



Dieselgate

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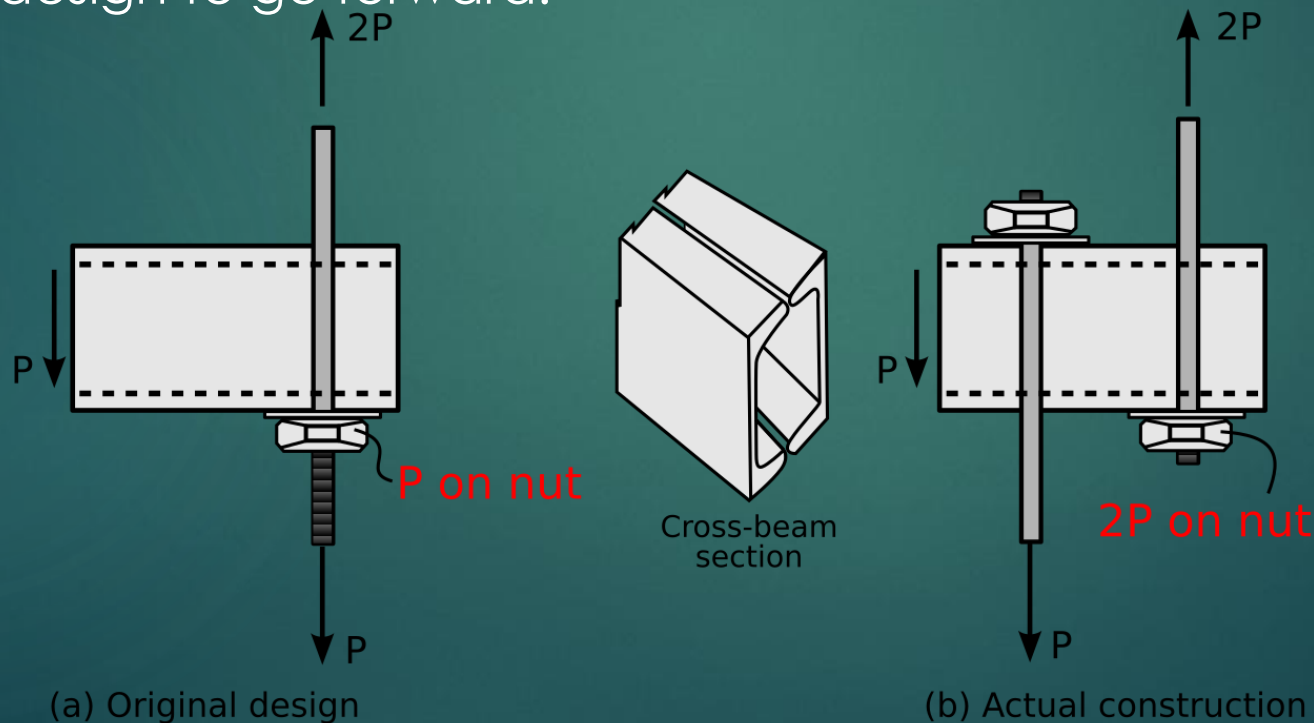
Tacoma Narrows Bridge

- ▶ Collapsed into Puget Sound four months after opening
- ▶ Intentionally designed to permit maximum flexibility in the span
- ▶ Engineers failed to account to adequately consider aerodynamic forces under strong winds and the resulting oscillations in the structure
- ▶ Error of omission – a bridge of this construction type had never been built on this scale.



Hyatt Regency Walkway Collapse

- ▶ Overhead walkway collapses, resulting in 114 fatalities and 216 injuries.
- ▶ As built did not match design specification.
- ▶ Insufficient oversight, negligence and unprofessional conduct allowed site modified design to go forward.



Challenger

- ▶ O-Rings in booster failed due to low temperatures at launch, material was no longer resilient or flexible and failed to function.
- ▶ Investigation found that NASA culture and decision making processes contributed to the accident
 - ▶ There was considerable pressure on the managers to increase the frequency of launches

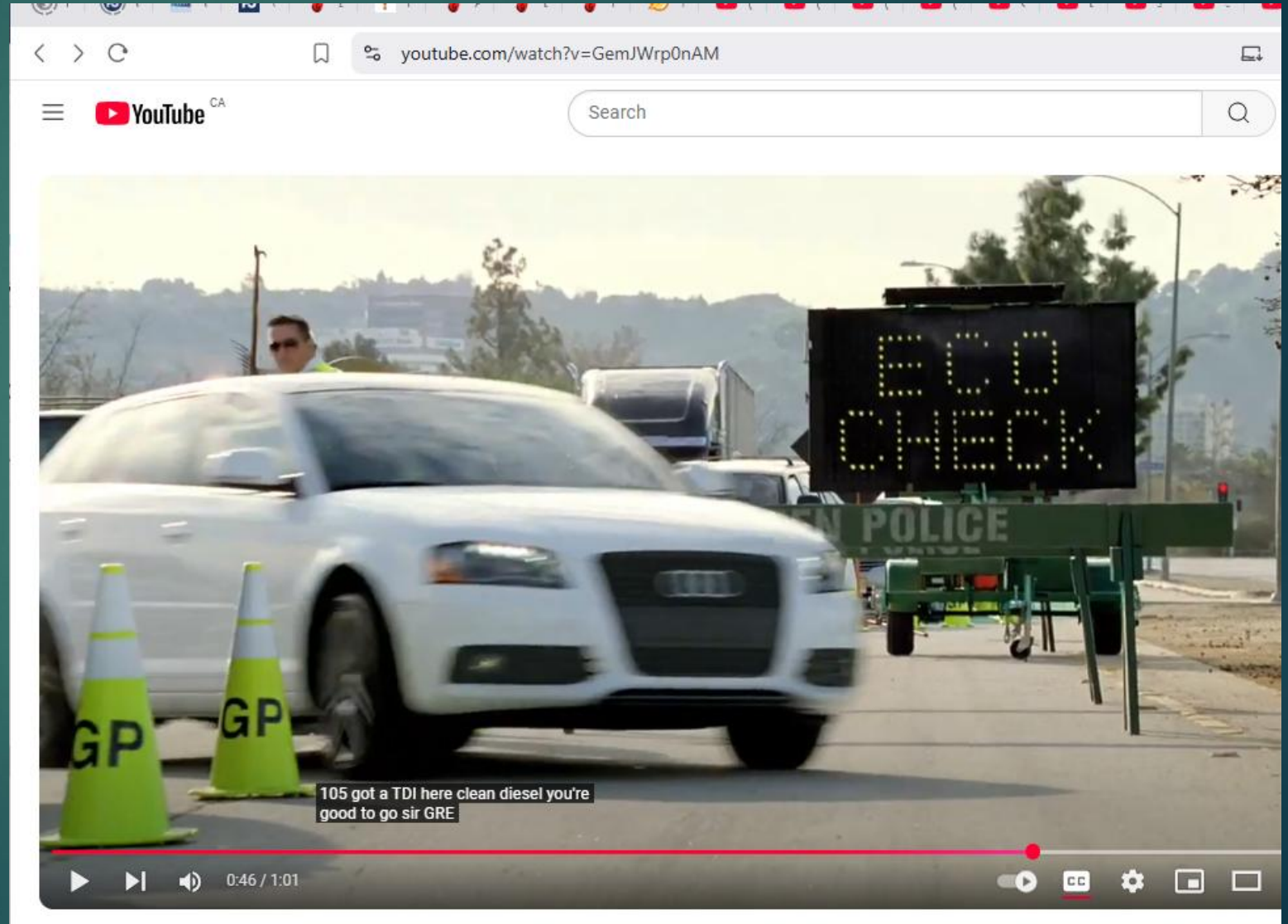


How Dieselgate is Different

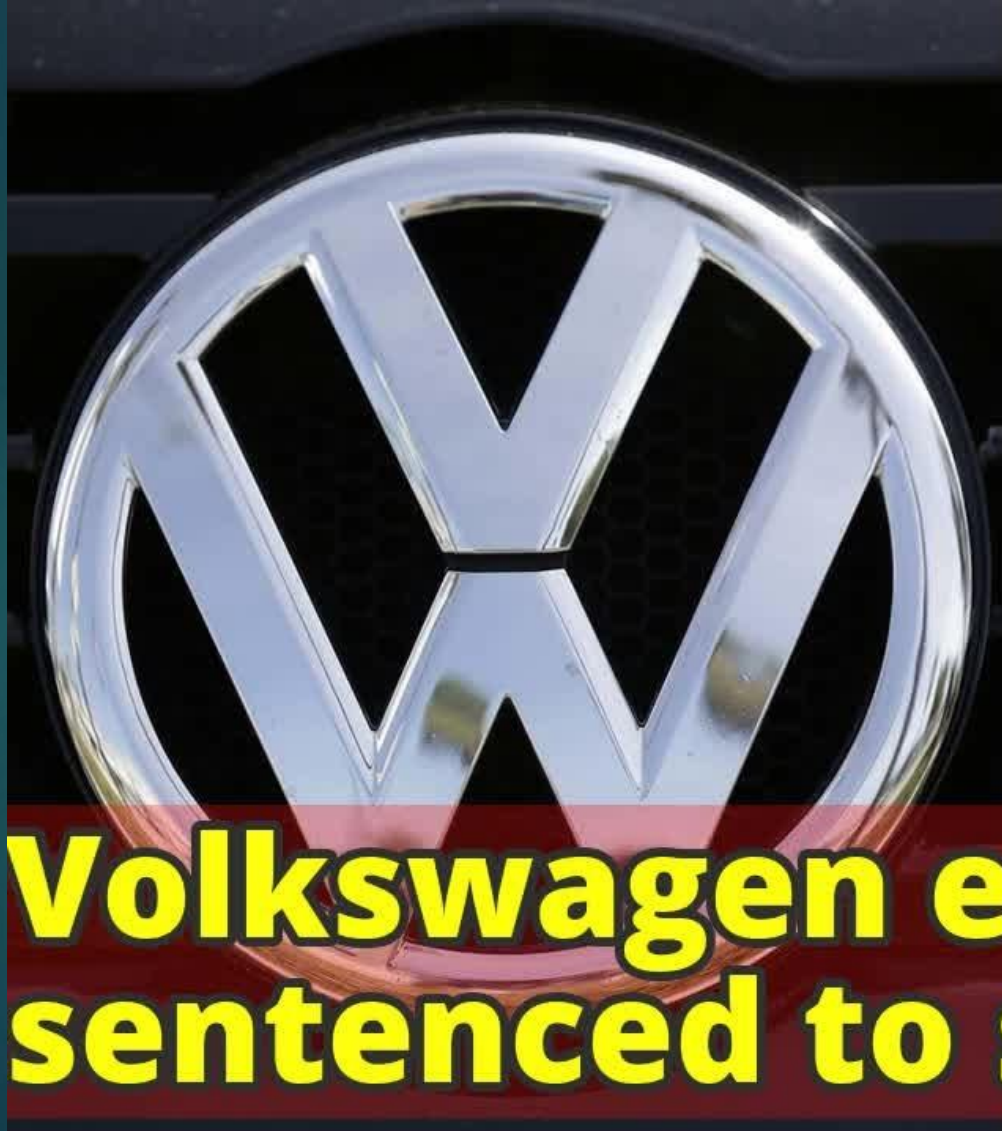
- ▶ Most engineering disasters are unintentional, resulting from
 - ▶ Errors of omission (new processes, new conditions)
 - ▶ Errors of oversight
 - ▶ Cultural pressures to proceed
- ▶ Dieselgate is different;
 - ▶ Engineers proceeded with malice aforethought to break the law
 - ▶ Intentionally misled customers and many governments
 - ▶ With a healthy bit of greenwashing

How it started – 2010 Superbowl Ad

▶ [The Green Police](#)



How it went



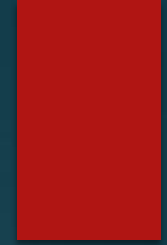
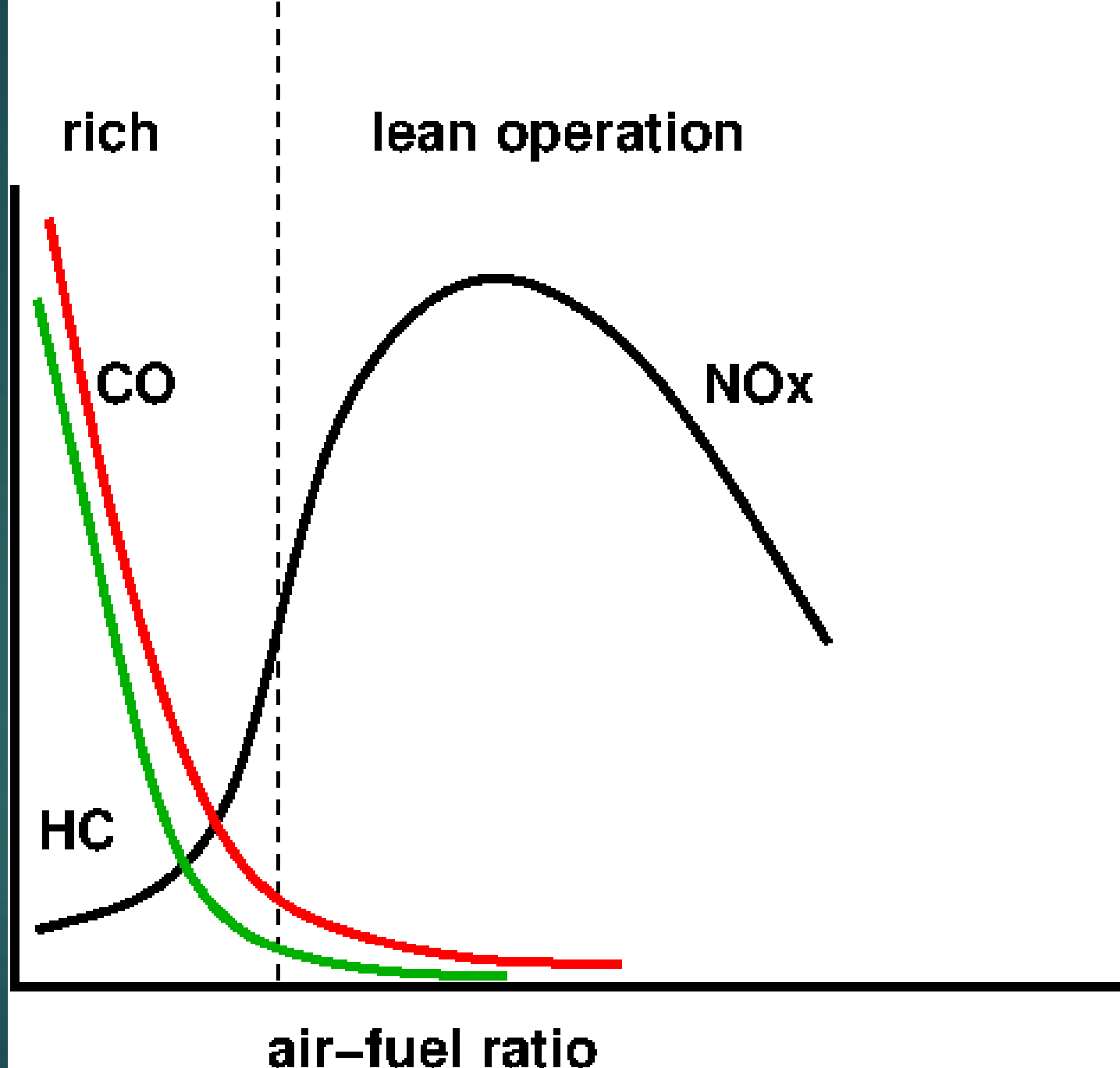
**Volkswagen executive
sentenced to seven years ...**

West Virginia University Tests

- ▶ In 2013, researchers at the **University of West Virginia** were conducting a study on the real-world emissions of diesel vehicles.
 - ▶ The team performed on road testing of the **Volkswagen Passat TDI** (Turbocharged Direct Injection) model and compared its performance against emissions standards in both laboratory and real-world conditions.
 - ▶ They used a **Portable Emissions Measurement System (PEMS)**, which allowed for the measurement of exhaust emissions while a vehicle is driven on the road.
- ▶ While the car passed laboratory testing (where emissions were found to be compliant with U.S. Environmental Protection Agency (EPA) limits), the researchers observed a significant difference in emissions when the car was driven on the road. In fact, NOx emissions were found to be 40 times higher than allowed.

West Virginia University Tests

- ▶ The researchers were puzzled by the difference in emissions, especially since the Passat had been marketed as an environmentally friendly vehicle with low emissions.
- ▶ They shared their findings with the **EPA in May 2014**, which then began its own investigation into the matter.
- ▶ On **September 18, 2015**, the **EPA** issued a formal notice of violation to **Volkswagen**, accusing the company of using illegal “defeat devices” in its diesel cars to manipulate emissions during testing.



Chemistry Behind Diesel Emissions Control

- ▶ **Nitrogen Oxides (NO_x):** NO_x forms when nitrogen in the air reacts with oxygen at high temperatures in the combustion process. This is especially a problem in diesel engines, which run at higher temperatures than gasoline engines, and have excess free oxygen available to react.



Selective Catalytic Reduction (SCR)

- ▶ Developed by Mercedes-Benz, and licensed by VW in 2005. SCR uses a catalyst and a reducing agent like urea (known as AdBlue) to convert NO_x into harmless nitrogen (N₂) and water (H₂O).
- ▶ Expensive, high maintenance and requires considerable space. Not ideal for the smaller vehicles Volkswagen tends to sell



Ammonia (NH₃) in the form of AdBlue reacts with NO_x gases to neutralize them, turning them into nitrogen and water.

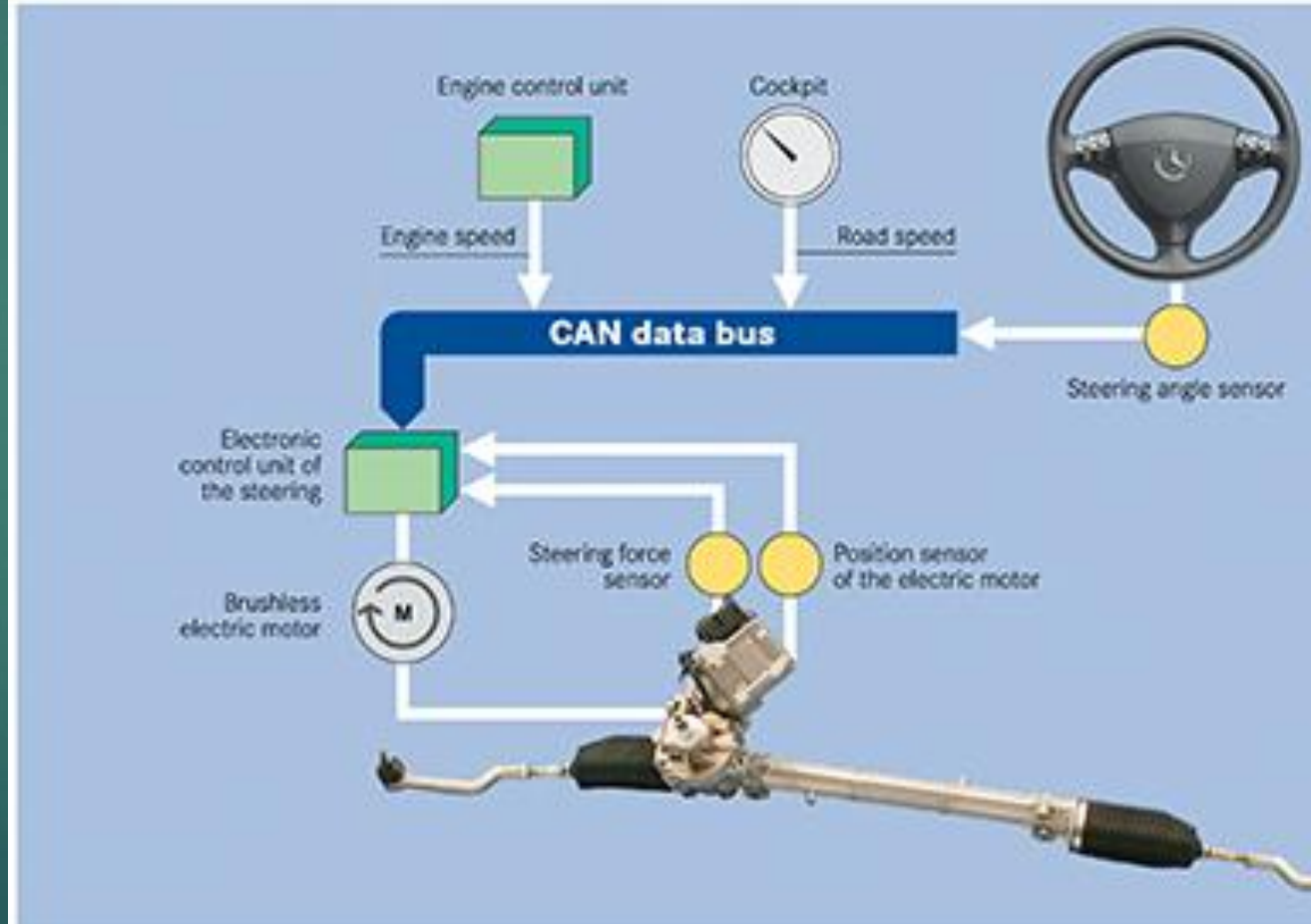
Volkswagen “Lean NOx Trap”

- ▶ Developed in-house by VW – VW cancels deal with Mercedes in 2007
- ▶ Uses zeolite traps to capture NOx
- ▶ Once trap is full, engine must run in regen, or regenerate mode to purge the trap and convert the NOx to N₂.
- ▶ Engine running in regen mode runs rich, consuming more fuel and producing carbon monoxide as a reactant to reduce NOx.
- ▶ Volkswagen touted the system as a miraculously simple, cheap and green way to control emissions – but it didn't really work, so...

Dynamic Stability Control

- ▶ Advances in technology led to the development of several safety enhancements – ABS, traction control, and **stability control**.
- ▶ Control systems for stability control required the system to know what the steering wheel was doing – leading to the development of the steering wheel angle sensor.

The electromechanical power steering system in the new Mercedes-Benz A-Class



How Volkswagen's Defeat Devices Worked

- ▶ The Cheat: VW installed software in their diesel engines that could detect when the vehicle was undergoing official emissions testing.
 - ▶ Test Mode: When the car was on a dynamometer (used for emissions tests), the steering wheel remained locked into a straight-ahead condition. The vehicle dynamics control system recognized this, and realized the vehicle was on a dynamometer and not actually being driven.
 - ▶ Real-World Driving Mode: Under normal driving conditions, the steering wheel moves continuously and the engine would revert to settings that maximized performance but reduced the activation of emission-control systems.
 - ▶ This increased fuel economy, power and reduced CO2 emissions.



Volkswagen's Response

- ▶ VW initially (~2014) insisted that the discrepancies were a technical glitch, and not a deliberate manipulation of the testing process. It took a year, and being confronted with evidence before an admission was made. After the EPA notice of violation came out on September 18, 2015, VW's CEO Martin Winterkorn resigned on September 23, 2015. Sales of VW diesel cars are halted on September 20, 2015.
- ▶ On October 8 2015, VW US CEO Michael Horn testified before a House committee that the decision to use the cheat software was made by “a couple of software engineers”. This did not go over well.
- ▶ Bosch had developed the cheat software in 2007, but it was intended for use during development, and they had explicitly warned VW not to use it to avoid emissions compliance.

What Motivated Volkswagen to Cheat?

- ▶ Tight Regulations
 - ▶ Fuel Efficiency
 - ▶ CO₂ Emissions
 - ▶ Cost of Compliance
- ▶ Financial Incentives
 - ▶ Diesel fuel was favored in Europe and taxed at a vastly lower rate
- ▶ Competitive Pressure
 - ▶ Resistance to licensing competitor developed technology

The Impact of the Cheat



- ▶ The cheat allowed millions of cars to emit much higher levels of NO_x, leading to significant air pollution, which contributes to smog, respiratory diseases, and premature deaths.

Legal and Financial Fallout

- ▶ VW faced \$30+ billion in fines, lawsuits, and compensation payments worldwide.
- ▶ The U.S. Department of Justice imposed a \$2.8 billion fine, and the company also agreed to set aside funds for environmental remediation and vehicle fixes.

Fixes and Fallout

- ▶ VW was forced to recall over 11 million affected vehicles worldwide and retrofit them to meet legal emissions standards, or in most cases *crush* them as salvage if the fix was not viable.
- ▶ Of the vehicles they fixed, the fixes resulted in lower fuel economy, lower power, and less reliability.



Lessons Learned

- ▶ Importance of Accurate Testing
 - ▶ Regulatory testing should mimic real-world conditions to prevent manufacturers from exploiting loopholes.
- ▶ Corporate Ethics
 - ▶ VW's scandal shows how not to handle a crisis, but also the consequences of perpetrating a massive fraud on multiple governments

Conclusion

- ▶ The Dieselgate scandal highlights the complexity of emissions compliance and how technology impacts how it is regulated, as well as the compromises we choose to make between various environmental impacts.