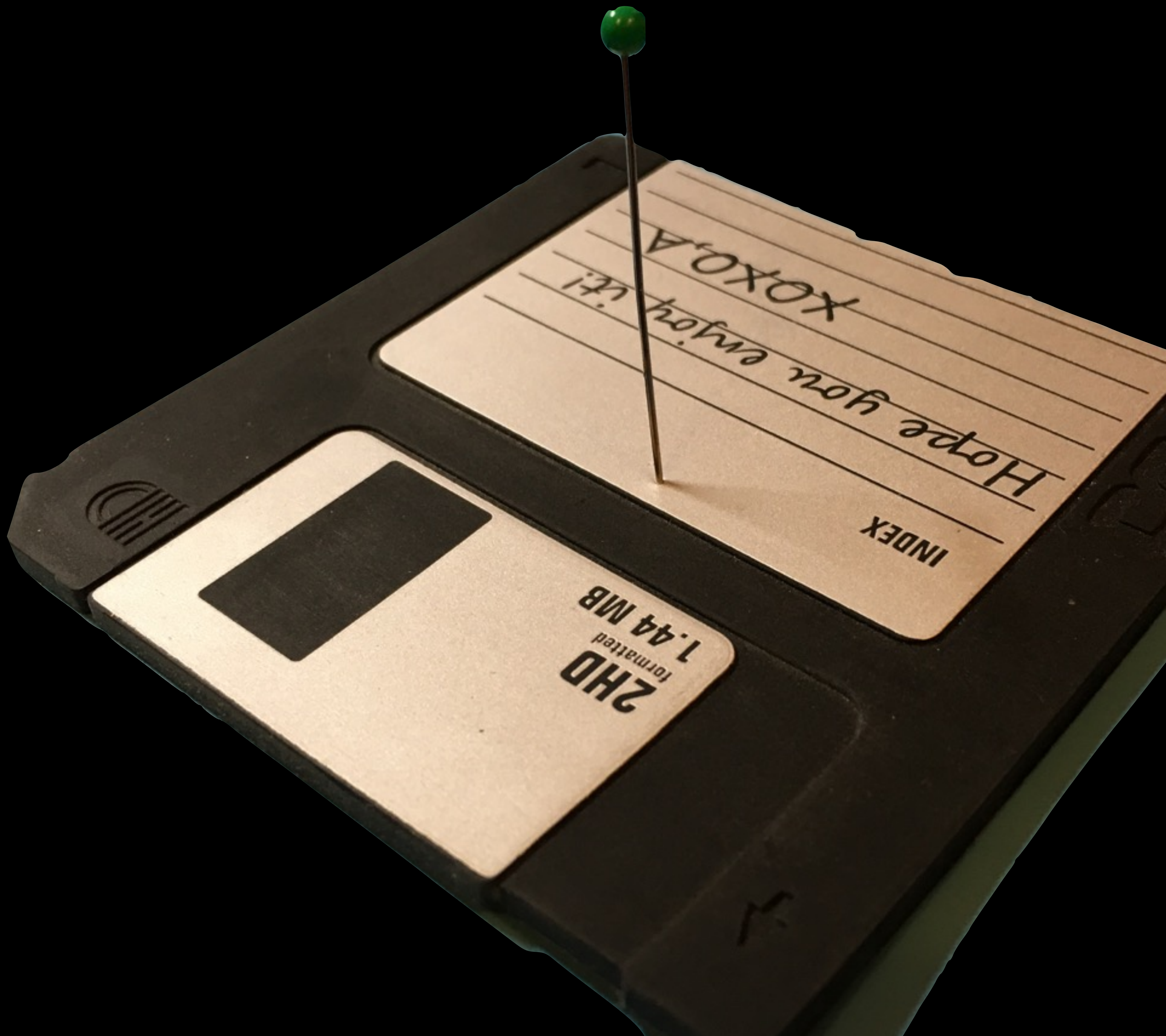
pin2pwn: How to Root an Embedded Linux Box with a Sewing Needle



Brad Dixon - Carve Systems

DEF CON 24

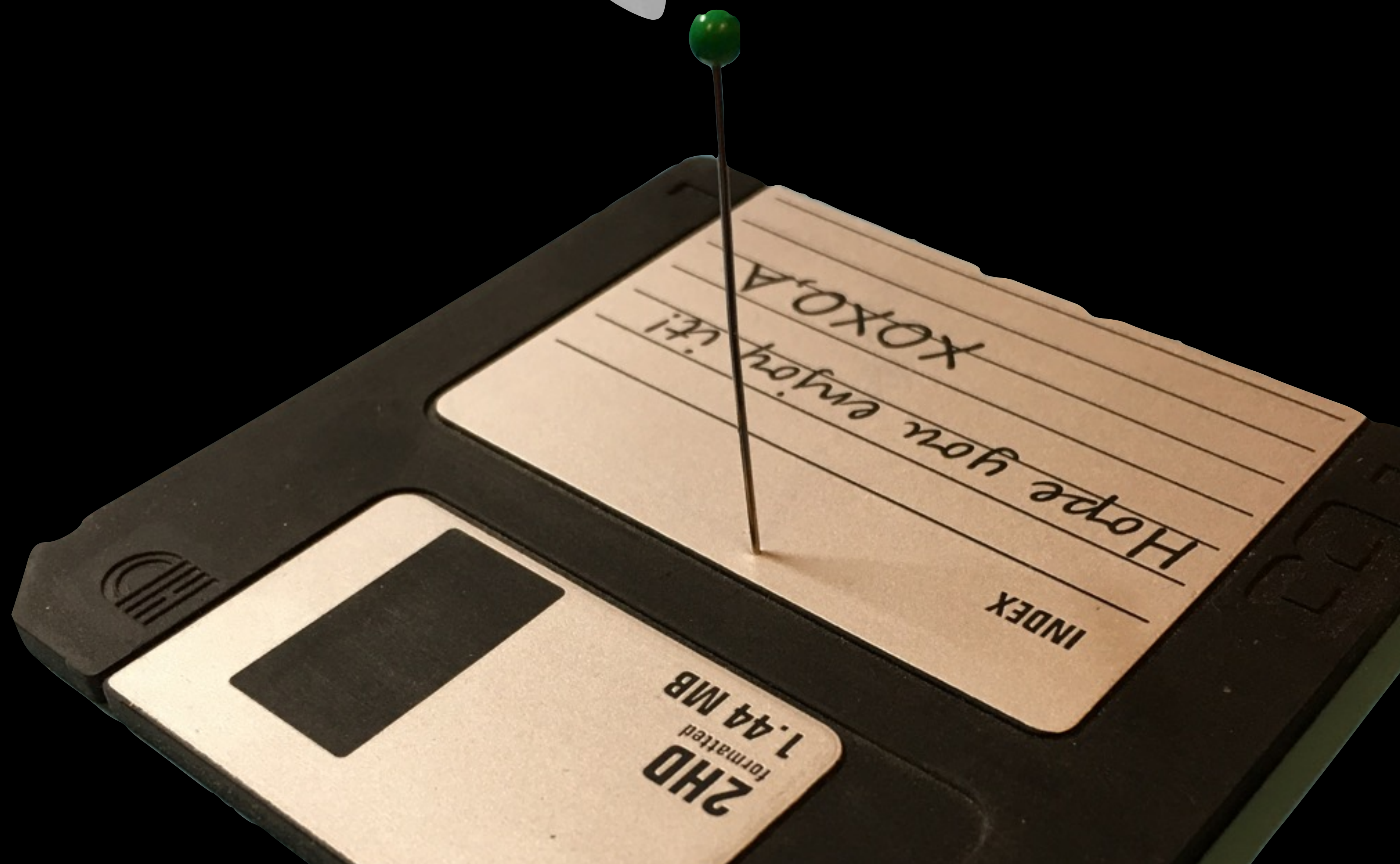
“USEFUL NOVELTY”

- It works
- Easy
- Teachable
- Dramatic

- Risky
- Crude
- Perhaps redundant

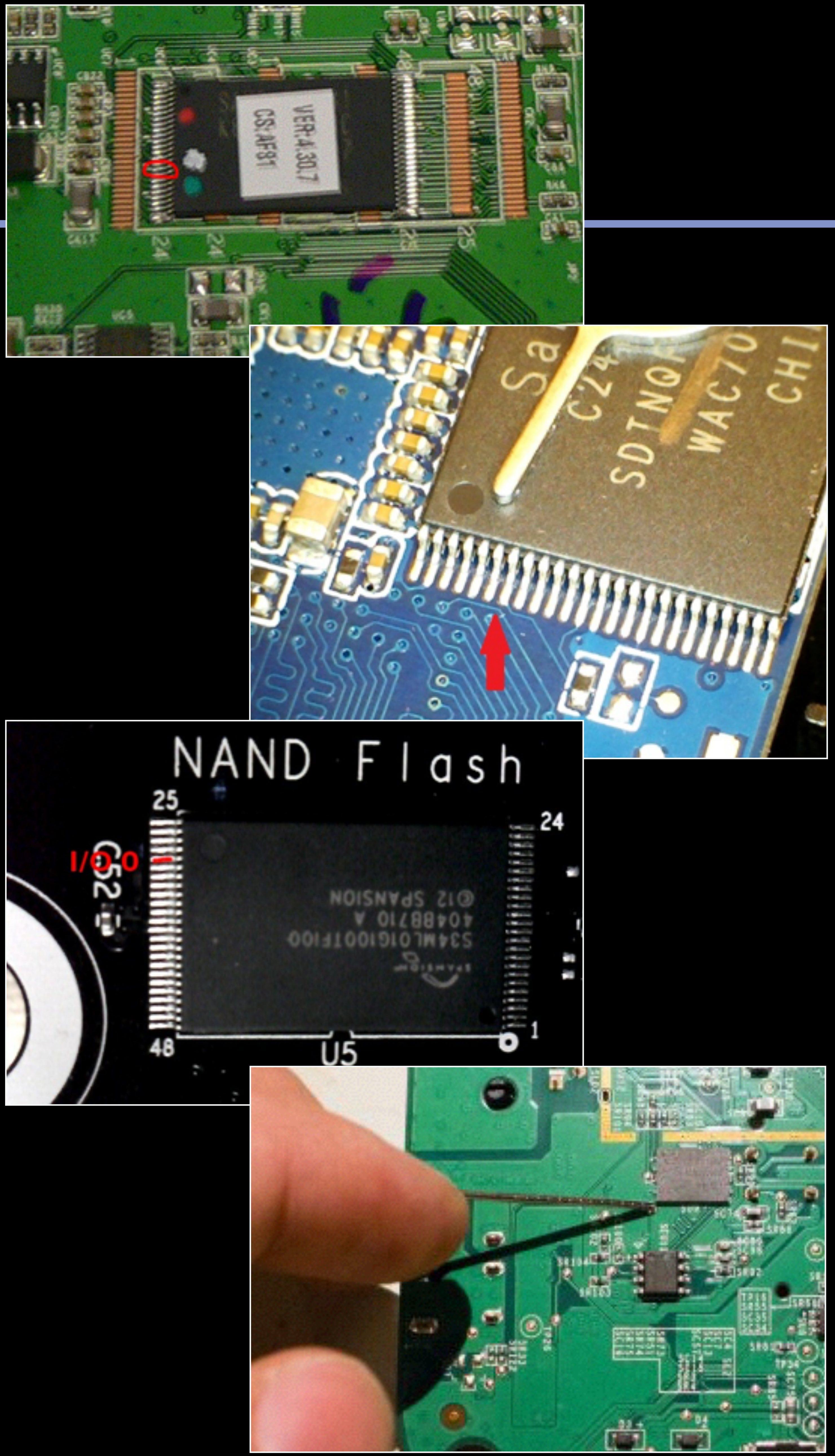
Demo

Actual hacking tool



Prior Art

- Significant body of work around fault injection and glitching at the IC level for secure processors
- Recent system-level applications:
  - 2004: WRT54 “Bricked Router” recovery, Administrator note by mbm
  - “How to Hack the Hudl – We give Rockchip a good seeing to”, Pen Test Partners blog post
  - “20 Devices in 45 Minutes”, CJ Heres et. al., DEF CON 22 (related)
  - “WINKHUB Side Channel Attack”, Kevin2600, 2016
  - “Getting Root on a Philips Hue Bridge”, Colin O’Flynn, 2016



For today…

- ***When*** this attack can be effective
- ***Why*** this attack works
- ***How*** to defend against this attack

RISKS TO HARDWARE

DEF CON 101

102 Ways to Brick your Hardware

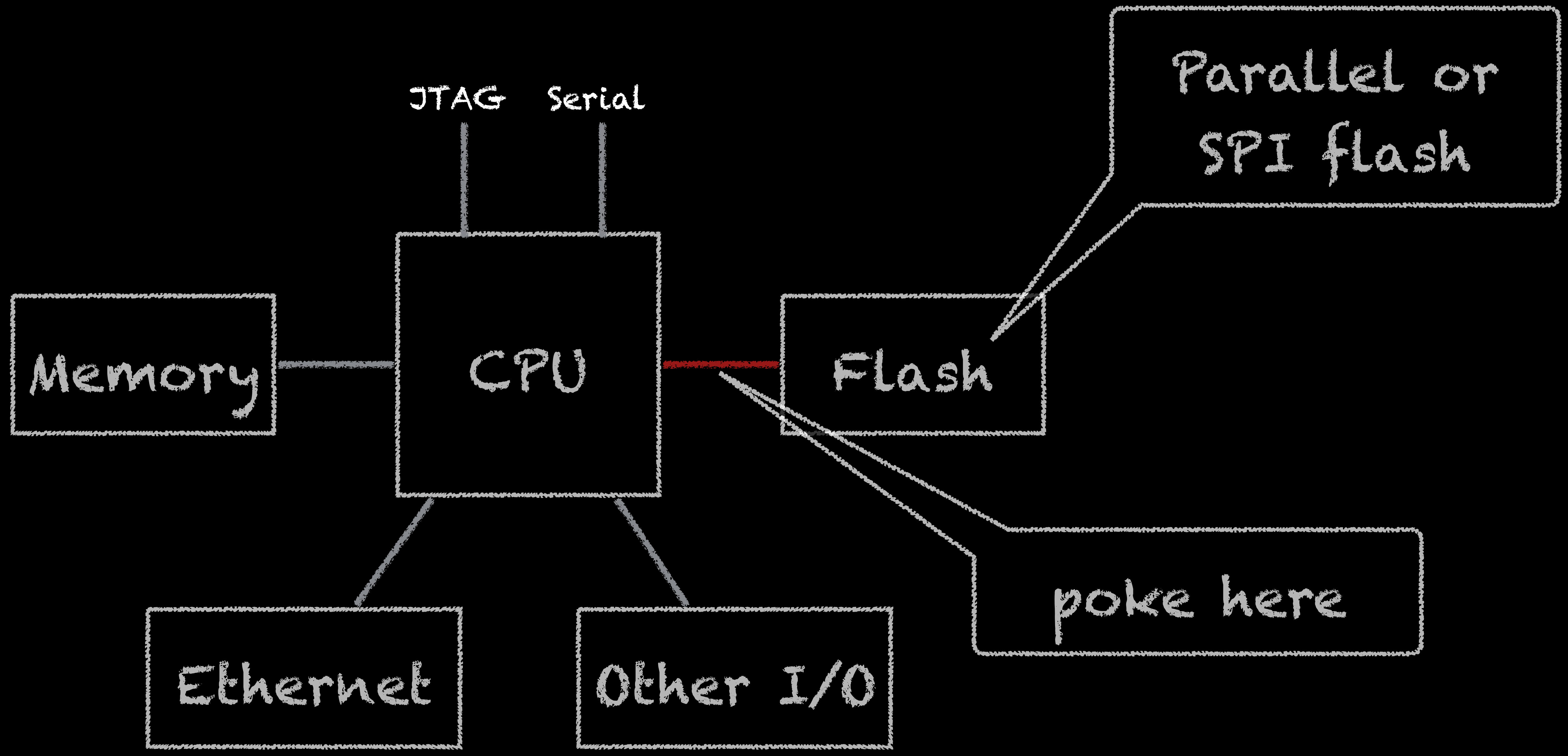
Joe FitzPatrick & Joe Grand

- I have not ***yet*** destroyed hardware but this is abuse of semiconductor devices.
- Use on equipment you can afford to destroy.
- Depending on the hardware you may have better and safer options. Use those first.

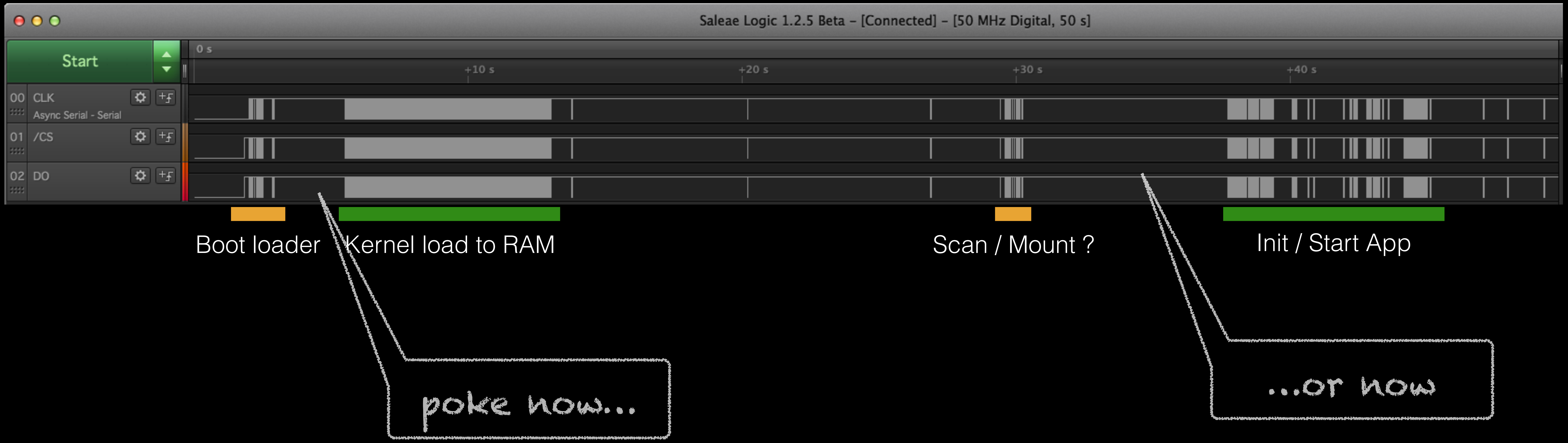
Generic Networked Doohickey Product Design

Order of Attack

1. Serial
2. JTAG
3. …
4. Flash to CPU interface



Why does this work?

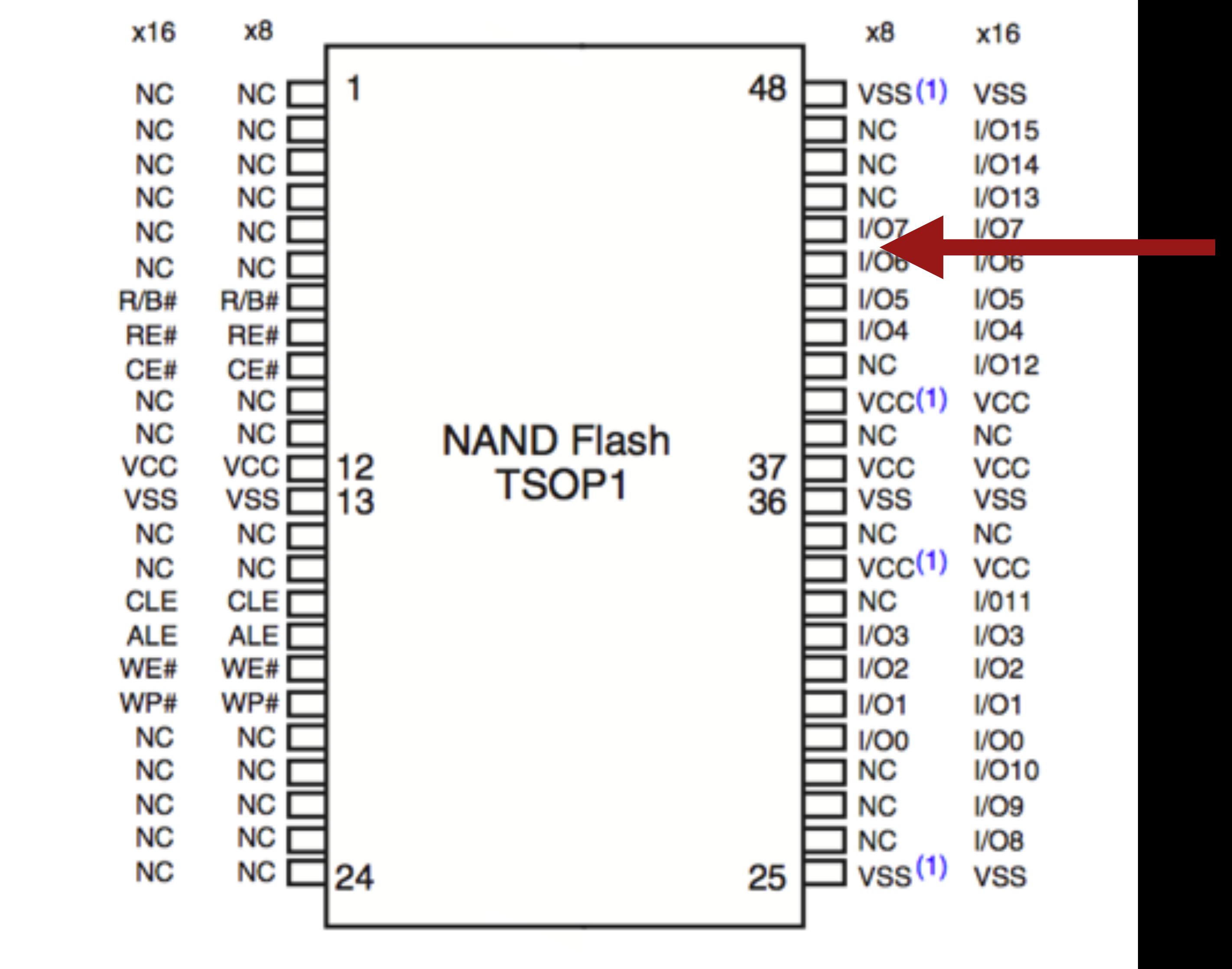


- Disrupt boot chain with a transient fault
- Activate an unexpected failure path

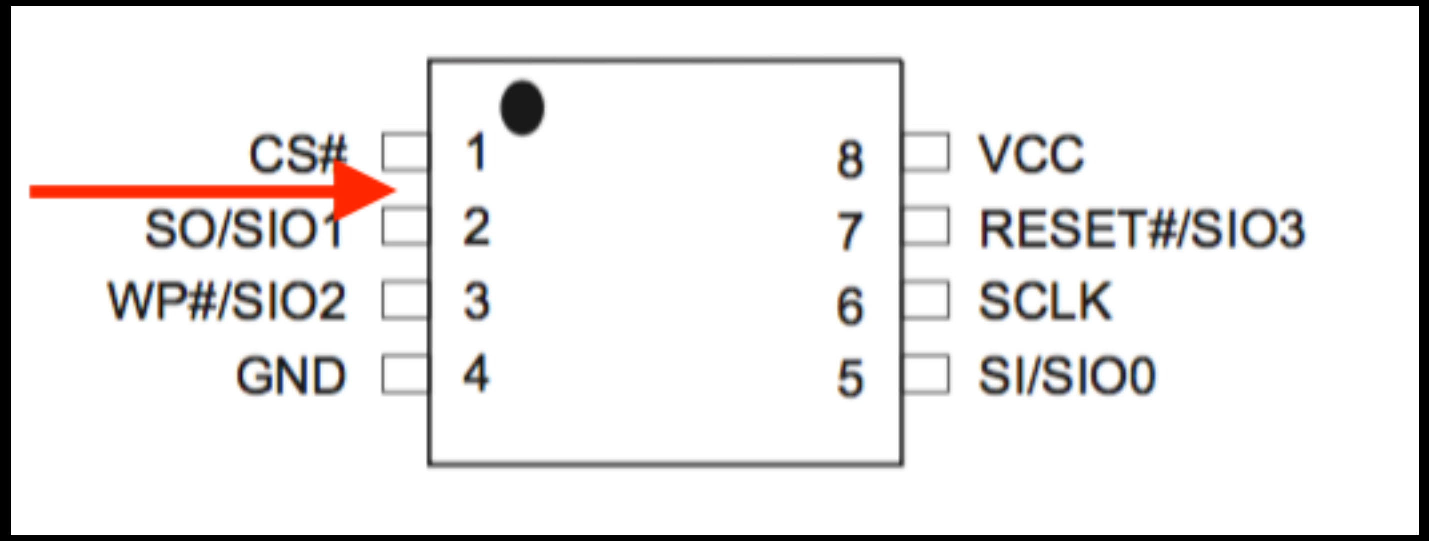
Scenario #1: Exploitable U-Boot Configuration

1. No JTAG.
2. Homegrown “secure” boot
3. Try to load and boot kernel #1
4. Try to load and boot kernel #2
5. If that fails then… return to U-Boot prompt!

Figure 1.2 48-Pin TSOP1 Contact x8, x16 Devices

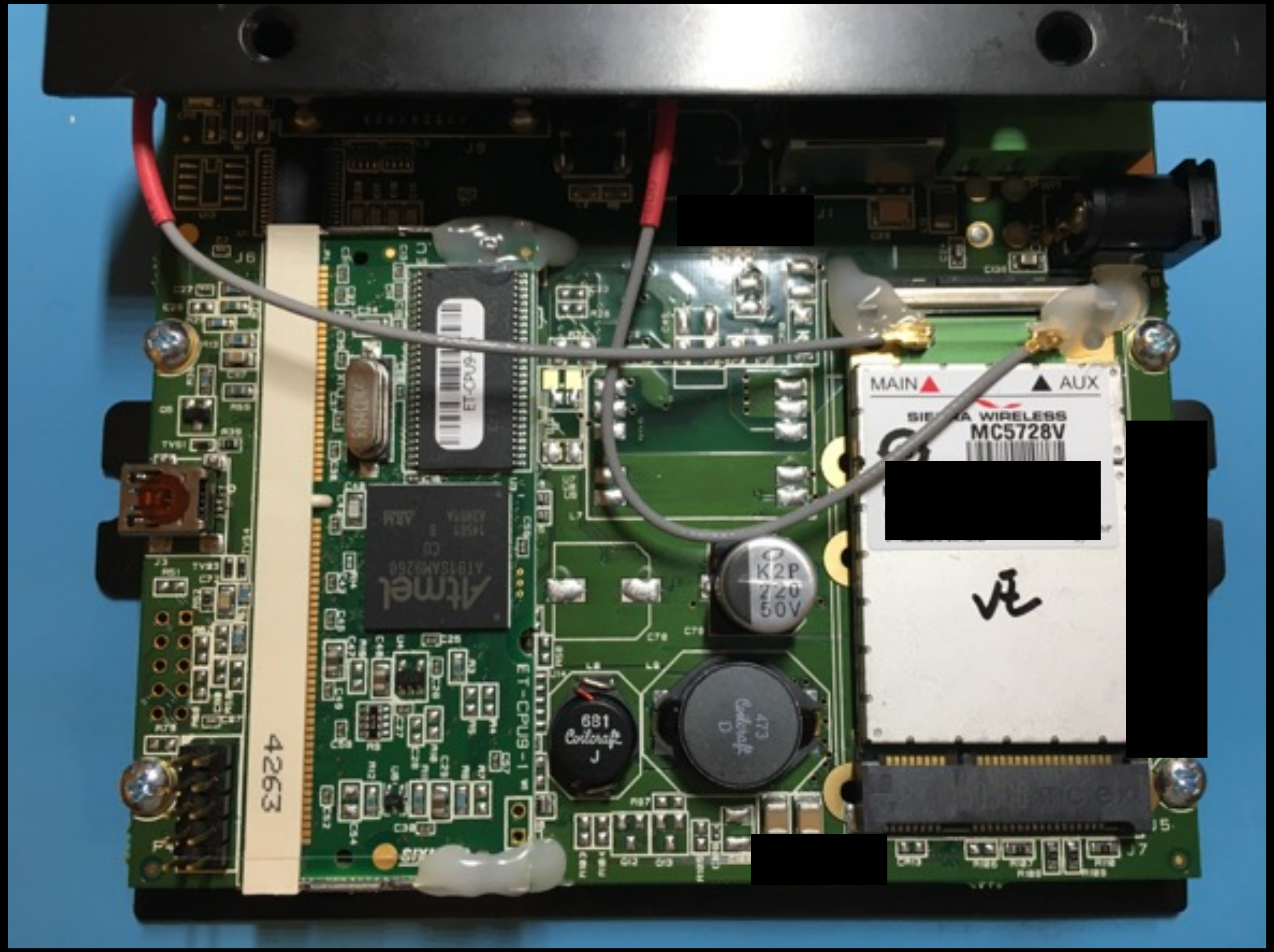


Scenario #2: Exploitable Init Configuration



- `/bin/init` reads `/etc/inittab`
- `/bin/init` runs `/etc/rc`
- `/etc/rc` starts application in the foreground
- Application grabs console and presents a login prompt with credentials we don’t know
- BUT… if the application fails to load then `/bin/init` runs `/bin/sh`

How To Using LTE Router #4



[redacted]
[redacted]
[redacted]
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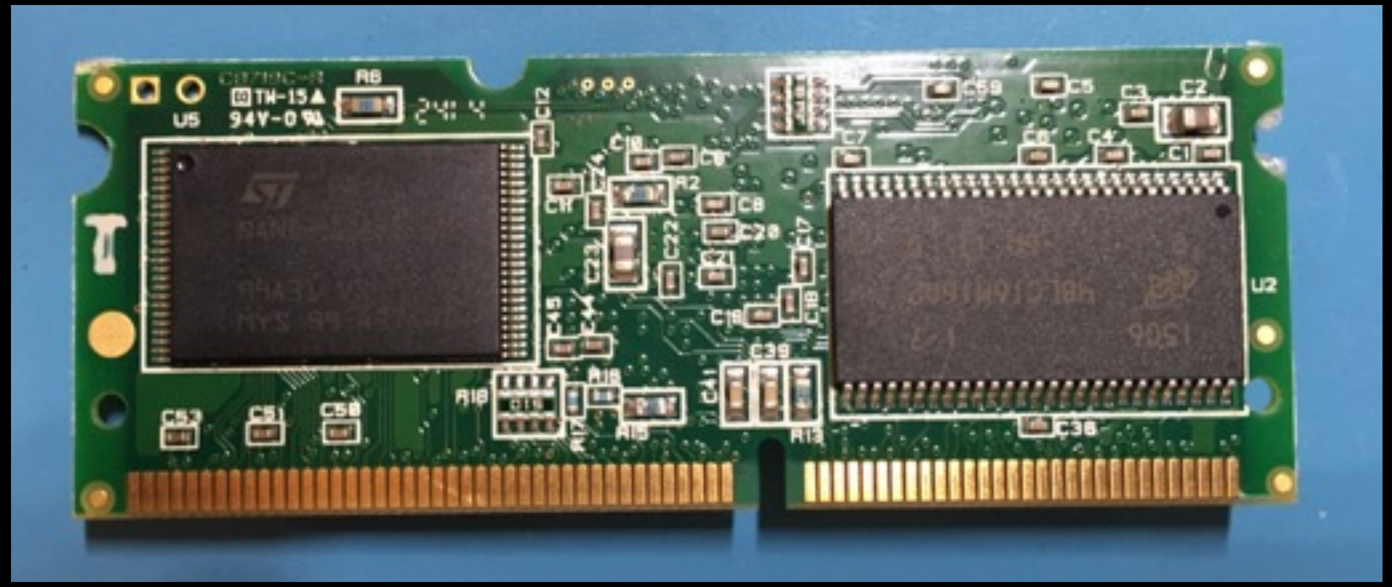
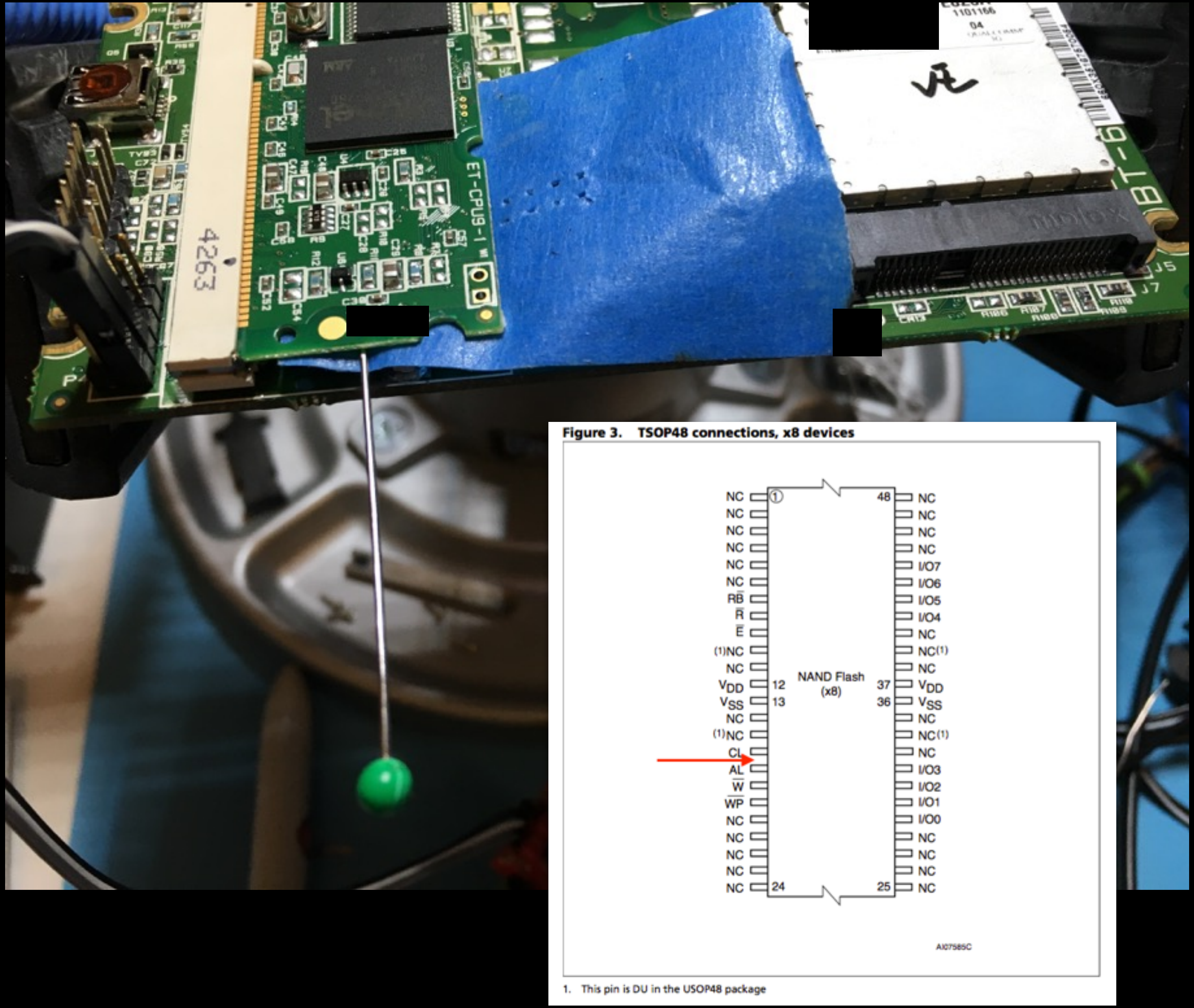




[redacted]
[redacted]
[redacted]

Figure 3. TSOP48 connections, x8 devices

1. This pin is DU in the USOP48 package

How To

Prepare

- Survey HW
- Identify ports to monitor boot
- Datasheets
- Inspect failure modes, if possible
- Get boot timing

Poke

- Select pins to poke
- Get some timing visibility
- Poke!
- May take a few attempts
- Power-off between tests

Pwn?

- Monitor for unusual behavior
  - Serial traffic
  - Fallback boot configurations
  - Re-activated JTAG
  - Boot from TFTP
  - Fail to USB DFU
  - New network ports
- Sometimes you get lucky!

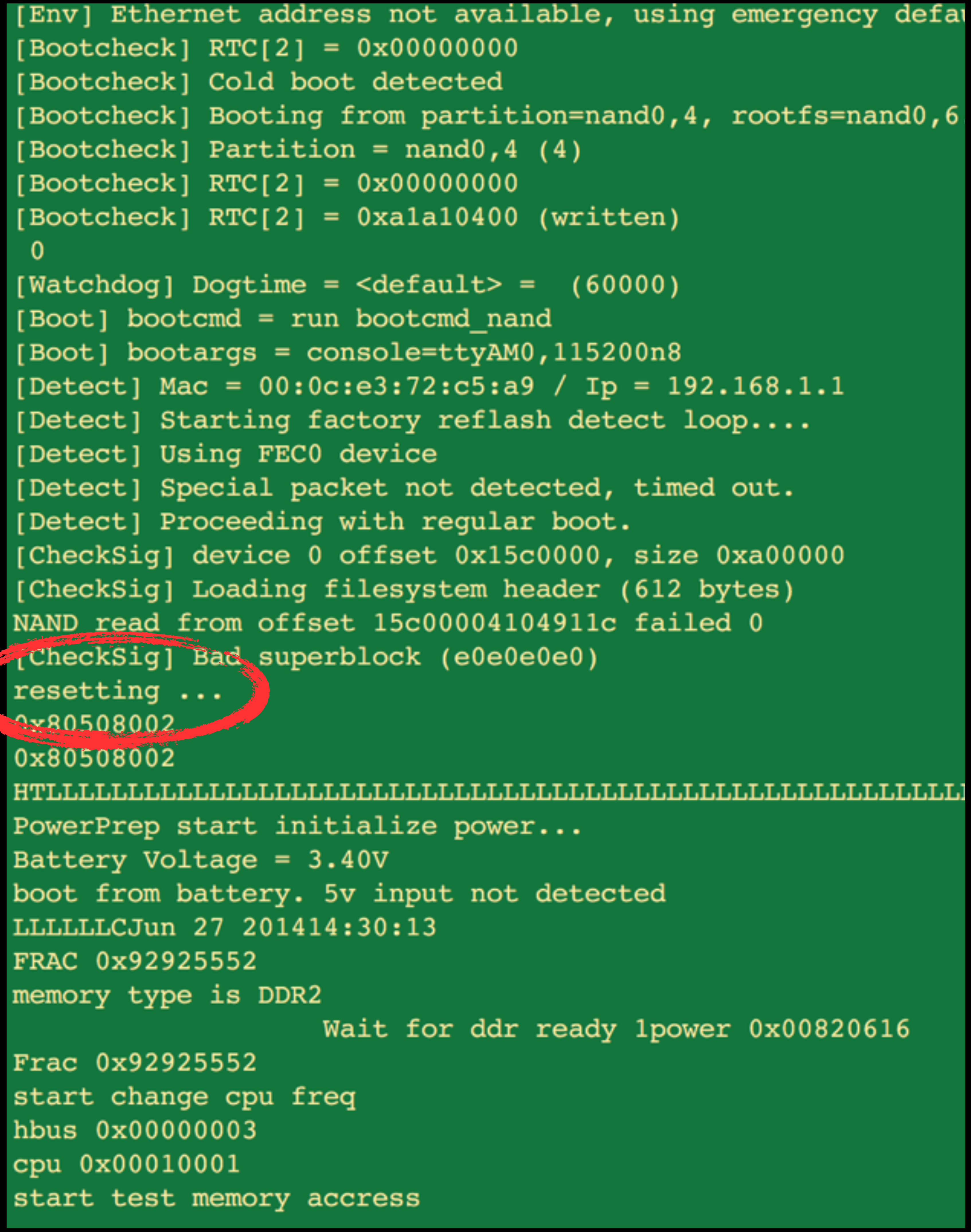
pin2pwn rampage results

Note: Table indicates pin2pwn vulnerabilities only

	Device	“secure” boot	Flash Type	uboot shell	root shell	Defense
1	LTE Router #3	No	Serial	✔		
2	LTE Router #4	No	Parallel	✔		
3	<redacted>	Yes	Parallel	✔		
4	<redacted>	No	Serial		✔	
5	LTE Router #5	No	Parallel			BGA
6	LTE Router #6	Yes	Parallel			Hash check
7	Home Automation Hub	No	Parallel			BGA, Fast

Defense: FAIL CLOSED

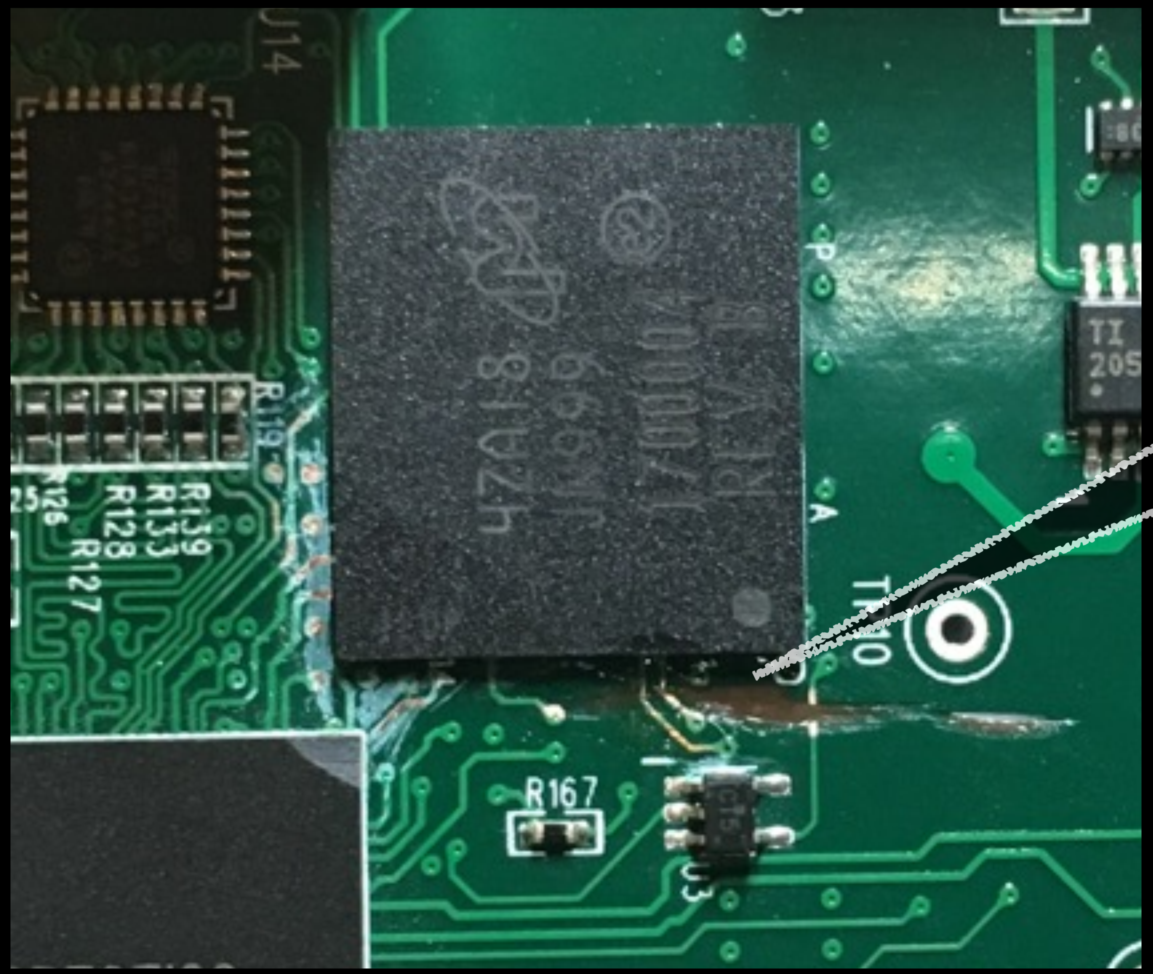
- Test your failure paths including transient hardware failure.
- Modify boot loaders to reboot at the end of the automated boot sequence.
- Enable watchdog time in bootloader, service in userspace
- Be cautious shipping “fail to debug mode” features in production configurations.



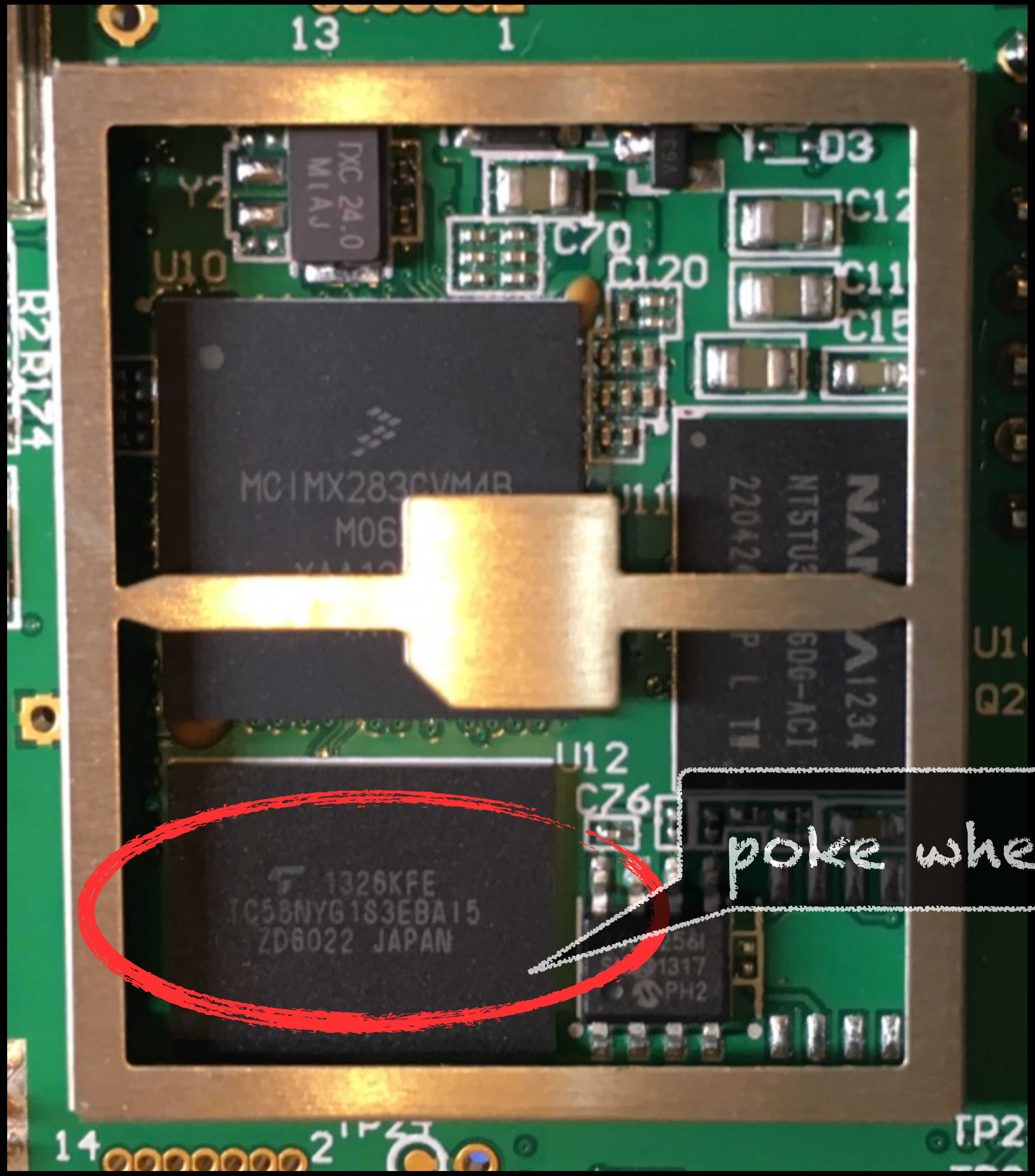
```
[Env] Ethernet address not available, using emergency defa
[Bootcheck] RTC[2] = 0x00000000
[Bootcheck] Cold boot detected
[Bootcheck] Booting from partition=nand0,4, rootfs=nand0,6
[Bootcheck] Partition = nand0,4 (4)
[Bootcheck] RTC[2] = 0x00000000
[Bootcheck] RTC[2] = 0xa1a10400 (written)
 0
[Watchdog] Dogtime = <default> =  (60000)
[Boot] bootcmd = run bootcmd_nand
[Boot] bootargs = console=ttyAM0,115200n8
[Detect] Mac = 00:0c:e3:72:c5:a9 / Ip = 192.168.1.1
[Detect] Starting factory reflash detect loop....
[Detect] Using FEC0 device
[Detect] Special packet not detected, timed out.
[Detect] Proceeding with regular boot.
[CheckSig] device 0 offset 0x15c0000, size 0xa00000
[CheckSig] Loading filesystem header (612 bytes)
NAND read from offset 15c00004104911c failed 0
[CheckSig] Bad superblock (e0e0e0e0)
resetting ...
0x80508002
0x80508002
HTLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
PowerPrep start initialize power...
Battery Voltage = 3.40V
boot from battery. 5v input not detected
LLLLLLCJun 27 201414:30:13
FRAC 0x92925552
memory type is DDR2
                   Wait for ddr ready 1power 0x00820616
Frac 0x92925552
start change cpu freq
hbus 0x00000003
cpu 0x00010001
start test memory accress
```

Defense: Hide your pins and traces

- BGA surface mount devices hide their pins under the package
- Takes away the easy places to poke
- Make sure to route using inner layers



vulnerable traces under soldermask



poke where?

Defense: Run silent, run fast

Saleae Logic 1.2.5 Beta – [Connected] – [100 MHz Digital, 20 s]

A1 - A2	=	2.538 s
B1 - B2	=	0.126 s
C1 - C2	=	15.18 s

Options
Start
Annotations
+2 s
+3 s
+4 s
A1
B1
C1
00 Channel 0
01 Channel 1
Async Serial - Serial
W 0.1332 s

- Very terse serial output.
- Fast kernel boot (0.1332 seconds) makes it sort of hard to jam the pin in there at the right time.

Thank you

CARVE SYSTEMS