day political and engineering debates on technology's role in solving or causing "grand societal challenges," which allegedly threaten humanity and the environment. This raises the question if, why, and how historians of technology can and should engage with these intellectually tricky and politically charged debates. The essay then presents the initiative of the Tensions of Europe network to develop transnational research groups and research agendas exploring this question, and introduces the five research agendas published in this forum. Finally, it raises five overall "grand challenges" to the field: How can we trace the histories of technology and grand societal challenges across temporal, spatial, sectoral, methodological, and political divides?

This *T&C* forum explores if, why, and how the field of history of technology can and should engage with ongoing debates on "grand societal challenges." Over the past decade or so, political, media, and scholarly debates have increasingly focused on the multiplication of social and environmental crises that seem to haunt our present-day world—from climate change and other environmental threats to increasing inequality; mass migration, financial, and security crises; deteriorating megacities; the threatened breakdown of unsustainable mobility, energy, and health systems, and more. Policymakers have devised programs to address these so-called grand challenges, such as the UN Sustainable Development Goals, the EU Societal Challenges, and myriad other programs of a similar nature. Scholars study the real, imagined, and contested features of these crises; discuss whether or not these characterize our current age and, perhaps even an

Erik van der Vleuten is professor of the history of technology at Eindhoven University of Technology, chair of its History Lab, and scientific director of the Foundation for the History of Technology SHT. He coordinates the global grand challenges program initiated by the Tensions of Europe research network.

0040-165X/20/6101-0009/260–71

earth-systemic state shift, the Anthropocene; and rethink research questions, perspectives, and concepts.[1]

Technology features prominently in these discussions. It counts both as a cause of, and as a solution to, today's social and environmental crises. From the greenhouse gas emissions and global inequalities of energy, transport, production, and consumption systems to technologies of (anti)-terrorism and ICT-shaped financial crises to the promises of smart, responsible, and sustainable innovation: technology seems to pervade most, if not all, of today's grand challenges and the debates about them. Indeed, digital knowledge infrastructures and media technologies shape our very identifications and interpretations of current challenges and potential solutions.[2]

Technology's pivotal role in today's societal challenges is underscored, but also complicated, by the bold claims of technology's main protagonists. Engineering community spokespersons have translated humanity's global challenges into the so-called grand challenges of engineering that engineers need to solve if we are to "ensure that human life as we know it can continue on this planet"—so say the presidents of the U.S., UK, and Chinese academies of engineering in a common manifesto.[3] Their argument: modern technology has solved major challenges before—clothing, housing, and feeding over 7 billion people, for example—and can do it again. And if technology *caused* some of today's problems, that, too, implies it holds the key to the solution.[4] This discourse to save the planet through innovation is widely shared by engineering associations, schools, and companies across the globe. However, this well-intended yet self-interested discourse is also problematic, because it tends to monopolize the problem definition and solution, silencing alternatives and ignoring the politics of technology and knowledge. Besides, science and technology studies (STS) scholars remind us, science and technology institutions also adopt "grand challenge" talk strategically in ongoing resource and reputation races.[5] It is imperative to identify the notion of "grand challenges" as a contested actor-defined concept.

Can and should the field of history of technology engage with such debates? And if so, how? Can we relate to, but not uncritically adopt, the language of technology's protagonists as well as its critics? Surely there is a

1. See, for example, Charles Perrow, *The Next Catastrophe*; Ulrich Beck, *World at Risk*; Manuel Castells et al., *Aftermath*; Jason W. Moore, *Anthropocene*; Christophe Bonneuil and Jean-Baptiste Fressoz, *Shock of the Anthropocene*.

2. Paul N. Edwards, "Knowledge Infrastructures"; Simon Cottle, "Rethinking Media and Disasters."

3. C. D. Mote et al., "Power of an Idea"; José R. Silva et al., "Era of Engineering Grand Challenges."

4. Rutger van Santen et al., *2030*; Rutger van Santen et al., *The Thinking Pill*.

5. Arie Rip, "Science Institutions and Grand Challenges"; Colette Bos et al., "Steering with Big Words"; Stefan Kuhlmann and Arie Rip, "Next-Generation Innovation Policy." See also Diana Hicks, "Grand Challenges in US Science Policy."

JANUARY
2020
VOL. 61

huge empirical basis for historical studies of technology and "grand challenges": the historical record is rife with social and environmental crises, and technology and technologists have long played their ambivalent roles as prominent cause and solution to such crises. Indeed, ever since the (civil) engineering profession's inception about two centuries ago, social challenges have co-shaped its research and innovation agendas, and technical solutions have co-produced new social and environmental problems that later generations of technologists again set out to solve.[6] A historical perspective can uncover these and many other long-term technological dynamics of crisis.

The transdisciplinary field of history of technology should be in a privileged position to develop historical interpretations and narratives of technology and grand societal challenges, for it has long studied the ambivalent interactions of technological, social, and environmental change. In the past decade, a number of colleagues have advocated this direction of study.[7] Others feel uncomfortable with political agendas and hype (including that surrounding "grand societal challenges") setting their research agenda. How can the field proceed in this intellectually tricky and politically charged debate? The following forum explores this challenge and discusses possible research topics and questions for a history of technology in an age of grand challenges. It asks what history of technology sensitivities and insights are relevant to current public and academic grand challenge debates, and, conversely, what new historical questions present-day debates may inspire. What are the challenges, opportunities, and pitfalls involved?

Forum Background and Contributions

The forum springs from a collaborative explorative research initiative of the Tensions of Europe research network. That initiative succeeds this network's previous program on the role of technology in European integration and fragmentation. At a meeting in the Netherlands in spring 2016 we formed a number of transnational working groups to build scholarly networks, identify relevant existing literature, and articulate research questions and agendas for particular grand challenges. Later, other teams were added either by invitation or on their own initiative; any serious scholarly group wishing to contribute to this historiographical exploration was and is welcome. By early 2019 that joint effort had resulted in over two dozen workshops and conferences, in which many relevant themes were debated

6. Erik van der Vleuten et al., *Engineering the Future*.

7. Wiebe Bijker, "Globalization and Vulnerability"; Arne Kaijser, "The Trail from Trail"; Finn Arne Jørgensen and Dolly Jørgensen, "The Anthropocene"; Johan Schot, "Confronting the Second Deep Transition"; Helmuth Trischler, "The Anthropocene"; Maria Paula Diogo et al., "Uncanny Nature."

with an ever-increasing number of interested and engaged scholars.[8] This forum presents tentative findings from five of these working groups.

We start by de-essentializing and historicizing the notion of crisis that informs much grand challenge discourse. In their contribution, Karena Kalmbach, Anna Åberg, and Andreas Marklund propose to investigate the historical interaction between crisis narratives and technological choices. They speak of a triple temporality of crisis: in periods of widespread anxiety, cultural memories and experiences of *past* crises and fears of *future* calamities were often combined into novel contemporary crisis imaginaries mediating contemporary technology choices. The authors illustrate this mechanism with examples from the realms of national security, nuclear energy, and space mining.

The next three contributions focus on a specific challenge domain. Matthias Heymann, Elena Kochetkova, Per Högselius, Ole Sparenberg, John Martin, Anna Åberg, and Frank Veraart place present-day debates on resource security in historical perspective. The authors raise historical questions about the cultural construction of such notions as "resources," "scarcity," and "resource crises"; highlight the spatial variety and connections of local, national, and global resource flows and associated global socioecological entanglements; and address the roles and limits of experts and expertise in the governance of resource crises and reconfiguration of natural environments.

Next, Ute Hasenöhrl and Jan-Henrik Meyer historicize current debates on "energy challenges" and "energy transition." They argue that historical research can uncover and unpack how past and present energy transitions are embedded within broader societal transitions, highlighting normative and perceptive changes as well as asymmetrical power relations. As important avenues for future research, they emphasize the long history of renewables in past social and environmental contexts; the historical roots, shaping, dynamics, and implications of today's incumbent fossil-fuel and nuclear-based energy systems; and the historical study of forces of change at work in past and present energy transitions.

Reporting from the research network on the sustainable urban-mobility challenge, Frank Schipper, Martin Emanuel, and Ruth Oldenziel enlist the notion of the "usable past" to identify historically shaped opportunities and barriers for mobility policies in cities across the globe. They confront expert discourses and social practices when historicizing today's dominant automobility-based urban-mobility systems, retrieving sidelined practices of low-emission mobilities such as pedestrianism and cycling, and identifying infrastructure and social-practice legacies on which sustainable mobility

8. Erik van der Vleuten, "Technology, Societal Challenges." See also "Technology and Societal Challenges, ca. 1815–2015" at www.tensionsofeurope.eu/second-flagship-program-technology-societal-challenges (last consulted 30 August 2019).

JANUARY
2020
VOL. 61

politics can be built. In this context they speak of a "U-turn from the present via the past to the future" in mobility history as well as policymaking.

The last contribution, finally, transcends specific crisis domains and queries the governance of science and technology in an age of grand challenges. More specifically, Efstathios Arapostathis and Leonard Laborie observe a co-shaping of global challenges and the governance of science and technology. They use the concept of science diplomacy to probe entanglements of technology, science, diplomacy, and diplomatic relations. They ask how democracy is at stake in such processes and make an argument for the historiography of science and technology to interact with political/civil society and scientific stakeholders in order to critically integrate historical stakeholder experiences into meaningful and relevant historical narratives.

"Grand Challenges" for the History of Technology

In addition to research questions for specific crisis domains and perspectives, the notion of a history of technology for an age of grand challenges also raises more fundamental and generic historiographical questions. These questions lead us into broader historiographical debates. By way of concluding this introductory essay, let me here briefly raise some of these broader questions—about the temporality, spatiality, sectorality, methodology, and politics of (the study of) technology and crises.

First, how should we locate technology and grand challenges in time? The contributors to this forum feel that historians can and should challenge the chronocentrism of many present-day public, political, and academic debates. Each contribution articulates different answers to Paul Edwards's provocative question: "Does it make any difference how the current state of affairs emerged?"[9] However, this challenge may also require us to rethink conventional periodizations and caesura, and even to problematize the distinction between past, present, and future. For example, the integrated study of humans, technology, and environmental crises leads us to institutional divides in the study of the past and to the Anthropocene literature's research challenge of bridging human time (history) and nonhuman time (geology, ecology), which requires transcending singular and linear time frames.[10] Can parallel interacting temporalities such as Braudel's events, conjunctures, and *longue durée* help interconnect, for example, terrorist attacks, financial crises, and climate change? Should we reactivate Ernst Bloch's notion of the simultaneous manifestation of nonsimultaneous historical trajectories that we know from technology history (e.g., tanks equipped with mail pigeons) as well as crisis history (unpre-

9. Gabrielle Hecht and Paul N. Edwards, "Taking on the Technosphere."

10. Helmuth Trischler and Fabienne Will, "Technosphere, Technocene"; Chakrabarty, "Anthropocene Time"; Chris Lorenz, "'Times They Are a-Changin.'"

dictable accumulations of diverse historical contingencies)? How can we mobilize the historiographies of reverberating technologies and crises through time—for example, studies of crisis aftermaths and technologies' afterlives, or conflicting and evolving cultural remembrances of technological crises such as Chernobyl 1986?[11] And as we have seen, contributions to this forum also connect past, present, and future, asking questions about the role of imagined futures in contemporary crisis experiences, and the relevance of past sociotechnical practices and experiences for achieving a more sustainable future (the "U-turn to the future" that brings, for example, renewable energy technologies or cycling to sustainability policymaking). Finally, while exploring these matters of temporality, can we avoid reproducing once more the unreflective imposition of Western (sometimes technology-based) time frames on the non-Western world that postcolonial historians have criticized so fiercely?[12]

This leads us to a second set of questions about situating technology and grand challenges in *space*. Much technology, and most present-day crises, display global dynamics or ramifications. Most contributors to this forum would agree that these cannot be properly studied in geographical isolation, much less from a Western-centric perspective. However, spatial delineation of the research topic remains a much-cited research virtue, and despite decades of critique, Western-centric historiography still thrives. How can we further strengthen histories situated in the Global South, bringing to the table a broader variety of perspectives on, for example, technology, crises, sustainability, and the Anthropocene? Should we connect such histories to Western/Global North histories or not, and if so, why and how? And considering the constant renegotiation of technology and crisis meanings on-site in specific local and social settings, can we avoid either ignoring or essentializing spatial difference?[13] The literature on global and transnational history of science, technology, and business offers ways to study technology-mediated connections across conventional spatial delineations such as Global North/South, Western/non-Western, local /nation-state/Europe/world systems, and center/periphery. That literature speaks of multiple geographies and warns against unacknowledged reproduction of conventional spatial categories as essentialist units of historical experience, as for example much nation-centric African history, comparative history, and transfer history once did. Instead, it suggests the symmetrical study of the (un)making of spatial connections and boundaries, in-

11. Rosalind Williams, "Rolling Apocalypse"; Heike Weber, "'Entschaffen'"; Susanne Bauer et al., "From Pripyat to Paris."

12. David Arnold, "Europe, Technology, and Colonialism"; Francesca Bray, "Flows and Matrices."

13. David Arnold, "Europe, Technology, and Colonialism"; Francesca Bray, "Flows and Matrices"; Jonas van der Straeten and Ute Hasenöhrl, "Connecting the Empire"; Gabrielle Hecht, *Entangled Geographies*; Gabrielle Hecht, *Being Nuclear*; Evelien De Hoop and Saurabh Arora, "Material Meanings."

JANUARY
2020
VOL. 61

cluding the continued relevance of classic historical formations such as the city, the nation, or world systems that persist despite multiple connections piercing their borders.[14] Moreover, Arne Kaijser has emphasized that transnational history is also a social challenge, requiring multinational research teams.[15] Though a few hundred scholars participated in the workshops informing this forum, the vast majority are European or North American, begging the question of how to better and meaningfully engage non-Western voices, both scholarly and lay.

Third, we may need to trace technology and crisis not only across temporal and spatial borders but also across sector borders (e.g., between energy, transport, food, financial, security, and military systems). Policymakers acknowledge this challenge in multisector programs such as "Inclusive Green Growth" programs or the "Water, Energy and Food Security Nexus." However, most political and research programs—including our own—tend to reproduce a single-sector focus. Can we transcend sector-centrism next to chronocentrism and Eurocentrism? Ongoing research on connected transitions or deep transitions across multiple sociotechnical systems suggests different actors and arenas germane to the study of cross-sector crises and transitions. These include system builders who entangle different sociotechnical systems (system entanglers); users in the consumption junction; mass media; governance actors; and metarules governing the dynamics of multiple systems.[16] As for time and space, the trick seems to be addressing crisis and transition across, as well as within, sector boundaries. For example, empirical studies of incident reports across critical infrastructure sectors found that crises regularly cascaded across sector boundaries, but also that most crises were contained within a few cascade pathways or particular sectors and died out before cascading into catastrophic societal collapse.[17]

The historical study across sectoral divides leads us to a fourth set of questions, about inter- and transdisciplinarity, and particularly about the methodological pluralism needed to track technologies and grand challenges across and within sector boundaries. The virtues of interdisciplinarity have been amply advocated, and the field of history of technology has long positioned itself as an interdisciplinary—and sometimes a transdisciplinary—discipline.[18] It is when we turn to methodology that many scholars hit the brakes, for what counts as good knowledge and good knowledge

14. Erik van der Vleuten, "Transnational History of Technology"; Simone Turchetti et al., "Have We Ever Been 'Transnational'?"; Marten Boon, "Business Enterprise and Globalization"; Michael Werner and Bénédicte Zimmermann, "Beyond Comparison"; Erik van der Vleuten and Torsten Feys, "Borders and Frontiers."

15. Kaijser, "The Trail."

16. Per Högselius et al., *Europe's Infrastructure Transition*; Schot, "Confronting"; Erik van der Vleuten, "Radical Change"; Laur Kanger and Johan Schot, "Deep Transitions."

17. Michel van Eeten et al., "The State and the Threat."

18. Melvin Kranzberg, "At the Start."

production remains central to much academic identity and boundary work. Methodological divides between the "two cultures" of the humanities and the sciences seem especially difficult to bridge.

And yet here, too, the notion of crisis seems to inspire crossovers. For example, discussions on mixed qualitative and quantitative methods have long been a rarity in the field of history of technology. Yet colleagues in the resource-challenge working group have recently combined quantitative sustainability measurement and historical time series with qualitative study of historical actor articulations of societal problems in order to track (un)sustainable development in time and space. What possibilities and pitfalls do such mixed-method approaches imply for the study of technology and grand challenges?[19] Likewise, notions of crisis (not least a "crisis of the humanities") feature in crossovers between history and computer science (i.e., digital history and the digital humanities). And the crisis-of-all-crises concept of the Anthropocene, according to Helmut Trischler, has become a trading zone for cross-disciplinary encounters between the humanities and the sciences, with—Trischler proposes—historians as prominent traders.[20] Should and can we live up to that promise and extend it to mixed-method methodologies?

This leads us to a fifth set of questions about the relationship between history and politics. All contributors to this forum feel that it is important to engage with the big issues of our time and bring in sociotechnical dynamics and inequalities into technology and crises research. Yet in our internal discussions, they disagreed about *how* to engage. Some cherish the divide between professional history and politics; reminiscent of the many abuses of history for political purposes in the nineteenth and twentieth centuries, they insist on studying the dynamics of technology and crises without preference for political priorities, public hype, or commercial interests (which, of course, in itself is a political choice). Others explicitly seek to *intervene* in ongoing political, public, and business debates and *interact* with relevant stakeholders; they build on such concepts as "policy-oriented history," "the usable past," knowledge "co-creation," and other ways of interfacing between history and policy.[21] How should scholars balance professional integrity and relevance? Or should we emphasize that this is not a zero-sum game and disentangle the question of history's contributions to policy, on one hand, from current policy debates inspiring innovative historiography, on the other? And can a rich tradition of STS

19. Harry Lintsen et al., *Well-Being, Sustainability and Social Development*; Frank Veraart et al., "Connected by Oil."

20. Andreas Fickers, "Towards a New Digital Historicism?"; Trischler, "The Anthropocene," 328–29.

21. Also compare Colin Divall, "Mobilizing the History of Technology"; Richard Hirsh, "Historians of Technology"; Richard Hirsh and Christopher Jones, "History's Contributions to Energy Research"; Per Lundin, "Making History Matter"; Colin Divall et al., *Transport Policy*.

work on the politics of knowledge help us be more reflective about the politics of our own knowledge-producing and disseminating activities, be it in an ivory tower or stakeholder co-creation mode?

Meaningfully and reflectively engaging across professional, intellectual and experiential divides in time, space, sector, methodology, and politics seem to me "grand challenges" for the history of technology in an age of "Grand Challenges." Needless to say, the questions raised here, like the other questions raised in this forum, are explorative and tentative; they are hereby submitted to broader scholarly debate.

JANUARY
2020
VOL. 61

Bibliography

Arnold, David. "Europe, Technology, and Colonialism in the Twentieth Century." *History and Technology* 21, no. 1 (2005): 85–106.

Bauer, Susanne, Karena Kalmbach, and Tatiana Kasperski. "From Pripyat to Paris, from Grassroots Memories to Globalized Knowledge Production: The Politics of Chernobyl Fallout." In *Nuclear Portraits: Communities, the Environment, and Public Policy*, edited by Laurel MacDowell, 149–89. Toronto: University of Toronto Press, 2017.

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

Bijker, Wiebe. "Globalization and Vulnerability: Challenges and Opportunities for SHOT around Its Fiftieth Anniversary." *Technology and Culture* 50, no. 3 (2009): 600–12.

Bonneuil, Christophe, and Jean-Baptiste Fressoz. *The Shock of the Anthropocene: The Earth, History and Us*. New York: Verso Books, 2016.

Boon, Marten. "Business Enterprise and Globalization: Towards a Transnational Business History." *Business History Review* 91, no. 3 (2017): 511–35.

Bos, Colette, et al. "Steering with Big Words: Articulating Ideographs in Research Programs." *Journal of Responsible Innovation* 1, no. 2 (2014): 151–70.

Bray, Francesca. "Flows and Matrices, Landscapes and Cultures." *Icon* 22 (2016): 8–19.

Castells, Manuel, João Caraça, and Gustavo Cardoso, eds. *Aftermath: The Cultures of the Economic Crisis*. Oxford: Oxford University Press, 2012.

Chakrabarty, Dipesh. "Anthropocene Time." *History and Theory* 57, no. 1 (2018): 5–32.

Cottle, Simon. "Rethinking Media and Disasters in a Global Age: What's Changed and Why It Matters." *Media, War and Conflict* 7, no. 1 (2014): 3–22.

De Hoop, Evelien, and Saurabh Arora. "Material Meanings: 'Waste' as a Performative Category of Land in Colonial India." *Journal of Historical Geography* 55 (2017): 82–92.

Diogo, Maria Paula, Ivo Louro, and Davide Scarso. "Uncanny Nature:

Why the Concept of Anthropocene is Relevant for Historians of Technology." *Icon* 23 (2017): 27–38.
Divall, Colin. "Mobilizing the History of Technology." *Technology and Culture* 51, no. 4 (2010): 938–60.
_____, Julian Hine, and Colin Pooley. *Transport Policy: Learning Lessons from History*. Farnham: Taylor & Francis, 2017.
Edgerton, David. *Shock of the Old: Technology and Global History Since 1900*. Oxford: Oxford University Press, 2007.
Edwards, Paul N. "Knowledge Infrastructures for the Anthropocene." *Anthropocene Review* 4, no. 1 (2017): 34–43.
van Eeten, Michel, et al. "The State and the Threat of Cascading Failure across Critical Infrastructures: The Implications of Empirical Evidence from Media Incident Reports." *Public Administration* 89, no. 2 (2011): 381–400.
Fickers, Andreas. "Towards a New Digital Historicism? Doing History in the Age of Abundance." *VIEW Journal of European Television History and Culture* 1, no. 1 (2012): 19–26.
Hecht, Gabrielle. *Being Nuclear: Africans and the Global Uranium Trade*. Cambridge, MA: MIT Press, 2012.
_____, ed. *Entangled Geographies: Empire and Technopolitics in the Global Cold War*. Cambridge, MA: MIT Press, 2011.
_____, and Paul N. Edwards. "Taking on the Technosphere (A Kitchen Debate)." In *Anthropocene Campus: The Technosphere Edition*. Berlin: Haus der Kulturen der Welt, 2016. Available at www.academia.edu (last consulted August 2018).
Hicks, Diana. "Grand Challenges in US Science Policy Attempt Policy Innovation." *International Journal of Foresight and Innovation Policy* 11, nos. 1–3 (2016): 22–42.
Hirsh, Richard. "Historians of Technology in the Real World: Reflections on the Pursuit of Policy-Oriented History." *Technology and Culture* 52, no. 1 (2011): 6–20.
_____, and Christopher Jones. "History's Contributions to Energy Research and Policy." *Energy Research and Social Science* 1 (2014): 106–11.
Högselius, Per, Arne Kaijser, and Erik van der Vleuten. *Europe's Infrastructure Transition: Economy, War, Nature*. Houndmills, Basingstoke: Palgrave Macmillan, 2015.
Jørgensen, Finn Arne, and Dolly Jørgensen. "The Anthropocene as a History of Technology." *Technology and Culture* 57, no. 1 (2016): 231–37.
Kaijser, Arne. "The Trail from Trail: New Challenges for Historians of Technology." *Technology and Culture* 52, no. 1 (2011): 131–42.
Kanger, Laur, and Johan Schot. "Deep Transitions: Theorizing the Long-Term Patterns of Socio-Technical Change." *Environmental Innovation and Societal Transitions* 32 (2019): 7–21.

JANUARY
2020
VOL. 61

Kranzberg, Melvin. "At the Start." *Technology and Culture* 1, no. 1 (1959): 1–10.

Kuhlmann, Stefan, and Arie Rip. "Next-Generation Innovation Policy and Grand Challenges." *Science and Public Policy* 45, no. 4 (2018): 448–54.

Lintsen, Harry, Frank Veraart, Jan Pieter Smits, and John Grin. *Well-Being, Sustainability and Social Development: The Netherlands, 1850–2050*. Berlin: Springer, 2018.

Lorenz, Chris. "'The Times They Are a-Changin': On Time, Space and Periodization in History." In *Palgrave Handbook of Research in Historical Culture and Education*, edited by Mario Carretero, Stefan Berger, and Maria Grever, 109–31. London: Palgrave, 2017.

Lundin, Per. "Making History Matter." *Mobility in History* 7, no. 1 (2016): 7–16.

Moore, Jason W., ed. *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*. Oakland: PM Press, 2016.

Mote, C. D., Ann Dowling, and Ji Zhou. "The Power of an Idea: The International Impacts of the Grand Challenges for Engineering." *Engineering* 2, no. 1 (2016): 4–7.

Perrow, Charles. *The Next Catastrophe: Reducing our Vulnerabilities to Natural, Industrial, and Terrorist Disasters*. Princeton: Princeton University Press, 2007.

Rip, Arie. "Science Institutions and Grand Challenges of Society: A Scenario." *Asian Research Policy* 2 (2011): 1–9.

van Santen, Rutger, Djan Khoe, and Bram Vermeer. *2030: Technology That Will Change Our World*. Oxford: Oxford University Press, 2010.

_____. *The Thinking Pill and Other Technology That Will Change Our Lives*. Amsterdam: Nieuw Amsterdam Uitgevers, 2007.

Schot, Johan. "Confronting the Second Deep Transition through the Historical Imagination." *Technology and Culture* 57, no. 2 (2016): 445–56.

Silva, José R., et al. "The Era of Engineering Grand Challenges." *Polytechnica* 1 (2018): 1–3.

van der Straeten, Jonas, and Ute Hasenöhrl. "Connecting the Empire: New Research Perspectives on Infrastructures and the Environment in the (Post) Colonial World." *NTM Journal for the History of Science, Technology and Medicine* 24, no. 4 (2016): 355–91.

Trischler, Helmuth. "The Anthropocene: A Challenge for the History of Science, Technology, and the Environment." *NTM Journal of the History of Science, Technology and Medicine* 24, no. 3 (2016): 309–35.

Trischler, Helmuth, and Fabienne Will. "Technosphere, Technocene, and the History of Technology." *Icon* 23 (2017): 1–18.

Turchetti, Simone, Néstor Herran, and Soraya Boudia. "Have We Ever Been 'Transnational'? Towards a History of Science across and beyond Borders." *British Journal for the History of Science* 45, no. 3 (2012): 319–36.

van der Vleuten, Erik. "Radical Change and Deep Transitions: Lessons from Europe's Infrastructure Transition, 1815–2015." *Environmental Innovation and Societal Transitions* 32 (2019): 22–32.

_____. "Technology, Societal Challenges, and Global Sustainability History." *Icon* 24 (2019): 34–52.

_____. "Toward a Transnational History of Technology: Meanings, Promises, Pitfalls." *Technology and Culture* 49, no. 4 (2008): 974–94.

_____, and Torsten Feys. "Borders and Frontiers in Global and Transnational History." *Journal of Modern European History* 14, no. 1 (2016): 29–34.

_____, Ruth Oldenziel, and Mila Davids. *Engineering the Future, Understanding the Past: A Social History of Technology*. Amsterdam: Amsterdam University Press, 2017.

Veraart, Frank, Jan Pieter Smits, and Erik van der Vleuten. "Connected by Oil: A Framework to Analyze the Connected Sustainability Histories of the Niger and Rhine Deltas, 1950–2015." *Extractive Industries and Society* (forthcoming).

Weber, Heike. "'Entschaffen': Reste und das Ausrangieren, Zerlegen und Beseitigen des Gemachten." *Technikgeschichte* 81, no. 1 (2014): 3–32.

Werner, Michael, and Bénédicte Zimmermann. "Beyond Comparison: Histoire Croisée and the Challenge of Reflexivity." *History and Theory* 45, no. 1 (2006): 30–50.

Williams, Rosalind. "The Rolling Apocalypse of Contemporary History." In *Aftermath: The Cultures of the Economic Crisis*, edited by Manuel Castells, João Caraça, and Gustavo Cardoso, 17–43. Oxford: Oxford University Press, 2012.