

F25-04: Drive Secure: Teaching Automotive Cybersecurity with RAMN

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Customer: Dr. Zeb Bowden at VTTI

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Introduction

- Our project objective was to create **automotive cybersecurity challenges** and documentation for beginners i.e. junior/seniors in college.

Hackers Remotely Kill a Jeep on the Highway—With Me in It

I was driving 70 mph on the edge of downtown St. Louis when the exploit began to take hold.

<https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/>

Thieves Exploit Technology to Break Into Cars

Wireless technology is making many new cars vulnerable to potential hackers.

<https://abcnews.go.com/world-news-tonight-with-david-muirT/video/thieves-exploit-technology-break-cars-39121081>

Millions of Vehicles Could Be Hacked and Tracked Thanks to a Simple Website Bug

Researchers found a flaw in a Kia web portal that let them track millions of cars, unlock doors, and start engines at will—the latest in a plague of web bugs that's affected a dozen carmakers.

<https://www.wired.com/story/kia-web-vulnerability-vehicle-hack-track/>

Team of hackers take remote control of Tesla Model S from 12 miles away

Chinese researchers were able to interfere with the car's brakes, door locks and other electronic features, demonstrating an attack that could cause havoc

<https://www.theguardian.com/technology/2016/sep/20/tesla-model-s-chinese-hack-remote-control-brakes>

Why Our Project Matters

- Over 100 Electronic Control Units (ECUs) in vehicles
- Cars have critical features controlled by ECUs
 - Steering
 - Acceleration
 - Airbags
- This makes cars susceptible to cybersecurity attacks
- How do you increase awareness of automotive cybersecurity risks?

Why it matters cont.

- Talk about the cost and size difference of getting into automotive security?
 - Cars are big, expensive, and proprietary

What is RAMN?

- Resistant Automotive Miniature Network
 - Electronic Control Unit (ECU) testbed
 - An ECU is an embedded system in automotive electronics that controls one or more of the electrical systems or subsystems in a car

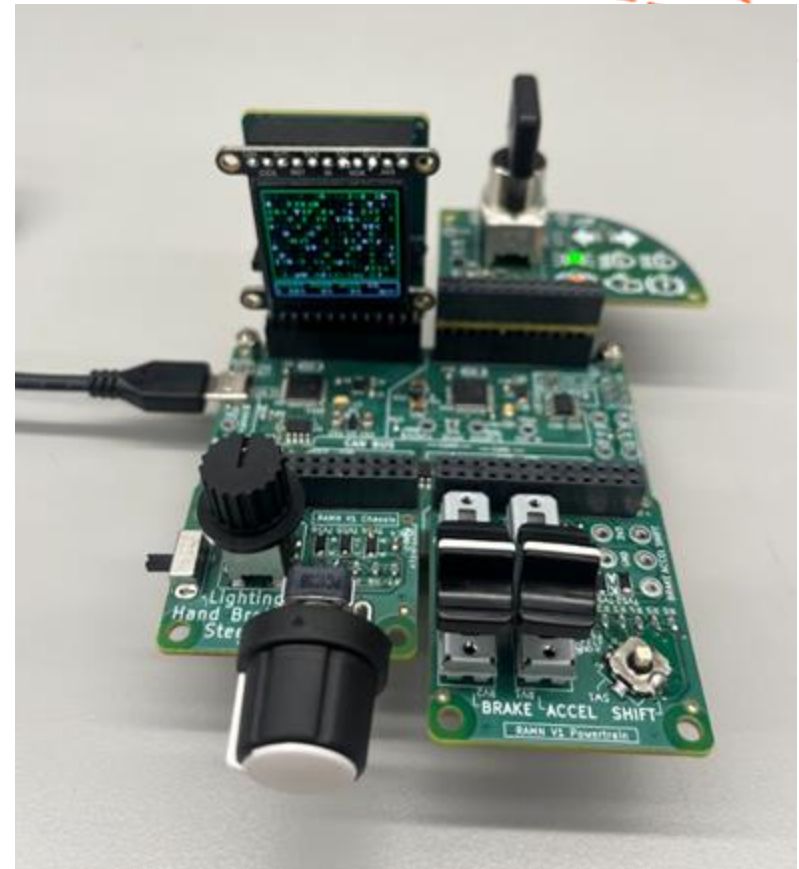


Figure 1. F25-04 RAMN board.

Pic/Explanation of Pods

- ECUs communicate over CAN
- Body pod does this
- Powertrain does this
- Blablabla
- **expansion and/or pod

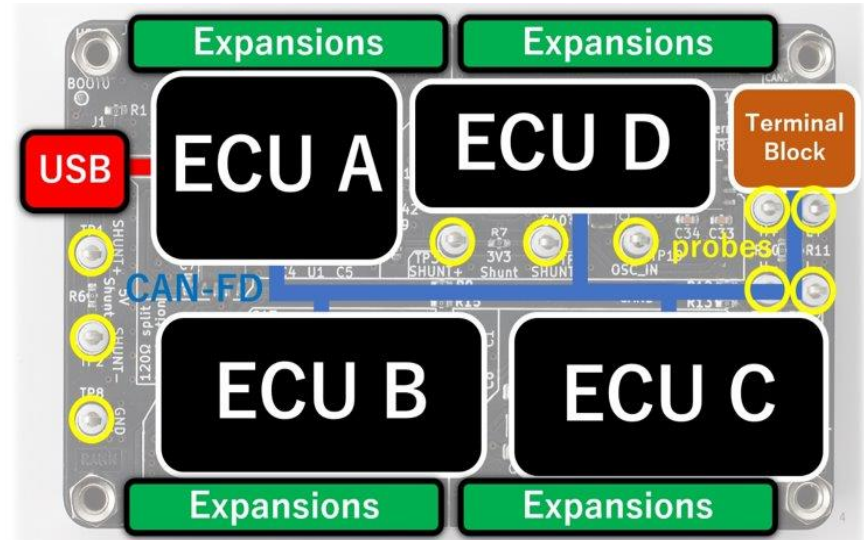


Figure 2. Overview of RAMN layout.

Image: "Documentation of ramn: Resistant automotive miniature network," Documentation of RAMN: Resistant Automotive Miniature Network - RAMN 1.0.0 documentation, <https://ramn.readthedocs.io/> (accessed Feb. 24, 2025).

Introduction & Objectives

- Overview
 - RAMN to be used as educational tool for cybersecurity at Virginia Tech Transportation Institute (VTTI)
- Goals and Objectives
 - Assemble RAMN
 - Create cybersecurity challenges for educational purposes
 - Provide documentation for future replication

Implications for Future Use

- Automotive Industry
 - Explore vulnerabilities of ECUs
 - Provide security measures against malicious hackers.
 - Ensure safety of automotive users.
- Education
 - Teach automotive vulnerabilities and how they are exploited.
 - Understand malicious interactions between devices.

Problem Statement

- Problem Description
 - Dr. Zeb Bowden at Virginia Tech Transportation Institute wants to utilize the RAMN to help develop cybersecurity practices and facilitate a learning environment for future cybersecurity and automotive engineers.
- Importance and impact of solving the problem
 - Used in the future by VTTI as an educational tool.
 - Documentation helps VTTI replicate and design their own challenges.



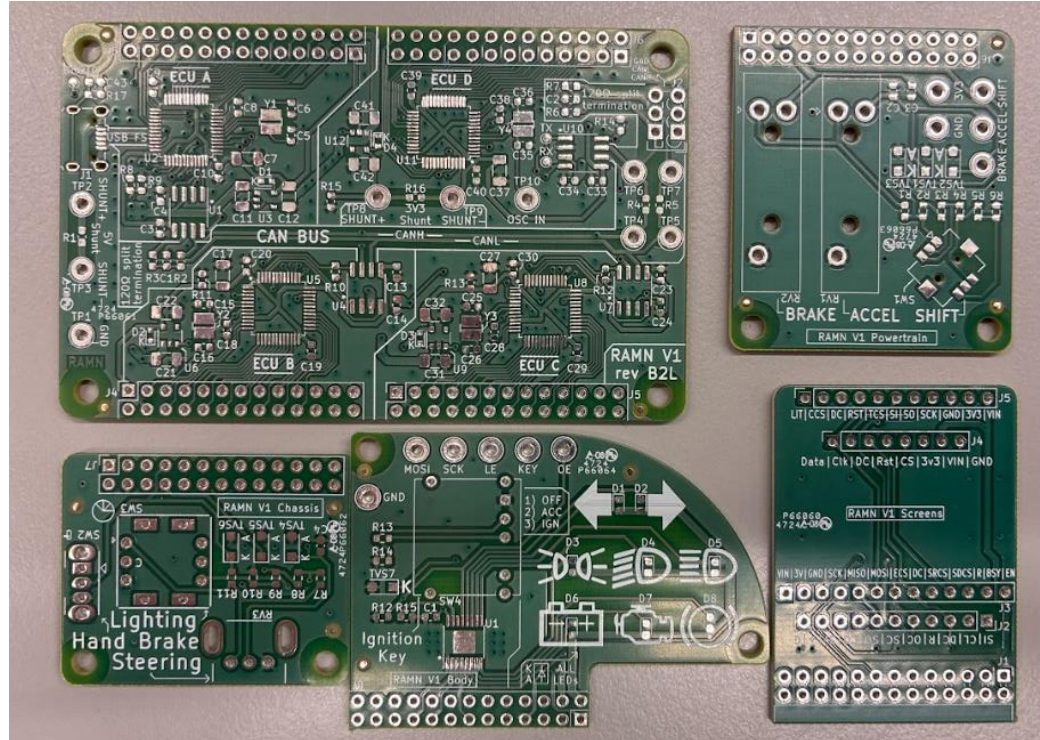
Our Approach

- Use existing RAMN documentation to understand how to use RAMN
- Use existing example code to help develop challenges
- Create documentation to fill gaps in RAMN documentation

Challenges We Encountered

- We received the RAMN parts unassembled
 - Most of the soldering require surface mount soldering
- RAMN documentation is not detailed
 - The documentation assumes the user has a good amount of experience with Linux and ECUs
 - Minimal experience with Linux and ECUs
 - Tasked to make instructions clear enough of a new user to understand our cyber security challenges

RAMN Parts, Unassembled





RAMN Documentation, Missing Details

- Insert pic

Schedule Milestones

- Solder training (February – April)
- Assemble the RAMN system (March – April)
- Have CARLA work with RAMN (March – November)
- Documentation of the RAMN (March – November)
- Test and replace the soldered parts (April – May)
- Assemble backup RAMN (September – October)
- Create cybersecurity challenges (September – November)
- Make the poster and presentation (October – November)

Our Solution

- Beginner-level Cybersecurity challenges
 - Capture the Flag
 - Brute Force Scripting
 - ECU Manipulation
- Documentation
 - Examples:
 - How install RAMN Firmware
 - How to fix RAMN Firmware when installed incorrectly
 - How to write a python script and run it on the RAMN
 - Overall guidance how to set up challenges without the user being left into the unknown



Documentation

Capture The Flag Challen

- Brooks
 - Brooks
- DIDs can contain sensitive information for different vehicles:



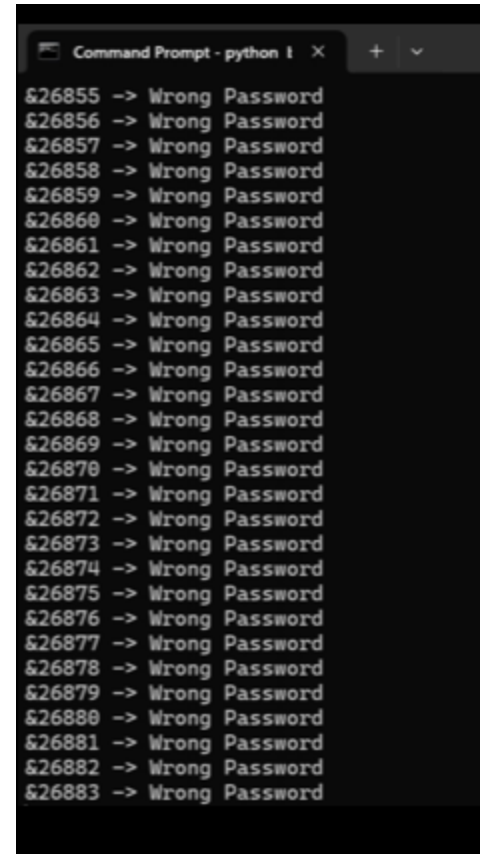
Documentation

A screenshot of a memory editing application window titled "Memory & File editing". The window displays a table with columns for "Address", "Value", and "Comment". The table contains several rows of data, including memory addresses and their corresponding values and comments.

Address	Value	Comment
00000000	00000000	
00000001	00000001	
00000002	00000002	
00000003	00000003	
00000004	00000004	
00000005	00000005	
00000006	00000006	
00000007	00000007	
00000008	00000008	
00000009	00000009	
0000000A	0000000A	
0000000B	0000000B	
0000000C	0000000C	
0000000D	0000000D	
0000000E	0000000E	
0000000F	0000000F	
00000010	00000010	
00000011	00000011	
00000012	00000012	
00000013	00000013	
00000014	00000014	
00000015	00000015	
00000016	00000016	
00000017	00000017	
00000018	00000018	
00000019	00000019	
0000001A	0000001A	
0000001B	0000001B	
0000001C	0000001C	
0000001D	0000001D	
0000001E	0000001E	
0000001F	0000001F	
00000020	00000020	
00000021	00000021	
00000022	00000022	
00000023	00000023	
00000024	00000024	
00000025	00000025	
00000026	00000026	
00000027	00000027	
00000028	00000028	
00000029	00000029	
0000002A	0000002A	
0000002B	0000002B	
0000002C	0000002C	
0000002D	0000002D	
0000002E	0000002E	
0000002F	0000002F	
00000030	00000030	
00000031	00000031	
00000032	00000032	
00000033	00000033	
00000034	00000034	
00000035	00000035	
00000036	00000036	
00000037	00000037	
00000038	00000038	
00000039	00000039	
0000003A	0000003A	
0000003B	0000003B	
0000003C	0000003C	
0000003D	0000003D	
0000003E	0000003E	
0000003F	0000003F	
00000040	00000040	
00000041	00000041	
00000042	00000042	
00000043	00000043	
00000044	00000044	
00000045	00000045	
00000046	00000046	
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00000049	00000049	
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0000004B	0000004B	
0000004C	0000004C	
0000004D	0000004D	
0000004E	0000004E	
0000004F	0000004F	
00000050	00000050	
00000051	00000051	
00000052	00000052	
00000053	00000053	
00000054	00000054	
00000055	00000055	
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00000057	00000057	
00000058	00000058	
00000059	00000059	
0000005A	0000005A	
0000005B	0000005B	
0000005C	0000005C	
0000005D	0000005D	
0000005E	0000005E	
0000005F	0000005F	
00000060	00000060	
00000061	00000061	
00000062	00000062	
00000063	00000063	
00000064	00000064	
00000065	00000065	
00000066	00000066	
00000067	00000067	
00000068	00000068	
00000069	00000069	
0000006A	0000006A	
0000006B	0000006B	
0000006C	0000006C	
0000006D	0000006D	
0000006E	0000006E	
0000006F	0000006F	
00000070	00000070	
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00000073	00000073	
00000074	00000074	
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00000076	00000076	
00000077	00000077	
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0000007A	0000007A	
0000007B	0000007B	
0000007C	0000007C	
0000007D	0000007D	
0000007E	0000007E	
0000007F	0000007F	
00000080	00000080	
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0000009B	0000009B	
0000009C	0000009C	
0000009D	0000009D	
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000000A1	000000A1	
000000A2	000000A2	
000000A3	000000A3	
000000A4	000000A4	
000000A5	000000A5	
000000A6	000000A6	
000000A7	000000A7	
000000A8	000000A8	
000000A9	000000A9	
000000AA	000000AA	
000000AB	000000AB	
000000AC	000000AC	
000000AD	000000AD	
000000AE	000000AE	
000000AF	000000AF	
000000B0	000000B0	
000000B1	000000B1	
000000B2	000000B2	
000000B3	000000B3	
000000B4	000000B4	
000000B5	000000B5	
000000B6	000000B6	
000000B7	000000B7	
000000B8	000000B8	
000000B9	000000B9	
000000BA	000000BA	
000000BB	000000BB	
000000BC	000000BC	
000000BD	000000BD	
000000BE	000000BE	
000000BF	000000BF	
000000C0	000000C0	
000000C1	000000C1	
000000C2	000000C2	
000000C3	000000C3	
000000C4	000000C4	
000000C5	000000C5	
000000C6	000000C6	
000000C7	000000C7	
000000C8	000000C8	
000000C9	000000C9	
000000CA	000000CA	
000000CB	000000CB	
000000CC	000000CC	
000000CD	000000CD	
000000CE	000000CE	
000000CF	000000CF	
000000D0	000000D0	
000000D1	000000D1	
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000000D4	000000D4	
000000D5	000000D5	
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000000D7	000000D7	
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000000D9	000000D9	
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000000DB	000000DB	
000000DC	000000DC	
000000DD	000000DD	
000000DE	000000DE	
000000DF	000000DF	
000000E0	000000E0	
000000E1	000000E1	
000000E2	000000E2	
000000E3	000000E3	
000000E4	000000E4	
000000E5	000000E5	
000000E6	000000E6	
000000E7	000000E7	
000000E8	000000E8	
000000E9	000000E9	
000000EA	000000EA	
000000EB	000000EB	
000000EC	000000EC	
000000ED	000000ED	
000000EE	000000EE	
000000EF	000000EF	
000000F0	000000F0	
000000F1	000000F1	
000000F2	000000F2	
000000F3	000000F3	
000000F4	000000F4	
000000F5	000000F5	
000000F6	000000F6	
000000F7	000000F7	
000000F8	000000F8	
000000F9	000000F9	
000000FA	000000FA	
000000FB	000000FB	
000000FC	000000FC	
000000FD	000000FD	
000000FE	000000FE	
000000FF	000000FF	

Brute Force Scripting

- Go through every possible password combination until the correct one is found
 - Create a python script for brute force in the RAMN
 - The output will be shown by running the script in Linux and will stop at the password that gives the flag



```
Command Prompt - python 1
&26855 -> Wrong Password
&26856 -> Wrong Password
&26857 -> Wrong Password
&26858 -> Wrong Password
&26859 -> Wrong Password
&26860 -> Wrong Password
&26861 -> Wrong Password
&26862 -> Wrong Password
&26863 -> Wrong Password
&26864 -> Wrong Password
&26865 -> Wrong Password
&26866 -> Wrong Password
&26867 -> Wrong Password
&26868 -> Wrong Password
&26869 -> Wrong Password
&26870 -> Wrong Password
&26871 -> Wrong Password
&26872 -> Wrong Password
&26873 -> Wrong Password
&26874 -> Wrong Password
&26875 -> Wrong Password
&26876 -> Wrong Password
&26877 -> Wrong Password
&26878 -> Wrong Password
&26879 -> Wrong Password
&26880 -> Wrong Password
&26881 -> Wrong Password
&26882 -> Wrong Password
&26883 -> Wrong Password
```



Documentation

ECU Manipulation

- Change values of physical inputs without utilizing physical controls.
 - Linux
 - Set up attack
 - Disable ECUs
 - Modify ECU values
 - Show output on CARLA / LCD Screen pod.
 - CARLA is an open-source driving simulator that we use to

```
colton@colton-ThinkPad-P1-Gen-2: ~  
colton@colton-ThinkPad-P1-Gen-2:~$ candump can0 | grep 062  
can0 062 [2] 0F FF
```

Figure X. CAN frame sent to change steering value.



Documentation

Documentation

- Streamlined process.
- Step-by-step instructions.
- Resources (hyperlinks).
- Debugging instructions.
- Entry-level Oriented.




Documentation

Documentation

The screenshot shows a web browser displaying the documentation for F25-04 RAMN. The browser's address bar shows the URL: `f25-04-drive-secure-automotive-cybersecurity-with-ramn.readthedocs.io/en/latest/index.html`. The page has a blue header with the RAMN logo and version 0.1.0, and a search bar. The main content area is white and features a welcome message, the Virginia Tech Transportation Institute logo, and a list of links. A blue note box states that the project is under active development. The page also includes a sidebar with navigation links and a footer with the Virginia Tech logo and contact information.

Welcome to F25-04 RAMN's documentation! [View page source](#)

Welcome to F25-04 RAMN's documentation!

VIRGINIA TECH 
TRANSPORTATION INSTITUTE

Hello, We are an ECE senior design team tasked by our customer to develop a cybersecurity challenge using the RAMN board. Below are import links that will be useful.

[Our Github](#)

[RAMN Github](#)

[RAMN Read The Docs](#)

1

Note
This project is under active development.

Contents

- Intro
 - What is RAMN?
 - What is on the Read the Docs?

Proposed Solution Cont.

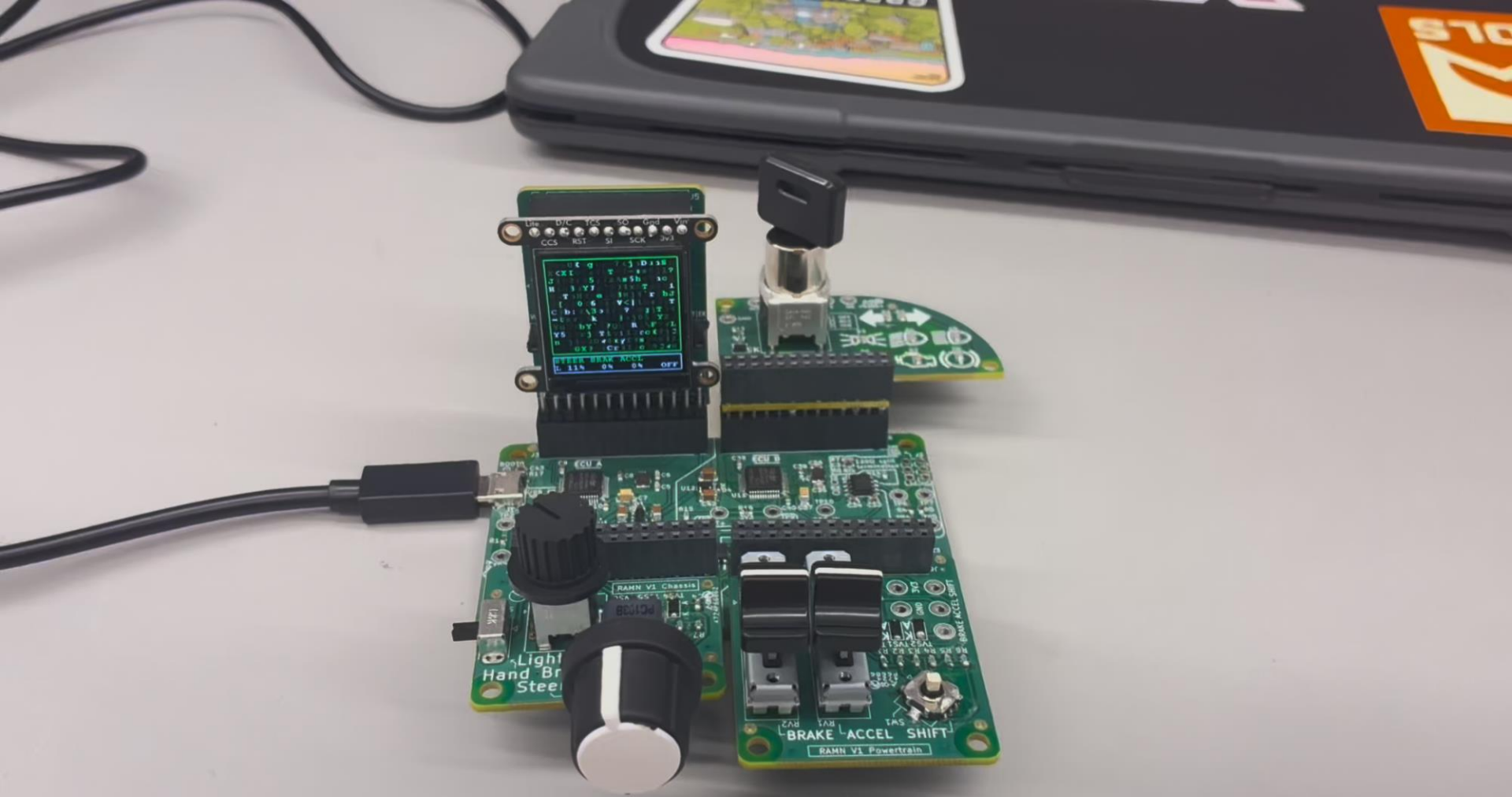
- What makes your solutions innovative?
 - Our work is focused on the automotive industry
 - Our work offers beginner level challenges as an educational tool
 - Our work provides more detailed documentation than other resources

Technical Requirements & Constraints

- What are the high-level requirements?
 - Assemble hardware
 - CARLA - Driving Simulation
 - Create cybersecurity challenges(CTFs)
- What are the high-level constraints?
 - Training Time (solder training)
 - Missing components for 2 RAMN systems (backup)

Resource Planning

- Resources Used
 - Soldering Equipment in the AMP Lab
 - Outsourced the main RAMN board to be soldered
 - Used the RAMN documentation made by the creators to download the RAMN code and necessary firmware
 - ST-Link V2 Debugger
 - Spent \$37.30 to buy extra parts





Summary of Results & Conclusions





Contributions

- Contributed to existing documentation
- Filled in the gaps with our own website
- Created our own challenges

Acknowledgments

- Sponsor: Virginia Tech, VTTI
- SME: Dr. Tim Talty
- Customer: Dr. Zeb Bowden
- Mentor: Dr. Joe Adams
- Creator of RAMN: Camille Gay
- ECE purchaser: Kim Medley
- Solder trainer: Rusty Stewart