Truck Hacking:

An Experimental Analysis of the SAE J1939 Standard

10th USENIX Workshop On Offensive Technologies (WOOT'16)

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Are trucks more secure than cars?

Outline

I. Motivation
II. Prior Work
III. Technical Background
IV. Targets
V. Attacks
    A. Instrument Cluster
    B. Powertrain
VI. Tools & Test Environment
VII. Future Work
VIII. Defenses

Why Heavy Vehicles?

- Disconnect between consumer automotive and heavy vehicle industries

- Higher impact than consumer vehicles
  - Heavy vehicles physically massive
  - Expensive & hazardous cargo
  - More susceptible to bad driving conditions
  - Backbone of economy
  - And...

… there are a couple potentially affected industries…

Heavy Trucks

Buses


SCHOOL BUS
AmTran
STOP
405
NORTH SYRACUSE
CENTRAL SCHOOLS
405


Hybrid
octranspo.com
5105
9 CENTRE RIDEAU
3 RIDEAU CENTRE
CENTRE RIDEAU
OC Transpo
The Telfer MBA
The power to outperform
5105
OC Transpo

Recreational Vehicles (RVs)

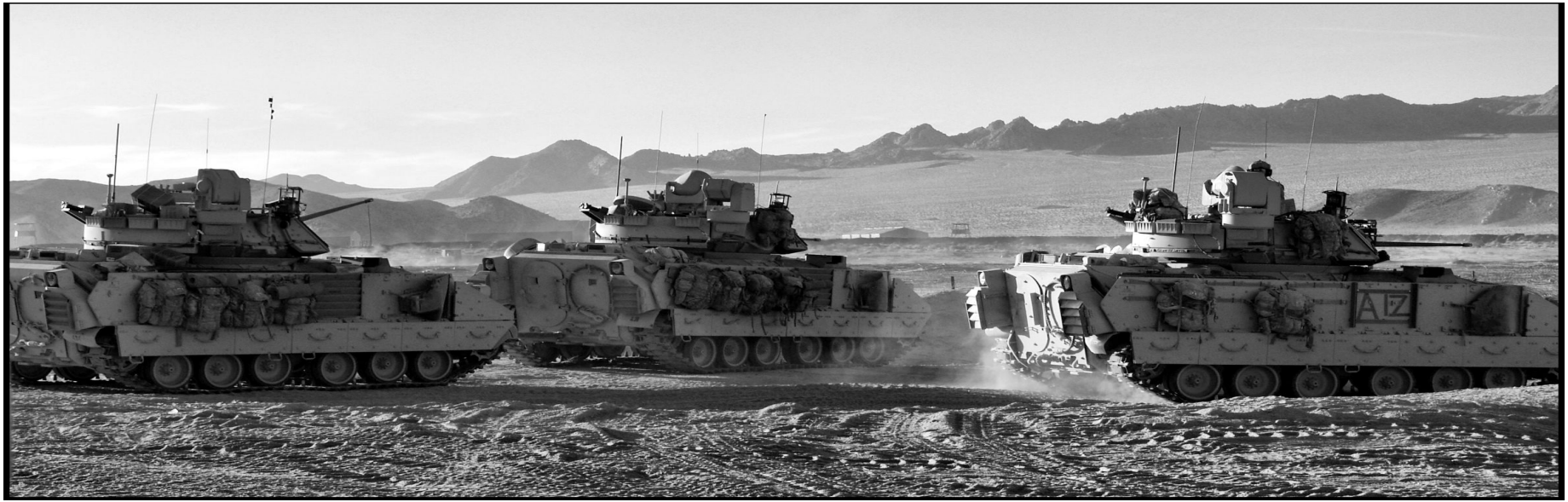
Agriculture Machinery

Forestry Machinery

Construction Vehicles

Heavy Haul & Passenger Locomotives

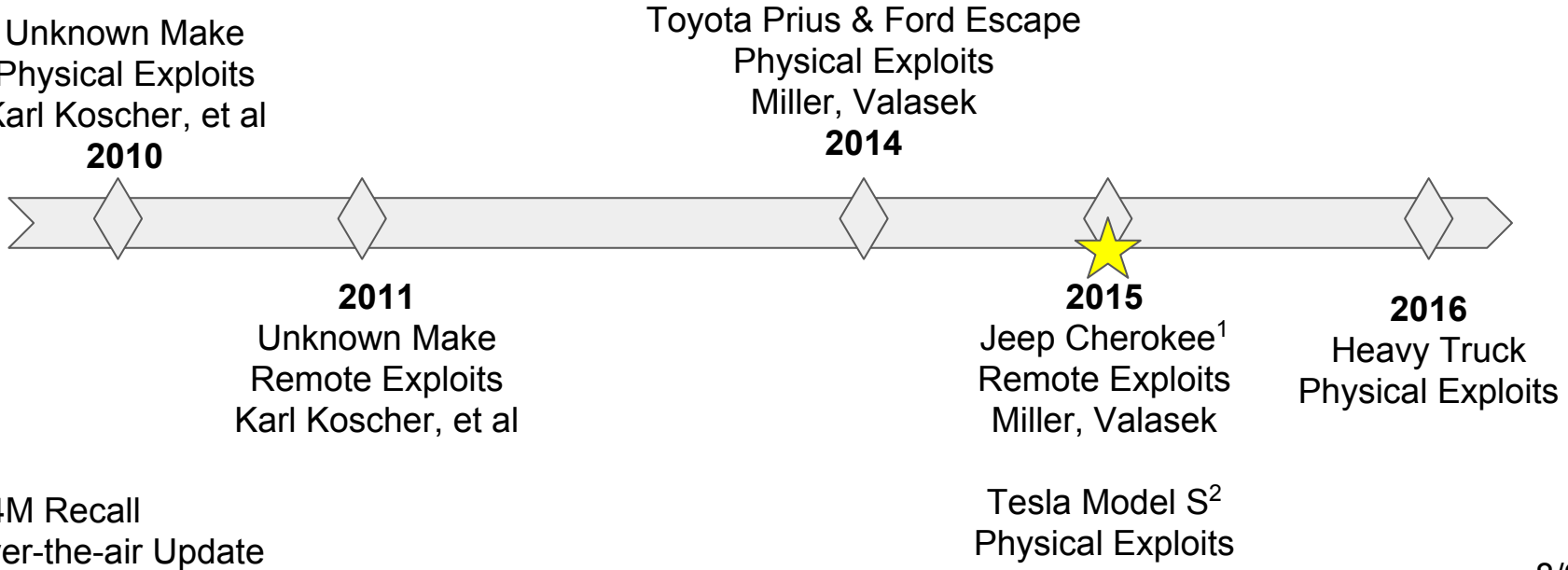
Military Vehicles (MiLCAN)



Marine Navigation Systems (NMEA2000)

Prior Work - CAN Exploits

- Consumer automobile segment scrutinized after public hacks in 2015
- Pattern of physical exploit ---> remote exploit

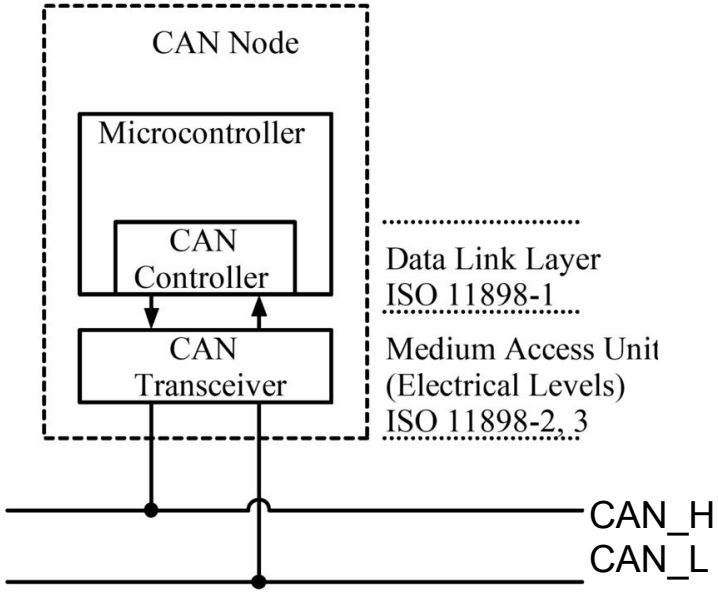


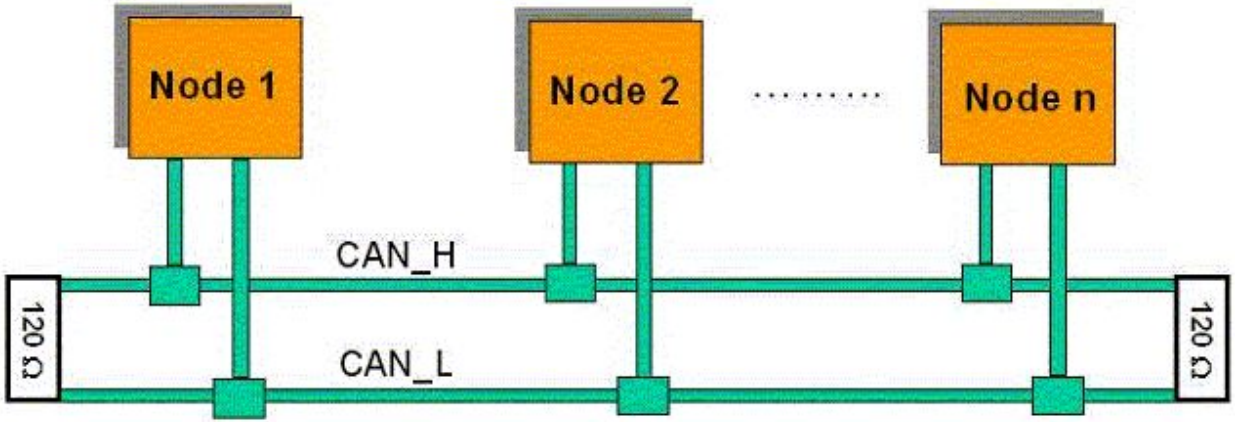
[1]1.4M Recall
[2]Over-the-air Update

So what is CAN?

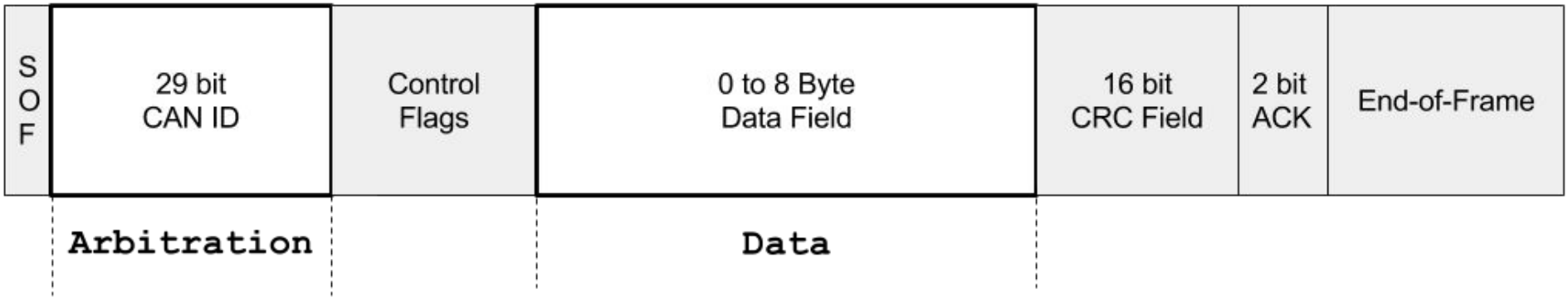
CAN Overview

- Broadcast transceiver
- Allows microcontrollers to communicate with each other
- Nodes see everything on the network





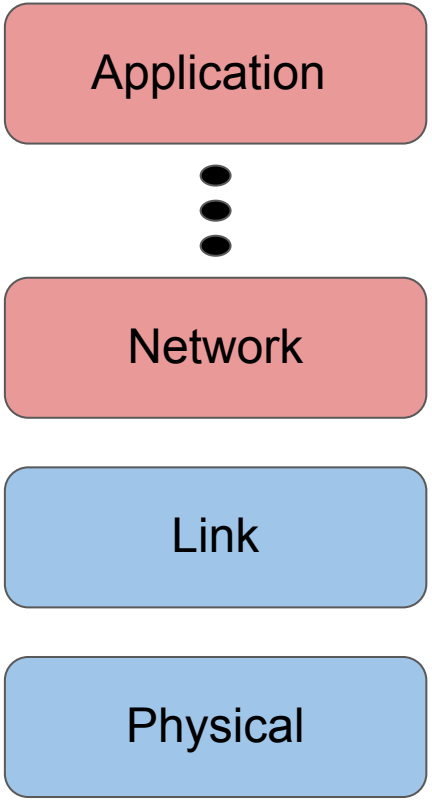
Extended CAN Frames



But what is J1939

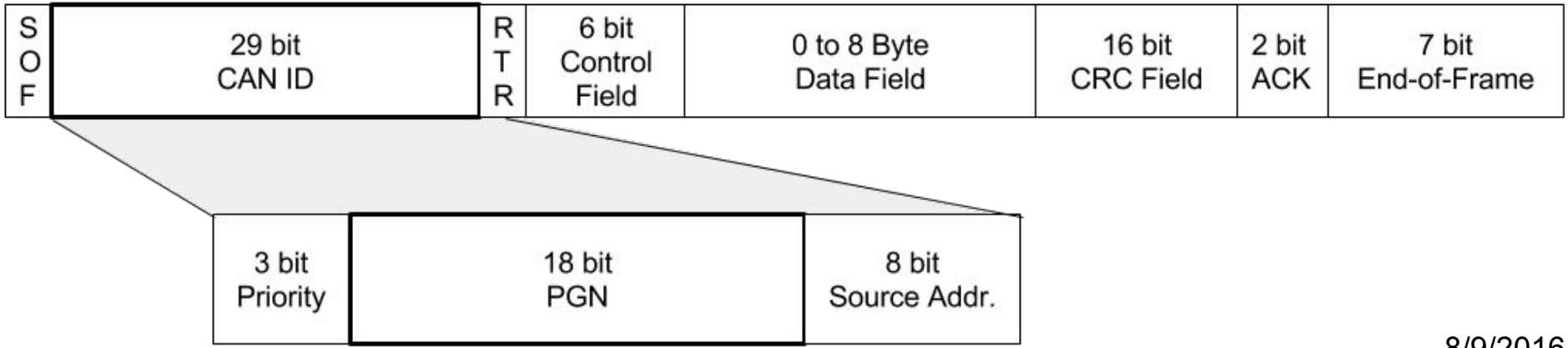
What is J1939?

- Not CAN
  - Built on top of it
  - Physical & link layer == CAN
- Defines network -> application layers
- Detailed documentation publicly available through Society of Automotive Engineers (SAE)

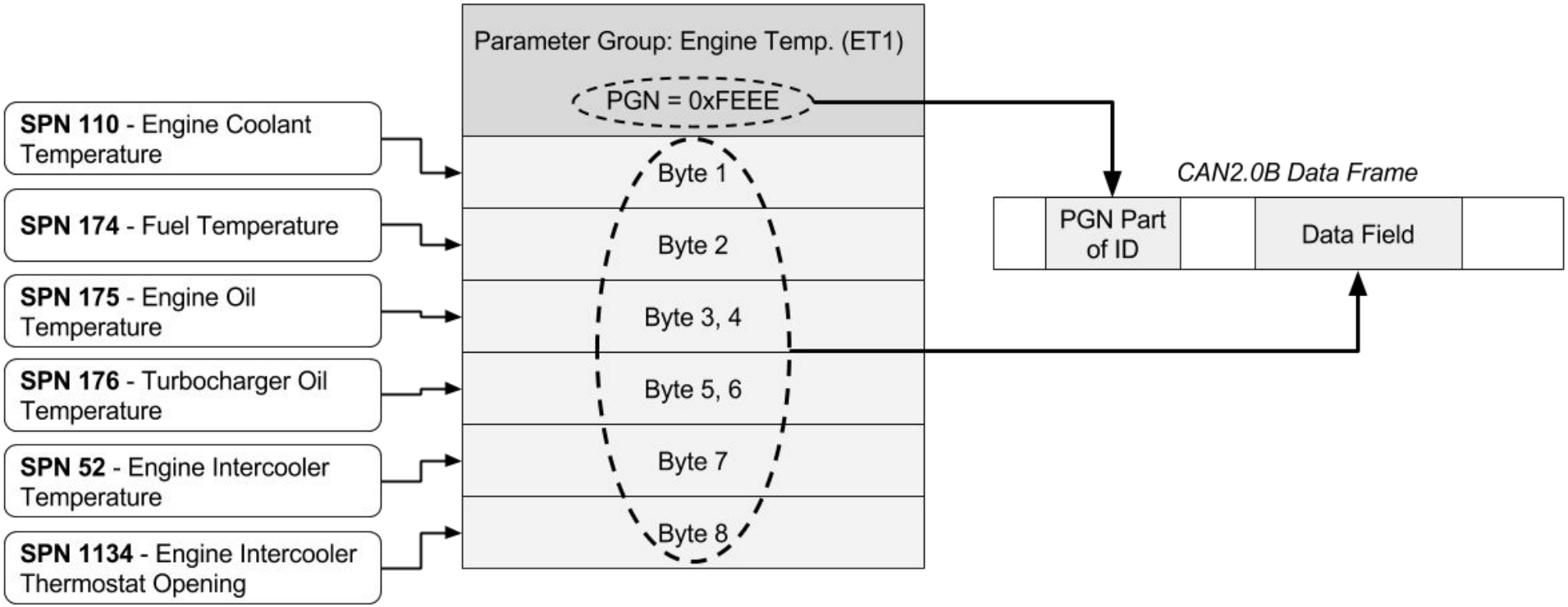


SAE J1939 Overview

- Successor to SAE J1708/J1587
  - J1708 == physical & link
  - J1587 == transport & application
- Inside the CAN ID:
  - PGN
  - SRC & DST



J1939 Overview Continued



Is security built on top?

IP/TCP + HTTP (no security) → IP/TCP + HTTPS (yay security!)

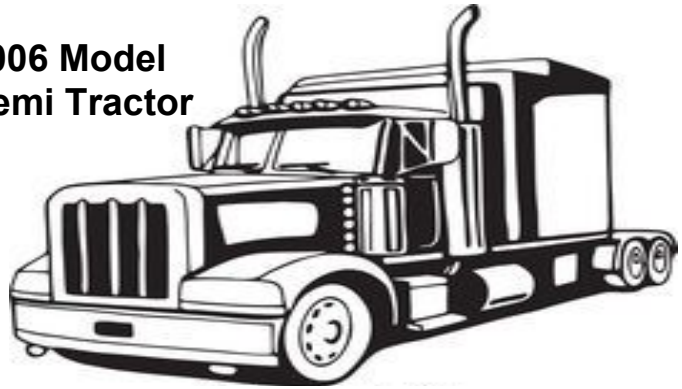
:D

CAN + Car app. layer (no security) → CAN + J1939 (security???)

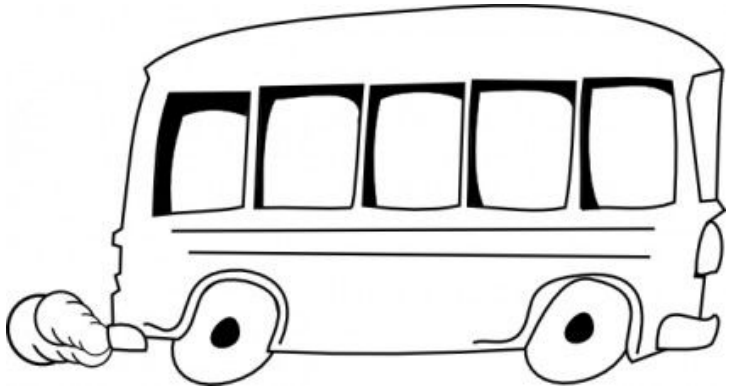
¯_(ツ)_/¯

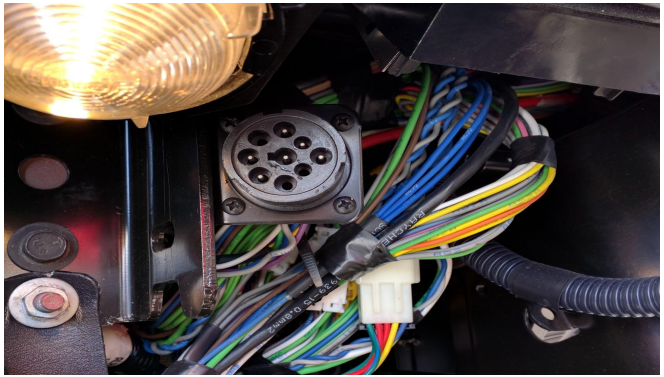
Our Targets

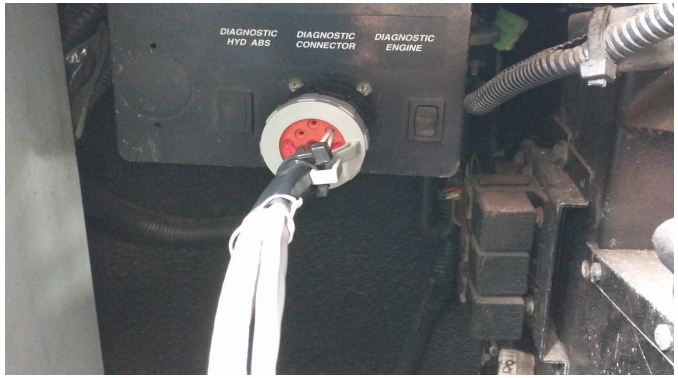
2006 Model
Semi Tractor



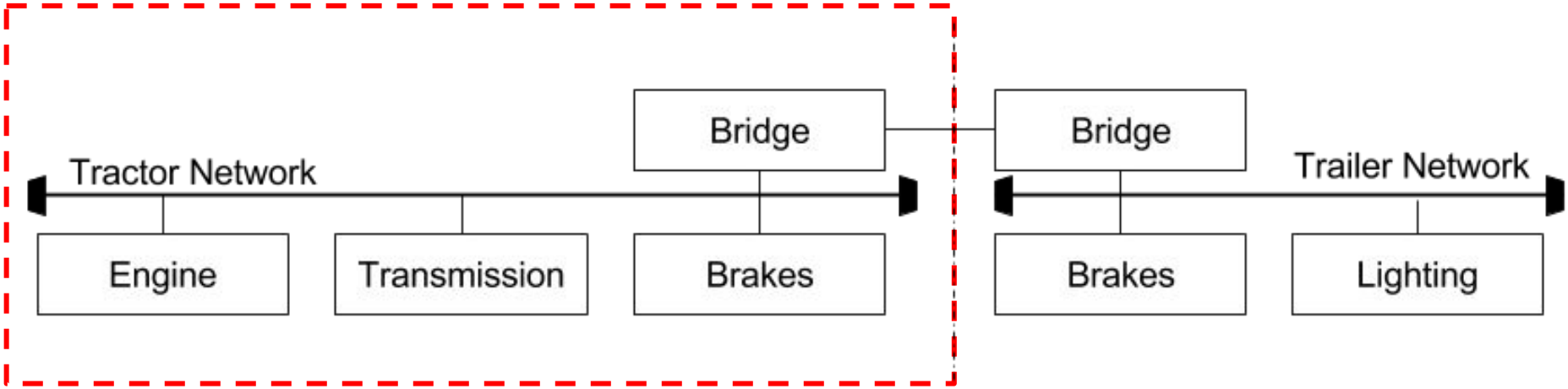
2001 Model School Bus







Typical Heavy Truck Network



Instrument Cluster Attack

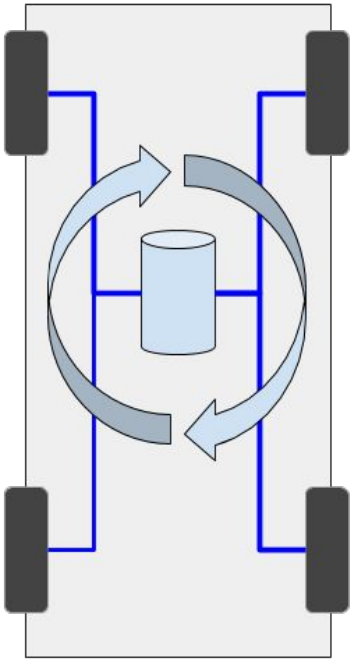
Experiment Progression:

Packet snooping & packet injection

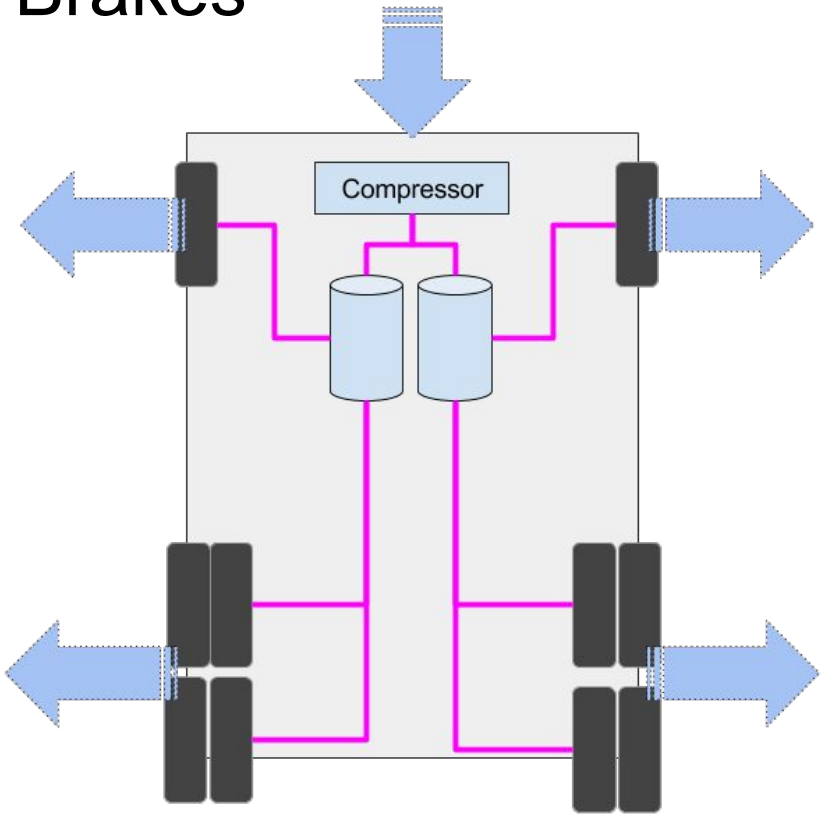
Heavily relied on by vehicle operators


10
15
20
25
30
35
40
0 RPM
5
25
35
45
55
65
75
85
0

Hydraulic & Pneumatic Brakes



Hydraulic Fluid-based Brakes



Pneumatic Brakes


0 RPM
X 100
MPH
KM/H
17
FAULTS

Powertrain Attack

Experiment progression:

Packet recording, replay attack, packet injection script

Powertrain Attack

Part 2: Electric Boogaloo

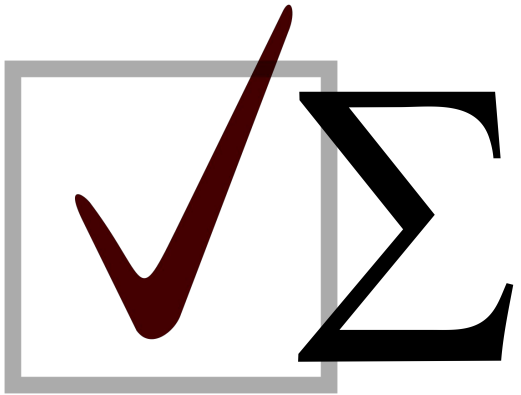
Unmodified attack from 2006 model year truck on 2001 model year school bus

8/9/2016

A very powerful message

- Single PGN for all these attacks
  - Remove driver's ability to input via accel. pedal
  - Disable engine brake
  - Command high and low RPM values

- Largest hurdle: implementing checksum
  - No RE required... checksum is public as well!



Making It Happen

Tools

- PEAK USB-PCAN
  - Data Collection
  - Packet Injection
  - Python APIs
    - Fuzzing Script
- Vector CANoe
  - Data Collection
  - Packet Injection
  - CAPL Scripting language
- Diagnostic Tool
  - ABS valve modulation
  - Engine cylinder cutoff

Test Environment

1. Idle Truck
    - Initial data gathering
    - Attack development
2. Public Roads
    - Data gathering in motion
3. MCity
    - Attacks while in motion

Looking towards the future...

Remote Compromises?

- Telematic Gateway Unit (TGU)
  - Cellular, Bluetooth, CAN (J1939) interfaces
  - C4MAX - Telnet port open by default

Spain	864
Chile	187
Morocco	138
United States	118
Germany	56

C4MAX units on public IP space

- Fleet Management Systems
  - Ubiquitous in several industries
  - GPS data, CAN bus access

Further Areas of Interest

- Diagnostics tool emulation
- More safety critical attacks
- Malicious trailers

So Many Activities...

- Autonomous Semi Trucks
- Connected Vehicles
  - V2V / V2I
- Cargo Ships
- Aircraft

Vulnerability Mitigation Techniques

- Securing the Vehicle Bus:
  - Network Segregation & Isolation
  - Intrusion Detection Systems
  - Message Ownership Verification
  - Message Authentication
  - Strict Message Timing Detection
- Best Practices from ‘traditional’ security domain:
  - Passwords on externally facing devices
  - Vendor Review

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