Learning to live together: cars, human and kerbs in solidarity

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Certificate of original authorship

I, Guillermo Fernández-Abascal declare that this thesis, is submitted in fulfilment of the requirements for the award of Master of Research in the School of Architecture / Faculty of Design, Architecture and Building at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Contents

Abstract

Recent developments in driverless technologies are bringing discussions about the urban environment to the forefront. Automotive and technological industries are envisioning the future of our cities while developing the vehicles themselves without establishing a conversation with the architectural discipline. Yet, proposed driverless scenarios appear to emphasize consensual solutions where idealized images of the street seamlessly integrate their technologies. Ignoring the immediate future, these visions focus on a more distant time where technology dominates: driverless cars populate the road, human behaviour and city infrastructure remain unchanged, and society has learned to live with autonomous vehicles.

This thesis explores the conflicts unleashed by new technology, how it triggers meaningful transformations in the city, and how these changes might happen in the near future. The fast and disruptive implementation of driverless technology does not foresee an urban solution. However, it does ask us to imagine how the cohabitation of humans and cars might be articulated in the urban environment since this is where the short-term negotiation between them will take place. The differences in the way that cars and humans sense and sense the city will define the terms of the discussion and the design of these spaces.

To explore these discussions and transformations, we first dissect the sensing devices that allow driverless technologies to navigate the urban environment whilst unpacking the interlinked socio-technical controversies inherited in their deployment. Secondly, we identify the *hybrid forum* as the only available space with the capacity to address the convolutions of the immediate driverless future. We finish by concentrating on *a thing*; a kerb is presented as the object of deliberation in this *hybrid forum*. It allows multiple agents to have discussions about safety, control, surveillance, security, empathy, trust, urban policy and automation; it sets the rules for cohabitation.

Introduction

> "I have sought to offer humanists a detailed analysis of a technology sufficiently magnificent and spiritual to convince them that the machines by which they are surrounded are cultural artefacts worthy of their attention and respect" [1]
>
> Bruno Latour

A reader's guide

This thesis is divided into two interconnected parts: a long-form text and seven project experiments. The text was developed in parallel to the projects, and the intersection between text and experiments challenges the ideas exposed within it. The ideas proposed in the text and the project experiments have consistently informed each other.

The vision, the discussion and *the thing* are the conceptual framework that link the text and the projects; they are the three main topics that guide the textual narrative and the experimental speculations. An additional story runs in parallel to the document in the form of footnotes. The footnotes trace the excessive amount of information constantly appearing across media and in academic publications that is linked to the research topic.[2] The footnotes inform and reinforce the hypothesis of the thesis. They are a fundamental part of the thesis and require to be read.

In the two years taken to complete this thesis, my writing, through theoretical discussion, has led to the development of seven associated projects.[3] All the projects were experiments that began as proposals for real-life scenarios; two evolved into major architectural installations, however only one materialised. Additionally, another experiment produced a series of objects through material experimentation; some of these objects are currently in the process of becoming commercially available. The other experiments did not move beyond their conceptual stages. Yet, all the seven experiments are the material evidence, or consequences of, my theoretical position.

Three short descriptions of the vision, the discussion and *the thing* are articulated in the following introduction providing the general structure of this thesis.

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[1] Latour, Bruno. *Aramis or the love of technology*, Cambridge, MA: Harvard University Press, 1996.

[2] The footnotes exemplify the broad scope of the thesis. Definitions, anecdotes, facts are taken from media such as *Reuters*, *The Guardian*, *The New York Times*, *The Economist* or *Wired*; scientific publications and such as *Science, Nature* or the *Journal of the air pollution control association*, new informative platforms such as *Medium* or *The Conversation; governance institutions for example the* United Nations, the European Commission, UK Government, the State of California or the city of Phoenix; mobility think thanks and transport forums, Universities including Warwick, Yale, MIT or Stanford; books including *Driverless. Intelligent cars and the Road, Acting in an uncertain world. An essay on Technical Democracy, Aramis or the Love of Technology or Material Participation.* These remarks are fundamental when dealing with the socio-technical controversies linked to the imminent arrival of driverless technologies.

[3] In the rest of document, I will use "we" to refer to the speculations and projects. All the ideas and the projects were developed collaboratively with different actors. This requires a specific tense for the remainder of the text. "We" is also commonly used in feminist and post-human studies as the selected voice of narration.

Vision

Driverless cars[4] construct images of their surroundings that are barely comparable to the images humans see; identifying these differences and understanding their implications is the aim of the first section of this thesis. This section works as a state-of-the-art in driverless technologies rather than a literature review. We start with a thorough, almost scientific, analysis of the sensing devices that autonomous vehicles currently use. Radar, ultrasonic sensors, LiDAR and cameras capture the environment while producing medium-specific maps. The combination of this real time-mapping with high definition maps (HD maps) takes us beyond the physical territory and unfolds the issues of safety, control, surveillance, security, privacy, urbanization, policy and automation. The socio-technical controversies are intertwined in the technologies of driverless vision: The way cars "see" defines the necessity for a new sensorial social contract.

Two experiments are directly connected to this topic: V.1.1 *Driverless vision Seoul*, V.1.2 *Driverless vision Sydney.* Only *V.1.1 Driverless vision Seoul* was fully implemented.

In both experiments, we have used fiction, film and architecture to explore visions of the immediate future through the eyes of the driverless car, challenging viewers to confront a not-so-distant reality. The resulting installations are both visualization tools and post-human parliaments. They help us to understand that reality is fundamentally linked to the point of view of the observer whilst triggering discussions about cohabitation, empathy, urban planning and air quality.

Discussion

After introducing the links between the technical aspects of autonomous vehicles and the societal concerns of its deployment, the second part of the document unpacks these relations, questions how to evaluate them, and presents the methods that can be used to do so. The scarce evidence explaining the advantages and disadvantages of autonomous vehicles confirms the potential for unforeseen complications or benefits in the future. The hypothesis: Only a *hybrid forum* has the capacity to address the complexities of the imminent future. This hypothesis is supported through the scrutiny of historical discussions surrounding vehicular agreements and international treaty techniques, and finally by proposing a specific *hybrid forum* that deals with the implementation of driverless cars. This *hybrid forum* questions the role of experts in a field that moves between cultural studies and the sciences whilst declaring safety as a first matter of concern.

Four experiments directly linked to this topic have been deployed: D.1.1 *The question: Do we want driverless cars?*, D.1.2 *How safe is safe? Defining a threshold of agreeable safety concerns* D.1.3 *The convention of cohabitation.* D.1.4 *Croydon as a lab. Secluded research*

[4] Here we refer to an automated road vehicle responsible for all elements of the driving task at all times. The documents employs alternative terms that may refer to some or all of these capabilities, including "autonomous" and "self-driving".

versus research into the wild. None of them have moved beyond the conceptual stages but have allowed for speculation in real-life scenarios.

The projects highlight how debate is not about driverless cars per se, but about exploring their effects, their benefits, and the destructive impact that these vehicles could potentially generate. They address technological acceptance and how initial decisions surrounding the adoption of these technologies determine their consequences; question whether safety can be defined as a mathematical model without considering trust, empathy and ethics in the equation ; define a "public" to discuss cohabitation; and interrogate whether driverless testing should be under laboratory-type conditions or "into the wild." These discussions on the relationship between scientific knowledge, technological systems, and society take place in *hybrid forums*.

Things

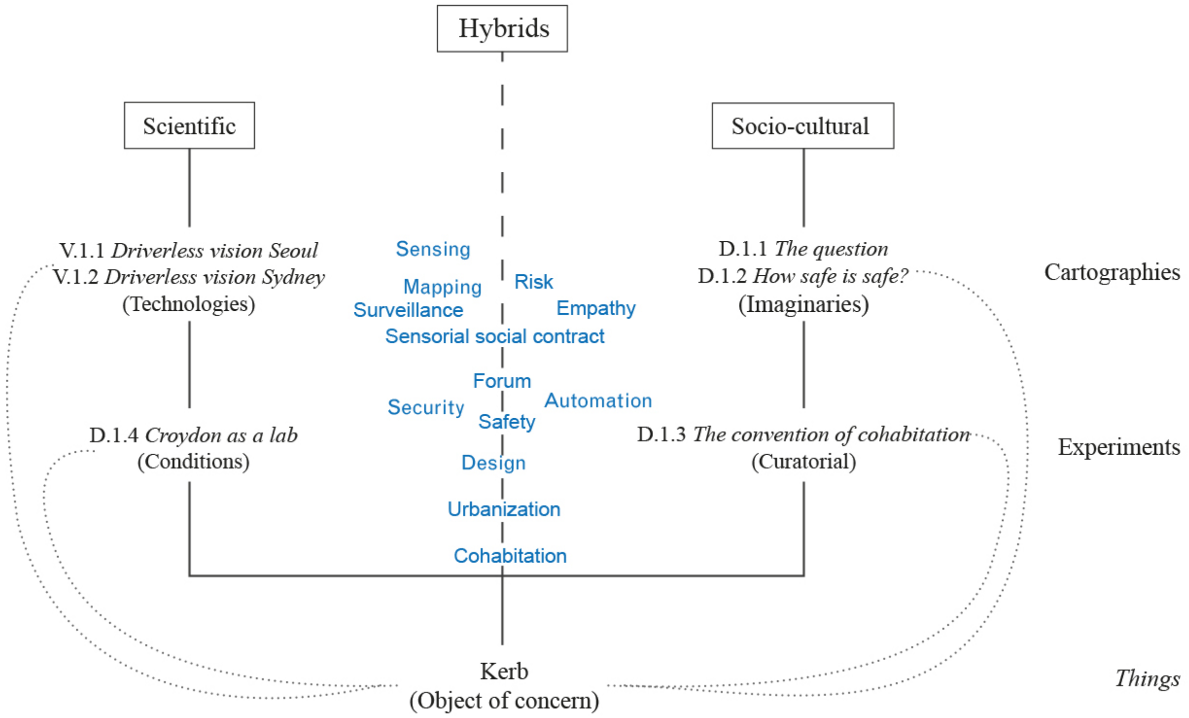
To conclude we have concentrated on *a thing*—in the *Latourian* sense—that could play a role in the *hybrid forum*. This final section addresses the ways in which kerbs and other devices produce a new means of understanding facts in the public sphere, and their uncertain political effects. The detailed description of the kerb makes it possible to see the multiplicity of political processes, the micro and macro scale, and the ways in which kerbs could become increasingly potent in the unfolding controversies surrounding driverless cars. This light infrastructural hypothesis is also supported by historical urban transformations such as the deployment of the automobile and current financial contexts. The kerb is not just an object of political deliberation; it is a participant in a shifting political assemblage.

One experiment closes this section: T.1.1 *Driverless kerb Sydney.*

Objects are central in *hybrid forum* debates. Here, the kerb is a technological apparatus and a governing piece of architecture to be discussed. The kerb activates discussion on objectivity, trust, safety, real estate, urbanization and beauty among other topics, turning the street into both a laboratory and a political arena.

What is at stake in this thesis is the question: Where does the architectural discipline get its intelligence from? We believe we can operate between the sciences and cultural studies. We need to look outside the discipline in order to increase our knowledge repository, and at the same time, we need to inspect the history of our rich field in order to validate our findings. A semi-autonomous approach to the discipline offers architects a way to remain relevant in society. This thesis aims to do so by offering the citizens of contemporary high-tech societies the resources with which to evaluate—scientifically, socially, economically, culturally, politically, ethically and urbanistically—the benefits and the risks, the perils and the promises, of driverless technologies.

Methodology



Methodology diagram

In this thesis we have explored how non-conventional research approaches such as digital methods and participatory design provide a way to complement the current research surrounding autonomous vehicles. By moving beyond the mere visualisation of data and simply describing the main actors directing the discussion, we aim to uncover the hidden technical and social aspects of driverless cars. We examine the emergent, not-yet-explicit ways of engaging with driverless technologies through seven experiments that demonstrate the ways in which technology impacts social, political, economic, and cultural relationships.

The seven projects are grouped thematically and follow the structure established in the thesis. The vision, the discussion, and *the thing* frame these projects or experiments; all projects expand beyond their initial categorizations. Six of these projects are briefly examined in this document. The seventh project, *Driverless vision Seoul* warrants further analysis and has added discussion since it has been fully implemented and provides a true-to-life example of my theoretical position.

Preface

Recent developments in driverless technologies are bringing discussions about urban environments to the forefront. While developing the actual vehicles, major players such as Waymo (Google), Volkswagen, and Uber have been equally invested in envisioning the future of cities. Yet, the proposed scenarios tend to emphasize consensual solutions in which idealized images of the streets seamlessly integrate driverless technology. Ignoring the immediate future, these visions focus on a distant time in which technology dominates: driverless cars populate the roads, human behaviour and city infrastructure remain unchanged, and society has learned to live with autonomous vehicles.[5]

This thesis argues that the conflicts unleashed by the new technology will trigger meaningful transformations of the city, and that these changes will happen in the near future. The fast, disruptive deployment of driverless technology does not preclude a specific urban solution. However, it does ask us to imagine how the cohabitation of humans and cars might be articulated in the urban environment, which is where the negotiation between the two will take place in the short term. The differences in the ways that cars and humans sense the city will define both the terms of the discussion and the design of these spaces.

Following the successful deployment of autonomous vehicles in secluded environments and major non-urban areas, dense urban environments have become the ultimate frontier for driverless technologies. Personal rapid transit systems (PRT) operating on independent

[5] Future scenarios tend to focus predictions on how driverless cars, when combined with the shared economy, could drastically reduce the total number of cars in urban environments. Brandon Schoettle and Michael Sivak from the University of Michigan Transportation Research Institute foresee a 43% decrease. (Schoettle, Brandon, and Michael Sivak. “Potential impact of self-driving vehicles on household vehicle demand and usage.” *Driverless transportation*. accessed September 2018. http://www.driverlesstransportation.com/wp-content/uploads/2015/02/UMTRI-2015-3.pdf). Sebastian Thrun, a computer scientist at Stanford University and former leader of Google’s driverless project predicts a 70% decrease. (Thrun, Sebastian. “If autonomous vehicles run the world.” *The Economist*. accessed September 2018. http://worldif.economist.com/article/12123/horseless-driverless). Matthew Claudel and Carlo Ratti anticipate an 80% reduction. (Claudel, Matthew, and Carlo Ratti. “Full speed ahead: how the driverless car could transform cities.” *McKinsey*. accessed September 2018. http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/full-speed-ahead-how-the-driverless-car-could-transform-cities). Luis Martínez of the International Transport Forum expects a 90% decline in his study of Lisbon mobility (Martinez, Luis. “Urban mobility system upgrade. How shared self-driving cars could change city traffic.” International Transport Forum. accessed September 2018. http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf) ; and in a similar exercise Dan Fagnant of the University of Utah forecasts a 90% decline for the city of Austin (Fagnant, Daniel. “Future of fully automated vehicles: opportunities for vehicle-and ride-sharing, with cost and emission savings.” *University of Texas*. accessed September 2018. https://repositories.lib.utexas.edu/bitstream/handle/2152/25932/FAGNANT-DISSERTATION-2014.pdf?sequence=1). All these hypotheses operate in a distant future when the technology has been fully implemented. IEEE predicts up to 75% of vehicles will be autonomous in 2040 and IHS has forecast that almost all vehicles will be driverless by 2050. IEEE. “Look ma, no hands!” *IEEE*. accessed September 2018. http://www.ieee.org/about/news/2012/5september_2_2012.html; IHS. *“Emerging technologies: autonomous cars—not if, but when.” HIS.* accessed September 2018. http://www.ihssupplierinsight.com/_assets/sampledownloads/auto-tech-report-emerging-tech-autonomous-car-2013-sample_1404310053.pdf.

tracks, like the self-driving pods in Heathrow Airport, have been successfully running since the end of last century.[6] Adaptive cruise control, automatic emergency braking, and automatic parking are already widely available in commercial cars. Tesla, BMW, Infiniti and Mercedes-Benz offer models with automatic lane-keeping, which guide the car along freeways and rural roads without relying on the driver.[7] Yet the city continues to resist the wave of autonomous cars.

The way a car map the environment is one of the main reasons. Urban environments multiply the chances of unforeseen events and dramatically increase the amount of sensorial information required to make driving decisions. The quality and amount of data is directly proportional to the price of the technology and to the car's subsequent ability to resolve eventful situations. It is also inversely proportional to the car's processing and decision-making speed. The means of achieving a balance between these two parameters (sensors'

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[6] Personal rapid transit (PRT) was developed in the 1950s as a more economical response to public transport than the conventional metro system supported by the Urban Mass Transportation Administration (UMTA). Originally PRT had a similar capacity to cars but as they evolved into bigger vehicles they lost some of their advantages, including light infrastructural requirements and maximum flexibility in the journeys routes. As a result, only one PRT was built—in Morgantown (USA). It has been operating successfully since then. We can position Heathrow's pods, the Sky Cube in Suncheon (Korea) and Masdar Abu Dhabi pods as the latest implementations of this technology.

[7] In January 2014, SAE International (Society of Automotive Engineers) issued a classification system that spans six levels of driver intervention, from *no automation* to *full automation* (0 to 5). This taxonomy aims to simplify communication and collaboration between the different agents involved. The system sets a crucial distinction between level 2, where the human driver operates part of the *dynamic driving task*, and level 3, where the automated driving system carries out all of the dynamic driving tasks (SAE. "Automated driving. Levels of automation are defined in new SAE International Standard J3016." *SAE*. accessed September 2018. https://www.sae.org/misc/pdfs/automated_driving.pdf). Later in 2014, Navya launched a self-driving vehicle (level 5) which has been performing successfully in different closed environments including Switzerland, France, the USA, England and Singapore. *Arma*, their latest carrier, is being trialled along fixed routes in urban scenarios. This shuttle can transport up to 15 passengers and drive up to 45 km/h. Other major players have been testing vehicles in closed environments and on public roads under special circumstances. When driven on public roads, the cars require at least one person to monitor the action and assume control if necessary. Some of the more popular testing programmes involve companies such as Waymo (Google), Tesla, or Uber. Google has been testing their cars since 2009 on freeways and in testing grounds. In 2012, they shifted to the city streets to perform tests in a more complex environment. Interestingly enough, the chosen location for this step was the infamous Venturian Strip of Las Vegas. In their latest published monthly report from November 2016 their vehicles operated 65% of the time on autonomous mode. Along the lifespan of the programme, they have accumulated more than 5 million self-driven miles. (Waymo. "Journey." *Waymo*. accessed September 2018. https://waymo.com/journey/).
Tesla started deploying their autopilot system in 2014 with a level 2 automated vehicle. In October 2016, Tesla announced that their vehicles had all the necessary hardware to be fully autonomous at level 5 capabilities. However, as they clearly state, its functionality depends on extensive software validation and regulatory approval. They currently offer multiple capacities such as adaptive cruise control or auto-steer. Initially, the systems could only be deployed along specific highways, but they now also perform in some urban situations. (Tesla. "Full self-driving capability." *Tesla*. accessed September 2018. https://www.tesla.com/autopilot). Uber joined the race in 2016. Their controversial programme offered, right after the nuTonomy pilot scheme, to carry fare-paying passengers in cars that have a high level of autonomy. These vehicles have two employees in the front seats to monitor and take control in case there are problems.

type and precision versus reaction speed and price) defines the different approaches in the development of driverless technologies.[8]

The way a car maps urban infrastructures is also a reason for the potential redesign of our streetscapes. The argument is positioned against the current imaginings of urban infrastructure remaining the same, even while self-driving cars share the streets with humans. Currently, in this future scenario, there is no apparent tension between the two, and no modifications to the urban environment are required. Our speculations call for minor infrastructural changes including lanes, kerbs, bollards, and barriers to accommodate for the deployment of driverless vehicles in the immediate future. We argue that the physical transformation of the street is trivial compared to much larger socio-economic urban implications.

[8] Tesla's current sensing system comprises eight cameras that provide 360 degrees visibility with a range of 250 metres. Twelve ultrasonic sensors and a forward-facing radar complement and strengthen the system. (Tesla. "Advanced sensor coverage." *Tesla*. accessed September 2018. https://www.tesla.com/autopilot.) Waymo and most of the other competitors follow a different approach. Waymo's most advanced vehicle, a Chrysler Pacifica Hybrid minivan customised with different self-driving sensors, relies primarily on LiDAR technology. It has three LiDAR sensors, eight vision modules comprising multiple sensors and a complex radar system to complement it. Waymo, "Introducing Waymo's suite of custom-built, self-driving hardware." *Medium.* accessed February 2017. https://medium.com/waymo/introducing-waymos-suite-of-custom-built-self-driving-hardware-c47d1714563.)

Driverless vision

> "In that empire, the art of cartography attained such perfection that the map of a single province occupied the entirety of a city, and the map of the empire, the entirety of a province. In time, those unconscionable maps no longer satisfied, and the cartographers guilds struck a map of the empire whose size was that of the empire, and which coincided point for point with it" [9]
>
> Jose Luís Borges

On perception and maps

The arrival of autonomous vehicles requires a new type of gaze—one that can renegotiate existing codes. Currently, human perception and means of gathering information define the visual and sonic stimuli that regulate urban traffic. Driverless sensors struggle with this information. The repetition of signage, for example, which is used to capture the driver's attention, often produces a confusing cacophony for autonomous vehicles. Dirty road graphics, misallocations of signage, consecutive but contradictory traffic signs, or even the lack of standardization of traffic signs and markings are all reasons for some of the most notorious incidents involving autonomous vehicles.[10] The assumption that driverless cars will fully adapt to these conditions is erroneous. It overlooks the history of streetscape transformations driven by changes in vehicular technologies.[11] More importantly, it ignores

[9] This is an extract from *Of exactitude in science*. It is a one-paragraph short story about the map-territory relation, written in the form of a literary forgery. Umberto Eco expanded upon the theme, quoting Borges's as the epigraph for his short piece *On the impossibility of drawing a map of the empire on a scale of 1 to 1*. Borges, Jorge Luis. "Of exactitude in science." *Quaderns" (*2002): 12-12.

[10] Prominent figures in the field such as Elon Musk from Tesla, North America Volvo CEO Lex Kerssemakers, and Carnegie Mellon University research scientist Christoph Mertz have all pointed out the problem of faded lanes. Paul Carlson from Texas A&M University aims for consistency in signage along American roads in order to accommodate automation more favourably. The news agency Reuters also points out that the lack of standardization in the US, as compared to most of the European countries who follow the Vienna Convention on Road Signs and Signals, causes problems. At the same time, several researchers at Sookmyung Women's University and Yonsei University in Seoul are focusing on how current automated sign recognition systems detect irrelevant signs placed along roads. This problematic cacophony is dramatically amplified in urban scenarios. Sage, Alexandria. "Where's the lane? Self-driving cars confused by shabby USA roadways." *Reuters*. accessed September 2018. http://www.reuters.com/article/us-autos-autonomous-infrastructure-insig-idUSKCN0WX131; Ng, Andrew and Yuanquin Lin. "Self-driving cars won't work until we change our roads—and attitudes." *Wired*. accessed September 2018. https://www.wired.com/2016/03/self-driving-cars-wont-work-change-roads-attitudes/; Brewster, Signe. "Researchers teach self-driving cars to 'see' better at night." *Sciencemag*. accessed September 2018. http://www.sciencemag.org/news/2017/03/researchers-teach-self-driving-cars-see-better-night).

[11] The relationship between the transformations of the streetscape and the arrival of new vehicular technologies also places driverless cars at the centre of the history of architecture. Since its inception, the car has often played a central role in architects' urban visions. The precepts of the Athens Charter and the images of the Ville Radieuse were explicit responses to the safety and functional issues associated with the popularization of car. The implementation of the Athens Charter was met with varying degrees of success. During the post-war reconstruction of Europe and the global explosion of suburban sprawl, it fuelled architectural controversies that questioned the role of cars in the definition of urban environments. Ian Nairn's *Outrage* (1955), Robin Boyd's *Australian ugliness* (1960), Appleyard, Myer, and Lynch's *The view from the road* (1964), Peter Blake's *God's own junkyard* (1964), Reyner Banham's *Los Angeles, the architecture of four ecologies* (1971), Venturi, Scott-Brown, and Izenour's *Learning from Las Vegas* (1972), and Alison and Peter Smithson's *AS IN DS:*

the fact that self-driving cars construct images that are barely comparable to human perception.[12]

Driverless cars take in real-time data through different on-board sensors. Although there is not an industry standard yet, certain trends are ubiquitous. The vehicles use a combination of radars, cameras, ultrasonic sensors and LiDAR (Light Detection and Ranging) scanners to get immediate information from the external environment.[13] The resulting perception differs greatly from that of humans. Driverless cars do not capture environmental sound. Colour rarely plays a role in the way they map the city. And, with various degrees of resolution, their sensors cover 360 degrees around the vehicle.

The way self-driving cars' sensors function defines their potential and their limitations. Some sensors detect the relative speed of objects in close range while others capture the reflectivity of static objects from far away. Some are able to construct detailed 3D models of objects no farther than a metre away; other sensors are indispensable for pattern recognition. Human drivers combine eyesight and hearing to make decisions; driverless cars' algorithms use information from multiple sensors in their decision-making processes. While each sensor in a driverless car captures its surroundings, it also produces a medium-specific map. The most prevalent sensors are radar, ultrasonic sensors, LiDAR and cameras. [14] Let us now look more closely at these.

Radars are object-detection systems that use radio waves to determine the range, angle, or velocity of objects. They have good range but low resolution, especially when compared to ultrasonic sensors and LiDAR scanners. They are good at near-proximity detection but less effective than sonar. They work equally well in light and dark conditions and perform through fog, rain, and snow. Although they are very effective at determining the relative speed of traffic, they do not differentiate colour or contrast, rendering them useless for optical pattern recognition, which is critical for monitoring the speed of other vehicles and surrounding objects. They detect movement in the city and are able to construct relational maps and capture cross-sections of the electromagnetic spectrum.

Ultrasonic sensors are object-detection systems that emit ultrasonic sound waves and detect their return to define distance. They offer a very poor range, but they are extraordinarily

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An eye on the road (1983) are some well-known examples of these debates. They also show how the topic lost traction in architecture debates at the end of last century.

[12] The way driverless cars sense the environment has been the focus of much of the research and media attention so far. Uber's arrival to the driverless race is linked to the famous Google lawsuit against Uber, which positions LiDAR technology at the centre of the dispute. This legal battle focuses the discussion on the car's ability to see the world. Davies, Alex. "Google's lawsuit against Uber revolves around frickin' lasers." *Wired*. accessed September 2018. https://www.wired.com/2017/02/googles-lawsuit-uber-revolves-around-frickin-lasers/.

[13] For a detailed list of the on-board sensors used by different self-driving car brands see footnote 4.

[14] Michael Barnard gives a thorough assessment of the strengths, weaknesses, and compromises inherent in these different sensors in his blog. Barnard, Michael. "Tesla & Google disagree about LiDAR — which is right?" *Clean Technica*. accessed September 2018. https://cleantechnica.com/2016/07/29/tesla-google-disagree-lidar-right/.

effective in close-range 3D mapping. Compared to radio waves, ultrasonic sound waves are slow. Thus, differences of less than a centimetre are detectable. These sensors work regardless of light levels and also perform well in snow, fog, and rain. They do not detect colour contrast or allow for optical character recognition but they are extremely useful in determining speed. They are essential for automatic parking and the avoidance of low speed collisions. They construct detailed 3D maps of the temporary arrangements of objects in proximity to the car.

LiDARs are surveying technologies that measure distance by illuminating a target with a laser light. They are currently the most widely adopted object-detection technology for autonomous vehicles. They generate extremely accurate representations of the car's surroundings but fail to perform over short distances. They cannot detect colour or contrast, they cannot recognise optical characters nor are they effective for real-time speed monitoring. Light conditions do not decrease their functionality, but snow, fog, rain, and dust particles in the air do, because LiDARs rely on light spectrum wavelengths. In addition to accurate point-cloud models of the city, they produce maps of air quality.[15]

RGB and infrared cameras are devices that record visual images. They have very high resolution and operate better over long distances than in close proximity. They can determine speed, but not at the level of accuracy of the radar. They can discern colour and contrast but underperform in very bright conditions and also as light levels fade. Cameras are key for character recognition software and serve as de facto surveillance systems.

This proliferation of real-time mapping is a defining element of the future urban milieu. The autonomous vehicles' capacity for storing the information that their sensors capture makes a big difference—the resulting image of the city could not differ more from traditional human-generated maps. These maps are a combination of sections of the electromagnetic spectrum, detailed 3D models around vehicles, detailed maps of air pollution, and interconnected surveillance systems. The base for these maps, however, is not produced by the car's sensors. Although contemporary autonomous vehicles can theoretically drive by relying solely on this instant mapping, in reality they navigate the environment combining the real-time acquired data and HD map stored in their hard drives.

HD maps help the car place itself in the world with a greater degree of accuracy, thus augmenting the sensors in the vehicle. These maps become extremely helpful in challenging situations like rainy or snowy conditions. More importantly, as they tell the cars what to expect on the road, the sensors can focus on processing moving agents like others cars or pedestrians, substantially improving their driving capabilities.

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[15] LiDARs have been used to observe particle concentrations in the atmosphere since the appearance of the technology in the 1960s. Warren B. Johnson. "Lidar applications in air pollution research and control." Journal of the air pollution control association, 1969, volume 19, no 3, pp.176-180. This new constant air quality maps generated by LiDAR scanners on-board of the vehicles could generate unprecedented environmental consciousness among society.

The inputs to construct these HD maps are threefold. First, a base map with information about roads, buildings, and so on. Currently, these base maps have been commodified by companies such as OpenStreetMap, which provides basic global data. This platform has become the common background for many of these new mappings start-ups, which build their cartographies on top of this. Imagery containing close-up details of streets is the second main component. Large quantities of real-time GPS location data from people with smartphones in their pockets constitute the third important input. This real-time information is supplemented with the data acquired by the vehicle's on-board sensors. The maps are continuously being updated with information on lane markings, street signs, traffic signals, potholes, and even the height of a kerb, with a resolution down to the centimetre.[16] These new cartographies are radically different to traditional travel maps or the first generation of digital maps that helped humans to move around the city. Originally, maps emerged as a two-dimensional representation of a space—this approach allowed humans to navigate different territories for centuries. During the last decade, digital maps have guided users through basic turn-by-turn directions while walking or driving. These HD maps are not the city as we see it because the cars require an unseen precision, a precision where the map becomes the territory that they respond to.[17]

The combination of real-time mapping and HD stored maps takes us beyond geographical or physical territories – the potential applications of which go far beyond self-driving vehicles. It, for example, makes issues around individual privacy and security evident. However, this combination also offers the possibility of transforming endless areas of research and design, and influencing policy and governance.

Towards a sensorial agreement

Interconnected sensors and HD maps can create a new common, ubiquitous global sensorium that further dissolves the distinction between nature and artifice.[18] Engaging citizens in this

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[16] HD maps seem indispensable to the future of driverless vehicles. The need for them has produced a wide variety of enterprises dedicated to this highly valuable parallel industry. Google is once again the leader, though Audi, BMW, Daimler, and Intel are among the main shareholders of Here, a technological map company, which itself was a product from Nokia. TomTom, partnering with Baidu and Civil Maps, who count Ford among their main investors, have also joined the race. (The Economist. "The battle for territory in digital cartography." *The Economist.* accessed September 2018. https://www.economist.com/news/business/21723173-not-all-roads-lead-google-maps-battle-territory-digital-cartography).

[17] In June 2017 during a test drive near Ford's Michigan headquarters, the team noticed something strange with their self-driving cars. Every car shifted slightly at the same point in the lane as if avoiding a pothole. But the problem was not in the cars, it was on the map. A minor glitch caused one pixel in the recently updated file to have the wrong data value. The map informed the cars that the terrain was 25 cm higher than it actually was. The new map looked perfect to the human eye but not to driverless vehicles. (Fiegerman, Seth. "The billion dollar war over maps." *CNN.* accessed September 2018. http://money.cnn.com/2017/06/07/technology/business/maps-wars-self-driving-cars/index.html).

[18] The term sensorium derives from the Latin *sēnsus* felt, from *sentīre* to perceive. It could be defined as the sum of an organism's perception, the seat of sensation where it experiences and interprets the environments where it lives. ("Sensorium." *Merriam Webster.* accessed September 2018. https://www.merriam-webster.com/dictionary/sensorium).

new sensorial environment makes them aware of the need for a Sensorial Social Contract.[19] This embeds the judgment of society, as a whole, in the sensorial governance of societal outcomes. In other words, driverless vehicles aren't just about cars, rather they are more akin to the interaction between a government and a governed citizenry. Modern government is the outcome of an implicit agreement—or social contract— between the ruled and their rulers, which aims to fulfil the general will of citizens. If the Enlightenment marked humanity's transition towards the modern social contract, then determining a sensorial agreement could serve as the first step towards cohabitation between humans and non-human entities. Following on from the concept of the social contract, where individuals consent, either explicitly or tacitly, to surrender some of their freedoms[20] for the general good, this new agreement requires individuals to assent to partially hand over safety, control, and privacy – a move that could then unleash wide societal concerns about individual rights, agency, and urban policy.[21]

Safety is one topic that supports the urgent need for a sensorial contract. The presence of self-driving cars in urban environments challenges accepted notions of safety. The risks involved with autonomous vehicles are both public and secretive. Accidents involving self-driving cars are well documented. Google publicly reported on this monthly until November 2016. Tesla and Uber are more secretive, but their accidents tend to become media events.[22] The ethical

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[19] The term Sensorial Social Contract derives from algorithmic social contract coined by MIT professor Iyad Rahwan, who developed the idea that by understanding the priorities and values of the public, we can train machines to behave in ways that a society would consider ethical. Rahwan, Iyad. "Society-in-the-loop. Programming the algorithmic social contract." *Medium*. accessed September 2018. https://medium.com/mit-media-lab/society-in-the-loop-54ffd71cd802.

[20] Coincidentally the car was advertised as the ultimate freedom machine – initially cars allowed people to choose where, when and how to we go. That illusion did not last long. Gratz, Roberta Brandes, and Norman Mintz. *Cities back from the edge: New life for downtown*. John Wiley & Sons, 2000.

[21] Several thinkers argue for new modes of governance to tackle today's society. For example, Indy Johar argues for innovation in social contracts. "These innovations inherently rely on an progressive social contract—where we all contribute to the development of shared public good."
Johar, Indy. "Societal innovation & our future cites. The case for a social contract for innovation." Dark Matter labs. accessed September 2018. https://provocations.darkmatterlabs.org/the-societal-contract-for-innovation-15593ae9a1d4.

[22] A fatal accident occurred on 7 May, 2016 in Williston, Florida when a Tesla Model S electric car was engaged in autopilot mode. (Singhvi. Anjali, and Karl Russell. "Inside the self-driving Tesla fatal accident." *New York Times*. accessed September 2018. https://www.nytimes.com/interactive/2016/07/01/business/inside-tesla-accident.html). Another lethal collision took place on 23 March 2018 in California while a Tesla Model X sport-utility had autopilot mode turned on. In these two incidents, Tesla drivers died as a result of the crashes but there were no other humans implicated. (Schmidt, Gregory. "Tesla says crashed vehicle had been on autopilot before fatal accident." *New York Times.* accessed September 2018. https://www.nytimes.com/2018/03/31/business/tesla-crash-autopilot.html). Uber briefly suspended their autonomous vehicles programme across their three testing locations – Arizona, San Francisco and Pittsburgh – after one of their vehicles was involved in an accident on 24 March 2017 in Arizona. Uber has just interrupted their programme again after the pedestrian fatality involving an autonomous Uber car on 18 March 2018 in Tempe, Arizona. Isaac, Mike "Uber suspends tests of self-driving vehicles after Arizona crash." *New York Times.* accessed September 2018. https://www.nytimes.com/2017/03/25/business/uber-suspends-tests-of-self-driving-vehicles-after-arizona-crash.html; Associated Press. "Arizona suspends Uber's self-driving car testing after fatality." The *Guardian.* accessed September 2018.

implications of these scenarios have been popularized by MIT interactive online test, Moral Machine.[23] Self-driving technologies imply a transfer of accountability to the algorithms that guide the vehicle. Most of the legal experts predict a trend towards increased manufacturer liability with the increased use of automation. Major players such as Volvo, Waymo, and Mercedes already supported this attribution of responsibility in 2015.[24] Car manufacturers will accept insurance liabilities after full level five automation is a reality. In the immediate future, vehicle manufacturers will probably settle suits quickly if they believe their technology is at fault, but put up a fight should the human operators of the other vehicles be in the wrong. This hypothesis was recently tested through two recent events. In January 2018, GM was sued by a motorcyclist in the first lawsuit to involve driverless cars. GM maintained their innocence as they believed their car was not responsible for the incident, but they finally settled. The first fatal accident involving pedestrians in March 2018 was also settled in private by Uber. This follows the precedent set by previous non-fatal accidents involving self-driving vehicles, which were also settled confidentially.[25]

But safety goes beyond the insurance conundrum and it raises issues of control too. Consider an AI algorithm that controls a self-driving car. One of the major concerns is that the system is a "black box". Once the system is trained, data can be fed to it and a useful interpretation of the data will be produced. But the actual decision-making process is not easily accessible for humans. In *Aramis or the Love of Technology*, Bruno Latour proves how the success of a new technology is deeply connected with the perceived dangers it entails.[26] To share the streets with computer-driven cars shakes collective notions of acceptable risk. The technology needs to prove trustworthy. And trust, in this case, results from a combination of scientific evidence, storytelling, public demonstrations constructed by engineers, and the economies and populations involved in driverless cars' development. When common agreements regarding trust and responsibility shift, the way we live together needs to be re-examined.[27] If dense urban environments intensify the conflicts between technology, ethics,

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https://www.theguardian.com/technology/2018/mar/27/arizona-suspends-ubers-self-driving-car-testing-after-fatality.

[23] Rahwan, Iyad, Jean-Francois Bonnefon, and Azim Shariff. "Moral machine—human perspectives on machine ethics." *MIT*. accessed September 2018. http://moralmachine.mit.edu/.

[24] Korosec, Kirsten "Volvo CEO: we will accept all liability when our cars are in autonomous mode." *Fortune*. accessed September 2018. http://fortune.com/2015/10/07/volvo-liability-self-driving-cars/; Whitaker, Bill "Hands off the wheel." *CBS*. accessed September 2018. http://www.cbsnews.com/news/self-driving-cars-google-mercedes-benz-60-minutes/.

[25] Gibbs, Samuel. "GM sued by motorcyclist in first lawsuit to involve autonomous vehicle." The *Guardian*. accessed September 2018. https://www.theguardian.com/technology/2018/jan/24/general-motors-sued-motorcyclist-first-lawsuit-involve-autonomous-vehicle; Reuters. "Uber settles with family of woman killed by self-driving car." The *Guardian*. accessed September 2018. https://www.theguardian.com/technology/2018/mar/29/uber-settles-with-family-of-woman-killed-by-self-driving-car.

[26] Latour, Bruno. *Aramis or the love of technology*, Cambridge, MA: Harvard University Press, 1996.

[27] Perrow analyses the social side of technological risk in *Normal accidents*. He argues that accidents are normal events in complex systems and are the predetermined consequences of the way we launch industrial ventures. He believes that the conventional engineering approach to ensuring safety (building in more warnings and safeguards) is inadequate, as complex systems assure failure. Perrow, Charles. *Normal accidents: living with high-risk technologies,* Princeton: Princeton University Press, 1999.

economy and collective safety, the realm of sensors renders the conflicts public by opening the "black box".

Surveillance is a second topic that reinforces the need for a sensorial contract in the autonomous-car-filled city. The huge amount of processed data also includes personal information from drivers, passengers, and pedestrians. The data amassed by companies like Uber, whose tactics regarding data management have generated several controversies, will be amplified to unprecedented levels, making the need for standards of privacy protection urgent.[28] Currently, industry agreements on privacy best practices include commitments to transparency, consumer choice, minimization of data collection and retention, and de-identification. The principles require increased protection for personally identifiable information, such as geolocation, driver behaviour, and biometric data. Accumulation of individuals' profiles and driving behaviours may prove to be valuable information for certain entities, such as insurance companies, vehicle manufacturers, advertisers, and law and traffic enforcement agencies. As a society, it is essential that we demand transparent processes for this data collection, as well as information about the purposes for which it is collected and by whom. Yet machine learning requires the constant feeding of information to improve its capacities; this conflicts with some of the data minimization principles.[29]

At the intersection of privacy and safety, the sensorial contract raises a third issue: security threats. The vehicles are vulnerable to hacks including the possibility of different actors taking over driving functions, either just for kicks or as a cyberwar tactic.[30] One of the main reasons why driverless vehicles are particularly sensitive to cyberattacks is the nature of their technology. Communication among the different sensors is fundamental for the efficiency of their systems but this also leaves them extremely exposed. The systems are designed to work

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Virilio claims how one cannot innovate without creating some damage. Virilio, Paul. *The original accident,* Oxford, UK: Polity Press, 2007.
Hod Lipson, professor from Columbia University and co-author of *Driverless: intelligent cars and the road ahead,* advises that the Department of Transportation should define a safety standard based on statistical goals, not specific technologies. They should specify how safe a car needs to be before it can drive itself, and then step out of the way. Mitchell, Russ. "Why the driverless car industry is happy (so far) with Trump's pick for transportation secretary." *LA Times*. accessed September 2018. http://www.latimes.com/business/autos/la-fi-hy-chao-trump-driverless-20161205-story.html.

[28] Uber's use of data has been in the middle of several lawsuits for years. "God view mode" (currently "Heaven mode") allowed Uber employees to track the movements of all passengers in real time without obtaining permission. "Hell" was used to identify drivers that were driving for both Uber and Lyft and ensured that those drivers were prioritized over drivers exclusively contracting for Uber in order to persuade them to drive only for them. Slattery, Martin "Between "Heaven mode" and "Hell": Uber's use of big data puts users in a purgatory of certainty around privacy issues*." Codea.* accessed September 2018. https://www.codea.com.au/publication/heaven-mode-hell-ubers-use-big-data-puts-users-purgatory-certainty-around-privacy-issues/.

[29] Lavery, Paul and Douglas McMahon. "Driverless cars—mapping the privacy issues." *Lexology.* accessed September 2018. https://www.lexology.com/library/detail.aspx?g=95e67012-d435-43b8-913d-d01fb50388d1; Goodman, Ellen P. "Self-driving cars: overlooking data privacy is a car crash waiting to happen." The *Guardian*. accessed September 2018. https://www.theguardian.com/technology/2016/jun/08/self-driving-car-legislation-drones-data-security.

[30] Garfinkel, Simon. "Hackers are the real obstacle for self-driving vehicles." *Technology Review.* accessed September 2018. https://www.technologyreview.com/s/608618/hackers-are-the-real-obstacle-for-self-driving-vehicles/.

together and involve innumerable agents. The rivalry between some of the companies means that they are reluctant to share knowledge about cyber threats and vulnerabilities or work together to develop more secure designs.

Another fundamental topic for concern is urbanization. It is not yet clear whether autonomous vehicles will promote more city densification, or urban sprawl. In history, the evolution of transportation has generally led to changes in urban form. The more radical the changes in transport technology have been, the more urban form has been altered. Theoretically, autonomous vehicles can use road networks more efficiently and thus free up road space if trip generation rates and population growth are held constant. This space can be redesigned for a whole new spectrum of opportunities on public land. [31] Yet, it is also likely these vehicles will enable previously suppressed trips to be taken. The resulting increase in traffic volume will reduce the potential to free road space for alternate uses, and more importantly, raises questions about further urban sprawl. The easier it is to get from one point to another, the farther away from the city centre people may opt to live; this could encourage an unsuspected increase in low-density urbanisation with unprecedented ecological consequences.[32]

An extra topic in the sensorial contract is the possible impact on public transport. Due to Uber and other shared mobility companies, the use of public transport has fallen substantially in many locations, particularly in the USA. The arrival of autonomous vehicles could draw even more people away from public transport into private vehicles. This move could discourage any further expenses dedicated toward improving public infrastructure. Large numbers of people (typically of lower economic status and the elderly) depend on public transport. Therefore, this move could also potentially increase inequality gaps. At the same time, driverless technologies could have a substantial impact on the "last mile" by making public transport in less dense areas more viable. Some cities are also trying to incorporate driverless technologies in their vehicular fleets by following their historical implementation in the metro and other rail services. This impact on public transport links directly to a fundamental issue inherent in the proposed sensorial social contract: automation.[33]

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[31] There are also multiple speculations about what to do with petrol stations and private parking in driverless car scenarios. Some top tier corporate architectural firms such as Gensler, Perkins + Will or KPF have all made proposals. Henderson, Jason, and Jason Spencer. "Autonomous vehicles and commercial real estate." *Cornell Real Estate Review* 14, no. 1 (2016): 14.

[32] Yigitcanlar, Tan, Graham Currie, and Md Kamruzzaman. "Driverless vehicles could bring out the best–or worst–in our cities by transforming land use." *The Conversation*. accessed September 2018. https://theconversation.com/driverless-vehicles-could-bring-out-the-best-or-worst-in-our-cities-by-transforming-land-use-84127; Hodgetts, Timothy. "Driverless cars could see humankind sprawl ever further into the countryside." *The Conversation*. accessed September 2018. https://theconversation.com/driverless-cars-could-see-humankind-sprawl-ever-further-into-the-countryside-83028.

[33] The Economist. "A new utopia. A chance to transform urban planning. How autonomous vehicles will reshape cities." *The Economist.* accessed September 2018. https://www.economist.com/special-report/2018/03/01/a-chance-to-transform-urban-planning.

Automation warrants its own chapter, we would like to briefly enumerate some of the problems that automation raises. Truckers, bus drivers, taxi drivers, chauffeurs and other vehicles operators will lose their jobs. Whether or not new jobs will appear in their place remains an open question in need of exploration. Additionally, the length of the periods of possible unemployment and the quality of these new positions are also unknown. Very different scenarios could play out when driverless cars take away human jobs. One could imagine a devastating situation that leads to a further increase in inequality or a very positive outcome, where people's quality of life is improved at all levels of society. In 2017, India became the first major economy to say 'no' to driverless cars. Their transport minister stated that India would not allow the entry of any technology that would take away jobs. There was no further explanation or discussion following this declaration.[34]

[34] Das Gupta, Moushumi "Won't allow driverless cars that take away Jobs: Nitin Gadkari." *Hindustan Times.* accessed September 2018. https://www.hindustantimes.com/india-news/won-t-allow-driverless-cars-that-take-away-jobs-says-union-minister-nitin-gadkari/story-JCDjBMoDQ4yzXrWv3ltxsK.html.

V.1.1 Driverless vision Seoul

Driverless vision Seoul examines the tension and reality of AI and humans merging and diverging as they negotiate Seoul's unique urban landscape—challenging us to consider how we can design cities for the future of autonomous vehicles.

Driverless vision aims to generate empathy between humans and non-humans, and to construct the trust required for negotiations that will settle how we will live together. By overlapping human and machine perceptions, the installation helps to identify the areas of the city that will need to be redesigned in the immediate future.

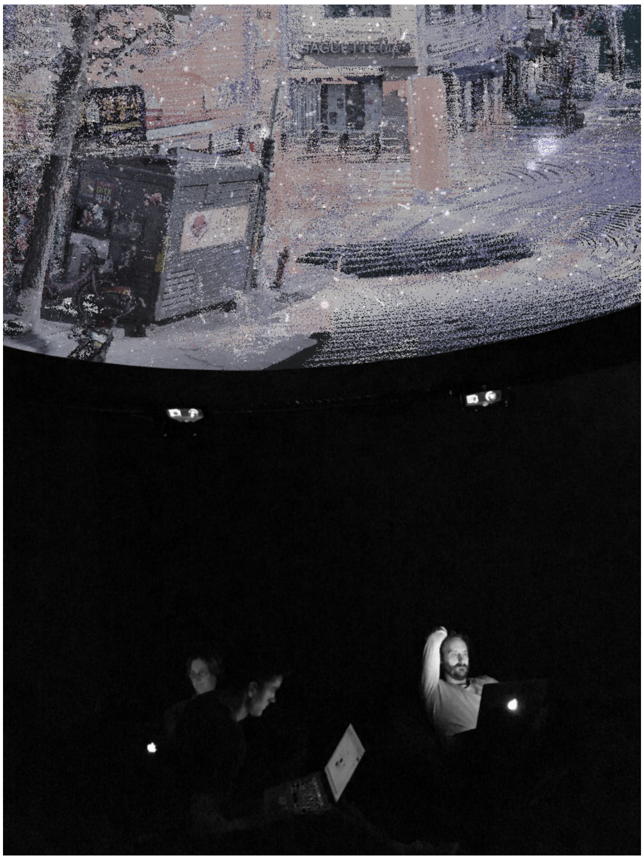
Driverless vision is the immersive experience of becoming an autonomous, self-driving vehicle. It explores the disruptive effects on the built environment caused by the deployment of technologies for autonomous mobility. Currently, the visual stimuli that organize traffic are designed for human perception. The arrival of driverless cars requires the emergence of an omnidirectional gaze in order to negotiate existing visual codes. To assume that driverless cars will fully adapt to future conditions of the city, however, neglects the history of transformations in urban streetscapes associated with changes in vehicular technologies. *Driverless vision* is an attempt to understand how driverless cars will change the city by immersing the audience in an urban journey experienced from the car's point of view, which involves seeing the streets of Seoul via videos and scanners, or through overlapping yet dissonant perceptions.

Driverless Vision Seoul. Image by Guillermo Fernández-Abascal.

Driverless vision Seoul was conceived by Urtzi Grau, Guillermo Fernández-Abascal and Daniel Perlin. The project was produced for the Seoul Biennale of Architecture and Urbanism in 2017. It involved utilizing an eight-meter diameter dome with 360 visuals developed with the generous support of Max Lauter, University of Technology Sydney, Rice University and Ocular Robotics.

V.1.2 Driverless vision Sydney

Driverless vision Sydney is an attempt to understand how driverless cars will change the city by asking the audience to look at the city from the car's perspective. *Driverless vision* uses a 7.5 m diameter dome and 360 visuals generating an immersive environment where humans will "see" the city as cars do. By locating this dome in the Paddington Reservoir Gardens, an intense mediation with the past history of the site is established. *Driverless vision* explores how the combination of radars, cameras, sensors and LiDAR will transform cities like Sydney. It gives humans access to the cars' vision by collaging images of Sydney produced by different sensors. It shows the information that cars miss by comparing their perception to the actual spaces in the city. It helps to identify the changes required in the streetscape to ensure a peaceful cohabitation of cars and humans. Therefore, this project is more than just a visualization tool, it is also an antechamber to the parliament of things.



Driverless Vision Sydney. Visualization by Guillermo Fernández-Abascal.

Driverless vision Sydney was conceived by Guillermo Fernández-Abascal and Urtzi Grau in collaboration with Ocular Robotics and Partridge. It was a finalist proposal for Art & About 2017.

Driverless vision Seoul: expanded analysis.

Context

Alejandro Zaera-Polo and Hyungmin Pai, curators of the inaugural Seoul Biennale of Architecture and Urbanism, invited Guillermo Fernández-Abascal (GFA2) and FKAA to develop an installation for "Imminent Commons: The Expanded City". The exhibition collected 40 projects addressing nine imminent commons folded into the curatorial statement of the Biennale at the Donuimun Museum Village. The nine commons were structured in resource-based commons: air, water, fire and earth; and technology-based commons: sensing, communicating, moving, making and recycling. Driverless vision was part of the moving common but also touched on sensing concerns.

From the beginning (August 2016), the commission linked a prototypical deployment, the exhibition installation, and a research paper. The show (2 September 2017- 5 November 2017) assembled objects -mostly 1:1 prototypes - related to biotechnologies, robots and social media, thus questioning where architects should get information from in the immediate future. The book (September 2017), the second volume of three books that compile the ideas tested in the Biennale, documents the deeper research associated with the installation. Participants included Philippe Rahm, Tomás Saraceno, David Benjamin, Liam Young, Andres Jaque, Beatriz Colomina, Rahul Mehrotra and Carlo Ratti, among other international researchers.

This exhibition positions itself along a lineage of recent architecture shows such as *The Future starts here*, *Fear and love* and *After belonging* [35] that gathered the work of some of the research-based practices that emerged after the Global Financial Crisis together with technological devices and artwork. The displays avoid traditional architectural representation as the vehicle to represent and debate architecture. In an opposite direction, a large number of architectural exhibitions including the *Make New History: 2017 Chicago Architecture Biennial* look inside the history of the discipline in order to resist neoliberal architecture.

Conceptual framework

The installation is both a visualization tool and a post-human parliament. It helps us to understand that reality is fundamentally linked to the point of view of the actor observing it. For humans, the city is what we perceive, but what is it for driverless cars? The installation depicts the urban environment from an autonomous vehicle's perspective. It connects to other recent investigations such as *Where the city can't see* [36] by Liam Young. In Liam's film, he

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[35] *The Future starts here* (Victoria and Albert Museum, London, 2018), *Fear and Love* (Design Museum London, 2016-17), *After Belonging (Oslo Triennale, 2016).*

[36] *Where the city can't see (2016)* is a project commissioned by Abandon Normal Devices and St Helens Heart of Glass & University of Salford Art Collection. It was produced by Liam Young and Abandon Normal Devices, with support from Forestry Commission England's Forest Art Works and

also uses a LiDAR scanner to depict the city as seen through the machines that now manage it. He explores the new subjects or agents that are emerging in contemporary urban scenarios, as humans are no longer at the centre of the world. His project tries to implicate the audience in conversations about how these technologies are changing the planet. He overlays the powerful visuals with narration and tries to emotionally charge this content so that people are compelled to consider whether or not these are technologies that one wants to see in the world. It is similar to our project in that our film uses data to create an image heavy experience, but its dramatization moves the conversation away from data to focus it in governance.

While Liam's film operates on a flat screen, we use a dome with an 8m diameter, which is suspended from the ceiling and elevated 1.7m from the floor, in order to facilitate an immersive experience. Six projectors and five speakers are located around the space, serving as engaged actors in the proposed conversations. In this sense it also operates in a similar way to *Black shoals stock market planetarium,* [37] where the audience is immersed in a world of real-time stock-market activity, represented as the night sky, which is full of stars that glow as trading takes place on particular stocks. Both *Where the city can't see* and *Black shoals stock market planetarium* aim to create awareness of specific topics among the public.

Artist Jonas Staal attempts to bring another subject to the public sphere – that of governance. He pushes the limits of representation with projects such as *New World Embassy: Rojava.* [38] Constructed in Oslo's City Hall, this temporary embassy represented the ideals of "stateless democracy" as developed by the Democratic Self-Administration of Rojava (northern Syria). The embassy consisted of a large-scale, oval-shaped structure, which was designed as an "ideological planetarium" and departed from the universalist symbols of the different political organizations in the Democratic Self-Administration of Rojava. It was active for two days during which time representatives from Rojava met with international politicians, diplomats, academics, journalists, students, and artists. Just like this embassy, our installation aims to become a space for discussion, but in our case with a focus on discussions about the future cohabitation between human and non-humans.

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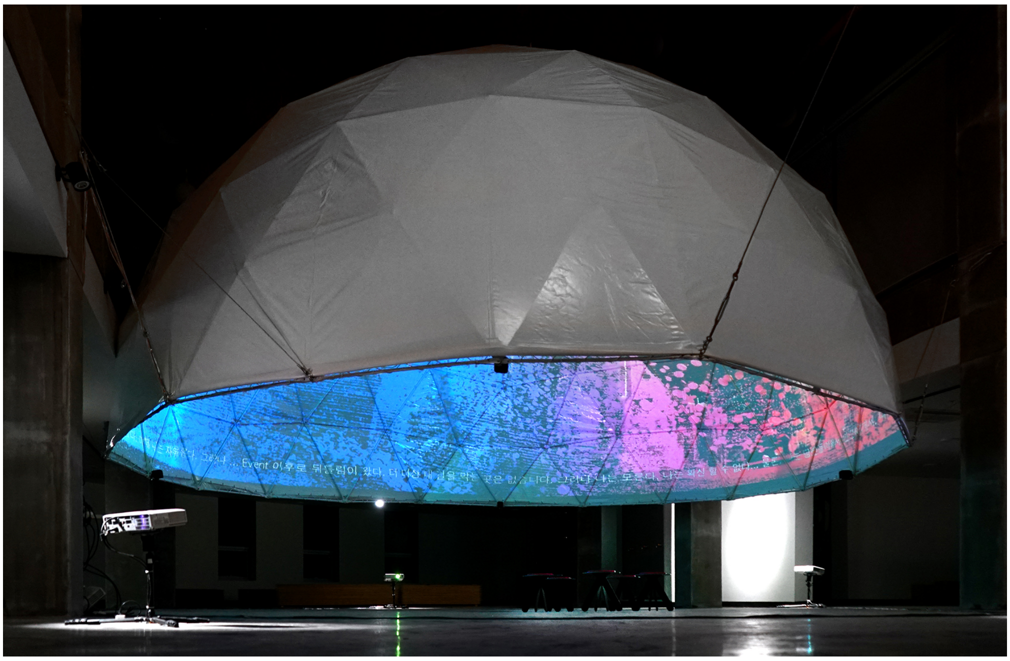
funding from Arts Council England. It was directed by Liam Young and the script is written by Tim Maughann.

[37] *Black shoals stock market planetarium* is an art project created by Joshua Portway and Lise Autogena. It started as an installation in a restaurant in the city of London in 1998; since then multiple iterations have been implemented in some of the more important cultural venues around the world including the Tate Britain (2000-2001), the Nikolaj Copenhagen Contemporary Art Centre (2003-2004), Sommerset House (2015-2016) and more recently at the Science-Art Museum in Singapore (2016).

[38] *New World Embassy: Rojava (2016)* is a project by the Democratic Self-Administration of Rojava and Studio Jonas Staal, commissioned by the Oslo Architecture Triennial.



Driverless Vision Seoul. Image by Max Lauter.

<u>Hypothesis</u>

The installation was intended to test two main ideas:

1. Self-driving cars construct images that are barely comparable to human perception. But what are the exact differences? How will these vehicles discern corners and the differences between the road below, the buildings alongside them and the sky above? Could the autonomous vehicle installation be used as a tool to identify the spaces that could benefit from redesign in the city?

2. Engaging citizens in this new sensorial environment could make them aware of the necessity of a sensorial social contract. But where do these discussions need to take place? Could we design new spaces for negotiation that allow the variety of agents required for socio-technical controversies? Can we bring together parliaments and laboratories under a single roof?

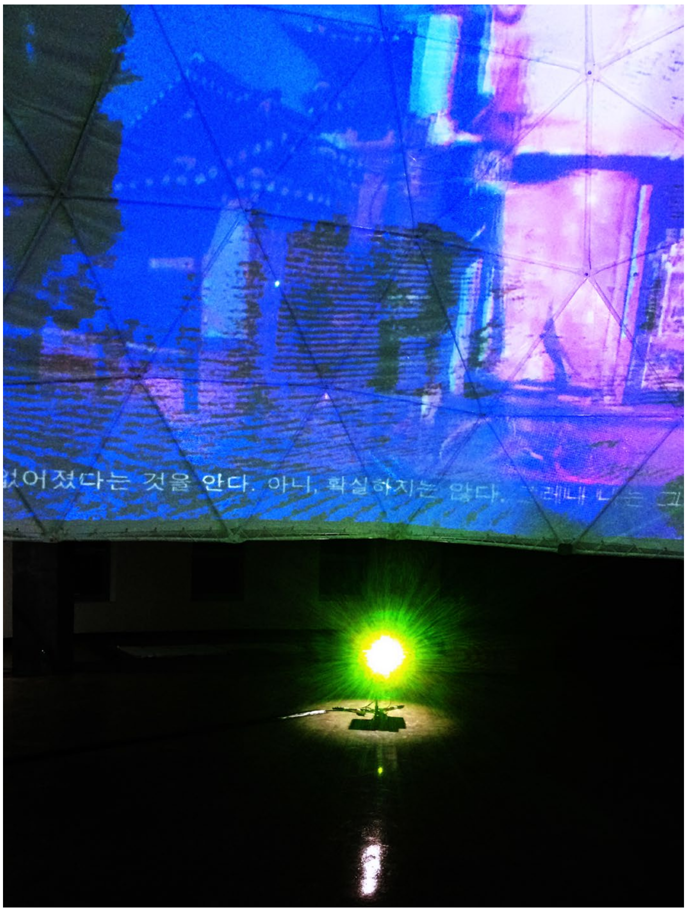
<u>Findings</u>

The project uncovered three main findings:

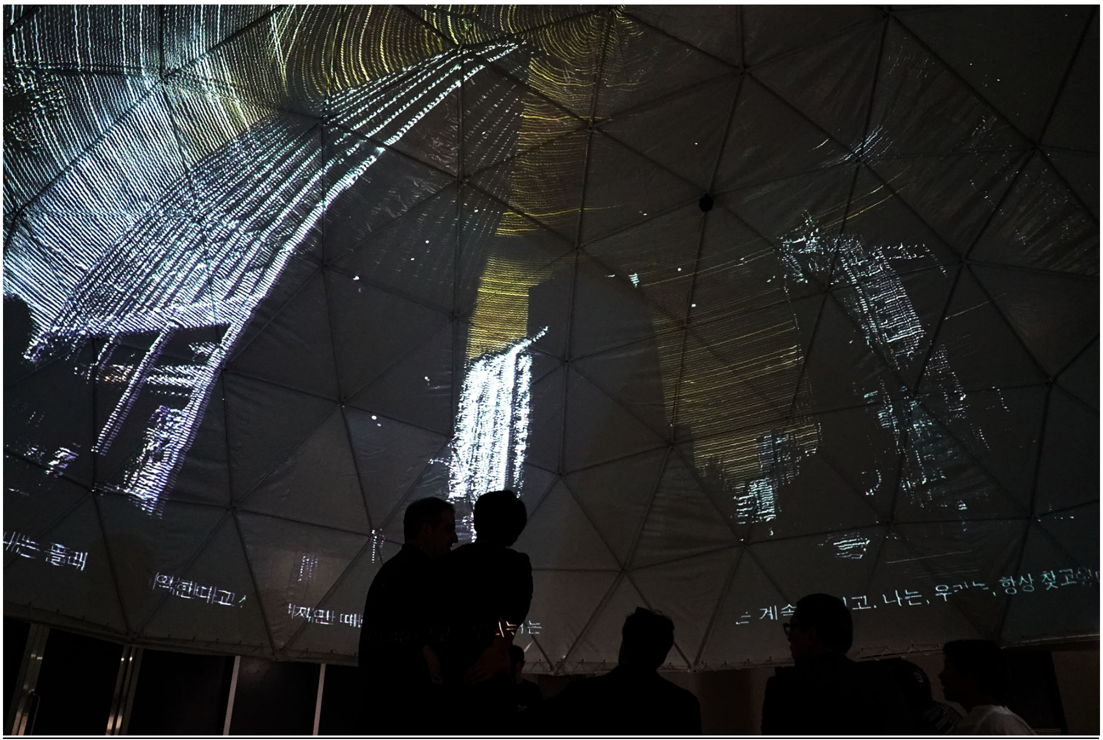
1. It allowed us to familiarize ourselves with an apparently complicated technology, which turned out to be pretty simple. We discovered the way it works through multiple scanning sessions in Sydney, Houston and Seoul along 2017. Most LiDAR systems, including ours, involve a camera spinning around on a tripod shooting out lasers at a high frequency. The camera then looks for that laser light to bounce back, and can work out the shapes and sizes of things based on how long it takes to do so. We also learned of the difficulties inherent in managing the generated data: the resulting point clouds had an immense density that was hardly operative and arduous to visualize.

2. Starting from the view of the road ahead captured by the LiDAR scanner, the images in the film were overlaid with another 360 camera images. This technique allowed for the exploration of dissonant perceptions. The video emphasized how the machine's intelligence becomes less and less correspondent to the human understanding of the world. We discovered that certain spaces are invisible to machines, such as mirrors and black rubbers. More importantly, we noticed constant dust, which translated into nebulous point clouds in Seoul’s virtual atmosphere and served to highlight the infamous air quality of the city. These new real-time air quality maps, generated by LiDAR scanners onboard the vehicles, could generate unprecedented environmental consciousness, which is critical for the future of the planet.

3. This hybrid approach – part tool and part parliament – fulfilled the mission of operating in a field that straddles science and culture. The installation shows that it is possible to create platforms where the decision making-process is enriched by constructed facts that inform the discussion. During the life of the project, the installation brought together experts, politicians, journalists, and citizens for conversations about humans, non-humans, empathy, city planning, safety, infrastructure, surveillance, cars, trust, autonomous vehicles and air quality among other themes.



Driverless Vision Seoul. Image by Guillermo Fernández-Abascal.



Driverless Vision Seoul. Image by Max Lauter.

<u>Full Credits</u>
Client
Commissioned by the Seoul Biennale of Architecture and Urbanism, 2017

Concept and Design
Urtzi Grau, Guillermo Fernández-Abascal, Daniel Perlin.
The short story is deeply inspired by the short poem *There will come soft rains (1918) by Sara Teasdale and the short story August 2026: There will come soft rains (1950) by Ray Bradbury.*

Filming / Sensing + Production
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Visual / Sound Design + Production
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Driverless discussion

"Science finds, industry applies, man conforms" [39]
The Chicago World's Fair, 1933

Learning to live together: a hybrid forum

Our hypothesis claims that only a hybrid forum has the capacity to tackle safety, control, security, and automation amongst other controversies linked to the imminent future of driverless technologies. Hybrid forums address the questions and problems involved at different levels in a variety of domains and have proven to be successful in dealing with several contentious affairs such as mad cow disease or nuclear waste disposal.[40] Hybrid forums bring together a collective of experts, including industry and technology stakeholders and politicians, with non-experts to discuss technical solutions. In the case of driverless vehicles, the range of stakeholders that need to come together to discuss issues associated with their implementation include citizens and experts in different fields such as robotics, deep learning, cybersecurity, insurance, law, ethics, infrastructure, technology, the traditional automotive industry – from drivers to engineers – and politicians. Hybrid forums allow for collective experimentation and learning in the face of the uncertainties and inequities engendered by the techno-sciences. Hybrid forums, as apparatuses of elucidation, facilitate a process of discussion, in which what counts as expertise and who counts as an expert are examined. Hybrid forums do not just include the knowledge of a plurality of actors independent of their institutional credentials, but are also spaces in which the identity of actors is open to negotiations and hybridization. As such, hybrid forums are spaces in which expertise emerges as a collective achievement.

Driverless cars do not fit in with the previous twentieth century vehicular agreements. Every time a major disruptive mobility technology has appeared, a new agreement has been set. We can see this in the initial International Convention on Motor Traffic in Paris (1909), the three United Nations Conventions on Traffic (Paris 1926, Geneva 1949, and Vienna 1968), the Chicago Convention on International Civic Aviation (1944), and the London Convention on Facilitation of International Maritime Traffic (1965).

The Vienna Convention on Road Traffic and the Vienna Convention on Road Signs and Signals set clear precedents on global mobility agreements.[41] The meeting's main purpose was to facilitate international road traffic and to increase road safety. The Vienna Convention

[39] These words become the unofficial motto of 1933 Chicago World's Fair, the objective of the event was to resurrect the public's confidence in science, which had been eroded by the use of chemical weapons during World War I. Grossman, Ron. "Century of progress: the science and the sleaze." *Chicago Tribune. accessed September 2018.* http://www.chicagotribune.com/news/ct-per-flash-century-progress-0526-20130526-story.html.
[40] Hybrid forums are analysed by Callon, Barthe, and Lascoumes's *Acting in an uncertain world*. They show how hybrid forums have proven successful in dealing with different controversial topics. Callon, Michel, Pierre Lascoumes, and Yannick Barthe. *Acting in an uncertain world: An essay on technical democracy.* Cambridge, MA: MIT University Press, 2011.
[41] Vienna Convention on Road Traffic and Vienna Convention on Road Signs and Signals were signed in 1968 and have been effective since 1978. Despite recent amendments in Vienna Convention treaties, the legislation does not reflect the current status of our environment. "United

on Traffic focused on traffic rules, and different parties agreed upon uniform traffic jurisdiction. One of the most controversial areas from the treaty affecting driverless technologies takes root in the given definition of driver: "any person who drives a motor vehicle or other vehicle (including a cycle), or who guides cattle, singly or in herds, or flocks, or draught, pack or saddle animals on a road."[42] In 2014, an important amendment was put in force to allow drivers to take their hands off the wheel. However, a driver was still required to be present and able to take the wheel at any time, thus keeping the human element in the equation.[43]

The Vienna Convention on Road Signs and Signals focused on the standardization of road signs and signals. All road signs were structured in seven categories, where each class was attributed specific and uniform shapes, sizes and colours. Road marking specifications were also standardized; these set the geometry, colour and possible word content. The convention also determined traffic lights' colours and meanings, and set their location and purpose. All of these agreements were based on human perception.

With the arrival of driverless vehicles, the agreements need to be renegotiated to accommodate both human and non-human sensing. Different items such as roads signs and traffic lights may eventually disappear as driverless cars gain the ability to safely navigate the roads. However, road markings will be particularly important as they provide critical information that allows the car to navigate. Currently the visual crispness of lane markers varies dramatically from place to place and presents itself as the perfect case study for the required homogenization of streetscapes. It is also indicative of the type of light infrastructural changes required in the immediate future for driverless cars.[44] The idea of

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Nations. Treaty Collection: XI. B-19. Transport and Communications - Convention on Road Traffic." *United Nations*. accessed September 2018. https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XI-B-19&chapter=11&Temp=mtdsg3&clang=_en; "United Nations. Treaty Collection: XI. B-20. Transport and Communications - Convention on Road Signs and Signals." accessed September 2018. https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XI-B-20&chapter=11&Temp=mtdsg3&clang=_en.

[42] "Chapter 1, Article 1." In Convention on Road Traffic. Vienna: United Nations, 1968. *United Nations*. accessed September 2018. https://www.unece.org/fileadmin/DAM/trans/conventn/crt1968e.pdf.

[43] This requirement caused several controversies in the USA. OTTO (a self-driving truck company currently integrated in UBER) released a commercial video of their truck circulating around Nevada without a driver behind the wheel. As part of this conversation, the USA Transportation Department is studying plans to exempt up to 100,000 autonomous vehicles from current safety standards, which were written based on the assumption that a human driver was responsible of the car's operation at all times. Harris, Mark. "How OTTO defied Nevada and scored a $680 million payout from Uber." *Wired*. accessed September 2018. https://www.wired.com/2016/11/how-otto-defied-nevada-and-scored-a-680-million-payout-from-uber/; Shepardson, David. "USA Congress plans self-driving car legislation to speed rollout." *Reuters*. accessed September 2018. https://www.reuters.com/article/us-usa-selfdriving-idUSKBN18X2W4; Shepardson, David. "USA transportation agency calls March 1 'summit' on autonomous cars. *Reuters*. accessed September 2018. https://www.reuters.com/article/us-autos-selfdriving-policy/u-s-transportation-agency-calls-march-1-summit-on-autonomous-cars-idUSKBN1FT2CV.

[44] Lipson, Hod, and Melba Kurman. *Driverless. Intelligent cars and the road ahead.* Cambridge, MA: MIT University Press, 2016. All the assumptions are based on the current vehicles sensing technologies previously analysed.

forming a universal traffic agreement is not new. Nevertheless, one of the biggest challenges of the Vienna Convention is the fact that significant players such as the USA, the UK[45] and China were never signatories to the treaty.[46] The proposed global agreement requires not only diverse participation but also massive adoption.[47] Big and controversial challenges like autonomous vehicles require worldwide consensus that go beyond nation states.[48] Other significant topics that are reaching universal agreement, such as the Paris Agreement, show that this is possible.[49]

If the format for discussion is the hybrid forum, the diplomatic precedent is the Paris Climate Agreement. The Paris agreement sets a clear precedent of successful forms of diplomacy based on flexibility. Adaptability offers a way to start negotiations and build necessary confidence and willingness to find common ground.[50] As Paris has proven, while an initial

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[45] The UK government has endorsed a non-regulatory approach to autonomous vehicles, an approach that positions the UK as the only country in the world where it is legal to take your hands off the steering wheel whilst driving on public roads, meaning that there is no need to go through a formal approval process to test driverless cars. Government statement. "Evidence check: "driverless cars." Parliament UK, accessed September 2018. https://www.parliament.uk/documents/commons-committees/science-technology/evidence-tests/Driverless-cars.pdf.

[46] USA's and Europe's last agreement on traffic dates from the 1949 Geneva Convention. The Vienna Convention replaced Geneva as most of the signatories joined Vienna agreements, but the United States was never part of it. Smith, Bryant W. "Automated vehicles are probably legal in the United States." *Stanford*. accessed September 2018. http://cyberlaw.stanford.edu/publications/automated-vehicles-are-probably-legal-united-states.

[47] Trump announced in June 2017 that USA would withdraw from Paris Climate Agreement. This could threaten the world's ability to solve the global climate crisis in time. Shear, Michael. "D. Trump will withdraw USA from Paris Climate Agreement." *New York Times*. accessed September 2018. https://www.nytimes.com/2017/06/01/climate/trump-paris-climate-agreement.html?mcubz=0.

[48] A big policy effort has been carried out since 2011 in different states in the USA and during the last of couple of years in Europe and Asia to introduce driverless cars into the equation. On September 2016, the USA Department of Transportation issued federal policy for automated vehicles. This first document was a performance guide for automated vehicles and also a model policy for individual states to follow. A national self-driving vehicle legislation to replace the implemented state-by-state rules is currently in progress. In 2016 European Transport ministers committed to support and facilitate all forms of self-driving vehicles in the "Amsterdam Declaration". They stated the common objective to regulate intelligent traffic throughout the EU by the year 2019. In 2017 Germany was the first European country to pass a self-driving law. West, Darrel. *Moving forward: self-driving vehicles in China, Europe, Japan, Korea, and the United States.* Washington: The Brookings Institution, 2016; Escritt, Thomas. "Germany adopts self-driving vehicles law." *Reuters.* accessed September 2018. https://www.reuters.com/article/us-usa-trade-china-factbox/factbox-u-s-companies-bemoan-impact-of-trump-trade-tariffs-idUSKCN1LQ1I6.

[49] Latour has also argued the necessity of global agreements to overcome the ecological crisis referring also to the Paris agreement as an example of *Realpolitik. (*Latour, Bruno. "Does the body politic need a new body?" Yusko Ward-Phillips lecture, University of Notre Dame, 3rd of November 2016). The proposed agreements are still based in traditional geopolitical policy. Some thinkers such as Benjamin Bratton move beyond this approach in *The Stack,* where he speculates about superseding Westfalian models of governance as a necessary step in the era of planetary scale operations. Bratton, Benjamin H. *The stack: On software and sovereignty*. MIT press, 2016.

[50] The Paris agreement continues the approach that guided the creation of the effective system for international coordination of trade policy though the General Agreement on Tariffs and Trade (GATT), currently the World Trade Organization (WTO). Trade diplomacy began in the 1940s with simple, self-enforcing agreements that aligned with national concerns; through continuous rounds of compromises, those national policies were moved forward and integrated. Easier problems were tackled first, building confidence that made it possible to tackle harder diplomatic challenges. The Paris agreement moves the world in this direction. Victor, David. "Why Paris worked: a different

agreement is important, the required compromises will go beyond mere policy to expand into immediate detailed solutions. We need to imagine new and effective ways of engaging society in these types of discussions on an unprecedentedly large scale.[51] Bold goals matter, but physical evidence matters more.

<u>The convention: the procedures</u>

We wish to propose a hybrid forum that will manifest as a global agency and deal with the development and implementation of driverless-car technologies.[52] The imagined inaugural assembly will scrutinise both the members and objectives of this agency. Other organisations such as the Society of Automotive Engineers (SAE International) are already operating in this field. SAE is a global body of scientists, engineers, and practitioners that advances autonomous vehicles for the benefit of society, but it is merely a technical organisation – valuable but incapable of addressing the socio-technical controversies that are inherent in this sphere.[53] In order to respond to such controversies, it is important that participants in the hybrid forum are not only industry experts or politicians.

On 14 April 2016 at the Informal Transport and Environment Council in Amsterdam, 28 EU ministers of transport endorsed the Declaration of Amsterdam, whereby signatories agreed on objectives that would allow for a more coordinated approach towards the introduction of automated driving.[54] However, the introduction of driverless cars is not only about transport

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approach to climate diplomacy." *Yale*. accessed September 2018. http://e360.yale.edu/features/why_paris_worked_a_different_approach_to_climate_diplomacy.

[51] The European Commission has acknowledged the necessity of cross-border agreements to deal with autonomous vehicles implementation as appears in March 2017 *White paper on the future of Europe:* "Europeans can use connected cars but may still face some legal and technical obstacles when crossing borders." ("White Paper on the future of Europe. Reflections and scenarios for the EU27 by 2025," *European Commission*. accessed September 2018. https://Ec.Europa.Eu/Commission/Sites/BetaPolitical/Files/White_Paper_On_The_Future_Of_Europe_En.Pdf). Three weeks after the publication of the paper, national leaders signed an agreement in Rome to not only allow cross-border tests and experiments but also to establish one single point of contact in each country to approve them. Digibyte. "EU and EEA Member States sign up for cross border experiments on cooperative, connected and automated mobility." *European Commission*. accessed September 2018. https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated.

[52] Lipson and Kurman argue for a similar agency devoted to the implementation of fully autonomous driving in the USA. This new entity, the Federal Autonomous Vehicles Agency, should set a strategy to make driverless cars a reality across fifty states. Lipson, Hod, and Melba Kurman. *Driverless. Intelligent cars and the road ahead,* Cambridge, MA: MIT University Press, 2016.

[53] SAE International is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle industries. Their core competencies are life-long learning and voluntary consensus standards development. Henry Ford was part of the first board and the current one includes major players such as Velodyne LiDAR and Airbus. "About SAE." *SAE International.* accessed September 2018. https://www.sae.org/about/.

[54] The first high level meeting, organized by the Netherlands, was held in Amsterdam on 15 February 2017 and focused mainly on the technical aspects of automated vehicles. It was attended by no less than 24 member states; the Directorate-General Grow; Connect, Move and Research of the European Commission and six industry partners. The next high level meeting was held in Frankfurt and there is an upcoming one in Gothenburg. One of the main outcomes of the Frankfurt forum was an EU-wide campaign to promote the development of necessary knowledge and realistic expectations among the population thereby creating an atmosphere of trust in the society. The suggested hybrid forum goes beyond some of the meritorious technical European experiments, as seen in Ertico or at Pegasus in

and its technical requirements but, as previously stated, is also about the societal implications.

When considering this imagined hybrid forum, we assume that we do not know the identities and roles of the actors that will constitute driverless futures so we will need to speculate about the new types of actors that may come about in automated mobility environments.[55] As a starting point, every member of the United Nations will have two representatives in the proposed global agency, initially relying upon the Minister of Transport and the Minister of Social Affairs.[56] These emissaries can be represented by specific actors – from industry partners and academics to citizens – depending on the expertise required at each session. This is a traditional strategy in technology conventions: industry normally represents government interests as governments are typically behind industry in terms of technology.[57] As the development of the technology is still at an early stage, the prospective actors are not fixed; future developments in the field will determine the need to incorporate other participants, including non-human agents. The proposed agency will be called the United Nations Global Autonomous Vehicles Agency (GAVA) and aims to guarantee that the right kinds of conversations are taking place. This committee will perform the function of representatives of 'the public interest' sitting in judgment on the extent to which driverless controversies are considered as matters of concern.[58]

The convention of safety

Safety has been championed as the main advantage of self-driving cars. Industry and politicians have consistently argued that driverless cars will avoid 90 per cent of road deaths. But so far, this statistic is yet to be proven. Most comparisons between the safety capabilities

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Germany. Ertico is Europe's Intelligent Transportation System organization that promotes research and defines ITS industry standards. It is a network of European transport ministries and industry bodies. Pegasus is an organisation run by the Federal Ministry for Economic Affairs and Energy (BMWi) partnering with different industry players including Audi, Volkswagen and Bosch. "On our way towards connected and automated driving in Europe." *Ministry of Infrastructure.* accessed September 2018. https://www.government.nl/binaries/government/documents/leaflets/2017/05/18/on-our-way-towards-connected-and-automated-driving-in europe/On+our+way+towards+connected+and+automated+driving+in+Europe.pdf; "Action plan automated and connected driving." *BMVI*. accessed September 2018. https://www.bmvi.de/SharedDocs/EN/Documents/DG/action-plan-automated-and-connected-driving.pdf?__blob=publicationFile.

[55] Marres, Noortje et al. "Surfacing social aspects of driverless cars with creative methods." *Warwick.* accessed September 2018. https://warwick.ac.uk/fac/cross_fac/cim/events/driverlesscarswithcreativemethods/

[56] This office takes different names in different states such as Minister of Employment, Social Affairs, Family and Gender Equality or Ministry of Labour, Family and Social Affairs.

[57] We are referring to organizations such as ITU, which is the UN's specialized agency for information and communication technologies (ICTs). The agency sets international standards known as ITU-T Recommendations, which act as defining elements in the global infrastructure of ICTs. "ITU-T in brief." *ITU*. accessed September 2018. https://www.itu.int/en/ITU-T/about/Pages/default.aspx.

[58] Other authors call for establishing new structures of governance that enable us to benefit from technological shifts whilst preventing and mitigating emerging or established risks. Johar, Indy. "#NextGenGov (the big boring bureaucratic revolution)." *Dark Matter labs.* accessed September 2018. https://provocations.darkmatterlabs.org/nextgengov-the-big-boring-bureaucratic-revolution-39ccc3a6c9f8.

of human drivers and automated vehicles have been at best uneven, and at worst, unfair.[59] This is why, once the agency is established, one of the discussions will focus on 'the conventions of safety', where members will collectively define at which point a self-driving car is safe enough to navigate our roads. Other transportation technologies are overseen by similar organisations, such as the Federal Aviation Administration (FAA), which governs air traffic in the USA. Just as the FAA defines standards of redundancy and self-testing for aircraft, the GAVA will also need to determine its own safety standards. The introduction of driverless cars interrogates accepted indications of risk, as we have already discussed. A risk-free self-driving car may never exist, especially if we decide to wait until the technology is "perfect". Accordingly, GAVA should seek to define when driverless technologies may become a viable option for our roads in terms of safety. Do they need to be three times or ten times safer than human-driven vehicles? Striking the right balance between pushing the technology through to implementation and prudence is extremely difficult when dealing with safety concerns.

GAVA would regulate a licensing scheme for autonomous vehicles based on safety standards. Several USA states have already instigated autonomous vehicle driver licences. For example, Waymo obtained the first autonomous licence from the state of Nevada after taking a test on 1 May 2012 in Las Vegas. However, they set the conditions of the test themselves, raising concerns about the amount of leeway offered to the private sector.[60] California issued the first licences in September 2014. As of 17 August 2018, there are 55 Autonomous Vehicle Testing Permit holders, and 468 autonomous vehicles operating with them. In April 2018, after amendments to regulations, California allowed autonomous cars to operate without a safety driver behind the wheel. However, these vehicles won't be operating

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[59] Hancock, Peter. "Are autonomous cars really safer than human drivers?" The Conversation. accessed September 2018. https://theconversation.com/are-autonomous-cars-really-safer-than-human-drivers-90202.

[60] Waymo had driven more than 1 million kilometres prior to the Nevada test. The exam was similar to a human drivers licence test but occurred under very particular circumstances. Waymo chose the test route, and set limits on the types of road and weather conditions that the vehicle would encounter. During the examination, its engineers, Chris Urmson and Anthony Levandowski, had to take control of the car twice. (Harris, Mark "How Google's autonomous car passed the first USA state self-driving Test." *IEEE Spectrum*. accessed September 2018. https://spectrum.ieee.org/transportation/advanced-cars/how-googles-autonomous-car-passed-the-first-us-state-selfdriving-test). In March 2018, Shanghai and Beijing released temporary licenses for autonomous vehicles. In Beijing, autonomous vehicles are eligible for public road testing only after they have completed 5,000 kilometers of driving in designated test fields and passed the required assessments. (Sui, Twinnie. "China issues first licenses to road test driverless vehicles." *Reuters*. accessed September 2018. https://www.reuters.com/article/us-china-autos-selfdriving/china-issues-first-licenses-to-road-test-driverless-vehicles-idUSKCN1GD5AW; Xinhua. "Beijing releases licenses for self-driving car road testing." *China Daily*. accessed September 2018. http://europe.chinadaily.com.cn/a/201803/22/WS5ab38a0ca3105cdcf6513a18.html). Singapore has positioned itself as an active player in autonomous-vehicle implementation since 2016 when NuTonomy started their programme there. Currently, they offer a gradual licensing system from an initial safety test to closed environments, to specific areas of the city up to access to all public roads. Channel New Asia. "Regulations in Place to Ramp up Driverless Vehicle Trials in Singapore." *Channel New Asia.* accessed September 2018. https://www.channelnewsasia.com/news/singapore/regulations-in-place-to-ramp-up-driverless-vehicle-trials-in-sin-7622038.

completely unmanned, as these regulations make it obligatory to have a remote operator monitoring the car, ready to take over if needed.[61]

California and Arizona are locked in an intense competition to attract self-driving car companies. Arizona has fewer regulations and nearly 600 self-driving cars on the roads, but most of the autonomous vehicle companies are based in California. This is in spite of the fact that California requires companies to obtain a licence, and submit periodical reports on software disengagements. Arizona requires no such public disclosure.[62]

California's Department of Motor Vehicles releases an annual report of the disengagements disclosed by the companies holding their autonomous licences. The results reveal how often humans had to wrest control away from the computer, and the reasons behind this. The 2017 rankings were as follows: Waymo leads again, reporting 5,596 miles per intervention; GM/Cruise follows with 1,214 miles travelled per disengagement; and Nissan is third with 209 miles per intervention (they travelled a total of 352,545 miles, 127,516 miles and 5,007 miles respectively).[63] These reports provide interesting data but are hardly comparable. Some companies may have driven more miles in much more complex scenarios than others. The urban situations encountered in San Francisco, for example, are far removed from the suburban setting of Silicon Valley. Weather conditions may have also differed, and each monitoring driver reacts differently to specific situations.

Regarding specific yearly programmes, Waymo reported 5,128 miles per intervention in 2016 and 1,244 in 2015 (with 636,868 miles and 424,331 miles driven in total each year). Yet these figures are not reliable either – they are not a scientific measure – as each

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[61] "Second Modified Express Terms Title 13, Division 1, Chapter 1 Article 3.7 – Testing of Autonomous Vehicles." *State of California Department of Motor Vehicles.* accessed May 2018. https://www.dmv.ca.gov/portal/wcm/connect/aa08dc20-5980-4021-a2b2 c8dec326216b/AV_Second15Day_Notice_Express_Terms.pdf?MOD=AJPERES.

[62] Arizona Governor Doug Ducey issued his famous permissive executive order in 2015. Under that order, any driverless car could be on Arizona roads as long as the passenger had a licence and the car had a basic liability insurance plan. Since mid-October 2017, Waymo has been operating its autonomous minivans on public roads in Arizona without a human behind the wheel. In March 2018, Ducey updated the order to clarify this situation: he specified that self-driving cars, with or without a person present in the vehicle, must follow all state and federal laws as well as regulations from the state Department of Transportation. A week after Uber's fatal accident in Arizona, Ducey suspended Uber's autonomous licence indefinitely. Other companies operating in the state were not affected by the suspension. Hawkins, Andrew J. "Waymo is first to put fully self-driving cars on USA roads without a safety driver." *The Verge.* accessed September 2018. https://www.theverge.com/2017/11/7/16615290/waymo-self-driving-safety-driver-chandler-autonomous; Hawkins, Andrew J. "The self-driving car war between Arizona and California is heating." *The Verge*. accessed September 2018. https://www.theverge.com/2018/3/2/17071284/arizona-self-driving-car-governor-executive-order).

[63] In March 2018, Uber was struggling to meet its target of 13 miles per disengagement in their Arizona autonomous programme, according to 100 pages of company documents obtained by *The New York Times*. Wakamayashi, Daisuke. "Uber's self-driving cars were struggling before Arizona crash." *New York Times.* accessed March 2018. https://www.nytimes.com/2018/03/23/technology/uber-self-driving-cars-arizona.html.

disengagement involves all sorts of variables, which the reports log erratically. These documents have been recognised as imperfect, and by no means offer a metric as to how safe the autonomous vehicles are in comparison to a human driver.[64] However, they do present certain benefits in terms of an exercise in transparency – though far from perfect, they help to build the required trust for future scenarios. Paul Godsmark, co-founder of Canadian Automated Vehicles Centre of Excellence, puts all the figures into perspective: the average USA driver drives 13,476 miles per year, and they have a crash every 165,000 miles. Other figures from governmental agency NHTSA suggest this number is skewed, as 55 per cent of crashes go unreported, indicating that USA drivers really have (mostly minor) crashes about every 80,000 miles. Using the lowest disengagement rate figures from Waymo, the best autonomous vehicles would be about 32 times or 16 times more likely to have an accident than the average human driver (they would be 16 times more likely if all the minor accidents involving human drivers, which are unreported, are allowed for). A disengagement does not mean the car was going to crash, only that the human driver wasn't fully confident in how it would behave.[65]

Without a standard agreement on what constitutes a disengagement and when to report it, the data generated is meaningless and cannot help define a safety threshold. Some experts, such as Lipson and Kurman, argue for fixing a specific number of miles per collision before allowing autonomous vehicles on public roads. They ask if 500,000 miles per collision would be sufficient, but they do not expand on what conditions would be necessary – in terms of the road and weather and so on – to arrive at this figure. Other experts advocate for a move away from the data-driven approach towards a mathematical model of safety, a model that has been named Responsibility Sensitive Safety (RSS). It was formulated by Mobileye's co-founder Amnon Shashua together with Shai Shalev-Shwartz and Shaked Shammah in 2017.[66] Their model aims for the standardisation of safety assurance, where there are minimal requirements

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[64] Annual reports can be found in the State of California Department of Motor Vehicles. ("Autonomous Vehicle Disengagement Reports 2017." *State of California Department of Motor Vehicles.* accessed September 2018. *https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/disengagement_report_2017).* Raj Rajkumar, autonomous technologies expert from Carnegie Mellon University, argues for more rigorous reports with an agreed format and defined terms. He also advocates for qualitative comments to add context. Bryan Reimer, from MIT, states that disengagement results are valuable but not a scientific measure of the complexity and operating characteristics of these vehicles. Davies, Alex. "The numbers don't lie: self-driving cars are getting good." *Wired.* accessed September 2018. https://www.wired.com/2017/02/california-dmv-autonomous-car-disengagement/; Financial Times."Waymo leads race to improve autonomous car performance." *Financial Times.* accessed September 2018. https://www.ft.com/content/1ec8370c-0717-11e8-9650-9c0ad2d7c5b5.

[65] Godsmark, Paul. "2016 disengagement reports show Waymo absolutely crushing the competition on every single metric." *Wonder how to.* accessed September 2018. https://driverless.wonderhowto.com/news/2016-disengagement-reports-show-waymo-absolutely-crushing-competition-every-single-metric-0176110/.

[66] Shashua, Amnon, and Shai Shalev-Shwartz. "A plan to develop safe autonomous vehicles and prove it." *Intel.* accessed September 2018. https://newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/10/autonomous-vehicle-safety-strategy.pdf.

that every self-driving car must satisfy, as well as a means of verifying those requirements. They deviate from the most widely applied approach, whereby safety validation becomes more accurate as more mileage is collected, as they consider this model inadequate for the task. The amount of data required to guarantee an acceptable fatality rate would only be generated after thirty billion miles of driving,[67] and even then the system would suffer from a lack of objective information, in terms of interpreting the data and explaining the actions undertaken, thereby making it difficult for society to accept the findings.

RSS proposes a formal model that covers all the main characteristics of an autonomous vehicle: the ability to sense, plan and act. The model guarantees that from a planning perspective the autonomous vehicle will never be responsible for an accident as it will always plan for safe driving manoeuvres. The PAC (Probably Approximate Correct) sensing model guarantees that, when a sensing error occurs, the fusion methodology employed will only require a reasonable magnitude of offline data collection to comply with the safety model. Basically, RSS constructs a mathematical model that determines fault when collisions occur by using a comprehensive set of driving scenarios and applying common sense. The formalization of this model of responsibility has a powerful result: it enables the vehicle's decision-making software to follow exact and mathematically established parameters, to continuously evaluate these rules, and to never make a command that would put the vehicle at risk of causing a collision.

If we are ever going to feel confident in driverless vehicles, we need to adopt another kind of safety certification, and defining a global standard of safety based on the RSS model seems like the right approach.[68] The GAVA safety certification would establish a new autonomous licence according to these safety standards. A permit that is perfectly tailored to the needs of autonomous vehicles would not be contested by every local politician or every private

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[67] According to Shalev-Shwartz, Shammah and Shashua, the probability of a fatality caused by an accident per one hour of (human) driving is known to be 10^{-6}. It seems reasonable to assume that for society to accept non-humans as a replacement behind the wheel, the fatality rate would need to be reduced by three orders of magnitude, namely a probability of 10^{-9} per hour. This estimate is inspired from the fatality rate when air bags are present and from aviation standards. In particular, 10^{-9} is the probability that a wing will spontaneously detach from the aircraft mid-flight. In this regard, attempts to guarantee safety by using a data-driven statistical approach (which relies on increased mileage for greater accuracy and assurance of safety) are naive at best. The amount of data required to guarantee a probability of 10^{-9} fatality per hour of driving is proportional to its inverse, 10^{9} hours of data, which is roughly in the order of thirty billion miles. Furthermore, this multi-agent system is flawed in terms of potential improvements: it interacts with its environment and thus cannot be validated offline, thus any change to the software of planning and control will require a new data collection of the same magnitude. Shalev-Shwartz, Shai, Shaked Shammah, and Amnon Shashua. "On a formal model of safe and scalable self-driving cars." *arXiv.* accessed September 2018. https://arxiv.org/pdf/1708.06374.pdf.

[68] Ramsey, Mike. "When are self-driving cars safe? It's a question disengagements can't answer." *Forbes.* accessed September 2018. https://www.forbes.com/sites/enroute/2018/02/02/when-are-self-driving-cars-safe-its-a-question-disengagements-cant-answer/#26bd83f967b1.

company. This system would avoid a patchwork of localised autonomous-vehicle rules, as well as private companies using cities as their private laboratories.[69]

[69] Driverless cars have faced challenges at the local level. When the California DMV announced that companies could test vehicles without human monitors inside, San Francisco Mayor Mark Farrell asked companies operating in the city to take part in a "safety assessment exercise" that would include working with first responders, transit operators, and officials to explain the technology in depth. While trust is fundamental in the discussion, safety cannot not be constantly contested by individual figures such as Mayor Mark Farrell. Davies, Alex. "Arizona won't be the last place to micromanage robocars." *Wired.* accessed September 2018. https://www.wired.com/story/uber-self-driving-crash-arizona-suspend-testing-ducey-governor/.

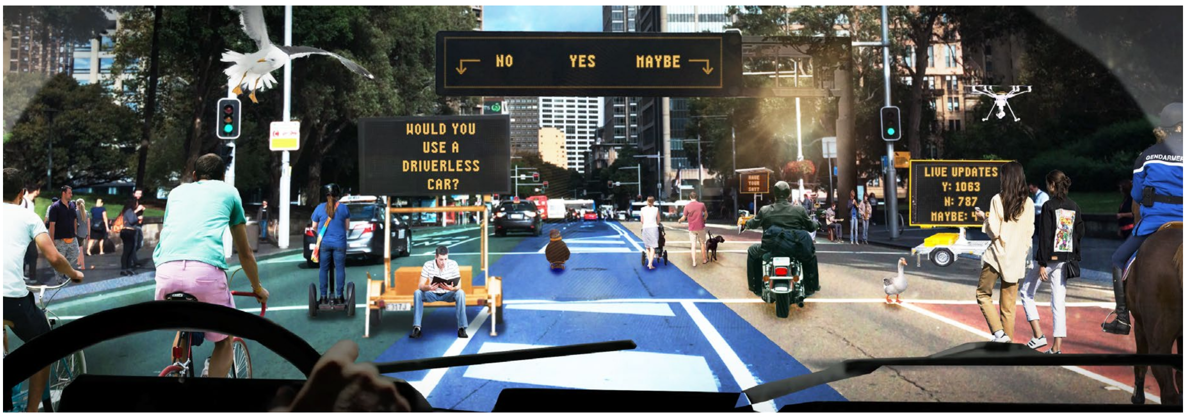
D.1.1 The question: Do we want driverless cars?
When democracy began taking shape in Athens more than 2500 years ago, citizens were asked to gather once a month to openly vote on laws, elect officials, and try political crimes. In the current crisis of political representation, new experiments need to be carried out in order to deal with the uncertainties and controversies around scientific and technological issues. Our proposal tries to deal with the problem of the social acceptability of technologies through greater citizen involvement.

The question takes driverless technologies as a case study. Animals, pedestrians, bikers and drivers are asked to express acceptance, rejection or indifference to the question 'Do we want driverless cars?'. As they navigate the street, they need to express their decision with a distinct physical gesture – a quick but meaningful move that implicates the participants in the decision-making process.

Each participant is counted electronically; updated data is constantly broadcasted to the world. The system makes no divide between human or non-human electors, and voters could engage several times with the question before them. Voting thus becomes a model study in technical democracy. How to deal with this public tool, the participator referendum device, has yet to be developed and subject to continuous revisions during the experiment.

The trial will run for one day in Park Street (-33.873503, 151.211354) in the middle of Hyde Park. The street will be divided into different lanes that denote the responses "Yes", "No" and "Maybe". Associated events will occur along the street to inform and amplify the discussion.

To date experts, technological companies and governments have claimed to be speaking in the name of citizens. Although it is not up to us as a society to decide if driverless technologies are feasible, it is up to us to decide how we can rule ourselves and how to implement this. The project emphasizes how initial choices about whether or not to adopt something are decisive in that such decisions results in specific consequences.



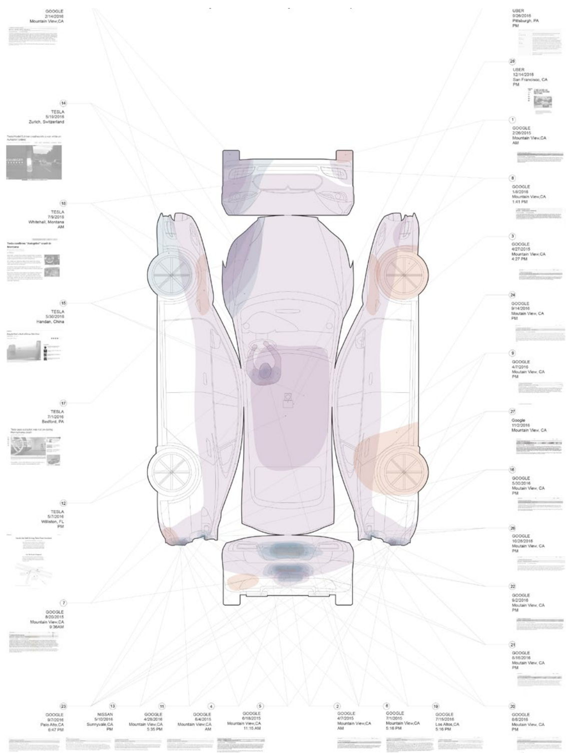
The question. Visualization by Gareth Bussey and Guillermo Fernández-Abascal.

The question was created by Guillermo Fernández-Abascal and Urtzi Grau in collaboration with Gareth Bussey. It was submitted for Art & About 2018.

D.1.2 How safe is safe? Defining a threshold of agreeable safety concerns
Society is unlikely to tolerate road fatalities caused by machines. It is impossible to guarantee zero accidents but at which point is a self-driving car safe enough to navigate our roads? We present a clear question to a diverse audience in order to define the optimal parameters in order to establish safety conventions. This survey brings together citizens and politicians, as well as experts in different fields – from robotics, deep learning, cybersecurity, insurances, law, ethics, infrastructure, technology, through to the traditional automotive industry.

The probability of a fatality caused by an accident per hour of (human) driving is known to be 10^{-6}. Is it reasonable to assume that for society to accept machines as a replacement for humans at the wheel that the fatality rate should be reduced by three orders of magnitude, namely a probability of 10^{-9} per hour? (*This estimate is inspired from the fatality rate of air bags and from aviation standards. In particular, 10^{-9} is the probability that a wing will spontaneously detach from the aircraft in mid-air).*[70]

Yes or no? If no, please provide an alternative figure.



How safe is safe? Document by Rice School of Architecture students with Guillermo Fernández-Abascal and Urtzi Grau. As part of this experiment, we documented the accidents where a driverless car was involved from February 2015 until January 2017 in the USA. We identified the role of each car part and each urban infrastructure affected in the incident.

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[70] This figure is taken from Responsibility Sensitive Safety (RSS). It was formulated by Mobileye's co-founder Amnon Shashua together with Shai Shalev-Shwartz and Shaked Shammah in 2017. Shalev-Shwartz, Shai, Shaked Shammah and Amnon Shashua, "On a formal model of safe and scalable aelf-driving cars." *arXiv.* accessed September 2018. https://arxiv.org/pdf/1708.06374.pdf.

The survey questions whether safety can be defined as a mathematical model without considering trust, empathy and ethics in the equation.

How safe is safe? is an uncompleted survey by Guillermo Fernández-Abascal, Urtzi Grau in collaboration with Rice School of Architecture.

D.1.3 The convention of cohabitation

The convention of cohabitation is a curatorial proposal for an exhibition about how we live together. It sets driverless technologies as a pretext to imagine how humans, cars and other agents may share the Earth in the near future. The exhibition is also a hybrid forum where experts, non-experts, ordinary citizens, and politicians come together to deal with the questions linked to the deployment of this technology.

The proposal aims to define a "public" that will discuss cohabitation. We speculate how these publics emerge in relation to issues and problems – the issue and public are mutually established. As Marres has stated, publics become a practical achievement; they are an outcome of diverse processes such as being affected by something, feeling implicated or sensing an emerging issue as having relevance. The objective is to create a broader public by connecting critical realms like architecture, visual arts, political sciences, sociology, visual arts and engineering. The project aims to do so by showing the work of different artists exploring driverless technologies, by having engineers and lawyers explain reports and regulations linked to autonomous vehicles and by organising public debates with multiple agents such as citizens, automotive experts, technology specialists and politicians . The exhibition may not present solutions but it does instigate the conversations that could eventually lead to an alternative deployment of the technology.

The convention of cohabitation. Image by Guillermo Fernández-Abascal.

The convention of cohabitation is co-curated by Guillermo Fernández-Abascal and Urtzi Grau. The exhibition includes works from Liam Young, James Bridle, Daniel Perlin, Brenton Alexander Smith, Natalie Jeremijenko, Benjamin H. Bratton, and Nick Axel among others. The hybrid forum incorporates citizens, politicians and experts from UPM, Arup, MIC, Toyota etc. in different weekly events. It is a proposal for *Conexiones* program at C Art C (Madrid Complutense University) in 2018.

D.1.4 Croydon as a lab: Secluded research versus research into the wild

The Croydon environment has incredible potential but it has failed to produce a truly distinctive urban realm with an identity capable of expressing this uniqueness. The proposal reinforces Croydon's position as a transport hub and digs into its past history as a car manufacturing area. We plan to transform Croydon into a technological nucleus, a testing ground for disruptive technologies such as driverless cars.

Our proposal for Croydon gravitates around the idea of developing a unique form of urbanity. We see this as a great opportunity to produce a global first in terms of urban realms, which will in fact be setting the precedent for the cities of the future. We will foster the investigation of innovative mobility solutions within Croydon and in relation to its surroundings with the aim of improving the coexistence of multiple agents (including driverless electric vehicles, cars, motorbikes, non-motorized modes and pedestrians) by creating a highly self-aware community. All of this will take into consideration the broader city context and the larger mobility patterns at play, as these in turn influence the mobility patterns of the smaller developments. This will require an attitude to the public space that accepts a certain amount of change and impermanence, and, most of all, the acceptance of the risk that this urban realm could potentially fail. Failure is never permanent; it is simply revisited in order to inform future undertakings.

Croydon could join Birmingham, Coventry, Oxford, Milton Keynes and Greenwich [71] as one of the testing grounds for autonomous vehicles, but it ambitions to further explore the upcoming required urban transformations. Radical changes in the constitutive elements of mobility scenarios, as well as the consequent unpredictability of their impacts, will require a careful assessment of the regulatory framework for mobility scenarios of the future. New revenue and finance models, new partnerships, and new transport behaviours will need new rules to guarantee a successful coexistence of people, urban environment and transport innovation.

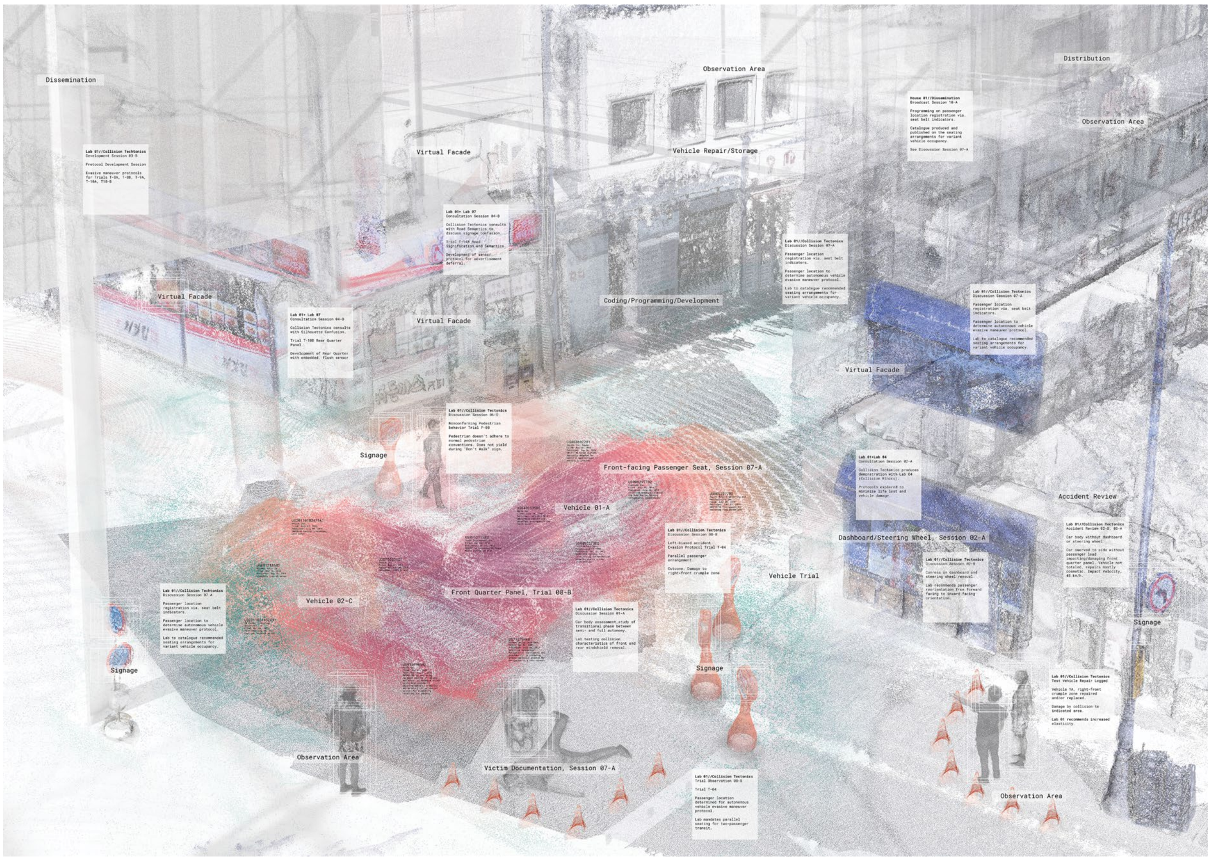
[71] The UK presents a very particular situation that we explore in this experiment. As Marres has pointed out, technical experiments have been carried out on public UK roads, with public funding but without the public being clearly informed beforehand. The tests are conducted in accordance with a government-approved *Code of Practice from July 2015*, which endorses a non-regulatory approach to the introduction of driverless cars. This is possible because the UK was never a signatory of the Vienna Convention. These test produced several interesting anecdotes, for example in Greenwich, cyclists were banned from the paths where driverless tests were taking place, thus excluding a fundamental actor from the street scape. And in Coventry and Milton Keynes, the trials were not made public until the driverless cars had disappeared from the road in the name of "safety" as organisers thought it would be too dangerous due to the large amounts of people and possible human interference with the machines through tricks and the like. Marres, Noortje. "Street tests of driverless cars: experiments in co-existence, or displacement?" *The Sociological review*. accessed September 2018. https://www.thesociologicalreview.com/blog/street-tests-of-driverless-cars-experiments-in-co-existence-or-displacement.html.

Urban sensing is becoming omnipresent, and driverless cars are generating an extraordinary amount of data. However, the collected data often doesn't reach citizens as it is usually managed by private companies and administrative bodies with the purpose of developing their own products and informing urban policy strategies. By introducing new visualization mechanisms, we would like to encourage public awareness and citizen engagement in both the machines and their immediate environments.

We believe Croydon has the type of population that would willingly engage with this experimental urban realm and become the first urban inhabitants of the city of the future. Driverless vehicles will be the first technology to be tested in this urban scenario where new street designs, protocols, events and urban choreographies will be mediated.

Existing participation initiatives appear to be designed to achieve particular pre-determined outcomes in terms of public perceptions of intelligent automotive technology. They are deployed as instruments for increasing public acceptance of this technology without raising any societal concerns about the deployment of driverless vehicles. This experiment moves away from the paternalistic approach of most driverless trials and aims to introduce a distinct approach to the arrival of technology in society. The experiment unveils the potentials and limitations of the technology and works from the belief that experimental validation of public knowledge must happen in the public domain. Of course, involvement with socio-technical devices often produces messy and uncertain practices that foreground the experimental and uncertain nature of public engagement. *Croydon as a lab* questions if driverless testing should be done under laboratory type conditions or "into the wild". [72]

[72] During the 20th century the car industry decided to confine trial areas to dedicated test sites and lab-based computer simulations, abandoning the street as their experimental fields. (Leonardi, Paul M. "From road to lab to math: The co-evolution of technological, regulatory, and organizational innovations for automotive crash testing." *Social studies of science* 40, no. 2 (2010): 243-274).
In recent years, industries and governments have made significant investment in so-called real-world testing of intelligent car technology on public roads. These tests take different forms, from the large-scale roll-out of experimental autonomous vehicles by tech companies like Waymo, to government-funded field experiments such as the ones in the UK and Australia. The last ones involve the construction of a location, which operates somewhere between laboratory conditions and field conditions. The environment is artificial enough for the correct functioning of the technology, while natural enough for social engagement with technology. Several critiques have arisen in relation to this – Marres and Karvonen et al. consider that the experiments are just dropping the laboratory into the streets rather than integrating with their local contexts. Marres, Noortje."What if nothing happens? Street trials of intelligent cars as experiments in participation." TechnoScience in Society, Sociology of Knowledge Yearbook. Nijmegen: Springer/Kluwer (2018). Evans, J.; Karvonen, A.; Bulkeley, H. (Editor); Castán Broto, V. (Editor); Hodson, M. (Editor); Marvin, S. (Editor). / Living laboratories for sustainability: exploring the politics and epistemology of urban adaptation. Cities and Low Carbon Transitions. London: Routledge, 2011).



Document by Rice School of Architecture students with Guillermo Fernández-Abascal and Urtzi Grau.

Croydon as a lab was envisioned by Guillermo Fernández-Abascal, Urtzi Grau in collaboration with Townshend Landscape Architects, MIC, 2x4 and Easymile for *Croydon i Street*.

Driverless *thing*

"We really need better lane markings in California. This is crazy."[73]
Elon Musk

Material evidence: a measured, light infrastructure

In this section, we look closely at the possible infrastructural changes linked to the deployment of driverless vehicles. Since they are the backdrop for discussions about safety, real estate, cohabitation, and regulation amongst other themes, these infrastructural changes appear as objects that need to be deliberated at hybrid forums. In the field of STS (Science, Technology and Society) there has been much conversation about the role of things in the political arena, what is called the "coming out of things".[74] Material studies have started to broadly explore this move towards objects in democracy and public action. They focus on the capacity of things to facilitate, inform and organize citizenship and engagement.[75] These studies have been particularly relevant to those working with environmental issues, which Noortje Marres has analysed. She explores the role of things in generating awareness and mobilizing publics when dealing with socio-technical controversies. Following this logic, we explore possible objects to be discussed at hybrid forums, and those of importance on the ground – that is, in the street. Specifically, we look at political objects, things with the capacity to prompt or transform a proliferation of public disagreements such as the ones related to driverless technologies.[76]

Accordingly, a hybrid forum could embrace the transformative capacity of things by setting new policy on road markings, just as the Vienna Convention did in 1968. The search for common standards assumes that some backward steps may need to be taken, that participants will have the means to be able to return to abandoned options at any moment, and that the methods of evaluation will be constantly revised in response to new knowledge and points of view. However, this constant scrutiny is far from being synonymous with indecision and temporization. The ultimate objective of a hybrid forum is to make decisions and, in this case, objects will be fundamental to pinpointing the necessary facts. We are referring here to experimental facts, the veracity of which are unstable: their epistemic status changes over time. It is no longer a given that the public's respect for facts can be secured through the authority of experts or grounded in statements that are validated outside the public domain. If

[73] This is an extract from of the press conference that Elon Musk gave on 14th October 2015. Sharpe, Bruce. "Transcript: Tesla autopilot press conference call." *SignsSoftNext*. accessed September 2018. http://singsoftnext.com/autopilot_press_call/.
[74] We refer here to figures such as Langdon Winner or Bruno Latour. Winner, Langdon. "Do artifacts have politics?" *Daedalus* (1980): 121-136. Weibel, Peter, and Bruno Latour. *Making things public*. 2005.
[75] Marres, Noortje. *Material participation: technology, the environment and everyday publics*. Springer, 2016.
Barry, Andrew. *Material politics: disputes along the pipeline*. John Wiley & Sons, 2013.
[76] As we have tried to explain along this document, driverless cars are itself a thing: an artefact for discussion.

the end is to gain wider credibility and support, the validation of facts will need to take place, at least in part, in the public sphere.[77]

A hybrid forum could also identify other objects of discussion – perhaps the possible redesigns of the streetscape linked to the implementation of driverless cars. As we have previously stated, most of the projected future scenarios accentuate romanticised images of the city, where the integration of driverless vehicles is flawless. In these imaginings, urban infrastructure stays the same while self-driving cars share the streets with humans; there is no apparent tension between the two and no alterations to the urban environment are required. In contrast – and based on the premise of building smart cars, not smart infrastructure – our hypothesis calls for minor infrastructural changes in order to accommodate the implementation of driverless vehicles in the immediate future.[78] The need for alterations is supported by the history of streetscape modifications, which have always been instigated by changes related to transport inventions, an example of which is the transition from horse-drawn transportation to automobile. Furthermore, we argue that the physical transformation of the street is trivial compared to its potential implications – socially, economically and on an urban level.[79]

Historical narratives love smooth transitions, such as that from horses to cars. In reality, there was a period of several decades when the presence of horses started to decline while automobiles began to populate the streets. Accordingly, the street underwent minor but crucial alterations during this period. A street's geometrical design is mainly determined by three factors: alignment, profile, and cross-section. [80] These elements were barely affected by

[77] "Knowledge democracy as a reconstructive project requires transformation of epistemic ideals, including that of facticity. Facts are too important to be reduced to vehicles of the restoration of authority: their validity is always experimentally acquired, and the experimental validation of public facts must today happen in the public domain. It will take time, but we will need to re-envision what a public fact is for a world that is not only marked by contingency but also by epistemic diversity and dynamism, and where, consequently, experts aren't and shouldn't be fully secure in their public authority." Marres, Noortje. "Why we can't have our facts back." *Engaging Science, Technology, and Society* 4 (2018): 423-443.
[78] Lipson and Kurman claim that it is much more valuable to invest in the development of the technology than in smart infrastructure. (Lipson Hod, and Melba Kurman. *Driverless. Intelligent cars and the road ahead,* Cambridge, MA: MIT University Press, 2016.)
[79] A century ago cars were introduced as a solution to the drawbacks of horses, which were clogging city streets with manure. The broader socio-economic consequences of cars were entirely unforeseen. Today the danger is that AVs will be treated merely as a technological solution to the problems associated with cars and that, once again, the wider impacts will be overlooked. (The Economist "Self-driving cars offer huge benefits—but have a dark side." *The Economist.* accessed September 2018. https://www.economist.com/news/leaders/21737501-policymakers-must-apply-lessons-horseless-carriage-driverless-car-self-driving).
[80] Alignment: the lines and curves that defined the route of the street along a territory.
Profile: the vertical aspect of the street. It determines how vehicles move horizontally and it is fundamental feature in street water management. .
Cross-section: it the defines the position and number of agents along the profile of the street. The number and width of the lanes for vehicles, bikes and pedestrians are determined through it. It also show kerbs, signage and other road features.

the introduction of cars. The streets' width remained intact, and the main alterations occurred on the street surface finishes. Motor and health lobbies pushed for high-quality, dust-free road surfaces. Dust was a major irritant at the time and believed to be a cause of disease, especially as so much of it was powdered horse waste. By the 1920s both asphalt and concrete were commonly used surface materials in urban settings.[81] The centreline appeared as a traffic safety device, as without the guide provided by lane markings drivers tended to veer towards the middle of the road. Both developments are connected to the first Road Commission of Wayne County, Michigan, in 1906, which sought to make roads safer (Henry Ford served on the board in the first year). The commission would order the construction of the first concrete road in 1909 and it conceived the centreline for highways in 1911 under Edward N. Hines' mandate.[82]

Continuing this historical trend, a hybrid forum could explore modest redesigns and alterations of certain infrastructure to accommodate the driverless car's singular way of experiencing the built environment. City planning has long privileged qualities of urban space based exclusively on human sensing and visual perception in particular. The eye has determined the elements for our system of roads. As autonomous vehicles learn to navigate the roads, the need for road signs and traffic lights may diminish. Low-tech painted lane markers and kerbs[83] may become the most important road infrastructures. The former provides critical visual information for the cars to navigate, and the latter offers visual data to operate, and more importantly, delineates the space for pedestrians and cars.

In the current global financial context, intelligent road infrastructure plans seem a remote option for most cities. Local governments have taken the majority of infrastructural responsibility from national governments. In this scenario, nearly all local governments struggle to keep their existing infrastructure in good shape, let alone consider new investments. The associated expenses also raise questions about which technologies to commit to.[84] Replacing pavements, painting lanes, keeping water systems running efficiently, and filling road holes are common tasks carried out by municipalities on a daily basis. This speculation connects these duties by planning a new type of infrastructure that accommodates both human and non-human needs.

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[81] Carlton Reid goes beyond these premises affirming that cyclists' requirements were the major reason behind paving the streets. Reid, Carlton. "How roads were not built for cars." *The Guardian*. accessed September 2018.

[82] Edward Hines (1870-1938) is considered one of the main innovators in road development. The first concrete road pavement, the centre line of a road to separate traffic in opposing directions, snow removal strategies, the concept of landscaping highway rights-of-way, and the beautification process of highways by eliminating power lines and billboard are all attributed to him. "Hines, Edward N, (1870-1938)." *Michigan Department of Transportation*. accessed September 2018. http://www.michigan.gov/mdot/0,4616,7-151-9623_11154_41535-126420--,00.html.

[83] Kerb refers to the edging of a sidewalk. It is spelt curb in the US and Canada, but "kerb" outside USA.

[84] See footnote 5 for an explanation about which technologies industry is committing to.

As the lines between technology and governance become more blurred, so too will the lines between public and private. In a similar way, hybrid forums merge technology and governance – they could involve various agents, led by public entities, debating driverless car implementation. Infrastructural changes linked to autonomous vehicles, even if the alterations are minor, could be developed through different joint ventures between the public and private sectors. These public-private partnerships[85] could provide cities access to funding and expertise that might not otherwise be directly available. Different actors could take part in these agreements, including national and local governments, universities, and technology and construction companies. Citizens will also become fundamental agents in the redesign of the streetscape. They could be involved in street experiments. These proposed tests embody a crucial connection between science, technology and society, one that allows the field to expand its range of political tools and participate in wider experimental cultures. As these developments occur, cities should always strive to keep control of the process in order to guarantee the common interests of the communities they serve.[86]

The prototype: the kerb as a case study

The immaterial effects of driverless sensing become new material in the city. These elements remain invisible to human beings. Likewise, physical features of the urban environment remain almost undetectable for car sensors. Out of these components, we have chosen the kerb as a test case for this light infrastructure approach, and as one of the first items to be discussed at a hybrid forum. The forum is understood as a place where we can negotiate elements from a hybrid culture, where objects are analysed through human and non-human sensing. The forum will constantly test findings and objects in the public domain; street demonstrations will be fundamental to establishing the facts for discussion. Building on the logic of the current public demonstrations of autonomous vehicles that occur around the globe, our speculations push the format of these trials further so that they become actual experimental tests. So far, these street trials have tried to put in place opportunities for social engagement with driverless cars where the public can test them, but they have not enabled a means of evaluating the social implications of technology.[87] They are mainly focused on the

[85] Public-private partnerships became popular for major infrastructural developments during the 1990s. They were commonly used, particularly in the Anglo-Saxon context, until the 2008 global financial crisis. At that time, this model suffered criticism due to the high returns rates of the private companies involved, and the collapse of certain projects associated with these principles. Some specialists, such as Nicole Dupuis, advocate for new updates of these models to promote smart infrastructure in the USA. Our hypothesis considers whether the potential benefits of this paradigm could also be useful for a light infrastructural approach. Dupuis, Nicole. "The age of the smart city. better cities through smarter infrastructure." *Van Alen.* accessed September 2018. https://www.vanalen.org/stories/the-age-of-the-smart-city/.
[86] IBM, Siemens and Cisco, three of the largest "smart city" protagonists, should not be the ones leading the planning of our infrastructure. They are valuable actors but the public sector should prevail in the decision making regarding urbanisation processes. de Graaf, Reiner. "The smarts cities of the future" in *Four walls and a roof. The complex nature of a simple profession.* Cambridge, MA: Harvard University Press, 2017.
[87] Marres analyses how these tests present a distinctive innovation in the procedures of introducing technology to society. She argues that further investigation of street trials is required in order to test their ability to serve as evaluative instruments for the introduction of intelligent technology to society – not just in terms of the technical elements, but also for the associated social, cultural and political implications. Marres, Noortje. "What if nothing happens? Street trials of intelligent cars as

technology and do not manage to engage other relevant agents, such as urban infrastructure, into the discussion. The street trials seem closer to an exhibition display than a science experiment, where participants are fascinated by the vehicle itself. The introduction of objects, such as kerbs, into the discussion are a necessary step to amplify the discussion.

The kerb itself is a simple demarcation between two spaces: the roadway and the sidewalk. It serves as a separation between humans and machines, as a key water management tool and helps to retain the edge of the top layer of pavement. It exemplifies the change of section specific only to urban conditions. This light piece of infrastructure has also become a crucial reference for driverless vehicles, as it allows them to safely navigate our cities. Experts point out possible sensing or legibility problems caused by eroded kerbs, citing rounded edges or dust accumulation on their surfaces as obstacles to vehicles getting a "read" of them.[88] But is this true? In principle, LiDAR sensors are not affected by any geometrical distortions, unlike other forms of data collection. Regardless, the kerb's geometry is a fundamental element in building the trust required for human and non-human coexistence. Our speculations, once safety issues are addressed, envision the disappearance of the kerb, thus making the sections of the street flat again and universally accessible. Kerbs are the ultimate barrier to the living street.

Historically, the physical manifestation of the kerb had little to do with transport but instead was created to better manage wastewater flows in dense and often insalubrious urban environments, and to prevent backflow from the streets into buildings. Kerbs were already present on some Roman roads; during the eighteenth century they appeared in different cities and became ubiquitous during the industrial revolution as a means to manage the movement of vehicles, people and water. We can identify two main types of kerb – one is combined with a gutter, the other is not. The so-called barrier typically follows four basic profiles: half-battered, splayed, bull-nosed and square. [89] They were traditionally built with natural stone but these have now largely been replaced by precast concrete. Beautification processes in

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experiments in participation." *TechnoScience in Society, Sociology of Knowledge Yearbook. Nijmegen: Springer/Kluwer* (2018).

[88] Huang, Albert S. "Lane estimation for autonomous vehicles using vision and LiDAR." (2010).

[89] Half battered kerbs: they have the upper 100mm (approx.) of the face angled back from the vertical at between 12.5° and 15° and are commonly used. Their profile provides a good level of containment for vehicles while being less likely to be damaged. They are also easier to lay asphalt up to than square or bull-nosed kerbs because the half-batter is less likely to be clipped by surfacing plant.
Splayed kerbs: they have the upper section (75mm approx.) angled back at 45°. Splay kerbs are sometimes called "countryside" kerbs after their extensive use on rural roads – their profile makes it easier for broken-down vehicles to move up onto the verge.
Bull-nose kerbs: they are used where a crossing is required. They are also known as chamfered kerbs as they have one rounded edge which means damage is less likely.
Square kerbs: they are essentially square or rectangular in profile. Because of sharp corners, they can be susceptible to damage and are sometimes manufactured with slightly rounded edges.
Other common kerbs are the transition kerbs, the quadrant and corners, containment kerbs and bus stops kerbs. "Making streets better: the joy of kerbs." *Cycling Embassy of Great Britain.* accessed September 2018. https://www.cycling-embassy.org.uk/sites/cycling-embassy.org.uk/files/documents/the-joy-of-kerbs-draft.pdf; "Road kerbs and channels" *Paving expert.* accessed August 2018http://www.pavingexpert.com/edging5.htm#drop.

cities across the globe have challenged this with the reappearance of granite, whinstone, gabbro and basalt as the constituent material.[90] The forum will debate the geometry, the materiality and the location of this thing. Their use is universal and their geometry and materiality are apparently uniform in every location.[91]

The kerb is a highly contested piece of urban real estate in many cities across the globe. Not only does it set the border line between humans and non-humans but it also delineates the space for parking. At the beginning of the twentieth century the kerb was essentially a transaction space – it was where the loading of passengers and goods occurred, and where parking was forbidden. Short-term street parking was largely unregulated and unpriced in most areas until the 1940s and 1950s. As the number of vehicles in public spaces grew, access to the kerb was allowed at any time. This led to the public expectation that people should be able to freely park their cars at their destinations for the duration of their activity there whenever they liked.

Up until today, the kerb area has accommodated and served as the following: pedestrian access to and from the sidewalk; emergency vehicle access; access to public transport; wayfinding for visually impaired people; goods delivery and pick-up; an interface with cycling infrastructure; pick-up and drop-off of passengers from taxis, ride services, private vehicles; repair and maintenance activities (street infrastructure); waste management and surface water runoff; commercial activities (kiosks, restaurants, food trucks, cafés, ambulant sellers); leisure and green spaces (trees, benches…). These and other concurrent demands around the kerb space involve a wide range of stakeholders and authorities whose activities are often disjointed and infrequently aligned with broader strategic objectives. New situations are emerging that are linked to the explosion of car-share services, the rise of small parcel deliveries associated with online shipping and the appearance of docked and dockless bike-share systems, as well as other urban mobility infrastructures. These situations are increasing pressure on the need for access to the kerb and could eventually unleash a change in its prevailing use – from parking to a pick-up/drop off scenario.[92] [93]
The kerb is a seemingly mundane object, but its importance derives from its role in fixing the minor but vital space required for the negotiation of cohabitation between humans and non-

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[90] There has also been a recent return to kerbless streets based on the concepts of the “shared street” and the “living street”, yet this remains the exception today.
[91] While ostensibly equal, kerbs are different in every location. Standards set minimum and maximum dimensions allowing the kerb to be specific to every single place. For example, in heavy rain areas, they are normally higher than in dry locations in order to manage the water properly.
[92] Long stay parking, including overnight, on the streets was initially illegal. Cars were supposed to park in a garage, as horses used to do in stables. “The shared-use city: managing the kerb.” *International Transport Forum.* accessed September 2018. https://www.itf-oecd.org/sites/default/files/docs/shared-use-city-managing-curb_3.pdf.
[93] The use of light infrastructure has been tested recently in different projects such as Sadiq-Kahn’s Times Square pedestrianizing temporary strategies. Rethinking streets and kerbs as flexible, self-adjusting devices could be an strategy to implement in driverless street trials. “A national model for better streets is suddenly at risk.” *Citylab.* accessed September 2018. https://www.citylab.com/transportation/2015/08/a-national-model-for-better-streets-is-suddenly-at-risk/402129/

human entities. Hybrid forums could question this light piece of infrastructure through multiple lenses, including that of the driverless car, in order to unpack questions of objectivity, transparency, community, empathy, trust, safety, politics[94], urbanization and beauty – among other topics linked to the arrival of driverless technologies.

[94] The role of certain design decisions relating to infrastructure in politics has been thoroughly explored in the history of architecture. The height of the tunnels of Long Island Parkway designed by the political scientist Robert Moses are good example of this. Langdon Winner argues that the extraordinary low clearance of the tunnels was decided upon in order to avoid the circulation of buses through them. They were a mechanism to manage which people could access that area. Winner, Langdon. "Do artifacts have politics?" *Daedalus* (1980): 121-136.

T.1.1 Driverless kerb Sydney

Things are not only a material assemblage, but are also composed of the social entities that represent them, as well as the possible agreements between humans and non-humans. Our aim is to understand how ordinary things become participants in the conduct of politics – in this case we explore the ways in which kerbs and other devices produce new means of understanding facts in the public sphere that has uncertain political effects. Through close attention to the description of the kerb, we make it possible to see the multiplicity of political processes, micro and macro, and the ways in which the kerb could became more and more potent in unfolding the controversies around driverless technologies. The kerb is not just an object of political deliberations, it could become a participant in a shifting political assemblage.

Driverless kerb Sydney is comprised of two kerb prototypes. Both of them question this light piece of infrastructure through the lens of driverless cars. Both of them start interrogating the geometry and materiality of this simple item. They appear as iterations of the most common Sydney kerb (630x270x150x450x100mm) and they are crafted with a reinterpretation of one of the most characteristic Sydney materials: terrazzo.

The kerb's geometry in Sydney is regulated by "Sydney Streets. Technical Specifications B4. Kerb and Gutter" produced by the City of Sydney, and by the "R15 Kerbs and Gutters Specifications" and the "R0300 Kerb and Channel Series" generated by the NSW Government of Transport, Roads and Maritime Services.[95] Our proposal is based on these standards and pushes its limits in order to raise a discussion about the demarcation between two spaces: the roadway and the sidewalk.

Terrazzo[96] is a manufactured and polished composite of chips, with durable aggregates set in a cement matrix with added colour. Terrazzo was traditionally used in Sydney in the early 1930s as an interior paving for bathrooms, laundries, toilets, access[97] and verandas in residential dwellings. Around the same time terrazzo was also used for partition walls in public toilets and stairways in commercial buildings. Recently, it has made a come-back and is being used in public toilet partitions, beach facilities and retail projects. Our proposal

[95] "Sydney Streets. Technical specifications B4. Kerb and gutter." *City of Sydney.* accessed September 2018. http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0007/142585/B4.-KERB-AND-GUTTER-4.pdf; "R0300 Kerb and Channel Series." *NSW Government of Transport. Roads and maritime services.* accessed September 2018. http://www.rms.nsw.gov.au/business-industry/partners-suppliers/document-types/standard-drawings/road/kerb-gutter.html.

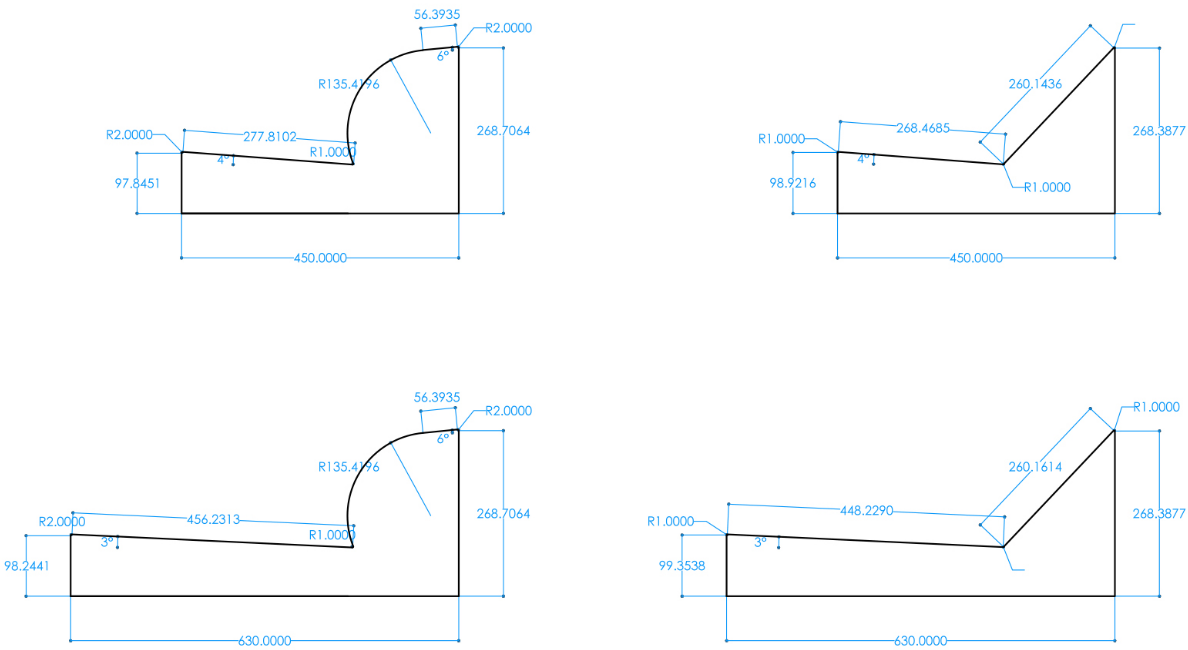
[96] Flooring material consisting of chips of marble or granite set in concrete and polished to give a smooth surface.("Terrazzo." Oxford. accessed September 2018. https://en.oxforddictionaries.com/definition/terrazzo).When polished it gets sealed and waterproof, making it appropriate material for managing water.

[97] In many Sydney residential projects, a piece of terrazzo marks the entrances to the house. It sets the border between the public and the private areas. In toilets, it also serves a demarcation for the more private areas.

brings this material to the street as a tool to stimulate discussion about the separation between water, humans and machines.

Kerb 1.0 is apparently friendly. It is smooth (rounded edges dominate its profile) and pink with some mirrored incrustations. However, driverless cars may struggle with it. Its concave and convex geometry provokes uncontrolled reflections, the stainless-steel mirrors replicate the laser lights and thus confuse LiDAR scanners. On top of this, the lack of contrast between the pink and the chips makes it undetectable, rendering the border useless. Kerb 2.0 is unfriendly at first sight. It has sharp edges, it is predominantly black (with some irregular white chips). Yet, driverless cars sense their clear borders perfectly because the high contrast between the base and chips stimulates LiDAR's sensing capabilities.

Driverless kerb is the first post-human infrastructure that recognizes that the field of view is not restricted to humans anymore. *Driverless kerb Sydney* uses mundane technology. Its deployment in everyday scenarios will generate awareness and mobilize publics when dealing with the socio-technical controversies around autonomous vehicles. *Driverless kerb Sydney* is not about kerbs but about objectivity, trust, safety, surveillance, urbanization and beauty among other topics. *Driverless kerb Sydney* turns the street into both a laboratory and a political arena.



Kerb 1.0 and 2.0 geometrical definition by Guillermo Fernández-Abascal.

Kerb 1.0 and 2.0 materiality studies by Guillermo Fernández-Abascal and Ivaylo Nachev.

Driverless kerb is an ongoing project by Guillermo Fernández-Abascal, Urtzi Grau in collaboration with Ivaylo Nachev and Huguet.

Postscript

Every generation has its own technological myths.[98] They rarely play out as smoothly as expected, and driverless cars will be no exception.[99] Throughout this thesis, we have explored the technical questions linked to impending technological progression, focusing our attention on the sensory mechanisms that allow driverless technologies to navigate the urban environment. At the same time, we have explored the interconnected socio-cultural implications of technology by concentrating on urban scenarios. We have argued for the necessity of a new sensorial and social contract that unpacks current urban issues such as safety, control, surveillance, security threats, urbanization, public transport policies, and automation. Furthermore, we have identified that only a hybrid forum has the capacity to address controversies linked to the imminent future of driverless technologies.

The discussion in this thesis is in fact about governance. We have investigated historical discussions surrounding vehicular agreements, survey flexibility, and adaptability as agreement techniques to finally propose a hybrid forum that deals with these socio-technological issues. This hybrid forum questions the role of experts in a field that moves between cultural studies and the sciences whilst steadily declaring safety as a first matter of concern. To conclude, we have scrutinised the role of things and their design within this hybrid forum. We have taken a kerb as a case study. This object allows policy makers, citizens, designers, politicians, and the automotive industry to hold conversations about cohabitation, safety, planning, trust, air-quality, and objectivity amongst other topics. This object exemplifies the importance of engaging the public in the construction of facts, and in the decision making processes that deal with the uncertainties and controversies around driverless technologies.

When combined with the long-form text, the different experiments have allowed us to test some of the speculations presented within it. The newness of driverless vehicles has been explored (V.1.1 *Driverless vision Seoul*), but the discussion is not about cars (V.1.1 *Driverless vision Seoul*, T.1.1 *Driverless kerb Sydney)*. It is about the ways in which technologies determine social, political, economic, cultural, and urban relationships (D.1.3 *The convention of cohabitation)*. Regarding the last point, driverless cars have the potential to reduce or increase traffic, make affordable transport more or less accessible, and lead to denser cities or even more urban sprawl. A century ago, cars appeared as a solution for cities immersed in heavy traffic from horse-powered vehicles and animal detritus. The broader social consequences of cars, both good and bad, were entirely unforeseen. Most architects,

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[98] James Bridle critically analyzes the relation between technology and society in different articles such as "The new aesthetic and its politics" or "Failing to distinguish between a tractor trailer and the bright white sky." We can position some of the critiques about driverless cars around specific aspects of his thesis, as many of these assessments come from a poor understanding of technology, which highlights the failure of the broader public to fully engage with technology. Bridle, James. "The new aesthetic and its politics." *Booktwo.* accessed September 2018. http://booktwo.org/notebook/new-aesthetic-politics/.

[99] There is already a growing appreciation that the technology has, so far, overpromised and under-delivered.

and city planners,[100] did not respond actively to their implementation and as a result cities around the world bulldozed their city centres and the global explosion of suburban sprawl occurred. It all depends on the rules[101] we set and how we establish them. (D.1.4 *Croydon as a lab: Secluded research versus research in the wild;* D.1.1 *The question: Do we want driverless cars?*; D.1.2 *How safe is safe? Defining a threshold of agreeable safety concerns).* If we treat driverless cars as a mere a technological solution to the problems associated with cars, once again, the wider impacts will be overlooked. Through the different projects, we have established links that turn the street into both a laboratory and a political arena in order to have more informed discussions about the future we want to have (V.1.1 *Driverless vision Seoul*, T.1.1 *Driverless kerb Sydney)*.

In this thesis, we have attempted to articulate that a hybrid forum is the required assembly to discuss the implementation of driverless cars as it allows different agents to address questions concerning safety, control, surveillance, security, empathy, trust, urban policy and automation. We also have a hunch about a new relevance of scale in urbanism that manifests itself in *the thing*. In this case, the kerb is where sensing is calibrated, where safety is at stake, where the water is controlled, where technologies may be embedded and where the human and non-human cohabitate. Consequently, driverless technologies must be discussed at 1:1 in hybrid forums.

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[100] There are some exceptions such as *The Futurists* or Le Corbusier who took cars as the driving force in the development of future cities. Corbusier, Le. *The city of to-morrow and its planning*. Courier Corporation, 1987.

[101] Existing planning policies are based on human driving systems. New legislation is required to tackle the impact of driverless cars. Regulations surrounding urban infrastructure, policy on data minimization, safety thresholds, tax systems supporting urban density, and public transport are some of the measures that need to be studied urgently. Kane, Michael, and Jake Whitehead. "How to ride transport disruption–a sustainable framework for future urban mobility." *Australian Planner* 54, no. 3 (2017): 177-185.

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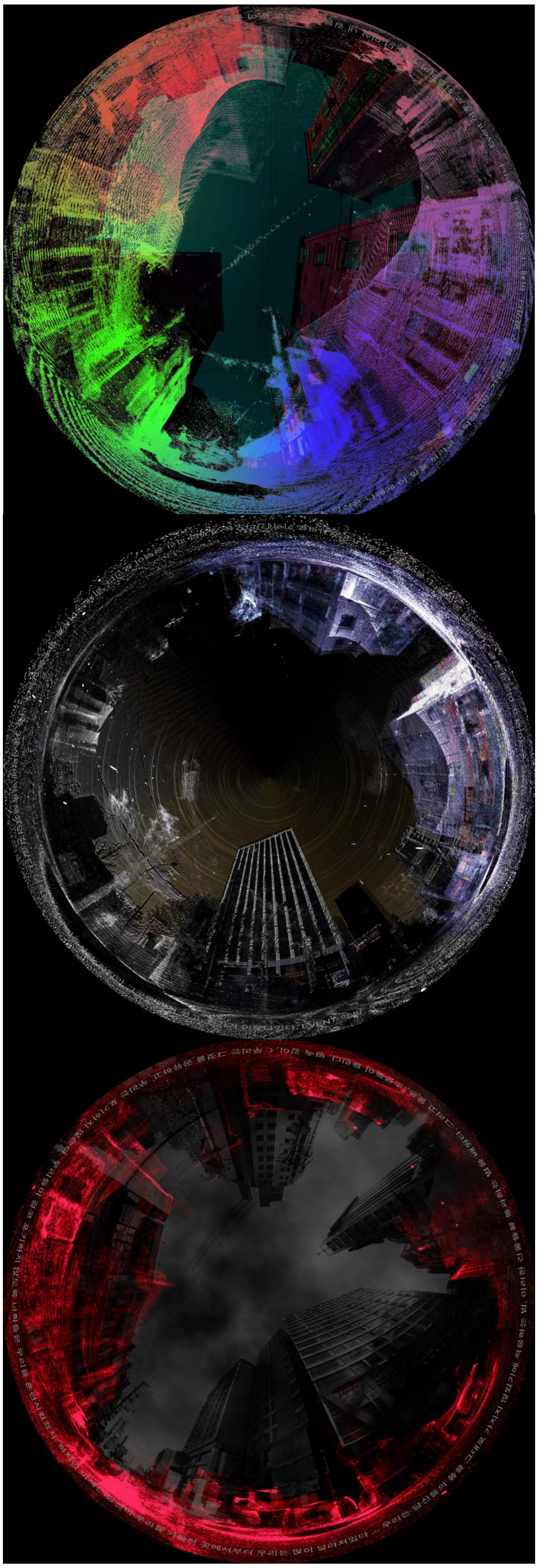
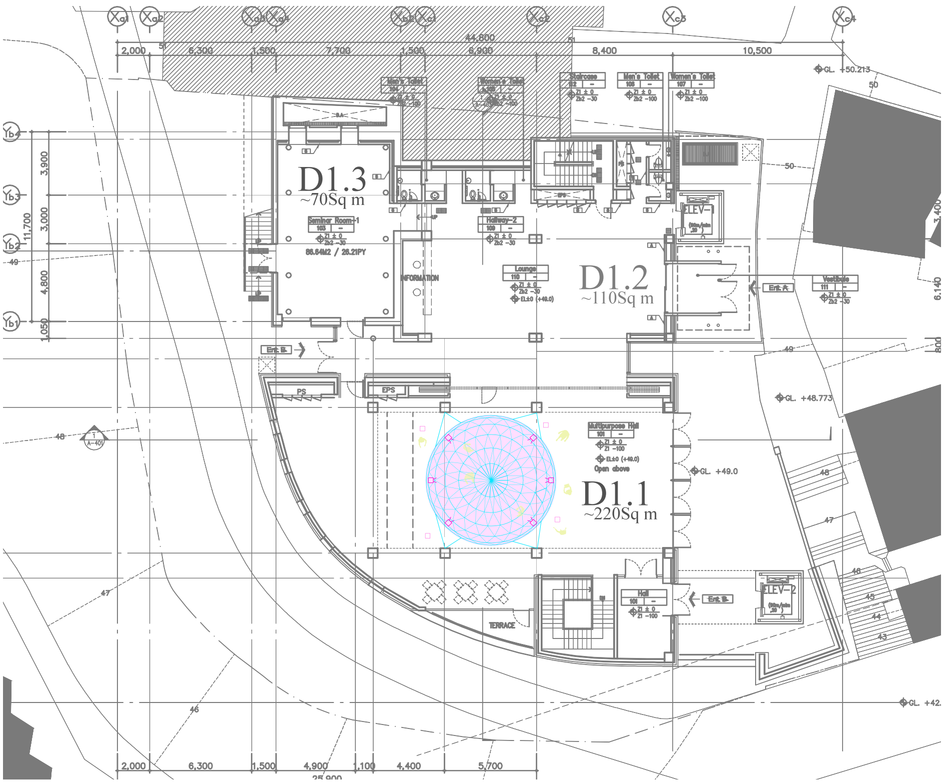
Annexes

Driverless vision Seoul extra documents



Three scenes of the film. Complete link: https://www.youtube.com/watch?v=p8Lt_NGLkNM

Section



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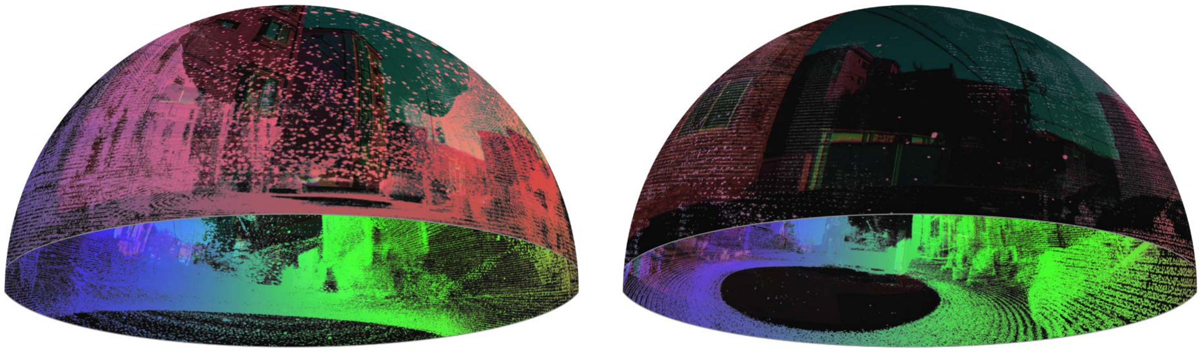

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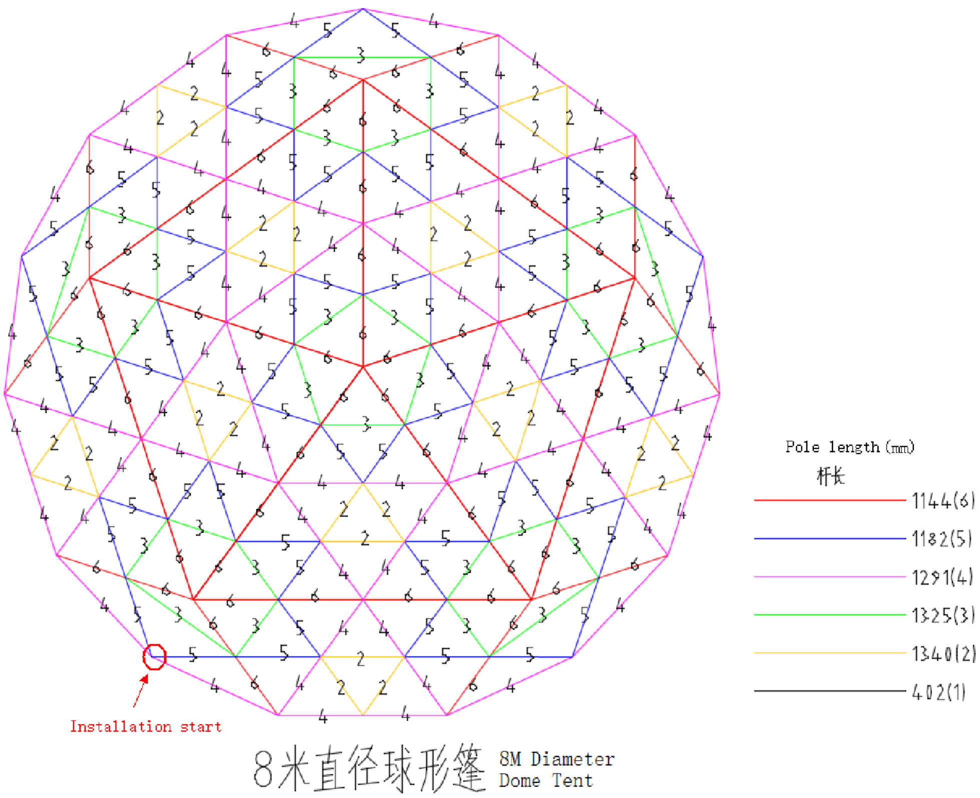
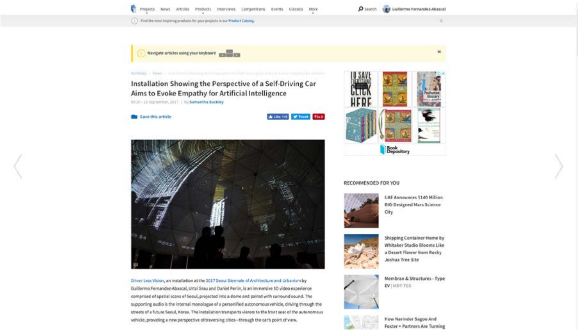
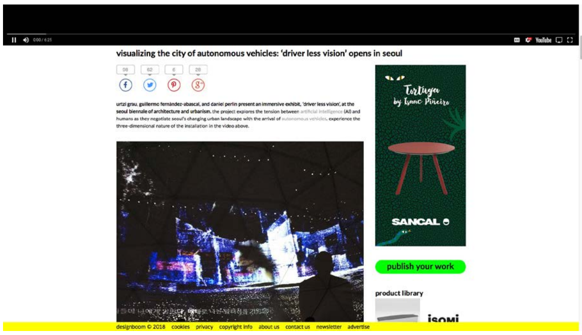
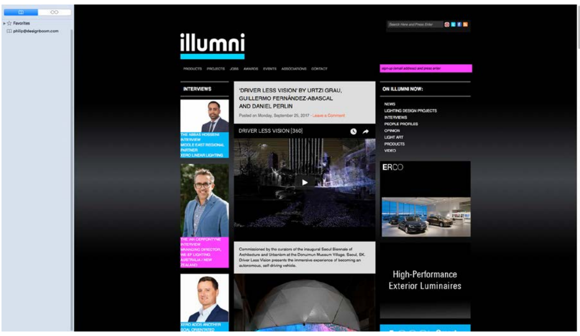


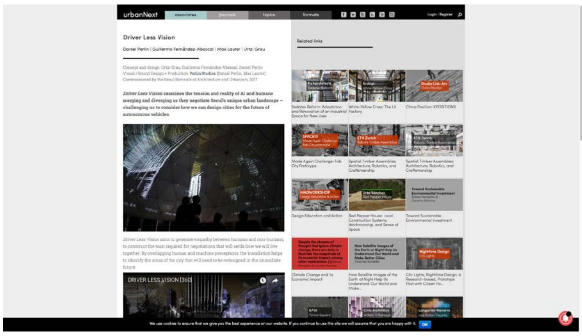
Assemblage diagram

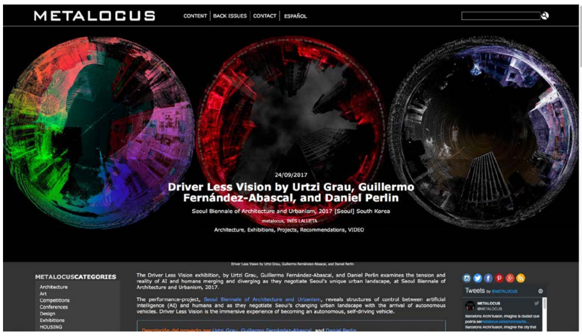
Driverless vision Seoul press coverage







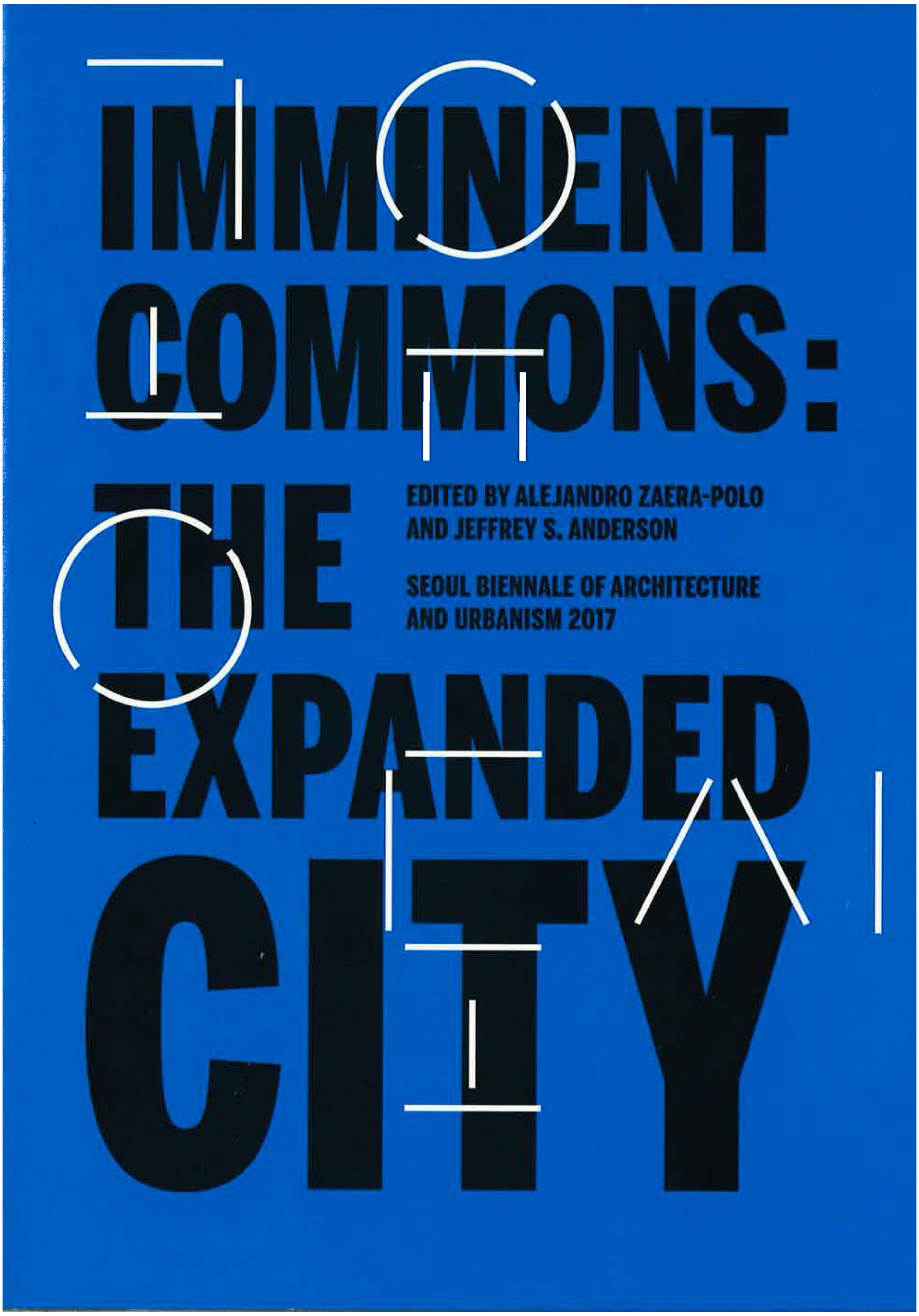




Publications

The following publications linked to the topic were published along the candidature:

Grau, Urtzi and Guillermo Fernandez-Abascal. “Driver-less vision: learning to see the way cars do.” *Imminent comons: the expanded city.* Edited by Alejandro Zaera-Polo and Jeffrey S. Anderson. Barcelona: Actar, 2017.



In the film, humans, animals, and machines come together in solidarity
Leo Carax

Driver-less Vision: Learning to See the Way Cars Do

Fake Industries Architectural Agonism, Guillermo Fernandez-Abascal.

Recent developments in driverless technologies have brought discussions around urban environments to the forefront. While developing the actual vehicles, major players such as Waymo (Google), Volkswagen, or Uber are equally invested in envisioning the future of cities. Yet, the proposed scenarios tend to emphasize consensual solutions in which idealized images of the streets seamlessly integrate driverless technology. Avoiding the immediate future, these visions focus on a distant time in which the technology has been hegemonically deployed: Only driverless cars circulate while humans, city infrastructure, and autonomous vehicles have learned to live together.[1]

1. Future scenarios tend to focus their predictions on how driverless cars combined with a sharing economy could reduce drastically the total amount of cars and on the implications of this reduction in urban environments. Brandon Schoettle and Michael Sivak of the University of Michigan Transportation Research Institute foresee a 43% contraction. (Brandon Schoettle and Michael Sivak, "Potential Impact of Self-driving Vehicles on Household Vehicle Demand and Usage," http://www.driverlesstransportation.com/wp-content/uploads/2015/02/UMTRI-2015-3.pdf ([accessed February 2017]). Sebastian Thrun, a computer scientist at Stanford University and former leader of Google's driverless project predicts a 70% ; see "If Autonomous Vehicles Rule the World," *The Economist*, http://worldif.economist.com/article/12123/horseless-driverless (accessed February 2017)). Matthew Claudel and Carlo Ratti anticipate an 80% reduction (Matthew Claudel and Carlo Ratti, "Full Speed Ahead: How the Driverless Car Could Transform Cities," Mckinsey.com, http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/full-speed-ahead-how-the-driverless-car-could-transform-cities, accessed January 2017). Luis Martínez of the International Transport Forum expects a 90% decline in his study of Lisbon mobility (Luis Martínez, "Urban Mobility System Upgrade: How Shared Self-driving Cars Could Change City Traffic," CITF, OECD, http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf, accessed January 2017). In a similar exercise, Dan Fagnant of the University of Utah forecasts a 90% decline for the city of Austin (Daniel James Fagnant, "Future of Fully Automated Vehicles: Opportunities for Vehicle- and Ride-sharing, with Cost and Emission Savings," Ph.D. diss., University of Texas, https://repositories.lib.utexas.edu/bitstream/handle/2152/25932/FAGNANT-DISSERTATION-2014.pdf?sequence=1 (accessed February 2017). All of these hypotheses operate in a distant future when the technology has been fully implemented. IEEE predicts up to 75% of vehicles will be autonomous in

This paper argues instead that the conflicts untapped by the new technology's disruptive effects will trigger the most meaningful transformations of the city and that these changes they will happen in the near future. The fast deployment of driverless technology does not preclude a specific urban solution. Rather, it requires our imagining how the cohabitation of humans and cars is going to be discussed. Our hypothesis entails that, in the short term, the urban realm will be the place where the negotiation will take place and that the differences in the ways cars and humans sense the city will define the terms of the discussion.

After successful deployment of autonomous vehicles in close circuits and major non-urban areas, the city has become the ultimate frontier for driverless technologies. Personal rapid transit systems (PRT) operating in closed systems like the self-driving pods in Heathrow Airport have been successfully running since the end of yhe last century.[2]

Adaptive Cruise Control, Automatic Emergency Braking, or Automatic Parking are widely available in commercial cars. Tesla, BMW, Infiniti, and Mercedes-Benz offer models with Automatic Lane Keeping that guides the car through freeways and rural roads without relying on the driver's hands, eyes, or judgment.[3] Yet the city seems to resist the wave of autonomous cars. Several reasons explain why. Urban environments multiply the chances of unforeseen events and dramatically increase the amount of sensorial information required to make driving decisions. The quality and amount of data is directly proportional to the price of the technology and to the chances of the car's successfully resolving difficult situations. It also is inversely proportional to the car's processing and decision-making speed.

2040 and IHS forecasts that almost all of the vehicles in use will be driverless by 2050; see IEEE, "Look Ma, No Hands!," http://www.ieee.org/about/news/2012/5september_2_2012.html (accessed February 2017) and IHS, "Emerging Technologies: Autonomous Cars—Not If, But When," http://www.ihssupplierinsight.com/_assets/sampledownloads/auto-tech-report-emerging-tech-autonomous-car-2013-sample_1404310053.pdf (accessed February 2017).

2. Personal rapid transit (PRT) was developed in the 1950s as a more economical response to the conventional metro system supported by the Urban Mass Transportation Administration (UMTA). Originally they had similar capacity to cars but as they evolved into bigger vehicles they lost these advantages. As a result only one PRT was built, in Morgantown, WV (USA). It has been operating successfully since then. We can position Heathrow's pods, the Sky Cube in Suncheon (Korea), or Masdar Abu Dabhi pods as their latest implementations of this technology.

3. In January 2014, SAE International (Society of Automotive Engineers) issued a classification system defining six levels of automation, spanning from no automation to full automation (0 to 5), with the goal of simplifying communication and collaboration among the different agents involved. The classification is based on the amount of driver intervention and attention required instead of the vehicular technological devices. The characterization sets a crucial distinction between level 2, where the human driver operates part of the dynamic driving task, and level 3, where the automated driving system carries out all dynamic driving task. SAE., "Automated Driving. : Levels of Automation Are Defined in New SAE International Standard J3016"," https://www.sae.org/misc/pdfs/automated_driving.pdf (accessed February 2017)). Later in 2014, Navya launched a self-driving vehicle (level 5) which has been performing successfully in different closed environments from Switzerland to France, the United States,

The equilibrium between these two opposed parameters defines different approaches to the driverless cars.[4] Eventually, it will also define how the streetscape needs to change to accommodate the cohabitation of autonomous vehicles, regular cars, pedestrians, and other forms of transportation.

The presence of self-driving cars in urban environments also challenges accepted notions of safety. Accidents involving self-driving cars are well documented. Google issued a public report monthly until November 2016. Tesla and Uber are more secretive, but their accidents tend to become media events.[5]

England, and Singapore. Arma, their latest carrier, is operating trials under fixed routes in urban scenarios. The shuttle can transport up to 15 passengers and drive up to 45 km/h. Other major players have been testing vehicles in closed environments and on public roads under special circumstances. When driven on public roads, the cars require at least one person to monitor the action and assume control if needed. Some of the more popular testing programmes involve companies such as Waymo (Google), Tesla, or Uber. Google has been testing their cars since 2009 on freeways and testing grounds. In 2012, they shifted to the city streets, identifying the need to do tests in more complex environments. In their latest published monthly report, in November 2016, their vehicles operated 65% of the time on autonomous mode. Along the lifespan of the programme they have accumulated more than 2 million self-driven miles.(Waymo, “Journey,” https://waymo.com/journey/ [accessed February 2017]).

Tesla started deploying their Autopilot system in 2014, with a level 2 automated vehicle. In October 2016, Tesla announced that their vehicles have all the necessary hardware to be fully autonomous (level 5 capabilities). However, as they clearly state, its functionality depends on extensive software validation and regulatory approval. They currently offered multiple capacities such as adaptive cruise control or autosteer. Initially, the systems could only be deployed on specific highways but at as of February 2017, they also perform in some urban situations. (Tesla, “Full Self-Driving Capability,” https://www.tesla.com/autopilot [accessed February 2017]).Uber joined the race in 2016. Their controversial programme offered, right after nuTonomy’s pilot scheme, to carry fare-paying passengers in cars that have a high level of autonomy. The vehicles deploying this service have two employees in the front seats to monitor and take control in case of problems.

4. Tesla’s current sensing system arrays eight cameras that provide 360 degrees of visibility with a range of 250 m. Twelve ultrasonic sensors and a forward-facing radar complement and strengthen the system. However, Waymo and most of the other competitors follow a different approach. (Tesla, “Advanced Sensor Coverage,” https://www.tesla.com/autopilot [accessed February 2017]).Waymo’s most advanced vehicle, a Chrysler Pacifica Hybrid minivan customised with different self-driving sensors, relies primarily on LiDAR technology. It has three LiDAR sensors, eight vision modules comprising multiples sensors and a complex radar system to complement it. (Waymo team, “Introducing Waymo’s Suite of Custom-built, Self-driving Hardware,” Medium, https://medium.com/waymo/introducing-waymos-suite-of-custom-built-self-driving-hardware-c47d1714563 [accessed February 2017]).

5. Tesla’s fatal accident occurred on 7 May 2016 in Willston, Florida, while a Tesla Model Selectric car was engaged in Autopilot mode; see Anjali Singhvi and Karl Russell, “Inside the Self-Driving Tesla Fatal Accident,” *New York Times*, 1 July 2016, https://www.nytimes.com/interactive/2016/07/01/business/inside-tesla-accident.html

The majority of these events involve single vehicles or collisions between two or more vehicles. Urban environments increase the chances of accidents involving pedestrians and other forms of non-vehicular traffic. The ethical implications of this scenario have been popularized by MIT's interactive online test, Moral Machine.[6]

Self-driving technologies imply a transfer of accountability to the algorithms that guide the vehicle. Most legal experts predict a trend towards increased manufacturer liability with increased use of automation. Major players such as Volvo, Google, or Mercedes already supported this solution in 2015. Car manufacturers will accept insurance liabilities after full automatization (level 5) is a reality.[7] But safety goes beyond the insurance conundrum. In *Aramis, or the Love of Technology*, Bruno Latour proves how the success of a new technology is deeply connected with the perceived dangers it entails.[8]

To share the streets with cars driven by computers shakes collective notions of acceptable risk. The technology needs to prove trustworthy. And trust, in this cases, results from a combination of scientific evidence, storytelling, and public demonstrations constructed by the engineers, economies, and populations involved in their development. When common agreements regarding trust and responsibility shift, the way we will live together needs to be settled, again.[9]

(accessed February 2017). Uber's most recent accident happened on 24 March 2017. Although they were not accused for being responsible of the accident, they temporarily suspended their programmes in their three testing locations: Arizona, San Francisco, and Pittsburgh. See Mike Isaac, "Uber Suspends Tests of Self-Driving Vehicles After Arizona Crash," *New York Times*, 25 March 2017, https://www.nytimes.com/2017/03/25/business/uber-suspends-tests-of-self-driving-vehicles-after-arizona-crash.html.

6. Iyad Rahwan, Jean-Francois Bonnefon, and Azim Shariff, "Moral Machine: Human Perspectives on Machine Ethics," http://moralmachine.mit.edu/ (accessed January 2017).

7. Kirsten Korosec, "Volvo CEO: We Will Accept All Liability When Our Cars Are in Autonomous Mode," *Fortune*, 7 October 2015, http://fortune.com/2015/10/07/volvo-liability-self-driving-cars/ (accessed February 2017), and Bill Whitaker, "Hands off the Wheel," *Sixty Minutes*, CBS, http://www.cbsnews.com/news/self-driving-cars-google-mercedes-benz-60-minutes/ (accessed February 2017).

8. Bruno Latour, *Aramis, or the Love of Technology* (Cambridge, MA: Harvard University Press, 1996).

9. Charles Perrow analyzes the social side of technological risk. He argues that accidents are normal events in complex systems; they are the predetermined consequences of the way we launch industrial ventures. He believes that the conventional engineering approach to ensuring safety, building in more warnings and safeguards, is inadequate because complex systems assure failure. Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*. (Princeton, NJ: Princeton University Press, 1999). Hod Lipson, professor at Columbia University and co-author of *Driverless, Intelligent Cars and the Road Ahead*, advises that the Department of Transportation should define a safety standard based on statistical goals, not specific technologies. They should specify how safe a car needs to be before it can drive itself, and then step out of the way.(Cited in Russ Mitchell, "Why the Driverless Car Industry Is Happy (So Far) with Trump's Pick for Transportation Secretary," Los Angeles Times, 5 December 2016, http://www.latimes.com/business/autos/la-fi-hy-chao-trump-driverless-20161205-story.html.

If dense urban environments intensify the conflicts between technology, ethics, economy, and collective safety, the realm of sensing renders the conflicts public. The arrival of autonomous vehicles entails the emergence of a new type of gaze that requires the negotiation of existing codes. Currently, human perception defines the visual and sonic stimuli that regulates urban traffic. The transfer of information has been designed, with few exceptions, to be effective for human vision and in some cases for human audition. Driverless sensors struggle with these logics; e.g., redundancy, used to capture drivers' attention, often produces a confusing cacophony for autonomous vehicles. Dirtiness on the road graphics, misallocations of signage, consecutive but contradictory traffic signs, or even the lack of proper standardization of traffic signs and markings are the reasons behind some of the most notorious incidents involving autonomous vehicles.[10]

Assuming that driverless cars will adapt to these conditions implies a double contradiction. It forgets the history of transformations of streetscape associated with the changes in vehicular technologies.[11] But more importantly, it ignores

10. Several relevant figures in the field such as Elon Musk from Tesla, Lex Kerssemakers, the North America Volvo CEO, and Christoph Mertz, a research scientist at Carnegie Mellon University, have pointed out the problem of faded lanes in the current development of the technology. Paul Carlson, from Texas A&M University, aims for consistency in signage along American roads in order to accommodate automation favorably. The agency Reuters also points out that the lack of standardization in the US compared to most European countries, which follow the Vienna Convention on Road Signs and Signals, causes a big problem. At the same time several researchers at Sookmyung Women's University and Yonsei University in Seoul are focusing on how current automated sign recognition systems detect irrelevant signs placed along roads. This problematic cacophony is dramatically amplified in urban scenarios. See Alexandria Sage, "Where's the Lane? Self-driving Cars Confused by Shabby U.S. Roadways," Reuters, http://www.reuters.com/article/us-autos-autonomous-infrastructure-insig-idUSKCN0WX131 (accessed December 2016); Andrew Ng and Yuanquin Lin. "Self-Driving Cars Won't Work Until We Change Our Roads—And Attitudes," *Wired* https://www.wired.com/2016/03/self-driving-cars-wont-work-change-roads-attitudes/ (accesed December 2016); and Signe Brewster, "Researchers Teach Self-driving Cars to 'See' Better at Night," *Science*, http://www.sciencemag.org/news/2017/03/researchers-teach-self-driving-cars-see-better-night (accessed March 2017).

11. The relationship between the transformations of the streetscape and the arrival of new vehicular technologies also places driverless cars at the center of the history of architecture. Since its inception, the car has often played a central role in architects' urban visions. The precepts of the Athens Charter and the images of the Ville Radieuse were an explicit responses to the safety and functional issues associated with the popularization of car. Its implementation, with different degrees of success, during the post-war reconstruction of Europe and the global explosion of suburban sprawl, fueled architectural controversies that questioned the role of cars in the definition of urban environments. Ian Nairn's *Outrage* (1955), Robin Boyd's *Australian Ugliness* (1960), Appleyard, Randolph Myer, and Lynch's *The View from the Road* (1964), Peter Blake's *God's Own Junkyard* (1965), Reyner Banham's *Los Angeles: The Architecture of Four Ecologies* (1971), Venturi, Scott-Brown and Izenour's *Learning from Las Vegas* (1973), and Alison and Peter Smithson's *AS IN DS: An Eye on the Road* (1983) are not only some well-known examples of these debates; they also show how the topic lost traction in architecture debates at the end of the last century.

the fact that self-driving cars construct images that are barely comparable to human perception.[12] Driverless cars take in real-time data through different on-board sensors. Although there is not an industry standard yet, certain trends are ubiquitous. The vehicles use a combination of radars, cameras, ultrasonic sensors, and LiDAR scanners to get immediate information from the external environment.[13] The resulting perception differs greatly from a human one. Driverless cars do not capture environmental sound. Colour rarely plays a role in the way they map the city. And, with various degrees of resolution, their sensors cover 360 degrees around the vehicle.

At the same time, car sensors and human senses share a logic of specialization. The human sense of hearing tends to recognize exceptional and abrupt changes in the sonic landscape—a siren, a claxon, a change in the sound of the engine. Even if human peripheral vision operates in a similar fashion, attention is essential for eyesight. Human vision requires continuity and focusses on subtle changes. Thus fog or darkness decrease the eye's ability to discern difference and decrease its effectivity. Similarly, the way self-driving cars' sensors function defines their potentials and limitations. Some sensors detect the relative speed of objects in close range while others capture the reflectivity of static objects far away. Some are able to construct detailed 3D models of objects no farther than a meter away while others are indispensable for pattern recognition. Human drivers combine eyesight and hearing to make decisions and driverless cars' algorithms use information from multiple sensors in their decision-making processes. Yet, autonomous vehicles' capacity for storing the information their sensors capture makes a big difference. As each of the four types of sensors in a driverless car captures the area they circulate, they also produce a medium-specific map of their environment.

Radars are object-detection systems that use radio waves to determine the range, angle, or velocity of objects. They have good range but low resolution, especially when compared to ultrasonic sensors and LiDAR scanners. They are good at near-proximity detection but less effective than sonar. They work equally well in light and dark conditions and perform through fog, rain, and snow. While they are very effective at determining relative speed of traffic, they do not differentiate colour or contrast, rendering them useless for optical pattern recognition. They are critical to monitoring the speed of other vehicles and objects surrounding the self-driving car. They detect movement in the city and are able to construct relational maps capturing sections of the electromagnetic spectrum.

Ultrasonic sensors are object-detection systems that emit ultrasonic sound waves and detect their return to define distance. They offer a very poor range, but they are extraordinarily effective in very-near-range three-dimensional mapping. Compared to radio waves, sound waves are slow. Thus, differences of less than a centimetre are detectable. They work regardless of light levels and also perform well in conditions of snow, fog, and rain. They do not provide any

12. Uber's arrival is linked to the famous Google lawsuit against Uber that position LiDAR technology at the centre of the dispute. Again, this legal battle locates the discussion of the car's ability to see the world. See Alex Davies, "Google's Lawsuit Against Uber Revolves Around Frickin' Lasers," *Wired,* https://www.wired.com/2017/02/googles-lawsuit-uber-revolves-around-frickin-lasers/ (accessed March 2017).

13. For a detailed list of the the onboard sensors used by different self-driving car brands, see footnote 4.

colour or contrast or allow optical character recognition, but they are extremely useful to determine speed. They are essential to for automatic parking and to avoid low-speed collisions. They construct detailed 3D maps of the temporary arrangement of objects in the proximity of the car.

LiDARs (Light Detection and Ranging) are surveying technologies that measure distance by illuminating a target with a laser light. They are currently the most extended object-detection technology for autonomous vehicles. They generate extremely accurate representations of the car's surroundings but fail to perform in short distances. They cannot detect colour or contrast, cannot provide optical character recognition capabilities, nor they are effective for real-time speed monitoring. Light conditions do not decrease their functionality, but snow, fog, rain, and dust particles in the air do. Due to their use of light spectrum wavelengths, LiDAR scanners can sense small elements floating in the atmosphere. They produce maps of quality of air quality.

RGB and infrared cameras are devices that record visual images. They have very high resolution and operate better in long distances than in close proximity. They can determine speed, but not at the level of accuracy of radar. They can discern colour and contrast but underperform in very bright conditions and also as light levels fade. Cameras are key for the car's optical-character recognition software and are *de facto* surveillance systems.

This proliferation of sensors in the environment is a defining factor of the imminent urban milieu. Environmental sensors connected to cars distribute instant remote sensing, enabling the constant flow of information on the urban environment while at the same time radicalizing issues of privacy, access, and control. They simultaneously react to and change the urban pattern, generating an unprecedented environmental consciousness. The resulting image of the city cannot differ more from human perception. It is a combination of sections of the electromagnetic spectrum, detailed 3D models around cars, detailed maps of air pollution, and an interconnected surveillance system. It is not the city as we see it.

And yet interconnected sensors can create a new common, a ubiquitous, global sensorium that obliterates further the distinction between nature and artifice. While the city is managed by non-human agencies, it continues to be designed around the assumption of a benign human-centered system. Engaging citizens in this new sensorial environment makes them aware of the necessity of a new sensorial social contract.[14] It embeds the judgment of society, as a whole, in the sensorial governance of societal outcomes. The city is therefore the space where we can gain mutual confidence trust, generating the necessary relationship for coming scenarios of coexistence. In other words, driverless vision isn't just about cars, rather it is more akin to the interaction between a government and a governed citizenry. Modern government is the outcome of an implicit agreement—or social contract—between the ruled and their rulers, aimed at fulfilling the general will of citizens.

14. "Algorithmic Social Contract" is a termed coined by MIT professor Iyad Rahwan and develops the idea that by understanding the priorities and values of the public, we could train machines to behave in ways that the society would consider ethical. See Iyad Rahwan, "Society-in-the-Loop: Programming the Algorithmic Social Contract," www.medium.com https://medium.com/mit-media-lab/society-in-the-loop-54ffd71cd802 (accessed March 2017).

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Driverless Vision: Towards a Sensorial Agreement

by

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"In the film, humans, animals, and machines come together in solidaridty."
-Leo Carax on his film Holy Motors

Driverless Vision: Towards a Sensorial Agreement

Guillermo Fernández-Abascal & Urtzi Grau

Introduction

Recent developments in driverless technologies are bringing discussions around urban environments to the forefront. While developing the actual vehicles, major players such as Waymo (Google), Volkswagen, and Uber have been equally invested in envisioning the future of cities. Yet, the proposed scenarios tend to emphasize consensual solutions in which idealized images of the streets seamlessly integrate driverless technology. Ignoring the immediate future, these visions focus on a distant time in which technology dominates: driverless cars populate the roads, human behaviour and city infrastructure remain unchanged, and society has learned to live with autonomous vehicles.[1] This paper argues that the conflicts unleashed by the new technology will trigger meaningful transformations of the city, and that these changes will happen in the near future. The fast, disruptive deployment of driverless technology does not preclude a specific urban solution. However, it does ask us to imagine how the cohabitation of humans and cars might be articulated in the urban environment, which is where the negotiation between the two will take place in the short-term. The differences in the ways that cars and humans sense the city will define both the terms of the discussion and the design of these spaces.

1 Future scenarios tend to focus predictions on how driverless cars, when combined with the shared economy, could drastically reduce the total number of cars in urban environments. Brandon Schoettle and Michael Sivak from the University of Michigan Transportation Research Institute foresee a 43% decrease. (Brandon Schoettle and Michael Sivak. "Potential Impact of Self-driving vehicles on household vehicle demand and usage." accessed February 2017. http://www.driverlesstransportation.com/wp-content/uploads/2015/02/UMTRI-2015-3.pdf). Sebastian Thrun, a computer scientist at Stanford University and fomer leader of Google's driverless project predicts a 70% decrease. (Sebastian Thrun, "If Autonomous vehicles run the world." *The Economist*. accessed February 2017. http://worldif.economist.com/article/12123/horseless-driverless). Matthew Claudel and Carlo Ratti anticipate a 80% reduction. (Matthew Claudel and Carlo Ratti. "Full speed ahead: How the driverless car could transform cities." *McKinsey*. accessed January 2017. http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/full-speed-ahead-how-the-driverless-car-could-transform-cities). Luis Martínez of the International Transport Forum expects a 90% decline in his study of Lisbon mobility (Luis Martinez. "Urban Mobility System Upgrade. How shared self-driving cars could change city traffic." accessed January 2017. http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf), and in a similar exercise Dan Fagnant of the University of Utah forecasts a 90% decline for the city of Austin (Daniel Fagnant." Future of fully automated vehicles: opportunities for vehicle-and ride-sharing, with cost and emission savings." accessed February 2017. https://repositories.lib.utexas.edu/bitstream/handle/2152/25932/FAGNANT-DISSERTATION-2014.pdf?sequence=1). All these hypotheses operate in a distant future when the technology has been fully implemented. IEEE predicts up to 75% of vehicles will be autonomous in 2040 and IHS has forecast that almost all vehicles will be driverless by 2050 (IEEE. "Look Ma, No Hands!" accessed February 2017. http://www.ieee.org/about/news/2012/5september_2_2012.html). (IHS. "Emerging Technologies: Autonomous Cars—Not If, But When." accessed February 2017. http://www.ihssupplierinsight.com/_assets/sampledownloads/auto-tech-report-emerging-tech-autonomous-car-2013-sample_1404310053.pdf).

Following the successful deployment of autonomous vehicles in secluded environments and major non-urban areas, dense urban environments have become the ultimate frontier for driverless technologies. Personal rapid transit systems (PRT) operating on independent tracks, like the self-driving pods in Heathrow Airport, have been successfully running since the end of last century.[2] Adaptive cruise control, automatic emergency braking, and automatic parking are already widely available in commercial cars. Tesla, BMW, Infiniti, and Mercedes-Benz offer models with automatic lane keeping, which guide the car along freeways and rural roads without relying on the driver.[3] Yet the city continues to resist the wave of autonomous cars. The way cars map their environment is one of the main reasons. Urban environments multiply the chances of unforeseen events and dramatically increase the amount of sensorial information required to make driving decisions. The quality and amount of data is directly proportional to the price of the technology and to the car's subsequent ability to resolve eventful situations. It is also inversely proportional to the car's processing and decision-making speed. The means of achieving a balance between these two parameters (sensors' type and precision versus reaction speed and price) defines the different approaches in the development of driverless technologies.[4]

On perception and maps

The arrival of autonomous vehicles requires a new type of gaze—one that can renegotiate existing codes. Currently, human perception and means of gathering information define the visual and sonic stimuli that regulate urban traffic. Driverless sensors struggle with this information. The repetition of signage, for example, which is used to capture the driver's attention, often produces a confusing cacophony for autonomous vehicles. Dirty road graphics, misallocations of signage, consecutive but contradictory traffic signs, or even the lack of standardization of traffic signs and markings are all

2 Personal rapid transit (PRT) was developed in the 1950s as a more economical response to public transport, as compared to the conventional metro system supported by the Urban Mass Transportation Administration (UMTA). Originally PRT had a similar capacity to cars but as they evolved into bigger vehicles they lost some of their advantages, including light infrastructural requirements and maximum flexibility in the journeys routes. As a result only one PRT was built—in Morgantown (USA). It has been operating successfully since then. We can position Heathrow's pods, the Sky Cube in Suncheon (Korea) and Masdar (Abu Dhabi) pods as the latest implementations of this technology.

3 In January 2014, SAE International (Society of Automotive Engineers) issued a classification system that spans six levels of driver intervention, from no automation to full automation (zero to five). This taxonomy aims to simplify communication and collaboration between the different agents involved. The system sets a crucial distinction between level two, where the human driver operates part of the dynamic driving task, and level three, where the automated driving system carries out all of the dynamic driving tasks (SAE. "Automated Driving. Levels of automation are defined in new SAE International Standard J3016." accessed February 2017. https://www.sae.org/misc/pdfs/automated_driving.pdf). Later in 2014, Navya launched a self-driving vehicle (level five) which has been performing successfully in different closed environments including Switzerland, France, the USA, England, and Singapore. Arma, their latest carrier, is being trialed along fixed routes in urban scenarios. This shuttle can transport up to fifteen passengers and drive up to 45 km/h. Other major players have been testing vehicles in closed environments and on public roads under special circumstances. When driven on public roads, the cars require at least one person to monitor the action and assume control if necessary. Some of the more popular testing programmes involve companies such as Waymo (Google), Tesla, or Uber. Google has been testing their cars since 2009 on freeways and in testing grounds. In 2012, they shifted to the city streets to perform tests in a more complex environment. Interestingly enough, the chosen location for this step was the infamous Venturian Strip of Las Vegas. In their latest published monthly report from November 2016, their vehicles operated 65% of the time on autonomous mode. Along the lifespan of the program, they have accumulated more than two million self-driven miles. (Waymo. "Journey." accessed February 2017. https://waymo.com/journey/).

4 Tesla started deploying their autopilot system in 2014 with a level two automated vehicle. In October 2016, Tesla announced that their vehicles had all the necessary hardware to be fully autonomous at level 5 capabilities. However, as they clearly state, its functionality depends on extensive software validation and regulatory approval. They currently offer multiple capacities such as adaptive cruise control or auto-steer. Initially, the systems could only be deployed along specific highways, but they now also perform in some urban situations. (Tesla. "Full Self-Driving Capability." accessed February 2017. https://www.tesla.com/autopilot). Uber joined the race in 2016. Their controversial program offered, right after the nuTonomy pilot scheme, to carry fare-paying passengers in cars that have a high level of autonomy. These vehicles have two employees in the front seats to monitor and take control in case there are problems. Tesla's current sensing system comprises eight cameras that provide 360 degrees visibility with a range of 250 metres. Twelve ultrasonic sensors and a forward-facing radar complement and strengthen the system. (Tesla. "Advanced Sensor Coverage." accessed February 2017. https://www.tesla.com/autopilot). Waymo and most of the other competitors follow a different approach. Waymo's most advanced vehicle, a Chrysler Pacifica Hybrid minivan customized with different self-driving sensors, relies primarily on LiDAR technology. It has three LiDAR sensors, eight vision modules comprising multiple sensors, and a complex radar system to complement it. (Waymo. "Introducing Waymo's suite of custom-built, self-driving hardware." Medium. accessed February 2017. https://medium.com/waymo/introducing-waymos-suite-of-custom-built-self-driving-hardware-c47d1714563).

reasons for some of the most notorious incidents involving autonomous vehicles.[5] The assumption that driverless cars will fully adapt to these conditions is erroneous. It overlooks the history of streetscape transformations driven by changes in vehicular technologies.[6] More importantly, it ignores the fact that self-driving cars construct images that are barely comparable to human perception.[7]

Driverless cars take in real-time data through different on-board sensors. Although there is not an industry standard yet, certain trends are ubiquitous. The vehicles use a combination of radars, cameras, ultrasonic sensors and LiDAR (Light Detection and Ranging) scanners to get immediate information from the external environment.[8] The resulting perception differs greatly from a human one. Driverless cars do not capture environmental sound. Colour rarely plays a role in the way they map the city. And, with various degrees of resolution, their sensors cover 360 degrees around the vehicle.

The way self-driving cars' sensors function defines their potential and their limitations. Some sensors detect the relative speed of objects in close range while others capture the reflectivity of static objects from far away. Some are able to construct detailed 3D models of objects no farther than a meter away; other sensors are indispensable for pattern recognition. Human drivers combine eyesight and hearing to make decisions; driverless cars' algorithms use information from multiple sensors in their decision-making processes. While each sensor in a driverless car captures its surroundings, it also produces a medium-specific map. The most prevalent sensors are radar, ultrasonic sensors, LiDAR, and cameras.[9] Let us now look more closely at these.

Radars are object-detection systems that use radio waves to determine the range, angle, or velocity of objects. They have good range but low resolution, especially when compared to ultrasonic sensors and LiDAR scanners. They are good at near-proximity detection but less effective than sonar. They work equally well in light and dark conditions and perform through fog, rain, and snow. Although they are very effective at determining the relative speed of traffic, they do not differentiate colour or contrast, rendering them useless for optical pattern recognition, which is critical for monitoring the speed of other vehicles and surrounding objects. They detect movement in the city and are able to construct relational maps and capture cross-sections of the electromagnetic spectrum.

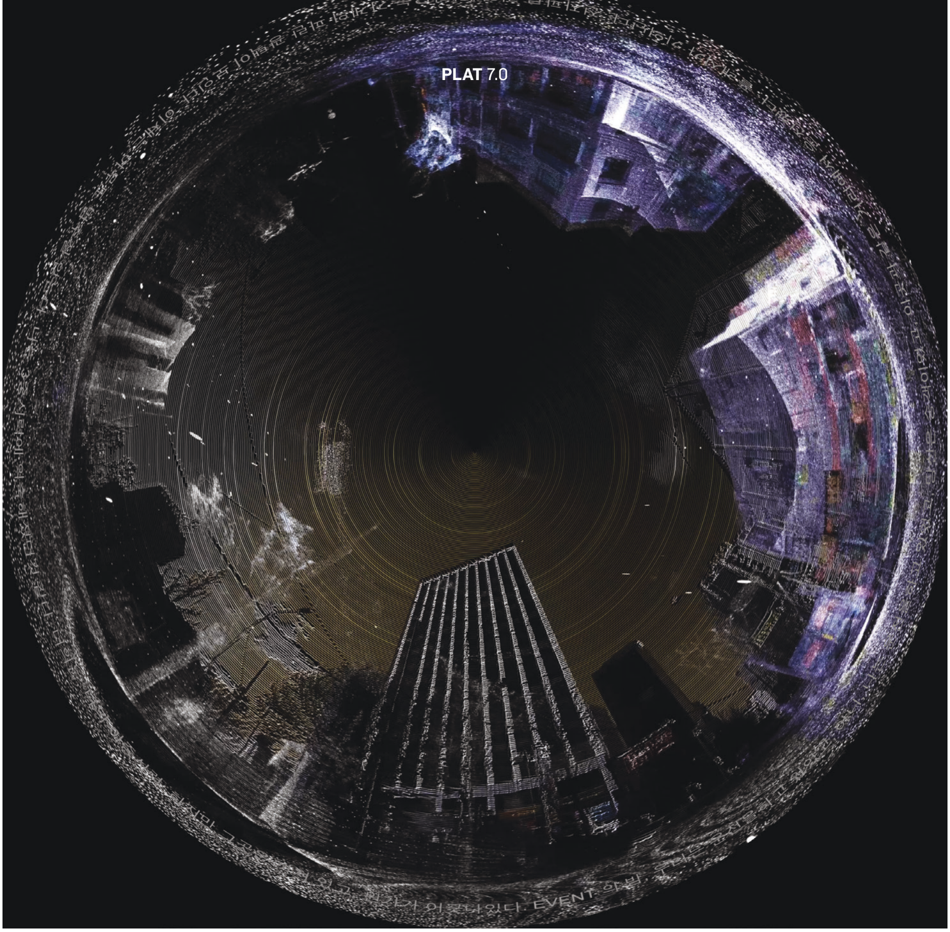
5 Prominent figures in the field such as Elon Musk from Tesla, North America Volvo CEO Lex Kerssemakers, and Carnegie Mellon University research scientist Christoph Mertz have all pointed out the problem of faded lanes. Paul Carlson from Texas A&M University aims for consistency in signage along American roads in order to accommodate automation more favorably. The news agency Reuters also points out that the lack of standardization in the US, as compared to most of the European countries who follow the Vienna Convention on Road Signs and Signals, causes problems. At the same time, several researchers at Sookmyung Women's University and Yonsei University in Seoul are focusing on how current automated sign recognition systems detect irrelevant signs placed along roads. This problematic cacophony is dramatically amplified in urban scenarios. (Alexandria Sage. "Where's the lane? Self-driving cars confused by shabby U.S. roadways." *Reuters*. accessed December 2016. http://www.reuters.com/article/us-autos-autonomous-infrastructure-insig-idUSKCN0WX131). (Andrew Ng and Yuanquin Lin. "Self-Driving Cars Won't Work Until We Change Our Roads—And Attitudes." *Wired*. accessed December 2016. https://www.wired.com/2016/03/self-driving-cars-wont-work-change-roads-attitudes/). (Signe Brewster. "Researchers teach self-driving cars to 'see' better at night." *Sciencemag*. accessed March 2017. http://www.sciencemag.org/news/2017/03/researchers-teach-self-driving-cars-see-better-night).

6 The relationship between the transformations of the streetscape and the arrival of new vehicular technologies also places driverless cars at the center of the history of architecture. Since its inception, the car has often played a central role in architects' urban visions. The precepts of the Athens Charter and the images of the Ville Radieuse were explicit responses to the safety and functional issues associated with the popularization of the car. The implementation of the Athens Charter was met with varying degrees of success. During the post-war reconstruction of Europe and the global explosion of suburban sprawl, it fueled architectural controversies that questioned the role of cars in the definition of urban environments. Ian Nairn's *Outrage* (1955), Robin Boyd's *Australian Ugliness* (1960), Appleyard, Myer, and Lynch's *The View from the Road* (1964), Peter Blake's *God's Own Junkyard* (1964), Reyner Banham's *Los Angeles, The Architecture of Four Ecologies* (1971), Venturi, Scott-Brown, and Izenour's *Learning from Las Vegas* (1972), and Alison and Peter Smithson's *AS IN DS: An Eye on the Road* (1983) are some well-known examples of these debates. They also show how the topic lost traction in architecture debates at the end of last century.

7 Uber's arrival to the driverless race is linked to the famous Google lawsuit against Uber, which positions LiDAR technology at the center of the dispute. This legal battle focuses the discussion on the car's ability to see the world. (Alex Davies. "Google's Lawsuit Against Uber Revolves Around Frickin' Lasers." *Wired*. accessed March 2017. https://www.wired.com/2017/02/googles-lawsuit-uber-revolves-around-frickin-lasers/).

8 For a detailed list of the onboard sensors used by different self-driving car brands see footnote 4.

9 Michael Barnard gives a thorough assessment of the strengths, weaknesses, and compromises inherent in these different sensors in his blog. (Michael Barnard. "Tesla & Google Disagree About LIDAR—Which Is Right?." *Clean Technica*. accessed June 2017. https://cleantechnica.com/2016/07/29/tesla-google-disagree-lidar-right/).



Ultrasonic sensors are object-detection systems that emit ultrasonic sound waves and detect their return to define distance. They offer a very poor range, but they are extraordinarily effective in close-range 3D mapping. Compared to radio waves, sound waves are slow. Thus, differences of less than a centimetre are detectable. These sensors work regardless of light levels and also perform well in snow, fog, and rain. They do not detect colour contrast or allow for optical character recognition but they are extremely useful in determining speed. They are essential for automatic parking and the avoidance of low speed collisions. They construct detailed 3D maps of the temporary arrangements of objects in proximity to the car.

LiDARs are surveying technologies that measure distance by illuminating a target with a laser light. They are currently the most widely adopted object-detection technology for autonomous vehicles. They generate extremely accurate representations of the car's surroundings but fail to perform over short distances. They cannot detect color or contrast, they cannot recognize optical characters nor are they effective for real-time speed monitoring. Light conditions do not decrease their functionality, but snow, fog, rain, and dust particles in the air do, because LiDARs rely on light spectrum wavelengths. In addition to accurate point-cloud models of the city, they produce maps of air-quality.[10]

10 LiDARs have been used to observe particle concentrations in the atmosphere since the appearance of the technology in the 1960s. (Warren B. Johnson. "Lidar Applications in Air Pollution Research and Control." *Journal of the Air Pollution Control Association 19*, no. 3 (1969):176-180).

RGB and infrared cameras are devices that record visual images. They have very high resolution and operate better over long distances than in close proximity. They can determine speed, but not at the level of accuracy of the radar. They can discern color and contrast but underperform in very bright conditions and also as light levels fade. Cameras are key for character recognition software and serve as de facto surveillance systems. This proliferation of real-time mapping is a defining element of the future urban milieu. The autonomous vehicles' capacity for storing the information that their sensors capture makes a big difference—the resulting image of the city could not differ more from traditional human-generated maps. These maps are a combination of sections of the electromagnetic spectrum, detailed 3D models around vehicles, detailed maps of air pollution, and interconnected surveillance systems. The base for these maps, however, is not produced by the car's sensors. Although contemporary autonomous vehicles can theoretically drive by relying solely on this instant mapping, in reality they navigate the environment combining the real-time acquired data and HD maps stored in their hard drives.

HD maps help the car place itself in the world with a greater degree of accuracy, thus augmenting the sensors in the vehicle. These maps become extremely helpful in challenging situations like rainy or snowy conditions. More importantly, as they tell the cars what to expect on the road, the sensors can focus on processing moving agents like other cars or pedestrians, substantially improving their driving capabilities.

The inputs to construct these HD maps are threefold. First, a base map with information about roads, buildings, and so on. Currently, these base maps have been commodified by companies such as OpenStreetMap, which provides basic global data. This platform has become the common background for many of these new mapping start-ups, which build their cartographies on top of this. Imagery containing close-up details of streets is the second main component. Large quantities of real-time GPS location data from people with smartphones in their pockets constitute the third important input. This real-time information is supplemented with the data acquired by the vehicle's on-board sensors. The maps are continuously being updated with information on lane markings, street signs, traffic signals, potholes, and even the height of a curb, with a resolution down to the centimeter.[11] These new cartographies are radically different to traditional travel maps or the first generation of digital maps that helped humans to move around the city. Originally, maps emerged as a two-dimensional representation of a space—this approach allowed humans to navigate different territories for centuries. During the last decade, digital maps have guided users through basic turn-by-turn directions while walking or driving. These HD maps are not the city as we see it because the cars require an unseen precision with the maps, a precision where the map becomes the territory that they respond to.[12]

The combination of real-time mapping and HD stored maps takes us beyond geographical or physical territories, and its potential applications go far beyond self-driving vehicles. They, for example, make issues around individual privacy and security extremely evident. However, it also comes with the possibility to transform endless areas of research and design, and to influence policy and governance.

11 HD maps seem indispensable to the future of driverless vehicles. The need for them has produced a wide variety of enterprises dedicated to this highly valuable parallel industry. Google is once again the leader, though Audi, BMW, Daimler, and Intel are among the main shareholders of Here, a technological map company, which itself was a product from Nokia. TomTom, partnering with Baidu and Civil Maps, who count Ford among their main investors, has also joined the race. ("The battle for territory in digital cartography." *The Economist*. accessed October 2017. https://www.economist.com/news/business/21723173-not-all-roads-lead-google-maps-battle-territory-digital-cartography).

12 In June 2017 during a test drive near Ford's Michigan headquarters, the team noticed something strange with their self-driving cars. Every car shifted slightly at the same point in the lane as if they were avoiding a pothole. But the problem was not in the cars, it was on the map. A minor glitch caused one pixel in the recently updated file to have the wrong data value. The map informed the cars that the terrain was 25 cm higher than it actually was. The new map looked perfect to the human eye but not to driverless vehicles. (Seth Fiegerman. "The billion dollar war over maps." *CNN*. accessed October 2017. http://money.cnn.com/2017/06/07/technology/business/maps-wars-self-driving-cars/index.html).

Interconnected sensors and HD maps can create a new common, ubiquitous global sensorium that further dissolves the distinction between nature and artifice.[13] Engaging citizens in this new sensorial environment makes them aware of the necessity of a Sensorial Social Contract.[14] It embeds the judgment of society, as a whole, in the sensorial governance of societal outcomes. In other words, driverless vehicles aren't just about cars, rather they are more akin to the interaction between a government and a governed citizenry. Modern government is the outcome of an implicit agreement—or social contract—between the ruled and their rulers, which aims to fulfil the general will of citizens. If the Enlightenment marked humanity's transition towards the modern social contract, then determining a sensorial agreement could serve as the first step towards cohabitation. Following from the concept of the social contract—where individuals consent either explicitly or tacitly to surrendering some of their freedoms for the general good—this new agreement requires individuals to assent to partially handing over safety, control, and privacy, a move that could then unleash wide societal concerns about individual rights and agency.

Learning to live together: a hybrid forum

Safety is one topic that can unpack the urgent need for a sensorial contract. The presence of self-driving cars in urban environments challenges accepted notions of safety. The risks involved with autonomous vehicles are both public and secretive. Accidents involving self-driving cars are well documented. Google publicly reported on this monthly until November 2016. Tesla and Uber are more secretive, but their accidents tend to become media events.[15] The ethical implications of these scenarios have been popularized by MIT interactive online test, Moral Machine.[16] Self-driving technologies imply a transfer of accountability to the algorithms that guide the vehicle. Most of the legal experts predict a trend towards increased manufacturer liability with the increased use of automation. Major players such as Volvo, Google, and Mercedes already supported this solution in 2015. Car manufacturers will accept insurance liabilities after full level five automation is a reality.[17] But safety goes beyond the insurance conundrum and it raises issues of control too. Consider an AI algorithm that controls a self-driving car. One of the major concerns is that the system is a "black box." Once the system is trained, data can be fed to it and a useful interpretation of those data will be produced. But the actual decision-making process is not easily accessible for humans. In *Aramis, or the Love of Technology*, Bruno Latour proves how the success of a new technology is deeply connected with the perceived dangers it entails.[18] To share the streets with computer-driven cars shakes collective notions of acceptable risk. The technology needs to prove trustworthy. And trust, in this case, results from a combination of scientific evidence, storytelling, public demonstrations constructed by engineers, and the economies and populations involved in driverless cars' development. When common agreements regarding trust and responsibility shift, the way we live together

13 The term sensorium derives from the Latin *sēnsus*, or felt, from *sentīre* to perceive. It could be defined as the sum of an organism's perception, the seat of sensation where it experiences and interprets the environments where it lives. ("Sensorium." *Merriam Webster*. accessed September 2017. https://www.merriam-webster.com/dictionary/sensorium).

14 The term Sensorial Social Contract derives from Algorithmic Social Contract coined by MIT professor Iyad Rahwan, who developed the idea that by understanding the priorities and values of the public, we can train machines to behave in ways that a society would consider ethical. (Iyad Rahwan. "Society-in-the-Loop. Programming the Algorithmic Social Contract." accessed March 2017. https://medium.com/mit-media-lab/society-in-the-loop-54ffd71cd802).

15 A fatal accident occurred on May 7, 2016 in Williston, Florida when a Tesla Model S electric car was engaged in autopilot mode. (Anjali Singhvi and Karl Russell. "Inside the Self-Driving Tesla Fatal Accident." *New York Times*. accessed February 2017. https://www.nytimes.com/interactive/2016/07/01/business/inside-tesla-accident.html). Uber's most notorious accident took place on March 24, 2017, and as a consequence the company temporarily suspended their programs in their three testing locations: Arizona, San Francisco, and Pittsburgh. (Mike Isaac. "Uber Suspends Tests of Self-Driving Vehicles After Arizona Crash." *New York Times* accessed March 2017. https://www.nytimes.com/2017/03/25/business/uber-suspends-tests-of-self-driving-vehicles-after-arizona-crash.html).

16 Iyad Rahwan, Jean-Francois Bonnefon, and Azim Shariff. "Moral Machine—Human Perspectives on Machine Ethics." accessed January 2017. http://moralmachine.mit.edu/.

17 Kirsten Korosec. "Volvo CEO: We will accept all liability when our cars are in autonomous mode." *Fortune*. accessed February 2017. http://fortune.com/2015/10/07/volvo-liability-self-driving-cars/; Bill Whitaker. "Hands off the wheel." *CBS*. accessed February 2017. http://www.cbsnews.com/news/self-driving-cars-google-mercedes-benz-60-minutes/.

18 Bruno Latour. *Aramis, or the love of Technology*. (Cambridge, MA: Harvard University Press, 1996.)

needs to be re-examined.[19] If dense urban environments intensify the conflicts between technology, ethics, economy, and collective safety, the realm of sensors renders the conflicts public by opening the "black box."

Surveillance is a second topic that unwraps the sensorial contract needed for this exigent condition of the autonomous-car-filled city. The huge amount of processed data also includes personal information from drivers, passengers, and pedestrians. The data amassed by companies like Uber, whose tactics regarding data management have generated several controversies, will be amplified to unprecedented levels, making the need for standards of privacy protection urgent.[20] Currently, industry agreements on privacy best practices include commitments to transparency, consumer choice, minimization of data collection and retention, and de-identification. The principles require increased protection for personally identifiable information, such as geolocation, driver behavior, and biometric data. Accumulation of individuals' profiles and driving behaviors may prove to be valuable information for certain entities, such as insurance companies, vehicle manufacturers, advertisers, and law and traffic enforcement agencies. As a society, it is essential that we demand transparent processes for this data collection, as well as information about the purposes for which it is collected and by whom. Yet machine learning requires the constant feeding of information to improve its capacities; this conflicts with some of the data minimization principles.[21]

At the intersection of privacy and safety, the sensorial contract raises a third issue: security threats. The vehicles are vulnerable to hacks including the possibility of different actors taking over driving functions, either just for kicks or as a cyberwar tactic.[22] One of the main reasons why driverless vehicles are particularly sensitive to cyberattacks is the nature of their technology. Communication among the different sensors is fundamental for the efficiency of their systems but this also leaves them extremely exposed. The systems are designed to work together and involve innumerable agents. The rivalry between some of the companies means that they are reluctant to share knowledge about cyber threats and vulnerabilities or work together to develop more secure designs.

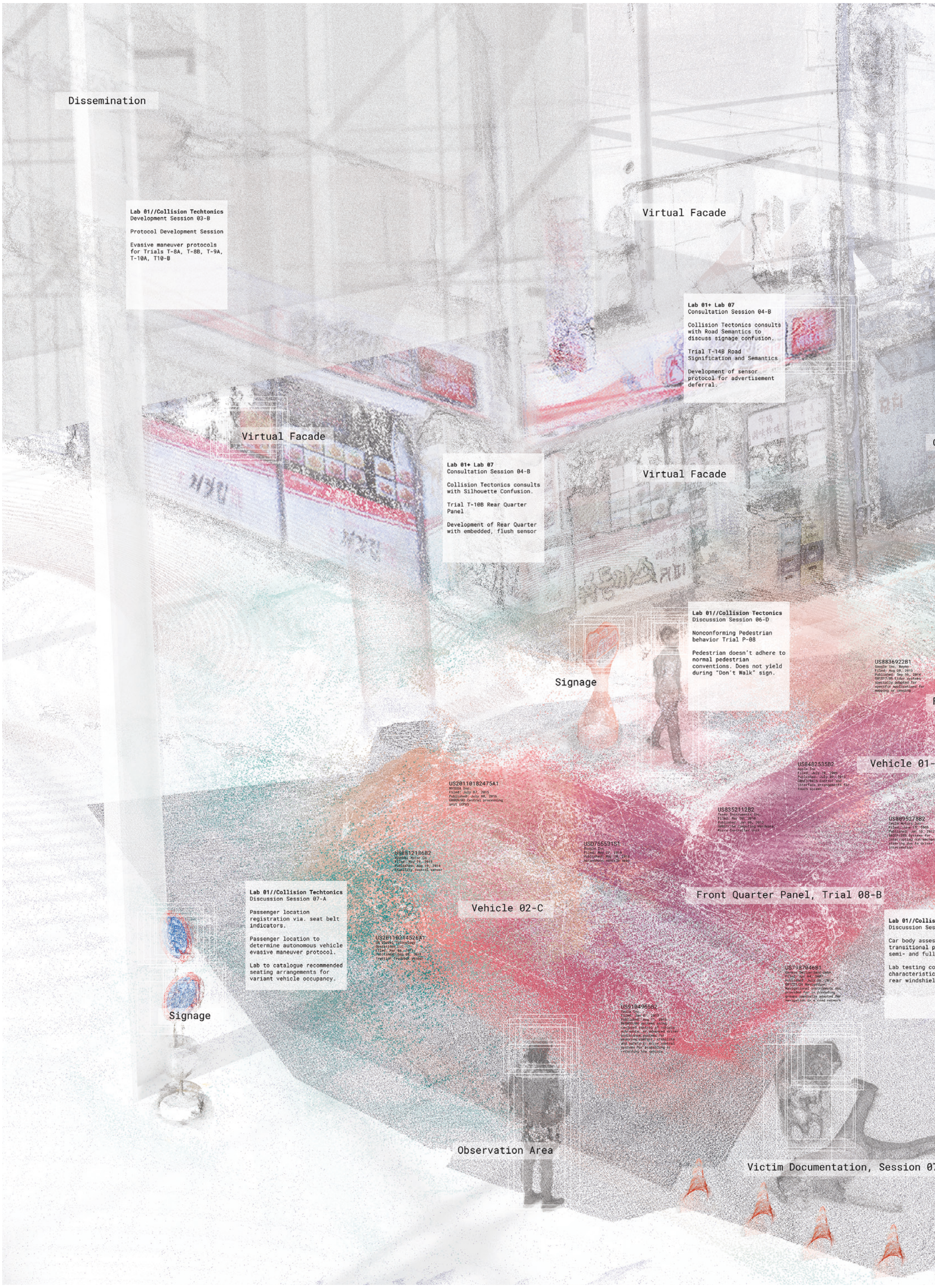
In a world dominated by uncertainties and controversies around scientific and technological issues, which are well-exemplified by driverless technologies, we need to identify new types of assembly that allow us to discuss questions about safety, control, and security. Hybrid forums address the questions and problems involved at different levels in a variety of domains and have proven to be successful in dealing with several contentious

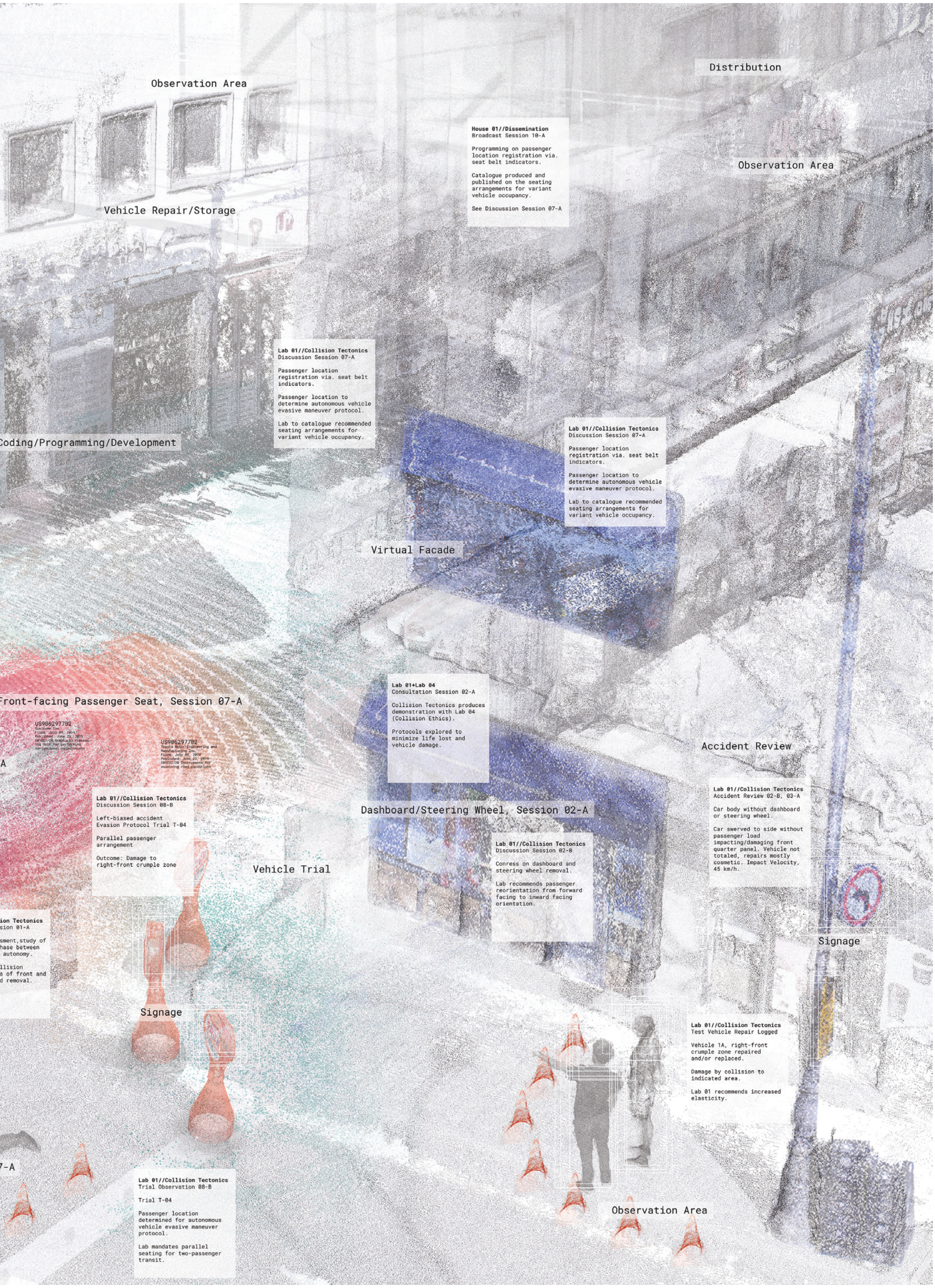
19 Perrow analyzes the social side of technological risk in *Normal Accidents*. He argues that accidents are normal events in complex systems and are the predetermined consequences of the way we launch industrial ventures. He believes that the conventional engineering approach to ensuring safety (building in more warnings and safeguards) is inadequate, as complex systems assure failure. (Charles Perrow. *Normal Accidents: Living with High-Risk Technologies*. Princeton: Princeton University Press, 1999). Virilio claims how one cannot innovate without creating some damage. (Paul Virilio. *The Original Accident*. Oxford, UK: Polity Press, 2007). Hod Lipson, professor from Columbia University and co-author of *Driverless: Intelligent Cars and the Road Ahead*, advises that the Department of Transportation should define a safety standard based on statistical goals, not specific technologies. They should specify how safe a car needs to be before it can drive itself, and then step out of the way. (Russ Mitchell. "Why the driverless car industry is happy (so far) with Trump's pick for Transportation secretary." *LA Times*. accessed December 2016. http://www.latimes.com/business/autos/la-fi-hy-chao-trump-driverless-20161205-story.html).

20 Uber's usage of data has been in the middle of several lawsuits for years. "God view mode" (currently "Heaven mode") allowed Uber employees to track the movements of all passengers in real-time without obtaining permission. "Hell" was used to identify drivers that were driving for both Uber and Lyft and ensured that those drivers were not prioritized over drivers exclusively contracting for Uber in order to persuade the dual Uber/Lyft drivers to drive for Uber only. (Martin Slattery. "Between 'Heaven mode' and 'Hell:' Uber's use of big data puts users in a purgatory of certainty around privacy issues." *Codea*. accessed October 2017. https://www.codea.com.au/publication/heaven-mode-hell-ubers-use-big-data-puts-users-purgatory-certainty-around-privacy-issues/).

21 Paul Lavery and Douglas McMahon. "Driverless Cars—Mapping the Privacy Issues." *Lexology*, accessed September 2017. https://www.lexology.com/library/detail.aspx?g=95e67012-d435-43b8-913d-d01fb50388d1. Ellen P. Goodman. "Self-driving cars: overlooking data privacy is a car crash waiting to happen." *The Guardian*. accessed September 2017. https://www.theguardian.com/technology/2016/jun/08/self-driving-car-legislation-drones-data-security .

22 Simon Garfinkel. "Hackers Are the Real Obstacle for Self-Driving Vehicles." technologyreview.com, accessed September 2017. https://www.technologyreview.com/s/608618/hackers-are-the-real-obstacle-for-self-driving-vehicles/.


Dissemination
Lab 01//Collision Techtonics
Development Session 03-B
Protocol Development Session
Evasive maneuver protocols for Trials T-8A, T-8B, T-9A, T-10A, T10-B
Virtual Facade
Lab 01+ Lab 07
Consultation Session 04-B
Collision Tectonics consults with Road Semantics to discuss signage confusion.
Trial T-14B Road Signification and Semantics
Development of sensor protocol for advertisement deferral.
Virtual Facade
Lab 01+ Lab 07
Consultation Session 04-B
Collision Tectonics consults with Silhouette Confusion.
Trial T-10B Rear Quarter Panel
Development of Rear Quarter with embedded, flush sensor
Virtual Facade
Lab 01//Collision Tectonics
Discussion Session 06-D
Nonconforming Pedestrian behavior Trial P-08
Pedestrian doesn't adhere to normal pedestrian conventions. Does not yield during "Don't Walk" sign.
Signage
Vehicle 01-
Front Quarter Panel, Trial 08-B
Vehicle 02-C
Lab 01//Collision Techtonics
Discussion Session 07-A
Passenger location registration via. seat belt indicators.
Passenger location to determine autonomous vehicle evasive maneuver protocol.
Lab to catalogue recommended seating arrangements for variant vehicle occupancy.
Lab 01//Collis
Discussion Ses
Car body asses
transitional p
semi- and full
Lab testing co
characteristic
rear windshiel
Signage
Observation Area
Victim Documentation, Session 07


Observation Area
Distribution
House 01//Dissemination
Broadcast Session 10-A
Programming on passenger location registration via. seat belt indicators.
Catalogue produced and published on the seating arrangements for variant vehicle occupancy.
See Discussion Session 07-A
Observation Area
Vehicle Repair/Storage
Lab 01//Collision Tectonics
Discussion Session 07-A
Passenger location registration via. seat belt indicators.
Passenger location to determine autonomous vehicle evasive maneuver protocol.
Lab to catalogue recommended seating arrangements for variant vehicle occupancy.
Coding/Programming/Development
Lab 01//Collision Tectonics
Discussion Session 07-A
Passenger location registration via. seat belt indicators.
Passenger location to determine autonomous vehicle evasive maneuver protocol.
Lab to catalogue recommended seating arrangements for variant vehicle occupancy.
Virtual Facade
Lab 01+Lab 04
Consultation Session 02-A
Collision Tectonics produces demonstration with Lab 04 (Collision Ethics).
Protocols explored to minimize life lost and vehicle damage.
Front-facing Passenger Seat, Session 07-A
US9062977B2
Qualcomm Inc.
Filed: July 09, 2014
Published: June 23, 2015
G01C21/20 Graphical Processing Unit for performing navigational calculations
US9062977B2
Toyota Motor Engineering and Manufacturing Inc.
Filed: July 09, 2014
Published: June 23, 2015
G01C21/20 Instruments for assessing road conditions
Accident Review
Lab 01//Collision Tectonics
Discussion Session 08-B
Left-biased accident Evasion Protocol Trial T-04
Parallel passenger arrangement
Outcome: Damage to right-front crumple zone
Dashboard/Steering Wheel, Session 02-A
Lab 01//Collision Tectonics
Accident Review 02-B, 03-A
Car body without dashboard or steering wheel.
Car swerved to side without passenger load impacting/damaging front quarter panel. Vehicle not totaled, repairs mostly cosmetic. Impact Velocity, 45 km/h.
Vehicle Trial
Lab 01//Collision Tectonics
Discussion Session 02-B
Conress on dashboard and steering wheel removal.
Lab recommends passenger reorientation from forward facing to inward facing orientation.
Signage
Signage
Lab 01//Collision Tectonics
Test Vehicle Repair Logged
Vehicle 1A, right-front crumple zone repaired and/or replaced.
Damage by collision to indicated area.
Lab 01 recommends increased elasticity.
Lab 01//Collision Tectonics
Trial Observation 08-B
Trial T-04
Passenger location determined for autonomous vehicle evasive maneuver protocol.
Lab mandates parallel seating for two-passenger transit.
Observation Area

affairs such as mad cow disease or nuclear waste disposal.[23] Hybrid forums bring together a collective of experts, including industry and technology stakeholders and politicians, with non-experts to discuss technical solutions. In the case of driverless vehicles, the range of stakeholders that need to come together to discuss issues associated with their implementation include citizens and experts in different fields such as robotics, deep learning, cybersecurity, insurance, law, ethics, infrastructure, technology; the traditional automotive industry; and politicians. Hybrid forums allow for collective experimentation and learning in the face of the uncertainties and inequities engendered by the techno-sciences. Hybrid forums, as apparatuses of elucidation, facilitate a process of discussion, in which what counts as expertise and who counts as an expert are examined. Hybrid forums do not just include the knowledge of a plurality of actors independent of their institutional credentials, but are also spaces in which the identity of actors is open to negotiations and hybridization. As such, hybrid forums are spaces in which expertise emerges as a collective achievement.

Driverless cars do not fit in with the previous twentieth century vehicular agreements. Every time a major disruptive mobility technology has appeared, a new agreement has been set. We can see this in the initial International Convention on Motor Traffic in Paris (1909), the three United Nations Conventions on Traffic (Paris 1926, Geneva 1949, and Vienna 1968), the Chicago Convention on International Civic Aviation (1944), and the London Convention on Facilitation of International Maritime Traffic (1965).

The Vienna Convention on Road Traffic and the Vienna Convention on Road Signs and Signals set clear precedents on global mobility agreements.[24] The meeting's main purpose was to facilitate international road traffic and to increase road safety. The Vienna Convention on Traffic focused on traffic rules, and different parties agreed upon uniform traffic jurisdiction. One of the most controversial areas from the treaty affecting driverless technologies takes root in the given definition of driver: "any person who drives a motor vehicle or other vehicle (including a cycle), or who guides cattle, singly or in herds, or flocks, or draught, pack or saddle animals on a road."[25] In 2014, an important amendment was put in force to allow drivers to take their hands off the wheel. However, a driver was still required to be present and able to take the wheel at any time, thus keeping the human element in the equation.[26]

The Vienna Convention on Road Signs and Signals focused on the standardization of road signs and signals. All road signs were structured in seven categories, where each class was attributed specific and uniform shapes, sizes, and colors. Road marking specifications were also standardized; these set the geometry, color, and possible word content. The convention also determined traffic lights' colors and meanings, and set their location and purpose. All of these agreements were based on human perception. With the arrival of driverless vehicles, the agreements need to be renegotiated to accommodate both human and non-human sensing. Different items such as roads signs and traffic lights will eventually disappear as driverless cars gain the ability to safely navigate

23 Hybrid forums are analyzed by Callon, Barthe, and Lascoumes's "Acting in an Uncertain World." They show how hybrid forums have proven successful in dealing with different controversial topics. (Michel Callon, Yannick Barthe, and Pierre Lascoumes. "Acting in an Uncertain World: An Essay on Technical Democracy." Cambridge, MA: MIT University Press, 2011.

24 The Vienna Convention on Road Traffic and The Vienna Convention on Road Signs and Signals were signed in 1968 and have been effective since 1978. Despite recent amendments in Vienna Convention treaties, the legislation does not reflect the current status of our environment. ("United Nations. Treaty Collection: XI. B-19. Transport and Communications—Convention on Road Traffic." United Nations. accessed June 2017. https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XI-B-19&chapter=11&Temp=mtdsg3&clang=_en).

25 United Nations. "Chapter 1, Article 1." in Vienna Convention on Road Traffic. accessed October 2017. Vienna, 1968. https://www.unece.org/fileadmin/DAM/trans/conventn/crt1968e.pdf.

26 This requirement caused several controversies in the USA. OTTO (a self-driving truck company currently integrated in Uber) released a commercial video of their truck circulating around Nevada without a driver behind the wheel. As part of this conversation, the U.S. Transportation Department is studying plans to exempt up to 100,000 autonomous vehicles from current safety standards, which were written based on the assumption that a human driver was responsible for the car's operation at all times. (Mark Harris. "How OTTO defied Nevada and Scored a $680 Million Payout from Uber." *Wired*. accessed July 2017. https://www.wired.com/2016/11/how-otto-defied-nevada-and-scored-a-680-million-payout-from-uber/.; David Shepardson. "U.S. Congress plans self-driving car legislation to speed rollout." Reuters. accessed July 2017. https://www.reuters.com/article/us-usa-selfdriving-idUSKBN18X2W4).

the roads. However, road markings will be particularly important as they provide critical information that allows the car to navigate. Currently the visual crispness of lane markers varies dramatically from place to place and presents itself as the perfect case study for the required homogenization of streetscapes. It is also indicative of the type of light infrastructural changes required in the immediate future for driverless cars.[27]

The idea of forming a universal traffic agreement is not new. Nevertheless, one of the biggest challenges of the Vienna Convention is the fact that significant players such as the US, the UK, and China were never signatories of the treaty.[28] The proposed global agreement requires not only diverse participation but also massive adoption.[29] Big and controversial challenges like autonomous vehicles require worldwide consensus.[30] Other significant topics that are reaching universal agreement, such as the Paris Agreement, show that this is possible.

If the format for discussion is the hybrid forum, the diplomatic precedent is the Paris Climate Agreement. The Paris Agreement sets a clear precedent of successful forms of diplomacy based on flexibility. Adaptability offers a way to start negotiations and build necessary confidence and willingness to find common ground.[31] As Paris has proven, while an initial agreement is important, the required compromises will go beyond mere policy to expand into immediate detailed solutions. We need to imagine new and effective ways of engaging society in these types of discussions on an unprecedentedly large scale.

Postscript

Every generation has its own technological myths. They rarely play out as smoothly as predicted and driverless cars will be no exception.[32] Self-driving technologies require deep discussion in order understand their cultural construction, technical operation, and societal impact. This paper is by no means an answer. It rather aims to open up the conversation beyond the seductive allure of technological evolution.[33]

27 Hod Lipson and Melba Kurman. Driverless. Intelligent Cars and the Road Ahead. Cambridge, MA: MIT University Press, 2011).

28 The USA's and Europe's last agreement on traffic dates from the 1949 Geneva Convention. The Vienna Convention replaced Geneva as most of the signatories joined Vienna agreements, but the United States was never part of it. (Bryant Walker Smith. "Automated Vehicles Are Probably Legal in the United States." The Center for Internet and Society at Stanford Law School. accessed July 2017. http://cyberlaw.stanford.edu/publications/automated-vehicles-are-probably-legal-united-states).

29 Trump announced in June 2017 that the USA would withdraw from the Paris Climate Agreement. This could threaten the world's ability to solve the global climate crisis in time. (Michael Shear. "D. Trump Will Withdraw U.S. From Paris Climate Agreement." *The New York Times*. accessed July 2017. https://www.nytimes.com/2017/06/01/climate/trump-paris-climate-agreement.html?mcubz=0).

30 A big policy effort has been carried out since 2011 in different states in the USA and during the last of couple of years in Europe and Asia to introduce driverless cars into the equation. On September 2016, the U.S. Department of Transportation issued federal policy for automated vehicles. This first document was a performance guide for automated vehicles and also a model policy for individual states to follow. A national self-driving vehicle legislation to replace the implemented state-by-state rules is currently in progress. In 2016 European Transport ministers committed to support and facilitate all forms of self-driving vehicles in the "Amsterdam Declaration." They stated the common objective to regulate intelligent traffic throughout the EU by the year 2019. In 2017 Germany was the first European country to pass a self-driving law. (Darrel West. "Moving forward: Self-driving vehicles in China, Europe, Japan, Korea, and the United States." Washington: The Brookings Institution, 2016.; "Germany adopts self-driving vehicles law." *Reuters*. accessed July 2017. https://www.reuters.com/article/us-usa-selfdriving-idUSKBN18X2W4).

31 The Paris Agreement continues the approach that guided the creation of the effective system for international coordination of trade policy though the General Agreement on Tariffs and Trade (GATT), currently the World Trade Organization (WTO). Trade diplomacy began in the 1940s with simple, self-enforcing agreements that aligned with national concerns; through continuous rounds of compromises, those national policies were moved forward and integrated. Easier problems were tackled first, building confidence that made it possible to tackle harder diplomatic challenges. The Paris Agreement moves the world in this direction. (David Victor. "Why Paris Worked: A Different Approach to Climate Diplomacy." Yale Environment 360. accessed June 2017. http://e360.yale.edu/features/why_paris_worked_a_different_approach_to_climate_diplomacy).

32 James Bridle critically analyzes the relation between Technology and Society in different articles such as "The New Aesthetic and its Politics" or "Failing to distinguish between a tractor trailer and the bright white sky." We can position some of the critiques to driverless cars in his thesis as many of them come from a weak technology literacy that show a popular failure to fully engage with technology. (James Bridle. "The New Aesthetic and its Politics." *Booktow*. accessed January 2018. http://booktwo.org/notebook/new-aesthetic-politics/).

33 Alex Williams and Nick Srnicek in their controversial new manifesto express a propositive, while unresolved, alternative for today's left. Against the politics of localism, direct action, and relentless horizontalism, they favor the modernity of abstraction, complexity, globalism, and technology. They seek to maintain the gains of late capitalism while going further than its value system, governance structures, and mass pathologies currently allow. (Alex William and Nick Srnicek "Accelerate Manifesto for an Accelerationist Politics." *Critical Thinking*. accessed January 2018. http://criticallegalthinking.com/2013/05/14/accelerate-manifesto-for-an-accelerationist-politics/).

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