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

By: Brooks O'Hanlan, Colton Smith, Jonas von Stein, William Min

SME: Dr. Tim Talty
Customer: Dr. Zeb Bowden at VTTI

Date: November 19th 2025

VIRGINIA TECH TRANSPORTATION INSTITUTE

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF
ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

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/

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

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

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 differenceof getting into automotive security?
  - Cars are big, expensive, andproprietary

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

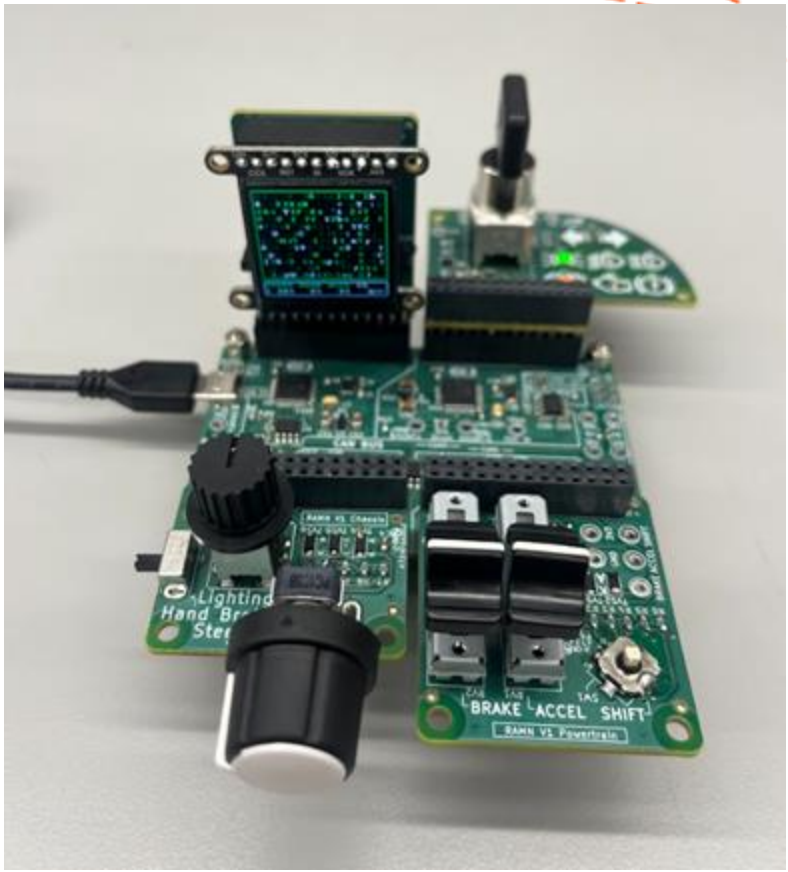


Figure 1. F25-04 RAMN board.

Pic/Explanation of Pods

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

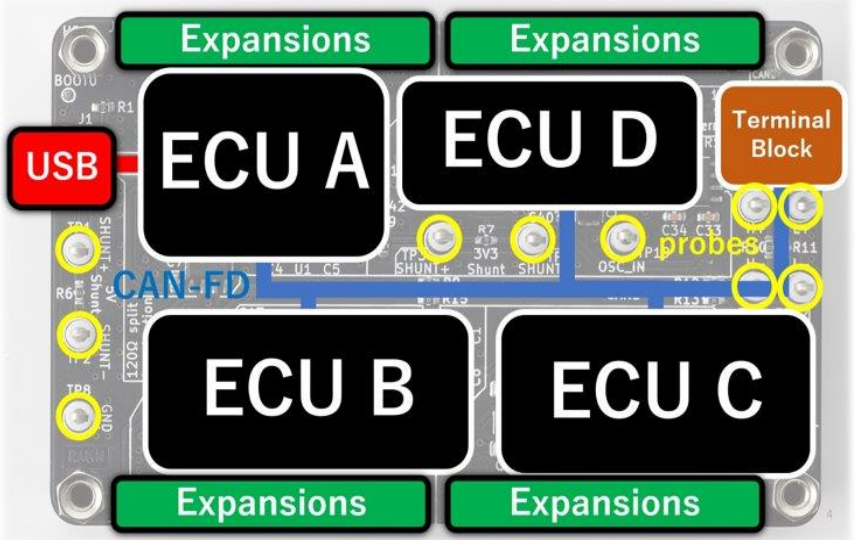


Figure 2. Overview of RAMN layout.

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

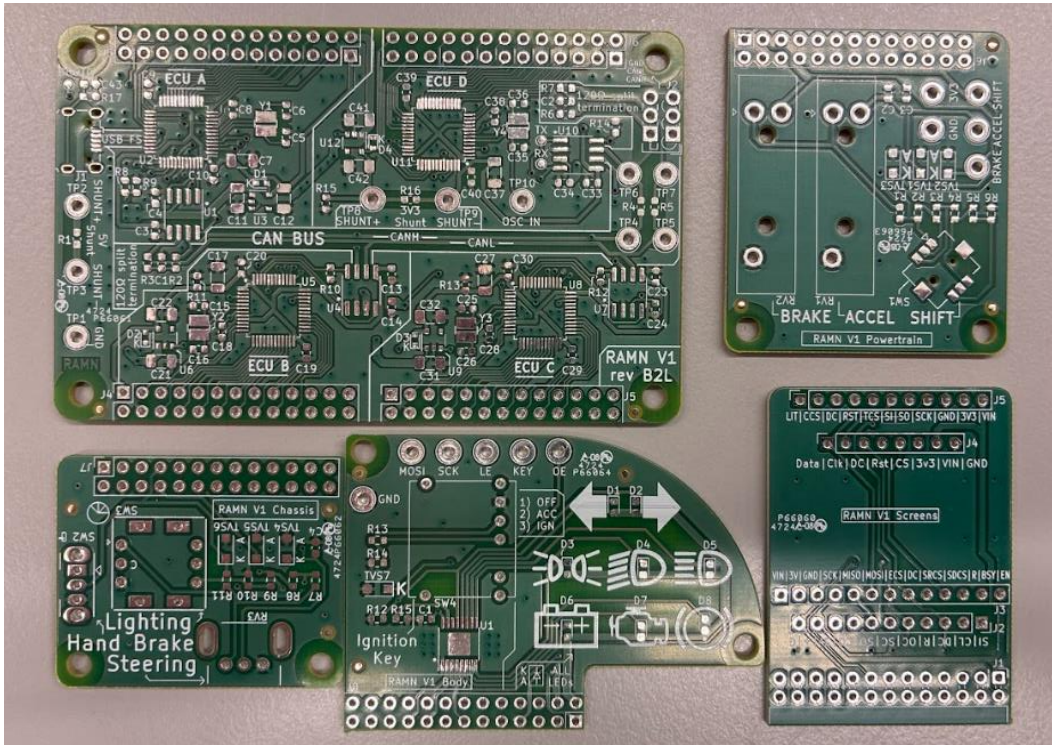
- Use existing RAMN documentation to understand how to use RAMN
- Use existing example code to help develop challenges
- Create documentation to fill gaps in RAMN documentation

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

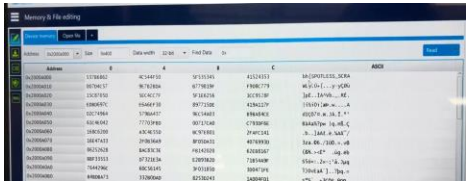
Documentation

Capture The Flag Challen

SCAN ME

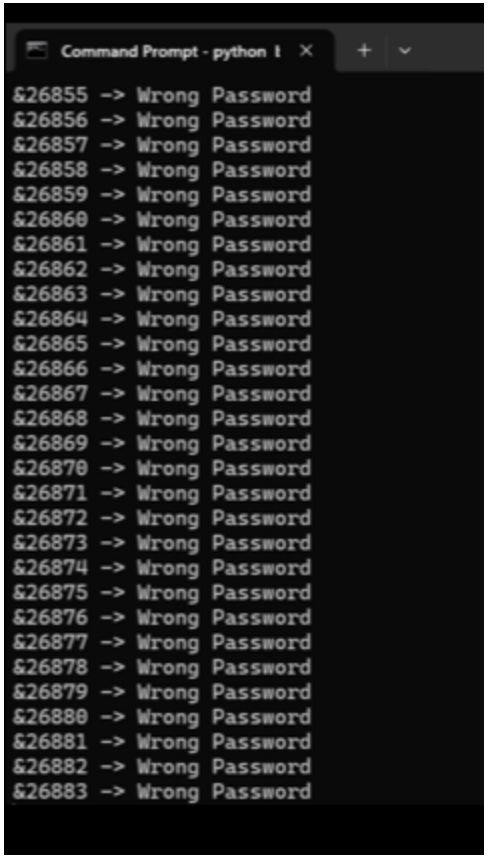
Documentation

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



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



SCAN ME

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

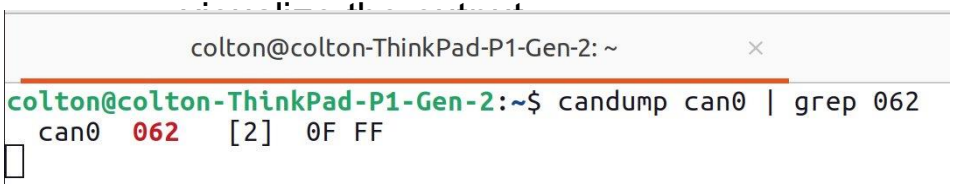


Figure X. CAN frame sent to change steering value.

SCAN ME

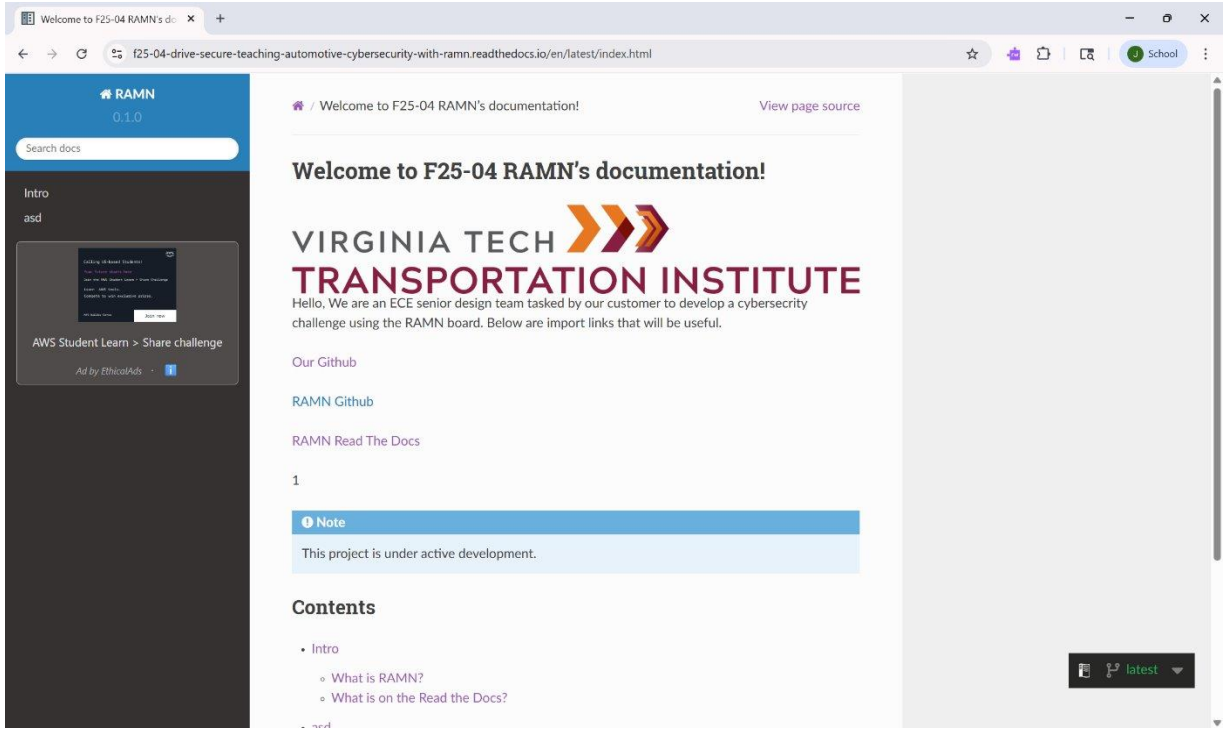
Documentation

Documentation

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

Documentation

Documentation



Proposed Solution Cont.

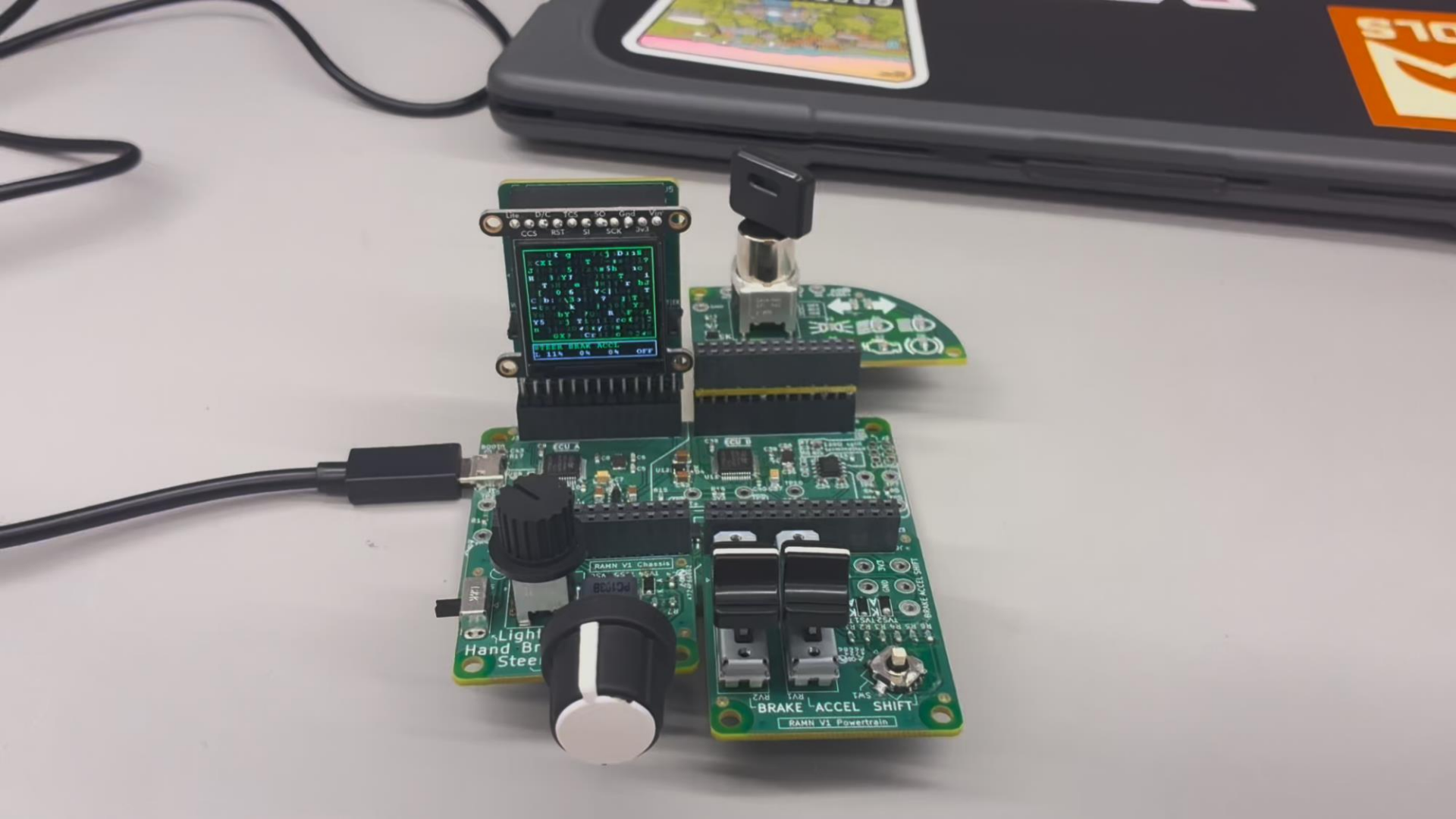
- What makes your solutions innovative?
  - Our work is focused on the automotive industry
  - Our work offers beginner level challenges as an educational tool
  - Our work provides more detailed documentation than other resources

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


RAMN V1 Chassis
BRAKE ACCEL SHIFT
RAMN V1 Powertrain

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