

COMPExpAnalysesOf AutoAttackSurfaces

P R N D 3 2 1



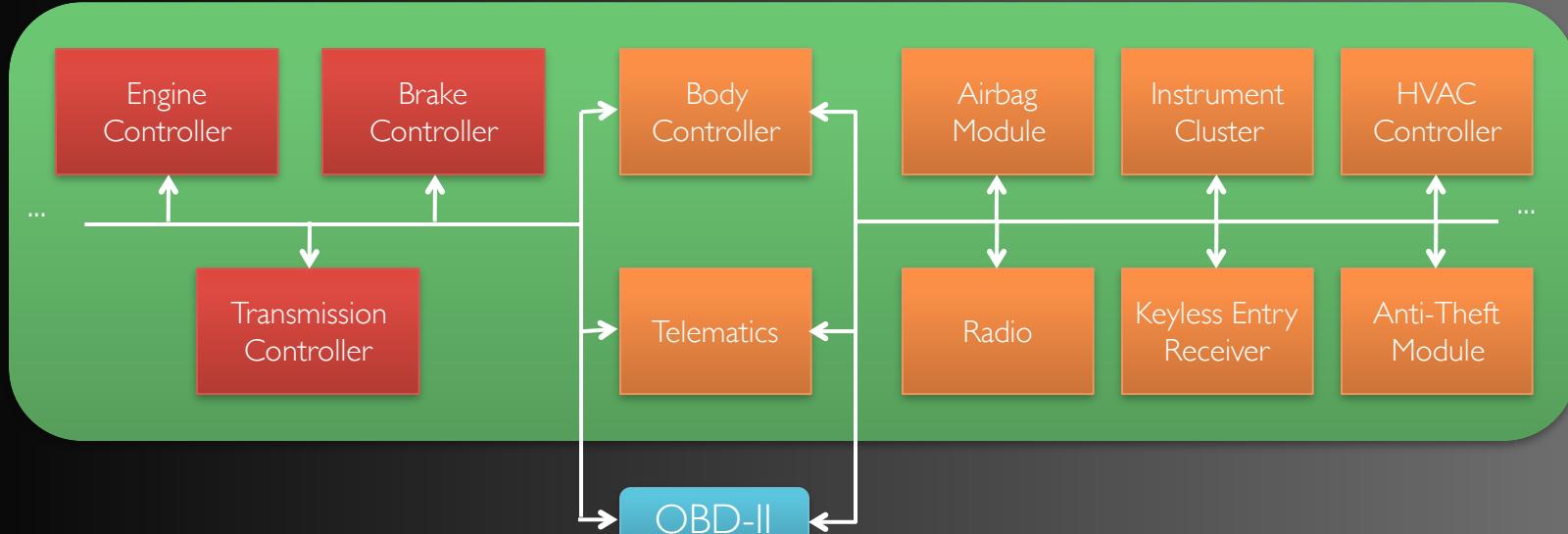
UCSDCSE

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Cars: a review



- Pervasive computer control (ECUs)
- ECU interconnections driven by safety, efficiency, and capability requirements

Oakland 2010, we showed...

- Safety-critical systems can be compromised
 - Selectively enable/disable brakes
 - Stop engine
 - Control lights
- Owning one ECU = total compromise
- ECUs can be reprogrammed (while driving!)
- Key question: Do we need physical access?

Outline

- Intro
- Synthesize attack surface
- Experimental attack evaluations
- Post-compromise control
- End-to-end evaluations
- Reflections and next steps

Threat model

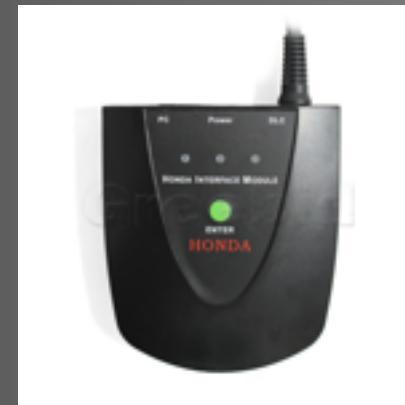
- Attacker capabilities
 - Indirect physical access
 - Short-range wireless signals
 - Long-range wireless signals
- Attack surfaces: what *might* be attacked

Indirect physical

- Definition:
 - Attacks over physical interfaces
 - Constrained: Adversary may not **directly** access the physical interfaces herself
- Extends attack surface to that of the device

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Short-range wireless

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Attack surfaces explored in depth

- Components we compromised
 - Indirect physical: diagnostic tool
 - Indirect physical: media player
 - Short-range wireless: Bluetooth
 - Long-range wireless: cellular
- ***Every attack vector leads to complete car compromise***

Overall methodology

- Extract device's firmware
 - Read memory out over the CAN bus (CarShark)
 - Desolder flash memory chips in ECUs
- Reverse engineer firmware
 - IDA Pro
 - Custom tools
- Identify and test vulnerable code paths
- Weaponize exploits



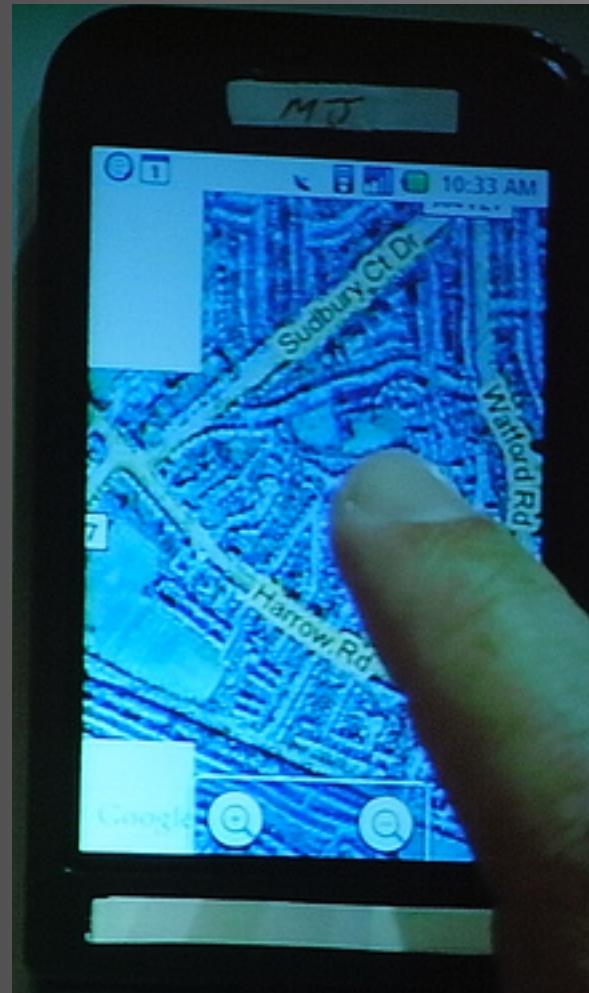
Indirect physical: Media player attack

- Code for ISO-9660 leads to
 - Attack 1: Vestigial radio reflash from CD code
 - Attack 2: WMA parsing bug; tricky overflow
- Karl writes an on-radio debugger in a night!

- Insert CD containing malicious WMA file
- Completely compromise car

Short-range wireless: Bluetooth attack

- Common embedded Bluetooth stack on telematics unit
 - strcpy() bug
- 1. Malicious, paired device can compromise telematics ECU
 - Android trojan
- 2. Can undetectably pair a device
 - USRP software radio
 - Brute force PIN

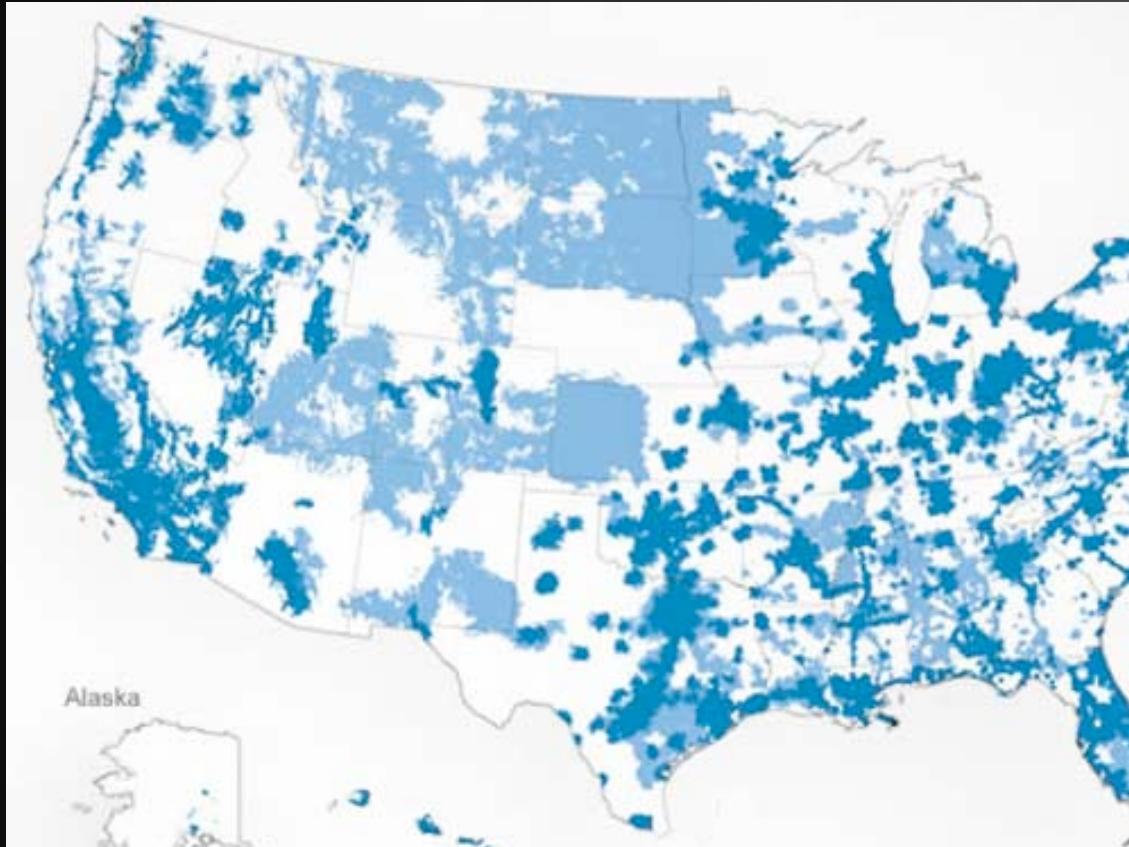


Long-range wireless: Cellular attack

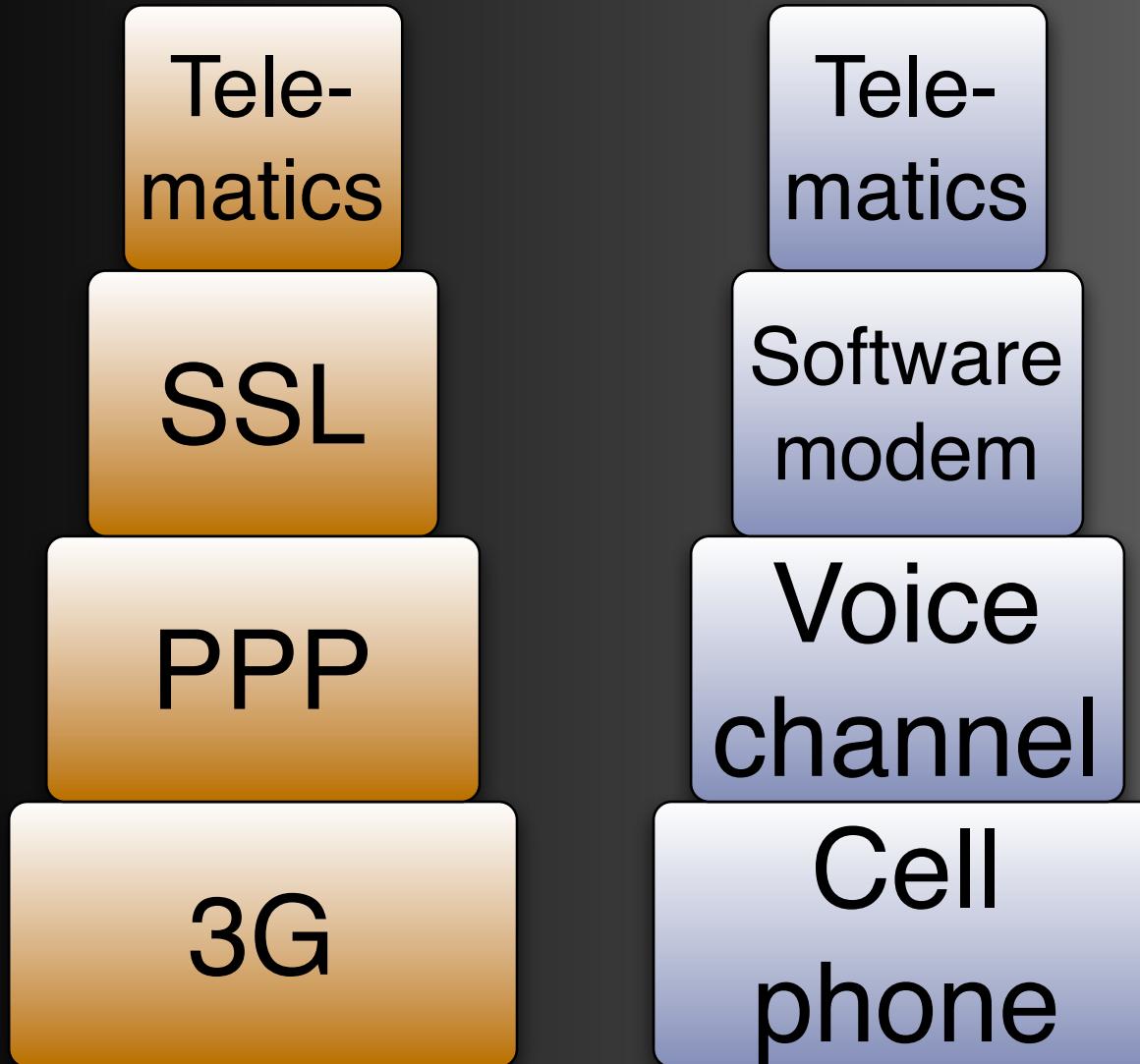
Long-range wireless: Cellular attack



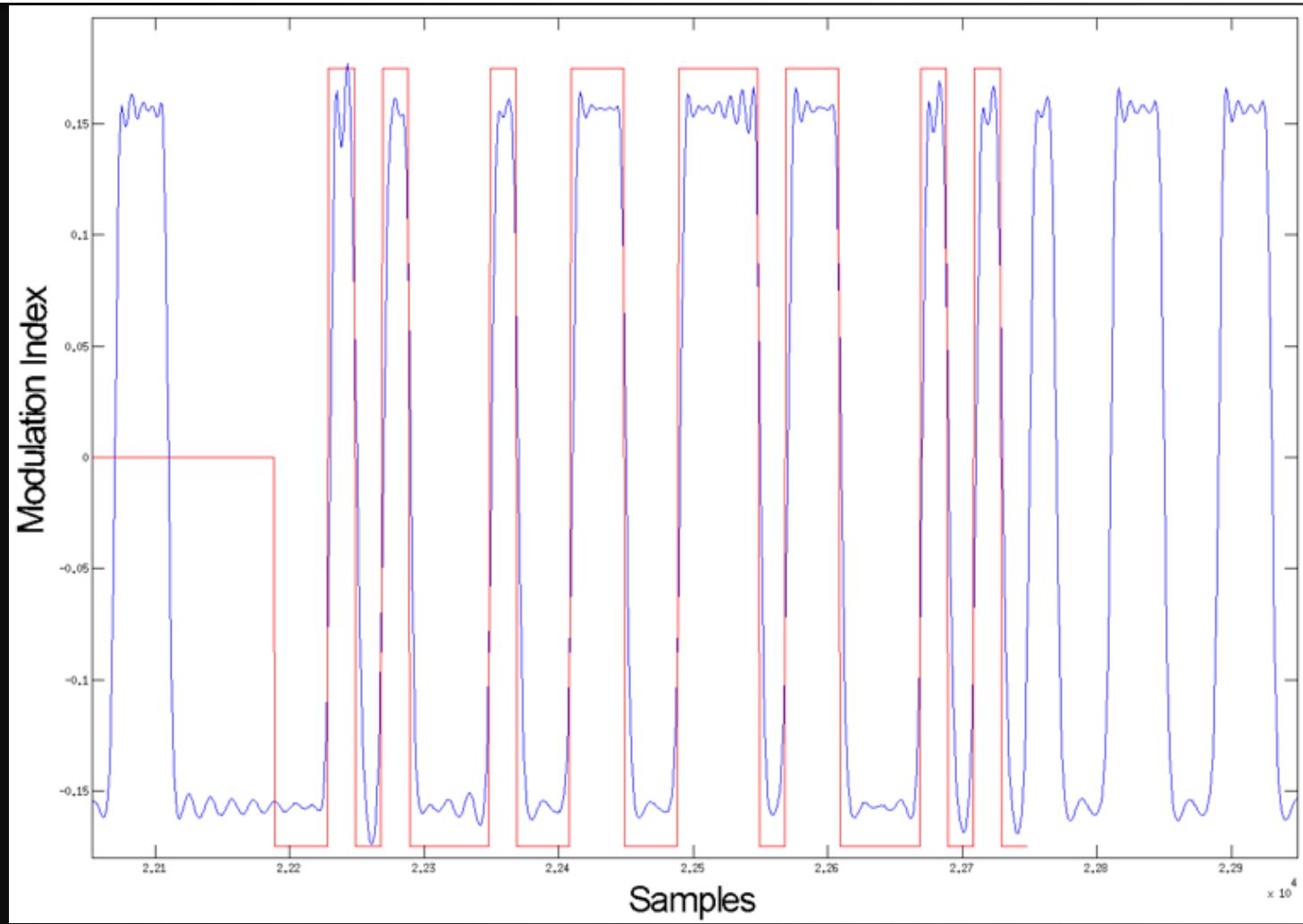
Long-range wireless: Cellular attack



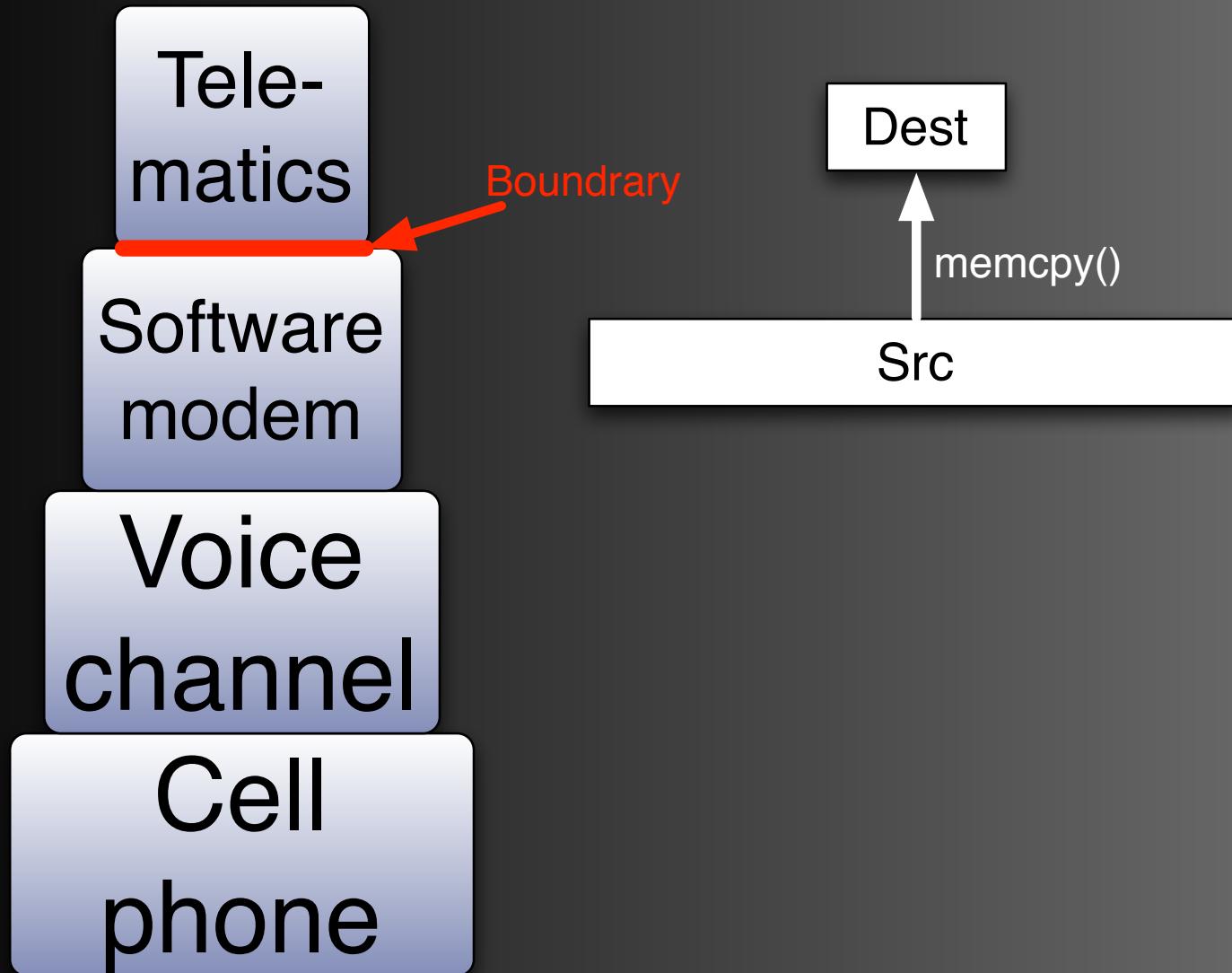
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Long-range wireless: Cellular attack

- Call telematics unit
- Transmit malicious payload
 - Instantiation 1. Implement modem protocol
 - Instantiation 2. Play MP3 into phone



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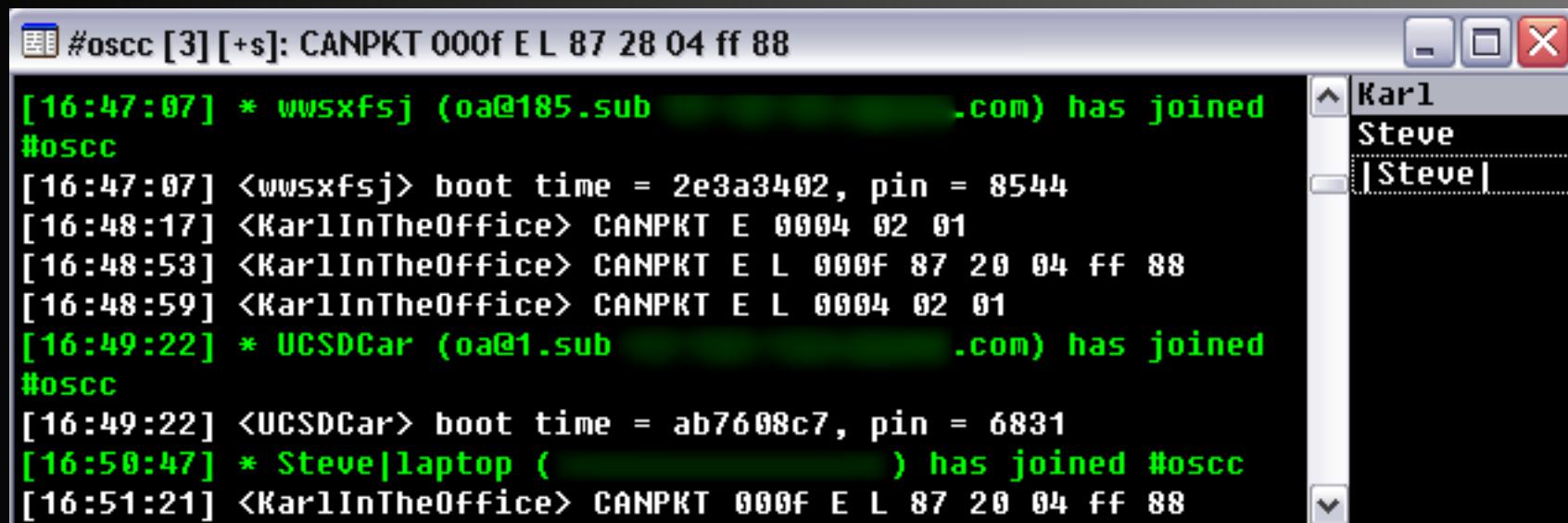
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Post-compromise control

- Wireless channels are game-changers
- Remotely trigger code from prior compromise
 - TPMS: proximity trigger
 - FM RDS: broadcast trigger
 - Bluetooth: short-range targeted trigger
 - Cellular: global targeted trigger
- We implemented all of these

Example: IRC over cellular

- Install IRC client on telematics unit
- Targeted/broadcast commands
- Download additional functionality



The screenshot shows a terminal window with the following details:

- Title Bar:** #oscc [3] [+s]: CANPKT 000f E L 87 28 04 ff 88
- IRC Channel:** #oscc
- Messages:**
 - [16:47:07] * wwsxfsj (oa@185.sub) has joined #oscc
 - [16:47:07] <wwsxfsj> boot time = 2e3a3402, pin = 8544
 - [16:48:17] <KarlInTheOffice> CANPKT E 0004 02 01
 - [16:48:53] <KarlInTheOffice> CANPKT E L 000f 87 20 04 ff 88
 - [16:48:59] <KarlInTheOffice> CANPKT E L 0004 02 01
 - [16:49:22] * UCSDCar (oa@1.sub) has joined #oscc
 - [16:49:22] <UCSDCar> boot time = ab7608c7, pin = 6831
 - [16:50:47] * Steve|laptop () has joined #oscc
 - [16:51:21] <KarlInTheOffice> CANPKT 000f E L 87 20 04 ff 88
- Right Panel:** A scrollable list of user names: Karl, Steve, and Steve.

```
* wwsxfsj (oa@185.sub .com) has joined
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Car theft

- Compromise car
- Locate car (via GPS)
- Unlock doors
- Start engine
- Bypass anti-theft





Surveillance

- Compromise car
- Continuously report GPS coordinates
 - Twitter-like service
- Stream audio recorded from the in-cabin mic
 - Detect voice (VAD)
 - Compress audio
 - Stream to remote computer





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Stepping back: Why?

- Lack of adversarial pressure to date
 - Code rife with “old” vulnerabilities, e.g., strcpy()
- Heterogeneous, distributed, multi-vendor system
 - Internals of components frequently opaque
 - Incorrect assumptions between different suppliers
 - Almost all bugs found at component boundaries

Where to go from here?

- Stakeholders responding today:
SAE, USCAR, US DOT
- Short term: lessons from the PC world
 - Cheap software update ■ Limit ECU communication
 - W^X (a.k.a. DEP) ■ No inbound calls
 - ASLR ■ Restrict internet connections
 - Stack cookies ■ Remove unnecessary binaries
e.g., ftp/telnet/nc/vi
 - Static analysis

Where to go from here?

- Long term – more challenging
- Constraints
 - Low margins
 - Complex business model
 - Which are hard; which can be relaxed?
- Safety most important
 - Fail stop vs. fail safe

Summary

- Current autos have broad (and increasing) external attack surface
- We demonstrated real attacks that compromised safety-critical systems
- Industry and government are responding





Thank You
www.autosec.org

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