Recovery of Partial Caterpillar Snapshot Event Data Resulting from Power Loss

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Presentation Overview

- Motivating Example
- Algorithm Development
- Testing in the Lab
- Field Success

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Motivating Crash Test

IPTM Special Problems 2015

Transit Bus Vs School Bus

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Aerial View

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School Bus Description

- 2001 Thomas Built Bus by Freightliner
- VIN: 4UZAAXAK332CJ34136
- Weight: 18,400 lb
  - Front: 7,000lb Rear: 11,400lb

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School Bus Power Plant

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School Bus Data Summary

- Engine
  - Make: Caterpillar
  - Model Number: 3126B
  - Serial Number: CKM01078
  - Engine Control Module Family: ADEM2000
  - 190 Hp @2100 RPM, 2500 RPM governed
- Transmission
  - Make: Allison
  - Model: AT-545
- Date of Manufacture: 02/22/01

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Crash Testing (Aside)

- Q: Can we actually crash a bus into a bus?
  - A: Yes
- Considerations:
  - Power for tow – Use the power band of the tow vehicle -> compound pulleys
  - Force of the pull – Ensure strength of components
  - Energy Management – Cables are dangerous
  - Brake systems – Stop the bus, if needed

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Crash Testing Parts

- Custom Spindles, Plates and Hubs
  - ½" plate steel, plasma cut for 5 lugs
  - 7000 lb trailer spindles welded to the plate

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Materials

- 3/8” galvanized steel cable (7x19) rated at 14,400 lb
- 4 ton Crosby/McKissick Snatch Blocks
- Hollow Polyester Rope - for Lifting
  - Flexible, 3/8" Diameter,
  - 3500 lb. Lifting Capacity
- Wire rope snake – 1200 lb work load
  - Breakaway at pickup

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Tow System in Action

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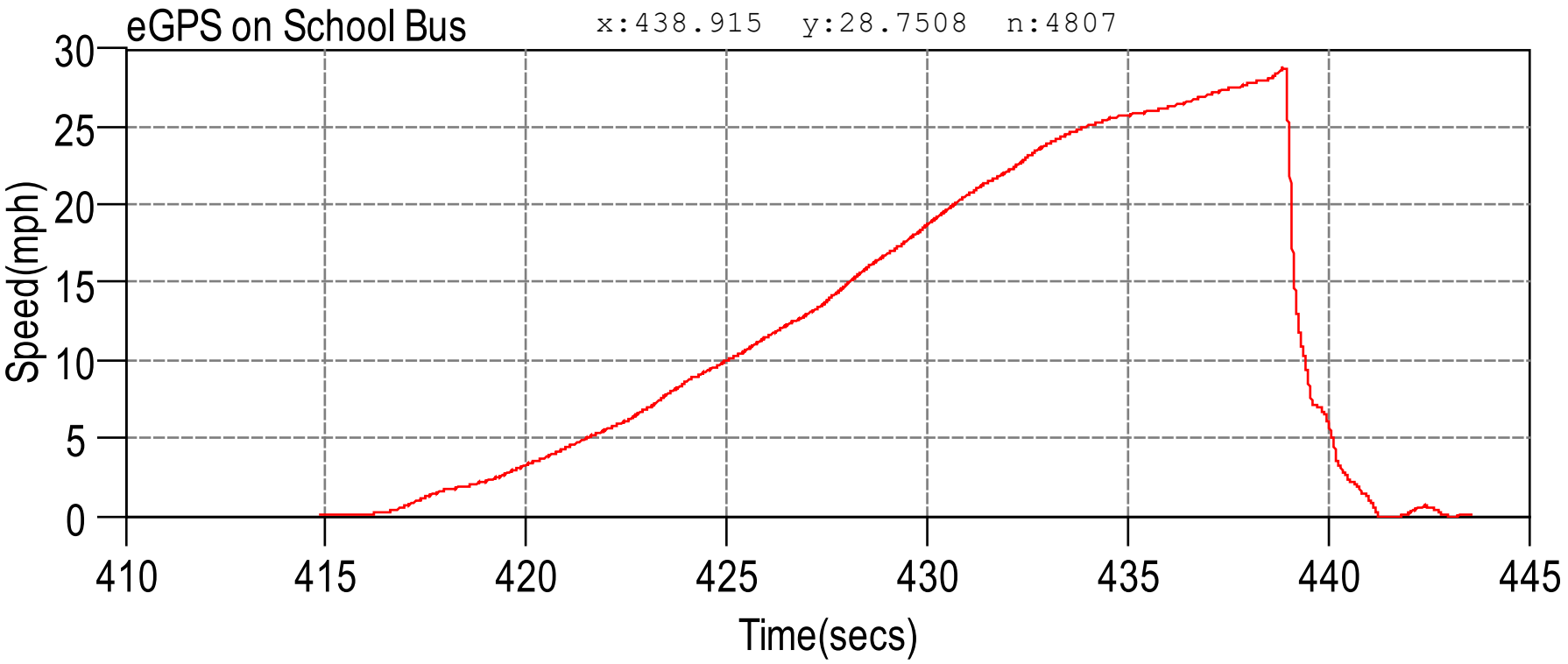
Crash Data

- Speed at impact



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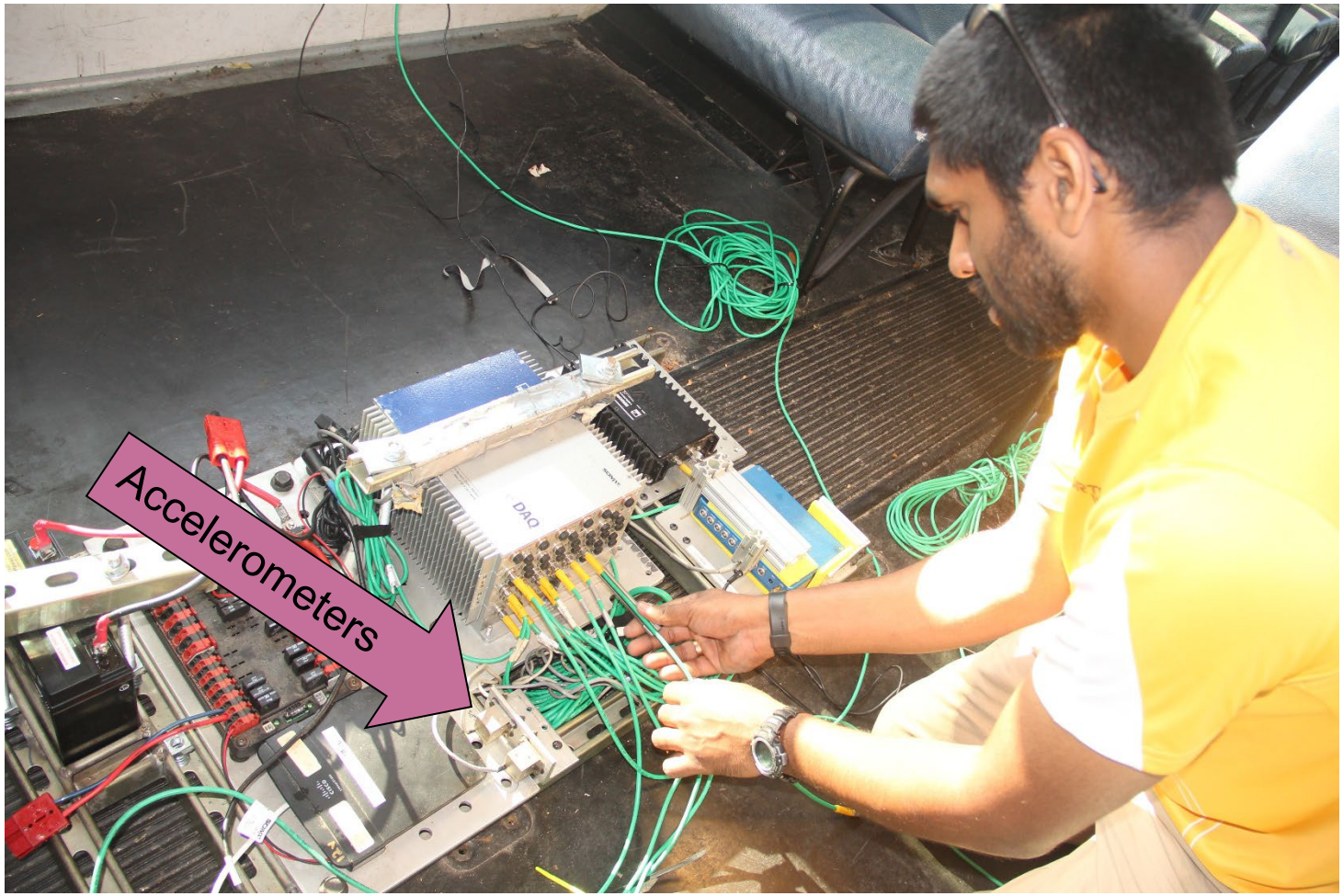
Accelerations and Delta-V of School Bus



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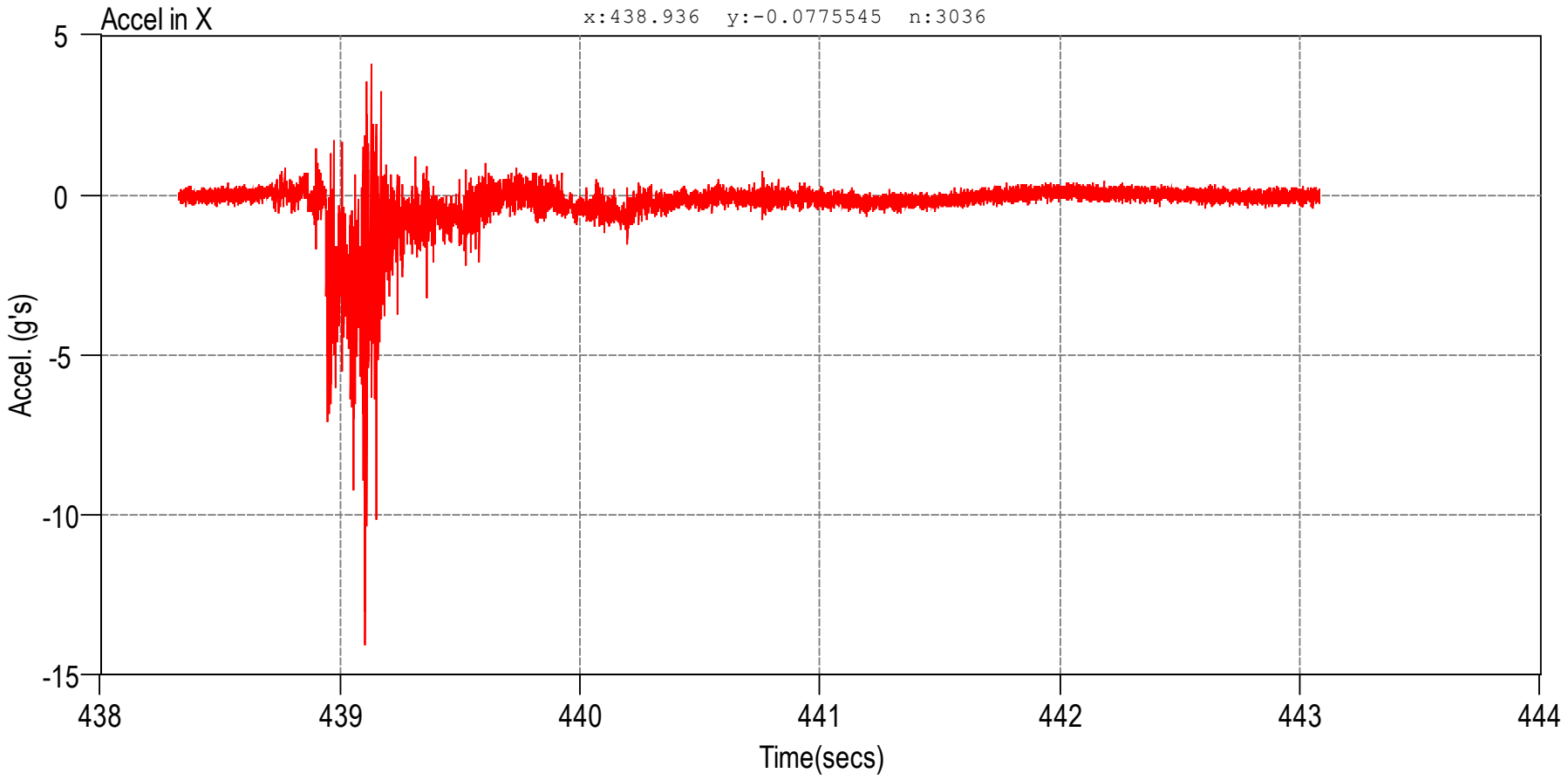
Acceleration in X for School Bus



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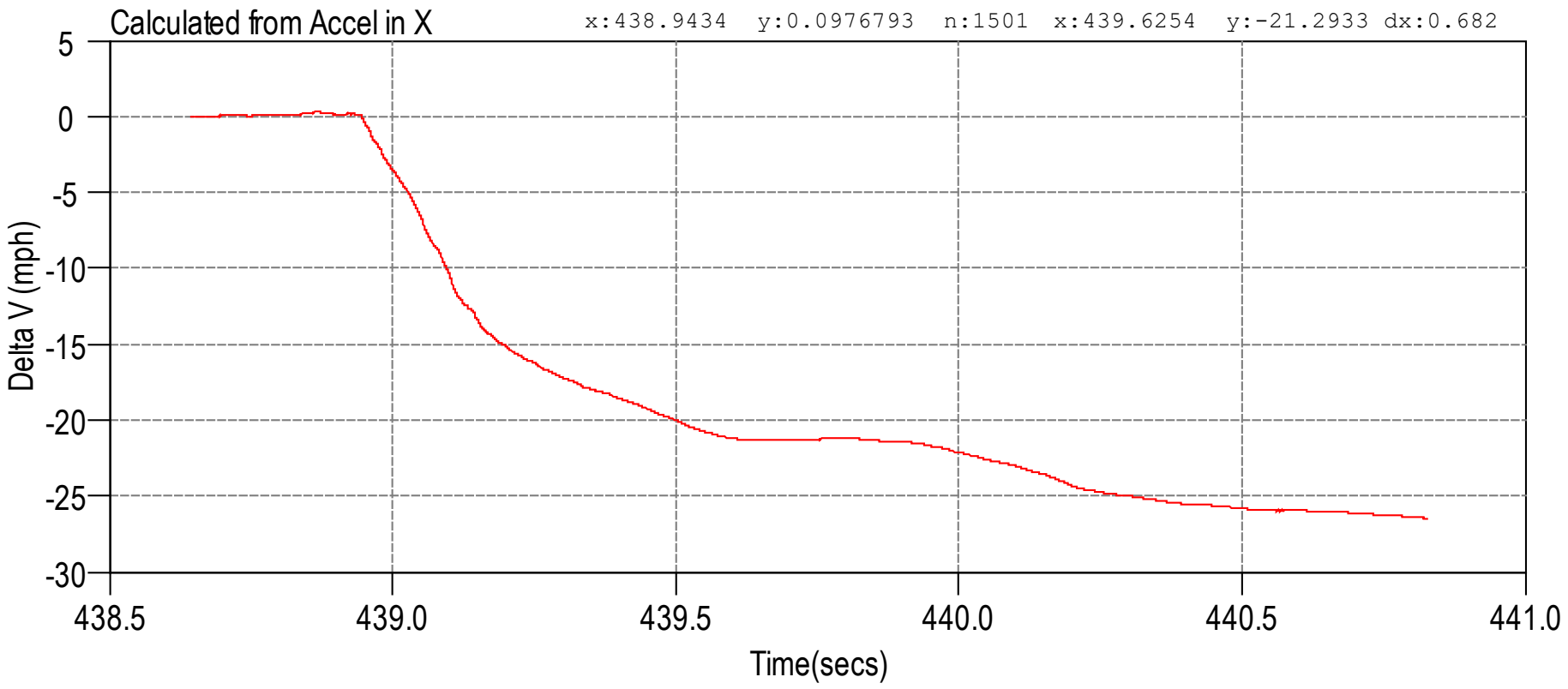
Delta-V in X for School Bus



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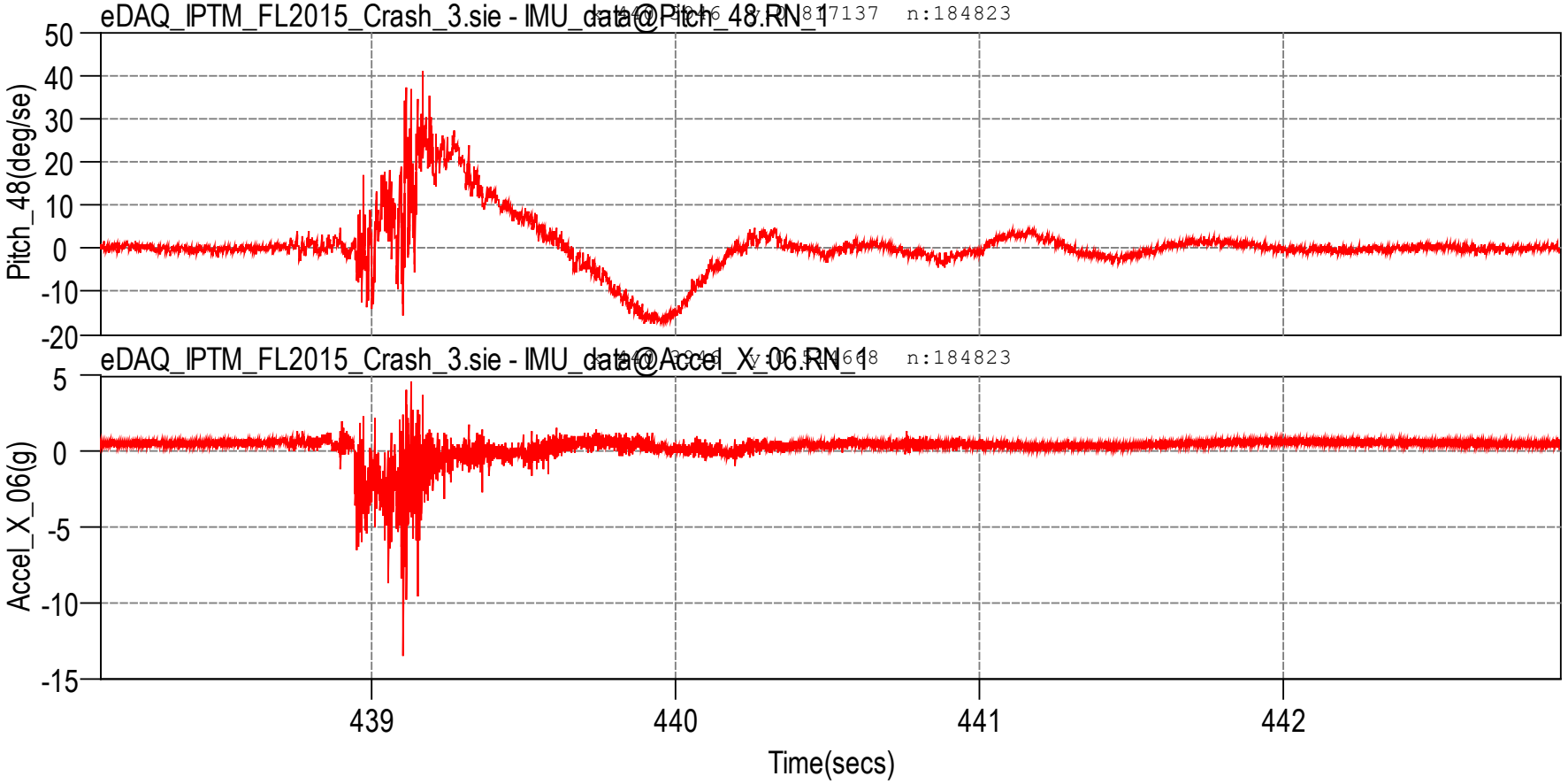
Pitch of School Bus



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Video Recap

EXTRACTING HVEDR DATA FROM THE SCHOOL BUS

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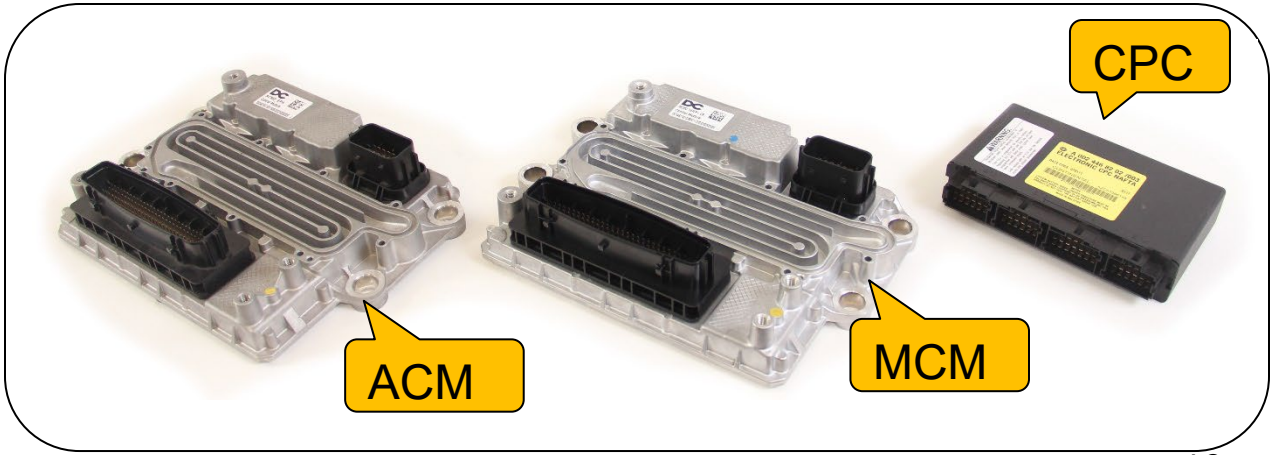
Heavy Vehicle Event Data Recorders

- Records set from events can be stored inside electronic control modules (ECMs)
- Most often these are the engine control modules
  - Detroit Diesel
  - Mercedes
  - Cummins
  - Caterpillar
  - Mack/Volvo
  - Navistar



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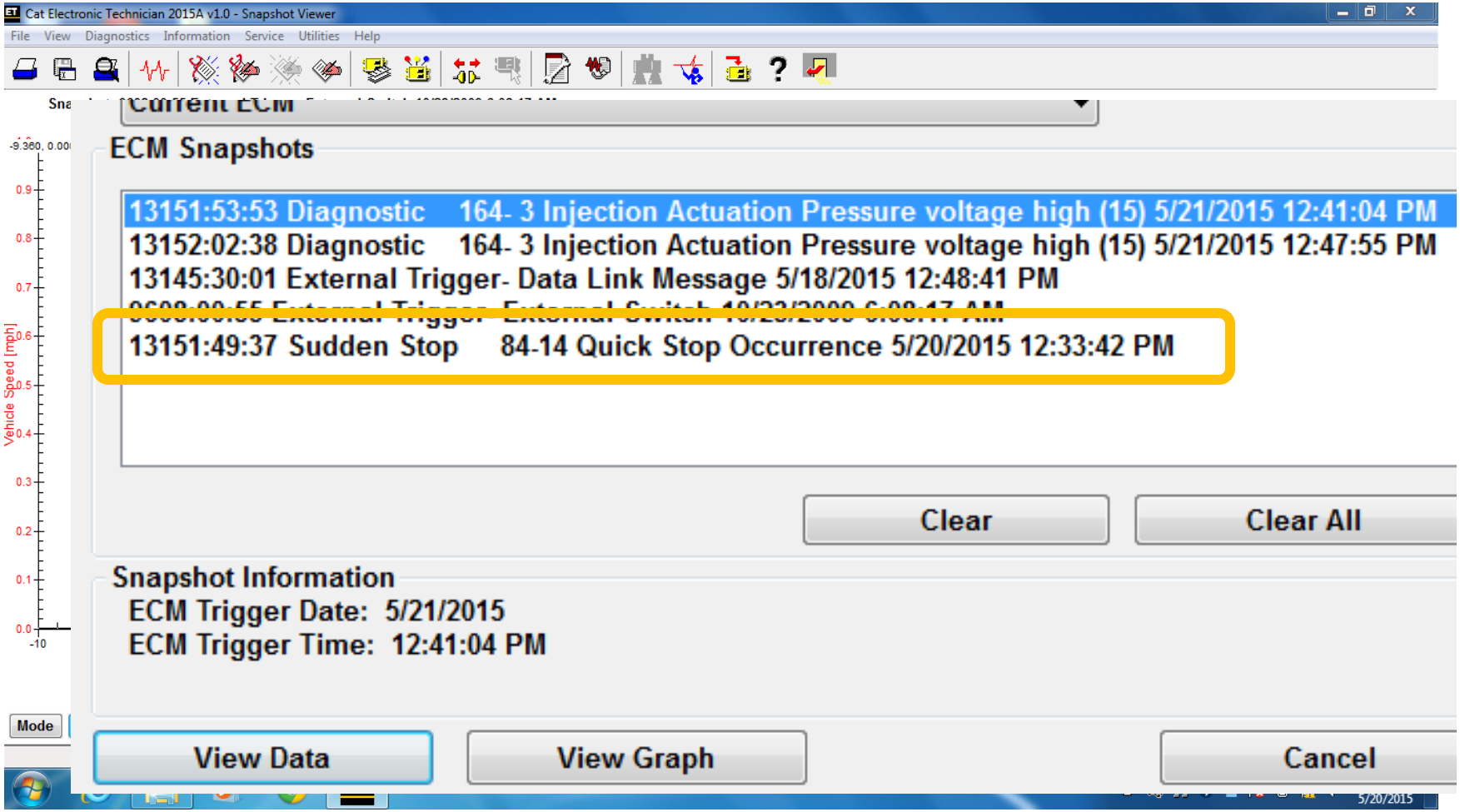
Downloading the CAT from the School Bus



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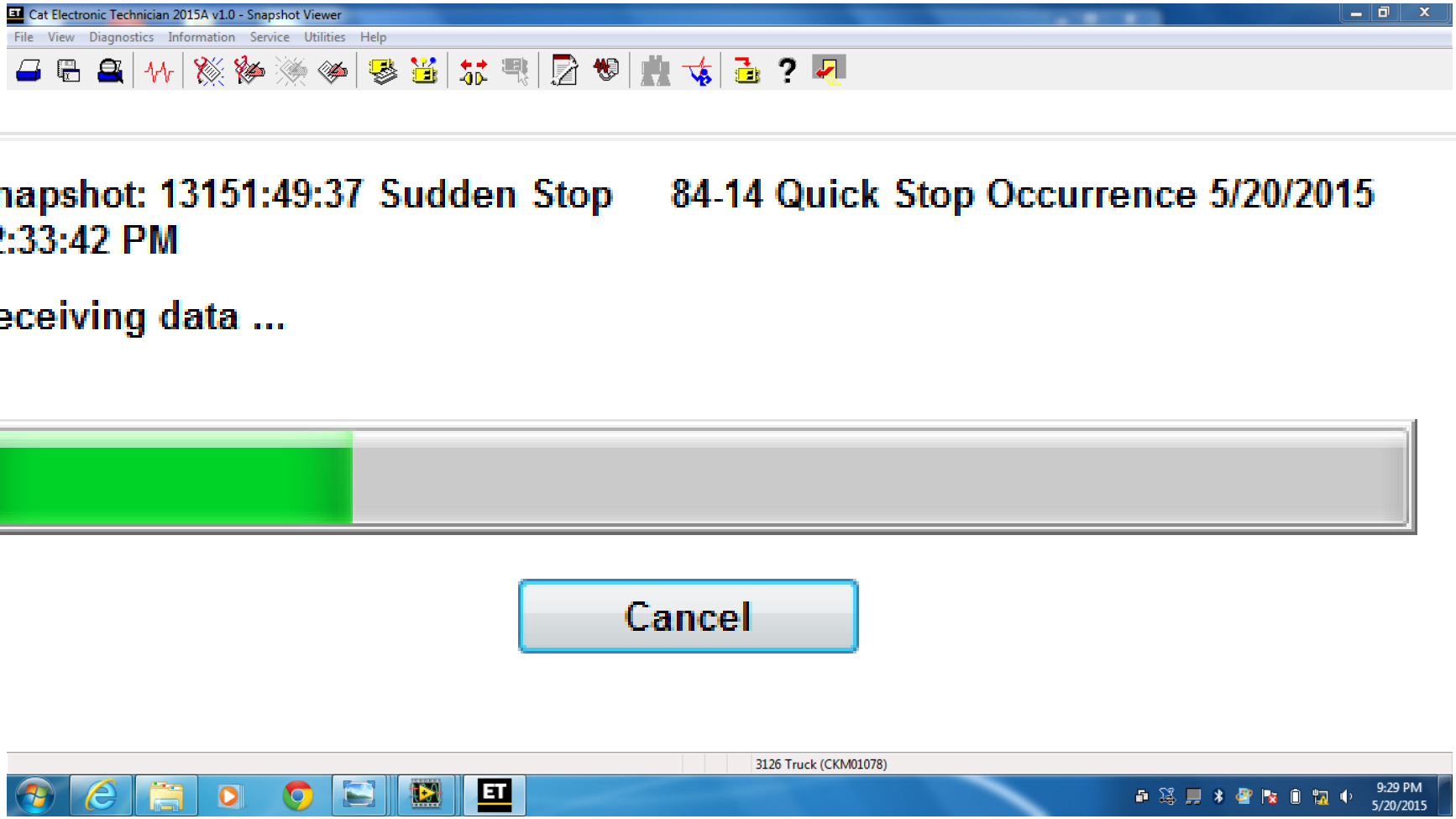
Getting Snapshot Data



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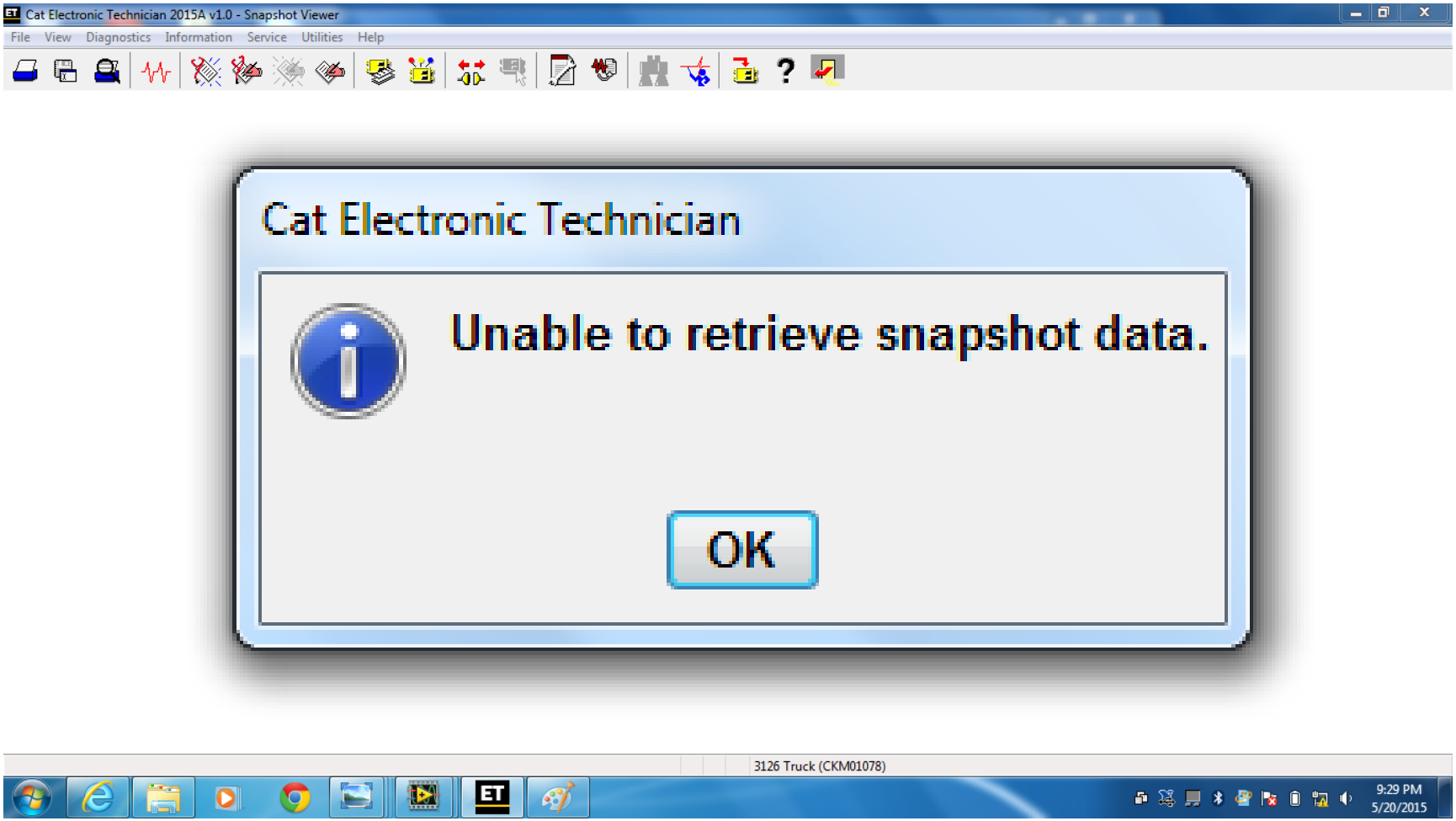
Except…



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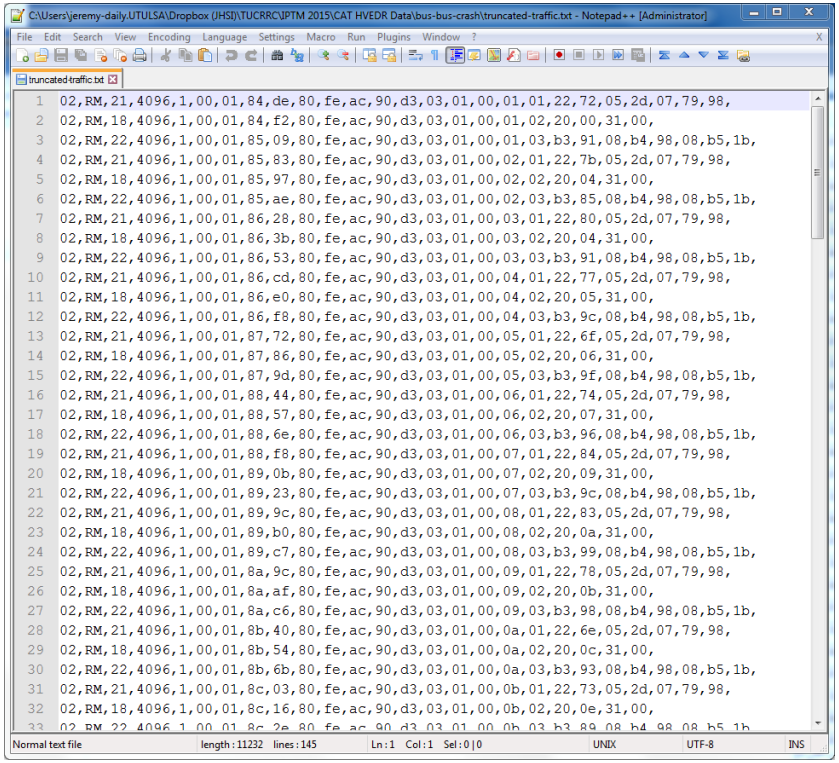
But we know data exists!

Data Bus was Recorded During the Crash

Network Logs from ET Showed Data for Quickstop



DATA EXTRACTION ALGORITHM

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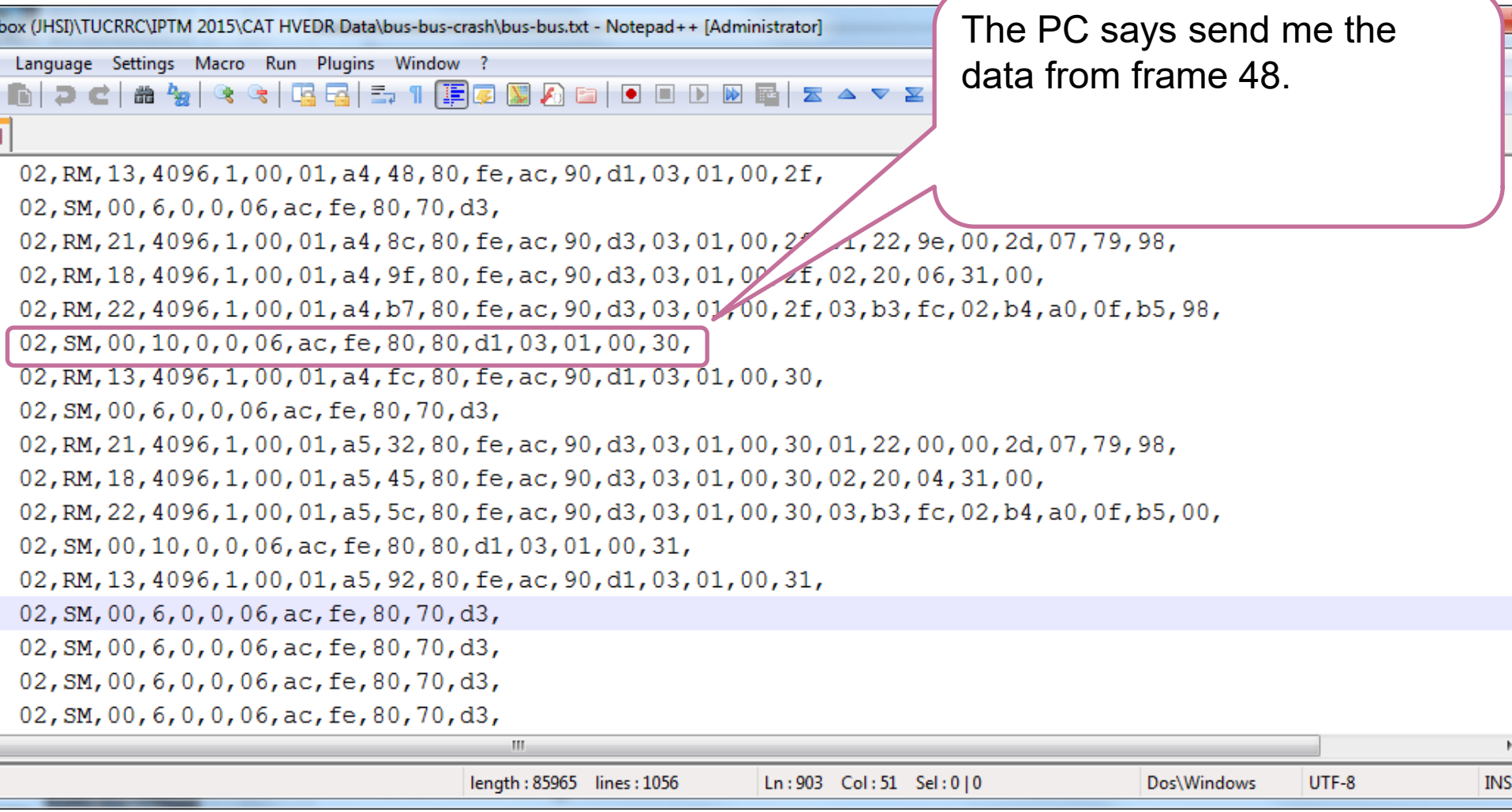
J1708 Network Analysis



The PC says send me the data from frame 48.

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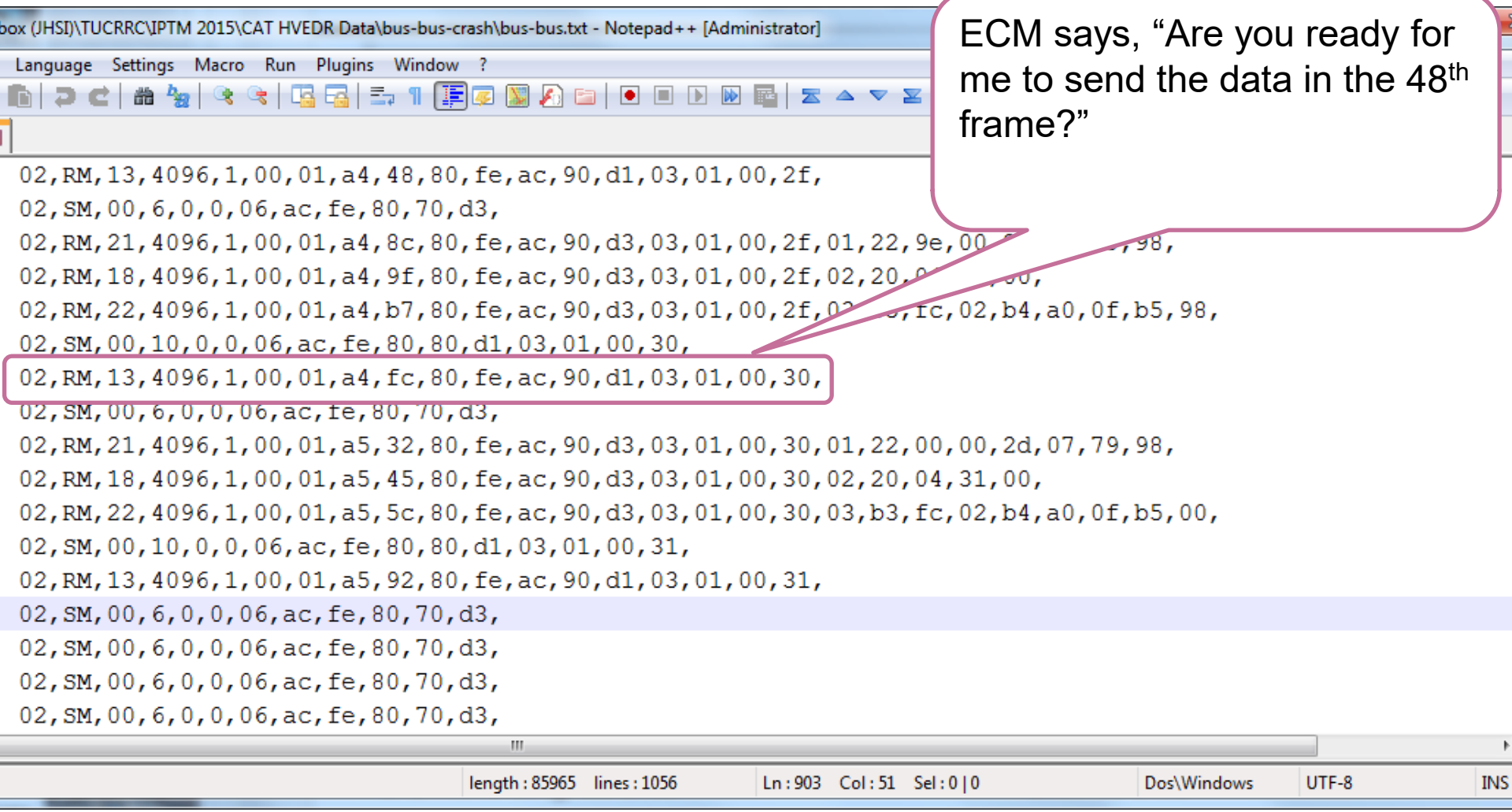
J1708 Network Analysis



ECM says, “Are you ready for me to send the data in the 48th frame?”

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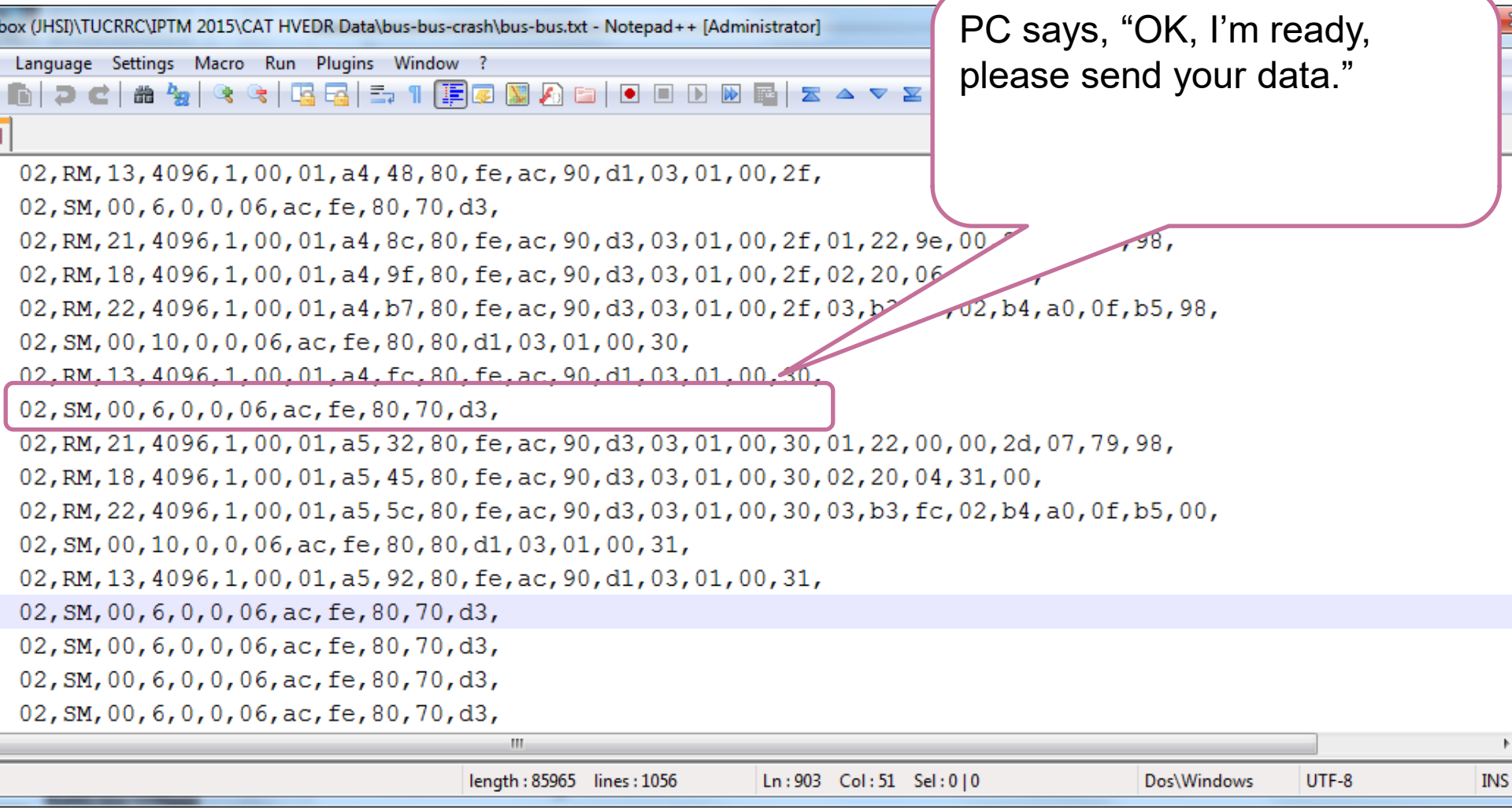
J1708 Network Analysis



PC says, “OK, I’m ready, please send your data.”

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J1708 Network Analysis

box (JHSI)\TUCRRC\IPTM 2015\CAT HVEDR Data\bus-bus-crash\bus-bus.txt - Notepad++ [Administrator]

Language Settings Macro Run Plugins Window ?

```
02,RM,13,4096,1,00,01,a4,48,80,fe,ac,90,d1,03,01,00,2f,
02,SM,00,6,0,0,06,ac,fe,80,70,d3,
02,RM,21,4096,1,00,01,a4,8c,80,fe,ac,90,d3,03,01,00,2f,01,22,9e,00,2
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02,SM,00,6,0,0,06,ac,fe,80,70,d3,
```

length : 85965 lines : 1056 Ln : 903 Col : 51 Sel : 0 | 0 Dos\Windows UTF-8 INS

ECM sends all the requested data for that frame in 3 J1708 messages.

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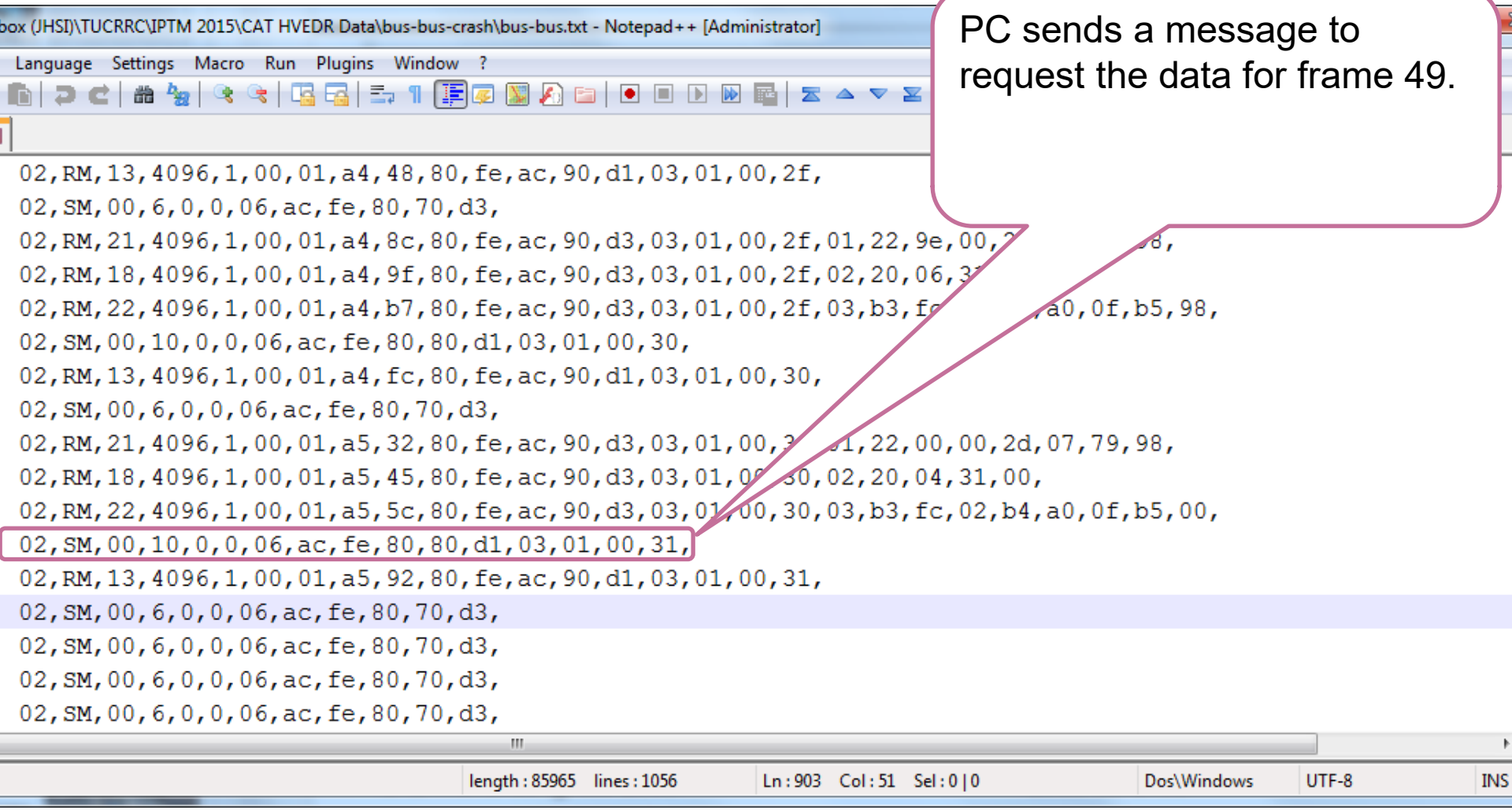
J1708 Network Analysis



PC sends a message to request the data for frame 49.

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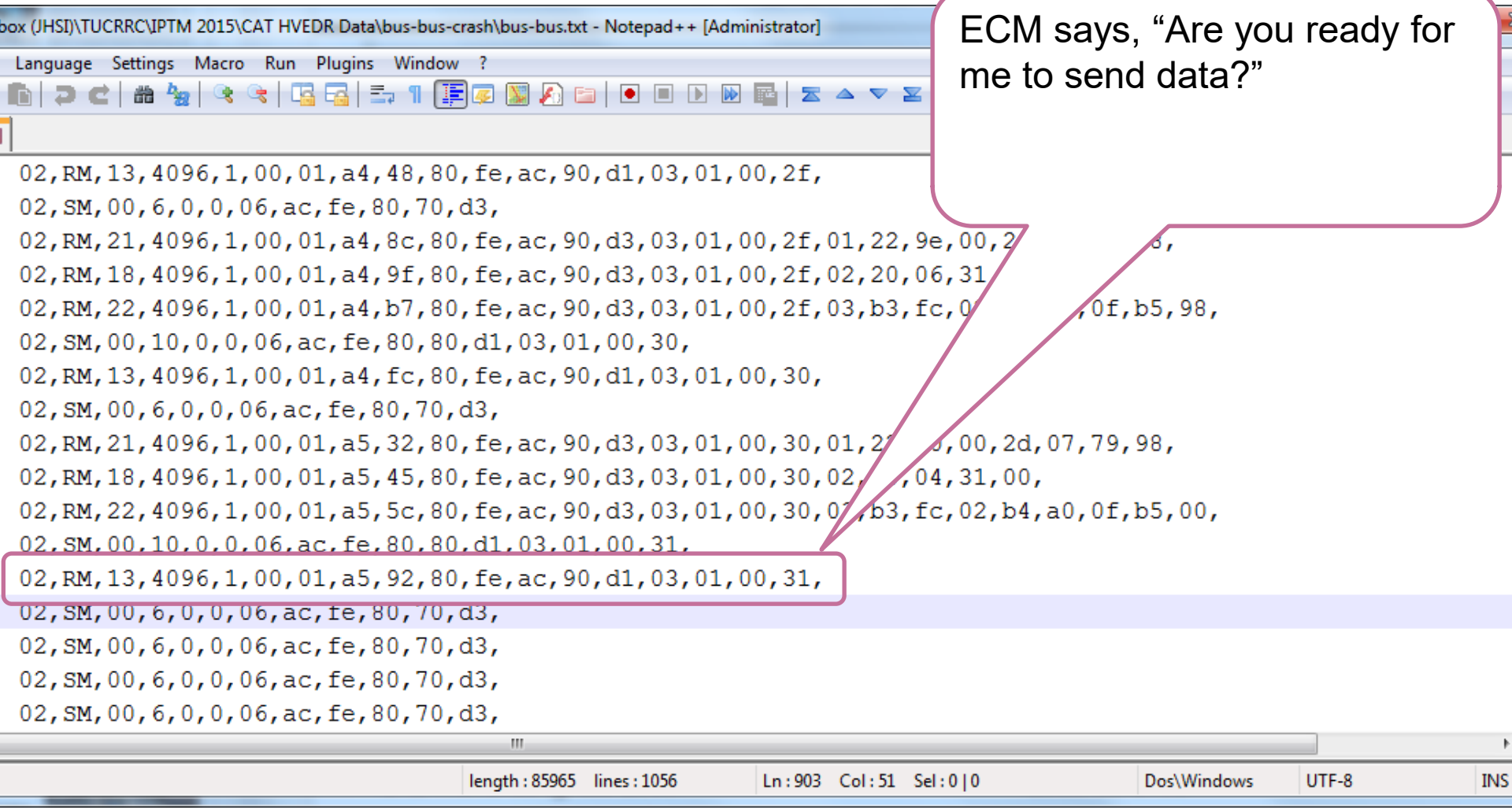
J1708 Network Analysis



ECM says, “Are you ready for me to send data?”

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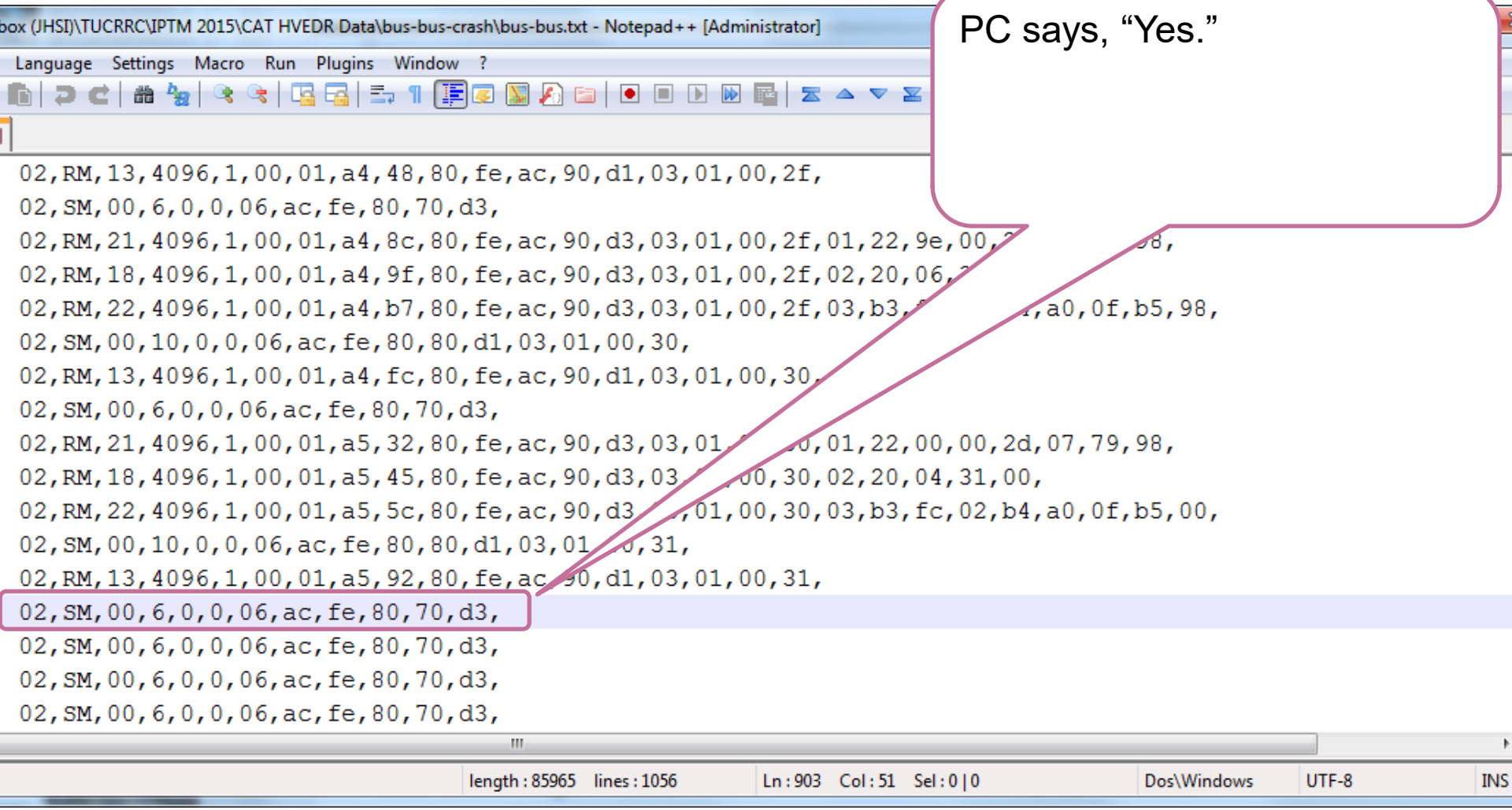
J1708 Network Analysis



PC says, “Yes.”

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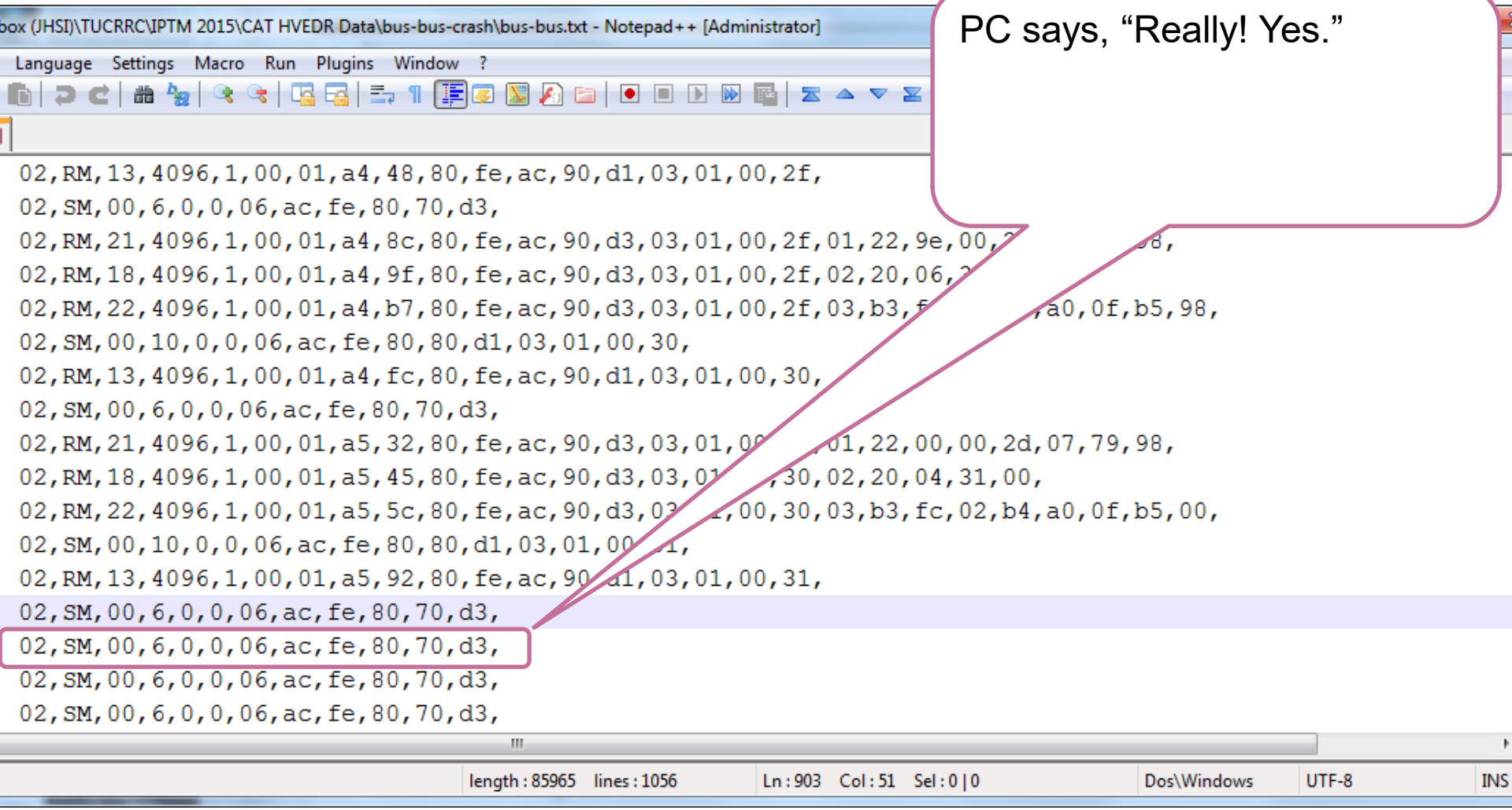
J1708 Network Analysis



PC says, “Really! Yes.”

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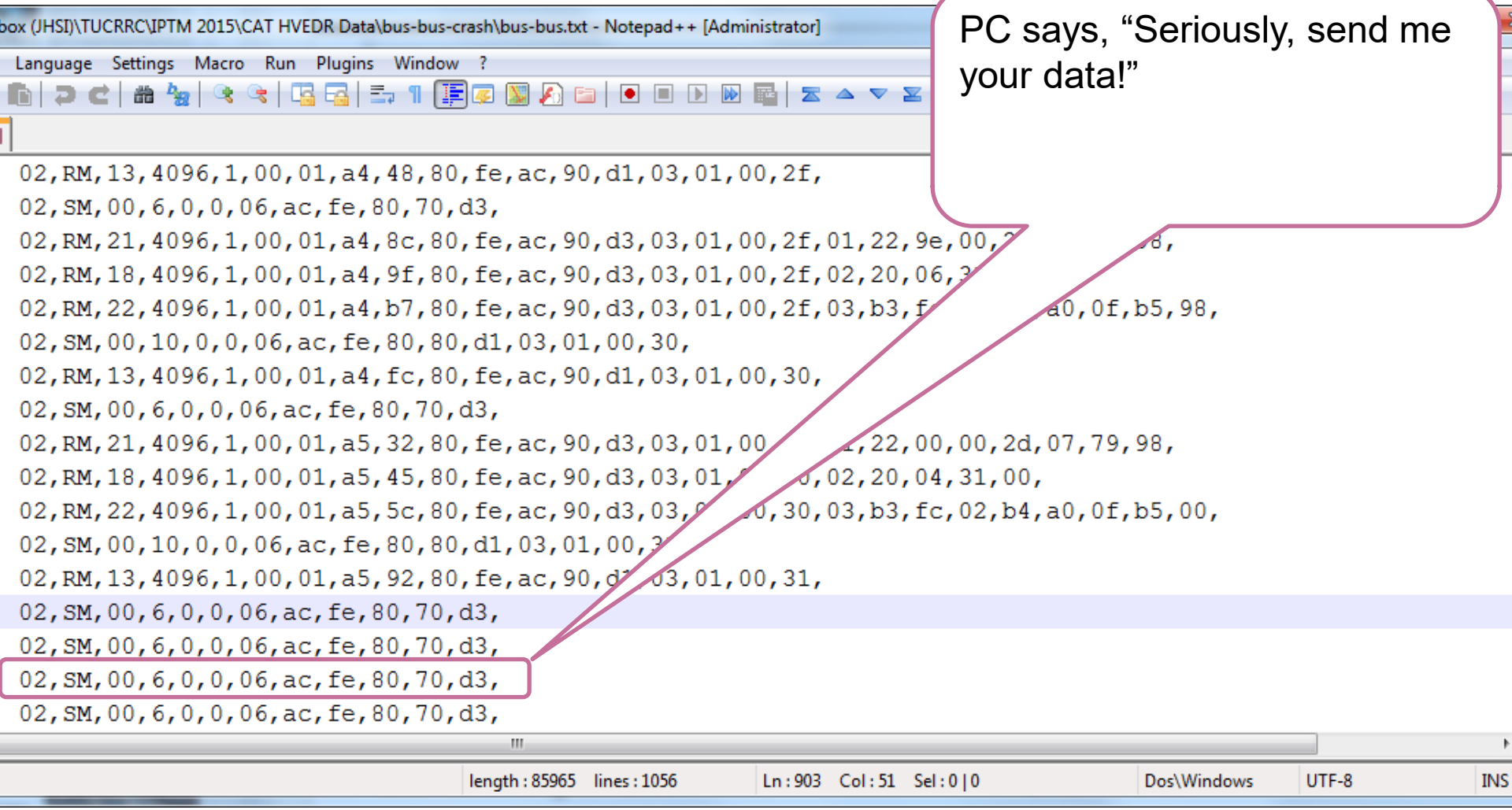
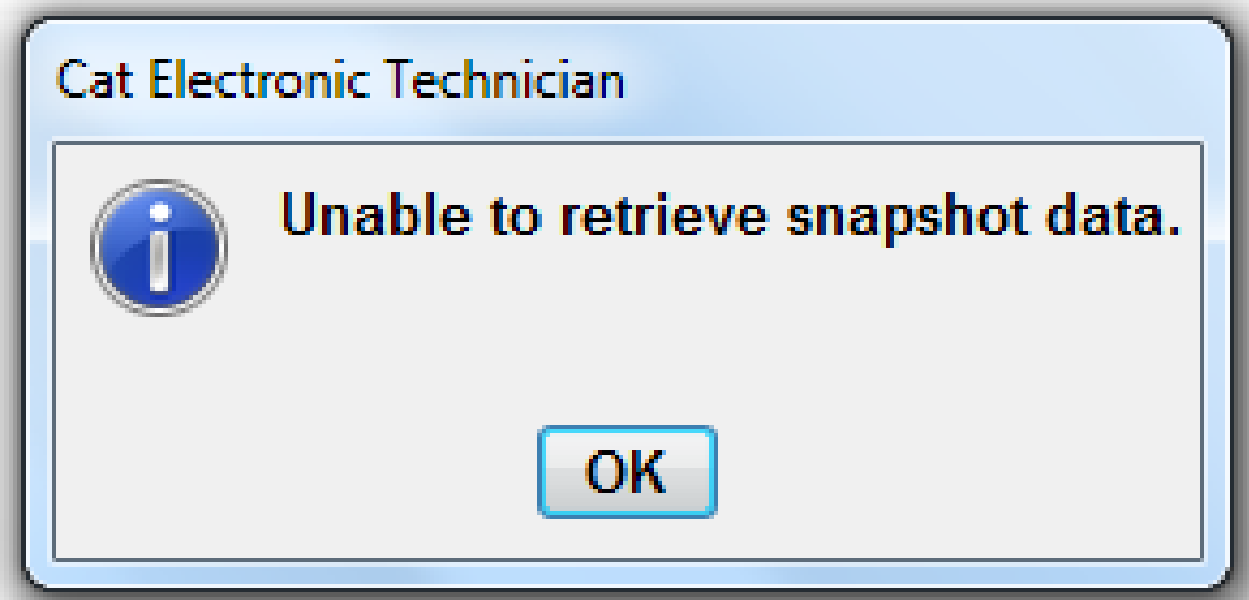
J1708 Network Analysis



PC says, “Seriously, send me your data!”


Cat Electronic Technician
Unable to retrieve snapshot data.
OK

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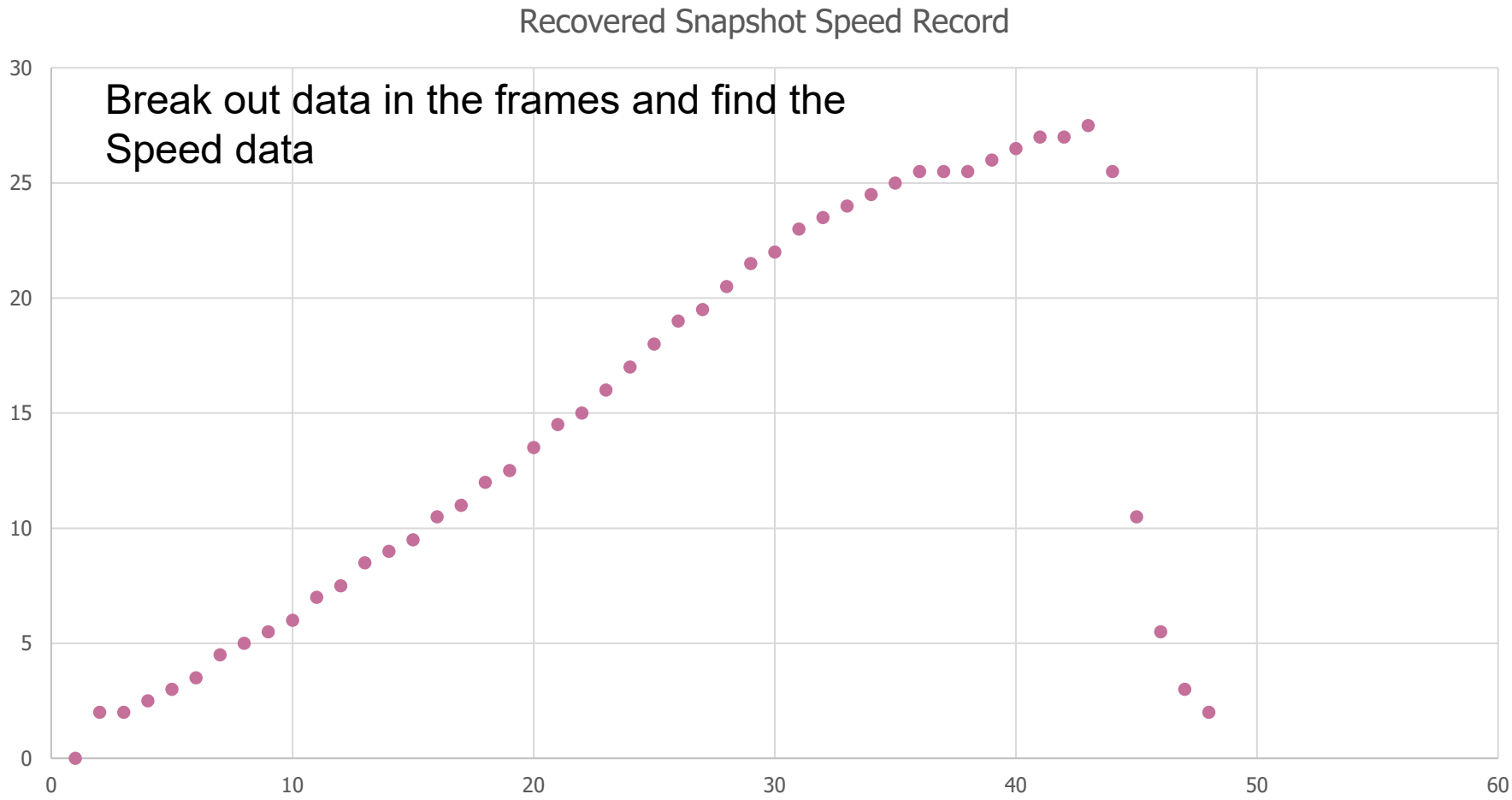
Recovered Speed Data



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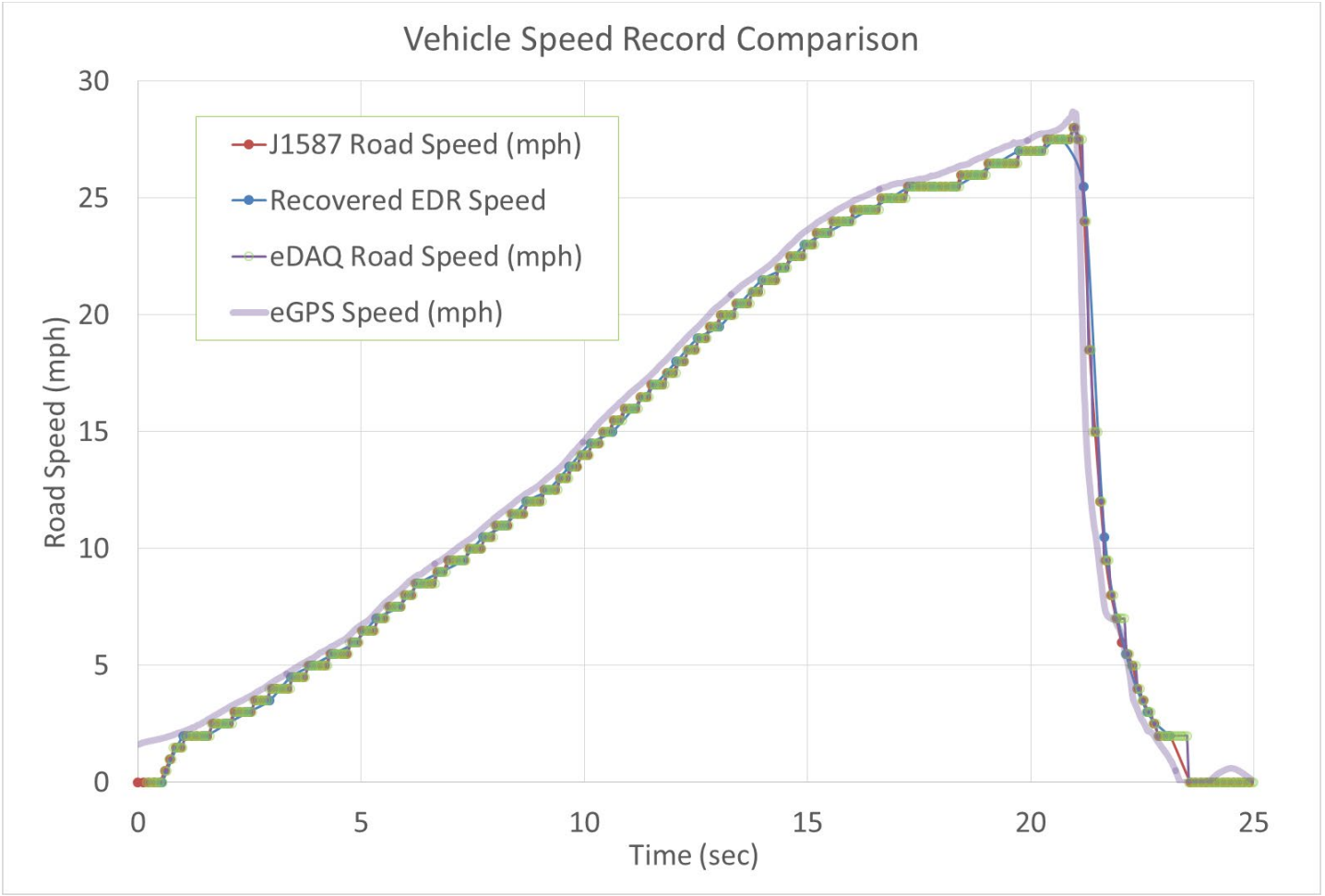
Synchronized Network Data



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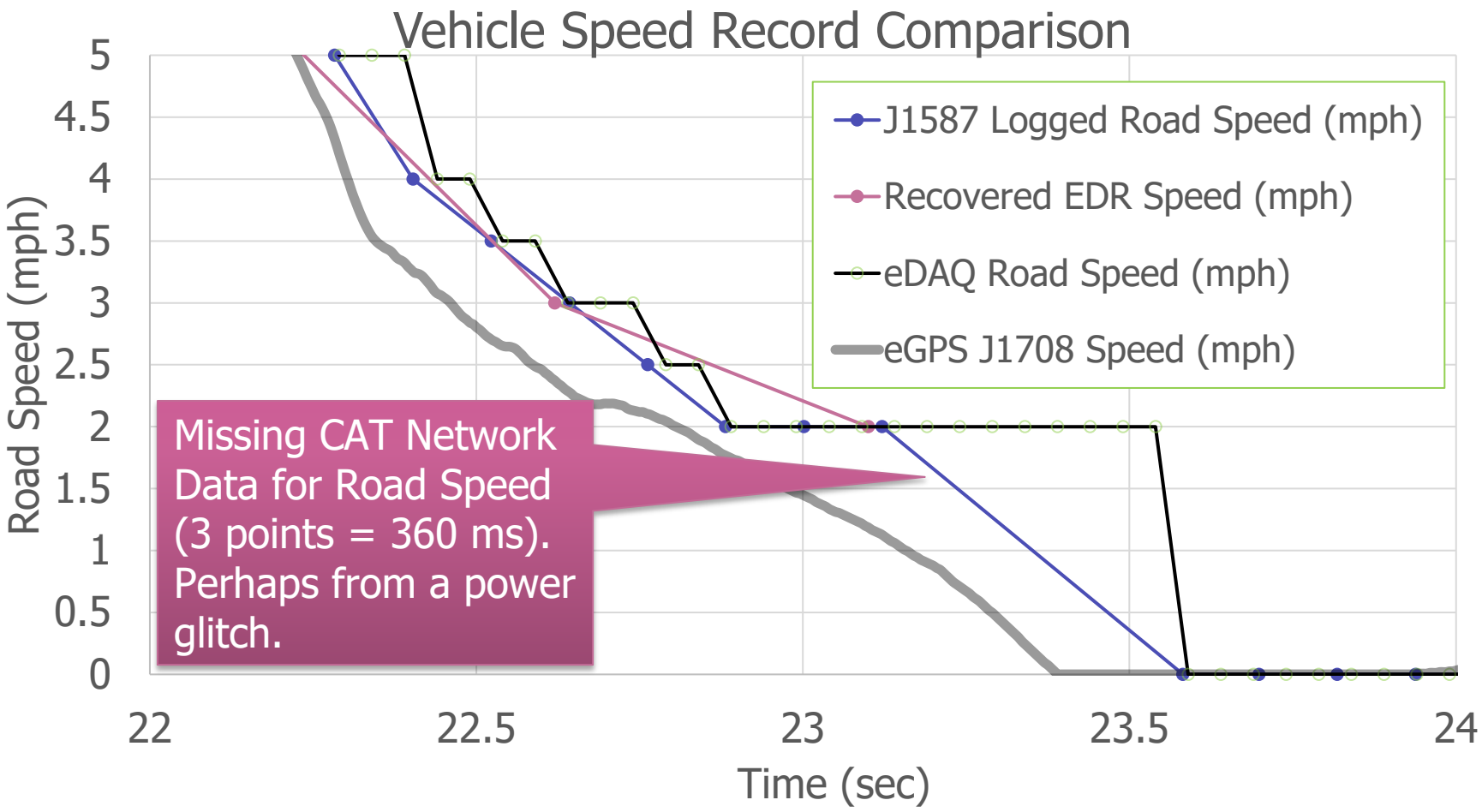
Power Glitch?



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Key Points from Crash Testing

- Crashing a Bus into a Bus
  - Upsized Cable System
- Mixed Vehicle Network, Vbox, IST, ACM, and eDAQ data.
- Recorded and synchronized J1708 network traffic into a crash.
- Manually recovered previously unobtainable information from CAT ECMs.

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Literature Review

- Messerschmidt, W., Austin, T., Smith, B., Cheek, T., et al., "Simulating the Effect of Collision-Related Power Loss on the Event Data Recorders of Heavy Trucks," 2010-01-1004
  - Cutting power after a hard brake produced a Snapshot that CatET Could not recover.
- Austin, T. and Farrell, M., "An Examination of Snapshot Data in Caterpillar Electronic Control Modules," 2011-01-0807
  - Survey of many Cat ECMs and data retention.

Thesis Statement:

CATERPILLAR ECMS HAVE RECOVERABLE DATA, EVEN AFTER A POWER LOSS

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Research Procedure

1. Build the extraction algorithm into a tool (Forensic Link Adapter).
2. Simulate speed data for Quickstop Events
3. Toggle power at various times after the Quickstop starts.
4. Extract the data with the Forensic Link Adapter.
5. Attempt extraction with CatET.

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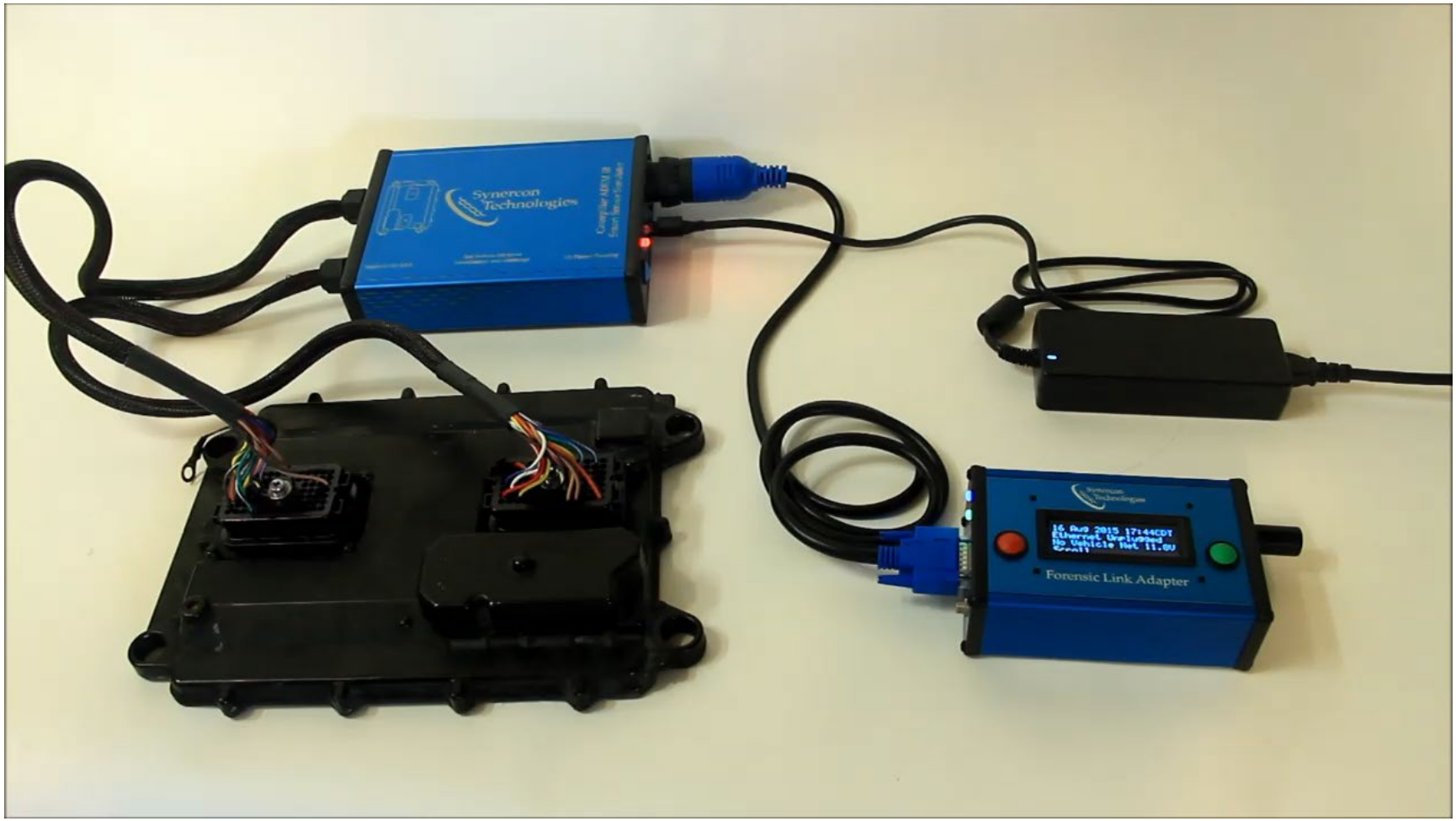
Step 1: Build a Tool



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Successful Snapshot Download Screen

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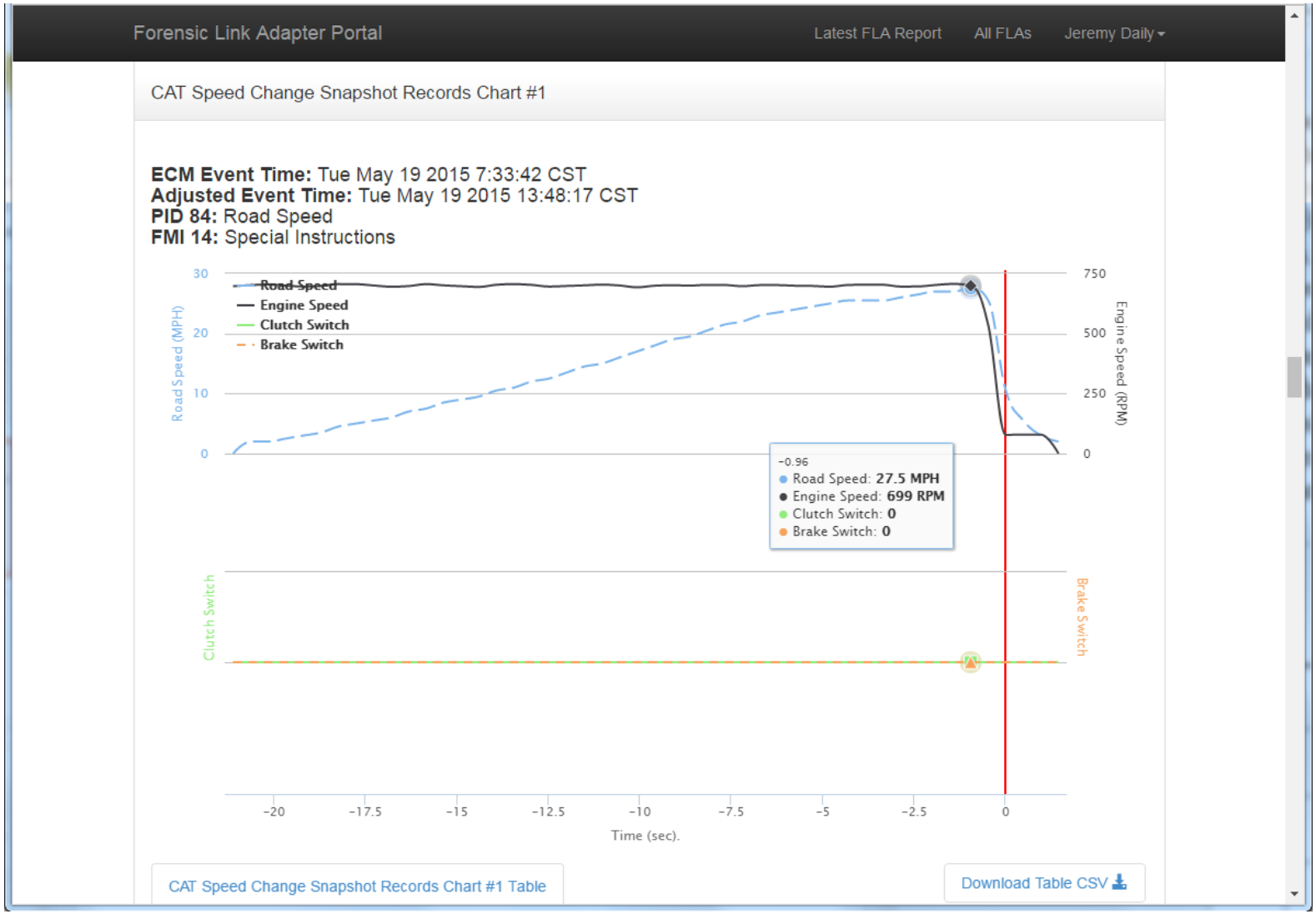
Results on the Forensic Link Adapter Portal



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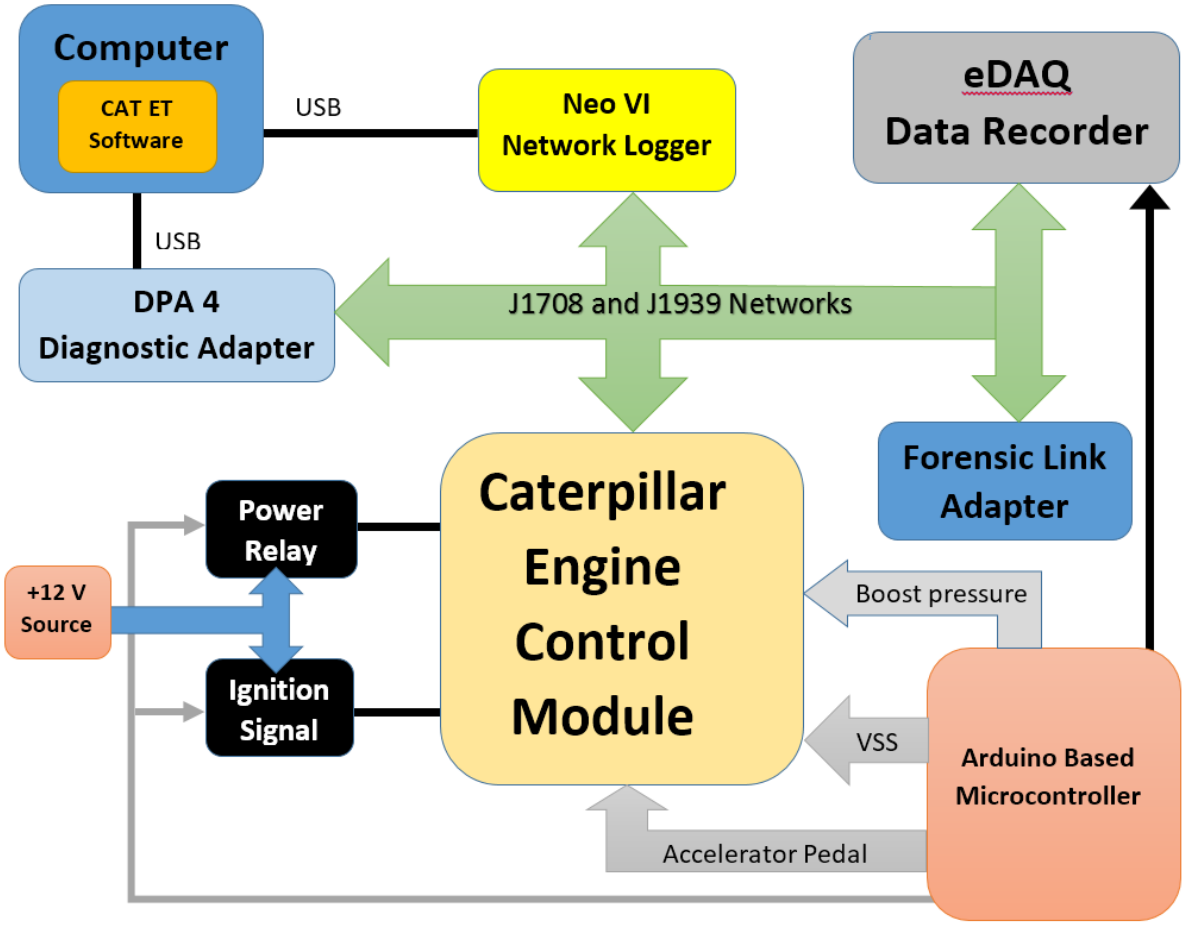
Test Setup Diagram



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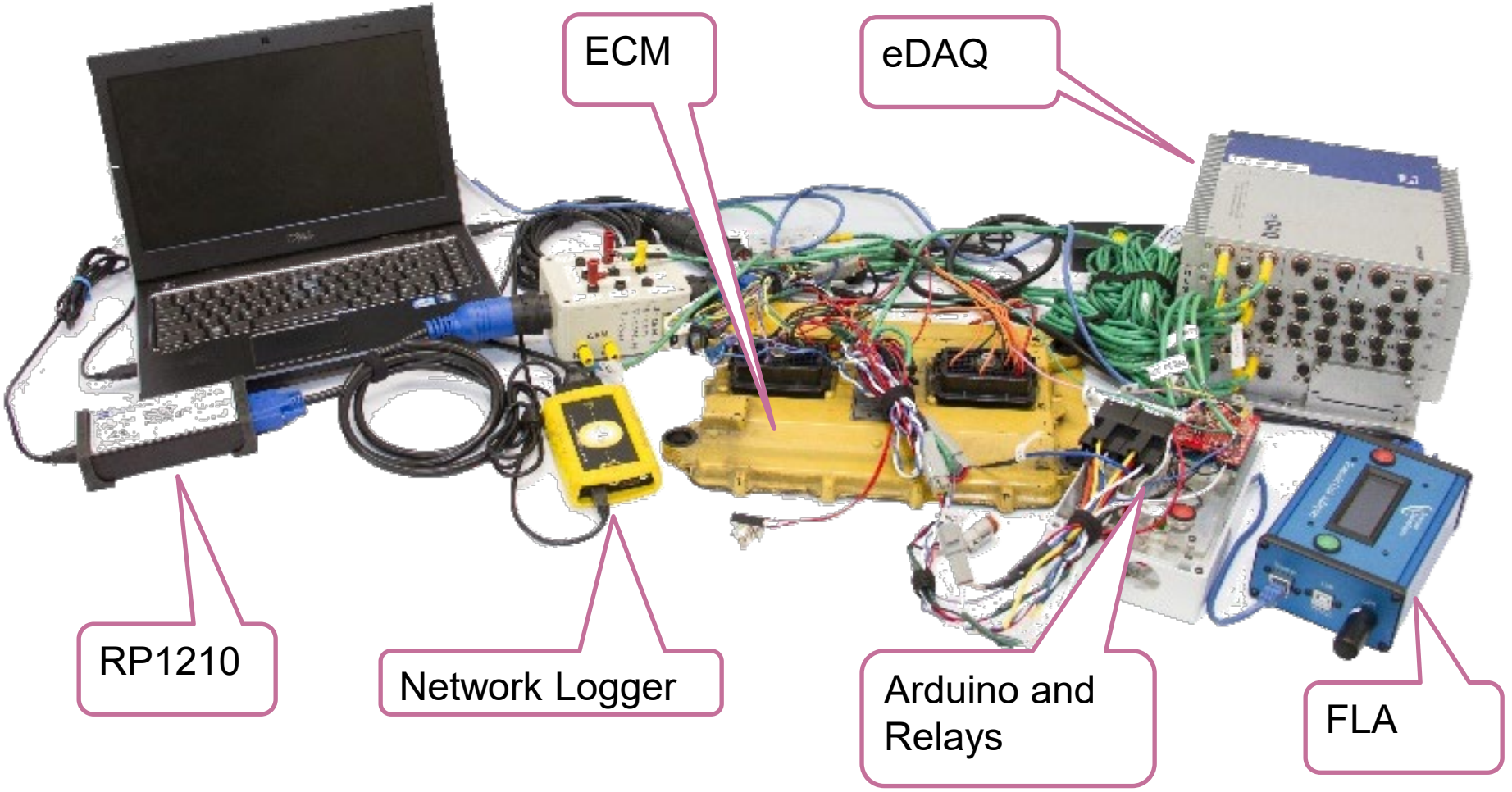
Physical Test Setup



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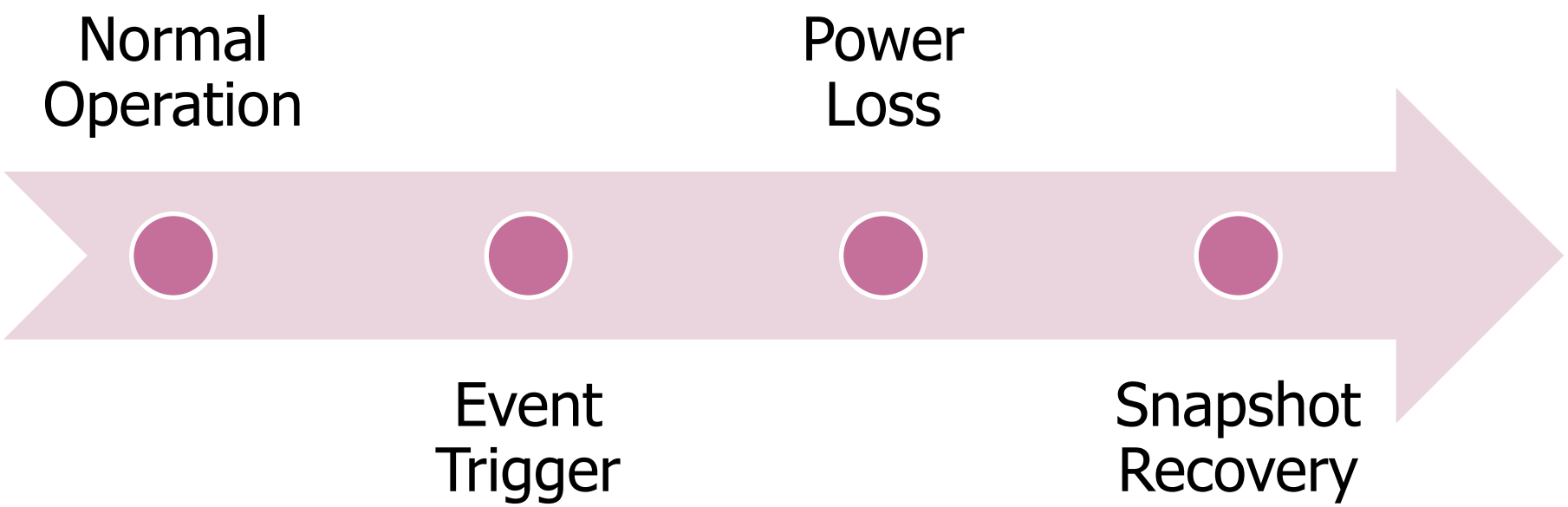
Test Sequence



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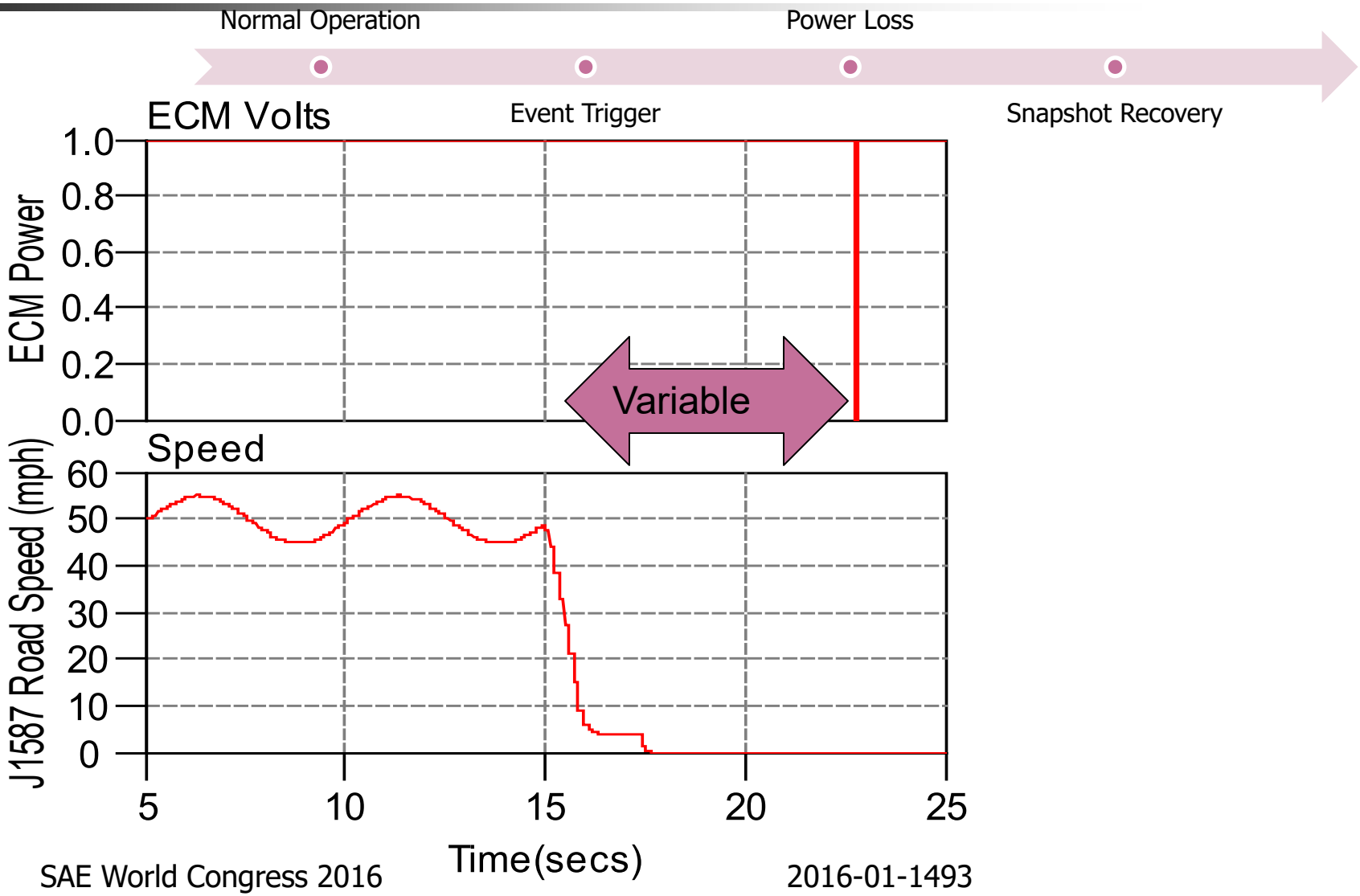
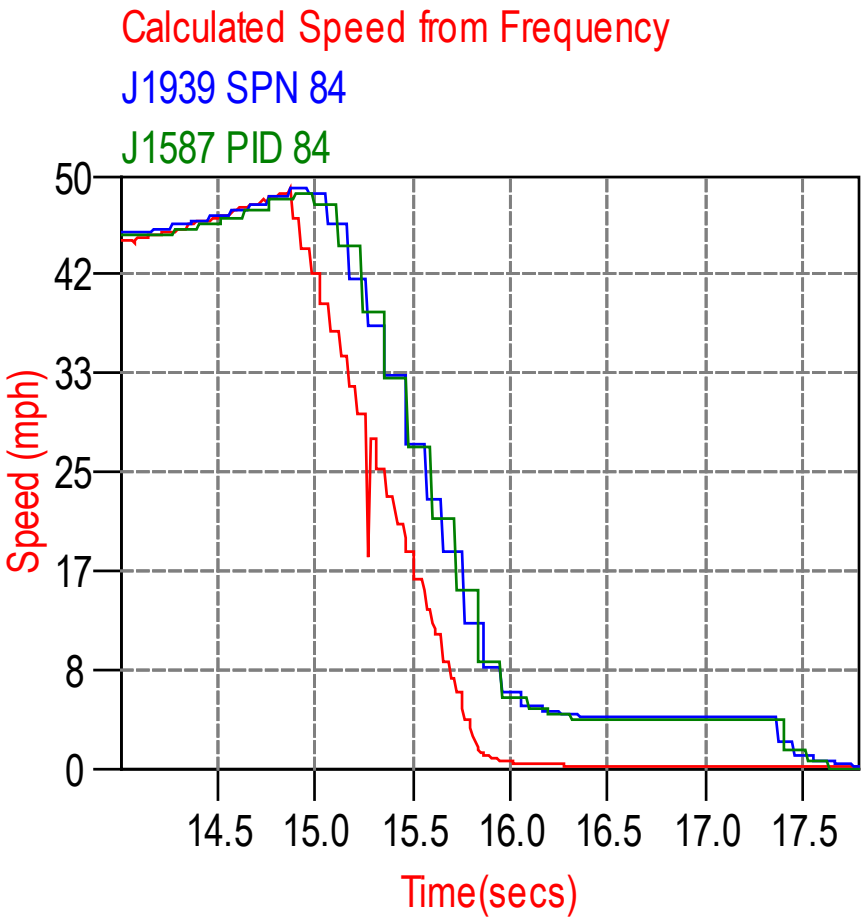
Test Sequence Signals



Signal Delay



- Speed signal generated by using the tone() function in Arduino.
- Frequency converted to speed with eDAQ
- Speed is delayed about 180 to 190 milliseconds
- About 4 mph is sustained for at least 1 second, even after the tone ring signal has dropped to zero

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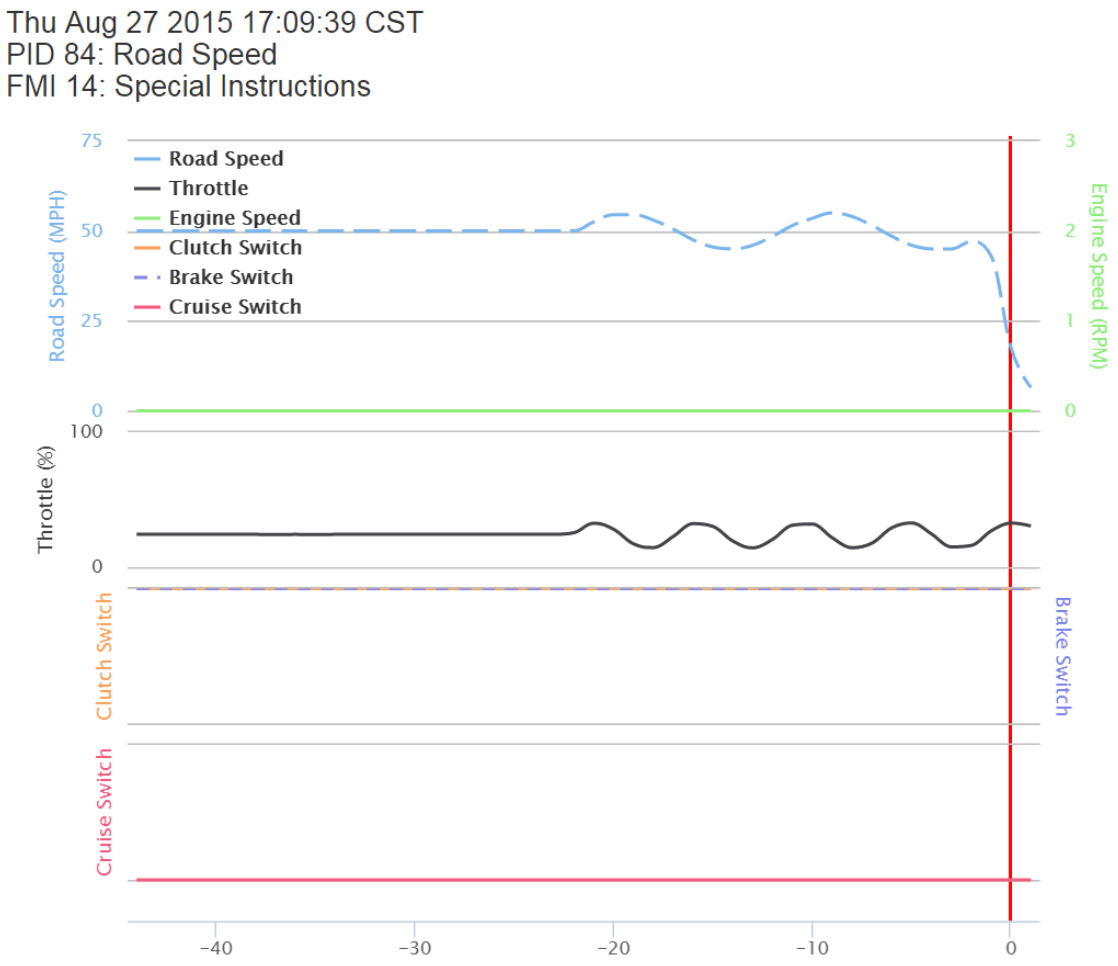
Snapshot Recovery



- Generated 41 Quickstop records.
- FLA recovered all available snapshots.
- CatET recovered only the snapshot that was 7.87 seconds after event trigger.
- Event to Power loss > 0.5 seconds

Limitations

- This study does not address accuracy, just availability.
- Only tested 6NZ (ADEM2000) and BXS (ADEM3) in the lab.
- BXS did not always record QuickStop events
  - Recoverable data has to exist first.
  - Conducive conditions may not produce records.
- Did not address off Engine fault codes.

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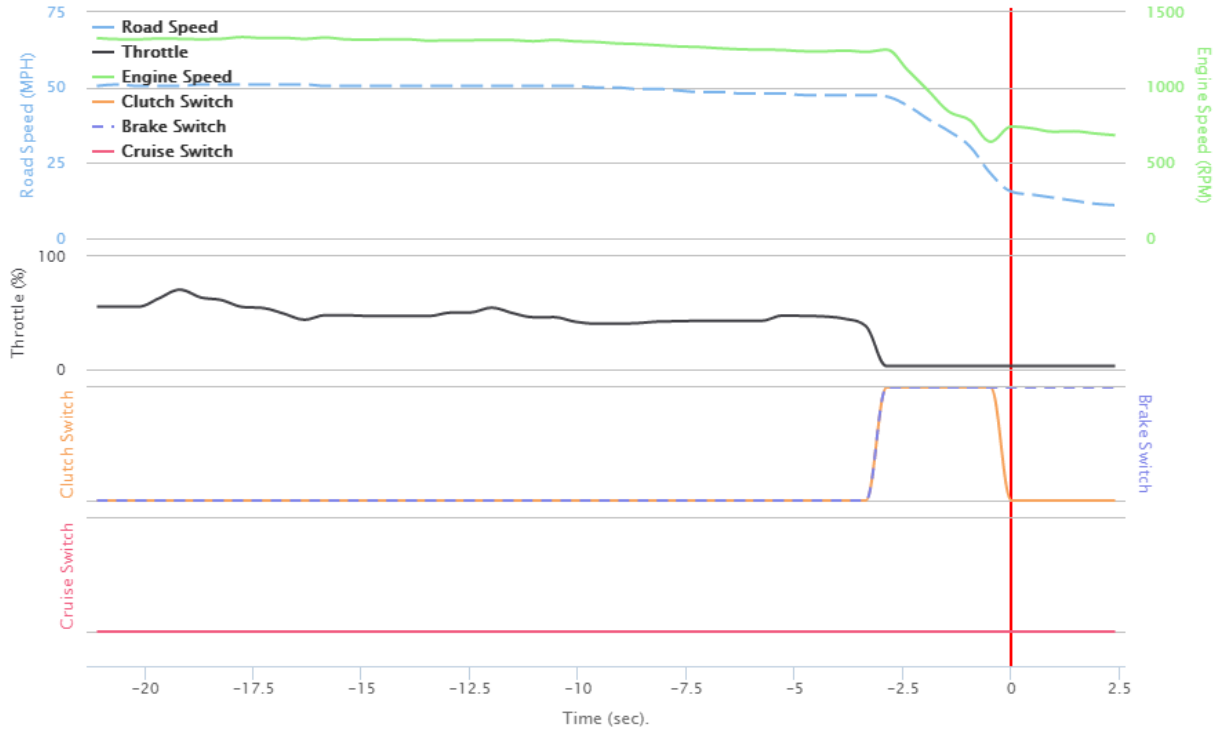
Field Success

- CatET couldn't get the data

Forensic Link Adapter Portal | Latest FLA Report | All FLAs | Jeremy Daily

CAT Speed Change Snapshot Records Chart #1

ECM Event Time: 6:23:33 EST (Hex: 84 17 0b 2d 03 1f)
Adjusted Event Time: Tue Apr 05 2016 18:19:42 EST
Diagnostic Clock: 54177:18:44 (Hex: d3 a1 24 98)
PID 84: Road Speed (Hex: 54)
FMI 14: Special Instructions (Hex: 0e)



CAT Speed Change Snapshot Records Chart #1 Table | Download Table CSV

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Summary

- Explanation and Demonstration of data extraction algorithm
- Description of Tool (FLA)
- Experiment showing
  - Power loss (even brief) stops the recording
  - Data can be recovered, if the recording started

More examples and information at
www.synercontechnologies.com