Commercial Transportation: Truck Hacking

NMFTA

National Motor Freight
Traffic Association, Inc.

Agenda

- 50 mins
- What is CT? Why does it matter?
- About
  - Trucks
  - Trailers
  - Maintenance
  - Distribution centers
  - Intermodal
- Vehicle Networks
  - J1939
  - J1708/J1587
  - J2497
- ‘Hacking’
  - CAN Attack Methods
  - What can you do?
  - What needs more?
  - Other ‘Hacking’
- Get Involved
- Tools
  - Examples
  - More
- Closing
  - Review
  - Call for Collaboration

About Me

- **Ben Gardiner**
  - Senior Cybersecurity Research Engineer contractor
  - Experience: Embedded systems dev, RE
  - CyberTruck™ Challenge Instructor
  - DC HHV & CHV volunteer
  - SAE volunteer

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About Commercial Transportation

What is Commercial Transportation (CT)?

- All transportation of goods or people for business purposes (a large topic)

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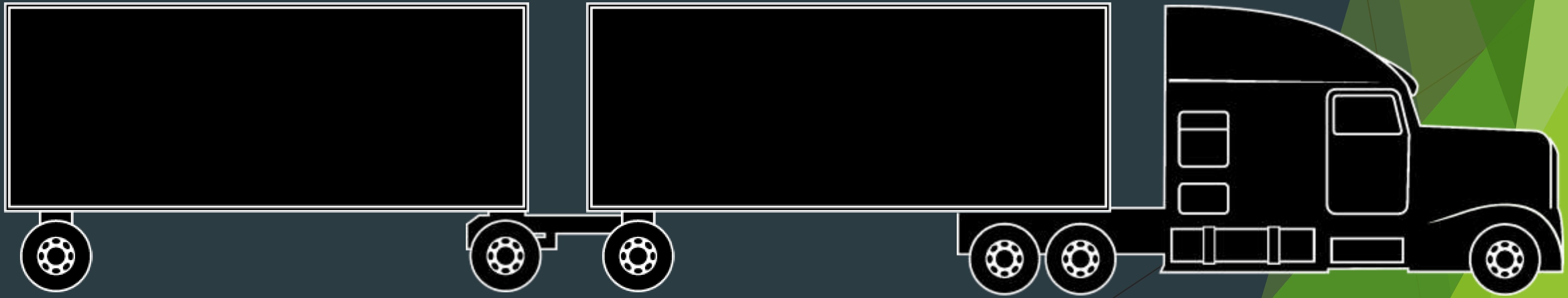
Why does CT Security Matter (Trucking Specifically)?

- "If you bought it, it came on a truck"
- Truck problems are big problems for society. c.f. "A week without Truck Transport" at iru.org
- Safety issues with Trucks are all our Issues



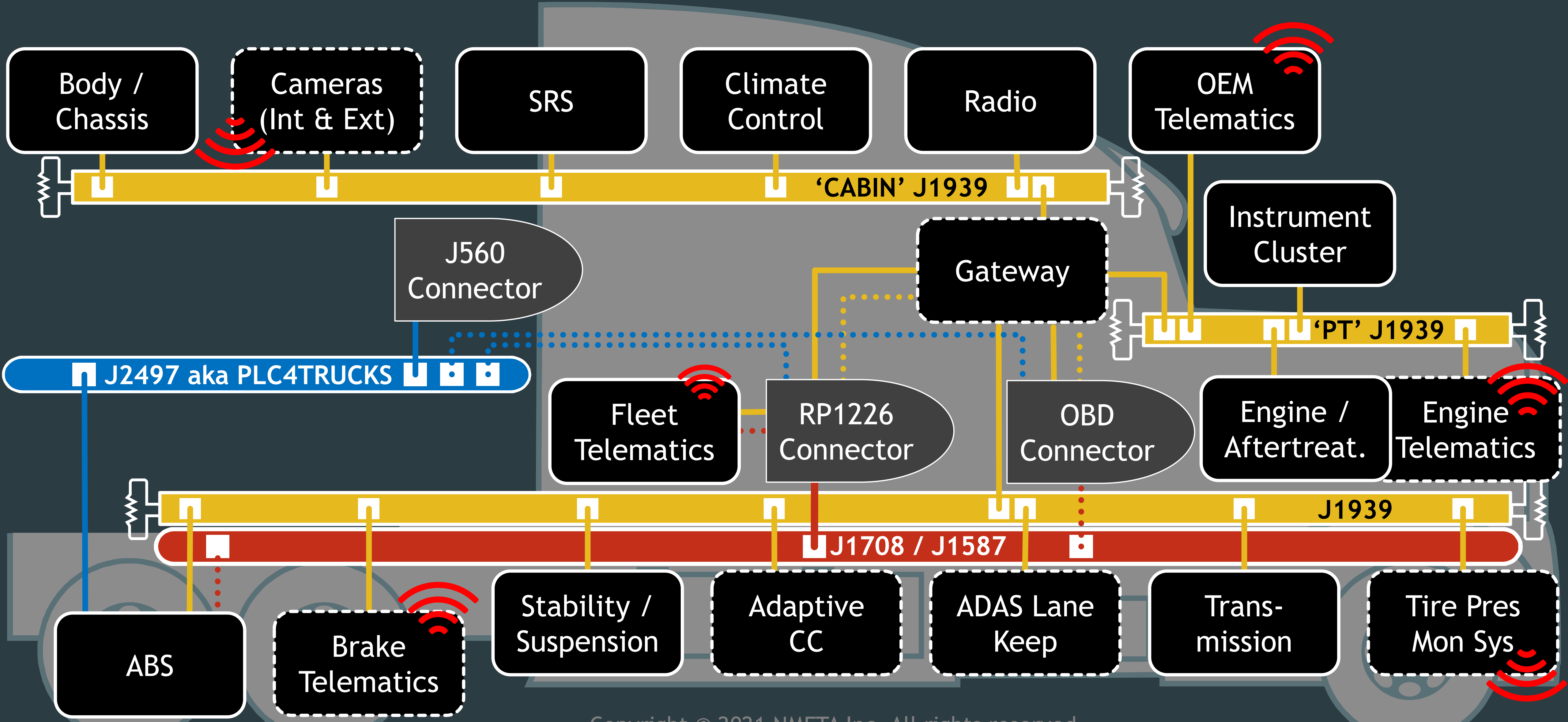
Why does CT Security Matter (All Modes)?

- The global supply chain links all of us
- All modes share technologies
  - e.g. the CanBusHack de-rate disablement abuse is applicable across modes [https://ioactive.com/guest-urban-johnson-nmfta/]

CC BY Vectors Market

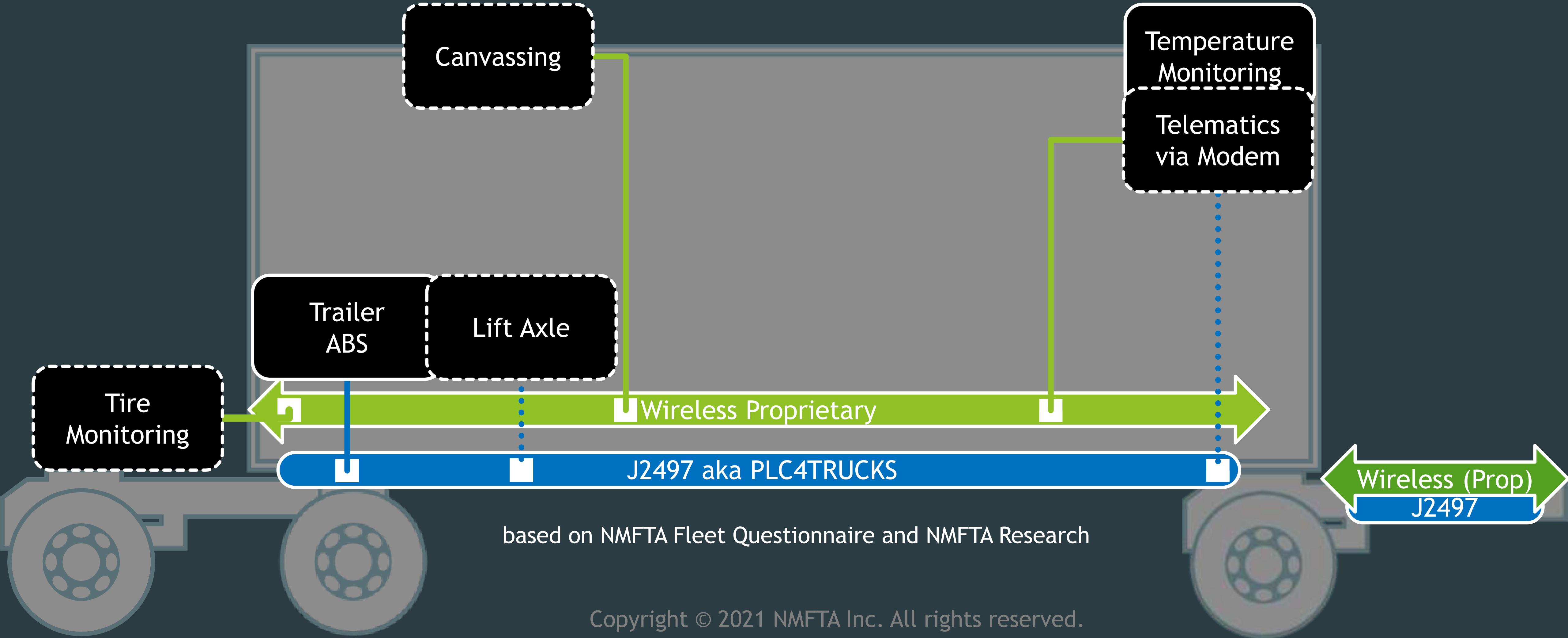
About Trucks

aka Tractors *aka* Power Units aka ‘The things that roll’.
If it isn’t moving then the fleet is losing money.



About Trucking: Trailers

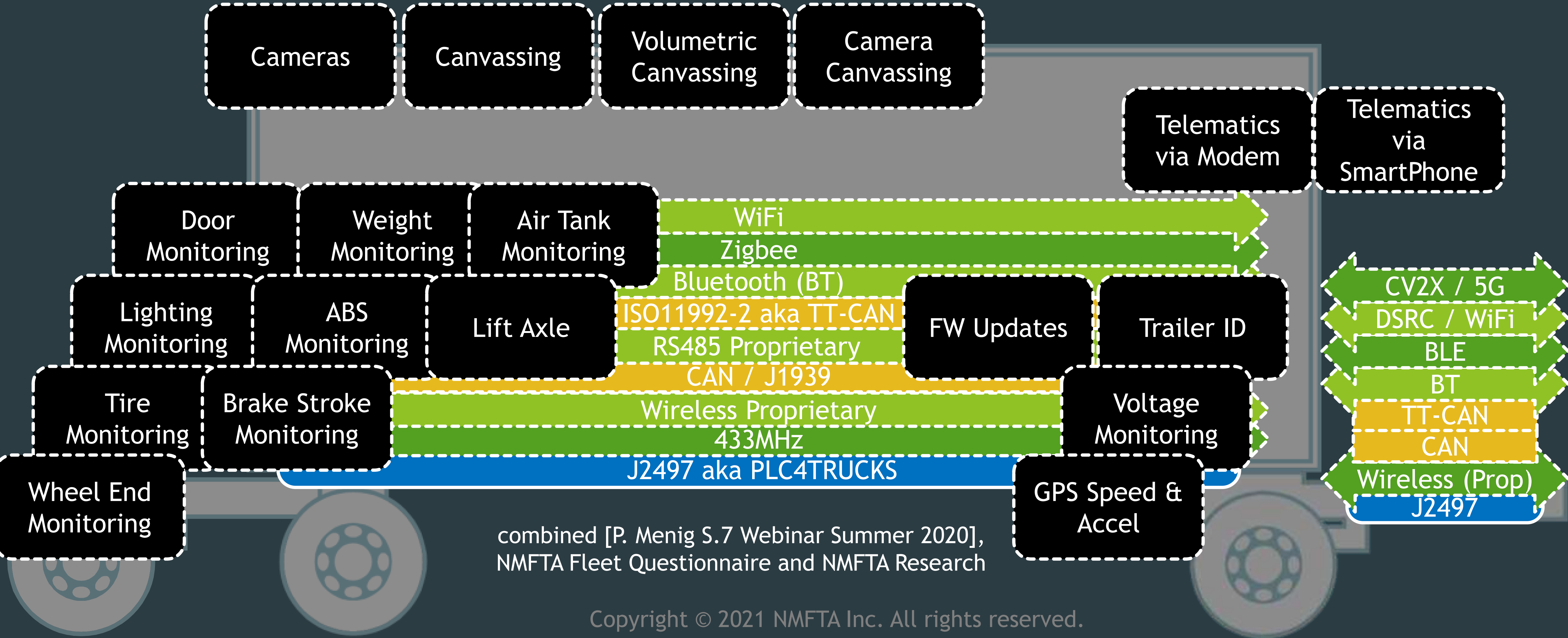
- The other things that roll
- Outnumber tractors (in North America)
- Many features today



based on NMFTA Fleet Questionnaire and NMFTA Research

About Trucking: Trailers

- And more growing everyday



combined [P. Menig S.7 Webinar Summer 2020], NMFTA Fleet Questionnaire and NMFTA Research

About Trucking: Maintenance

CC BY Oksana Latysheva, UA

- Commercial Vehicles are owned for and by commercial motor freight carriers and leasing companies (e.g. Penske).

The fleets protect their investments with preventative maintenance.

- Tractors spend more time in a service center connected to diagnostics than any passenger car [haystack and sixvolts, *Cheap Tools for Hacking Heavy Trucks*]
- Diagnostics software is authorized to do lots of very powerful things including [Burakova, Hass, Millar, and Weimerskirch, *Truck Hacking: An Experimental Analysis of the SAE J1939 Standard*]:
  - disabling engine cylinders and
  - cycling ABS pressure valves
- Most diagnostics software is low-quality windows software

About Trucking: Distribution Centers

- Fleets make extensive use of distribution or service centers.
  - e.g. Less Than Truckload (LTL) -> ‘*terminals*’
- Trailers spend a lot of time here: either docked or parked
- Distribution centers have:
  - A lot of technology
  - (and a lot of attack surface)
  - that’s a whole other topic

About Trucking: Intermodal

- Some fleets make extensive use of *intermodal* aka ‘shipping containers’ which were designed to be able to go from the deck of a ship to a train or tractor-trailer and vice-versa
  - intermodal also includes the interchange of trailers between trucks and railroads, and trucks and barges or ships
- Some intermodal containers have networking interconnects to the vehicle networks on which they are being carried
- Many intermodal containers have their own telematics modems. [https://seanews.co.uk/features/a-world-where-all-shipping-containers-are-smart-and-connected/]

CC BY Joedamadman

CC BY Doug Wertman

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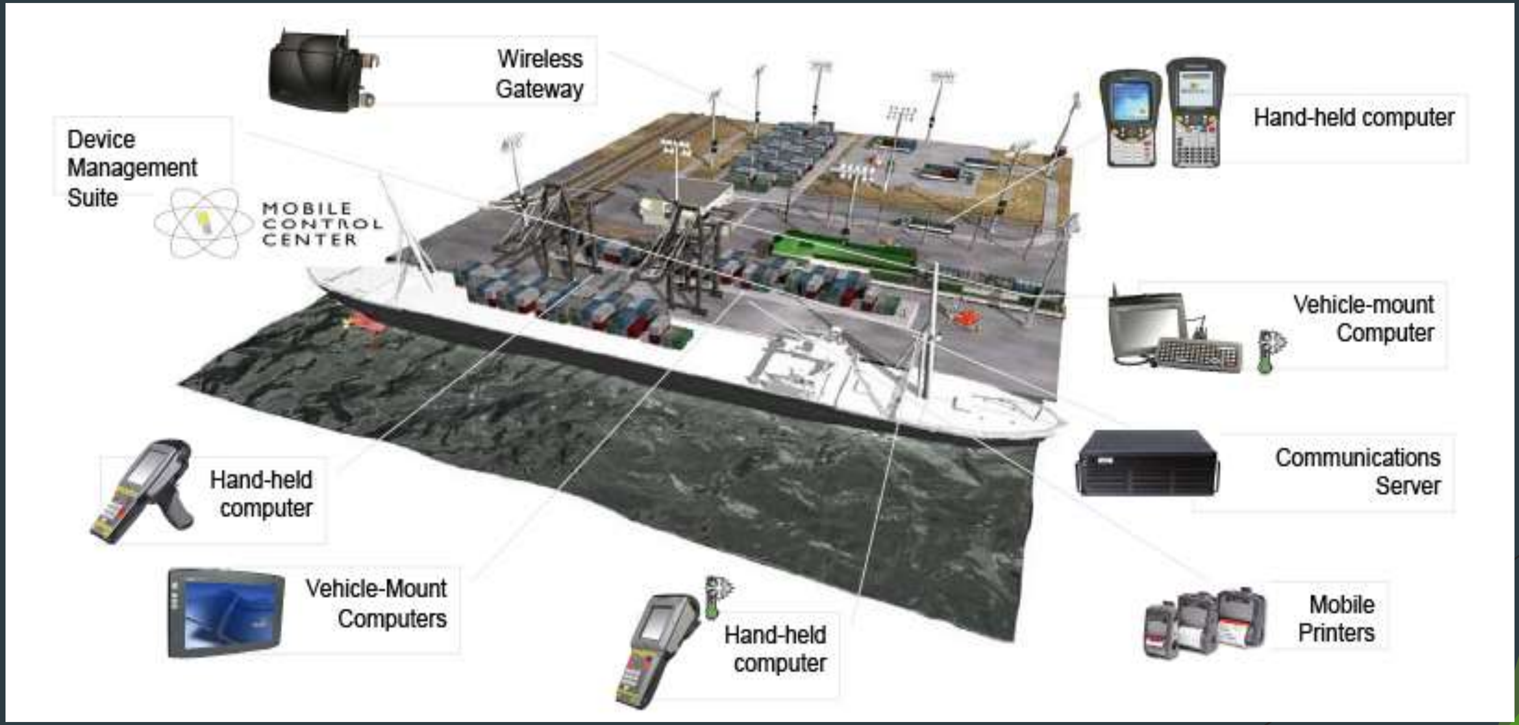
About the Other Modes

- The modes share technologies
  - e.g. Ships use J1939 -- there it is called NMEA
  - e.g. Trains use J1939 too… Where there’s a diesel engine there is J1939
- Also: all of the modes are bolting-on "Internet of Things" (IoT) ‘stuff’

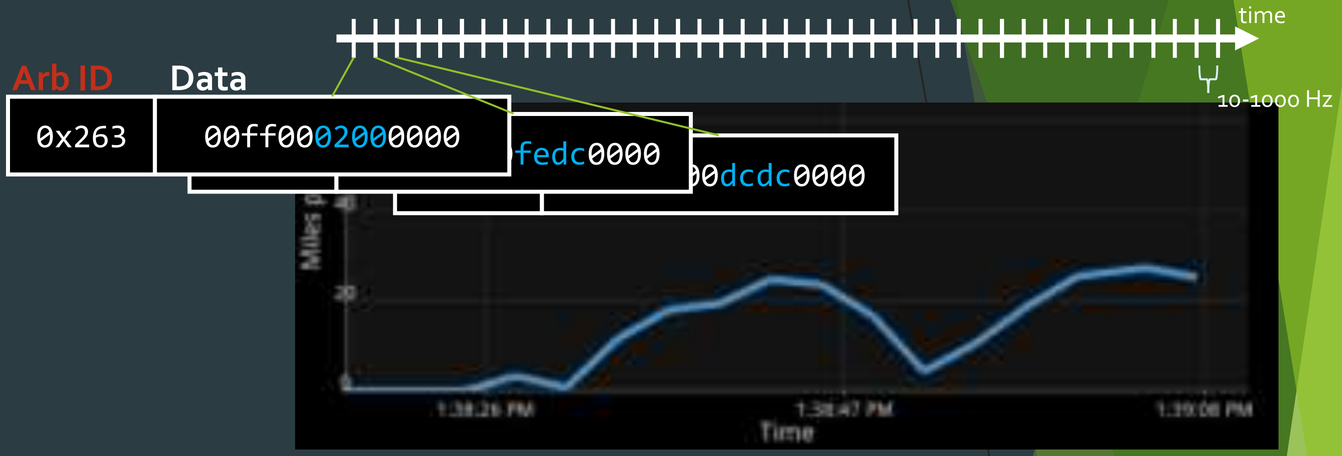


from: http://www.teamliftss.com/workshop/port-intermodal-solutions/

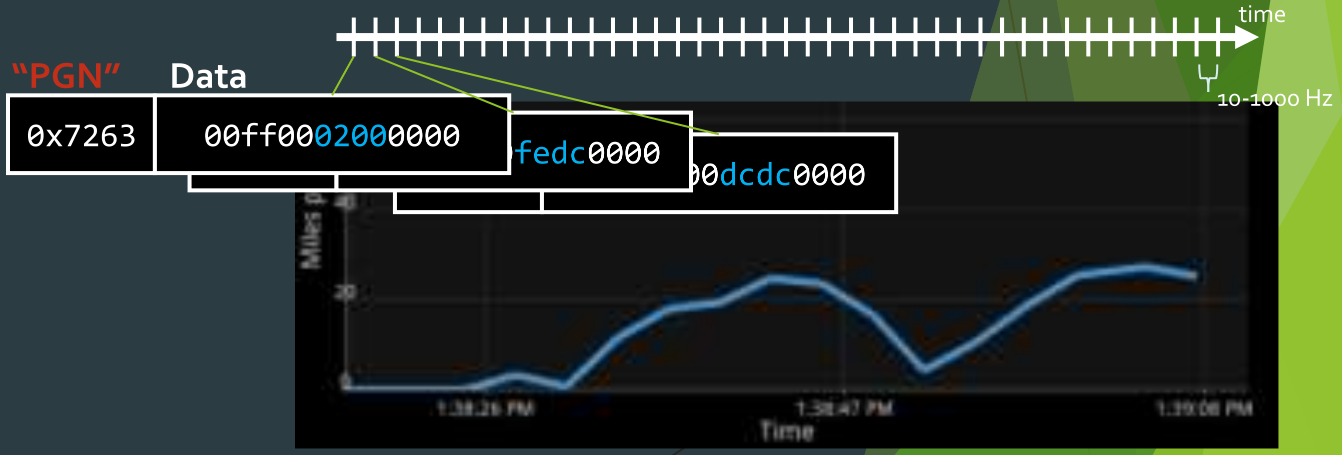
Truck Vehicle Networks: J1939

J1939 in relation to CAN in Passenger Cars

- Both: encoding time-varying signals into bitfield locations and diagnostics
- Passenger cars:
  1. *proprietary* Arbitration ID,
  2. *proprietary* bitfield locations,
  3. standard diagnostics (mostly)
- J1939:
  1. standard PGNs (mostly),
  2. standard SPNs (mostly),
  3. *proprietary* diagnostics



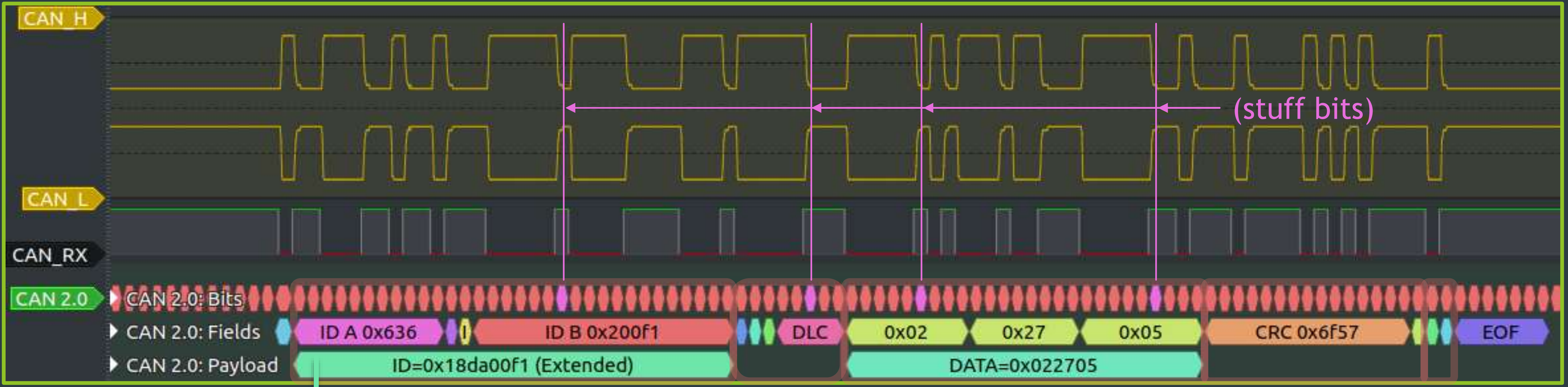
Ford OpenXC Platform 2017



Ford OpenXC Platform 2017

J1939 Specifics: CAN Frames

sigrok with kentindell/canhack can2 decoder:



29bit Arbitration ID

Control Field

Data Field (8byte max)

Error Checking

ACK

	ID A											ID B																	
Arb ID bits (host):	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
for unicast:						PGN>>8								Dest Addr															
for bcast:						PGN																							
for all:	priority			res	page																	Source Addr							

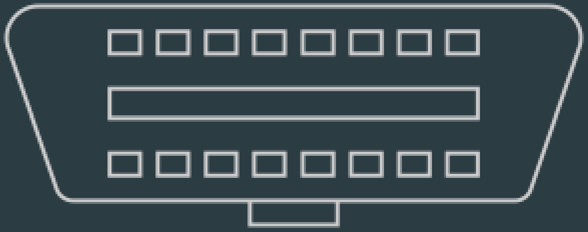
J1939 Features

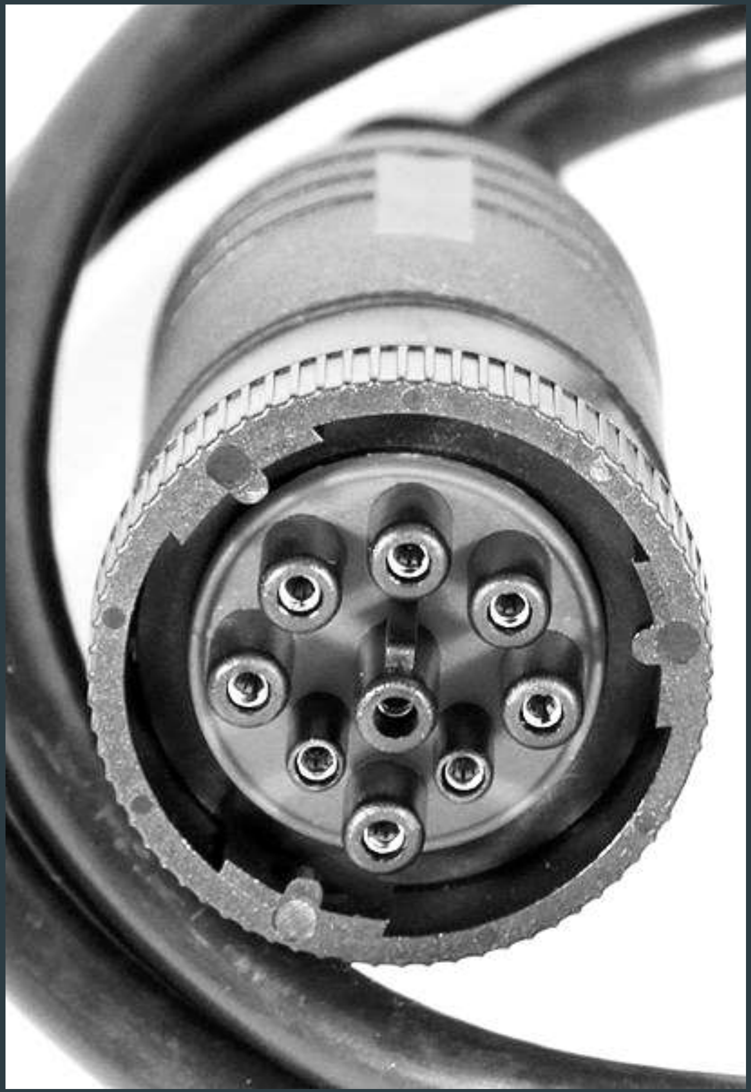
- Both unicast (PGNs < 0xF000) & broadcast (>= 0xF000)
- Transport fragmentation and reassembly (PGNs 0xEC00 and 0xEB00)
- Address claiming (0xEE00)
- Request of PGNs (0xEA00)
- Proprietary messages:
  - destination-specific (propA 0xEF00, propA2 0x1EF00) and
  - broadcast (propB0 0xFF00-0xFFFF, propB1 0x1FF00-0x1FFFF)
- Dump, reconfigure, reflash (☜‘the fun stuff’) is all protected by a challenge-response system called *Seed-Key Exchange*
  - over ISO 15765-2 aka *ISO-TP* for UDS (0xDA00)

- For more details see Hannah Silva’s CyberTruck Challenge^{TM} 2021 Training www.cybertruckchallenge.org/wp-content/uploads/2021/08/Truck-Networks-Print.pdf

Finding J1939 (1/6)

- In-cab or On-Board Diagnostics J1939 connector
- Black or Green
- Some OEMs use the passcar OBD-II connector.





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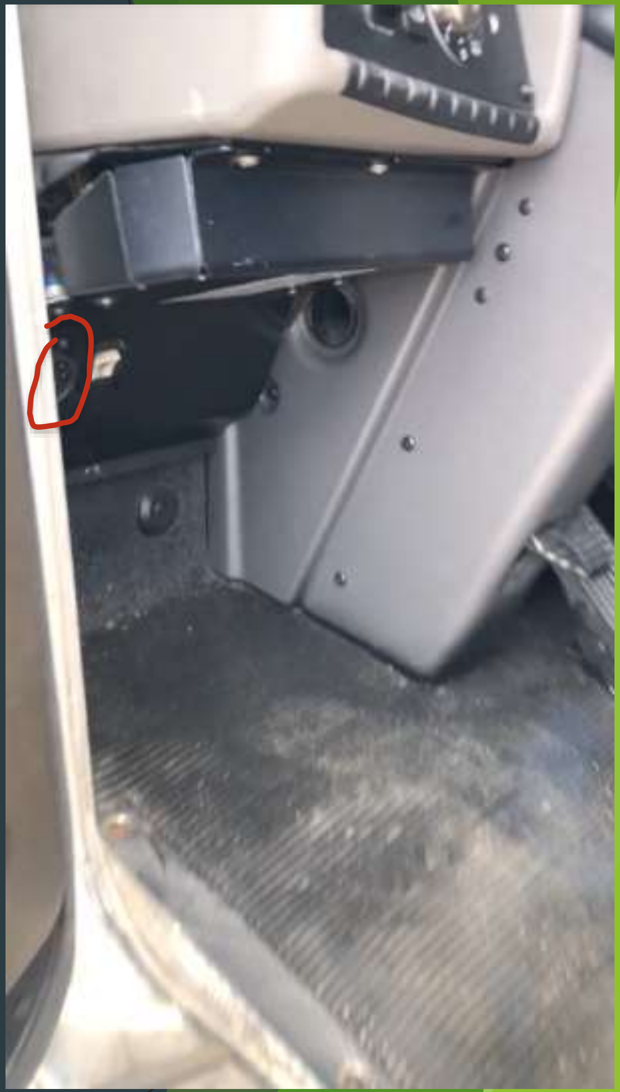
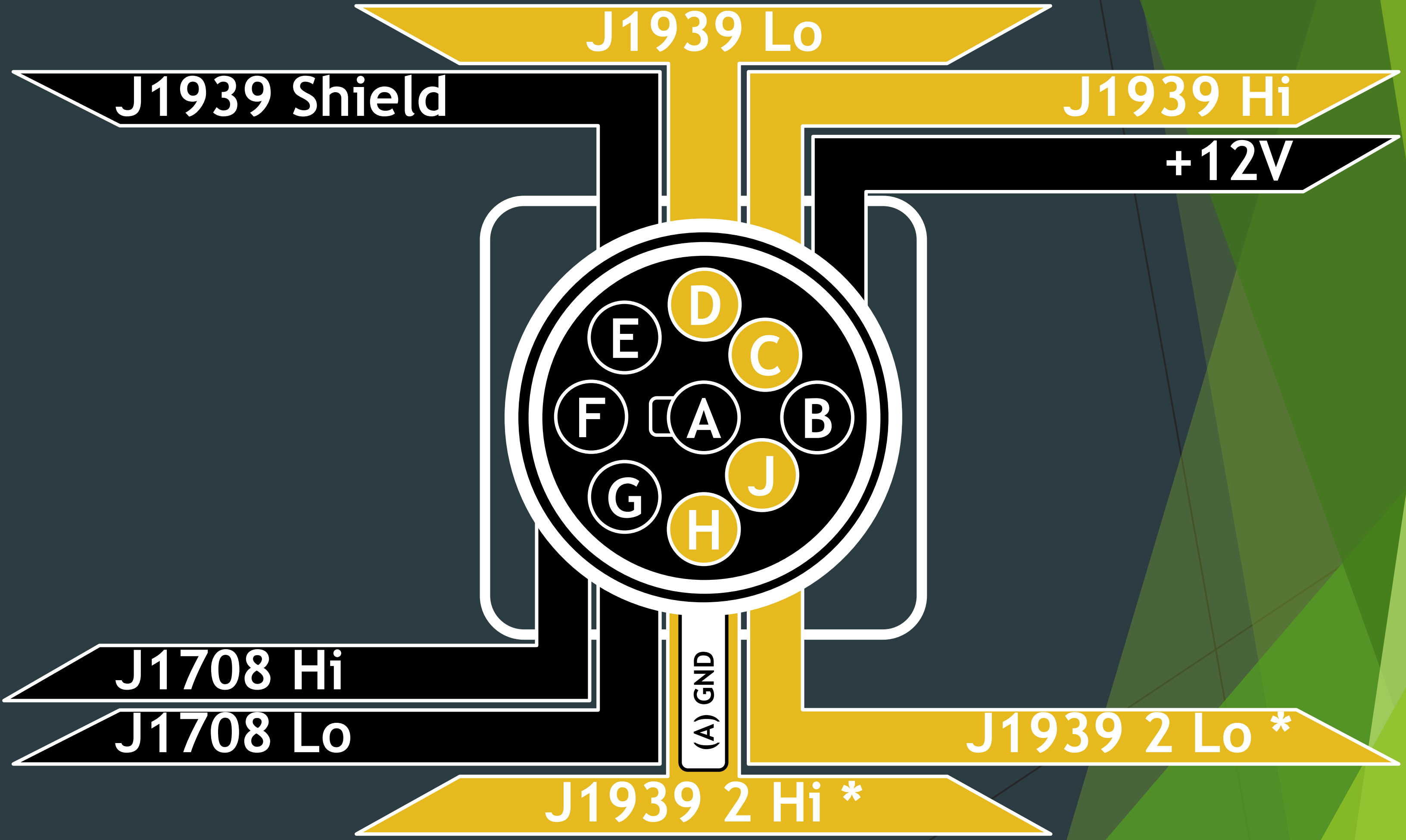


Dr. Jeremy Daily

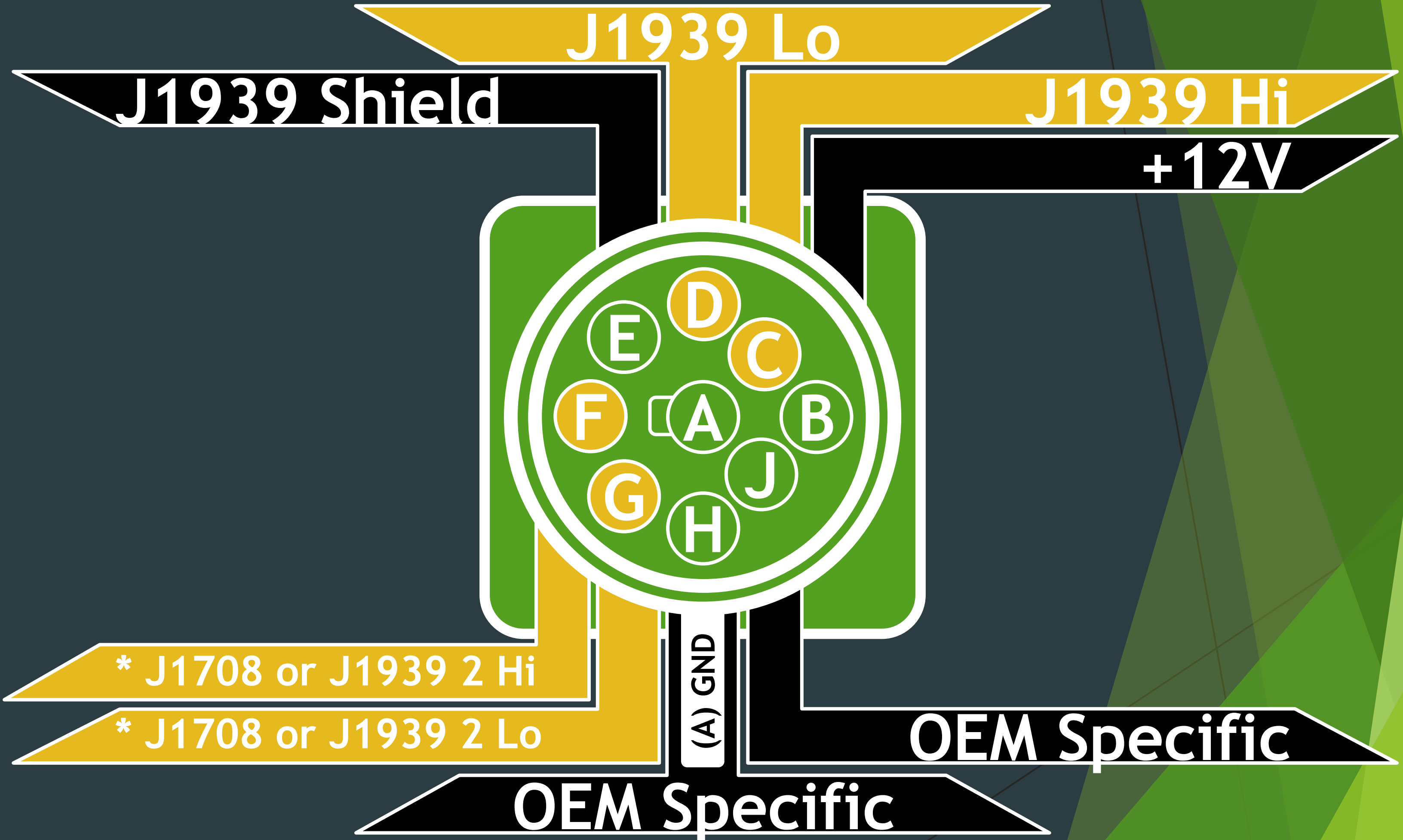
Finding J1939 (2/6)

- On black socket
- (* means optional)



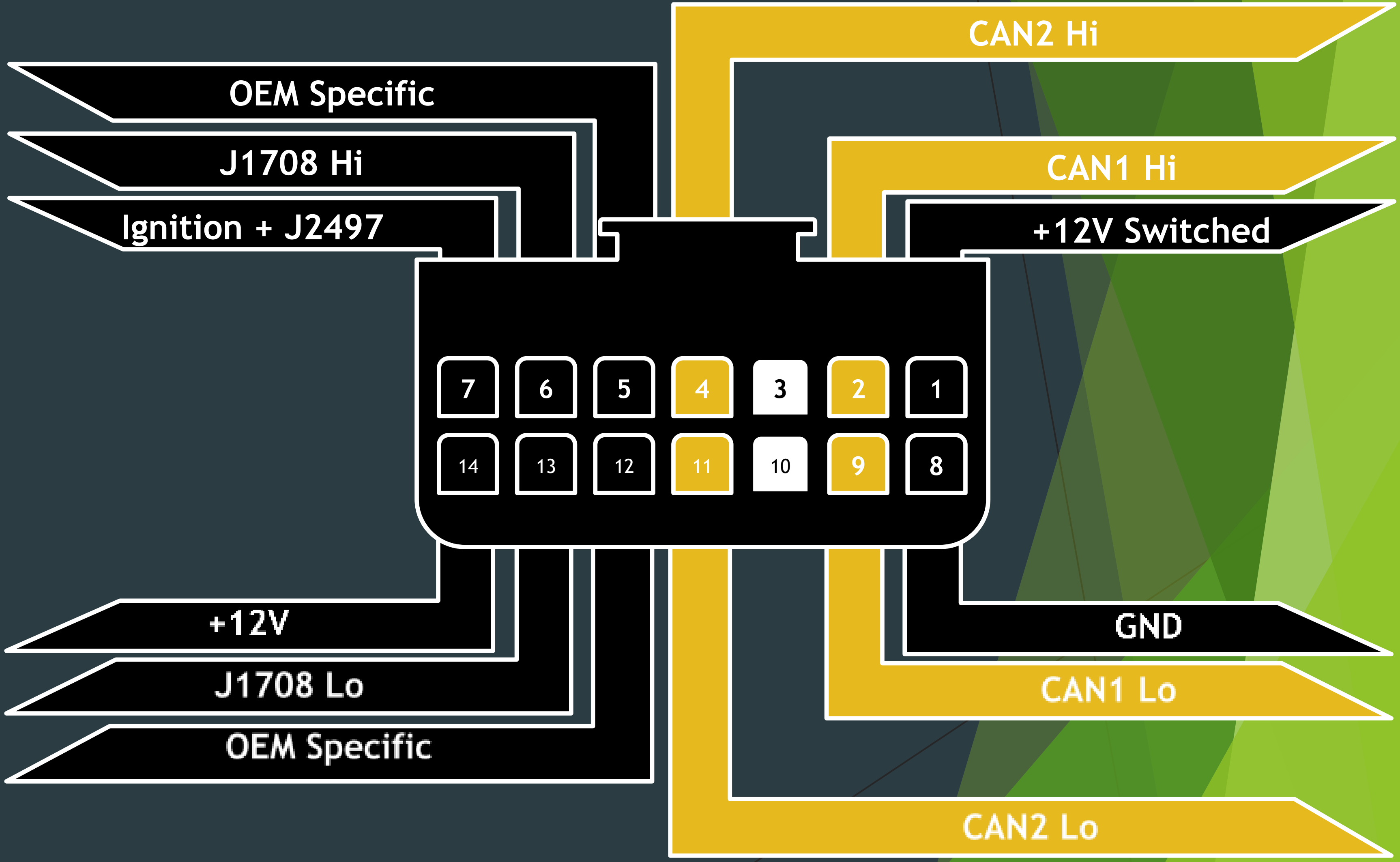
Finding J1939 (3/6)

- On green socket



Finding J1939 (4/6)

- On the RP1226 (Aftermarket/ Telematics) Connector
- Found behind dash or in berth



Finding J1939 (5/6)

- Other wires in the truck too…
  - ~6 separate CAN segments ☞

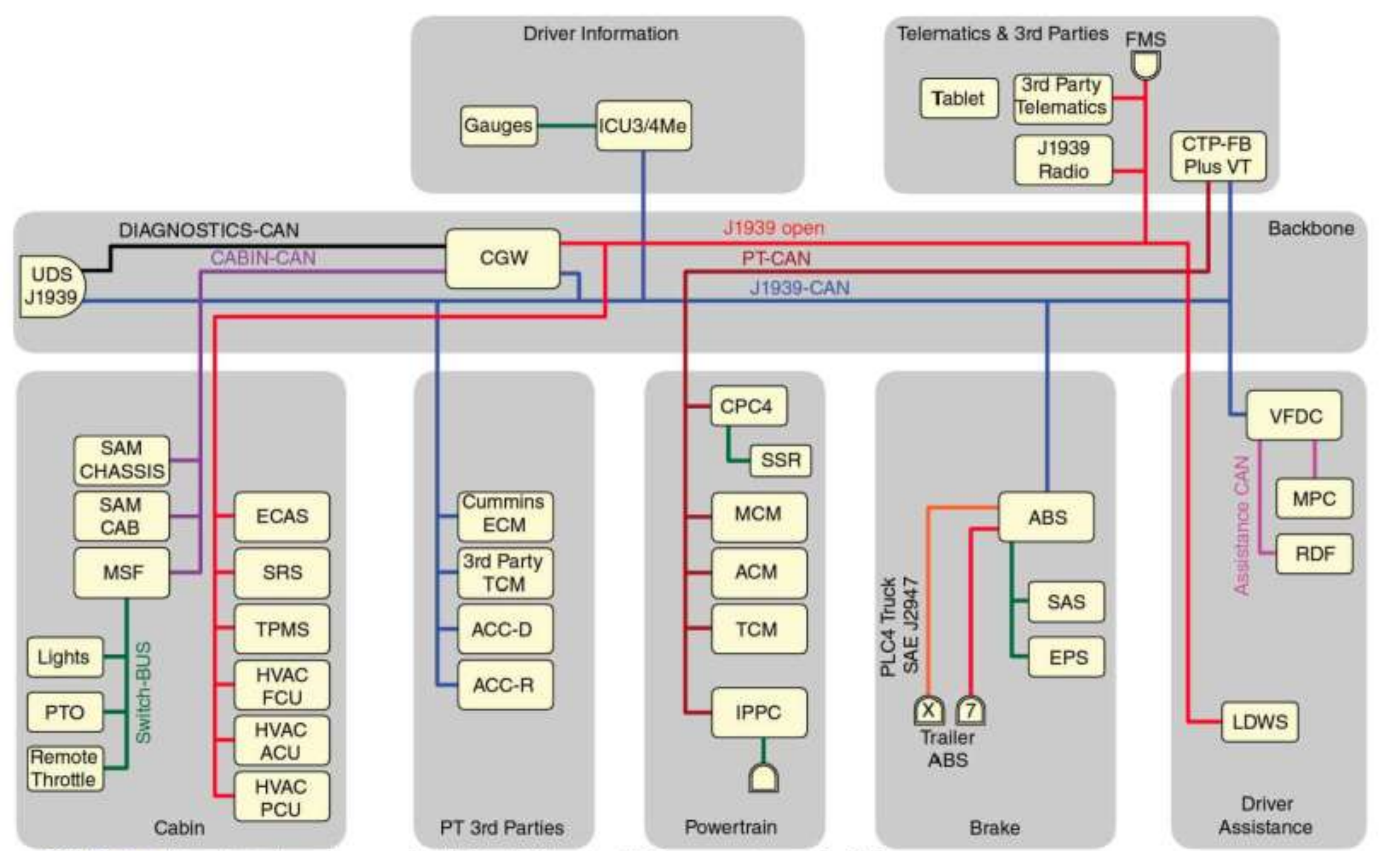
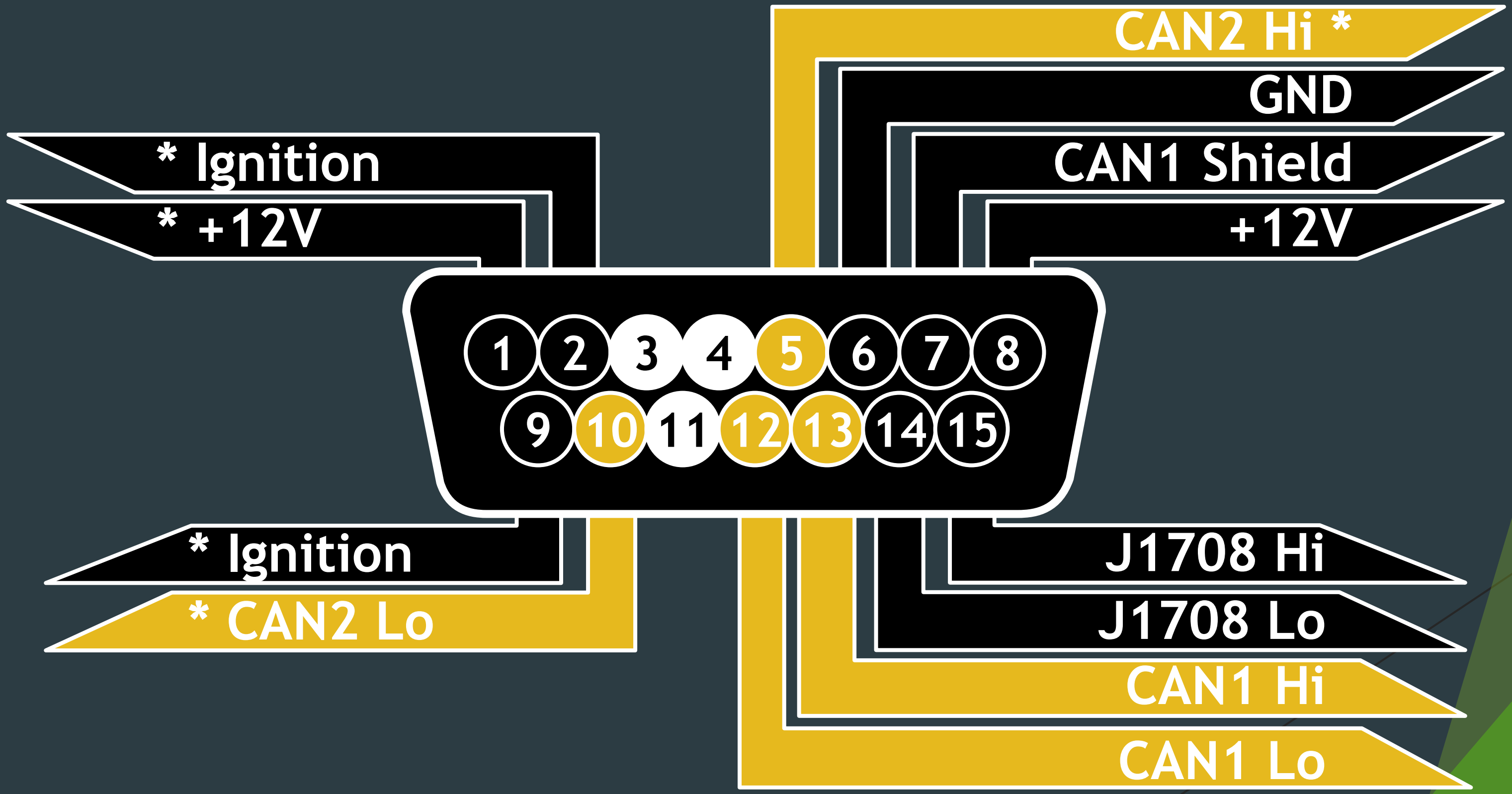


FIGURE 26-25 Three J-1939 channels are used on the latest HD tractors. UDS now operates over the CAN.

[Duffy, Owen C., and Gus Wright. *Fundamentals of Medium/Heavy Duty Commercial Vehicle Systems*: 2014 NATEF Edition. Jones & Bartlett Publishers, 2015]

Finding J1939 (6/6)

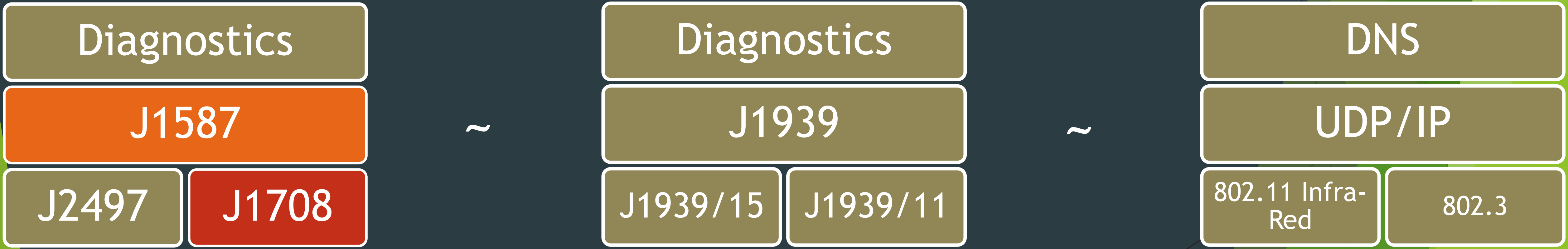
- On a DB-15 Connector (common in heavy vehicle cables)



Truck Vehicle Networks: J1708/J1587

J1708/J1587 Specifics (1/3)

- Predates J1939 by many years. Sometimes still found in the tractor. Always still found in the Trailer as J2497 (more on that later).
- J1708/J1587 by analogy:



Diagnostics

J1587

J2497 | J1708

~

Diagnostics

J1939

J1939/15 | J1939/11

~

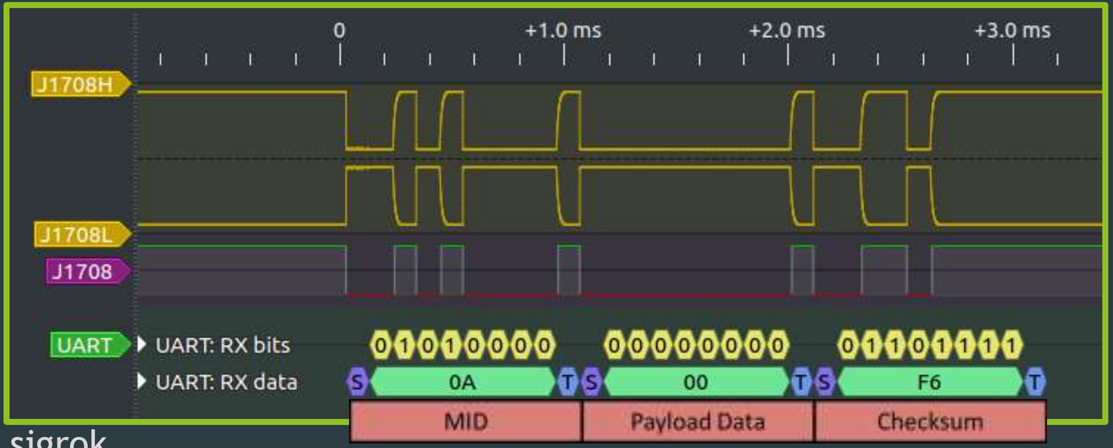
DNS

UDP/IP

802.11 Infra-Red | 802.3

J1708/J1587 Specifics (2/3)

- Has similar bus arbitration to CAN: lowest first byte wins.
- 9600bps / 8N1
- Very much like an RS-485 bus at physical layer
- Has RT constraints for framing and bus arbitration
- The first byte is like a source address: the MID



sigrok

- Some noteworthy MIDs from the specs (J1708/J1587/J2497)
  - 111 is used for factory test
  - 128-255 are defined by J1587
  - 64 & 172 are off-board diagnostics
  - 48 & 153 are on-board diagnostics
  - 182 is off-board programming
  - 163 is ‘vehicle security’
  - 207 is for drivetrain bridge
  - 217 & 218 tractor & trailer bridges
  - 87 is for J2497 active ABS event
  - 125 is for J2497 identification
  - 10 (0x0a) and 11 (0x0b) are J2497 lamp on/off

J1708/J1587 Specifics (3/3)

- signals are identified by a PID byte prepended to the signal
- can be multiple PIDs in one J1587 frame

MID	PID 1	Data 1	…	PID n	Data n	Checksum
128-255	□	□ … □	…	□	□ … □	□

□ - byte

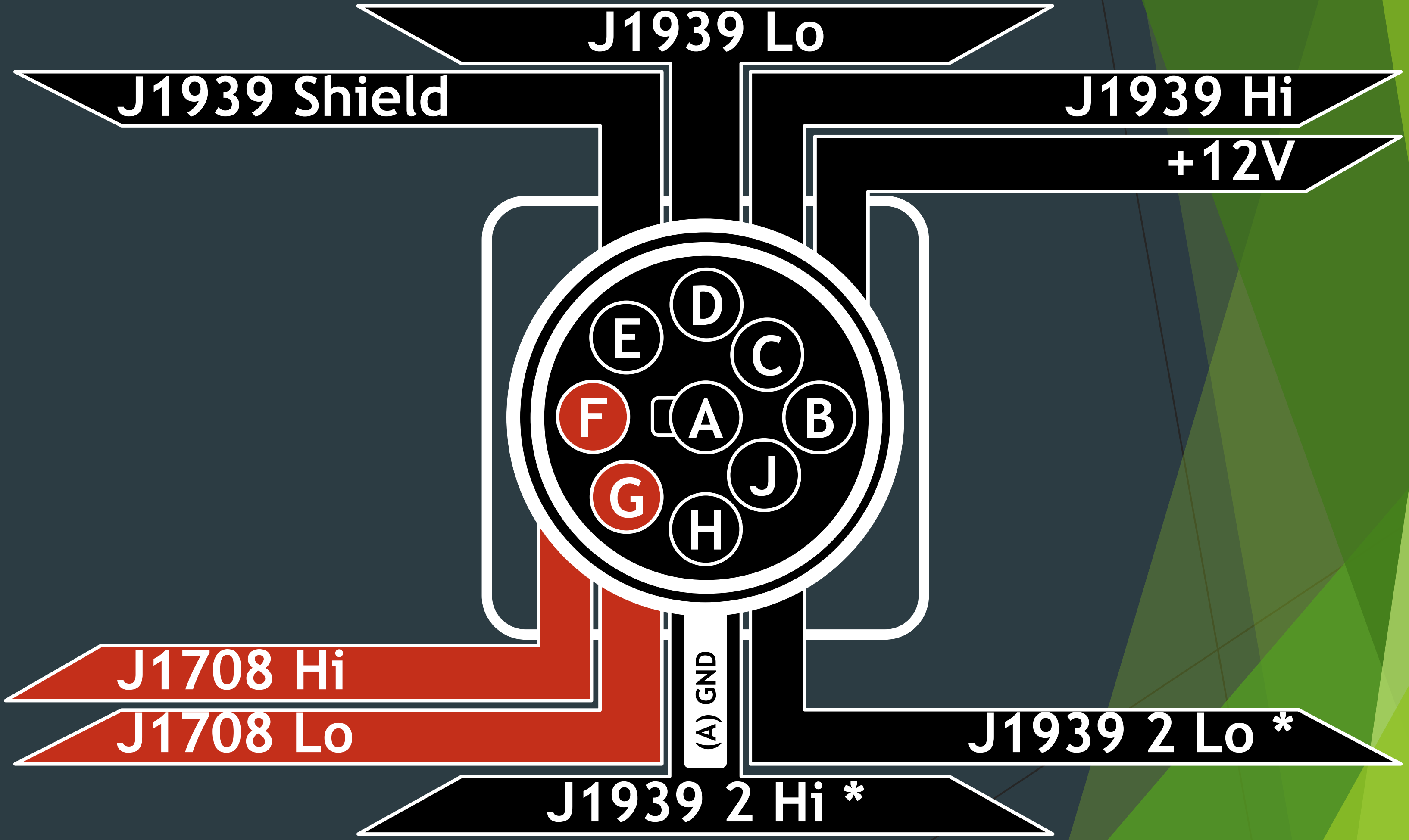
- PIDs range: 0-1021
  - PIDs > 255 use multi-byte PID extension
- Decoding of PIDs is done by reference to the J1587 specification.
  - There are tools that can convert the SAE PDF into a database and do decode.

J1587 Features

- Mostly broadcast (some unicast)
- Requests for data:
  - PID 0 (broadcast) / PID 128: Component specific (unicast)
- Has fragmentation and reassembly (Frames *should be* less than 21 bytes if the vehicle is in motion)
  - PID 192: ‘multisection’ parameter (broadcast)
  - PID 197 and 198: transport protocol (unicast)
- ‘Standardized Free-Format Data’ requests on transport protocol
  - e.g. ‘Programmable Params’ / ‘Calibration’, ‘Executable Code’
- Proprietary messages: ‘Data Link Escape’ (unicast) ☜ ‘the fun stuff’
  - PID 254 and 510
  - e.g. “AC FE 80 F0 17”
    is from MID 0xAC to ‘MID’ 0x80

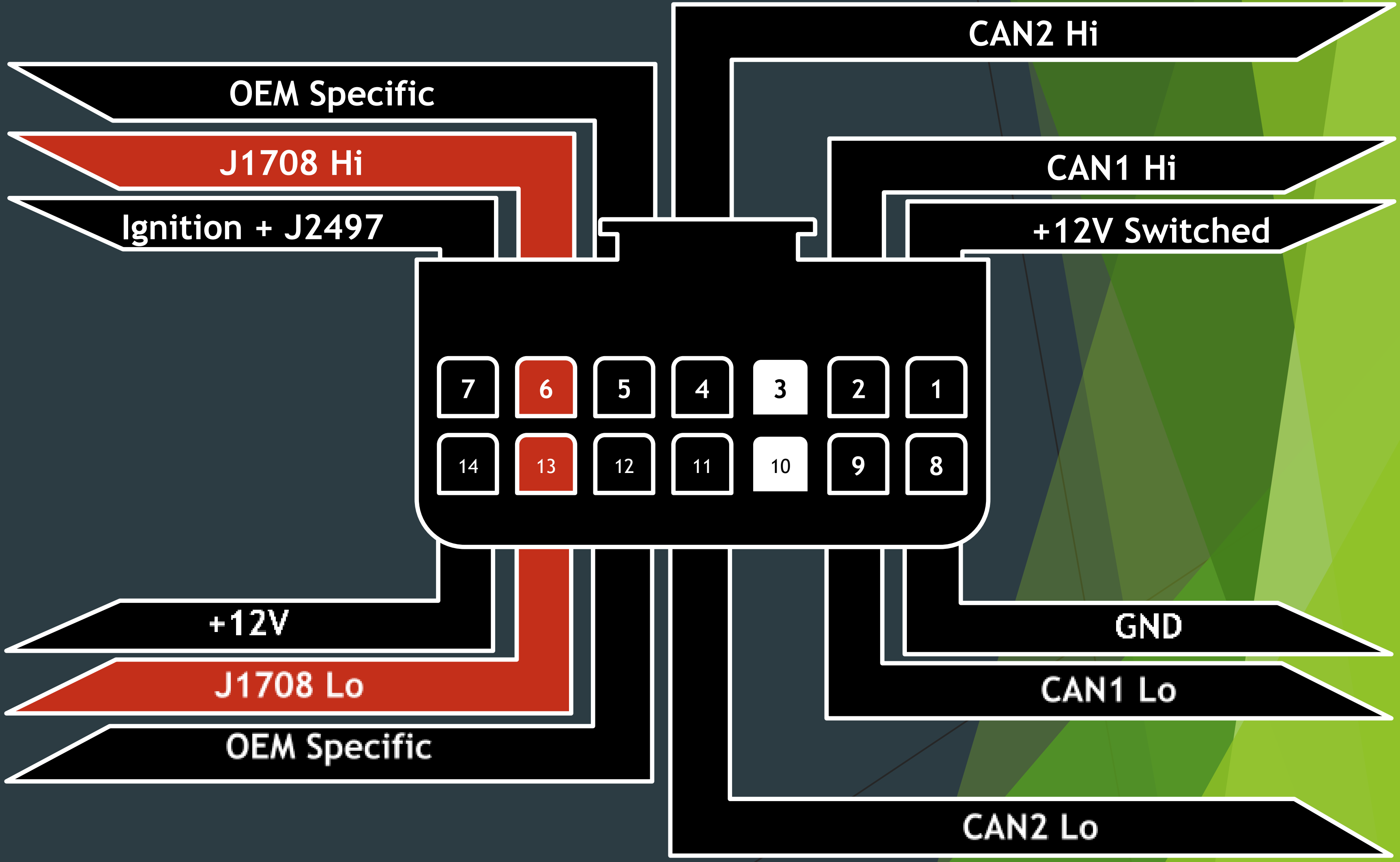
Finding J1708/J1587 (1/3)

- Present on black socket
- Optional on green socket



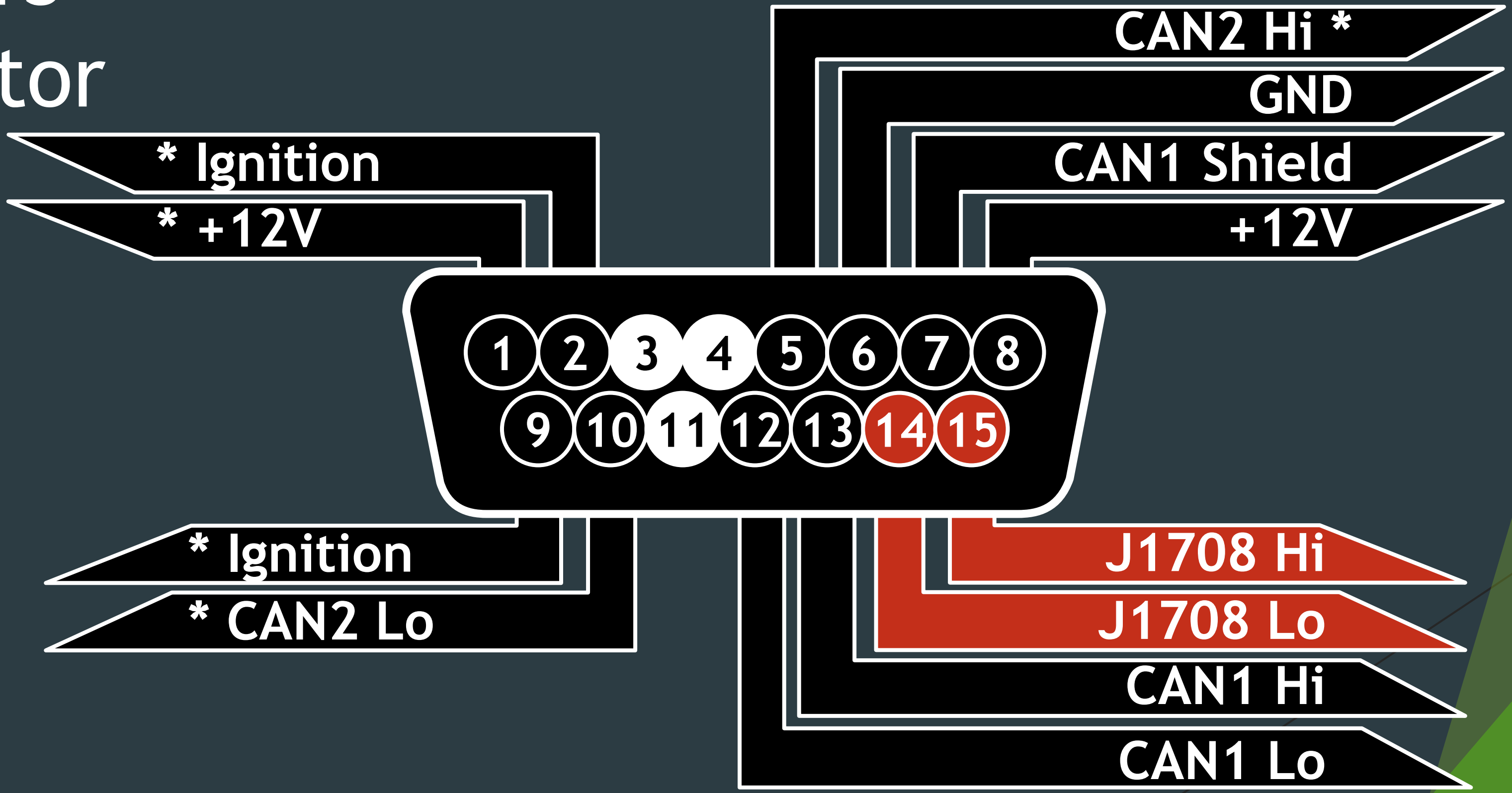
Finding J1708/J1587 (2/3)

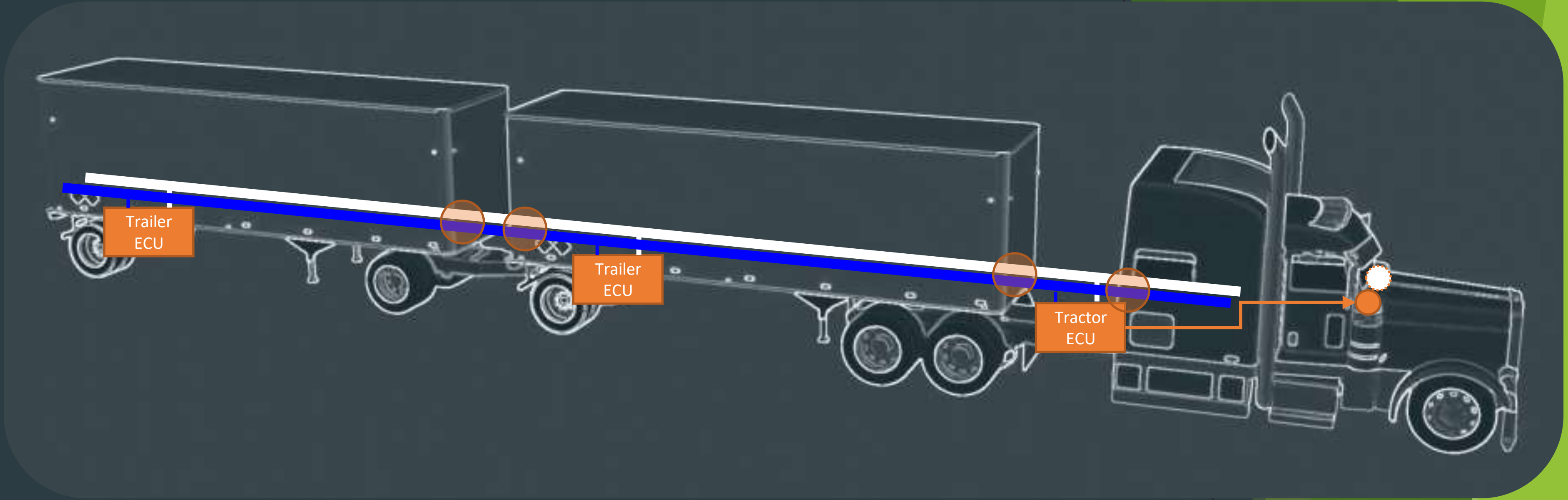
- On the RP1226 (Aftermarket/ Telematics) Connector



Finding J1708/J1587 (3/3)

- On DB-15 Connector

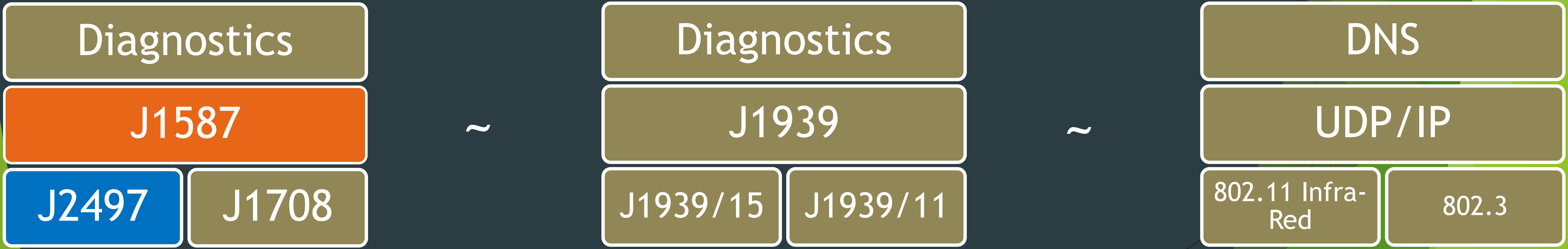




Truck (and Trailer) Vehicle Networks: J2497

J2497 Specifics (1/2)

- Roughly speaking, it is “J1708 over trailer power lines”
- a.k.a. *PLC4TRUCKS*
- Again by analogy:



Diagnostics

J1587

J2497 | J1708

~

Diagnostics

J1939

J1939/15 | J1939/11

~

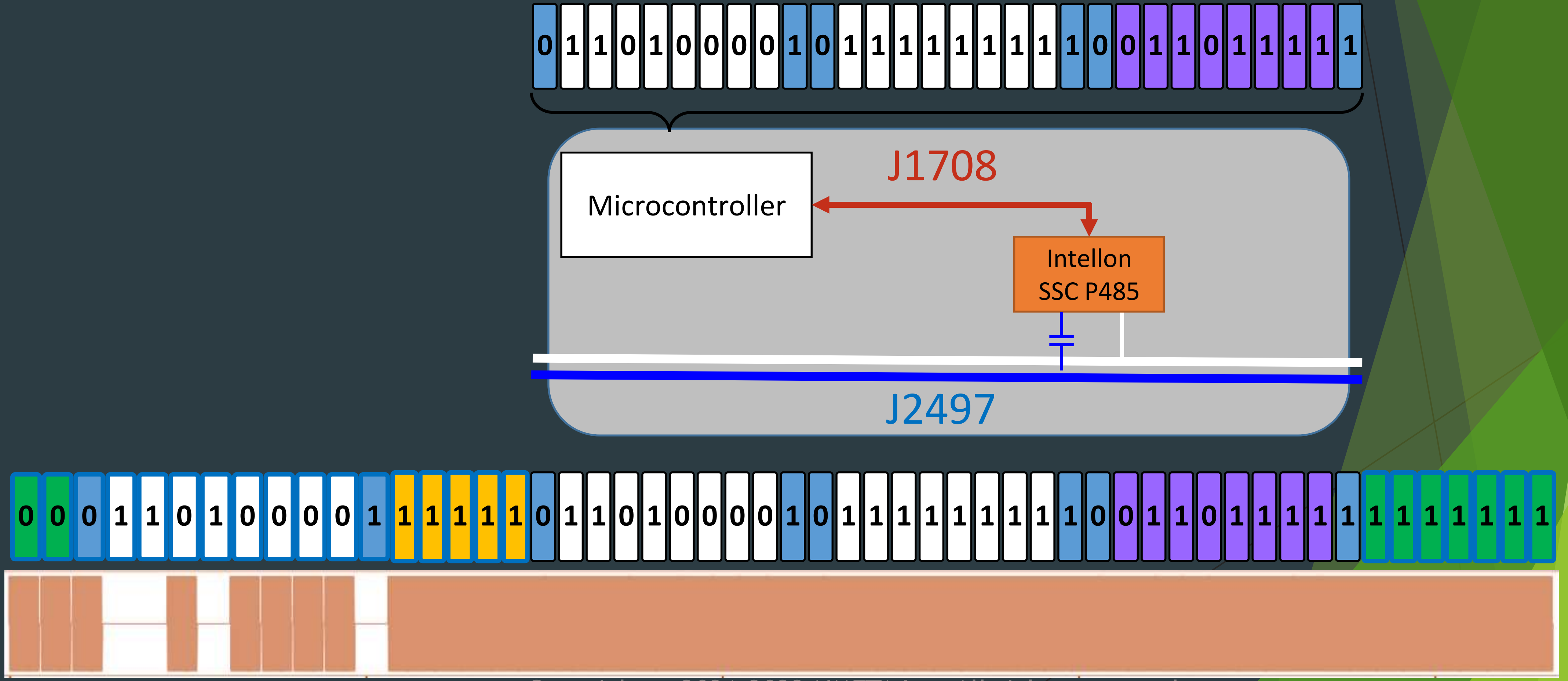
DNS

UDP/IP

802.11 Infra-Red | 802.3

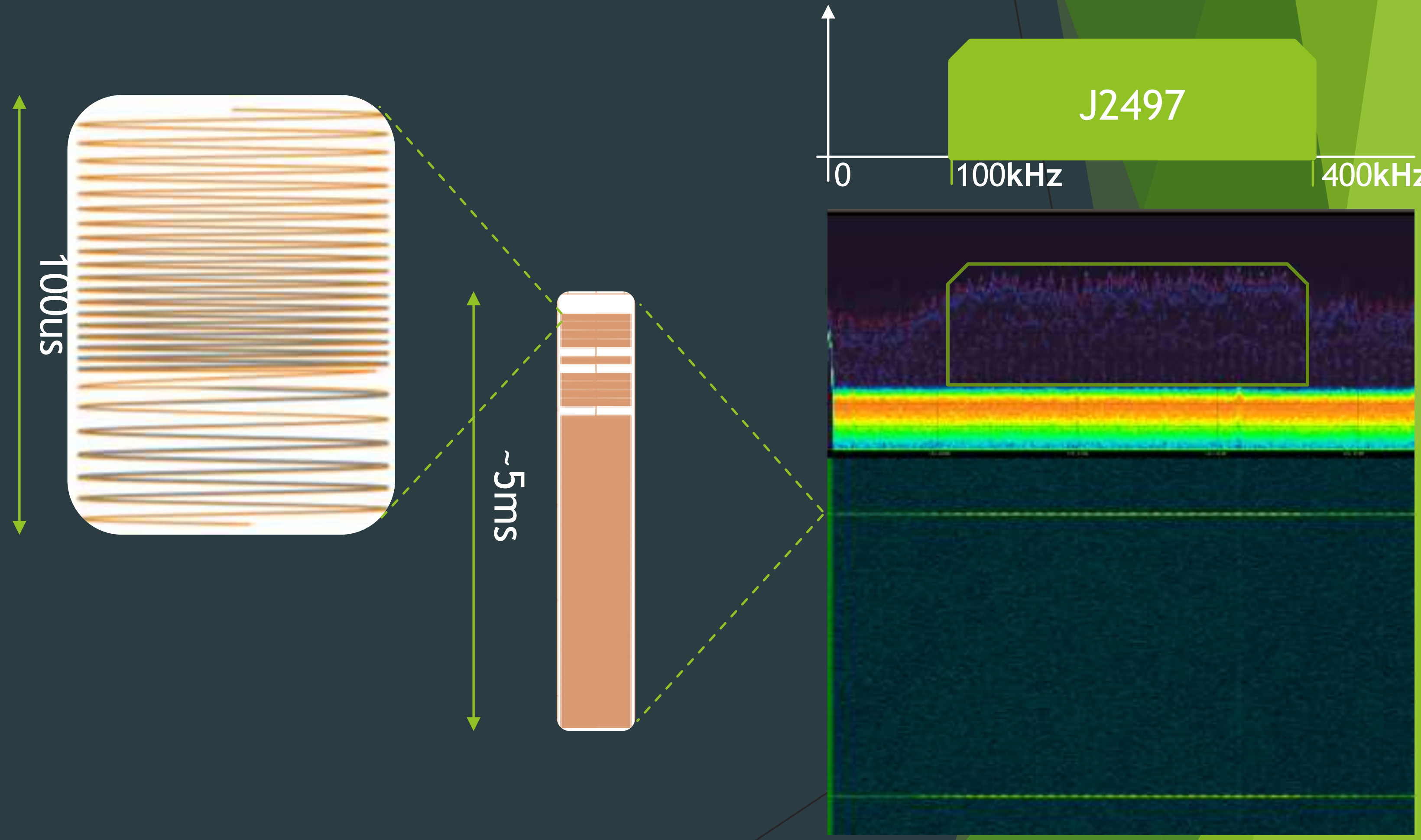
J2497 Specifics (2/2)

- J1708 ↔ J2497
  - Implemented almost exclusively by the Intellon SSC P485 chip



J2497 Specifics (3/4)

- The chirps are 100us in duration, between 2.5 and 7V peak-peak
- The chirps sweep from 203KHz through 400KHz (63us) then to 100KHz (4us) and back to 203KHz (33us) to finish



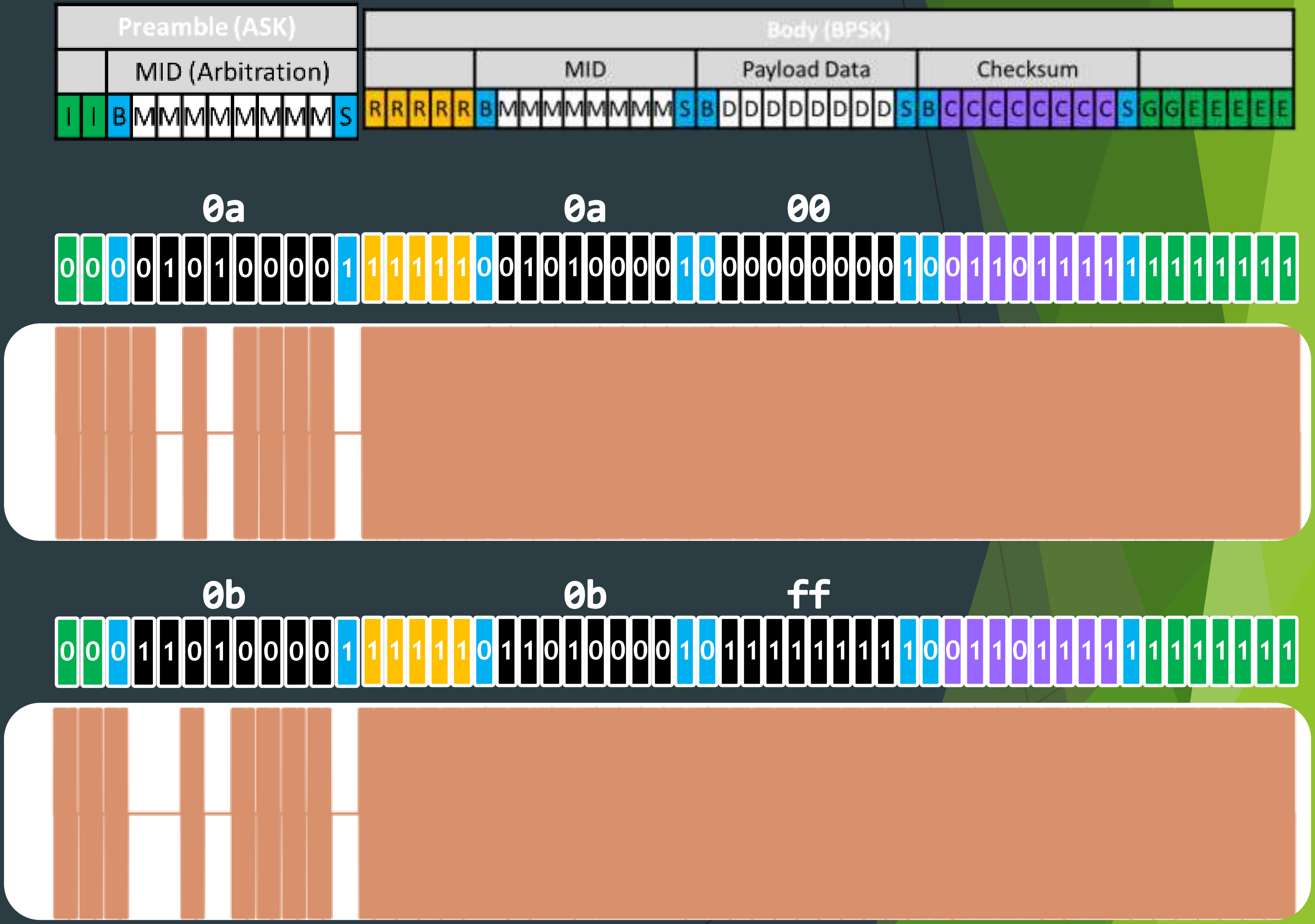
J2497 Specifics (4/4)

Preamble

- Amplitude Shift Keying (ASK)
- Bit time 114us (14us silence after 100us chirp)
- Logic ‘0’ = chirp present
- Initial symbols (1-2 logic ‘0’)
- Start bit (logic ‘0’)
- MID bits (duplicated in body)
- Stop bit (logic ‘1’)

Body

- Phase Shift Keying (PSK), 180deg difference
- Bit time 100us
- Logic ‘0’ symbol is arbitrary per device, determined by the symbol transmitted in the preamble
- Sync symbols (5 logic ‘1’)
- J1708 Body Bytes. MID followed by Data
  - Start bit (logic ‘0’)
  - Data bits (8)
  - Stop bit (logic ‘1’)
- J1708 Checksum Byte
  - Start bit (logic ‘0’)
  - Checksum bits (8)
  - Stop bit (logic ‘1’)
- Gap (0-4 logic ‘1’) & End symbols (5 logic ‘1’)



Preamble (ASK) | Body (BPSK)

MID (Arbitration) | MID | Payload Data | Checksum

I I B M M M M M M M M S | R R R R R B M M M M M M M M S B D D D D D D D D S B C C C C C C C C S G G E E E E E

0a 0a 00

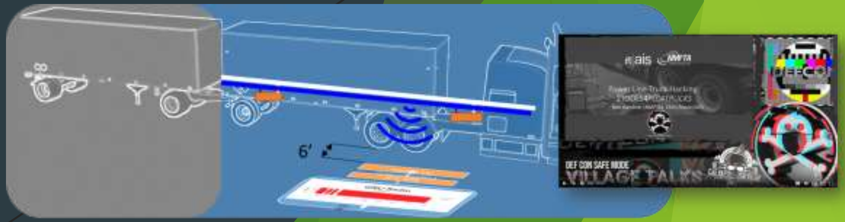
0 0 0 0 1 0 1 0 0 0 0 1 1 1 1 1 1 0 0 1 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1

0b 0b ff

0 0 0 1 1 0 1 0 0 0 0 1 1 1 1 1 1 0 1 1 0 1 0 0 0 0 1 0 1 1 1 1 1 1 1 1 1 0 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1

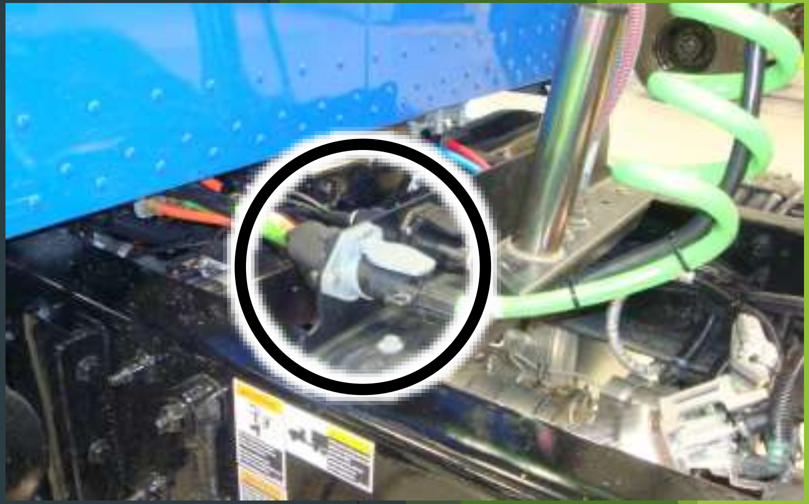
J2497 Features

- Primary purpose is for 0a00 and 0bff LAMP ON and LAMP OFF messages. But *there's more*:
- Has all the feature of J1708/J1587 plus:
  - dynamic address (MID) claim (PID 4)
  - data transfer *bridging* (PIDs 204 and 460)
- Trailer brake diagnostic functions such as ABS air pressure valve cycling and ECU reconfiguration
- Some trailer brake ECUs have scripting languages programmable over J2497
- because of the added preamble/MID byte it is possible to create J2497 frames that <u>override bus arbitration</u>
  - e.g. a J2497 priority of maximum 00 and a J1708 priority of minimum ff which overrides all J2497 traffic but is received as MID ff
- Radiates enough energy to be read remotely at 6ft from trailer



Finding J2497 (1/5)

- Will always be on the power pin (AUX) of the trailer J560 connector ☞ (at back of tractor / front of trailer)



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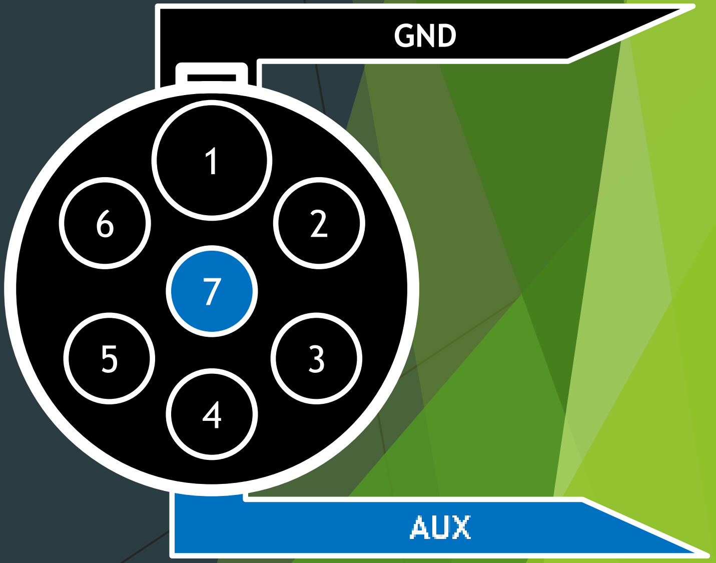
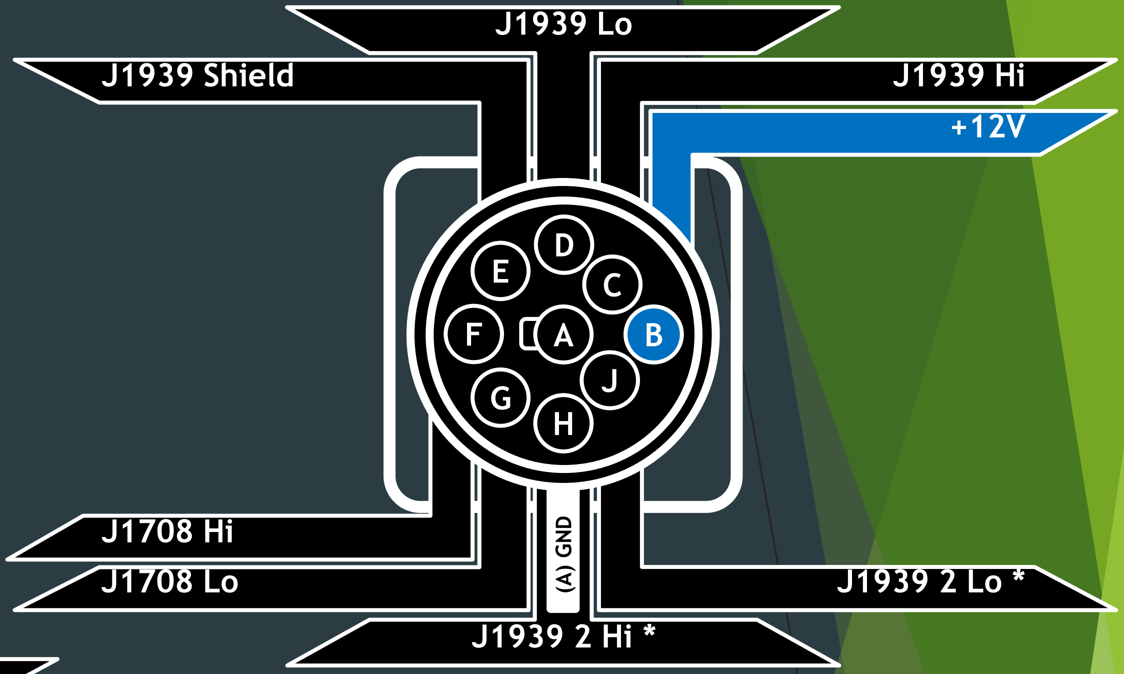
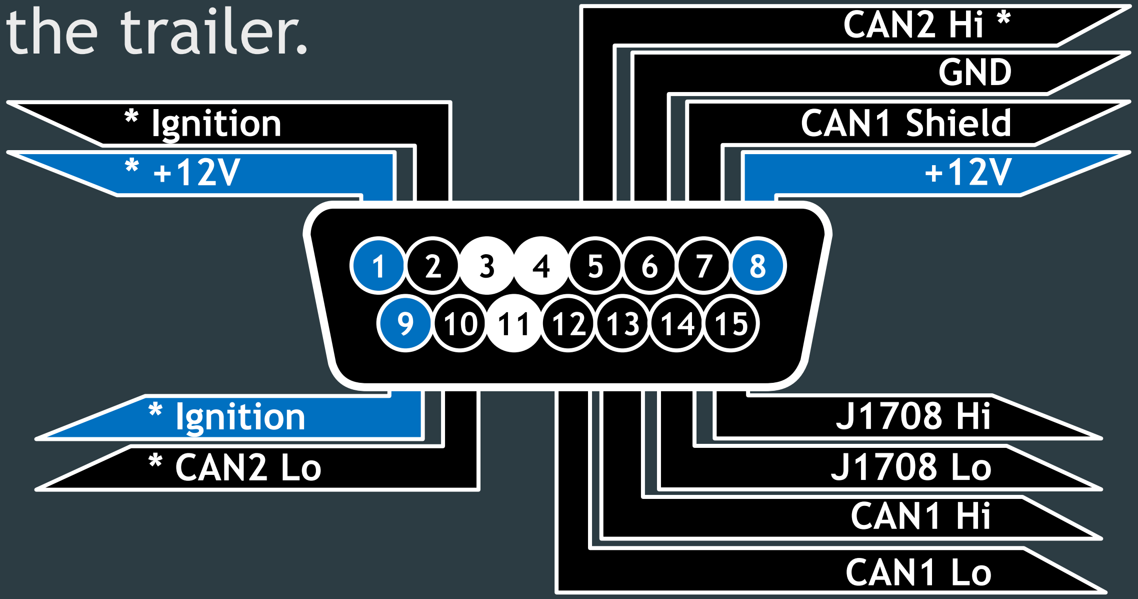


www.ebay.ca/itm/Bendix-ABS-Trailer-Remote-Diagnostic-Unit-TRDU-PLC-Adapter-9-pin-Connection

Finding J2497 (2/5)

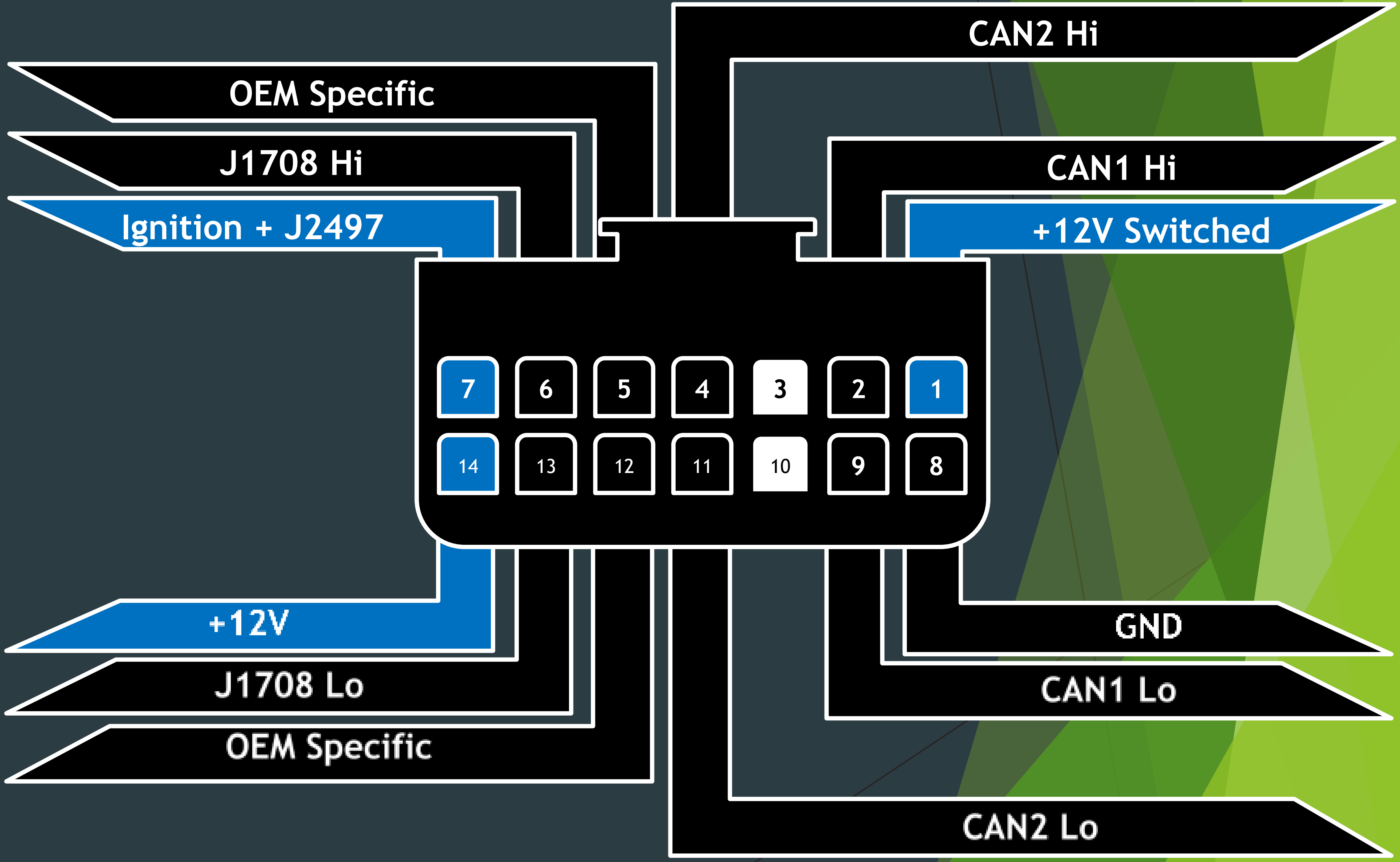
- Might be on the power pins of the diagnostics connector
- What you find could be filtered/segmented from the trailer.





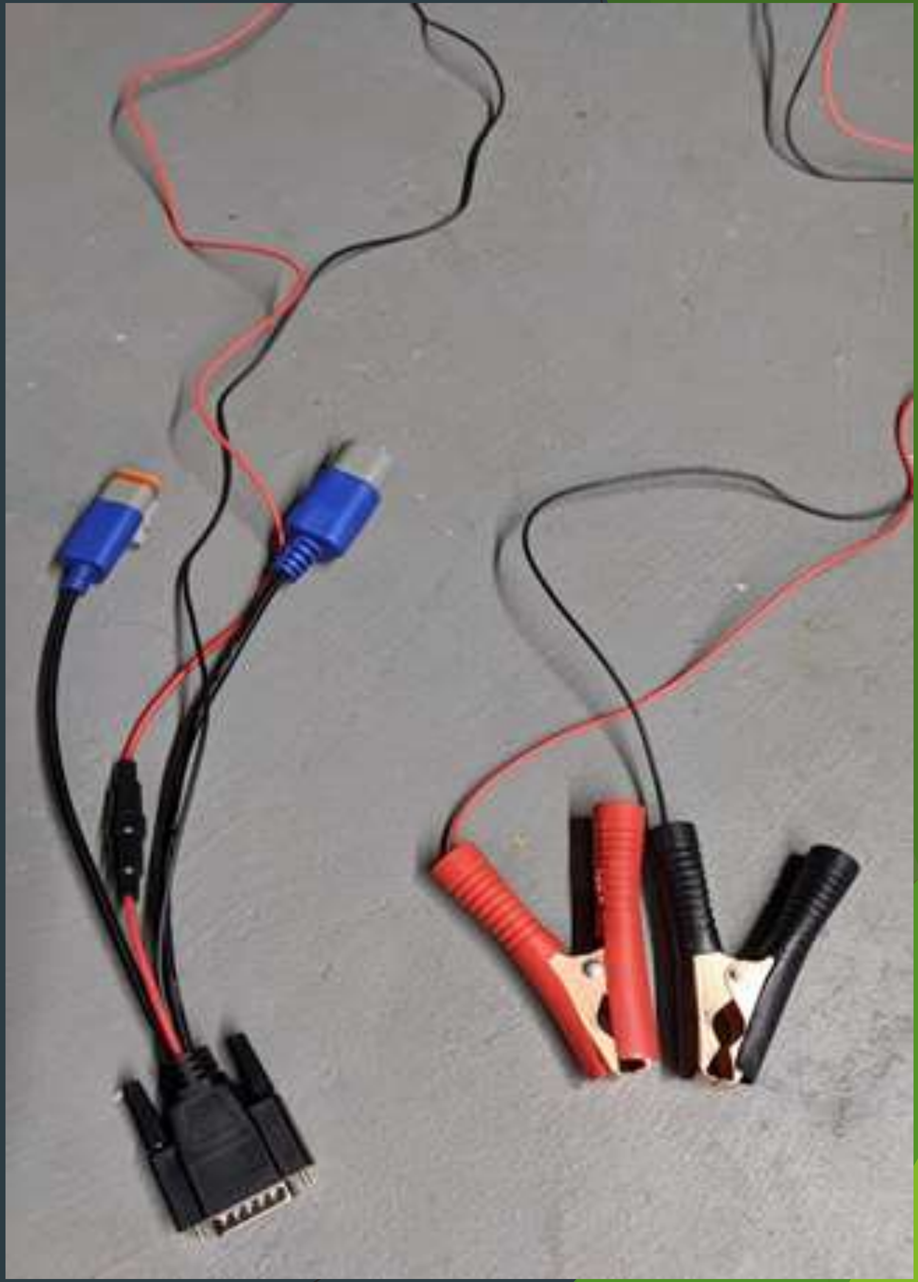
Finding J2497 (3/5)

- Should be on the RP1226 (Aftermarket/ Telematics) Connector



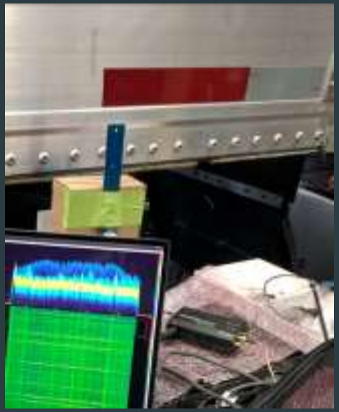
Finding J2497 (4/5)

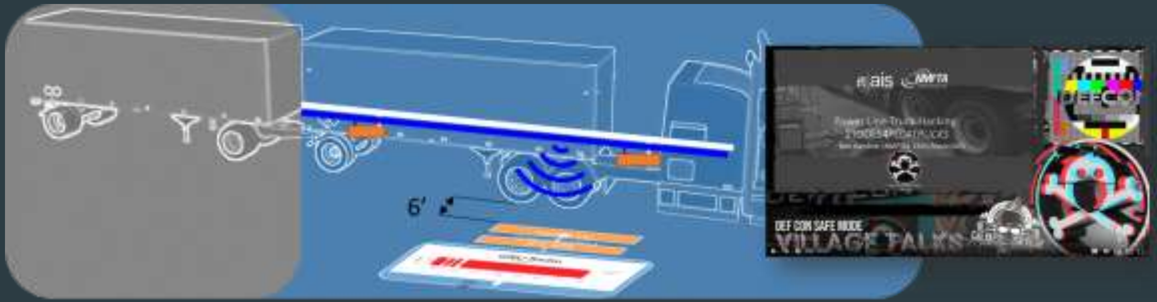
- Might be on the battery terminals -- but what you find could be filtered/segmented from the trailer.



Finding J2497 (5/5)

- Might just radiate away from the trailer. ICSA-20-219-01





Chris Poore & Ben Gardiner. *Power Line Truck Hacking: 2TOOLS4PLC4TRUCKS*

- Might be writable via RF. ICSA-22-063-01

Chris Poore & Ben Gardiner. *Trailer Shouting, DEF CON 30* :

Other Vehicle Networks

Vehicle Networks: Intermodal

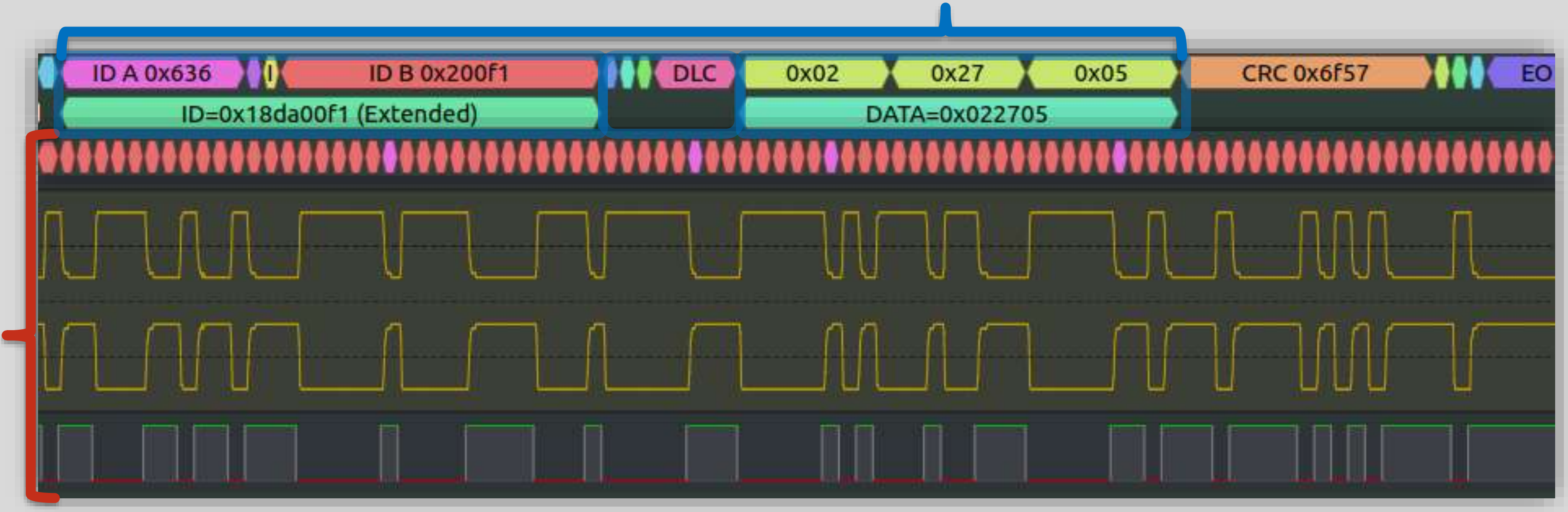
- J1939 is found wherever there’s a diesel engine
  - Probably also J1708/J1587
- J2497 might be found on containers

Vehicle Networks: More

- LIN
- CAN-FD, CAN-HG
- Automotive Ethernet (BroadR-Reach)
- Much More Wireless

‘HACKING’

CAN Attack Methods (below J1939)

	ALL e.g. *Socket CAN*	
Bus Flood	Y	
(Simple) Spoofing	Y	
?		

```
while True:
  sock.send(b'\x00\x00\x00\x00\x01\x00')
```

```
sock.send(b'\x18\xda\x00\xf1\x03\x02\x27\x05')
```

CAN Attack Methods (below J1939)

	ALL e.g. *Socket CAN*	*CAN Hack*	*CANT*	***CANHack*** **by Dr. Ken Tindell @ CANIS** ***CANT*** **by b1tbane & ehntoo @ GRIMM** --- **Notes:**
Bus Flood	Y			
(Simple) Spoofing	Y			← the means for nearly all the attacks discussed next
Bus-Off / Bus Killer		Y	Y	target an ECU and destroy its frames repeatedly with selective bit override Cho et. Al & Maggi, F. c.f. also ICS-ALERT-17-209-01
(ASAP) Spoofing		Y		takes advantage of bitbanging to ensure attack frame is entered into arbitration ASAP after the target frame
Double Receive		Y		make a transmitter double-send a frame, error is only visible to transmitter and every other node receives same frame twice
Freeze / Overload		Y	Y	send a number of overload frames after a target frame
Error Passive Spoofing / Data Replacer		Y	Y	put a target into error passive mode then put an attack frame in front of a target frame aka *"bit smashing"*
Janus [Tindell]		Y		create a custom bitstream for two sampling point values so that receivers configured to those sampling points will receive different frames
Bus Short			Y	(cyber paperclip mode): shorts CAN_H+CAN_L **(requires analog switch)**
NACK			Y	clobber ACK bit by asserting a recessive state on the bus **(requires analog switch)**
(Improved) Data Replacer			Y	" but can clobber also dominant bits **(requires analog switch)**

CAN Attack Methods (below J1939)

	ALL e.g. *Socket CAN*	*CAN Hack*	*CANT*	*CANHack* by Dr. Ken Tindell @ CANIS *CANT* by b1tbane & ehntoo @ GRIMM --- Notes:
Bus Flood 👍J1708	Y			
(Simple) Spoofing 👍J1708	Y			← the means for nearly all the attacks discussed next
Bus-Off / Bus Kille 👍J1708		Y	Y	target an ECU and destroy its frames repeatedly with selective bit override Cho et. Al & Maggi, F. c.f. also ICS-ALERT-17-209-01
(ASAP) Spoofing 👍J1708		Y		takes advantage of bitbanging to ensure attack frame is entered into arbitration ASAP after the target frame
Double Receive		Y		make a transmitter double-send a frame, error is only visible to transmitter and every other node receives same frame twice
Freeze / Overload		Y	Y	send a number of overload frames after a target frame
Error Passive Spoofin / Data Replacer 👍J1708		Y	Y	put a target into error passive mode then put an attack frame in front of a target frame aka "*bit smashing*"
Janus [Tindell]		Y		create a custom bitstream for two sampling point values so that receivers configured to those sampling points will receive different frames
Bus Short			Y	(cyber paperclip mode): shorts CAN_H+CAN_L **(requires analog switch)**
NACK			Y	clobber ACK bit by asserting a recessive state on the bus **(requires analog switch)**
(Improved) Data Replacer			Y	" but can clobber also dominant bits **(requires analog switch)**

What can you do on Heavy Vehicle Networks (1/11)?

- Some examples that have been made public
- Each result is true only on specific model year builds of trucks

What can you do (2/11)?
J1939: Vehicle Disable / Limp by DEF Additive Message Manipulation

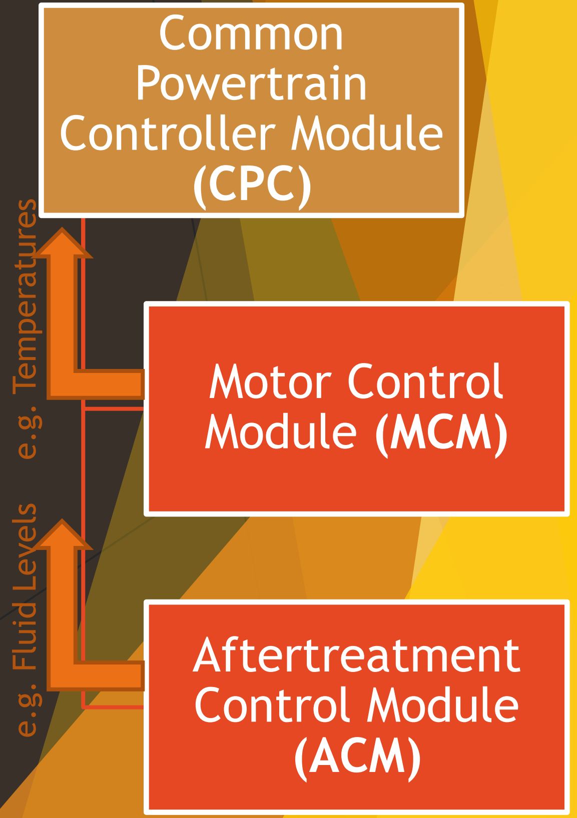
- [Jonson, Urban. *A comprehensive review of cyber security for heavy vehicles for the NMFTA membership.* (2015) http://www.nmfta.org/documents/ctsrp/nmfta heavy duty vehicle cyber security whitepaper v1.0.3.6.pdf]

What can you do (3/11)?
J1939: Denial of ECUs

- [Mukherjee, Subhojeet & Shirazi, Hossein & Ray, Indrakshi & Daily, Jeremy & Gamble, Rose. (2016). *Truckers Beware: Practical Denial-of-service Attacks in Embedded Networks of Commercial Vehicles.* http://www.cs.colostate.edu/dbsec/HeavyVehicle/wp-content/uploads/9783319498058-c2.pdf]

What can you do (4/11)?
J1939: Vehicle Disable / Limp by Engine De-Rate Message Manipulation Research by CanBusHack

- [Jonson, Urban. *IOActive Guest Blog | Urban Jonson, Heavy Vehicle Cyber Security Program, NMFTA*. (2020). https://ioactive.com/guest-urban-johnson-nmfta/]
- More details available at ctsrp.nmfta.org


Common Powertrain Controller Module (CPC)
e.g. Temperatures
Motor Control Module (MCM)
e.g. Fluid Levels
Aftertreatment Control Module (ACM)

What can you do (5/11)? J1708/J1587: Malicious Misconfiguration of a Truck ECM

- [Haystack and sixvolts. *Cheap Tools for Hacking Heavy Trucks*. DEF CON 24 Car Hacking Village. https://github.com/TruckHacking/DEFCON24/raw/master/Cheap-Tools-For-Hacking-Heavy-Trucks-Slides.pdf]

What can you do (6/11)?
J1939: Instrument Cluster Override

- [Yelizaveta Burakova, Bill Hass, Leif Millar, and André Weimerskirch, *Truck Hacking: An Experimental Analysis of the SAE J1939 Standard*, Usenix WOOT, August 11-12, 2016, Austin, TX, USA. http://www.weimerskirch.org/files/BurakovaEtAl_TruckHacking.pdf]

What can you do (7/11)? J1939: RPM control and Engine Brake Disable

- [Yelizaveta Burakova, Bill Hass, Leif Millar, and André Weimerskirch, *Truck Hacking: An Experimental Analysis of the SAE J1939 Standard*, Usenix WOOT, August 11-12, 2016, Austin, TX, USA. http://www.weimerskirch.org/files/BurakovaEtAl_TruckHacking.pdf]

What can you do (8/11)?
J1708/J1587: Disable Engine Cylinders

- [Yelizaveta Burakova, Bill Hass, Leif Millar, and André Weimerskirch, *Truck Hacking: An Experimental Analysis of the SAE J1939 Standard*, Usenix WOOT, August 11-12, 2016, Austin, TX, USA. http://www.weimerskirch.org/files/BurakovaEtAl_TruckHacking.pdf]

What can you do (9/11)?
J1708/J1587 / J2497: Cycle ABS Air Release Valves

- [Yelizaveta Burakova, Bill Hass, Leif Millar, and André Weimerskirch, *Truck Hacking: An Experimental Analysis of the SAE J1939 Standard*, Usenix WOOT, August 11-12, 2016, Austin, TX, USA. http://www.weimerskirch.org/files/BurakovaEtAl_TruckHacking.pdf]

What can you do (10/11)?
J2497: Remote Read and Write of Traffic

- [Poore, Chris & Gardiner, Ben. *Power Line Truck Hacking: 2TOOLS4PLC4TRUCKS*. DEF CON 28 SAFE MODE Car Hacking Village. https://youtu.be/sf3JznYTo0I]
- [Poore, Chris & Gardiner, Ben. *Trailer Shouting Talking PLC4TRUCKS Remotely with an SDR* DEF CON 30. https://youtu.be/Na8K_fVEzQo]

What can you do (11/11)? Summary

Network	'Hacking'	*Who*
J1939	Vehicle disable/limp by DEF message manipulation	Jonson (NMFTA)
J1939	Denial of ECUs	Mukherjee et. al.
J1939	Vehicle disable/limp by de-rate message manipulation	Leale (CanBusHack)
J1708/J1587	Malicious misconfiguration of truck ECM	Haystack et. al.
J1939	Instrument Cluster override	Burakova et. al.
J1939	RPM control and engine brake disable	Burakova et. al.
J1708/J1587	Disable engine cylinders	Burakova et. al.
J1708/J1587 / J2497	Cycle ABS air release valves	Burakova et. al.
J2497	Remote read and write of traffic	Poore (AIS) et. al.

What needs more ‘Hacking’?

- Abuse of J1939 and/or J2497 features:
  - ECU Firmware Dumping and Re-flashing
  - Seed-Key Exchange
  - Interesting Body Control Functions
  - ADAS features
- Vehicle Network Gateways
  - Sometimes being introduced for security purposes
  - Always security relevant (pivoting)

Other Truck & Trailer Hacking

- Like car hacking, this is also the “*Olympics of Hacking*” -- Will Caruanna
- All the usual IoT mobile, game hacking and RF stuff applies
  - Telematics (usually IoT)
  - Mobile (usually Android)
  - Diagnostics & Maintenance Tools (usually Windows)
  - RF (usually ¯_(ツ)_/¯)

Get Involved

Get Involved: CyberTruck Challenge ™

An event specifically to train students. Attended by industry and cybersecurity experts. >10K in free training per-person. Several Trucks present each year. Stipends available for students.

www.cybertruckchallenge.org/participate/

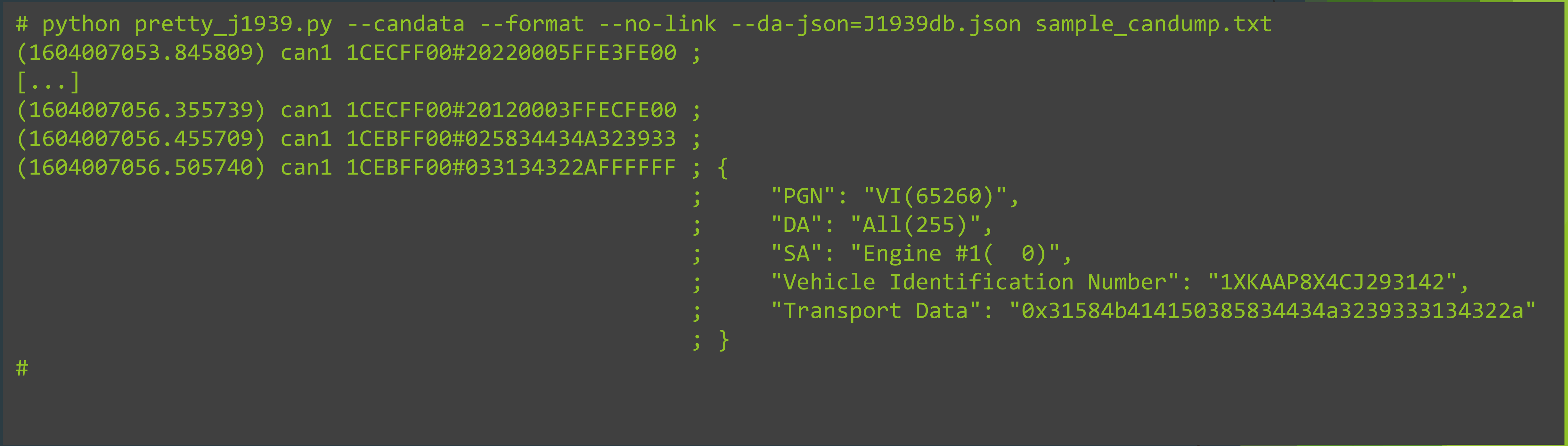
Get Involved: Bench Setups

- Necessary
  - If you are hacking on a truck then it isn't making the fleet any money
- You can build a Truck in a Box:
  - see Haystack and sixvolts. *Cheap Tools for Hacking Heavy Trucks*.
  - For the really gory details see Córcega, Jose L. DESIGN OF A FORENSICALLY NEUTRAL ELECTRONIC ENVIRONMENT FOR HEAVY VEHICLE EVENT DATA RECORDERS. Master's Thesis, University of Tulsa. 2015.

Tools for Truck Hacking / Vehicle Networks

Example: decoding J1939 with pretty_j1939.py

https://github.com/nmfta-repo/pretty_j1939

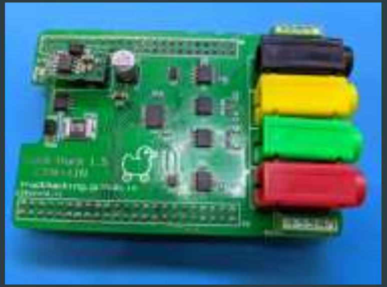


```
# python pretty_j1939.py --candata --format --no-link --da-json=J1939db.json sample_candump.txt
(1604007053.845809) can1 1CECFF00#20220005FFE3FE00 ;
[...]
(1604007056.355739) can1 1CECFF00#20120003FFECFE00 ;
(1604007056.455709) can1 1CEBFF00#025834434A323933 ;
(1604007056.505740) can1 1CEBFF00#033134322AFFFFFF ; {
                                                   ;     "PGN": "VI(65260)",
                                                   ;     "DA": "All(255)",
                                                   ;     "SA": "Engine #1(  0)",
                                                   ;     "Vehicle Identification Number": "1XKAAP8X4CJ293142",
                                                   ;     "Transport Data": "0x31584b414150385834434a3239333134322a"
                                                   ; }
#
```

CAN Data from public logs at
engr.colostate.edu/~jdaily/J1939/candata.html

Example: sending J1939 with SocketCAN on a TruckDuck (1/3)

- The TruckDuck https://github.com/TruckHacking/TruckDuckHardware by sixvolt & haystack, @DEF CON 24. Later revisions 1.5 YEET and MEGA.



THE UNIVERSITY OF TULSA
Heavy Truck Cape with BeagleBone Black
CYBERTRUCK CHALLENGE
Ben Gardiner
USB IP Address 192.168.7.2
+5 VDC Only for barrel jack

- Also remixed as the TruckCape by Dr. Daily: ☞ https://oshpark.com/profiles/jeremy-daily

Example: sending J1939 (2/3)

```
import socket
import struct

sock = socket.socket(socket.PF_CAN, socket.SOCK_RAW, socket.CAN_RAW)
sock.bind(("can0",))

can_id = 0x18EEFF00                                 # broadcast address claims
can_id |= socket.CAN_EFF_FLAG                # Set the extended frame format bit

can_data = bytes.fromhex('06 03 BF 01 00 00 00 10') # ex address claim msg

can_dlc = min(len(can_data),8)
can_packet = struct.pack("<lB3x8s", can_id, can_dlc, can_data[:can_dlc])
sock.send(can_packet)
```

From Dr. Daily’s github.com/SystemsCyber/TruckCapeProjects/
Presentation on this topic available at ctsrp.nmfta.org

Example: sending J1939 Alternatives (3/3)

There's a whole bunch of other ways to send J1939 with Python

- Using Linux (since 5.4) `.CAN_J1939` e.g. via cpython (since 3.9)
  - Also how haystack's https://github.com/TruckHacking/py-hv-networks works (with backport)
- https://github.com/juergenH87/python-can-j1939 is actively developed
  - Uses also `.CAN_RAW` on various python-can drivers
  - The API here is best suited to developing J1939 ECUs
- And CanCat and TruckDevil
  - No SocketCAN option

Example: decoding J1708/J1587/J2497 with pretty_j1587.py

- github.com/ainfosec/pretty_j1587
- Developed by Dan Salloum @ AIS

```
# echo ac#ff0189 | ./pretty_j1587.py -f -
MSG: [0xac,0xff,0x1,0x89]
MID 0xac (172):  Off-board Diagnostics #1
PID 0x101 (257): Cold Restart of Specific Component
  DATA: 0x89

# echo ac#f31089 | ./pretty_j1587.py -f -
MSG: [0xac,0xf3,0x10,0x89]
MID 0xac (172): Off-board Diagnostics #1
PID 0xf3 (243): Component Identification
  DATA: 0x10, 0x89
```

J1587 Data from DEF CON 28 CHV CTF attempts by uhlox (Aug 2020)

Example: sending J1708/J1587/J2497 with j1708send.py on a TruckDuck

- https://github.com/TruckHacking/plc4trucksduck

```
# j1708send.py --interface=plc 0a00

#
```

For more ways to send J2497 see: *Power Line Truck Hacking: 2TOOLS4PLC4TRUCKS*

More Tools for Truck Hacking Vehicle Networks (1/8)

- e.g. TruckDevil, CanCat, canmatrix, gr-j2497, py-hv-networks, Nexiq USBLink, DGTech DPA4.

TruckDevil (2/8)

- https://github.com/LittleBlondeDevil/TruckDevil
- By Hannah Silva
- For reading, decoding, logging and sending messages on J1939.
- Works with
  - the (very affordable) Macchina M2 via custom FW
  - and any SocketCAN device (via python-can)
- Being grown into an attack framework, starting with a fuzzer
- Training videos available at ctsrp.nmfta.org

CanCat (3/8)

- https://github.com/atlas0fd00m/CanCat
- By atlas and also GRIMM CyPhy team
- Works with the M2 via custom FW
- includes J1939 support

canmatrix (4/8)

- https://github.com/ebroecker/canmatrix
- by Eduard Bröcker
- Converts between many CAN signal definitions, including support for J1939

gr-j2497 (5/8)

- https://github.com/ainfosec/gr-j2497
- Developed by Chris Poore @ AIS
- MIT licensed
- Flow graphs with a custom block for reading J2497/PLC4TRUCKS traffic

py-hv-networks (6/8)

- github.com/TruckHacking/py-hv-networks/blob/master/hv_networks/J1587Driver.py
- Developed by haystack and sixvolts
- The core of the TruckDuck features
- A set of python libraries for send+receive of J1939 and J1708/J1587 traffic

Nexiq USBLink (7/8)

- A RP1210 Vehicle Diagnostic Adapter (VDA)
- One RP1210 VDA is necessary to use any OEM/supplier diagnostics packages
- This adapter is cheap and easy to find
- Has a DB15 connector for which there are many cables available for purchase as well

DG Tech DPA4 (8/8)

- Another RP1210 compatible adapter
- Also has the most-useful DB-15 connector
- Drivers include a very useful data logging feature (called ‘debug file’ in the settings)

CLOSING

Review

- Commercial Transportation is important to us (all)
- Trucks have 3 main types of vehicle networks: J1939, J1708/J1587, and J2497
  - Two (J1939 and J2497) are on all trucks in North America
  - Some are shared with other modes of transportation
- Talented/helpful people have published ~10 'attacks' on vehicle networks
- There are plenty of opportunities for more (abuse aka 'logic bugs' in particular)
- There are a host of free tools for interacting with vehicle networks
- There are many ways for you to get involved !

Collaboration / about the NMFTA CTSRP

The NMFTA Commercial Transportation Security and Research Program (CTSRP) funds and collaborates on a wide array of topics affecting commercial transport, e.g.

- vehicle security offense & defense (topics of this talk)
- backend systems security
- distribution and service center security
- mainframe & ‘mid’ (IBM z & IBM i series) security

If you are interested in collaborating on a particular project idea, reach out to us please: https://ctsrp.nmfta.org/

Thank You

National Motor Freight Traffic Association, Inc.

References and Resources

References: Public Papers and Presentations for Truck Hacking

- Daily, Jeremy & Kongs, Andrew & Johnson, James & Corcega, Jose. (2015). *Extracting Event Data from Memory Chips within a Detroit Diesel DDEC v. 2015*. 10.4271/2015-01-1450. https://synercontechnologies.com/wp-content/uploads/2016/05/2015-SAE-Presentation-On-Chip-Level-Forensics.pdf

- Mukherjee, Subhojeet & Shirazi, Hossein & Ray, Indrakshi & Daily, Jeremy & Gamble, Rose. (2016). *Truckers Beware: Practical Denial-of-service Attacks in Embedded Networks of Commercial Vehicles*. http://www.cs.colostate.edu/dbsec/HeavyVehicle/wp-content/uploads/9783319498058-c2.pdf

- Jonson, Urban. *A comprehensive review of cyber security for heavy vehicles for the NMFTA membership*. http://www.nmfta.org/documents/hvcs/nmfta%20heavy%20duty%20vehicle%20cyber%20security%20whitepaper%20v1.0.3.6.pdf?v=1

- Haystack and sixvolts. *Cheap Tools for Hacking Heavy Trucks*. DEF CON 24 Car Hacking Village. https://github.com/TruckHacking/DEFCON24/raw/master/Cheap-Tools-For-Hacking-Heavy-Trucks-Slides.pdf

- Yelizaveta Burakova, Bill Hass, Leif Millar, and André Weimerskirch, *Truck Hacking: An Experimental Analysis of the SAE J1939 Standard*, Usenix WOOT, August 11-12, 2016, Austin, TX, USA. http://www.weimerskirch.org/files/BurakovaEtAl_TruckHacking.pdf

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- Thuen, Corey. IOActice: *Heavy Trucks and Electronic Logging Devices: What Could Go Wrong?* https://act-on.ioactive.com/acton/attachment/34793/f-d8737079-c6eb-411c-94d1-f52ffc9df975/1/-/-/-/-/IOActive-ELoggingDeviceVulnerabilities.pdf

- Salloum, Dan & Hayes, Thomas. *Before J1939: A J1708/J1587 Protocol Decoder*. DEF CON 28 SAFE MODE Car Hacking Village. https://www.youtube.com/watch?v=hal-E4mProk

- Poore, Chris & Gardiner Ben. *Power Line Truck Hacking: 2TOOLS4PLC4TRUCKS*. DEF CON 28 SAFE MODE Car Hacking Village. https://www.youtube.com/watch?v=sf3JznYTo0I

References: Public Papers and Presentations for Vehicle Hacking

- Cho et al. *Error Handling of In-vehicle Networks Makes Them Vulnerable* (2016) https://tagi98.github.io/files/publication/ktcho_busoff.pdf]
- Maggi, Federico. *A Vulnerability in Modern Automotive Standards and How We Exploited It*. (2017) https://documents.trendmicro.com/assets/A-Vulnerability-in-Modern-Automotive-Standards-and-How-We-Exploited-It.pdf
- Brom, Tim and Johnson, Mitchell. *When CAN CANT* (2018) https://www.youtube.com/watch?v=TRn_Rz2JIYQ
- Tindell, Ken. *CAN BUS: ATTACKS AND MITIGATIONS* (2020) https://asrg.io/events/15/
- Gardiner, Ben. REMOTE WRITING TRAILER AIR BRAKES WITH RF (2022) https://act-on.ioactive.com/acton/attachment/34793/f-ab6fea27-1929-4ad1-8cd6-7d2094910f66/1/-/-/-/-/Trailer-Air-Brakes-RF-NMFTA.pdf

Links to More Resources for Truck Hacking

- CyberTruck Challenge ™ https://www.cybertruckchallenge.org/participate/truck-challenges/
- NMFTA CTSRP unrestricted http://www.nmfta.org/pages/hvcs
- NMFTA CTSRP access-controlled but still free: https://hvcslistservice.nmfta.org/
- NMFTA github org https://github.com/nmfta-repo
- DG Tech reference on heavy vehicle pinouts: https://www.dgtech.com/wp-content/uploads/2016/04/Pinouts_ICR.pdf
- Vector References on Vehicle Networks https://elearning.vector.com/?lang=en
- Truck Hacking github org https://github.com/TruckHacking
- UTulsa github org https://github.com/orgs/Heavy-Vehicle-Networking-At-U-Tulsa/teams
- Colorado State github org https://github.com/SystemsCyber
- Colorado State Heavy Vehicle CAN data https://www.engr.colostate.edu/~jdaily/J1939/candata.html

- SAE J1939: https://www.sae.org/publications/collections/content/j1939_dl/
- SAE J1939-DA: https://www.sae.org/standards/content/j1939da_202012/
- SAE J1939-21: https://www.sae.org/standards/content/j1939/21_201810/
- SAE J1939-81: https://www.sae.org/standards/content/j1939/81_201703/
- SAE J1708: https://www.sae.org/standards/content/j1708_200408/
- SAE J1587: https://www.sae.org/standards/content/j1587_201301/
- SAE J2497: https://www.sae.org/standards/content/j2497_201207/