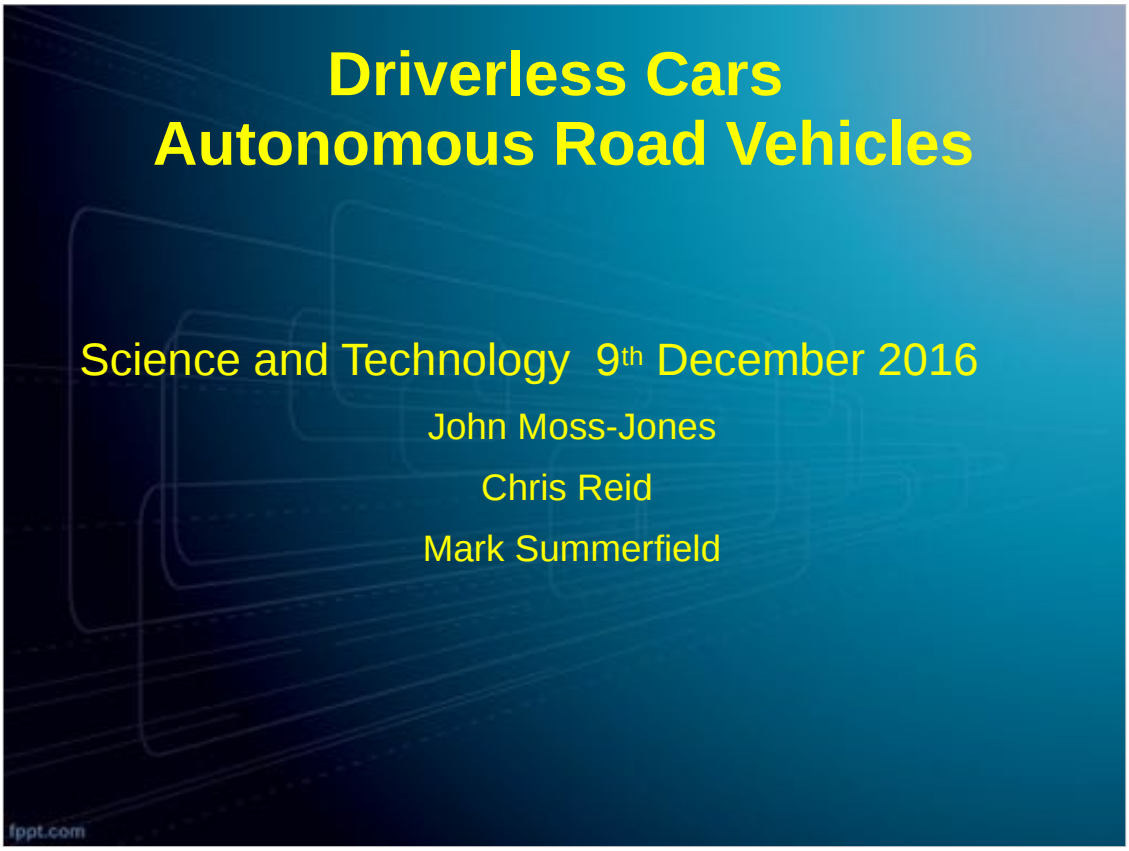


Good morning - John Chris and I are going to talk you today about driverless cars or ARVs. This is something that will affect us all so we thought it would be good to get some awareness of the topic within the group and get you slightly more involved than in the normal S&T format.

Many of you will have responded to John following the request for views on the subject and we have used these to try and make sure we include the groups thoughts as much as possible. Many of you replied in the form of questions .... please don't imagine we know all the answers!

This is an “inevitable technology”, by this I mean it is sure to be adopted - however it is early days and many aspects of how and when it will become part of our social structure are still very much unknown. However ...It will be a major change for all of us. If you are in doubt..Think back to mobile phones - another “inevitable technology”. I remember all the arguments in the early 90s..... battery won't last, too big to fit in a pocket, too heavy, they will be too expensive for everyday use, I don't want people to phone me all the time..... etc. Today there are more mobile phones than people on the earth.

Many reasons why this will be an “inevitable” change but 1.25 million people killed by “cars” every year. >90% human error – 40% involve alcohol.

ARVs are a complex subject so we have split the topic (arbitrarily) into Technical, Social and Economic aspects to make it more manageable. All of theses areas overlap and interact with each other - so don't feel constrained by our structure.

We will start with a short talk on each of the three topics areas then you will be invited to form into groups and present your groups views in a 10 minute summary.

If possible keep questions for the groups sessions – we are short of time

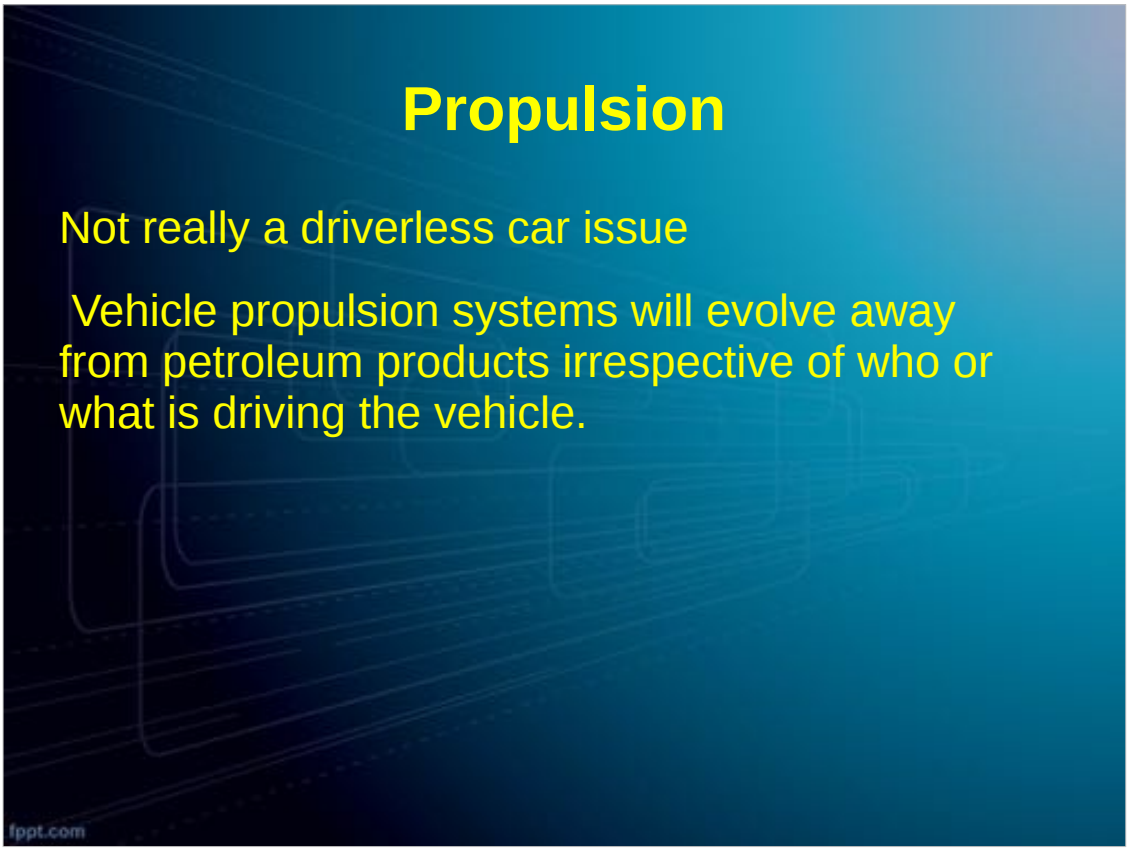
Driverless Cars
Main Technical Focus

- Propulsion
- Sensing and Range Finding
- GPS and Mapping
- Data analysis and situational understanding
- Data Networking
- Security and Reliability

At this point in the development of this technology - not all the answers are known.

This list attempts to outline the five main areas where technical development is being directed and I will cover each in a little more detail.

Six on the list but ….



**Propulsion **- I’m not really going to address this because it's not specific to ARVs.

Vehicle propulsion systems will evolve away from petroleum products irrespective of who or what is driving the vehicle.

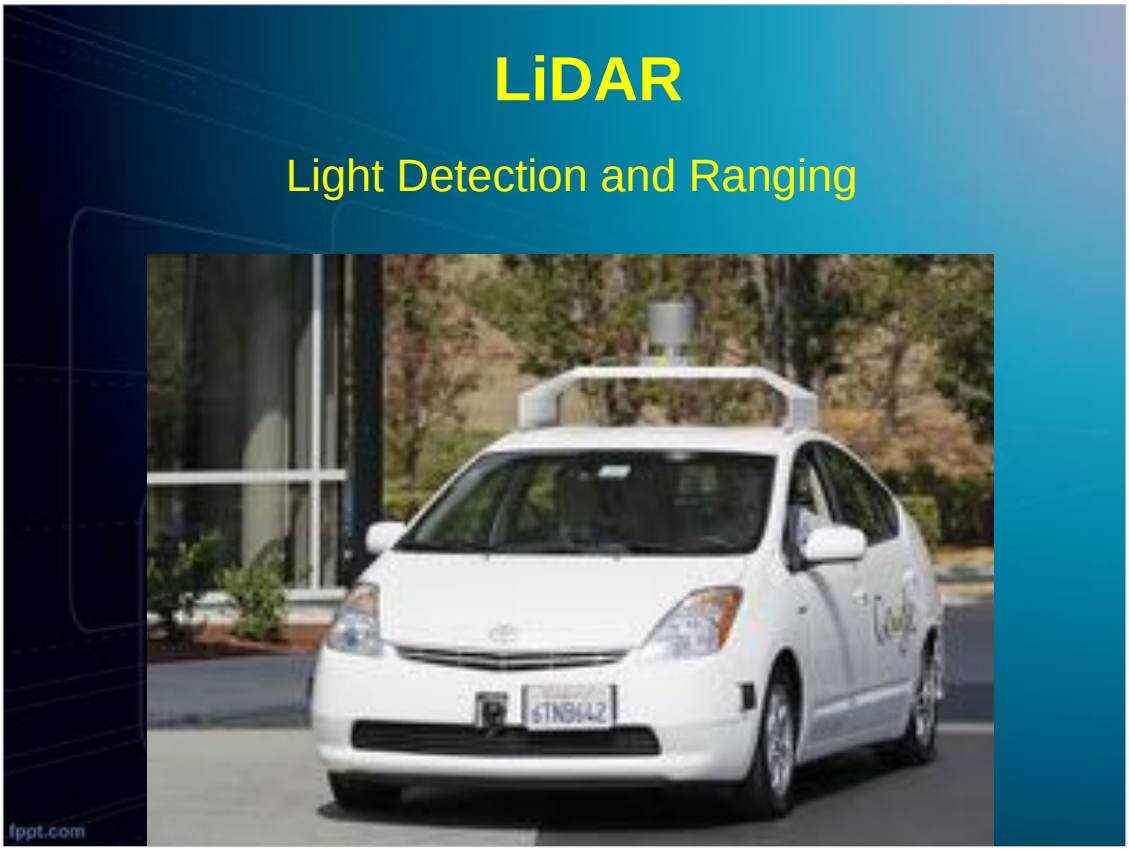
Clearly there is a move towards electric propulsion and several examples of this exist on the roads today - Nissan Leaf, Tesla, BMW, Renault etc. Hydrogen fuelled vehicles are also a possibility and will become more attractive unless the electric storage issues can be resolved.

Storage of electrical power, fast charging infrastructure and grid capacity are really the only major hurdles to ubiquitous electric vehicles.

Sensing and Range Finding

- *The means by which the vehicle senses where it is and what is around it. This can break down into a number of areas:*
- Detecting static objects such as buildings lamp posts, obstacles
- Detecting other cars, people, bicycles, dogs etc.
- Detecting the road - edges, lanes, signs, traffic lights
- This may use a combination of sensors such as Lidar, Radar, ultrasonics and cameras

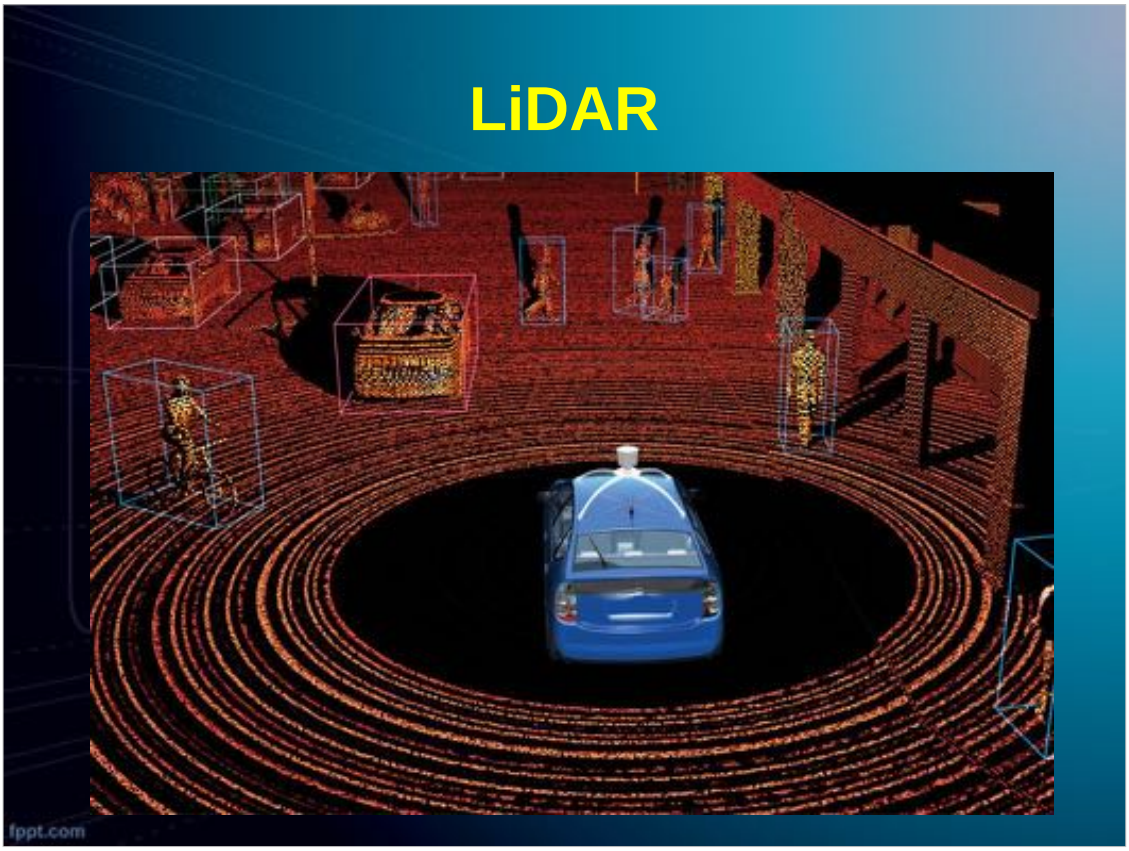
So what is LiDAR ??



LiDar uses light to measure the distance from a sensor to an object. A light beam is scanned over an area and an accurate 3d map generated using the reflected time data.

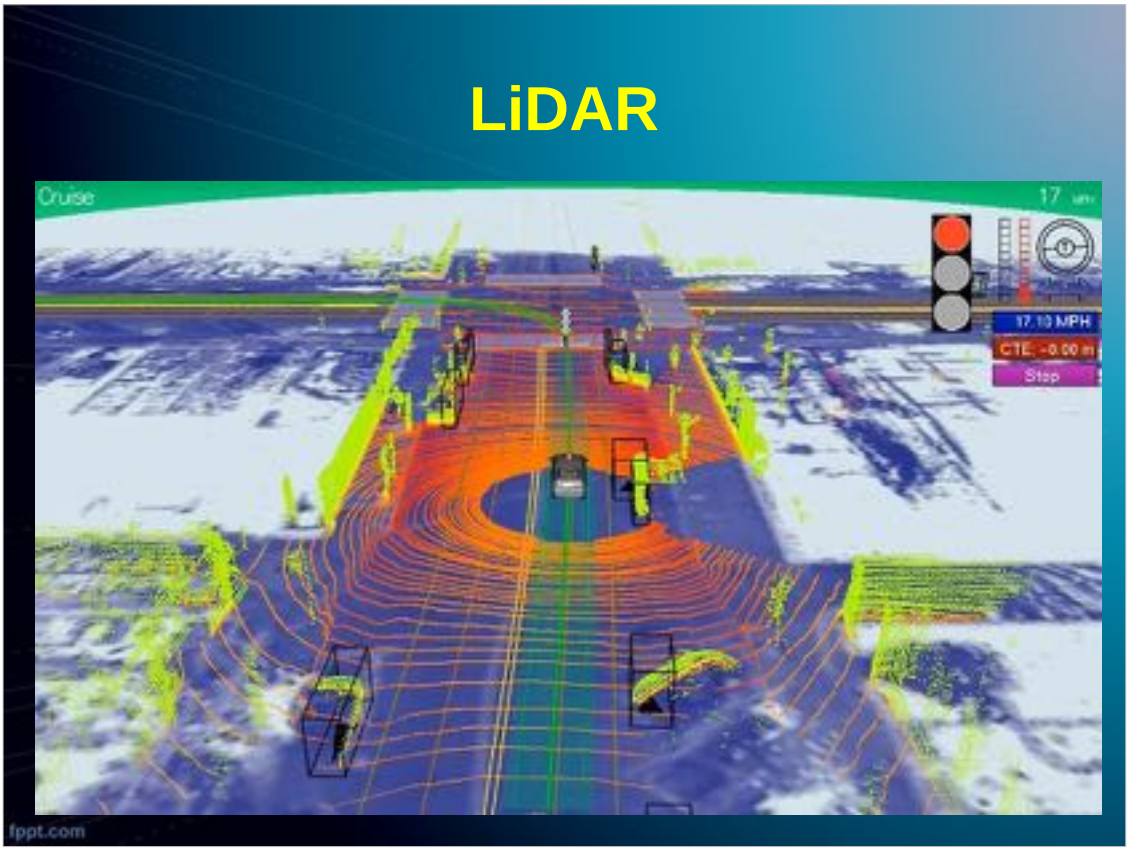
Large amounts of data are generated - typically 100k + points per second.

LiDAR

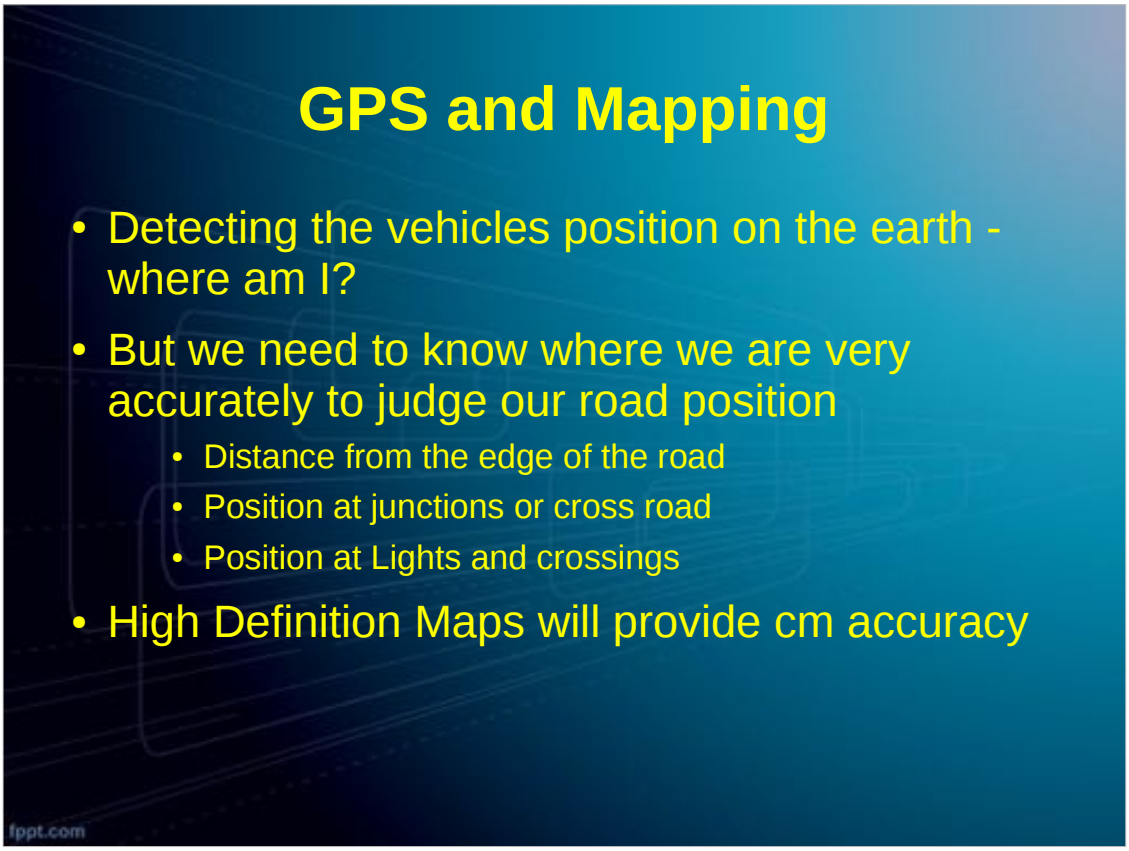


- Detects distance by reflection time (like radar)
- Car generates a 360 deg map of the objects around it.
- May have issues with fog and smoke etc like we do
- Can detect the colour of objects because different colours reflect differently
- Accurate within centimetres
- Generates large amounts of data for processing
- LiDar technology is well established for mapping – usually from aircraft. (which don’t need real time processing)

LiDAR

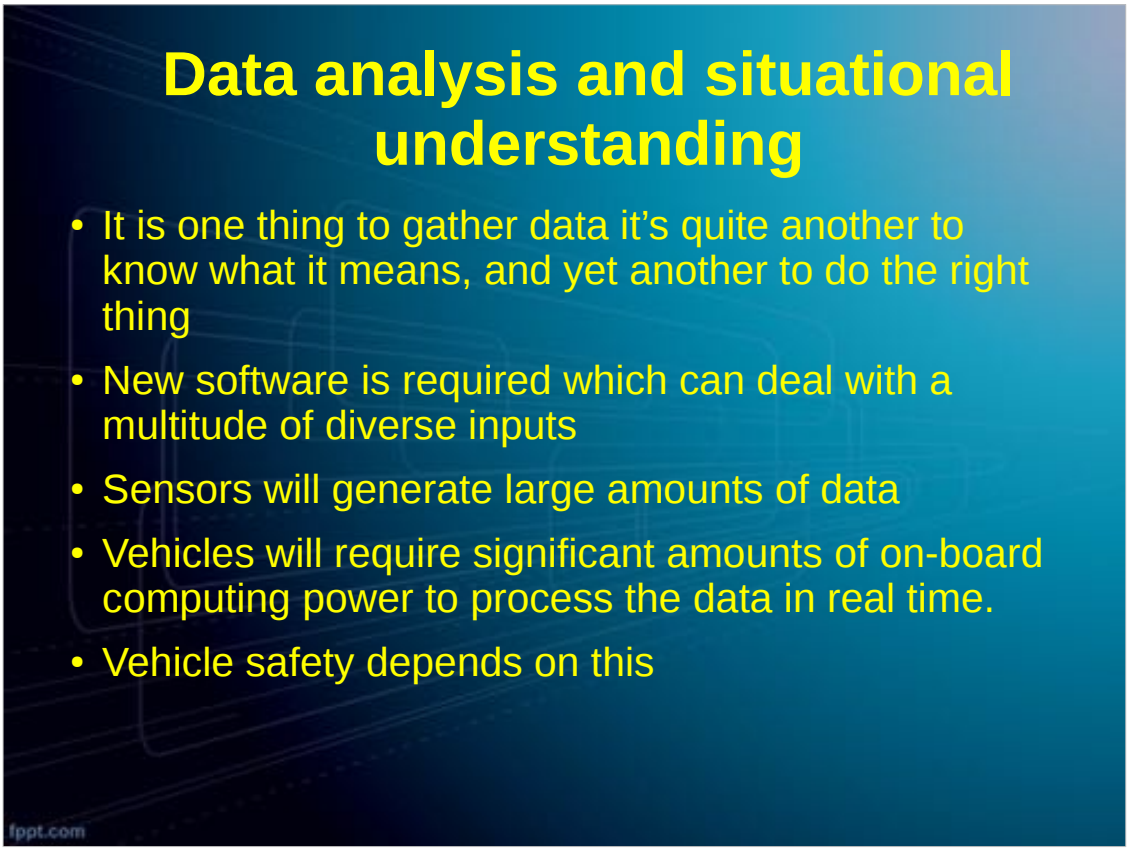


- 200m range as opposed to the average humans 50m range for object awareness
- The software will keep track of objects it detects and try to anticipate their movements



GPS technology is well established but is only accurate to within a few metres. This is fine for a rough position but not sufficient to keep a car on the correct side of the road.

- GPS needs to be supplemented with high definition mapping accurate to a few mm.
- HD maps are under development in a number of countries
- GPS will be good enough to get you roughly where you want to go but you will need HD maps and LiDAR to drop you at your front door or get you into your driveway or maybe even stay on the road.

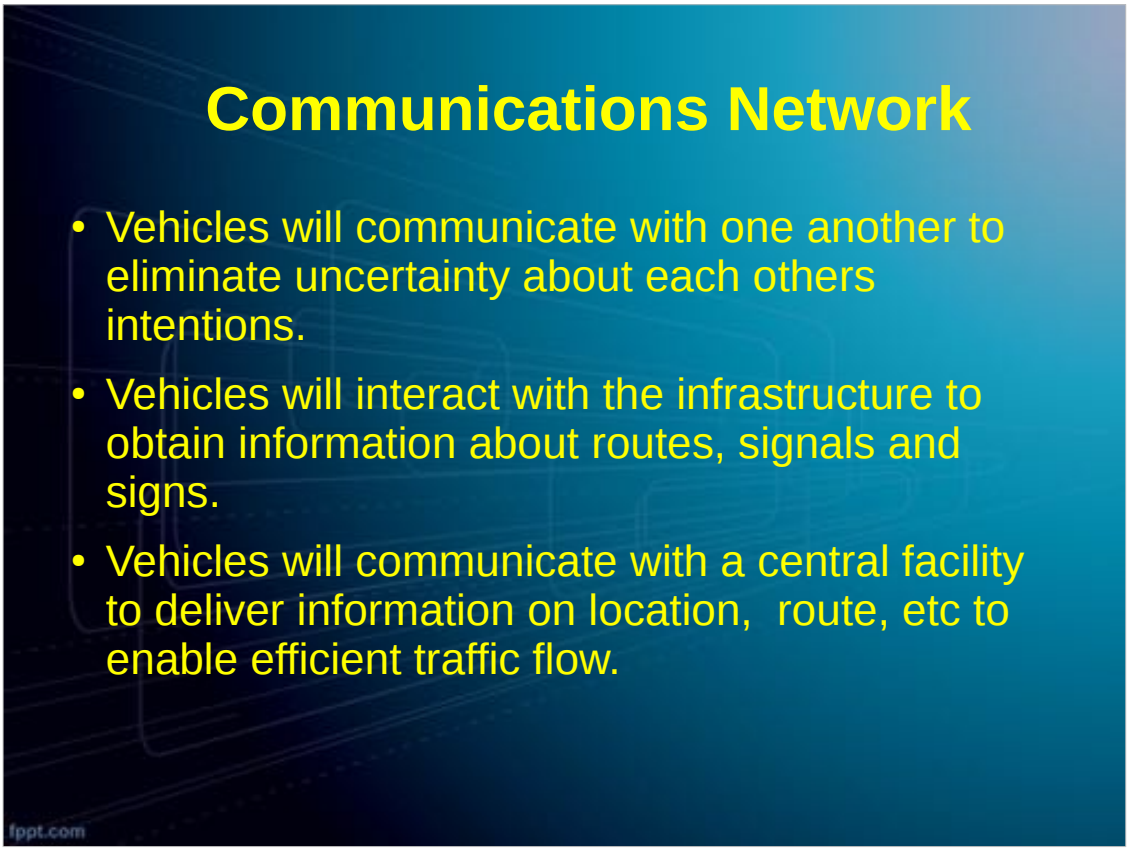


Making sense of the data- So far we have discussed the acquisition of information using LiDAR and GPS - however there is a big challenge ahead in creating software systems that can bring all this information together and direct the vehicle to behave in a sensible manner.

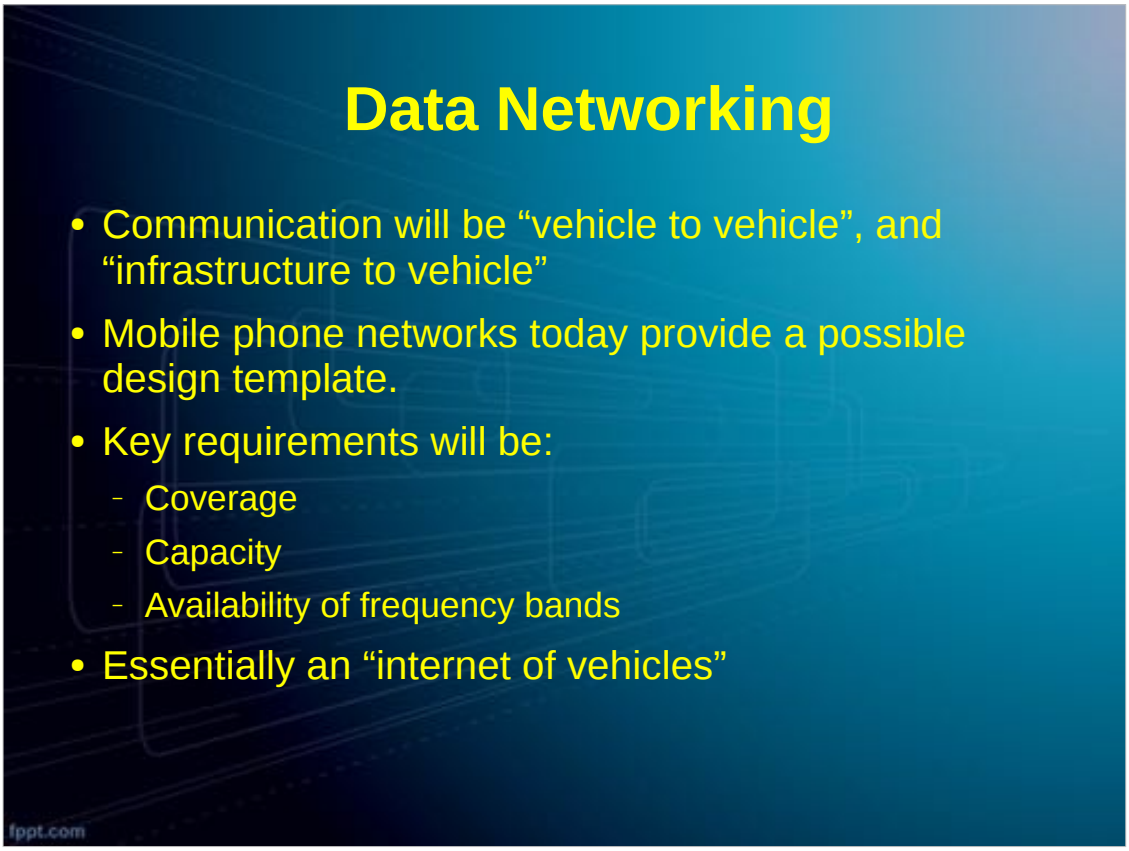
-The key thing to remember is that traditional software approaches tends to be based on programs in which a certain sensor configuration triggers a "lookup" of what to do – "if then". What is needed for ARVs is a generic approach which can deal with circumstances which have never been encountered before. ie what to do if there is an elephant on the road, or a herd of sheep. This will call for massive computer power and clever software.

-The good news is that clever software is evolving (eg Alpha go) and computers are getting smaller and faster all the time.

- Current ARVs are estimated to use the equivalent of 5 or more high performance PCs to process their data. This is likely to increase.



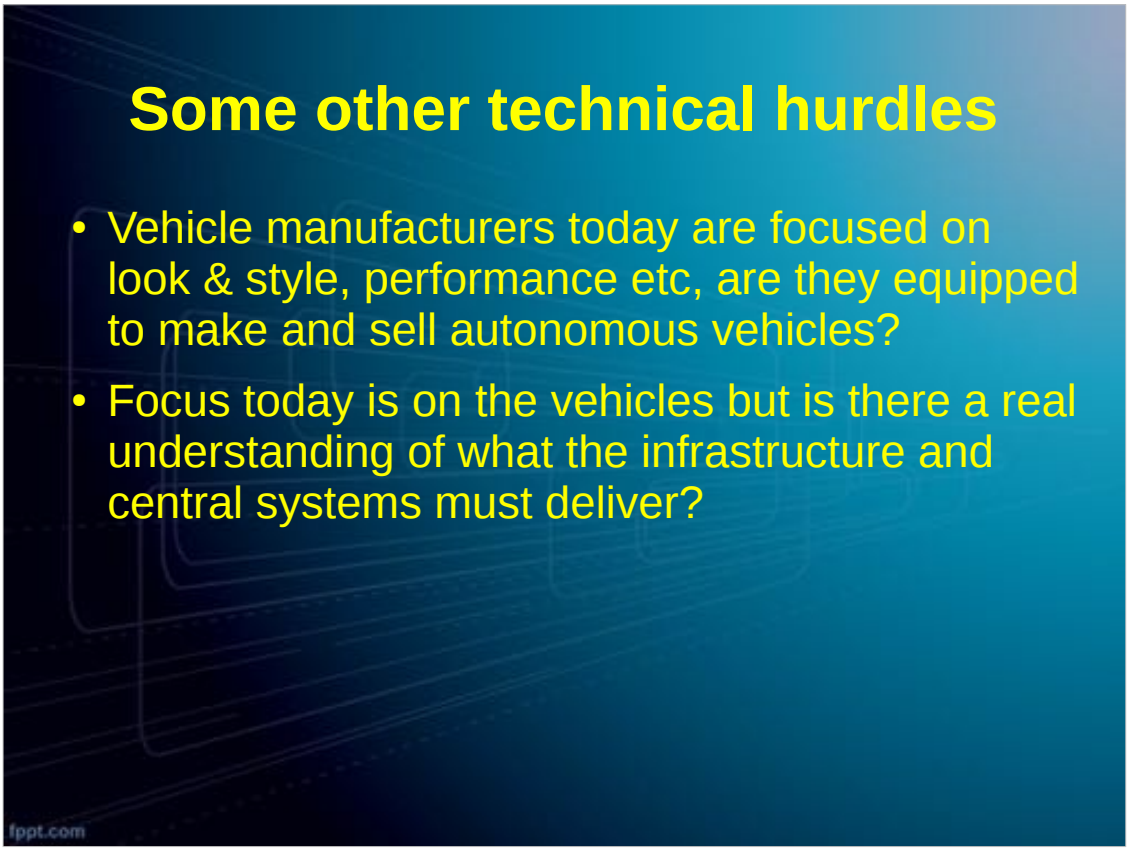
- Driving today relies on trying to guess what the other vehicles intentions and many accidents happen when we get this wrong - people behaving in an unexpected way tend to cause accidents.
- ARVs will talk to one another - not only that, they will talk to the infrastructure. So things like speed limits, traffic lights, one way streets and double yellow lines areas will all be virtual.
- People are inherently unreliable - car indicators and brake lights will be replaced with electronic messages requesting lane changes or warning of slowing down, or merely transmitting current speed.
- All this will require a local network so all vehicles in the immediate vicinity can be aware of what each other are doing. Local is important - we don't all need to know that someone if turning left in Inverness.



-All this will need a network infrastructure that does not exist today.
- However we do already have experience in this area - mobile phone networks are complex and offer a lot of what is needed. However we need greater capacity 5G? and we need to reserve frequency bands on the already crowded spectrum.
- Will this all be part of the internet as we know it today and what are the implications for capacity?
- Car systems will have to be tolerant to situations where the car in front does not respond in time.
- The transition with both human driven and autonomous vehicles will present a challenge
- What about horses and bicycles?

Security - ARV's will need to be secure to avoid intrusion into the car control software. Not really a different problem to the one we already face on internet connected systems.

Reliability - probable that aircraft style reliability will be required. This will require duplication of essential systems, strict maintenance regimes and self monitoring. This type of thinking and technology already exists.



- Just look at any car advert today... no mention of technology
- Will we see the emergence of names never before associated with cars - we already have Google, Apple and Tesla to name 3
- Can we have an approach that allows the infrastructure to grow slowly or do vehicles have to wait until it's all in place?

Next ……

- Technical challenges pale into insignificance beside the social and economic issues as you will gather from John and Chris.

U3A Autonomous Road Vehicles – Economic Factors

No	Title	Content
1	Black Slide	
2	ARV Title	ARV are coming. ARV is a better term than Driverless Cars because ARV introduction will embrace more than just cars. It is likely that the first applications will be taxis, buses and heavy trucks as their operations will lend themselves to running over standard routes,or operations within relatively small urban areas.
3	ARV Magazine Pages	All the major UK/US motor manufacturers are working on ARV projects. Tesla and Volvo predict they will have vehicles ready in 2018, Honda, Renault and Toyota in 2020, and Ford BMW and Peugeot Citroen in 2021.
4	Google ARV 1	Google is operating ARV as we speak. They have driven an estimated 1,500,000 miles to date in several US States in 22 of these small Google prototypes and 26 Google modified Lexus cars.
5	Google ARV 2	There has been one recorded accident where a Lexus was damaged by a school bus changing lanes. A Tesla has been in collision with a white truck it confused with the sky.
6	ARV Composite	ARV are operating here too. Nissan in association with Oxford University, and others are driving ARV in Milton Keynes where the grid road pattern lends itself to easier road map data storage. The May 2016 Queen's Speech announced that the Government will bring forward a Bill to make operation and insurance of ARV as free of red tape as possible. This was a response to applications by Nissan.
7	The Economy	When ARV use becomes widespread, it will have profound effects on the economy. As a simple definition, the UK economy is the total of goods and services, and remuneration transactions within the UK. As more goods (Stuff) and services are provided more efficiently, their real price falls, and the economy expands. There are winners and losers as this occurs. We want you to think about how the introduction of ARV may affect the way we live in future.
8	Nissan Plant	Most private cars spend 90% of their lives stationary in garages or car parks. Car use has fallen during the last decade, and the average yearly total distance travelled is 6,500 miles. Public transport use has grown in parallel with private vehicle use decline. If ARV taxis make it easy to travel door to door at will, will people buy more or fewer private cars?
9	Nissan Workers	And will more or fewer workers be employed in already highly automated vehicle plants.
10	Drivers	A very large number of people drive for their living. ARV introduction is likely to reduce the number of drivers needed. Will

		these people easily find other employment, and will it be at a similar level of income? How will this effect the economy?
11	Uber Driver	Uber is believed to have over 1,000,000 drivers signed on world wide. They are currently not employees of Uber, and receive no employer benefits like guaranteed working hours, holidays, insurance etc. The CEO of Uber has said that he wishes to replace the existing self employed driver system with a fleet of Uber ARVs which will be more efficient and produce higher profits. Will this be a benefit for the drivers, and the economy?
12	Garage Workers	If there are fewer vehicles produced, but with a higher utilisation rate. Will this require more or fewer vehicle support and maintenance workers ?
13	Accidents	ARV are very likely to have far fewer accidents than human drivers. This will reduce repair costs, medical expenses, and accident and rescue people and vehicle requirements. Will this be an advantage for the economy? NB. Worldwide, according to the World Health Organization, 1.24 million people die annually due to highway accidents. It is estimated that traffic fatalities cost $260 billion each year and that accident injuries account for another $365 billion. This represents a total of $625 billion annually from highway fatalities and injuries. Alcohol is involved in 39% of accidents.
14	Insurance?	ARV accidents will happen, albeit rarely. Who will accept liability for accidents and the responsibility for repair costs and compensation? The vehicle insurance market is likely to decline. Will this be good for the economy?
15	Car Parks	With fewer vehicles operating at a higher utilisation rate, there will be a reduced need for large car parking spaces.
16	Affordable Housing	These spaces could be used to provide affordable housing in inner cities where it is urgently needed. Will this be good for the economy?
17	The Economy	The World Economic Forum estimates that the digital transformation of motor vehicles will generate $67Bn of benefits to the economy, and $3.6 trillion of societal benefits. What do you think? Your task is to think about the pluses and minuses, and give us your opinion on whether ARV will result in economic expansion, stasis or contraction. Who will benefit most?
18	Black Slide	

Notes on AUTONOMOUS ROAD VEHICLES (ARV) Psychological, social and civil issues.
jmj 09 Dec 2016

AUTONOMOUS ROAD VEHICLES (ARVs) ARE COMING, AND WILL BE TRANSFORMATIONAL FOR MANY ASPECTS OF SOCIETIES - ECONOMIC, PSYCHOLOGICAL, SOCIAL, LEGAL, IN TOWN AND ROAD DESIGN.

1. The Broad picture

We are living through a period of fast and accelerating technological change. It is difficult, but we need to fully grasp that all aspects of computer technology, A.I. and robotisation are developing at a rapid and accelerating pace.

When I researched 'The future of work' there was little in the media about driverless cars. Eighteen months later the media are full of papers, reports, research, comment and 'predictions' about autonomous road vehicles - ARV - and its probable implications.

But let us be clear. No-one knows how, or on what time-scale, the coming transformation will evolve.

In 1900 more than 300,000 horses were needed to keep London on the move, hauling everything from private carriages and cabs to buses, trams and delivery vans.

But there was a crisis. The streets were deep in manure accompanied by swarms of flies, and stench.

Enter the internal combustion engine. Within 15* years everything had changed. Horse buses and horse trams had disappeared in London, and motor taxis heavily outnumbered horse-drawn cabs. Buses were fully

mechanized in an even shorter period - between 1904 and 1914

But it took 50* years to complete the transformation from a society based on horse drawn transport to a society based on I.C.Engines.

* Note the time difference between the initial phase, and the complete changeover.

2. The Second Transport Transformation

We are entering a second transport transformation from driven vehicles to autonomous vehicles.

Another caution here. As we speak at least 33 major companies are working on AVR. (33 auto companies and other tech heavyweights are said to be working on ARV i.e.: Apple, Audi, BMW, Bosch, Scania, Delphi, Ford, GM, Google, Honda, Hyundai, Jaguar, Mercedes, Microsoft, Nissan, Nvidia, PSA, Tata, Tesla, Toyota, Uber, VW, Volvo, Yutong ... ...)

Unexpected technological developments will appear.

There are likely to be two lines of technological development:

a. incremental change in current vehicles increasingly incorporating function-specific automation: such as cruise control, lane guidance and automated parallel parking. Tesla (and others) appears to be using this approach.

b. One step to fully autonomous vehicles - likely to be available in c. 3 - 5 yrs. Probably there will be early adoption as taxis. Uber are active in this.

(In addition to these two modes, battery development will mean electric vehicles will replace ICE vehicles more quickly than has previously been thought. Although ARV's are likely to be ICE powered in early models, electric ARVs will quickly predominate.)

Many current estimates expect ARV to be seen on our streets within three years and widespread within 5 years.

3. Psychological, social and civil issues

It is likely that most passengers will be uneasy, even frightened, during their first trips in autonomous vehicles. ARV passengers will be able to watch tv, or films, play games, phone, use internet, hold in-vehicle conversations. It is likely that, as in other change situations in our lives, the new norm will become standard and unexceptional. But over what time scale?

There is another huge psychological-social issue. Why do you have a car? You may answer - to take me from A to B - perhaps adding - in comfort. But why did you chose the specific car you drive? Ownership psychology - a marker of who you are, or perhaps who you would like to be seen as - wealth, character - sedate ? racy ? smart ? informed re cars ? sexy? tough ? You write your script.

As soon as autonomous taxis and hire-cars enter the market - probably within three years - they will rapidly become cheaper and safer than conventional cars. Owner-drivers will be daily faced with a life-changing decision: to continue owning a car, or switch entirely to using taxis / hire cars. But what about that psychological identity fix plus making in-car time useful?

Thus an interesting market competition will develop: economics versus convenience plus in car useful time and enjoyable facilities ie car becomes extension of your office, plus entertainment.

Complex psycho-social changes - difficult to predict.

As use of driverless taxis and hire cars increases, fewer people will buy cars causing major disruption to car manufacture, vehicle repair and servicing, and insurance. Effects of this may be soon be seen as fully autonomous cars enter the market.

It's a good bet that Auto companies are already working on attractive car interiors with 360 deg swivel chairs, tv/audio facilities, drinks cabinet, etc.

At the moment there are c. 37 million licensed vehicles in UK of which c. 30 million are cars, c. 3.5 million are vans or trucks (some vans are personal vehicles)c. 300,000 drivers are in taxi and private hire vehicle trade. c. 1,000,000 jobs in bus driving, c. 1,000,000 in truck driving, c. 2,000,000 in vehicle repair and servicing. That is a total of at least 4,300,000 jobs. (See Chris's paper on economics)

There is likely to be a gradual, but eventually substantial, loss of driving and vehicle repair and servicing jobs. The vehicle insurance business will also be disruputed because of fewer vehicles and accidents.

Another huge effect will be changes in town and road layouts, and reduction in road furniture and signage.

There is a little advertised statistic which may become important. What % of an average car's life is spent moving? Many studies say c. 4 - 5% ! We are paying

huge amounts of money to buy. insure, fuel, garage, service, repair, park, tax etc our car fo a useful 5% of its life. Ouch.

A recent UK study has looked at the transformative implications of self-driving vehicles on cities. The biggest effect will be a gradual reduction in number of vehicles. In most cities, designated parking accounts for a large amount of land, which ends up being useless for most of the day.

The authors found that shared autonomous vehicles could increase available urban space by 15 to 20 percent, largely through the elimination of parking spaces. Today central London has about 6.8 million parking spaces and a parking coverage of around 16%! Many large cities have even larger coverage ratios for parking space of up to 30%. Freeing up this space would make our cities greener, increase quality of life and also create the potential for additional housing.

The authors also consider autonomous-vehicle-only development areas and highways that are limited to autonomous vehicles. This could reduce costs as lane markings and signage would no longer be needed, the lanes could be narrower and throughput per lane would be higher.

One engineering study found that automation could quadruple capacity on any given highway.

With 1775 reported road fatalities in the UK in 2014, and 195,000 casualties of all severities, road accidents cost the UK upwards of £10 billion each year. While the number of fatalities has fallen by nearly half since 2005, upwards of 90% of all accidents continue to be caused in some way by driver error.

As taxi-hire-car mode becomes widespread there would be no need for garages or car parking spaces adjacent to living accomodation. Garages could become additional useful space for a house. Parking bays could be used for greenery, parking on roadsides generally would be eliminated allowing faster and safer vehicle movements.

Street clutter can be virtually eliminated, as AVs will not need to gather information from the roadside. In a zone designed and built for AVs from the outset, direction signs, speed limit signs and traffic lights will no longer be required. Visible displays cou[jmj 2016]ld be reduced and intersections could be simplified.

There is a key decision to make about whether to dedicate routes for driverless vehicles or to aim for 'mixed operation' where today's cars and freight use the same roadspace as ARV. Mixed operation on higher speed routes introduces some pragmatic challenges: driverless vehicles will behave differently to driven cars, and every nonconnected, driven vehicle will affect all others around it. There are useful parallels with rail, where higher speed services, local services and freight are separated wherever possible onto separate lines.

Over three or four decades towns, roads, transport, indeed societies, will have changed beyond recognition.

All part of the oncoming transformation of societies (and paid work) by A.I., robotics, and I.T.