Introduction

Auto-Mobilities. Automation, Safety and Responsibility in the History of Mobility[1]

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"A phantom car will haunt the streets of Milwaukee today", the *Milwaukee Sentinel* ominously announced to its readers on December 8, 1926. "Driverless, it will start its own motor, throw in its clutch, twist its steering wheel, toot its horn and it may even 'sass' the policeman at the corner."[2] The spectacle of this newest technological marvel, "prowl[ing] in and out of the busy traffic", seemingly without human intervention, immediately caught the imagination of contemporary observers. "The effect is uncanny and mystifying", reported a local paper in Fredericksburg, Virginia, the site of a subsequent demonstration.[3] While in retrospect, the spooky imagery of these early reports appears to indicate a certain sense of unease at the prospect of mobile machines moving about uncontrolled, this did not stop the demonstrations from becoming a great success with the public. "Wherever the 'Phantom Auto' has been shown it has attracted huge crowds eager to witness the startling performance", the Fredericksburg *Free-Lance Star* attested.[4] Apart from its sheer novelty value, the supposedly "driverless" car—which was in reality radio-controlled by a human operator, following closely behind in a second car—also seemed to offer a glimpse into an exciting and highly desirable future. This was especially true with regard to safety. Since error-prone, undisciplined human drivers were thought to be at fault for the vast majority of accidents, taking them out of the equation altogether appeared like the ideal solution to the problem of traffic safety. Over the following two decades, various derivatives of the "Phantom Car" therefore served as inspirational centerpieces of so-called

1 Earlier versions of the contributions published in this issue were discussed at a workshop on *Who's Driving? Agency and Evidence in the History of Technical Safety* in December 2018 at Deutsches Museum (Munich), organized by Karin Zachmann and Stefan Esselborn in the framework of DFG Research Group 2448 *Practicing Evidence*. We would like to thank all participants for their insightful contributions, from which this issue has profited at least indirectly. Special thanks for proofreading and language editing to Victoria Woolven.

2 "'Phantom Auto' Will Tour City", The Milwaukee Sentinel, December 8, 1926.

3 "'Phantom Auto' to be Operated Here. Driver-less Car to be Demonstrated About City Streets Next Saturday", The Free-Lance Star (Fredericksburg), June 18, 1932.

4 Ibid.

"safety parades", held across the United States to educate the population on traffic safety issues.[5]

Both the glowing promises of a better, safer future and the deep-rooted fears of losing control will sound familiar to anyone who has followed the contemporary debates on autonomous vehicles (AV) during recent years. Predicted to be no more than "twenty years away" for the better part of a century—as Jameson Wetmore noted almost twenty years ago[6]—the development of automated automobiles[7] has lately accelerated to a point at which it has begun to resemble no longer a distant vision, but a (presumably) imminent reality. Autonomous driving has become "one of the most highly anticipated technological developments of our time",[8] fueling not only intense public interest, but also a large and steadily growing body of scientific research and scholarly writing. In the mass media, within the automotive engineering community, and in the social sciences, analyses of (and speculation about) the supposedly revolutionary impact of AVs on a wide range of economic, social, legal, ethical, urban and architectural, gender-related, or environmental issues abound.[9]

By contrast, the historical dimension has so far been largely absent from the discussion. In corporate communication and popular technology journalism, both heavily dominated by a rhetoric of "innovation" and "disruption", today's generation of self-driving vehicles is usually presented as a completely new and unprecedented development, which has only become technically imaginable in the last few years. As far as historical developments are mentioned at all, they are mostly presented as a slightly curious backstory with little connection

5 Cf. Fabian Kröger, "Automated Driving in Its Social, Historical and Cultural Contexts", in Autonomous Driving. Technical, Legal and Social Aspects, ed. M. Maurer et al. (s.l. 2016), 41–68, here 43f.

6 Jameson M. Wetmore, "Driving the Dream. The History and Motivations Behind Sixty Years of Automated Highway Systems in America", Automotive History Review (summer 2003), 4–19.

7 For the purpose of this introduction, I am using "automated" automobiles to refer generally to attempts to replace human drivers with technical systems, in accordance with the definition of automation given below. This includes (but is not restricted to) the development of "autonomous" vehicles, which is the stated goal of most contemporary efforts. Systematically as well as historically, the difference between both is significant.

8 David Bissell et al., "Autonomous Automobilities. The Social Impacts of Driverless Vehicles", Current Sociology 88, No. 1 (2018), 117.

9 For an overview from an engineering, legal, and public policy perspective, cf. Markus Maurer et al. (eds.), Autonomous Driving. Technical, Legal and Social Aspects (s.l. 2016); as well as the (so far) six-volume, series by Gereon Meyer and Sven Beiker (eds.), Road Vehicle Automation (Cham 2014–2019). For a quick first impression from the point of view of sociology and mobility studies see Bissell, "Autonomous Automobilities"; for a more extensive analysis Aharon Kellerman, Automated and Autonomous Spatial Mobilities (Cheltenham, Northampton 2018). There is now even a teaching-oriented textbook: Bern Grush and John Niles, The End of Driving. Transportation Systems and Public Policy Planning for Autonomous Vehicles (Amsterdam, Oxford, Cambridge, MA 2018).

to present-day projects.[10] Without a doubt, there are very significant technical differences between the radio-controlled "Phantom Car" of the 1920s, and the heavily computerized AV prototypes which tech companies and "traditional" automobile corporations alike are testing on public roads at the moment. The most important differences arguably pertain to the enormous increase in computing power, the advancements in sensor technology, and the progress in artificial intelligence and data-driven machine learning, which have ushered in a new era in the development of robotics.[11] However, there are also good arguments for seeing the "Phantom Car" and the newest Uber, Waymo or Nuro not as polar opposites, but as inhabiting a continuous historical spectrum. In this issue, we would like to suggest at least three respects in which a broader and more in-depth historical contextualization can contribute to contemporary debates on present realities and future possibilities of self-driving vehicles: the history of (socio-technical) visions and imaginaries of automated driving, the history of the automation of automobile (sub-)systems, and the history of automation (of control) in the context of other technologies of mobility.

There is no denying the fact that, from a perspective centered on everyday user experience and consumer (car) cultures, the history of automated automobiles has barely even begun. Until very recently, self-driving cars were at best a technological fringe issue, whose actual existence was restricted to little more than a handful of highly experimental prototypes surrounded by grand ideas. As Martina Heßler has suggested, this mismatch between the often largely speculative character of historical automation discourses and the recent shift towards technology-in-use within the field might be one explanation for the relative dearth of newer work on the topic.[12] However, as a number of recent publications have made clear, visions, "sociotechnical imaginaries", and "technology futures" constitute very rewarding objects of

10 For instance, the "historical" chapter in a recent "guide for policymakers" on the issue only starts its presentation in the 1980s, arguing that earlier visions of automated driving had been mere "science fiction" in the absence of necessary computer technology; cf. James M. Anderson et al., Autonomous Vehicle Technology. A Guide for Policymakers (Santa Monica 2014), 55–57.

11 Bissell et al., "Autonomous Automobilities", 3.

12 This is certainly even more applicable to automated driving than to the related field of automation in production, to which her argument originally referred. Cf. Martina Heßler, "Einleitung. Herausforderungen der Automatisierung. Forschungsperspektiven", Technikgeschichte 82, No. 2 (2015), 99–108.

research in the history of technology.[13] Which "vanguard visions"[14] managed to grip the popular imagination at particular points in time, and what kinds of technical solutions and social preconditions they were built on, can tell us much not only about the technological development itself, but also about their place in society. In the case of automated driving, Jameson Wetmore and Fabian Kröger have demonstrated the potential of this approach.[15] They have pointed to strong continuities, but also significant differences between earlier visions and imaginaries, and the automobile futures widely propagated today.

Secondly, the emphasis on the novelty of autonomous driving also tends to obscure the fact that automation often resembles a step-by-step process, rather than one big jump in development. Instead of focusing on a question of binary choice between "manual" and "fully autonomous" modes of operation, we should understand automation more broadly as "a device or system that accomplishes (partially or fully) a function that was previously, or conceivably could be, carried out (partially or fully) by a human operator".[16] Applying this definition to automobile technology, a long and nuanced history of the automation of driving comes into view. Translated literally, "automobiles" have always been "self-driving vehicles". Efforts to improve their safety, speed and comfort by bypassing the unreliable "human factor" and transferring certain tasks to the machine are by no means a new phenomenon, but have been part of automobile history since the very beginning —and a source of discussions and controversies for just as long.[17] A number of different examples come to

13 For some recent approaches to visionary elements in the history of technology see e.g. Sheila Jasanoff and Sang-Hyun Kim (eds.), Dreamscapes of Modernity. Sociotechnical Imaginaries and the Fabrication of Power (Chicago, London 2015); Uwe Fraunholz and Anke Woschech (eds.), Technology Fiction. Technische Visionen und Utopien in der Hochmoderne (Bielefeld 2014); Helmuth Trischler and Robert Bud, "Public Technology. Nuclear Energy in Europe", History and Technology 27, No. 2 (2019), 1–26. Slighty older, but still influential is the work of Joseph Corn and Brian Horrigan, Yesterday's Tomorrows. Past Visions of the American Future (New York 1984).

14 Cf. Stephen Hilgartner, "Capturing the Imaginary. Vanguards, Visions, and Power in the Biosciences and Beyond", in Science and Democracy. Making Knowledge and Making Power in the Biosciences and Beyond, eds. id., C. Miller and R. Hagendijk (New York 2015), 33–55.

15 Cf. Wetmore, "Driving the Dream"; Kröger, "Automated Driving"; id., "Fahrerlos und unfallfrei. Eine frühe automobile Technikutopie und ihre populärkulturelle Bildgeschichte", in Technology Fiction, eds. U. Fraunholz and A. Woschech, 93–114.

16 R. Parasuraman et al., "A Model for Types and Levels of Human Interaction with Automation", IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans 30 (2000), 287. In the language of Bruno Latour, one could also see this as a (particularly obvious) example of "delegation to non-humans", cf. Bruno Latour, "Where are the Missing Masses? The Sociology of a Few Mundane Artifacts", in Shaping Technology/Building Society. Studies in Sociotechnical Change, eds. W. E. Bijker and J. Law (Cambridge, MA 1992), 225–289.

17 With thanks to Silke Zimmer-Merkle, who made this point very convincingly in her workshop contribution.

mind: from the introduction of the electric starter in the early 1910s, via the first "Cruise Control" systems in the late 1950s, the spread of Airbags and Anti-Lock Braking (ABS) in the 1970s and 1980s, to today's parking assistants and Advanced Driver Assistance Systems (ADAS).[18] Some of these systems have been in everyday use for so long that they have become all but invisible as instances of automation. However, according to recent prognoses, new additions in this domain will have a much bigger impact on existing road traffic systems than "truly" autonomous vehicles for some time to come.[19]

Thirdly, automobiles were not the only—and in many respects, not the first—technology of mobility to which efforts towards partial or complete automation have been applied. From the perspective of a history of automated control, the genealogy of autonomous driving reaches back at the very least to nautical innovations of the late nineteenth and early twentieth century, such as Robert Whitehead's torpedo guidance system and Elmer Sperry's gyroscopic stabilizer, which in turn were the predecessors of the first airplane autopilots.[20] Less well known, but likewise potentially relevant are projects and ideas for the automation of railways and other collective transport systems, not least because they offered competing visions for the future of mobility.[21] Looking beyond mobility technologies as such, there is a large and rich body of literature on topics such as the history of automata and robots,[22] the automation of production,[23] or the development of cybernetics and artificial intelligence.[24]

18 The history of some of these subsystems has already been studied in some detail, if not necessarily with a focus on automation. See for instance on the electric starter Henk de Boer, Theo Dobbelaar and Gijs Mom, Das Auto und seine Elektrik (Stuttgart 1990); on airbags Jameson M. Wetmore, "Delegating to the Automobile. Experimenting with Automotive Restraints in the 1970s", Technology and Culture 56, No. 2 (2015), 440–463; on Anti-Lock Braking Ann Johnson, Hitting the Brakes. Engineering Design and the Production of Knowledge (Durham 2009); on parking assistants Kurt Möser, "Einparken zwischen Kompetenzlust und Automatisierungsdruck", Traverse 1 (2009), 32–36.

19 Sven Altenburg, Hans-Paul Kienzler and Alex auf der Maur, Einführung von Automatisierungsfunktionen in der Pkw-Flotte. Auswirkungen auf Bestand und Sicherheit, Prognos-Bericht im Auftrag des ADAC e.V. (2018), www.prognos.com/uploads/tx_atwpubdb/ADAC_Automatisiertes_Fahren_Endbericht_final_01.pdf, accessed April 14, 2020.

20 Stuart Bennett, "A Brief History of Automated Control", in IEEE Control Systems Magazine 16, No. 3 (1996), 17–25; Christopher Bissell, "A History of Automatic Control", in Springer Handbook of Automation, eds. Y. Hasegawa and S. Nof (Berlin 2009), 53–69.

21 E.g. Barbara Schmucki, "Individualisierte kollektive Verkehrssysteme und kollektive individuelle Verkehrssysteme. Die Vision von Neuen Technologien zur Lösung der Verkehrsnot in den Städten in den 1970er Jahren", in Geschichte der Zukunft des Verkehrs. Verkehrskonzepte von der frühen Neuzeit bis zum 21. Jahrhundert, eds. H. Dienel and H. Trischler (Frankfurt a.M. 1997), 147–169.

22 E.g. Minsoo Kang, Sublime Dreams of Living Machines. The Automaton in the European Imagination (Cambridge, MA 2011); Adelheid Voskuhl, Androids in the Enlightenment. Mechanics, Artisans, and Cultures of the Self (Chicago, London 2013).

23 For a literature review cf. Heßler, "Herausforderungen der Automatisierung".

24 E.g. Ronald R. Kline, The Cybernetics Moment, Or, Why We Call Our Age the Information Age (Baltimore 2015). For a history of AI in West Germany see the new BMBF research

Although the automation of automobiles—for a number of technological, socio-cultural and historical reasons—differed significantly in many respects from developments in other fields, there are many direct historical cross-connections to be investigated. In addition, a wider comparative perspective might help to identify general patterns and issues, as well as specificities and differences. Understanding autonomous machines as instances of the "technological sublime", for example, which mixes elements of awe, exhilaration and anxiety, seems to fit very well with the recorded reactions to the "Phantom Car" cited above.[25]

In this special issue, we propose to open up a wider historical perspective on automated driving by bringing together contributions that approach the issue from the three main angles indicated here. In order to add to the coherence of the issue, we have chosen to focus on two thematic lenses, which we believe are crucial for understanding the history of automated driving. The first is the issue of safety, which seems to constitute one of the central threads of the story. On the one hand, while there are a number of reasons to automate driving machines, prospective safety benefits have always been one of the most important arguments for the automation of automobiles—from the earliest efforts, such as the "Phantom Car", to the latest contemporary projects, some of which are presented by their promoters as near-humanitarian missions for saving millions of lives.[26] On the other hand, widespread skepticism about the safety of self-driving cars has been almost equally persistent. In the wake of a number of recent high-profile accidents, such as the Uber crash in Tempe, Arizona in 2018, safety concerns are today believed to constitute the main impediment to the widespread introduction of the new technology.[27] At the same time, safety is extremely difficult to prove and possibly even harder to communicate, as decades of risk research have shown.[28] We therefore want to ask specifically about the role of safety in the history of automated (auto-)

project at Deutsches Museum, http://www.deutsches-museum.de/forschung/forschungsbereiche/wissenschaftsgesch/digitale-kulturen/ki-forschung/, accessed April 14, 2020.

25 Cf. Julia M. Hildebrand, "On Self-Driving Cars as a Technological Sublime", Techné. Research in Philosophy and Technology 23, No. 2 (2019), 153–173.

26 Cf. Jameson Wetmore's article in the present issue.

27 Cf. e.g. Deloitte, "What's ahead for fully autonomous driving. Consumer opinions on advanced vehicle technology" (2017), https://www2.deloitte.com/content/dam/Deloitte/de/Documents/manufacturing/us-manufacturing-consumer-opinions-on-advanced-vehicle-technology.pdf; Ellen Edmonds, "AAA. American Trust in Autonomous Vehicles Slips", 22.5.2018, https://newsroom.aaa.com/2018/05/aaa-american-trust-autonomous-vehicles, both accessed April 14, 2020. For an analysis of the Tempe crash see Madeleine Clare Elish, "Moral Crumple Zones. Cautionary Tales in Human-Robot Interaction", Engaging Science Technology and Society 5 (2019), 40–60.

28 On the difficulties of proving safety by quantitative risk analyses and communicating numerical risks in a different technical field cf. Stefan Esselborn and Karin Zachmann, "Safety by Numbers. Probabilistic Risk Analysis as an Evidence Practice for Technical Safety in the German Debate on Nuclear Energy", History and Technology (forthcoming).

mobilities. How did the main stakeholders use it to make the case for (or against) automation? What evidence did they produce to back up their claims?

Secondly, the issue of safety is closely related to the even larger problem of the distribution of control, and thus responsibility, between humans and machines. This does not only concern the deceptively simple question of who is/was in charge in a given situation, but also refers to the complicated problem of moral and legal liability. Furthermore, as Martina Heßler reminds us, when talking about the relationship between "the human" and "the machine", we need to be aware that both of these notions not only refer to a variety of concrete historical experiences, but also to socially constructed ideals and abstractions, which were often defined specifically in opposition and delimitation to one another.[29] How control and responsibility were (re-)distributed also affected the identity of the person (or entity) behind the wheel. This leads to a number of further questions: How did different degrees of automation interact with the (self-)image of human drivers? Which skills were (thought to be) necessary to (safely) operate such a machine, and who possessed them? In what sense did automation lead to a "de-skilling" of operators, and what new skills had to be acquired?

To explore these and similar questions, this special issue unites three articles, covering diverse chronological and thematical fields. Firstly, *Stefan Esselborn* discusses the spread of the "crashworthiness" idea—the requirement that automobiles had to keep their occupants safe in the event of a crash—in the 1960s and early 1970s. This constitutes an example of partial automation in the sense of the definition citied above, he argues, because it entailed the re-distribution of responsibility (and potentially legal liability) for safety from human drivers to cars and their manufacturers. Focusing specifically on the so-called Experimental Safety Vehicle (ESV) program of the early 1970s, his contribution adds a transnational perspective to the so far strongly U.S.-centered literature on the issue. He is particularly interested in the role that the ESV program—and not least to the experimental prototypes themselves, which materially anchored the discussion by functioning as "evidence objects"—played in the negotiations between governments, regulating agencies and multinational car companies on what exactly constituted of a "safe" car.

In his contribution, *Sam Hind* leaves the field of automotive history in the narrower sense and delves into the history of aviation and airplane autopilots—probably the best known, and arguably also the most intensively scrutinized system of automated mobility. He concentrates on the consequences of the introduction of so-called "fly-by-wire" technology, i.e. the replacement of the mechanical transmission of the pilot's steering impulses with a system that

29 Cf. Martina Heßler, "Menschen–Maschinen–MenschMaschinen in Zeit und Raum. Perspektiven einer historischen Technikanthropologie", in Provokationen der Technikgeschichte. Zum Reflexionszwang historischer Forschung, eds. id. and Heike Weber (Paderborn 2018), 35–68.

uses electric impulses, allowing the interposition of an automated computer system. As a consequence, airplanes equipped with the technology operate in a state of "distributed control" between the human pilots and the automated system, in which the exact distribution varies dependent on the situation and "mode" the system is in. This, he argues, brought important improvements in efficiency and safety, but also regularly resulted in "automation surprises", sometimes with catastrophic consequences. In this context, the contribution particularly highlights the role of sensors, as well as the consequences of distributed control for flying as a skilled practice. Since fly-by-wire was first developed in the 1960s and became widely available with the launch of the Airbus 320 in the late 1980s, there is already a large and well-documented body of historical experience of the technology, which can offer potential insights into similar developments in the automobile sector.

Finally, *Jameson Wetmore* expands and updates his earlier work by analyzing visions for automating road traffic in the United States from the late 1930s to today. He identifies four different historical junctures, at which the issue received a particularly high amount of attention—the late 1930s and early 1940s, the 1950s, the 1990s and the early 2000s—and compares them to contemporary scenarios developed in the last ten years. For each of these visions of future socio-technical systems, he analyzes continuities and discontinuities in technological principles and implementations, motivations and legitimations, as well as actors and organizations involved in their (potential) implementation. While for example safety has always been one of the goals of automation from the late 1930s to today's AV projects, other factors, such as the role of publicly provided infrastructure and the state as an actor have changed greatly. Exploring "ideas discarded along the way", he argues, will give us a fuller picture of potential options and ultimately enable us to make more informed decisions on what kind of automated automobility we want to build in the future.

Taken together, we believe these case studies can contribute to the reframing of some central questions in the history of automation and the automobile: what automation may have meant and looked like at different times and in different places, how responsibility was distributed between "the human" and "the machine", and what arguments and evidence were mobilized for and against different versions and visions of automated (auto-)mobilities.

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