NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Energy Research Institute @ NTU

Determining perception range requirements from ODD and traffic conditions

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A reminder from the kickoff meeting…

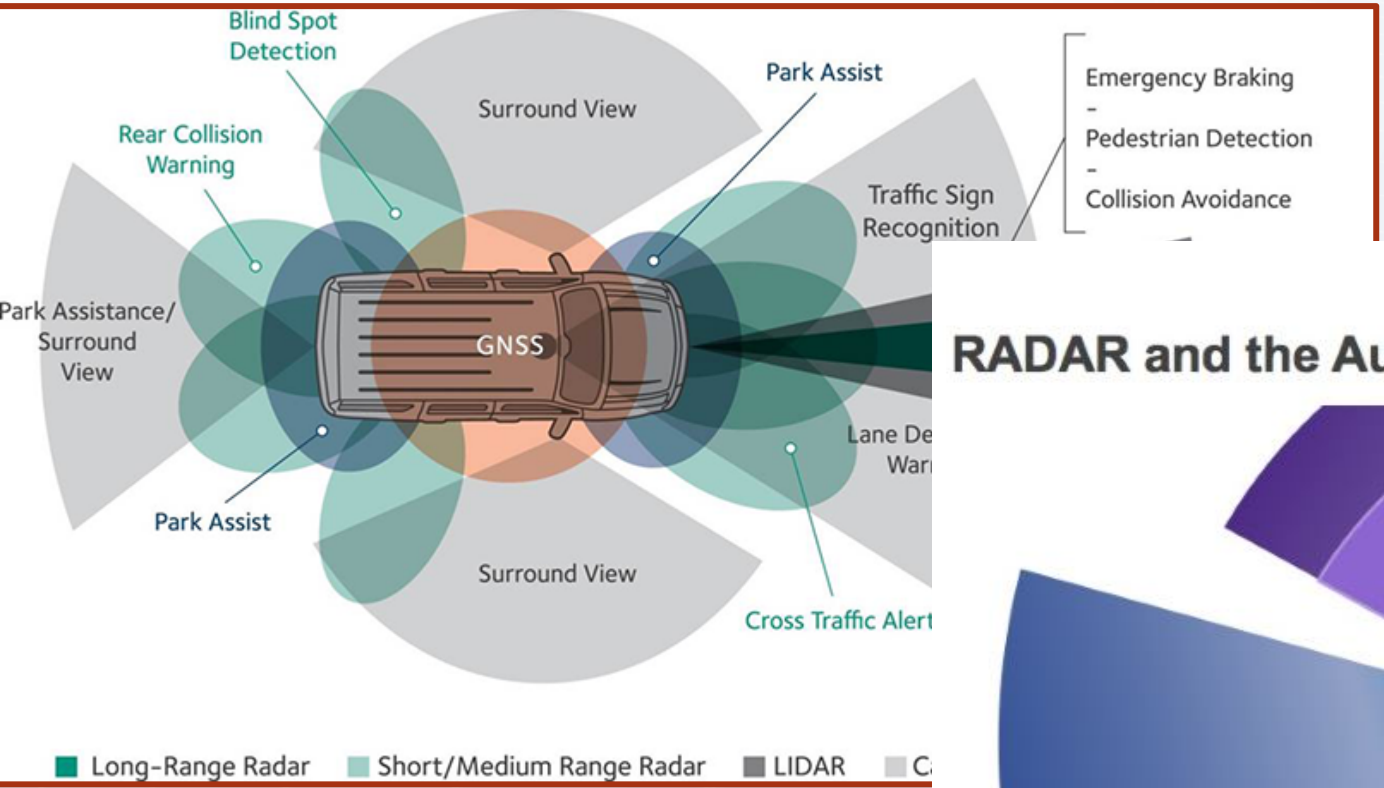
- AI should be held to same legal standards as human drivers

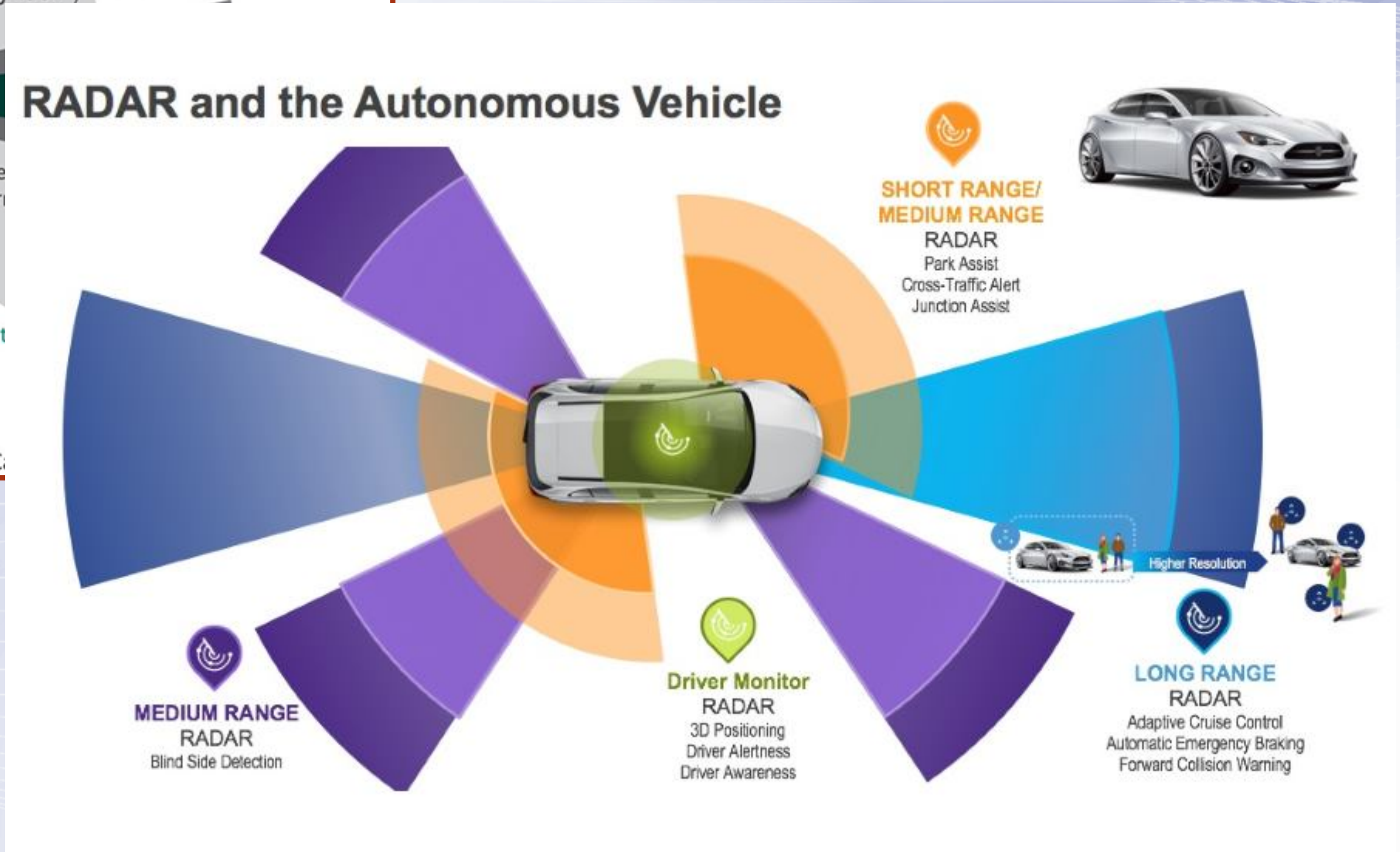
  - It starts with a universal assumption that all road users are; "aware, willing and able" to avoid collisions

    - Meeting the minimum public expectation is that AI Drivers never engage in reckless, dangerous or careless driving…
    - …by comparing AI Driver performance to that expected of a **competent** and **careful** driver (with humans as the starting baseline)

    - **i.e.: It is possible to never have a collision and yet still drive very badly**, and thus not meeting the minimum public expectation.

The type of image you see for sensor systems





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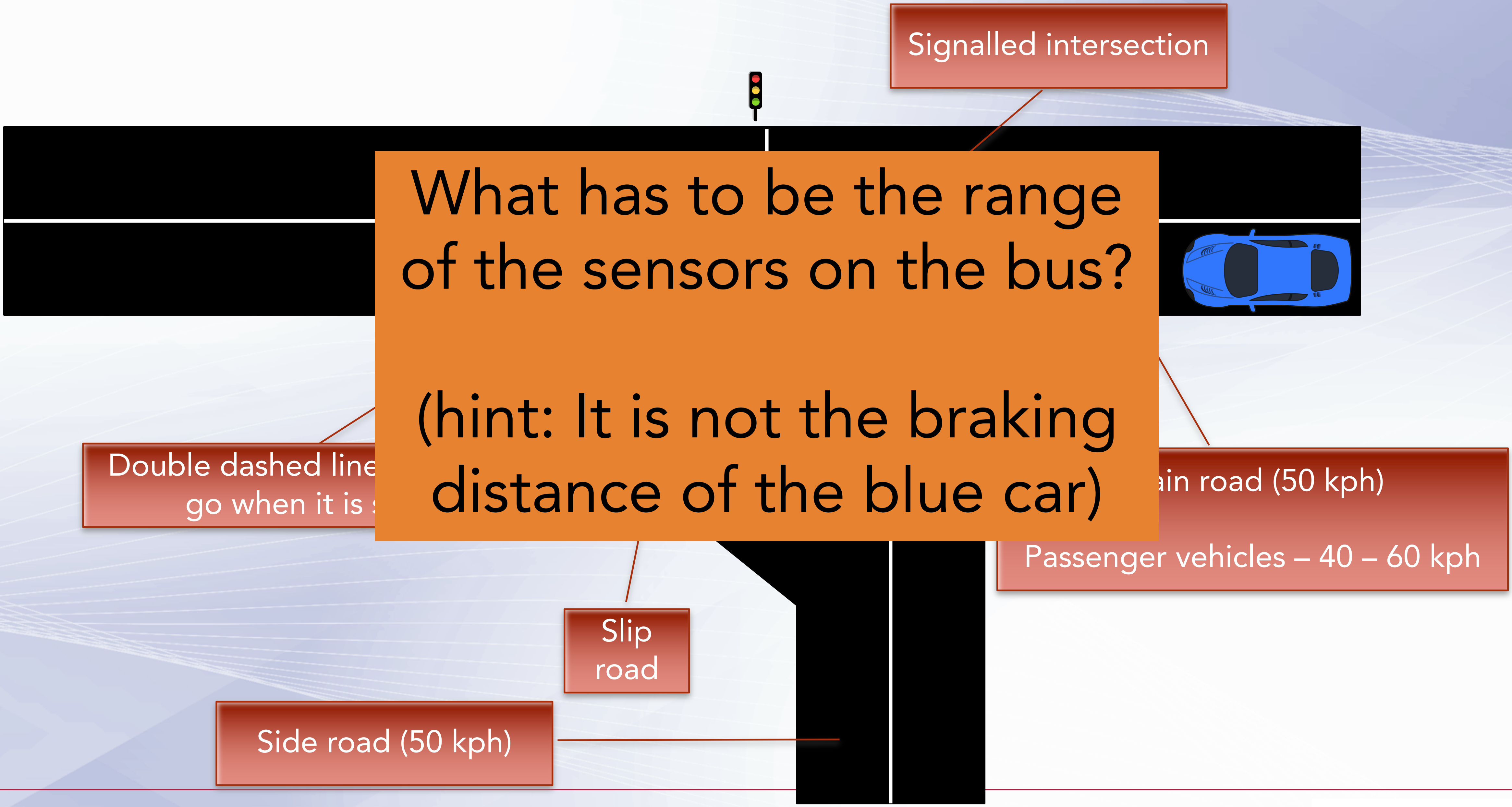
(draft rejected) Guidelines for a minimum detection range vs speed

- Speed should account for the current and upcoming range of object sensor detection and visibility to other road users. Ideally the range of object sensor detection should always exceed the safe stopping distance of the vehicle (based on current speed). When faced with areas of occlusions or range restrictions, an AV shall react to reasonable worst-case assumptions of actors being present just outside of field of view. In the event that occlusions will not be satisfactorily removed without forward motion, the AV should be allowed to creep forward at a reduced speed until the occlusions have been removed.

Two problems with this:

1) It assumes that that you are only responsible for not hitting others.
2) An emergency stop now or then is ok .

Problem observed: frequent takeover by safety driver



What has to be the range of the sensors on the bus?

(hint: It is not the braking distance of the blue car)

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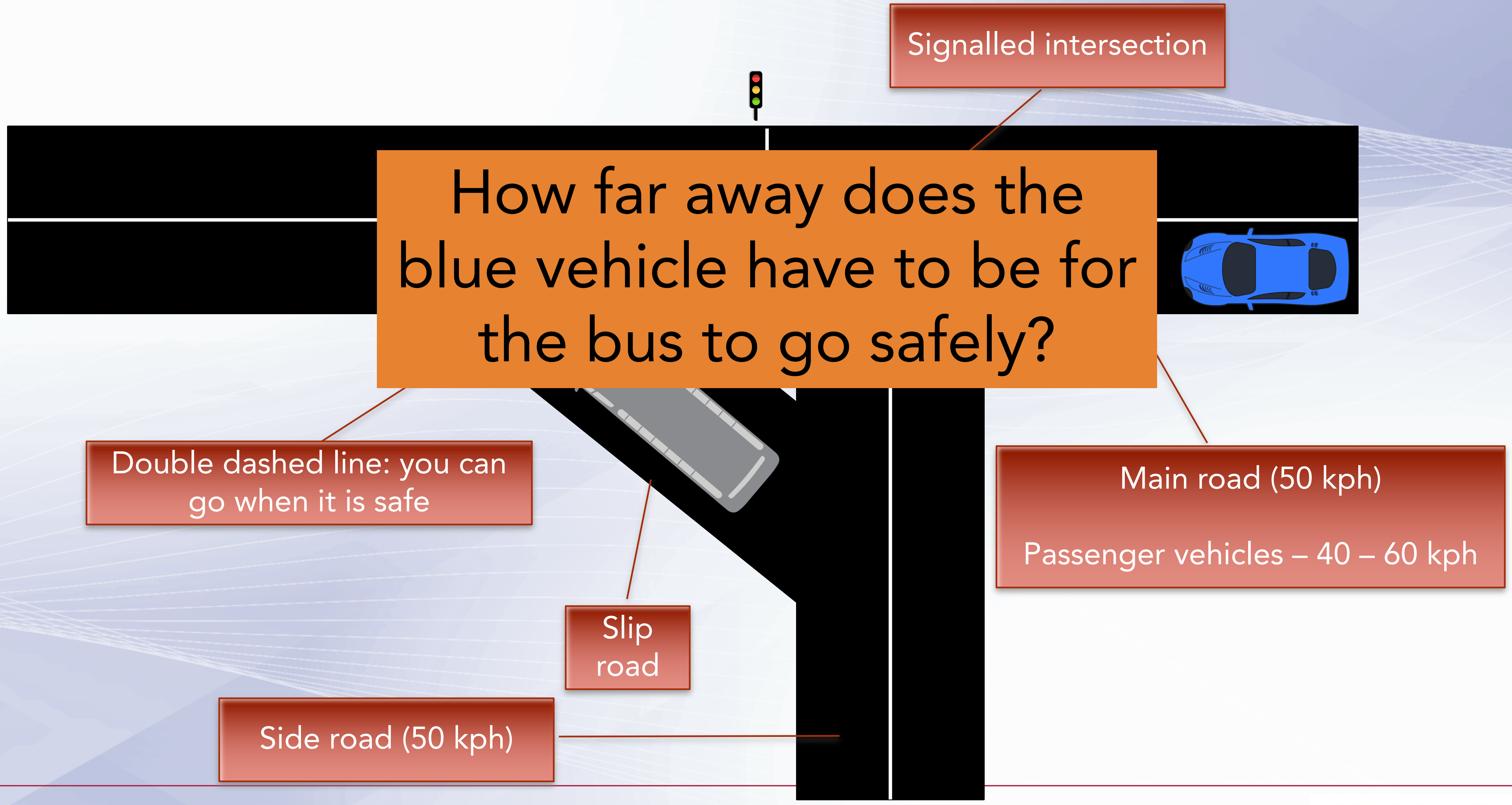
Problem observed: frequent takeover by safety driver



What are the traffic conditions here

- Bus
  - To prevent standing passengers from falling
    - It can only accelerate at maximum 1 m/s^2 once it is on the main road
    - It can only accelerate at around 0.5 m/s^2 max while turning on the main road
  - It is probably maxed out at 35-40 kph on the main road

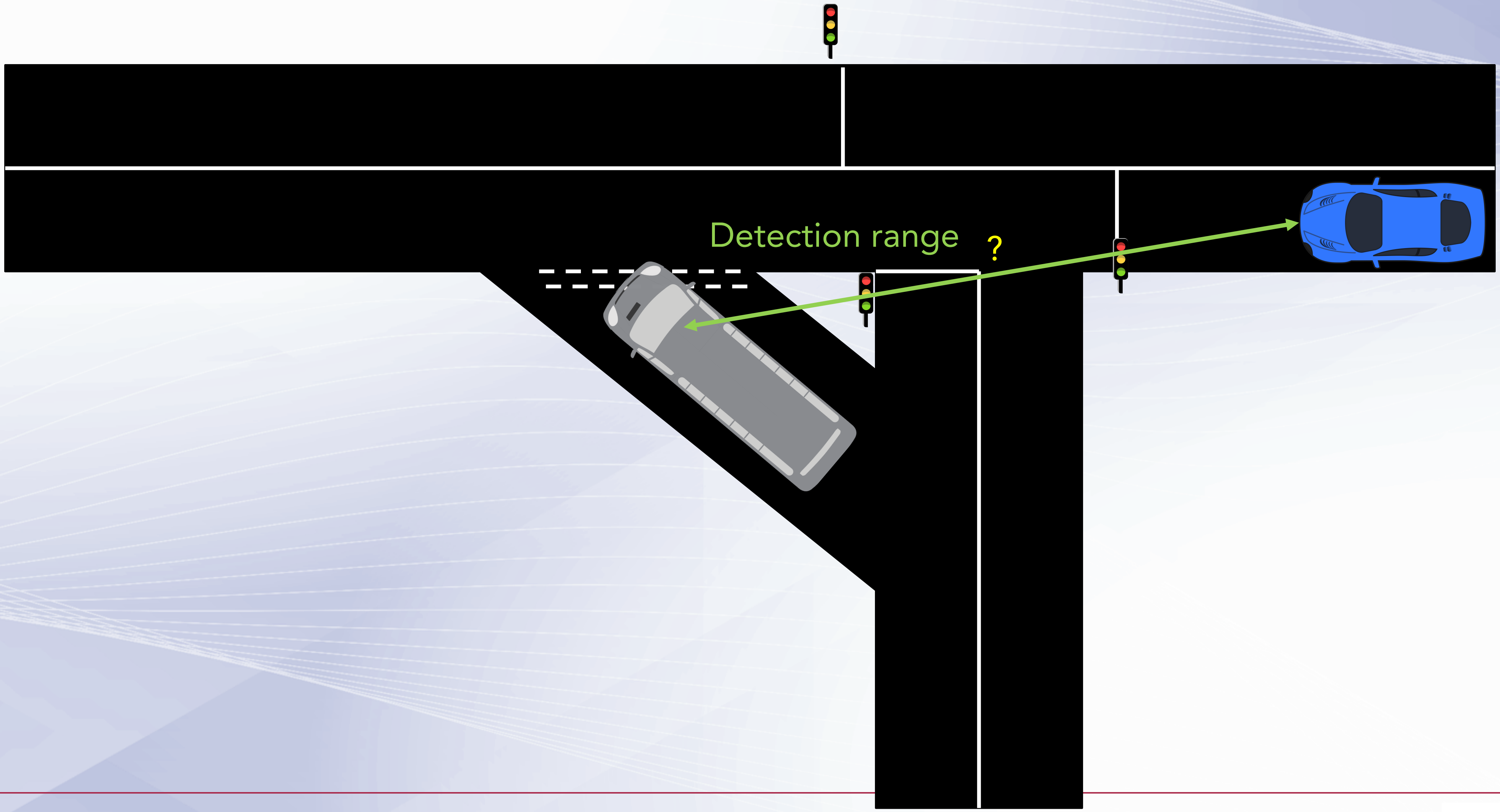
- Car
  - While the bus is accelerating on the main road
    - It should not have brake for the bus
    - It is reasonable to have to lift the throttle and reduce speed by about 20% if needed
  - When the bus has reached its driving speed of 40 kph
    - The car should slow down and follow the bus
    - Distance to the bus should be at least 10-15m (bus reduces forward visibility)

So what is the safe detection distance?

- Some assumptions:
  - Bus acceleration at 0.5 m/s^2 for simplification
  - Bus final speed is 36 kph (10 m/s)
  - Bus length is 10 m

  - Car approaches at 54 kph (15 m/s)
  - Car slows down to 36 kph (10 m/s)
  - Average speed for simplification is 12.5 m/s
  - Final gap with bus is 10 m

Start situation



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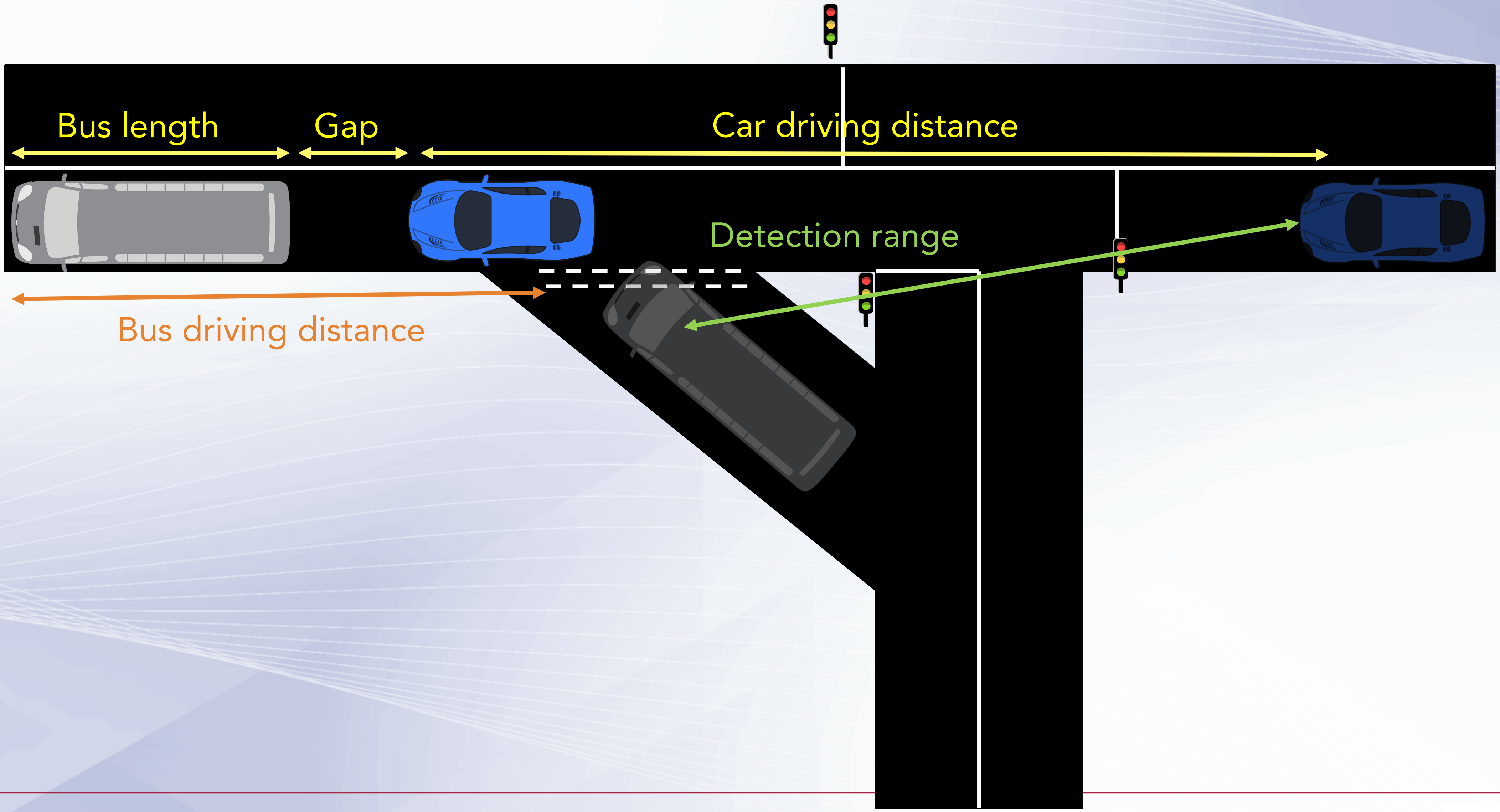
End situation



So what is the safe detection distance?

- Calculation
  - Event duration is 20 sec
  - Bus will have moved 100 m
  - Car will have moved 250m
  - Final gap is 10+10 = 20 m (front bus to front car)
  - Detection distance = 250+20-100 = **170m**

So what is the safe detection distance if it were 2 cars?

- Some assumptions:
  - Car 1 acceleration at 2 m/s^2 for simplification
  - Car 1 final speed is 46.8 kph (13 m/s)
  - Car 1 length is 5 m

  - Car 2 approaches at 54 kph (15 m/s)
  - Car 2 slows down to 46.8 kph (13 m/s)
  - Average speed for simplification is 14 m/s
  - Final gap with car 1 is 10 m

So what is the safe detection distance if it were 2 cars?

- Calculation
  - Event duration is 6.5 sec
  - Car 1 will have moved 39 m
  - Car 2 will have moved 91 m
  - Final gap is 10+5 = 15 m
  - Minimum detection distance = 91+15-25 = **81m**

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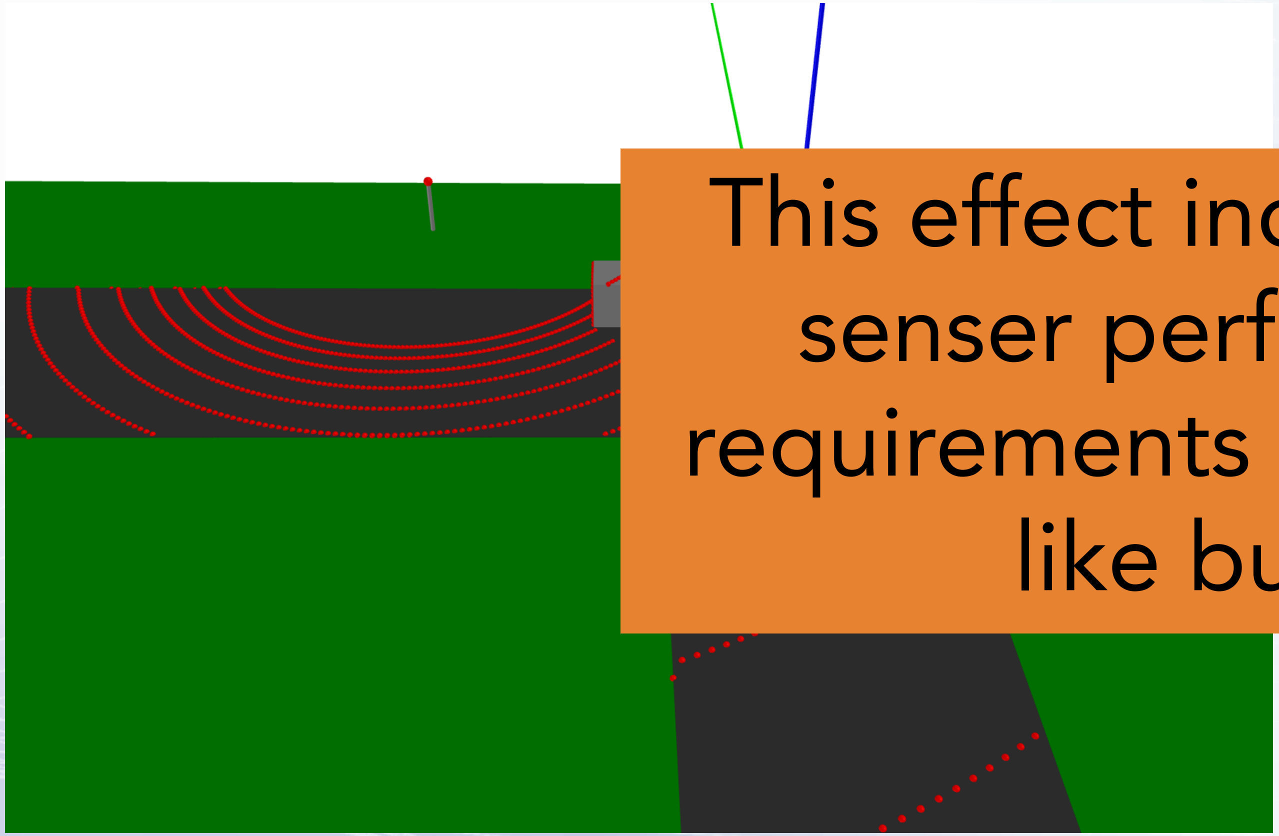
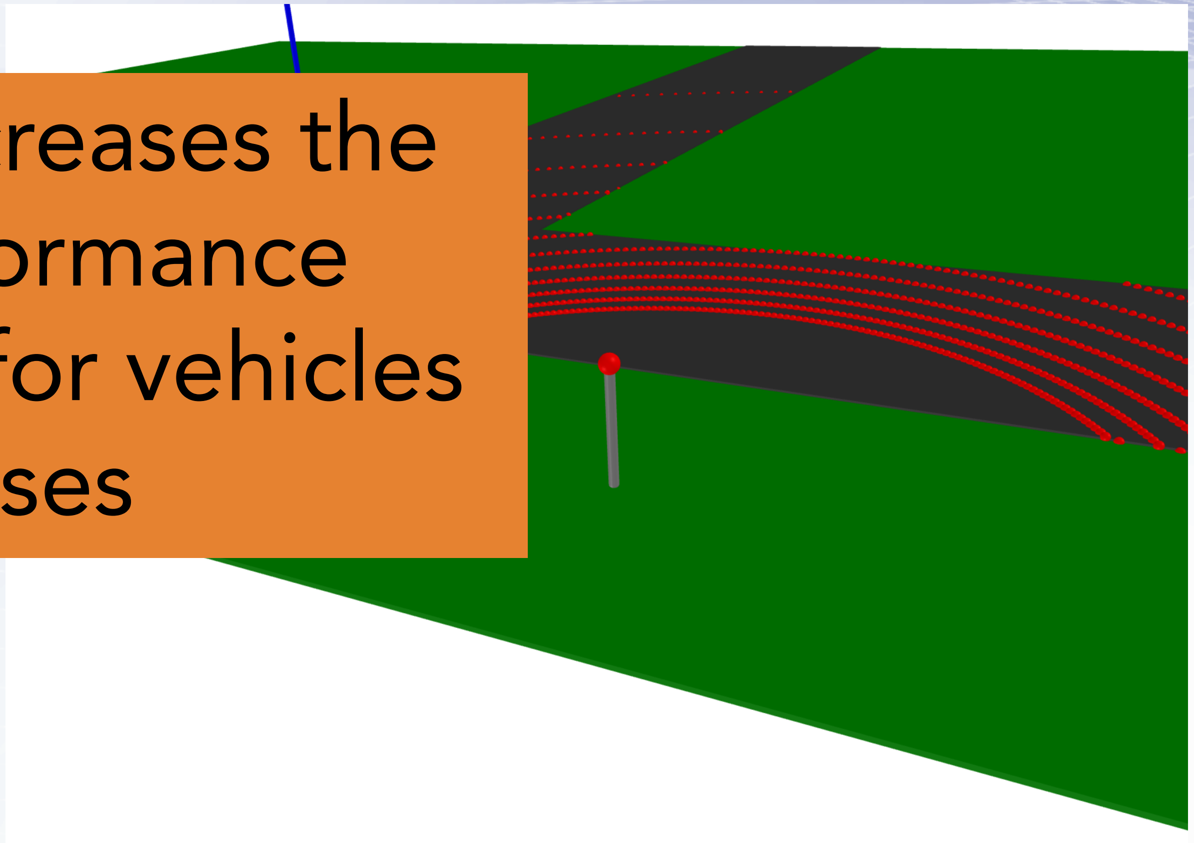
Lidar coverage example





This effect increases the senser performance requirements for vehicles like buses

Fig 6 and 7. A single sensor at an elevation of 2.4m - Perspective view

Cause of problem of frequent takeover by safety driver

- Vehicle should be detected at 150m minimum and probably closer to 200m away to cater for all variables.
  - However, if the range was 100m it would probably not cause a dangerous situation, but you might not meet the "average driver" requirement.
- Actual perception range for the vehicle was less than 50 m (note: it was an early R&D vehicle).
  - Due to the road profile, even with a perfect sensor system, a 150m range was not achievable.
- Requirements were all based on the need for the vehicle to brake in time for other traffic.
  - No consideration was made for the vehicle to give way to other traffic.
    - When calculated based on the need to be able to stop in time; the slower, the better
    - When calculated based on the need to give way to other traffic; the slower, the bigger the problem
- The problem became obvious because of the amount of traffic on the main road: at least 50% of the time there would be a car which the vehicle would have to give way to.

Conclusions

- Speed **differences** are big issues and need to be taken care of.
- There needs to be a specific analysis of the ODD to analyze if the performance of the perception system is acceptable.
- Defining acceptable driving behaviour is very important.
  - Adjusting driving behaviour could resolve issues with the perception system.
- It is unrealistic to expect that the AV always behaves like an exceptionally courteous drive, but if more than 50% of the time others have the brake (not necessarily hard braking), the vehicle is a less than average driver.
- Tradeoffs are needed and they will depend on developer, ODD and other factors.
  - But if they are well defined and documented, it can be adjusted to address behavioural issues.

Thank you

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