FIVE AI

Autonomous Driving: European play

11 October 2018

¶ EU28 only, excluding freight
˜ European Commission Apr 2018

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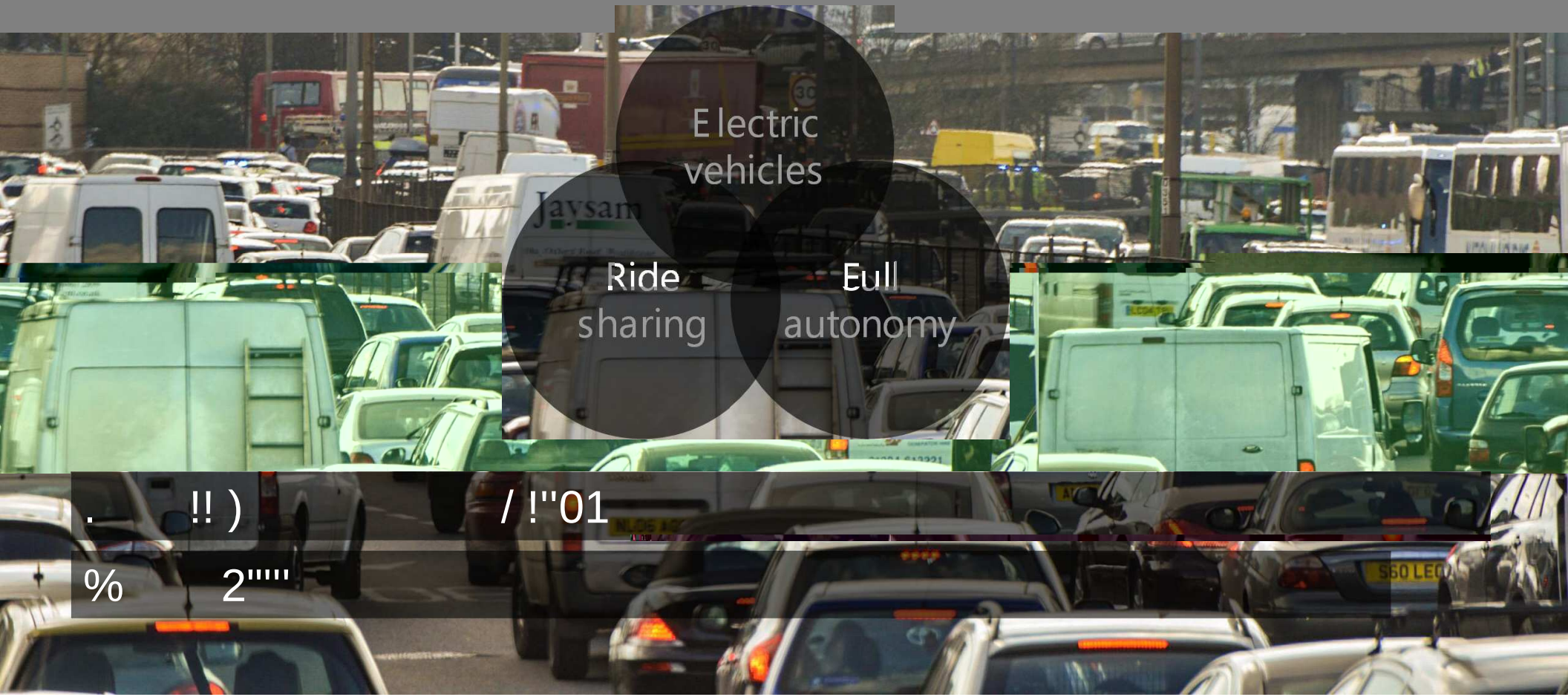
This 100 year-old business model has become unsustainable

& -



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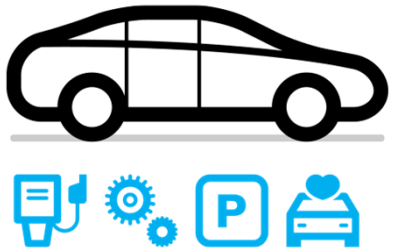
Develop and train safe autonomous driving for European cities

Operate a fleet of AVs to deliver demand-responsive mobility services to consumers

The economics are obvious



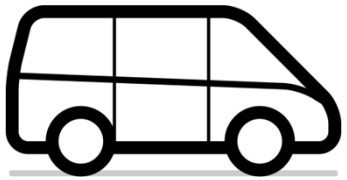
$19,000

$1,436 pa

Private car

Cost $1.06 per mile§

$35,000



$50,000

$20,000 pa

Shared AV

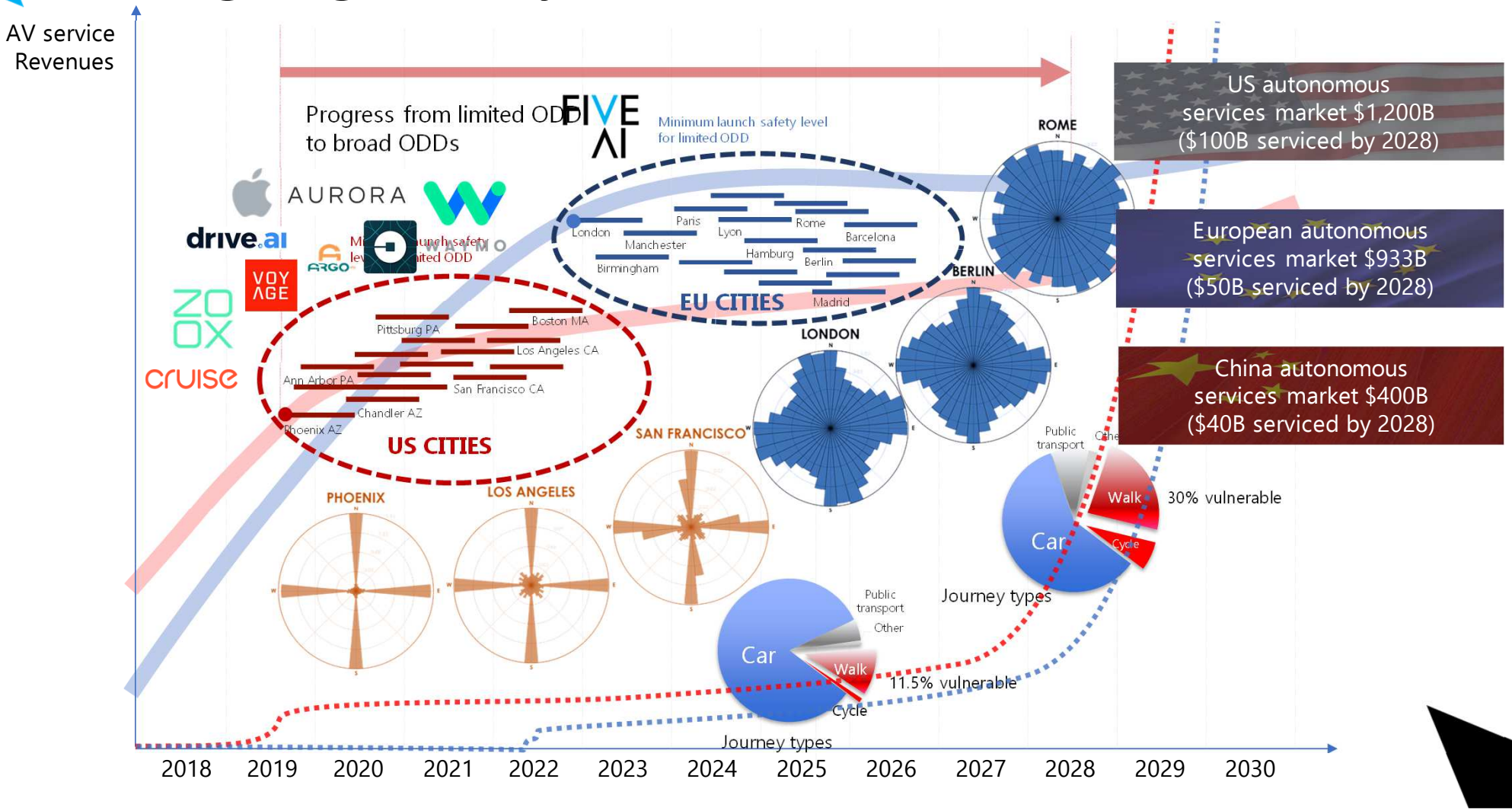
Cost $0.15 per seat mile¶

§ 230 hours/year @ 1.5 seat occupancy

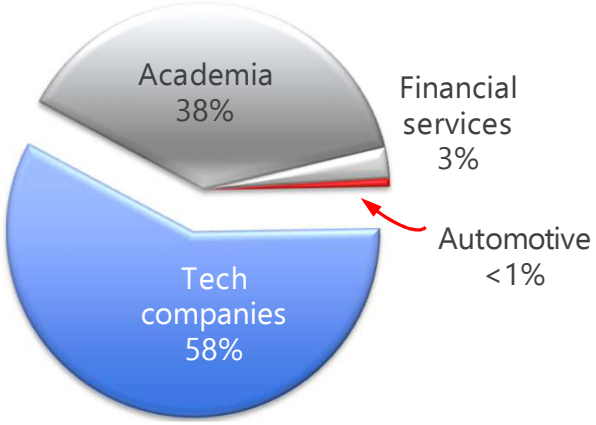
¶ 12 hours operation, 330 days/year

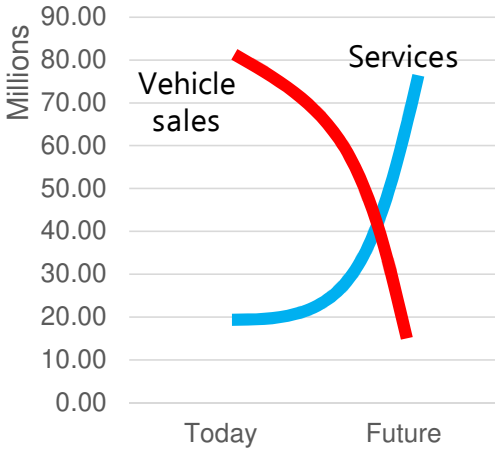
The complicated question is “when are we going to see safe AVs on Europe’s streets”?

Strong regionality of the market



Difficult for OE Ms





European PhDs join tech……

Academic talent in ML and CV wants to work in tech companies or stay in academia§

it's hard to disrupt……

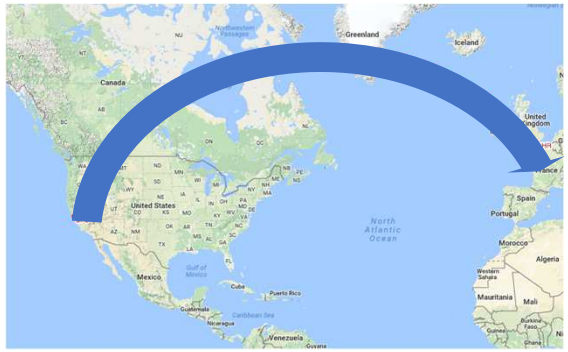
Incredibly hard to justify cannibalizing their own successful $1.6 trillion industry

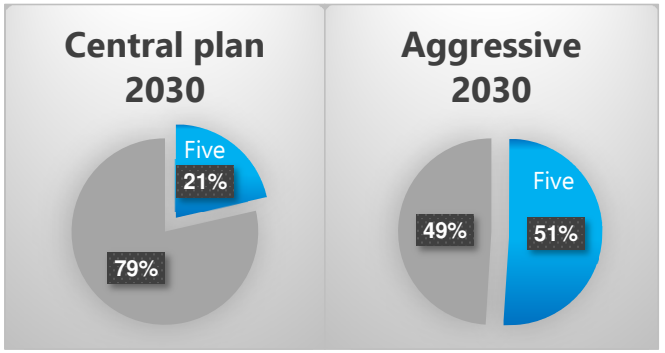
series production pressure

Engineering focus on L2-L3 autonomous features to sell to car buyers

§ 148 PhD graduates from 3 top schools Oxford, Cambridge & Imperial
Supervised by Ghahramani, Torr, Zisserman, Davison and Newman

Difficult for US competitors





Heavy 6,000 mile trips……

Local teams need to be significantly sized; payback is much higher on US markets

plus barriers to entry……..

City and national governments will positively prefer European city stakeholders to build and deliver services

means a huge space left for us

We expect to be the largest player in Europe, our market share is investment-dependent

The opportunity is clear

How E urope and why **Five**?

Notable ML/CV science leaders

Early life	Name	Entities	Citations
EU	Geoff Hinton	Toronto/Google	238,448
US	Jtendra Malik	UC Berkeley	145,127
EU	Andrew Zisserman	Oxford/Google	141,985
CA	Yoshua Bengio	Montreal	129,066
EU	Sebastian Thrun	Stanford/Udacity	91,184
EU	Luc van Gool	Leuven/Toyota	91,109
EU	Yann LeCun	NYU/FAIR	80,611
EU	Cordelia Schmid	INRIA	80,526
EU	Andrew Blake	Turing/Five/Samsung	49,712
US	Ross Girshick	UC Berkeley/FAIR	44,898
EU	Zoubin Gharahmanni	Cambridge/Uber	43,129
EU	Andrew Fitzgibbon	Microsoft	29,149
EU	Philip Torr	Oxford/Five	28,599
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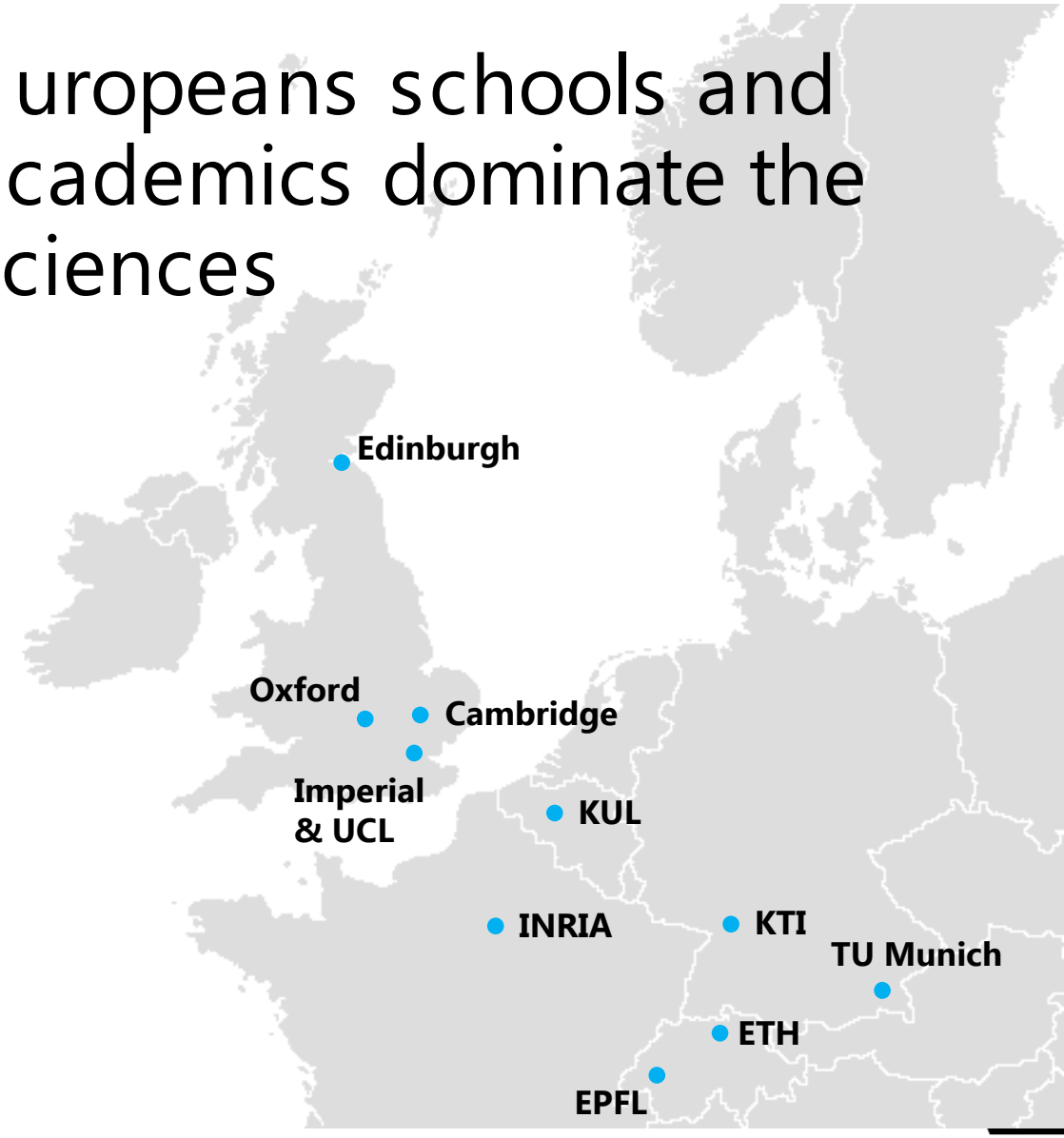
EU	Daniel Cremers	TU Munich	23,382
US	Kai Wang	UCSD/Zoox	23,366
EU	Josef Sivic	Czech TU	22,827
EU	Andrew Davison	Imperial/Dyson	19,905
EU	David Silver	UCL/DeepMind	16,202
EU	Paul Newman	Oxford/Oxbotica	15,780
CA	Raquel Urtasan	Toronto/Uber	14,127
US	Drew Bagnell	CMU/Aurora	11,506
US	Dave Ferguson	Stanford/Nuro	9,075
EU	Vlad Minh	UCL/DeepMind	8,435
EU	James Philbin	Oxford/Zoox	8,306
EU	Andreas Geiger	MPI/Tubigen	8,113
EU	Vladen Koltun	Berkeley/Intel	7,997
US	Janxiong Xiao	Princeton/AutoX	7,909
US	Sergey Levine	US Berkeley/Google	6,417
US	Dmitor Dolgov	Stanford/Waymo	3,808
US	Chris Urmson	Stanford/Aurora	3,087
EU	Stuart Golodetz	Oxford/Five	2,916
US	Jesse Levinson	CMU/Zoox	2,867
EU	Sadeep Jayasumana	Oxford/Five	2,563
EU	Alex Kendall	Cambridge/Wayve	2,110
EU	Ingmar Posner	Oxford/Oxbotica	1,426

Europeans schools and academics dominate the sciences



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UDACITY

FIVE AI

ZOOX

AURORA

NURO

ZOOX

AutoX

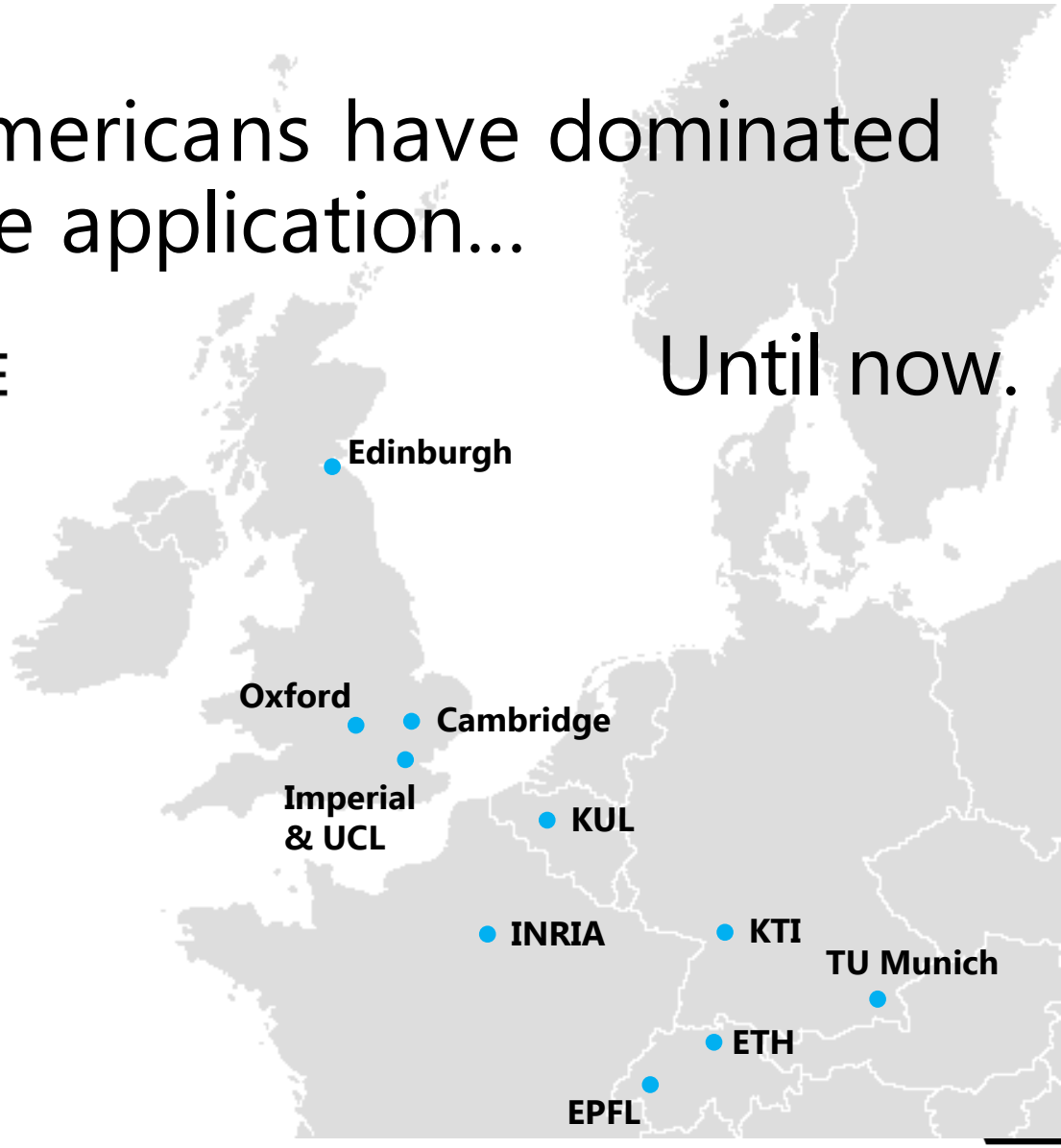
WAYMO

AURORA

ZOOX

Americans have dominated the application…

Until now.



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Our founders

Stan Boland, CEO

Physicist who's founded, led and built three semiconductor & communications tech startups already (bought by Broadcom, NVIDIA and Huawei for >$1 billion). Once ran a public company. Was a Board member of ARM.

Ben Peters, VP Product

Engineer who's led product lines in automotive semiconductor technology with industry leader NXP in Hamburg and successfully refocused startup internet of things business then bought by Huawei.

John Redford, Chief Architect

Mathematician who's been CTO at industry pioneer Acorn, co-founded a semiconductor and communications business bought by Broadcom for $640M and is a multi-disciplinary expert in imaging, embedded systems and microprocessors.

Simon Walker, VP AV Engineering

Engineer with a PhD in cryptography who's led research teams at Nokia and TeliaSonera before joining a startup bought by NVIDIA for $430M where he developed algorithms for cellular modems that seriously out-performed Qualcomm.

Our scientific advisors

Professor Philip Torr
University of Oxford
Chief Scientific Advisor

Computer vision god who's built Europe's largest research group in computer vision, based at the **University of Oxford**. Cited over 28,000 times, his research interests span visual geometry**,** scene understanding, tracking, simulation, verification. Awarded Five AI Chair at University of Oxford in Computer Vision in 2018 by the Royal Academy of Engineering.

Professor Andrew Blake
Scientific Advisor

Computer vision godfather and a pioneer at **Oxford** before leading Microsoft's Research group in **Cambridge**, which produced the Kinect. Andrew was appointed the founding director of the **Alan Turing Institute**, the UK's centre for artificial intelligence research, and led all of its research work. He is cited over 49,000 times.

Professor Alessio Lomuscio
Scientific Advisor

Verification god who's professor in logic for multi-agent systems at **Imperial College London**. Alessio is an expert on model checking for multi-agent systems and is a significant contributor to DARPA's assured autonomy program

Professor John McDermid
Scientific Advisor

Safety god who's professor of software engineering at the **University of York** where he founded the High Integrity Systems Engineering group (HISE). John is Europe's foremost authority on safety assurance with respect to high-integrity systems and has worked with Bosch, Rolls-Royce, Siemens, NASA and many others.

Our policy advisor

Leon Daniels

Managing Director for surface transport at **Transport for London** for over 6 years until end-2017, responsible for all policy and operations of bus, urban rail, cycling, taxis, private hire and boats servicing over 14 million Londoners. In this role, he both granted and later rescinded Uber's license to operate. He has worked for both Conservative party and Labour party mayors. Highly respected across all government departments and a great pragmatist, Leon is recognised for his world-class experience, expertise and knowledge of public sector transport in the UK, Europe and Asia.

Our leadership

Stan Boland
CEO

Ben Peters
VP Product

John Redford
Chief Architect

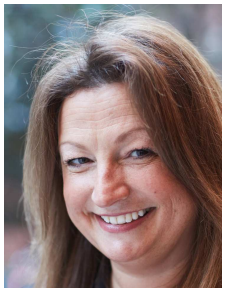
Simon Walker PhD
VP AV Engineering

Subramanian Ramamoorthy PhD
VP Prediction & Motion Planning

Computer Scientist, Bangalore.
PhD from **UT Austin**.
Joined from University of **Edinburgh**.
Research leadership record in robotics.

John Lusty
VP Simulation

Computer Scientist, Cambridge.
Joined from **Facebook** (Oculus VR) where he built London team to >40.
Career in AAA games development, including **Square Enix** where he led global tech team of 120+.



Michelle Coventry
VP People

Engineer, Loughborough.
Joined from **Kindred Capi**tal where she built amazing teams across tech space.

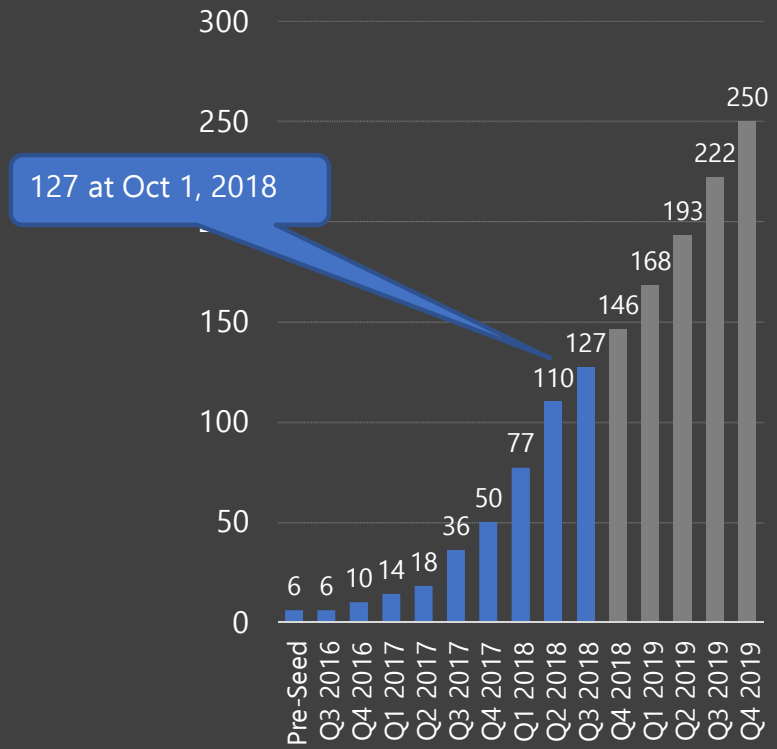
Laura Brown
VP Finance

Zoologist, Bristol.
Previously Financial Controller at **Icera** Inc., and before that **KPMG**.

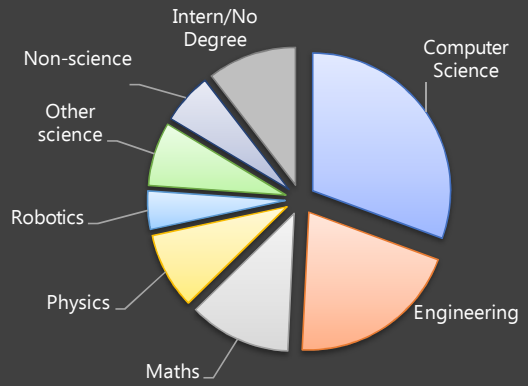
Claire Bennett
General Counsel

Physicist, Cambridge.
Joined from partner role at **DLA Piper**
Career in intellectual property at **Bird & Bird** and DLA Piper.

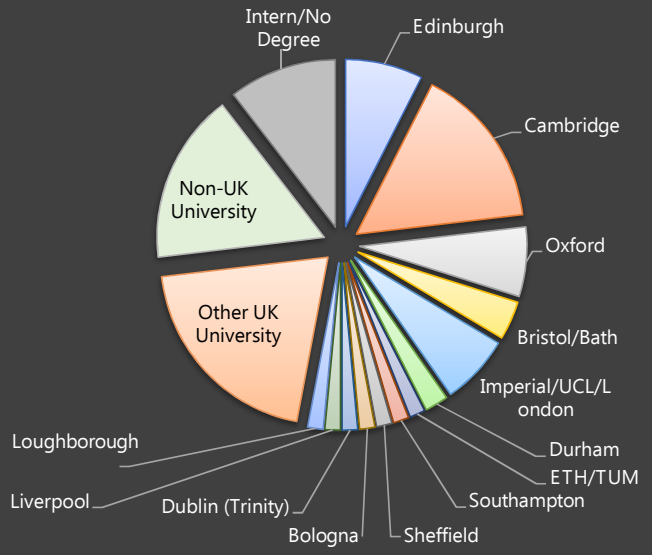
Our team



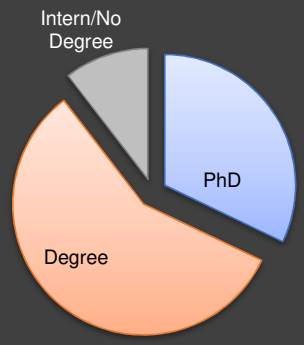
Multi-disciplinary



from European & global top schools



including 32% with PhDs



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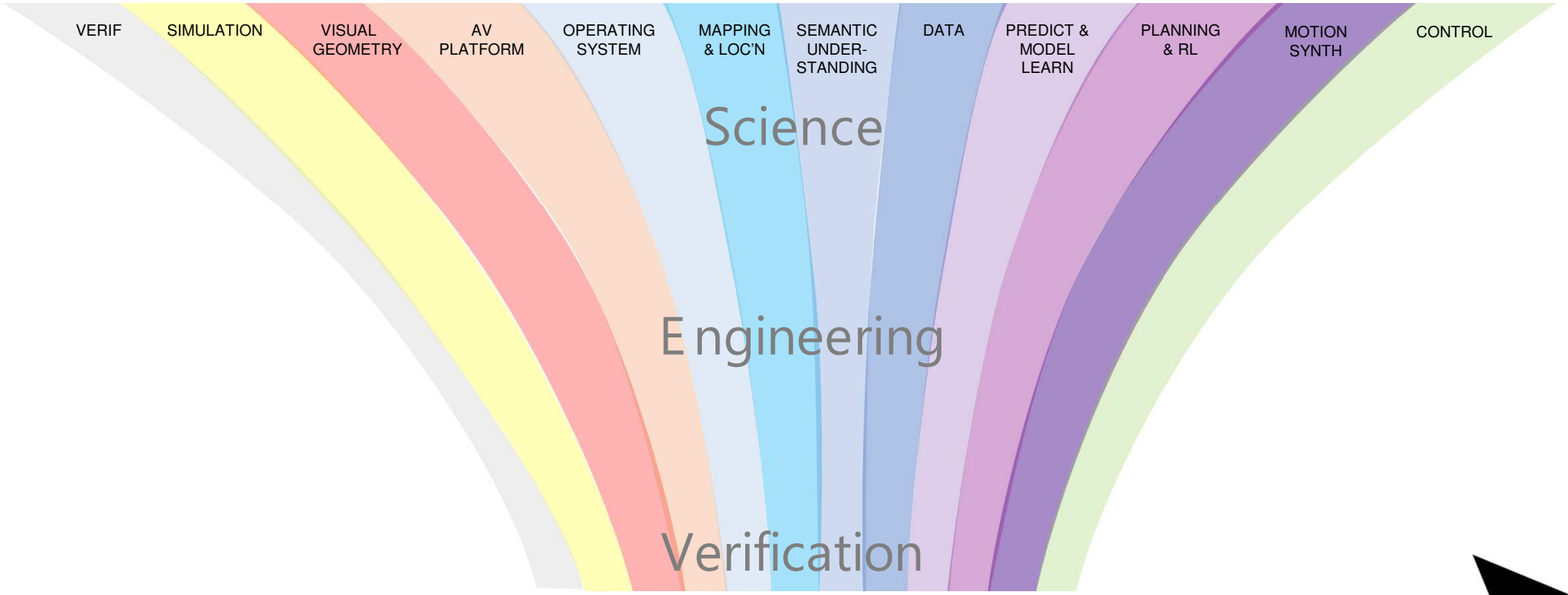
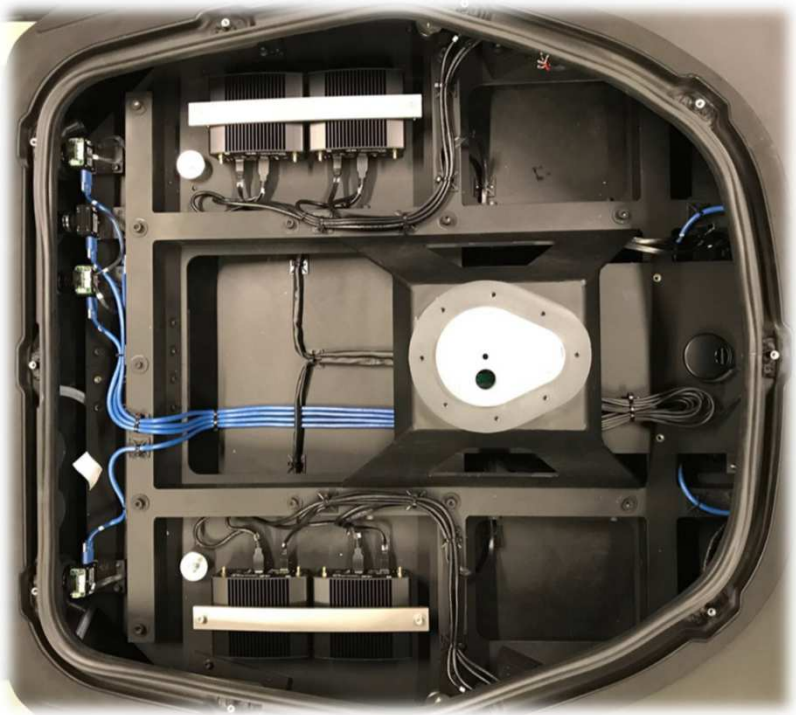
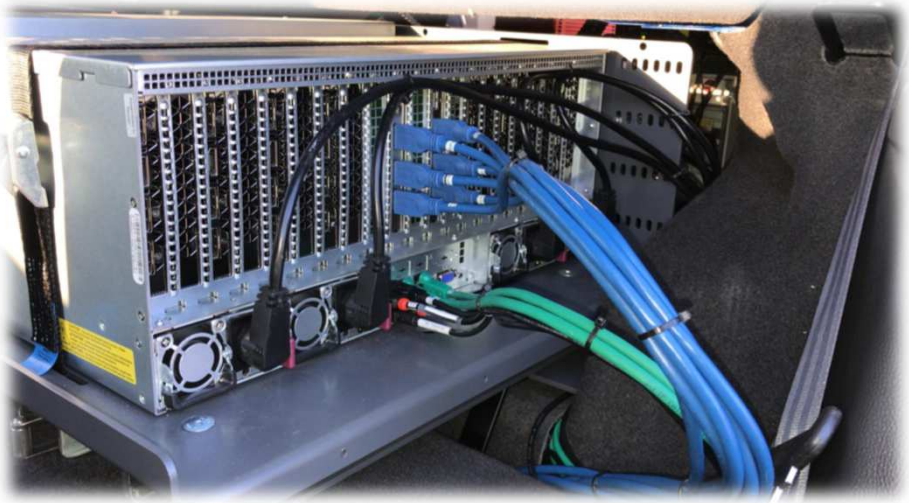
It’s all about verifiable safety

It's a broad and deep challenge

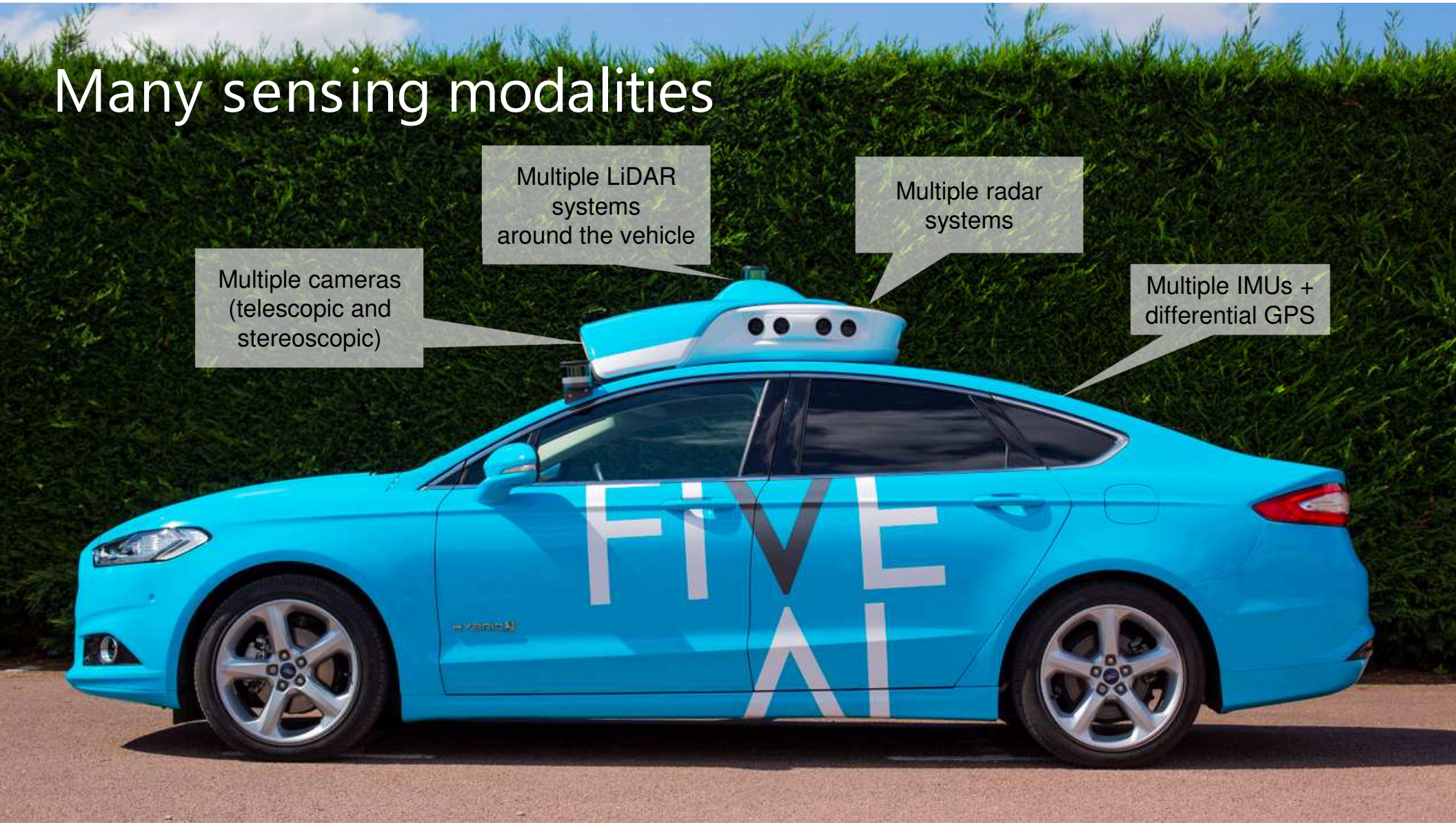


Current development platform

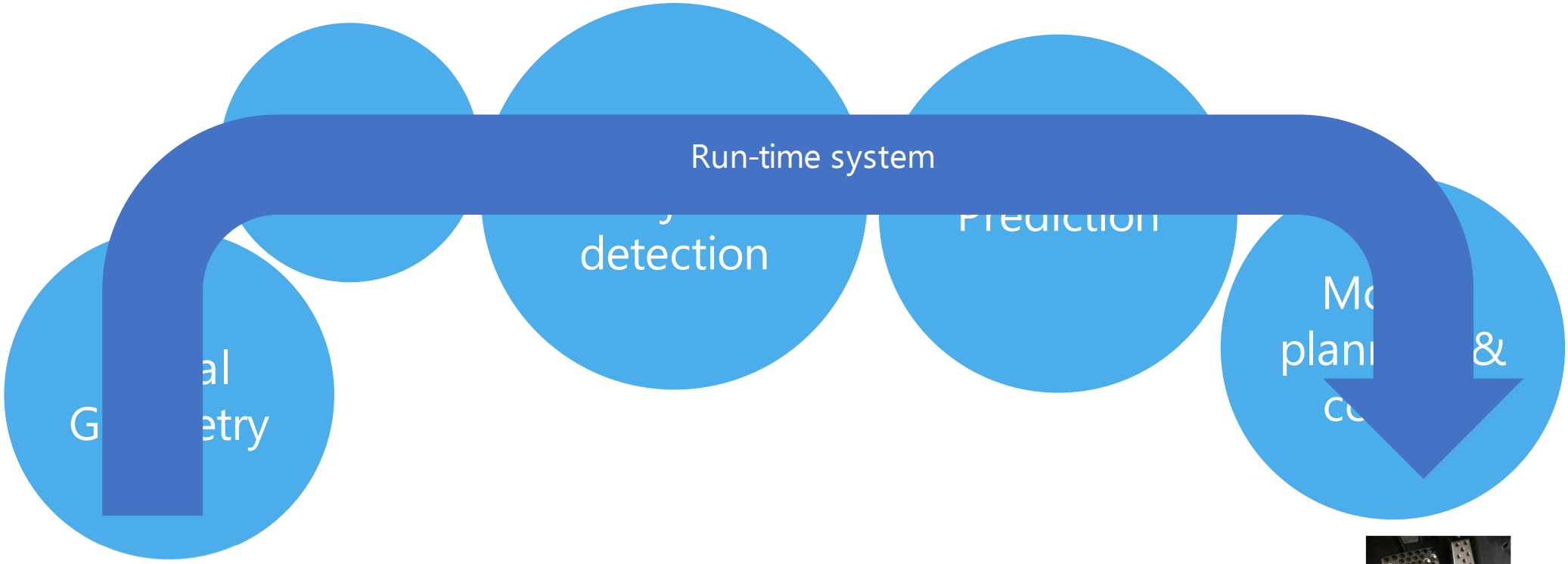




Many sensing modalities



Modular system



25 sensors (& increasing)

Vehicle controls

Dense real-time 3D reconstruction

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Offline domain analysis

Localization

Scene and object detection

Hierarchical segmentation

Prediction

Motion planning & control

Visual Geometry

Domain analysis

25 sensors (& increasing)

Vehicle controls

Access to 1,300 CCTV cameras across London

Here we find behavioral exceptions in the long tail we use to build contextual libraries

Inferring beliefs and vector fields

Large scale simulation

Localization

Scene and object detection

Prediction

Motion planning & control

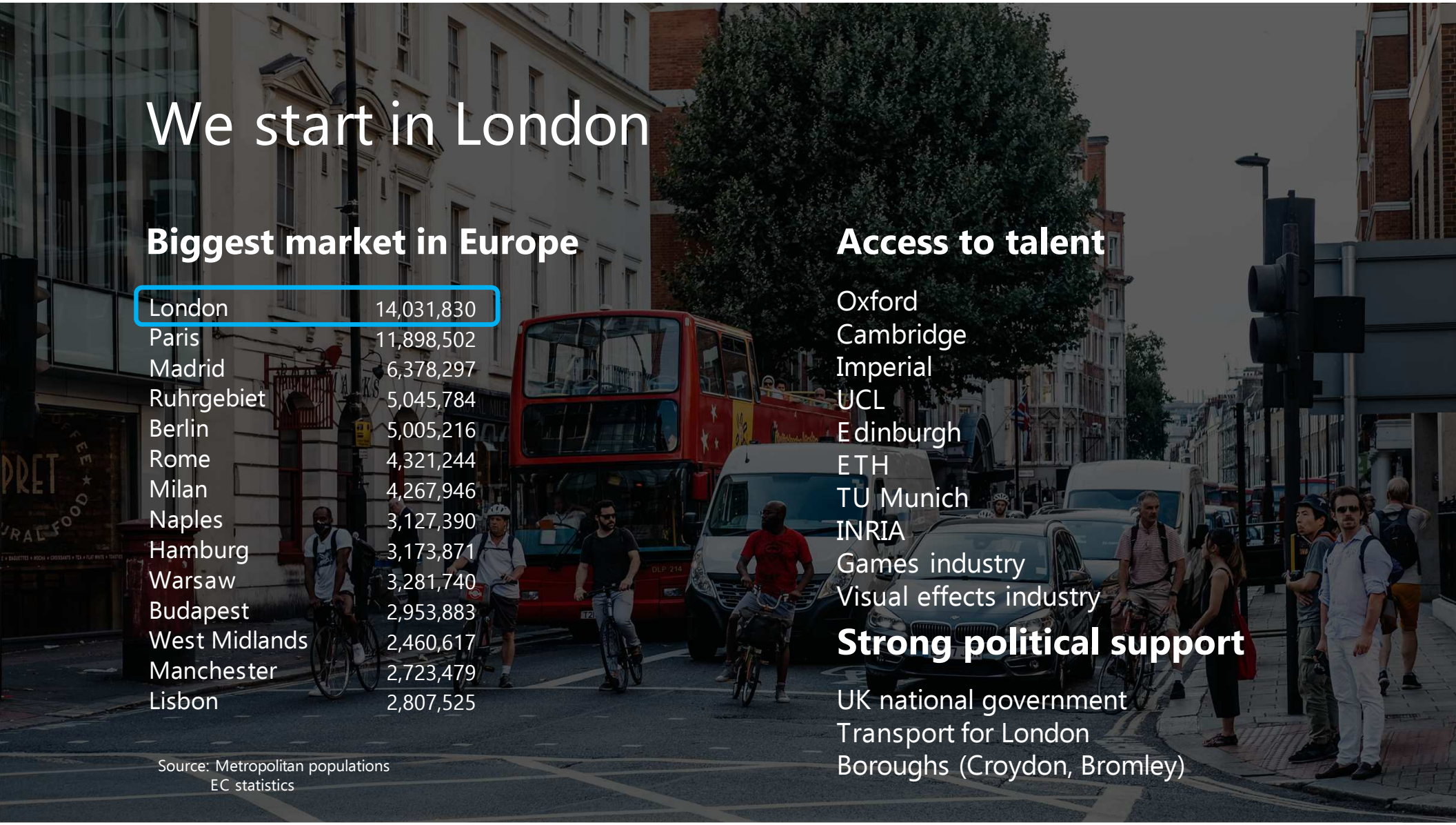
Visual Geometry

Simulation

Requirements discovery

25 sensors (& increasing)

Vehicle controls



We start in London

Biggest market in Europe

London	14,031,830
Paris	11,898,502
Madrid	6,378,297
Ruhrgebiet	5,045,784
Berlin	5,005,216
Rome	4,321,244
Milan	4,267,946
Naples	3,127,390
Hamburg	3,173,871
Warsaw	3,281,740
Budapest	2,953,883
West Midlands	2,460,617
Manchester	2,723,479
Lisbon	2,807,525

Source: Metropolitan populations
EC statistics

Access to talent

Oxford
Cambridge
Imperial
UCL
Edinburgh
ETH
TU Munich
INRIA
Games industry
Visual effects industry

Strong political support

UK national government
Transport for London
Boroughs (Croydon, Bromley)

No company is better aligned than Five

Transport for London

TfL poster Child

Only London Passenger AV project

Only CCTV camera access

Centre for Connected & Autonomous Vehicles

CCAV poster child

Biggest single grant check $15M

Department for Transport

Department for Business, Energy & Industrial Strategy

Future of Mobility

Five's CEO is one of only five steering group members for UK government's flagship "Future of Mobility" Industrial Strategy Grand Challenge

Law Commission
Reforming the law

Major contributor

Five is helping frame and draft the future legal framework for AVs in UK which in turn might influence the whole of Europe

HM Treasury

BBB poster child

Five is engaged with HM Treasury on defining future Government Innovation funding

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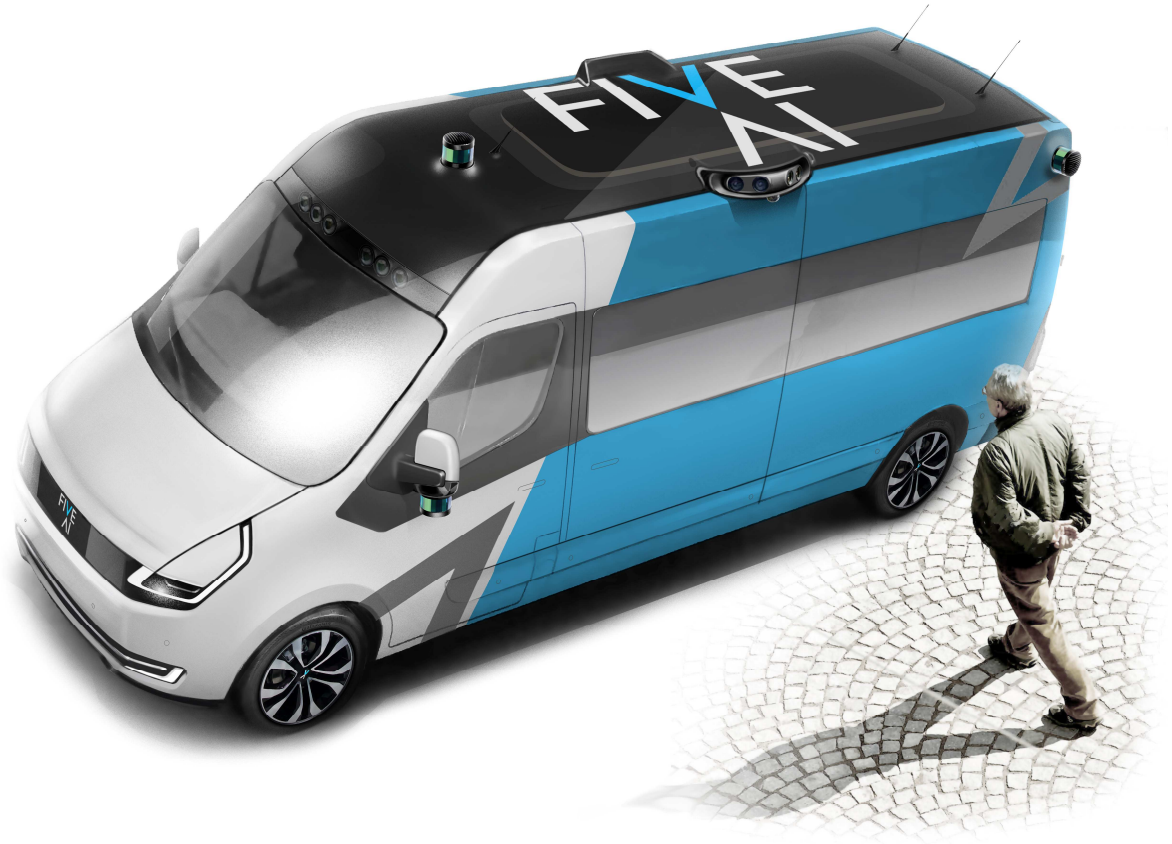
Public road testing



Only AV MaaS trial supported by Transport for London (TfL)

Supported by $15M UK government grant

Trial full-stack service in Q1 2020 with c.30 vehicles

Commercial service start mid-2022 to early 2023

STREETWISE project

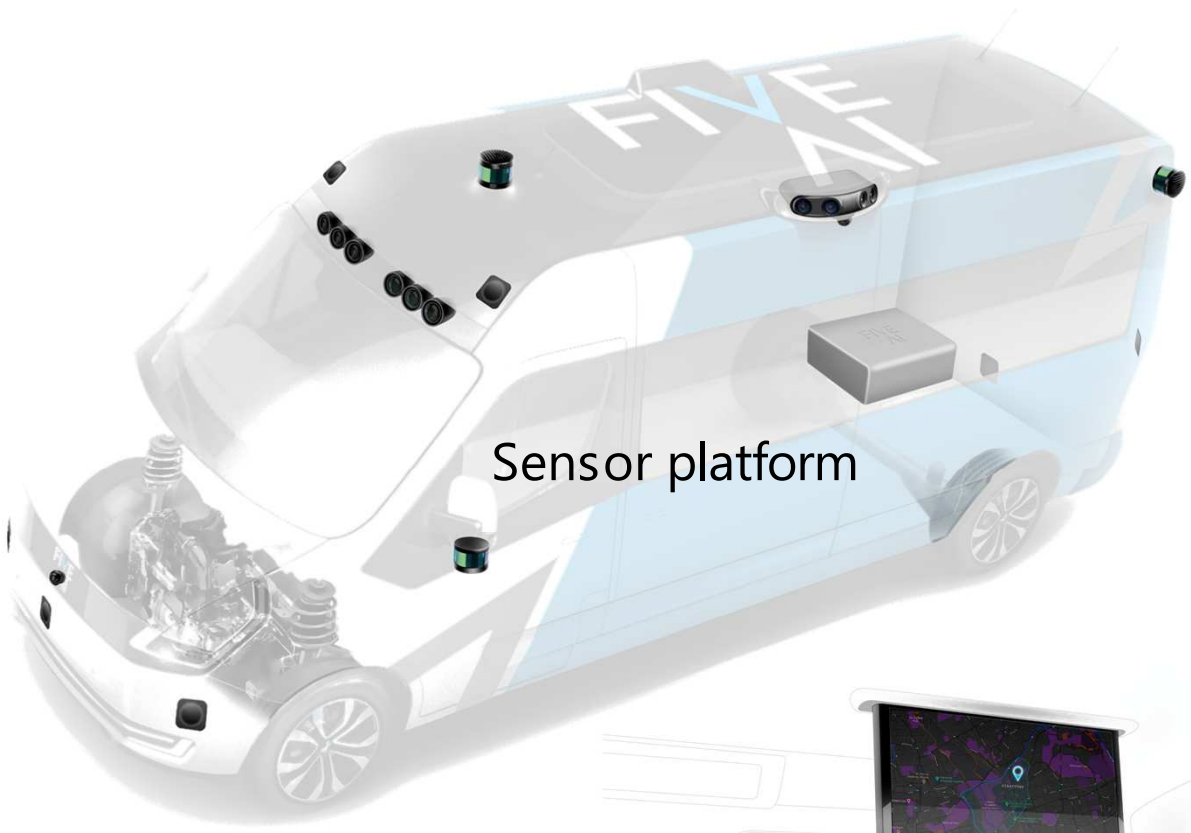
Transport for London

DirectLine Group

UNIVERSITY OF OXFORD

McLaren APPLIED TECHNOLOGIES

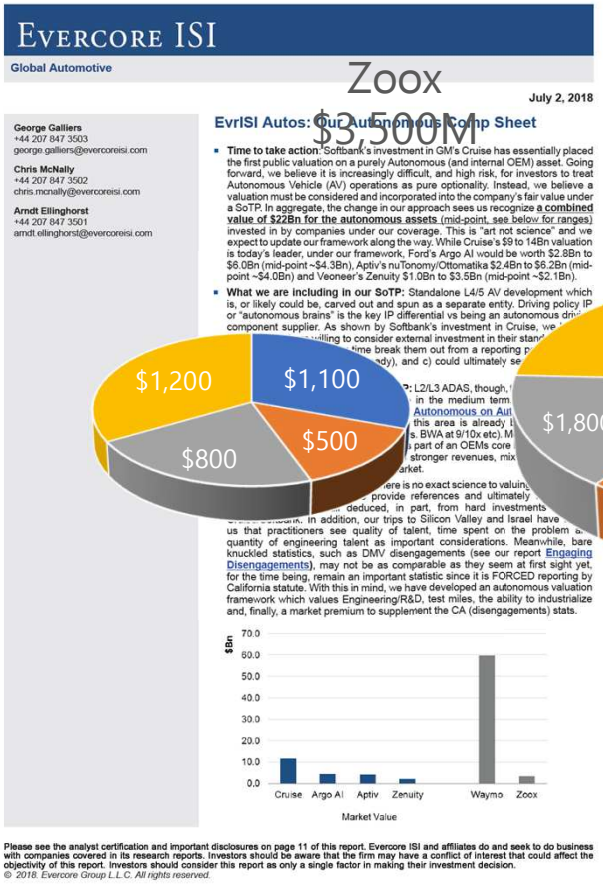
TRL



Spacious interior

Value of today's AV companies

July 2018 research



EVERCORE ISI

Global Automotive

July 2, 2018

EvrISI Autos: Our Autonomous Comp Sheet

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- **Time to take action:** Softbank's investment in GM's Cruise has essentially placed the first public valuation on a purely Autonomous (and internal OEM) asset. Going forward, we believe it is increasingly difficult, and high risk, for investors to treat Autonomous Vehicle (AV) operations as pure optionality. Instead, we believe a valuation must be considered and incorporated into the company's fair value under a SoTP. In aggregate, the change in our approach sees us recognize **a combined value of $228Bn for the autonomous assets** (mid-point, see below for ranges) invested in by companies under our coverage. This is "art not science" and we expect to update our framework along the way. While Cruise's $9 to 14Bn valuation is today's leader, under our framework, Ford's Argo AI would be worth $2.8Bn to $6.0Bn (mid-point ~$4.3Bn), Aptiv's nuTonomy/Ottomatika $2.4Bn to $6.2Bn (mid-point ~$4.0Bn) and Veoneer's Zenuity $1.0Bn to $3.5Bn (mid-point ~$2.1Bn).
- **What we are including in our SoTP:** Standalone L4/5 AV development which is, or likely could be, carved out and spun as a separate entity. Driving policy IP or "autonomous brains" is the key IP differential vs being an autonomous dri... component supplier. As shown by Softbank's investment in Cruise, we... willing to consider external investment in their stand... time break them out from a reporting p... ady), and c) could ultimately se...

...P: L2/L3 ADAS, though, ... in the medium term ... Autonomous on Aut... this area is already l... s. BWA at 9/10x etc). M... part of an OEMs core ... stronger revenues, mix ... arket.

...ere is no exact science to valuin... provide references and ultimately ... deduced, in part, from hard investments ... In addition, our trips to Silicon Valley and Israel have ... us that practitioners see quality of talent, time spent on the problem ... quantity of engineering talent as important considerations. Meanwhile, bare knuckled statistics, such as DMV disengagements (see our report Engaging Disengagements), may not be as comparable as they seem at first sight yet, for the time being, remain an important statistic since it is FORCED reporting by California statute. With this in mind, we have developed an autonomous valuation framework which values Engineering/R&D, test miles, the ability to industrialize and, finally, a market premium to supplement the CA (disengagements) stats.

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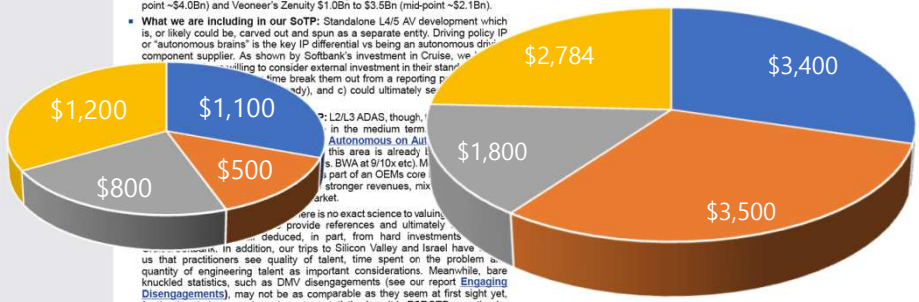
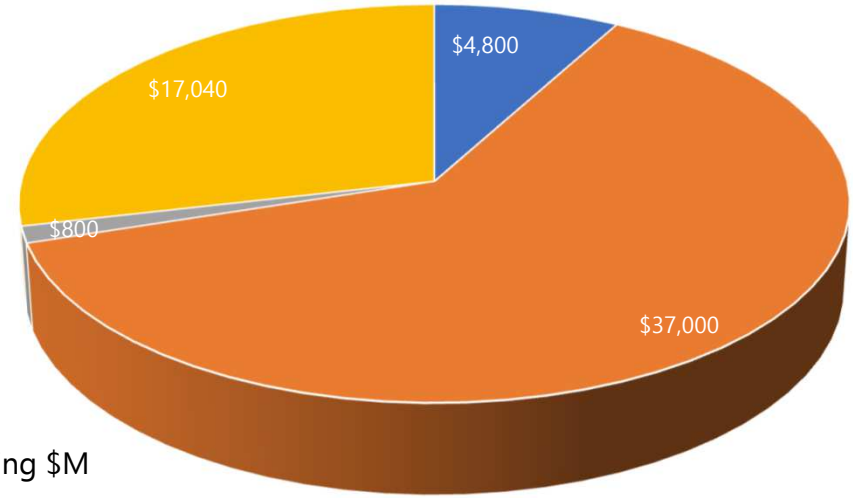
Zoox
$3,500M



Cruise
$11,500M

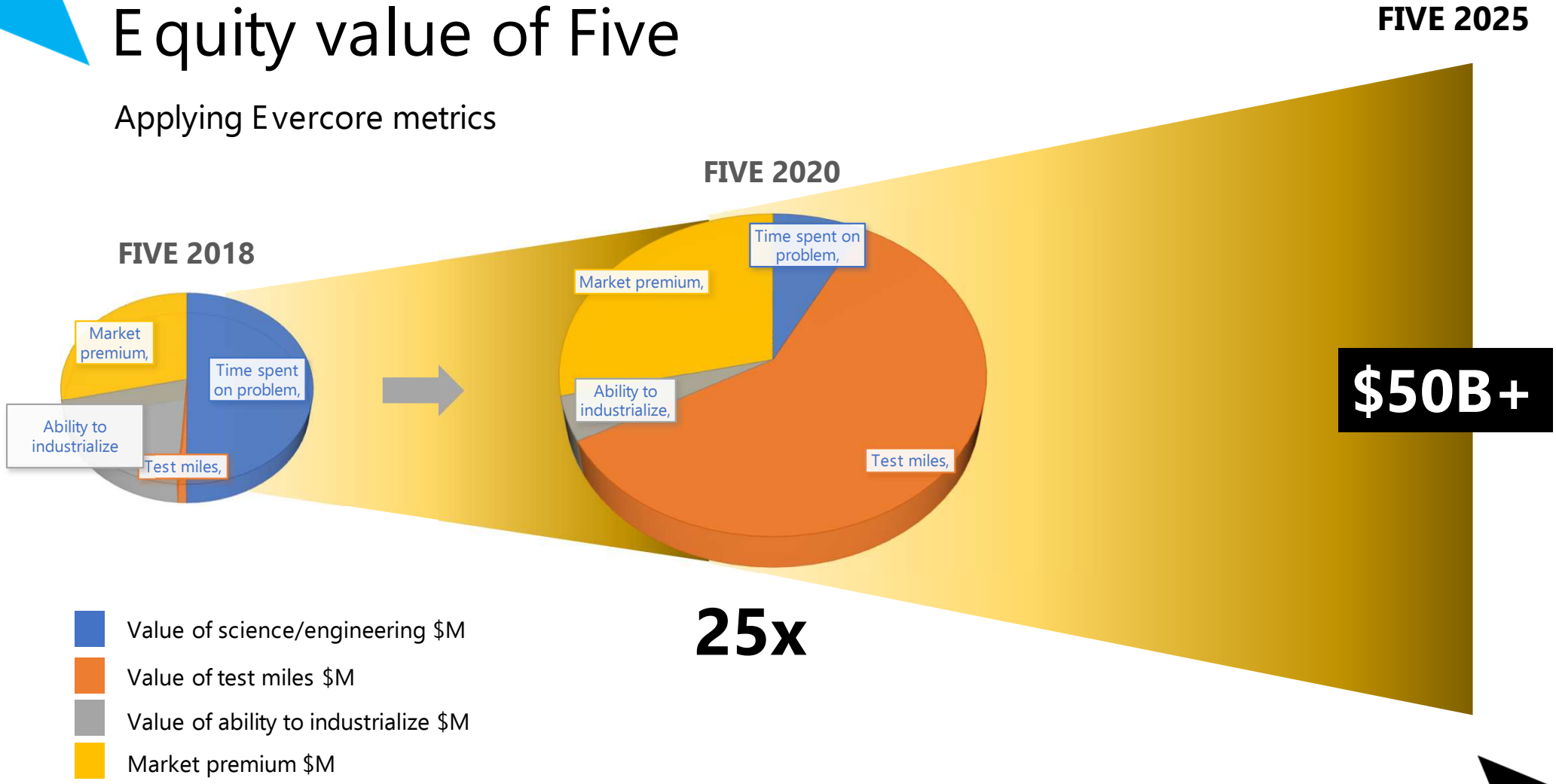
Waymo
$60,000M



- Value of science/engineering $M
- Value of test miles $M
- Value of ability to industrialize $M
- Market premium $M

Equity value of Five

Applying Evercore metrics



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Thank you

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