SLOWER THAN YOU THINK

AD PUNCTUM | Automotive Strategy

November 2017

Autonomous Vehicles: Implications On Performance And Design

EXECUTIVE SUMMARY

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- **Autonomous vehicle top speed is a function of sensor / AI reliability**
- **AVs are unlikely to travel above 70 mph for cars and 60 mph for large trucks**
  - Below the legal speed limit in some countries
  - Potentially could be even lower to reduce false positive emergency braking
  - In extreme weather (e.g. ice), maximum speed would be reduced further
- **Lower performance enables different engineering trade-offs**
  - Some elements can be made cheaper and lighter
  - Implications for the content per vehicle of Tier 1 suppliers
- **Vehicles will need to package protect for step changes in sensor performance**
  - Vehicles that cannot use the latest generation sensor may find their utilisation reduced (in a similar fashion to obsolete aircraft)

AV TOP SPEED IS A FUNCTION OF SENSOR / AI SET

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- **Autonomous vehicle top speed will be limited by its ability to detect dangerous situations and stop or react before there is an accident**

- **In many situations, AVs will be subjected to harsher standards than humans**
  - Although it is legal for humans to drive at higher speeds in icy conditions with limited visibility, visual range is insufficient to prevent accidents
  - This will help AVs to drive more safely than humans

- **Top speed can be determined from sensor range, braking distances and safety margins**

Top Speed Will Be Governed By The Ability To Detect And Avoid Danger. Autonomous Vehicles Will Be Held To A Higher Standard Than Humans.

DETECTION PERFORMANCE -- STATE OF THE ART

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Long Range Radar

Automotive grade long range radar has a usable range of around 250 metres (lower for less metallic surfaces / smaller cross sections)*

LIDAR

Range of at least 150 metres even for objects with poor reflectivity

Objects with highest reflectivity seen up to 250 metres

Camera -- 5x zoom

(Likely 120fps minimum)

< 20m

~100m with good visibility

Camera -- 10x zoom

(Likely 240fps minimum)

< 20m

~ 200m with good visibility

Camera -- 15x zoom

(Likely 240fps minimum)

< 20m

Almost 300m with good visibility

Almost all conditions

Ideal conditions (but not reliable)

* See comments on slide 11

Current Automotive State Of The Art Performance Is A Range Of ~250m.
Radar Is Currently The Most Reliable For Very Long Ranges In All Weathers.

LIDAR'S NOT-SO-SECRET WEAKNESS

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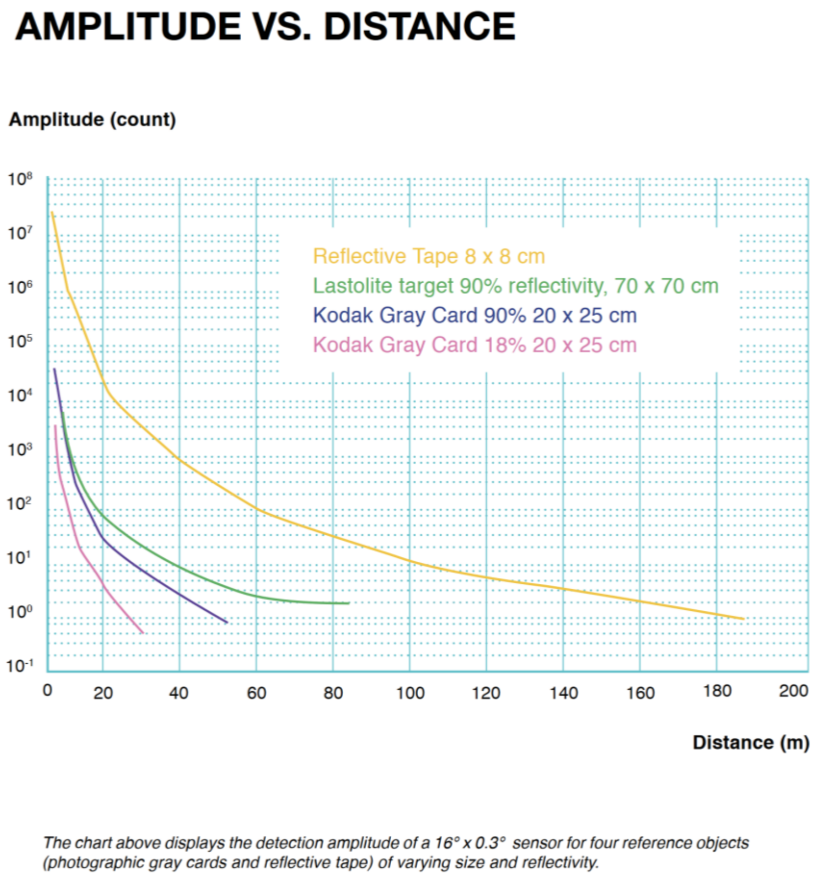
- **Lidar's ability to detect objects is related to their size, material and colour**
  - Amount of light reflected varies
- **200m range is a common headline but this often relates to easiest conditions only**
  - Lidar manufacturers are open about this
- **More powerful lidar (400m+) exists**
  - Probably needs more development for everyday automotive application



Source: Leddartech

Although Headline Lidar Detection Ranges Of 200m Are Commonplace These Often Relate To Best-Case Conditions.

LIKELY SENSOR SUITE RELIABILITY*

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	All Weather			Good Weather			Overall Ability (worst case)		
	Object Detection	Object Speed Tracking	Object Detection	Object Detection	Object Speed Tracking	Object Detection	Object Detection	Object Speed Tracking	Object Detection
135m to target	Radar & Lidar	Radar & Lidar	Radar & Lidar	Radar & Lidar & Camera	Radar & Lidar & Camera	Radar & Lidar & Camera	Good	Good	Okay
180m to target	Radar & Lidar	Radar & Lidar	Radar & Lidar	Radar & Lidar & Camera	Radar & Lidar & Camera	Radar & Lidar & Camera	Good	Good	Okay
230m to target	Radar	Radar	Radar	Radar & Camera	Radar & Camera	Radar & Camera	Good	Good	Poor

* First & second generation of vehicles (2020 – 2025)

All-Weather Object Recognition Is Likely To Be Weak Until The Vehicle Is Within 150 metres of The Target.

WHY TODAY'S STATE OF THE ART MATTERS

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- Artificial intelligence is trained used data that is be representative of reality
- Although sensor range will improve in future (particularly lidar), 1st and 2nd generation vehicles will be trained using today's state of the art
- Advances in AI will be required to update the sensor type without compromising the object recognition patterns previously developed
- Today's state of the art still requires development to become production-ready for vehicles covering tens of thousands of miles each year
  - Boring things like reliability, power consumption, cost, alignment and protection from the elements still being worked on

2020-25 Vehicles Likely To Feature Sensors With Similar Range And Resolution To The Best Offerings Being Demonstrated Today.

CALCULATING AV SENSOR RANGE REQUIREMENT

- **Minimum detection distances are derived for each speed level**

- **Car braking assumed to be in wet conditions***
  - Some products perform (much) better than stopping distances used; but…
  - Must assume AV is avoiding a rear end collision with following vehicle that is driven by a human with average performance

- **HGV braking distance derived from test data****

- **Processing time is calculated as 0.5 seconds**

- **Safety margin of 2.0 seconds* -- vehicle stops a safe distance from the obstacle**

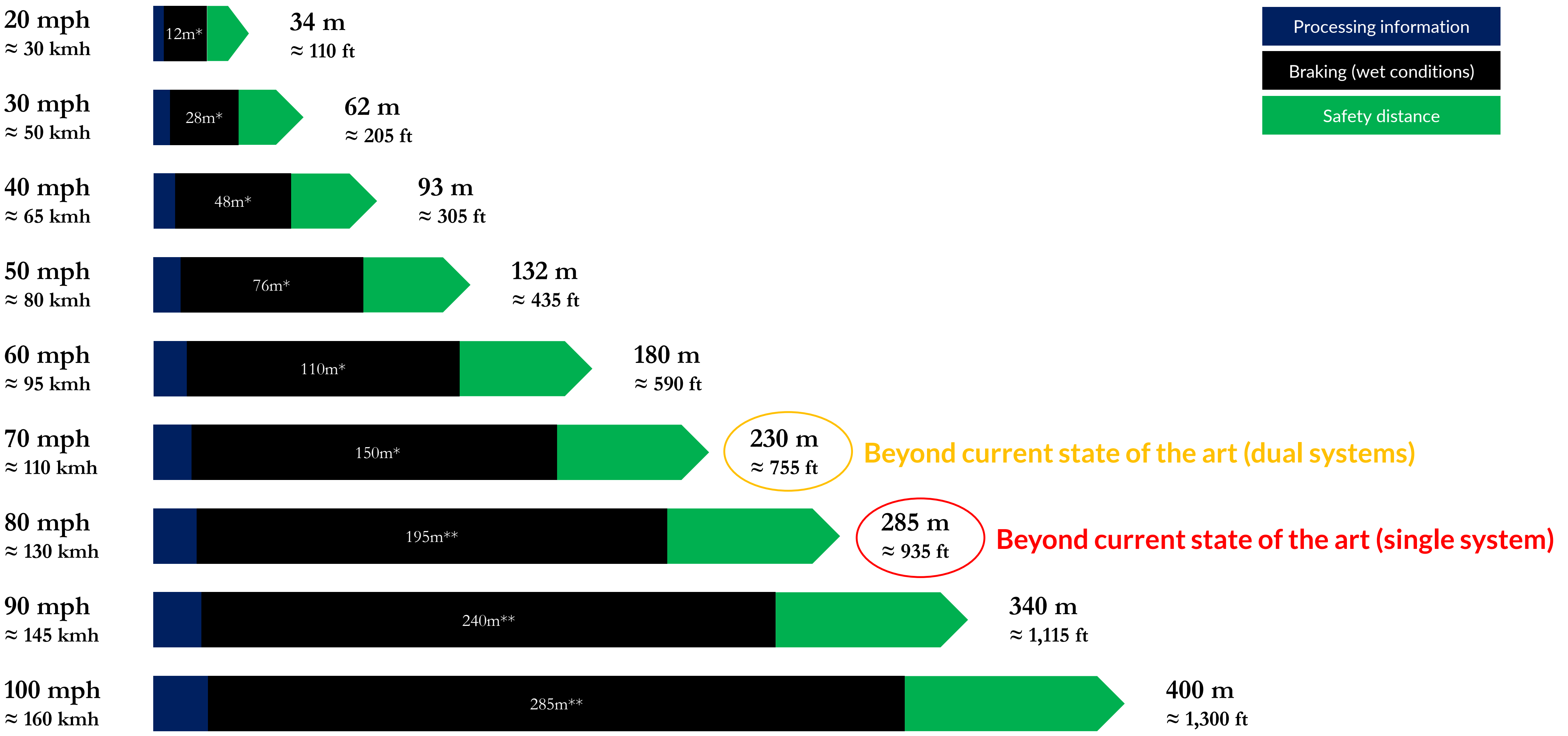
Processing time → Braking time → Safety distance from obstacle

HGV = Heavy Goods Vehicle

* UK Government advice

** Original test was of a laden vehicle in dry conditions

SPEEDS AND STOPPING DISTANCES -- CAR



* source: UK Government   ** source: Ad Punctum analysis

SPEEDS AND STOPPING DISTANCES -- HGV

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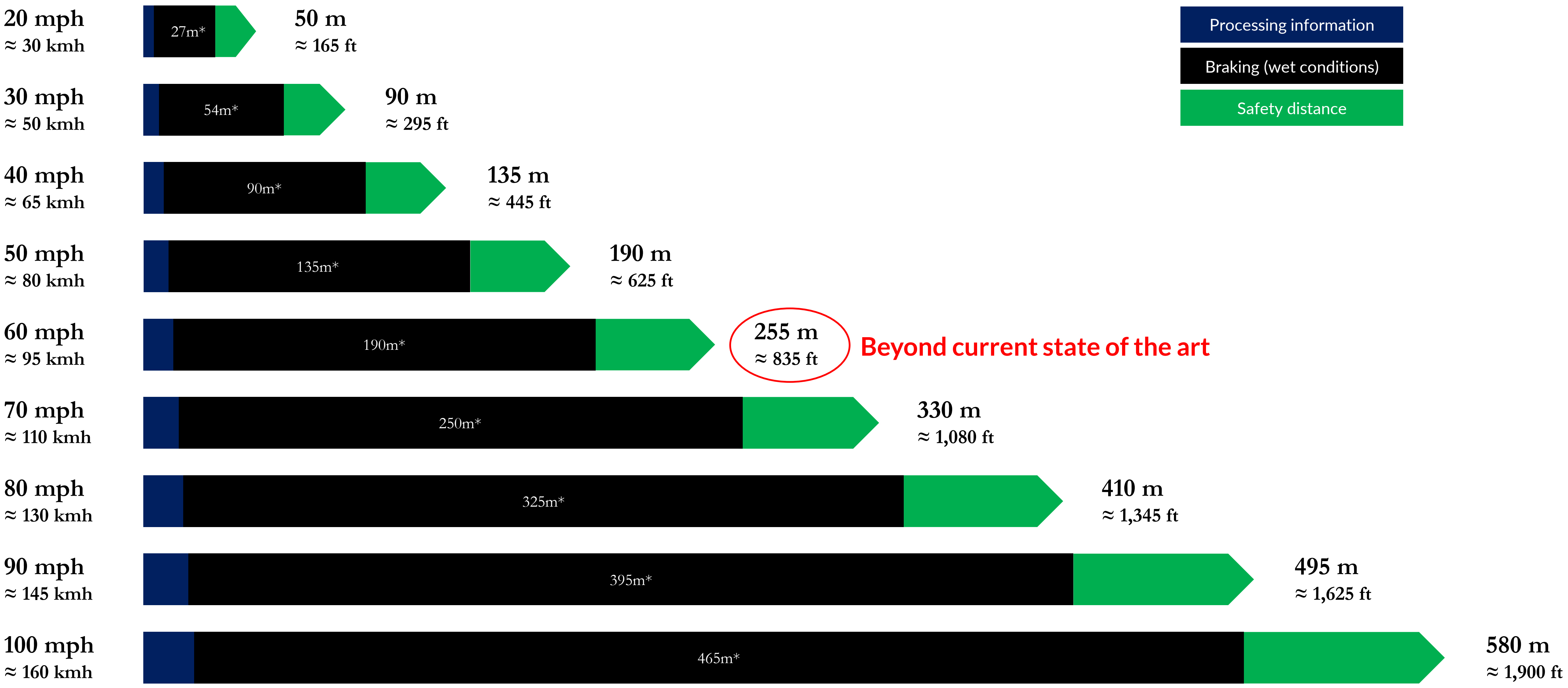

* Distance for a laden vehicle, source: Ad Punctum analysis

HGV = Heavy Goods Vehicle

THE PROBLEMS WITH LONG RANGE RADAR…

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- **Long range radar can detect objects and assess their speed but struggles with recognising what the objects are**
  - Many radars have poor resolution at maximum range (+/- 2m at >200m)
  - Compounded by differences in reflectivity (metal is easier to spot than flesh)

- **Radar can spot a stationary object at long range but may be unable to distinguish between a plastic bag (no problem) and a piece of debris (bad)**
  - Emergency braking each time a stationary object is detected would lead to excessive false positives
  - In practice, AVs are likely to slow but not emergency brake when seeing objects at long range with radar alone
  - Further reduces top speed due to longer stopping distances

Long Range Radar Has Poor Object Recognition.
Top Speed Lower Than Theoretical Maximum Reduces False Positives.

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Question:
Isn’t moving more slowly a bad thing?

Answer:
There are some benefits…

BENEFITS OF LOWER TOP SPEEDS

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- **Reduced wear and tear on the road surface**
  - In an ideal world… leading to lower road taxes (as if)
  - Lower road noise too
- **Reduced fuel consumption (whether ICE or electric)**
  - Slower moving vehicles will encounter less air resistance
- **Less severe accidents**
  - Even for uncontrolled mechanical failures, impact velocity will be reduced
- **We'll get to appreciate the scenery more**
- **<u>One downside:</u> slow moving AV trucks could hold up other traffic…**

Question:

It’s just too slow for me. Is there anything that can be done to increase speeds?

WHAT CAN BE DONE TO INCREASE TOP SPEEDS?

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- **Create step changes in sensor performance that increase detection range**
  - Both radar and lidar have military applications with longer ranges
  - Progress may be slow -- radar range increased ~10% in last decade*
- **Improve brakes / tyres to reduce stopping distances from high speed**
  - Increased chance of human drivers crashing into the back of the AVs (bad!)
- **Have different speed limits in dry and wet conditions**
- **Use vehicle-to-infrastructure communication to guide vehicle position**
- **Use fixed infrastructure for high speed travel, rather than vehicle's own power**
  - In a hyperloop-type system, a more powerful central control could take over detection and decision making (or simply run with larger gaps)

* Long range automotive applications (partly a function of cost and power consumption)

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Question:
How will this affect the design of the vehicles?

IMPLICATIONS FOR VEHICLE DESIGN

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	Attribute Choices	Fuel Economy	Weight	Cost
Tyres	Further reductions in rolling resistance may be possible	Better	Unchanged	Unchanged
Motor (ICE or electric)	Same acceleration (torque) but lower maximum speed (power output)	Unchanged	Lighter	Cheaper
Gearbox (if any)	Lower top speed = fewer gears	Unchanged	Lighter	Cheaper
Battery (if any)	Lower maximum power draw, reduced size for same range	Better	Lighter	Cheaper
Drivetrain	Less extreme loads	Unchanged	Lighter	Cheaper
Suspension	Lower vehicle momentum, less extreme loads	Unchanged	Lighter	Cheaper
Brakes	Better brakes = shorter stopping distance, higher maximum speed	Unchanged	Unchanged	Increased
Body – Chassis	Less strength required due to lower weight of other componentry	Better	Lighter	Cheaper
Body -- Crash Structure	Strong rear crash structure (human drivers keep driving into the back)	Worse	Heavier	Increased
Aerodynamics	Subject to lower maximum speeds and less air resistance	Better	Unchanged	Unchanged

Note: list above excludes AV sensors and processing equipment – will make vehicle heavier and more expensive

If Vehicles Are Created With Maximum Speeds Governed By Detection Distances Then Different Design Choices Can Be Made.

CONCLUSIONS

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ABOUT AD PUNCTUM

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- Consultancy and research firm founded by an ex-automotive OEM insider
- Ad Punctum researches emerging trends and key issues ranging from the disruptive impact of on-demand mobility to Brexit
- Periodically publishes relevant research to make it freely available and drive understanding and debate on interesting topics
- Please contact sales@adpunctum.co.uk or visit www.adpunctum.co.uk to learn more about us and discuss any specific queries you might have

WHAT WON'T HELP IMPROVE PEFORMANCE…

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- **Increase the gap between vehicles, so there is a bigger safety margin**
  - But if the vehicle can't see the one in front, how does it know it is safe?
- **Reduce safety margins**
  - Unlikely without regulatory blessing, and why would they give it?

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