CISPA HELMHOLTZ CENTER FOR INFORMATION SECURITY

RUHR UNIVERSITÄT BOCHUM RUB

Drone Security and the Mysterious Case of DJI's DroneID

Network and Distributed System Security (NDSS) Symposium
San Diego, 2023

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Thorsten Eisenhofer*, Tobias Scharnowski*, Felix Domke‡,
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*Ruhr University Bochum
†CISPA Helmholtz Center for Information Security
‡Independent

Consumer Drones

- Mainstream product
- High popularity

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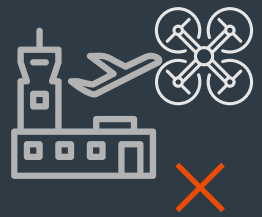

- Disturb air traffic
- Expensive shutdowns

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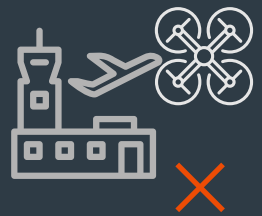

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- Smuggling
- Bypass physical barriers

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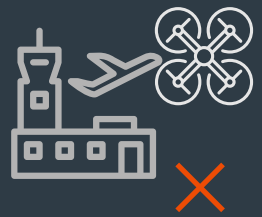
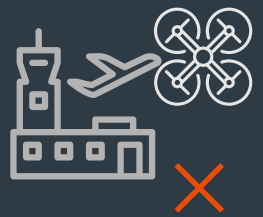


- Disturb air traffic
- Expensive shutdowns

- Smuggling
- Bypass physical barriers

Low entry barrier for air mobility in a *traditionally heavily* regulated sector!

Vendors know these problems!



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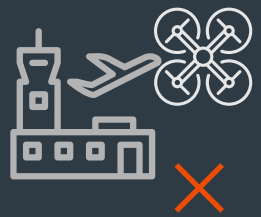

Position tracking

DJI Aeroscope

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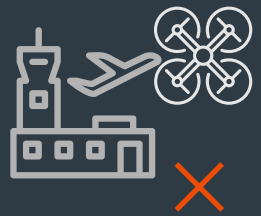

Position tracking
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Software limits
Geofencing

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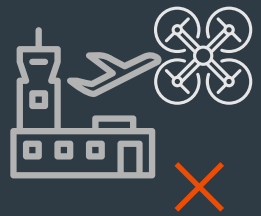

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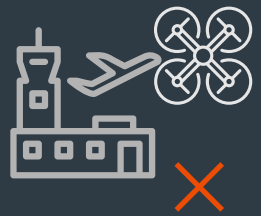

Position tracking
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Software limits
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Are these countermeasures sufficiently implemented?

How to dissect complex systems?

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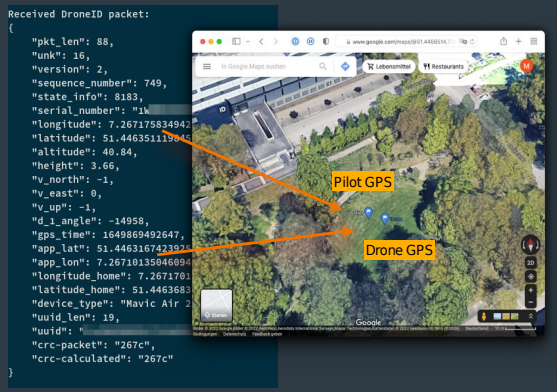
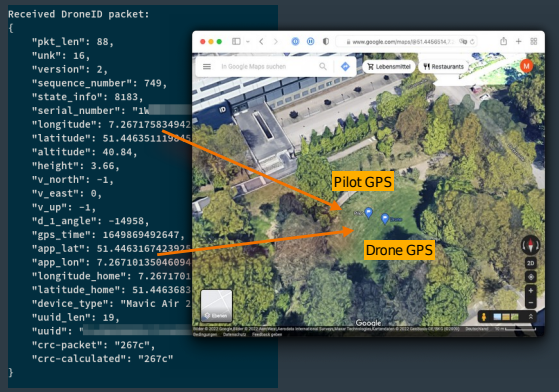
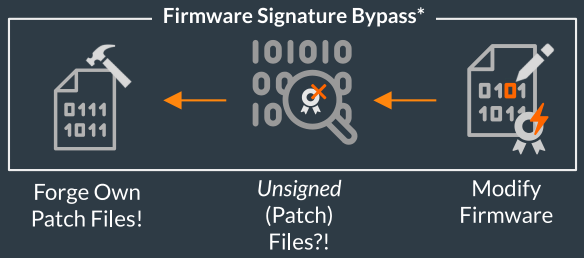


Drone and pilot’s location tracking

Wireless Analysis

How to dissect complex systems?





Drone and pilot's location tracking

Firmware signature verification bypass

Wireless Analysis

Static Analysis

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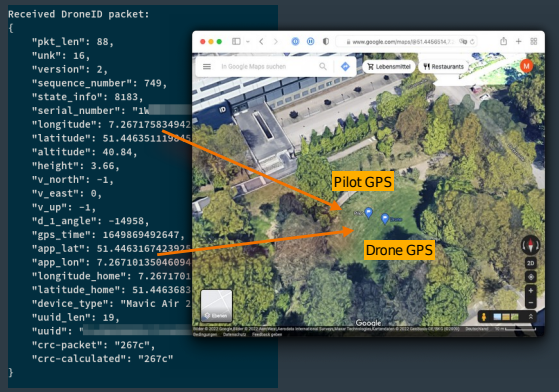

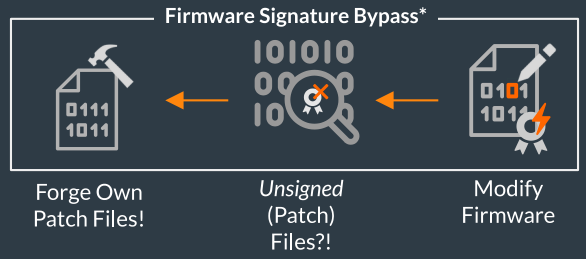

ID	Oracle	Component	Observable Behavior	Classification	Severity	Remote	Vulnerable Devices
#1	ADB check	`dji_sys` binary	ADB started (root access)	arbitrary code exec	mid	✗	Mini 2
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#7	crash	flight controller	critical error (drone reboot)	denial of service	mid	✓	Mini 2
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#9	crash	unknown	critical error (drone reboot)	denial of service	mid	✓	Mini 2
#10	crash	unknown	critical error (drone reboot)	denial of service	mid	✓	Mini 2
#11	crash	unknown	critical error (drone reboot)	denial of service	low	✓	Mini 2
#12	crash	unknown	critical error (drone reboot)	denial of service	low	✓	Mini 2
#13	crash	flight controller	critical error (drone reboot)	denial of service	low	✓	Mavic Air 2
#14	UI change	WiFi chip	change SSID	arbitrary code exec	mid	✓	Mini 2, Mavic 3
#15	UI change	flight controller	change serial number	identity spoofing	mid	✓	Mini 2

Drone and pilot's location tracking

Firmware signature verification bypass

Vulnerability detection via fuzzing

Wireless Analysis

Static Analysis

Dynamic Analysis

Our focus: DJI drones

Photo: Copyright dji.com

Our focus: DJI drones

- Market share (94% Consumer)

Our focus: DJI drones

- Market share (94% Consumer)
- They take security seriously
  - Whitepaper
  - Bug bounty program

Photo: Copyright dji.com

Our focus: DJI drones

- Market share (94% Consumer)
- They take security seriously
  - Whitepaper
  - Bug bounty program
- Inconsistent statements about transmitted signals

Wireless Physical Layer

The Mysterious Case of DJI's DroneID

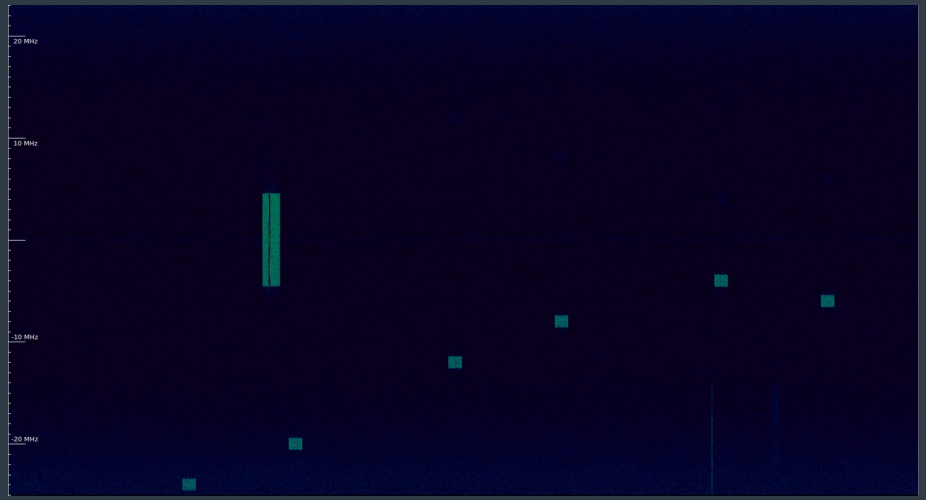
Static Analysis

Hands on the Drone

Dynamic Analysis

Fuzzing Drones for Pain and Profit

Listening on the Wireless Physical Layer ...



Capture Raw
Signal Data

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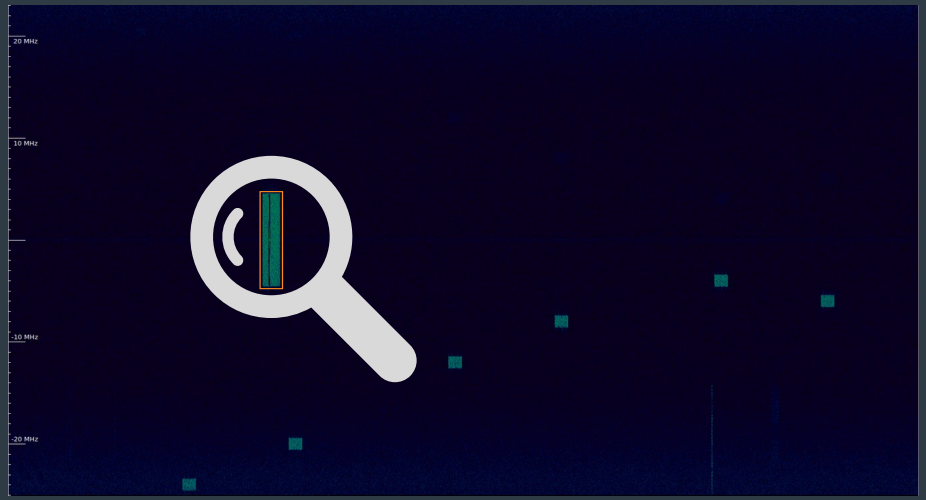

Capture Raw Signal Data

Packet Detection

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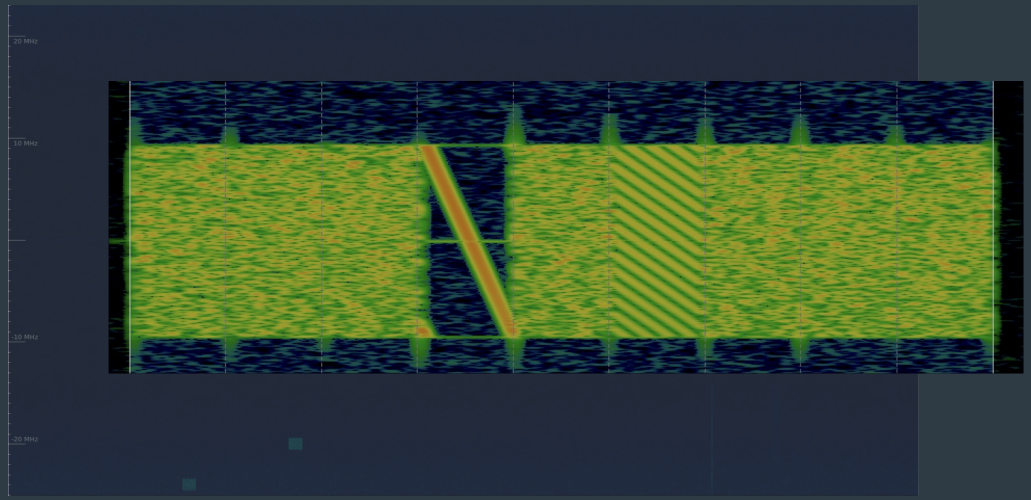

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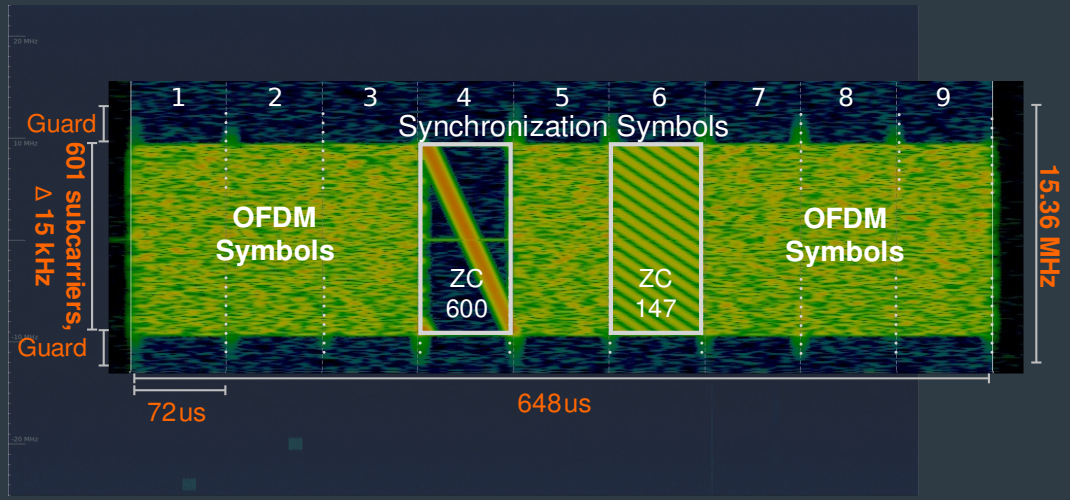

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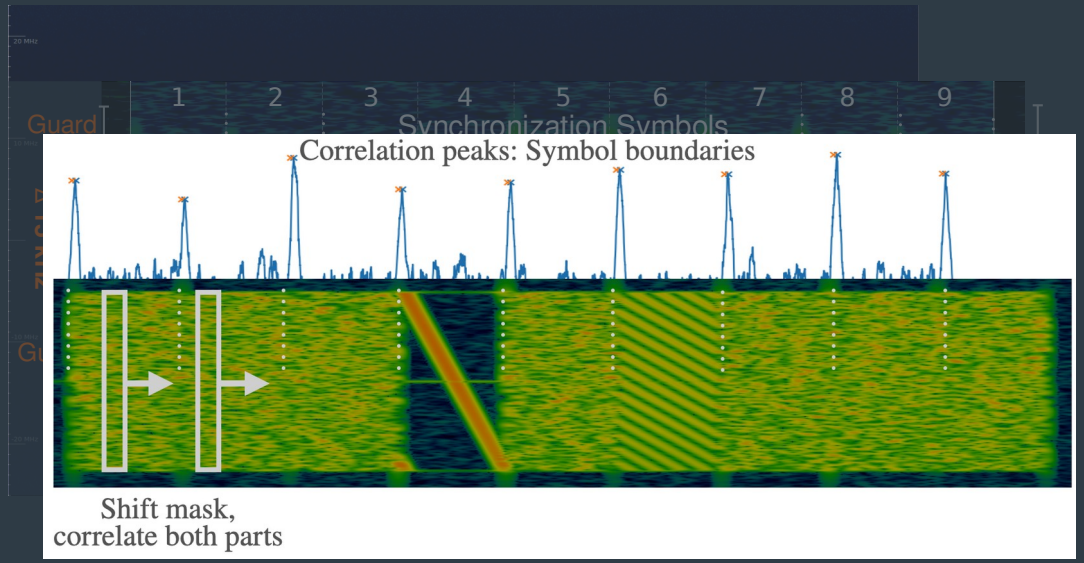

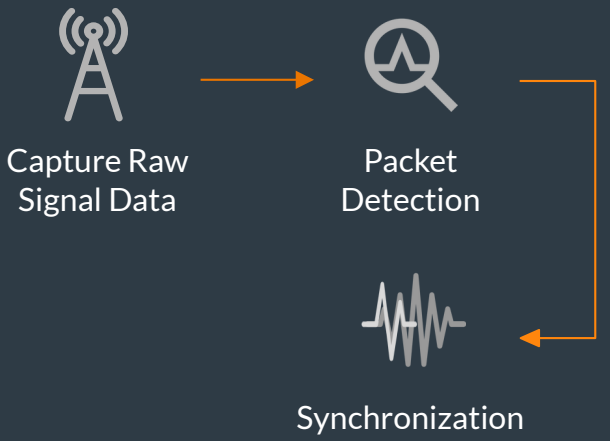

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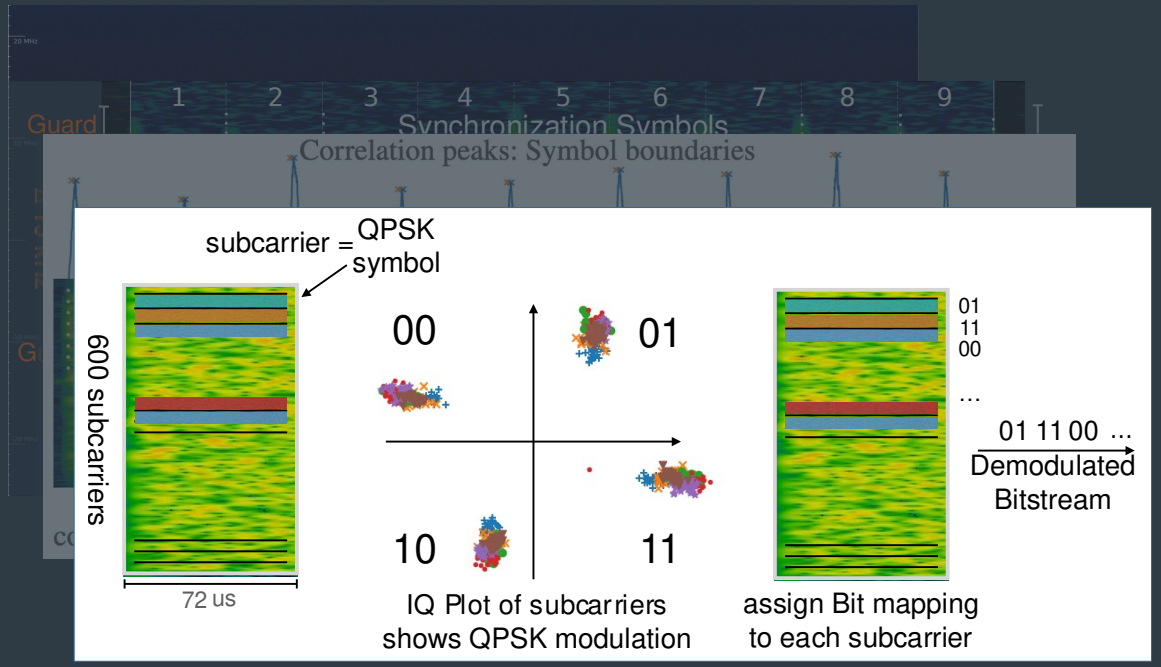

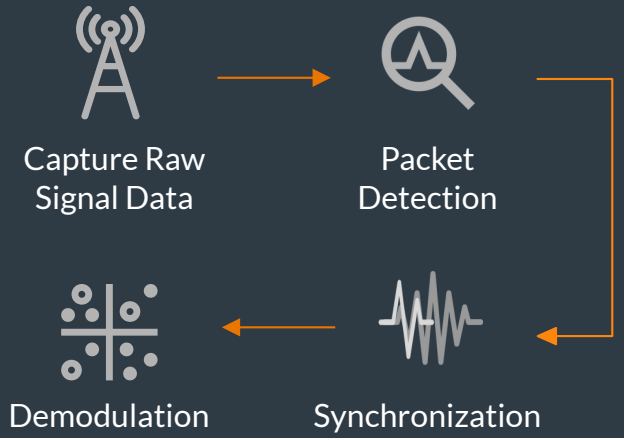

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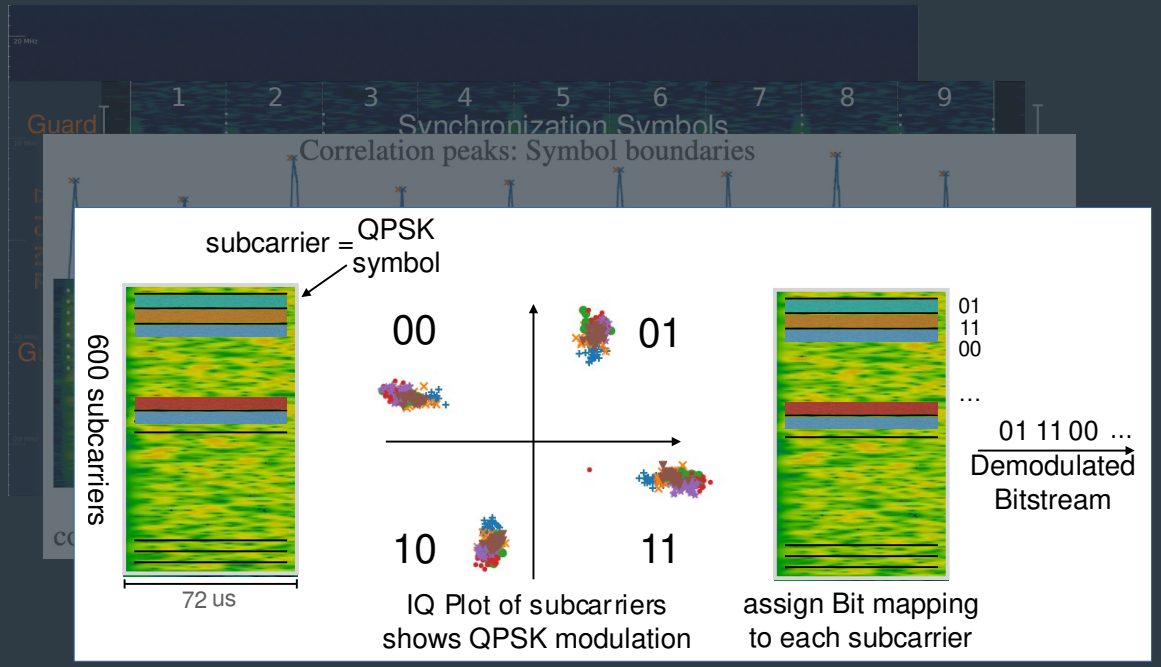

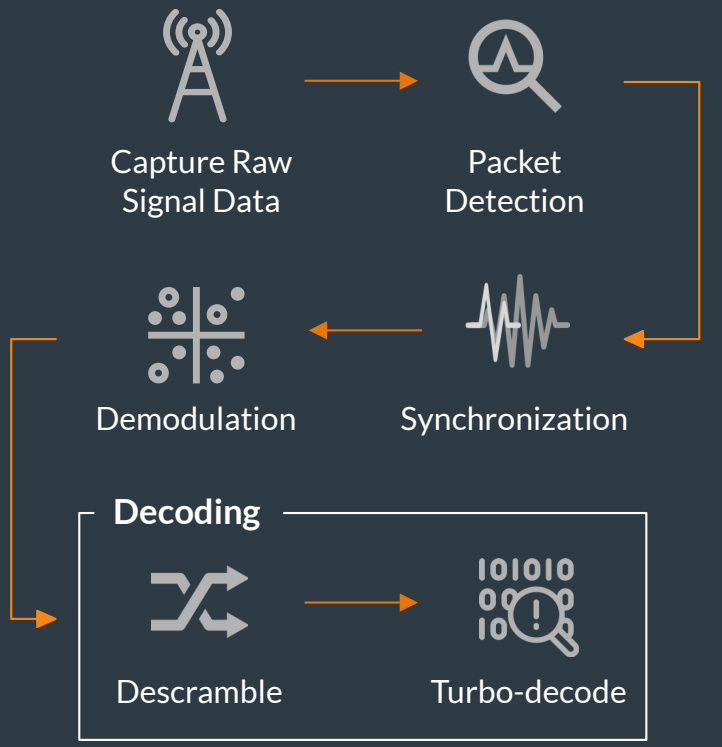

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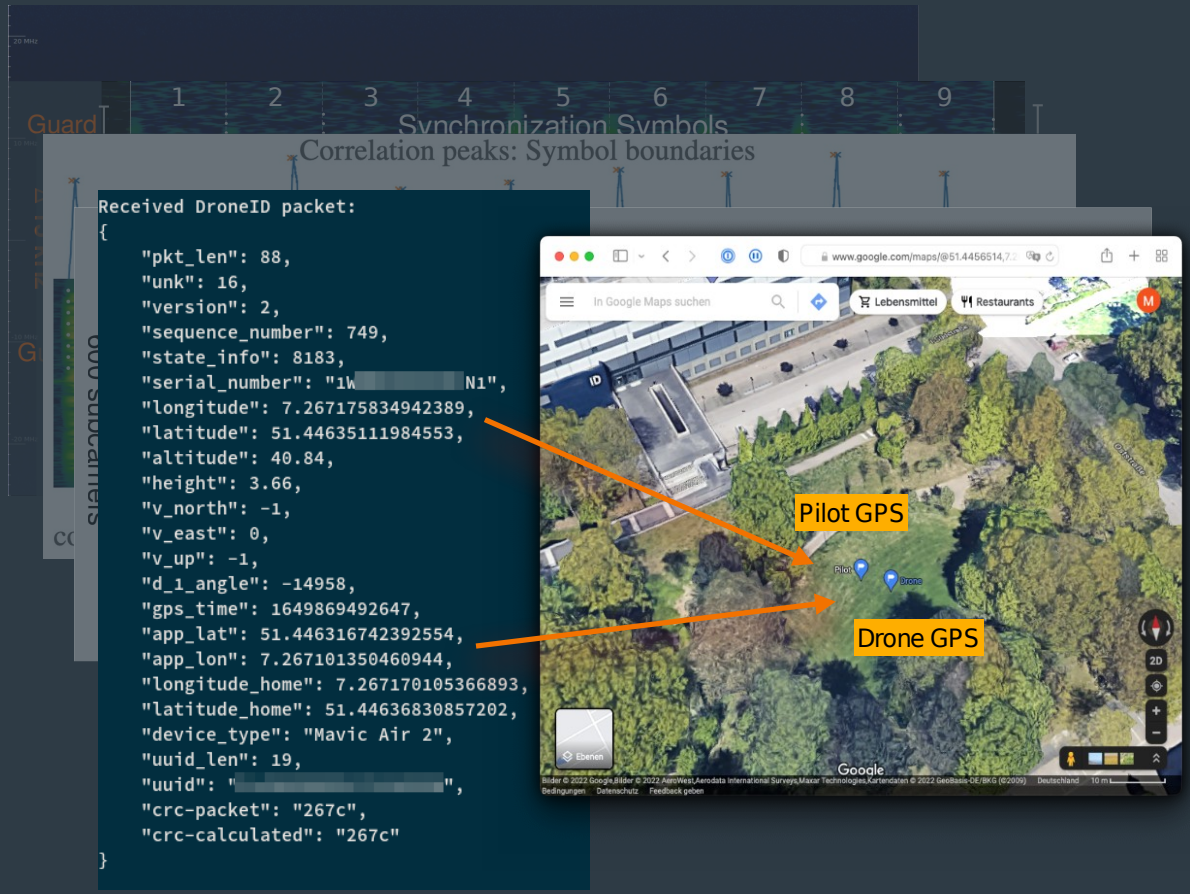

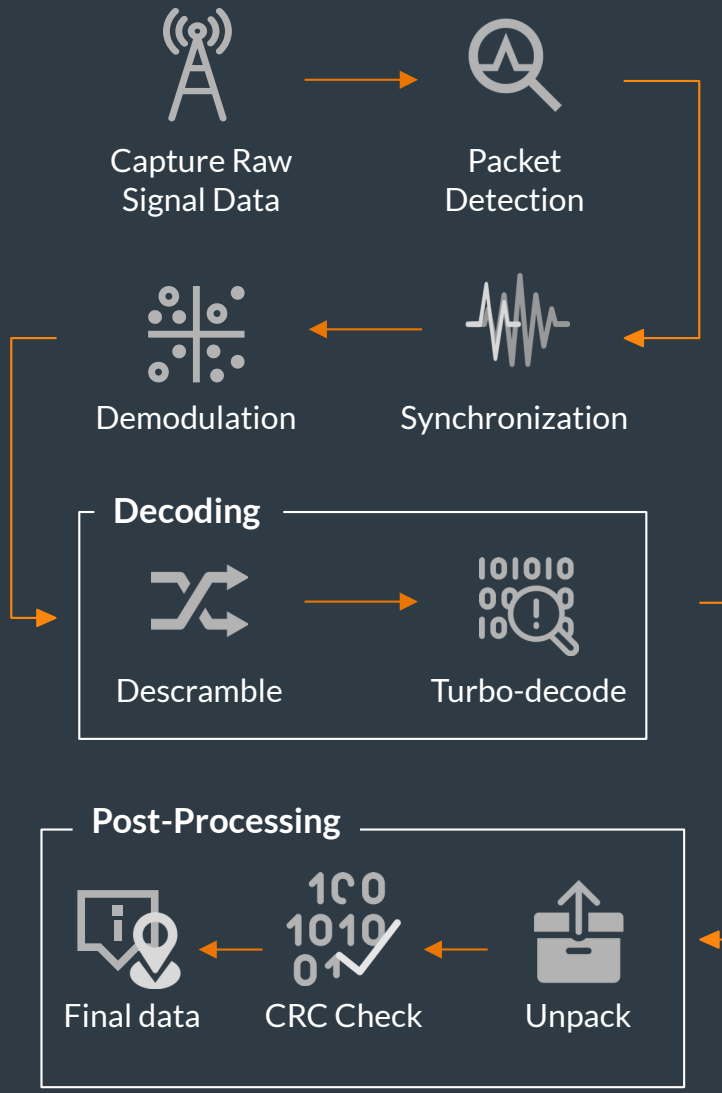

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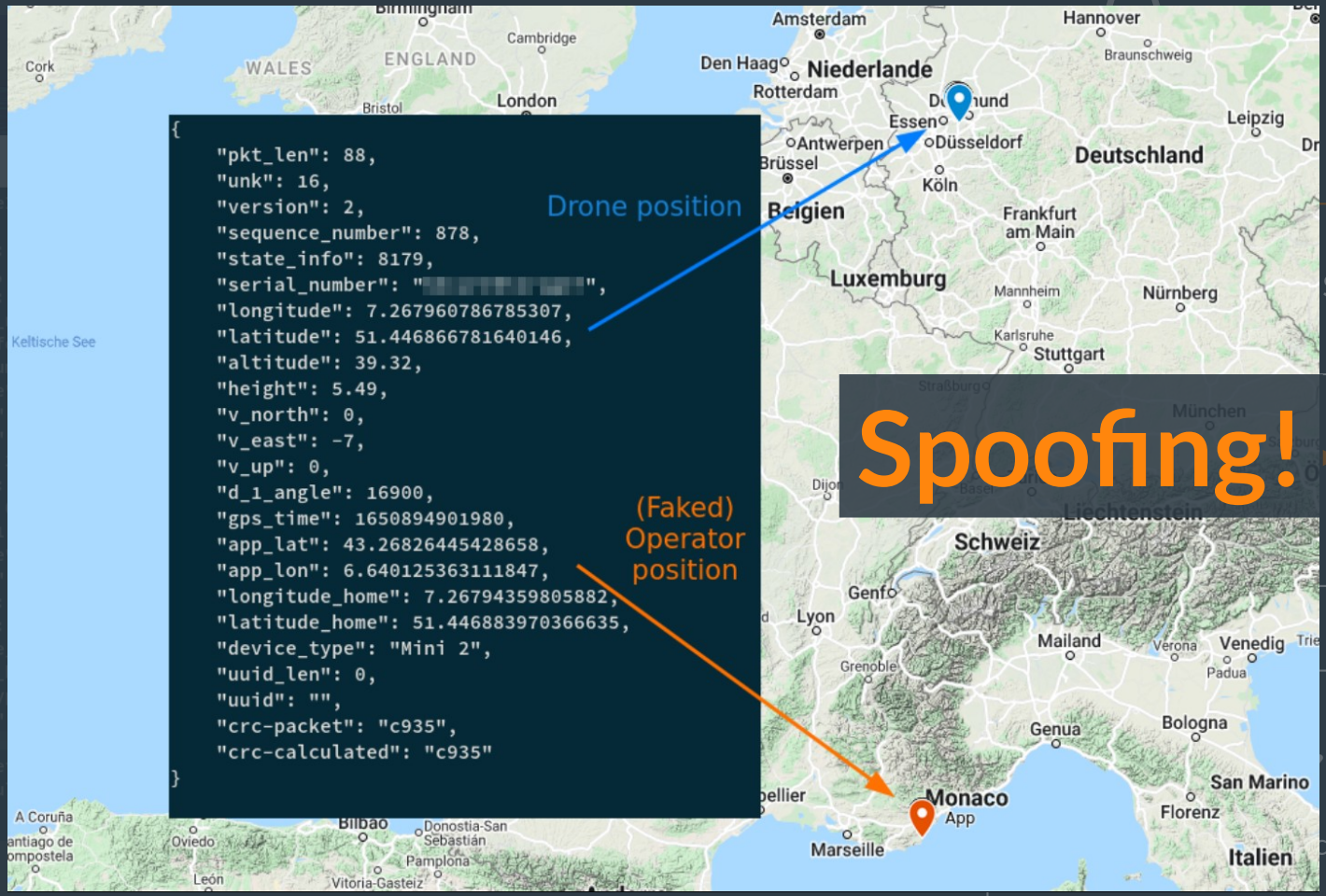


Wireless Physical Layer

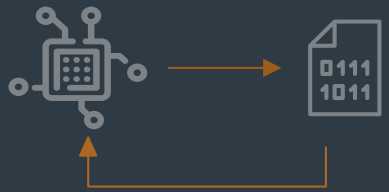
The Mysterious Case of DJI's DroneID

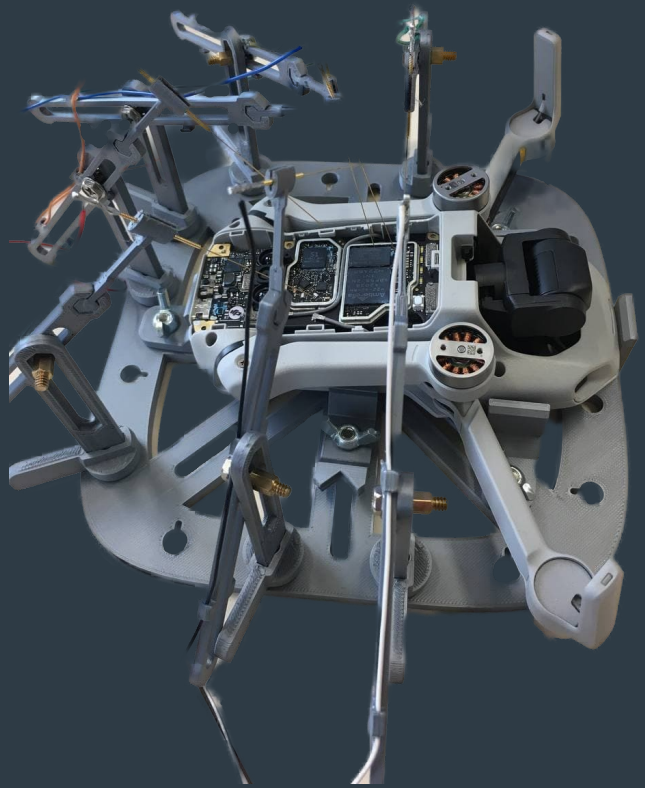
Static Analysis

Hands on the Drone

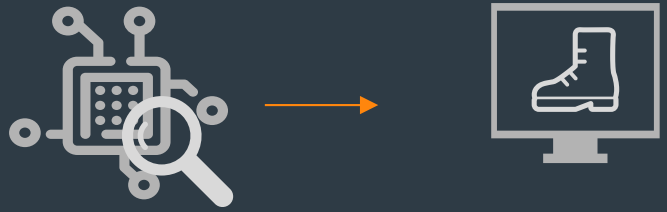
Dynamic Analysis

Fuzzing Drones for Pain and Profit





Analyze
PCB



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Analyze PCB

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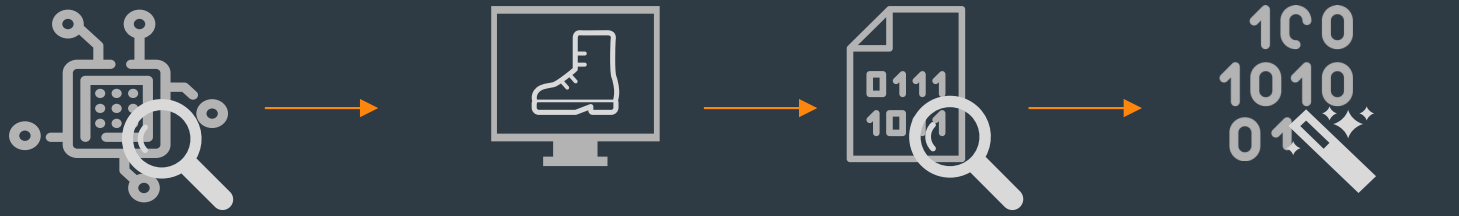
Check Bootloader Firmware



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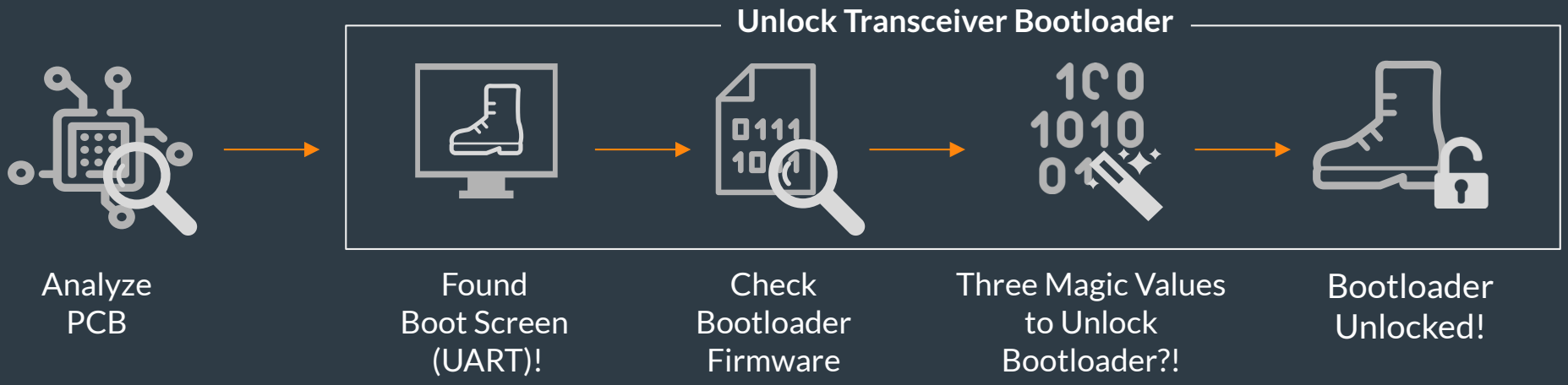
Three Magic Values to Unlock Bootloader?!


Unlock Transceiver Bootloader
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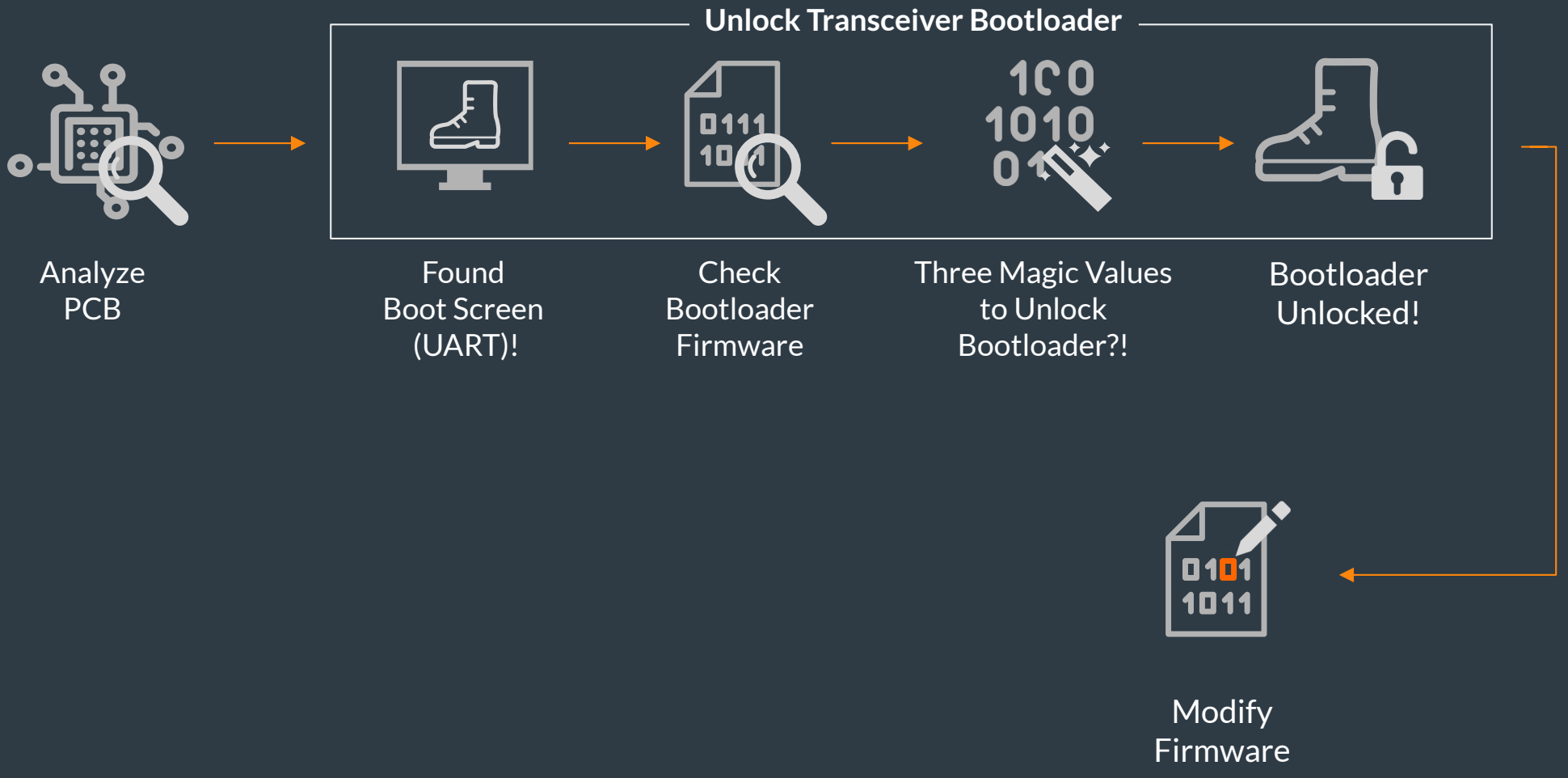
Bootloader Unlocked!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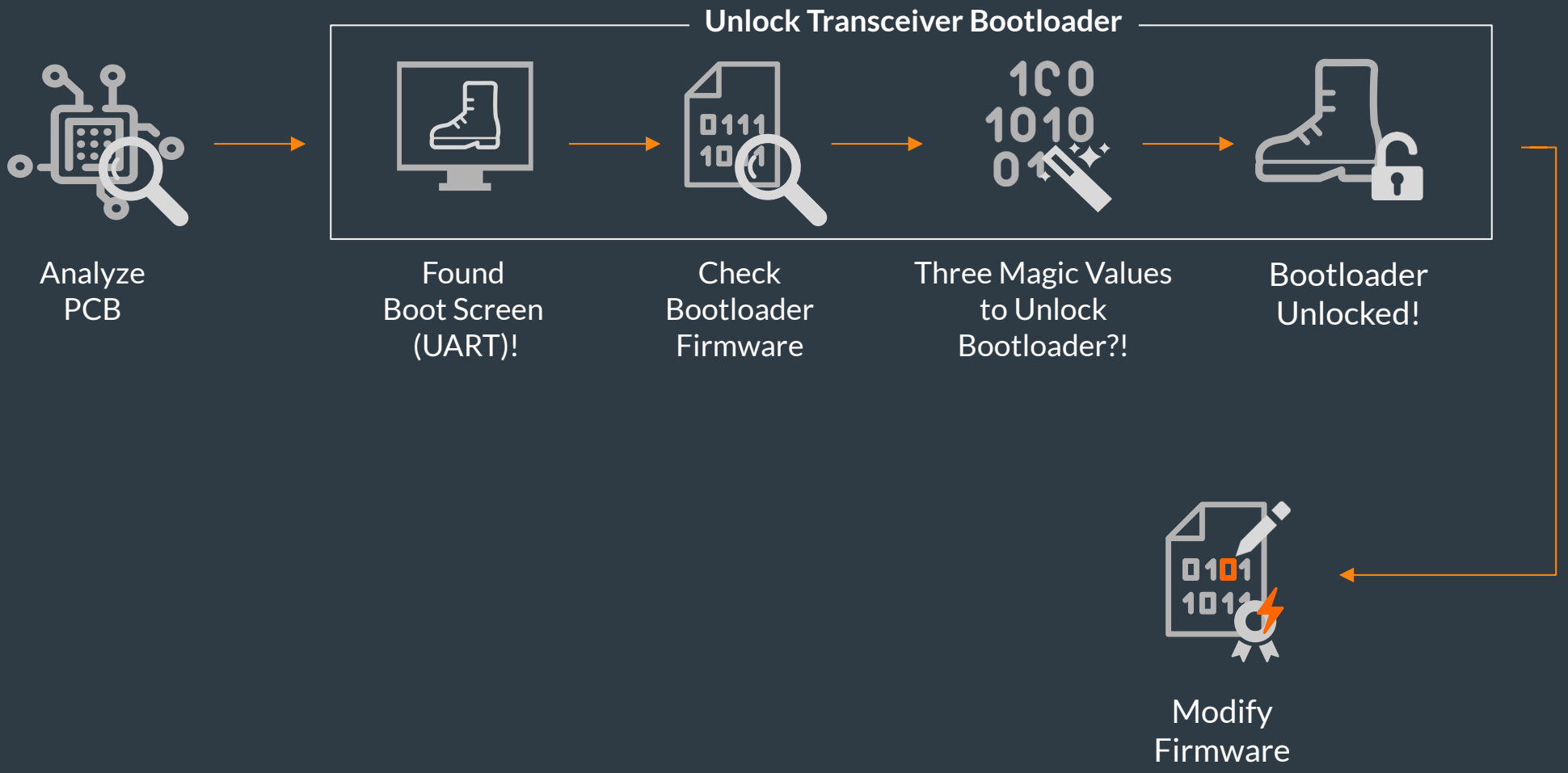
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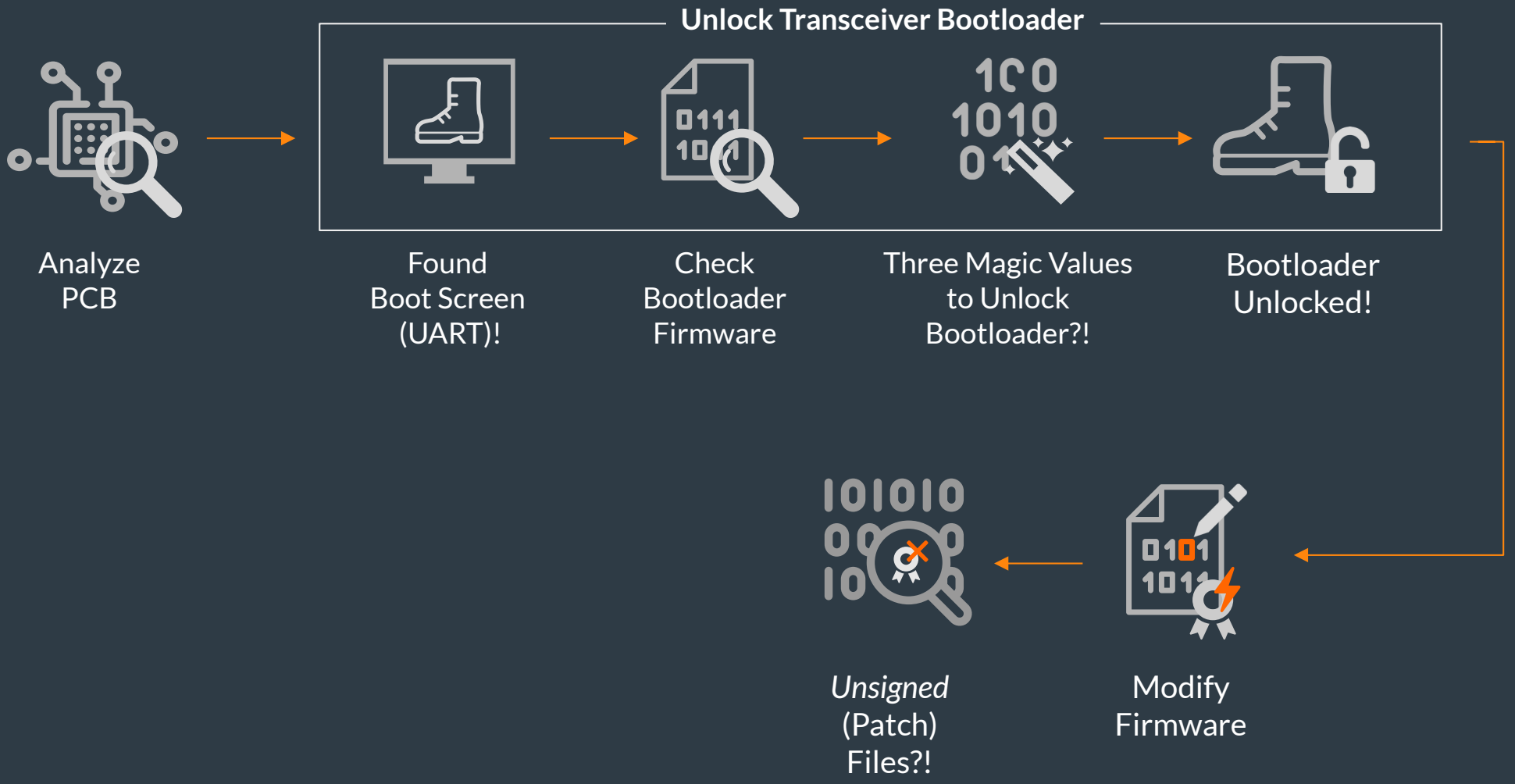
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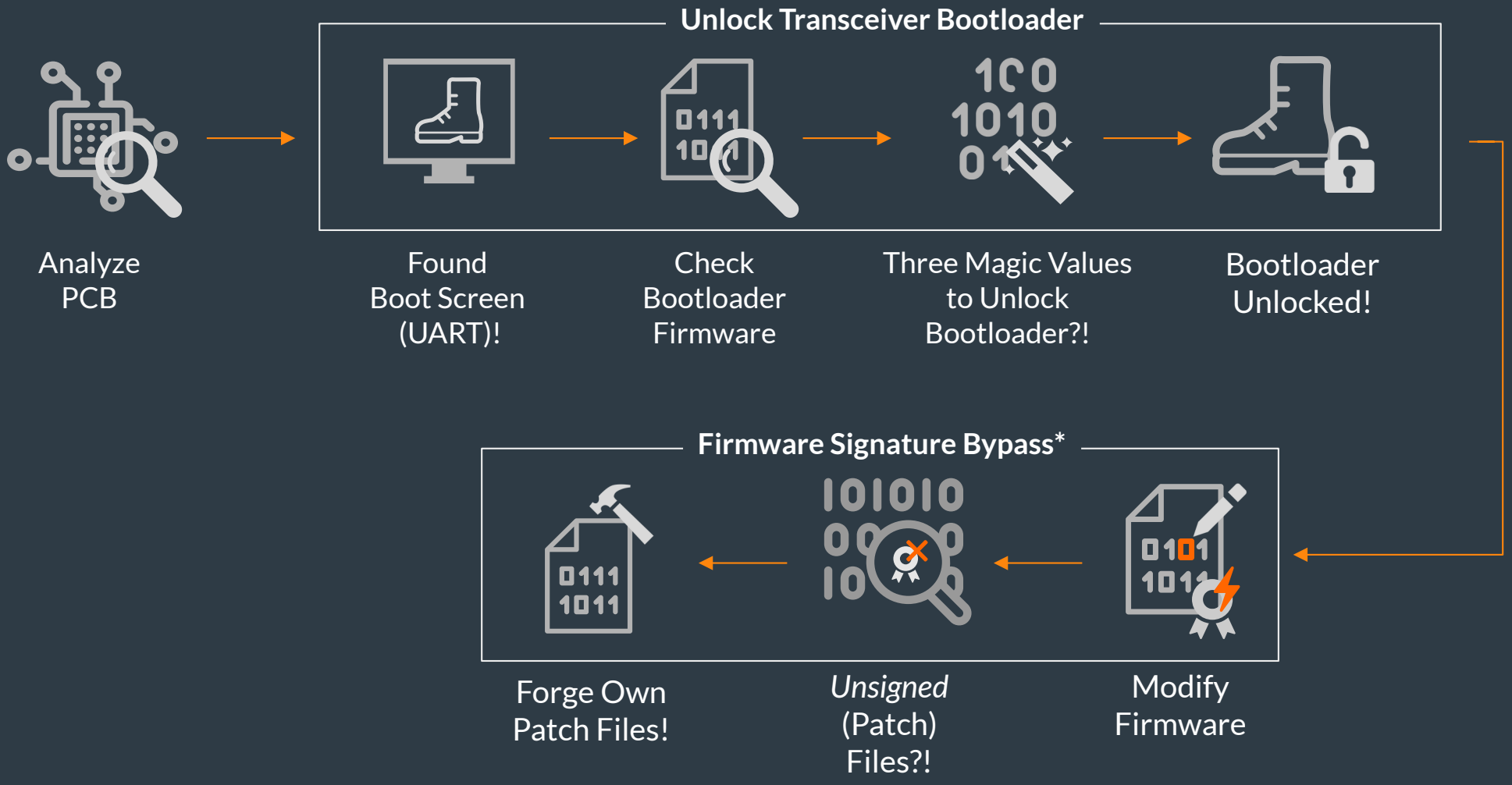
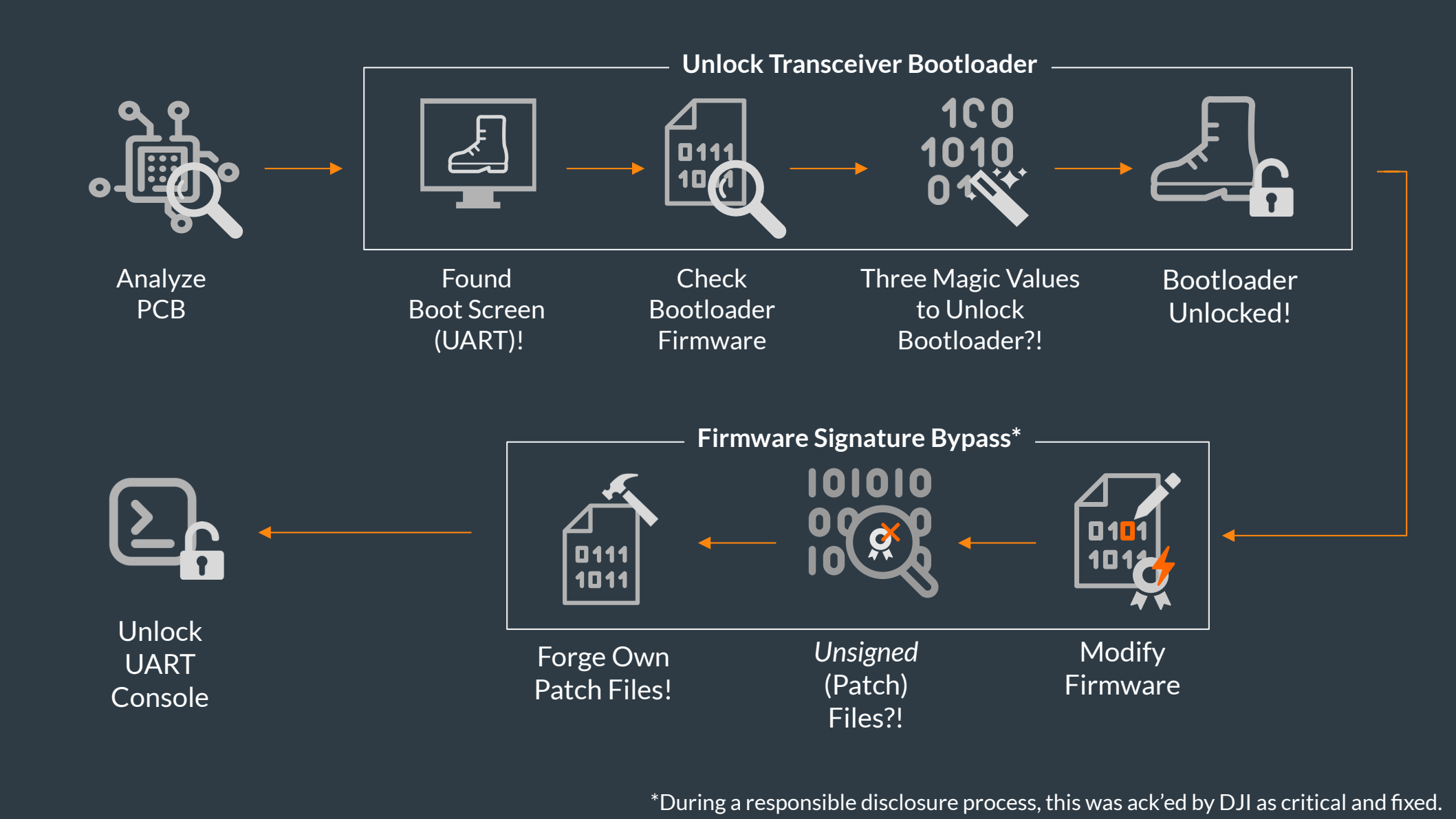
Unsigned (Patch) Files?!



*During a responsible disclosure process, this was ack'ed by DJI as critical and fixed.



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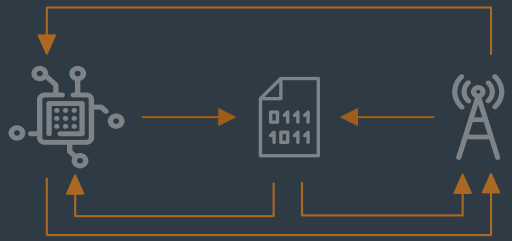

How to Fuzz R*eal* Drones?

How to Fuzz R*eal* Drones?

Fuzzer

Prerequisites:

- A drone and fuzzer

How to Fuzz R*eal* Drones?

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How to Fuzz R*eal* Drones?

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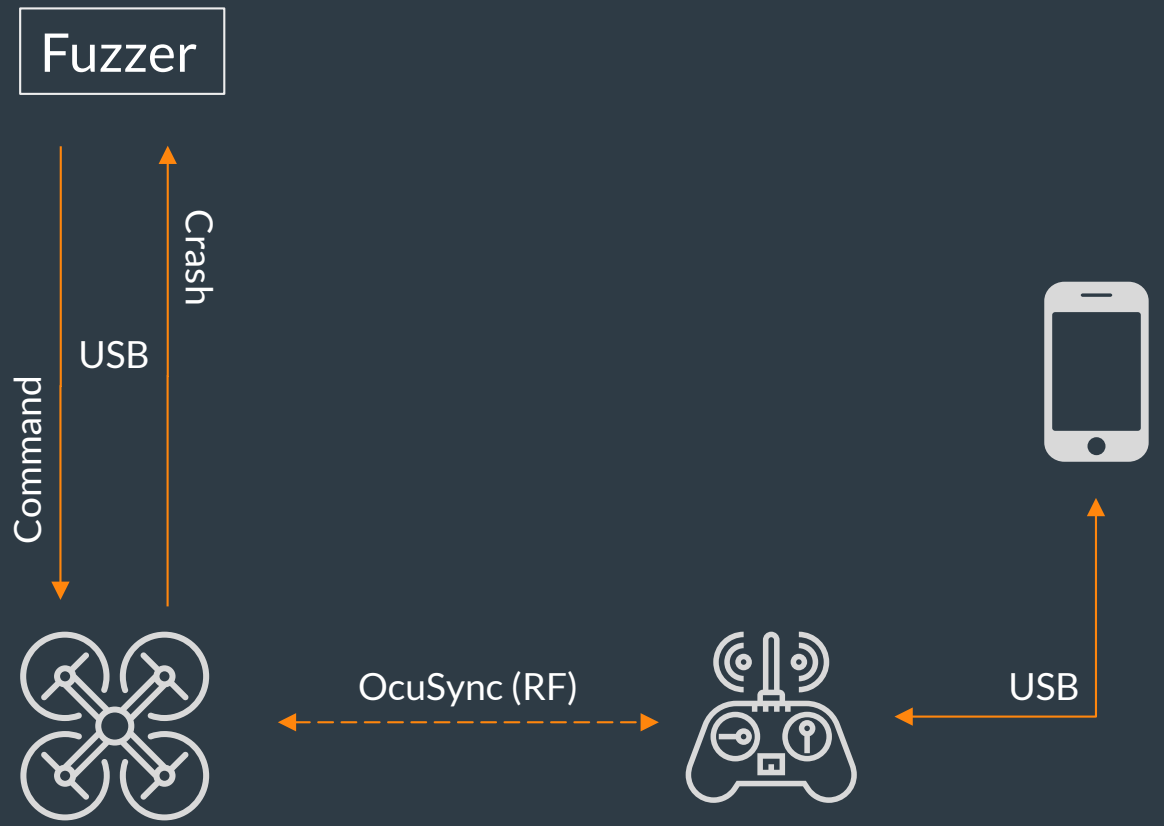

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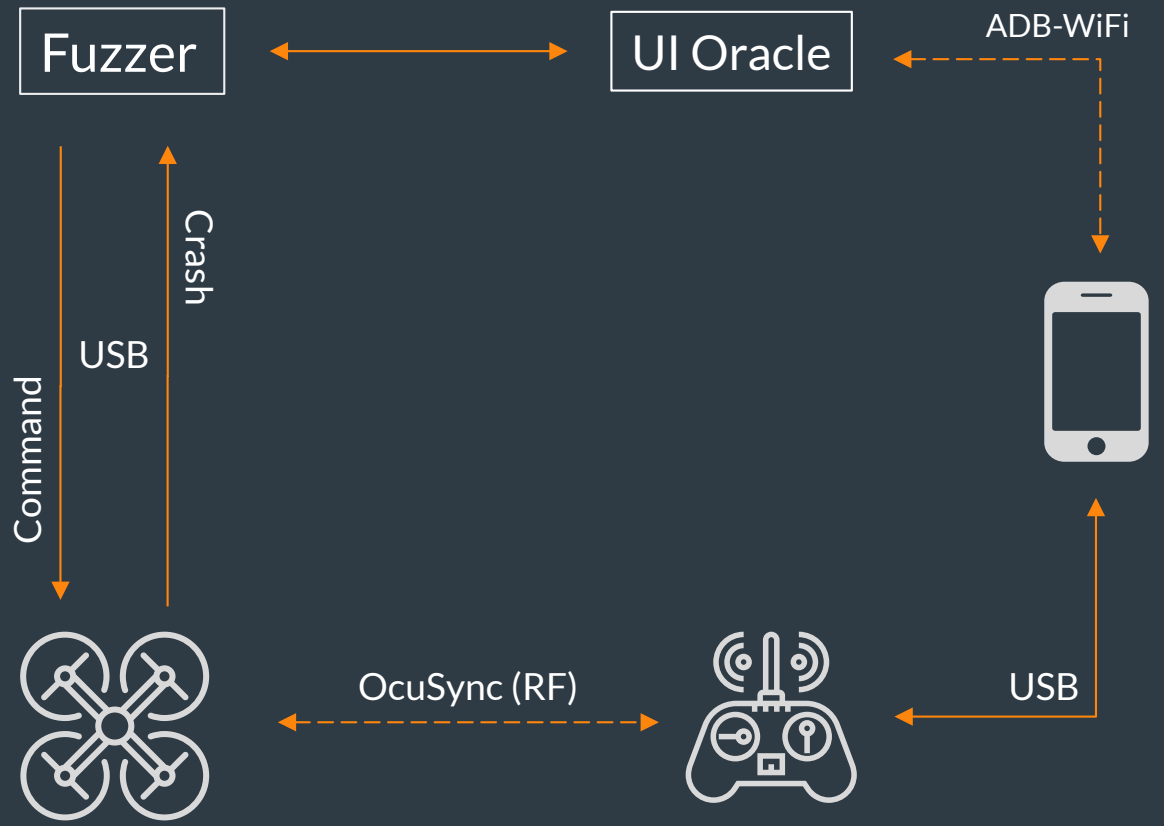

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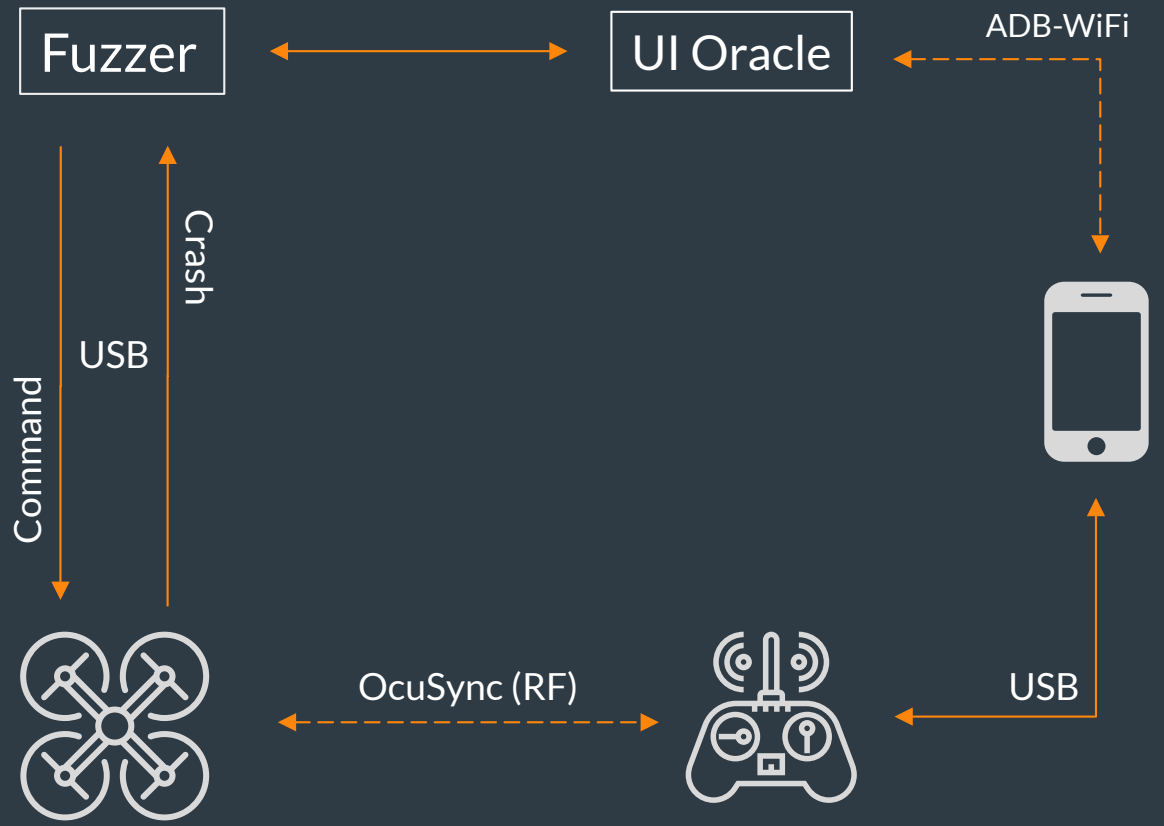
Reproducible bugs!



Does fuzzing work?

ID	Oracle	Component	Observable Behavior	Classification	Severity	Remote	Vulnerable Devices
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#9	crash	unknown	critical error (drone reboot)	denial of service	mid	✓	Mini 2
#10	crash	unknown	critical error (drone reboot)	denial of service	mid	✓	Mini 2
#11	crash	unknown	critical error (drone reboot)	denial of service	low	✓	Mini 2
#12	crash	unknown	critical error (drone reboot)	denial of service	low	✓	Mini 2
#13	crash	flight controller	critical error (drone reboot)	denial of service	low	✓	Mavic Air 2
#14	UI change	WiFi chip	change SSID	arbitrary code exec	mid	✓	Mini 2, Mavic 3
#15	UI change	flight controller	change serial number	identity spoofing	mid	✓	Mini 2

*Following responsible disclosure, DJI fixed these bugs.

Does fuzzing work?

ID	Oracle	Component	Observable Behavior	Classification	Severity	Remote	Vulnerable Devices
#1	ADB check	`dji_sys` binary	ADB started (root access)	arbitrary code exec	mid	✗	Mini 2
#2	crash	flight controller	critical error (drone reboot)	buffer overflow	mid	✓	Mavic Air 2
#3	crash	flight controller	critical error (drone reboot)	buffer overflow	mid	✓	Mavic Air 2
#4	crash	flight controller	critical error (drone reboot)	buffer overflow	mid	✓	Mavic Air 2
#5	crash	flight controller	critical error (drone reboot)	buffer overflow	mid	✓	Mavic Air 2
#6	crash	flight controller	critical error (drone reboot)	buffer overflow	mid	✓	Mavic Air 2
#7	crash	flight controller	critical error (drone reboot)	denial of service	mid	✓	Mini 2
#8	crash	flight controller	critical error (drone reboot)	denial of service	mid	✓	Mini 2
#9	crash	unknown	critical error (drone reboot)	denial of service	mid	✓	Mini 2
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#12	crash	unknown	critical error (drone reboot)	denial of service	low	✓	Mini 2
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- DroneID decodable
  - Tool available
- DroneID can be spoofed / disabled

Position tracking

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- Firmware signature verification bypassed

Position tracking 

Hardware protection 

Summary of Findings

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  - Tool available
- DroneID can be spoofed / disabled

- Debugging interfaces enabled
- Firmware signature verification bypassed

- Fuzzing
  - 15 vulnerabilities (3 x low, 12 x medium)

Position tracking 

Hardware protection 

Software limits 

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Questions?