A Trusted Business Card

WHY?

- To celebrate TCG's 25th
- To demonstrate full supply chain protection on an inexpensive IoT device
  - Supply chain of embedded electronics is now critical
  - Tired of the excuses that trusted computing is too complex and too expensive
- It's an Arduino development board
  - Learn how to write arduino sketches
- It's an esp32 development board
  - Learn esp-idf command line build and flash tools
- It's a TPM development board
  - Prototype new and interesting TPM applications

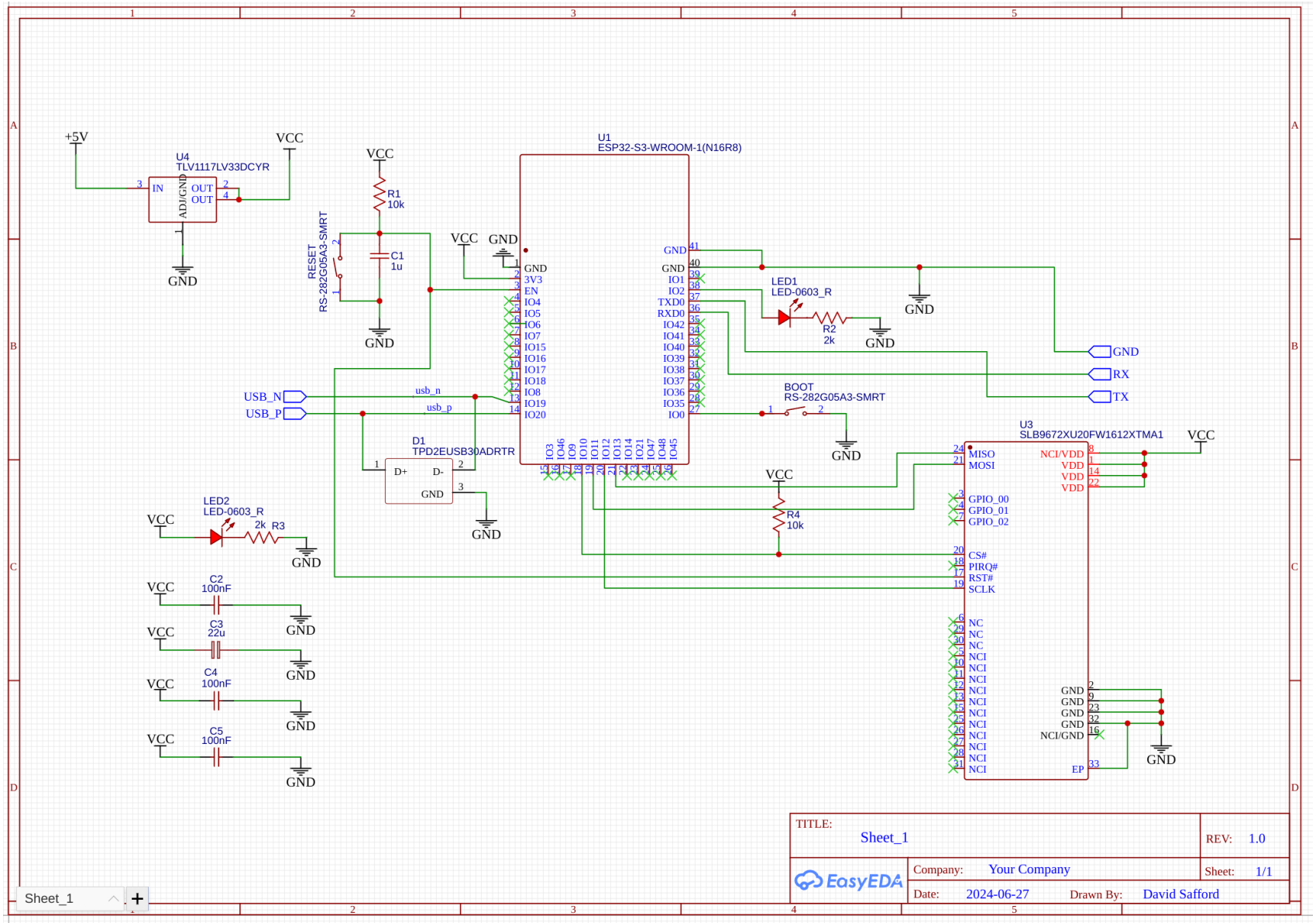
What

- Hardware
  - ESP32-S3-Wroom
    - 32bit dual core
    - 16mb flash
    - 8mb PSRAM
    - efuse based secure boot*
  - Infineon SLB9672 TPM
- Firmware
  - Application
  - WolfTPM/WolfSSL
  - WolfTPM HAL
  - tinyusb
  - FreeRTOS
  - esp-idf bsp
- Software
  - certify/verify scripts
  - Openssl
  - Paccor
  - certgen/cel_verify C

100% Open Hardware and Open Source
*not activated on demo cards, so you can play

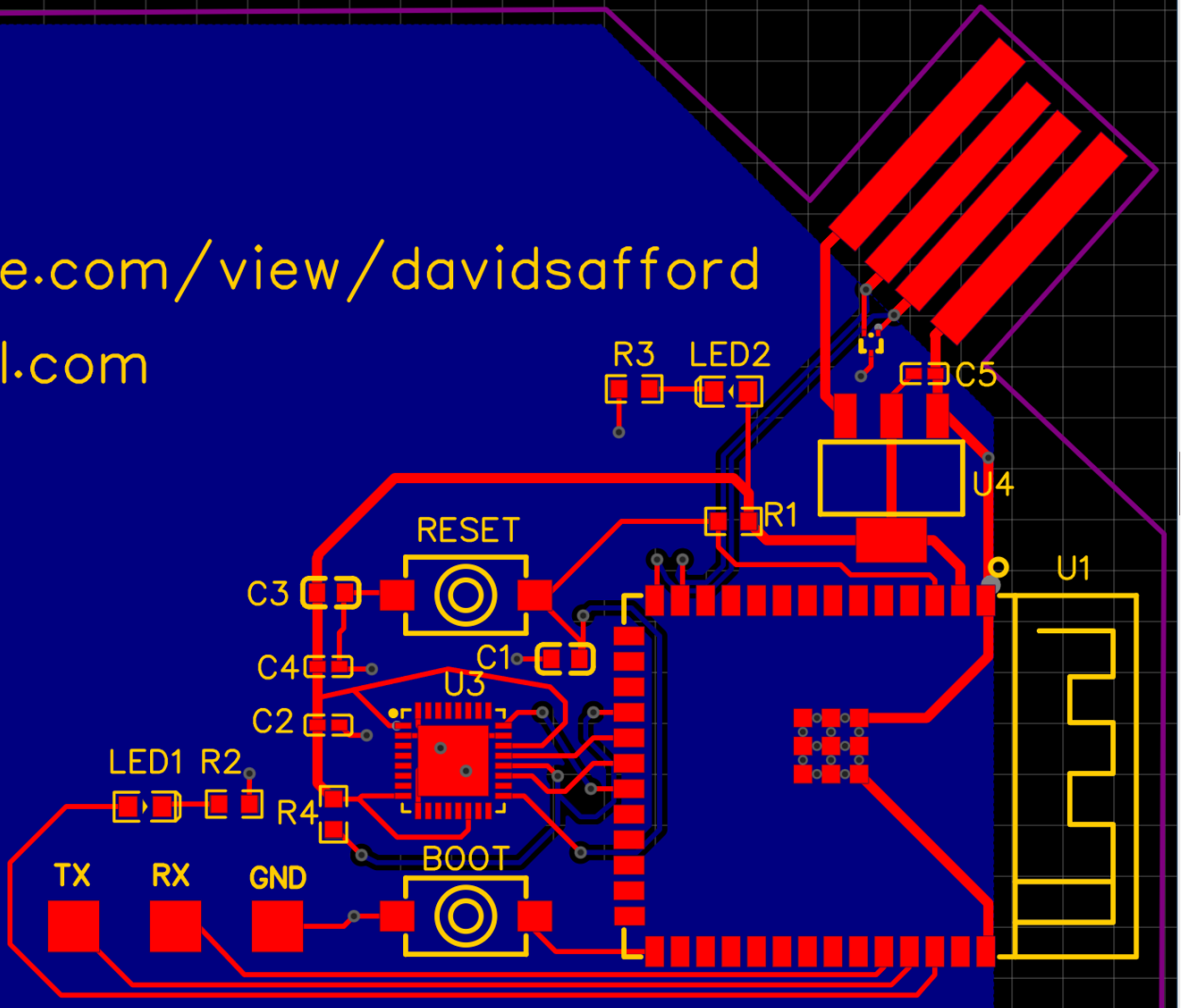
Application Functionality

- USB-MSC: VFAT thumb drive to serve resume, certs and log
- USB-ACM: Firmware loading and debug over serial
- Full Supply chain attestation
  - Endorsement Key Cert
  - Platform Cert
  - Attestation Key Cert
- WolfTPM provides full TPM stack on the card,
- Measured boot and runtime
- CEL-IMA-TLV attestation with signatures in RIM


+5V
VCC
U4
TLV1117LV33DCYR
IN
OUT
OUT
ADJ/GND
GND
R1
10k
C1
1u
RESET
RS-282G05A3-SMRT
U1
ESP32-S3-WROOM-1(N16R8)
GND
3V3
EN
IO4
IO5
IO6
IO7
IO15
IO16
IO17
IO18
IO8
IO19
IO20
IO3
IO46
IO9
IO10
IO11
IO12
IO13
IO14
IO21
IO47
IO48
IO45
GND
IO1
IO2
TXD0
RXD0
IO42
IO41
IO40
IO39
IO38
IO37
IO36
IO35
IO0
LED1
LED-0603_R
R2
2k
BOOT
RS-282G05A3-SMRT
USB_N
USB_P
usb_n
usb_p
D1
TPD2EUSB30ADRTR
D+
D-
GND
LED2
LED-0603_R
2k
R3
C2
100nF
C3
22u
C4
100nF
C5
100nF
R4
10k
U3
SLB9672XU20FW1612XTMA1
MISO
MOSI
GPIO_00
GPIO_01
GPIO_02
CS#
PIRQ#
RST#
SCLK
NC
NCI
NCI/VDD
VDD
GND
NCI/GND
EP
RX
TX
TITLE:
Sheet_1
REV:
1.0
Company:
Your Company
Sheet:
1/1
Date:
2024-06-27
Drawn By:
David Safford
EasyEDA
Sheet_1

David Safford
https://sites.google.com/view/davidsafford
david.safford@gmail.com

TCG 25



BOM Cost (qty 1)

- PCB (jclpcb.com) $3
- Esp32 $4
- TPM $5
- Everything else $3

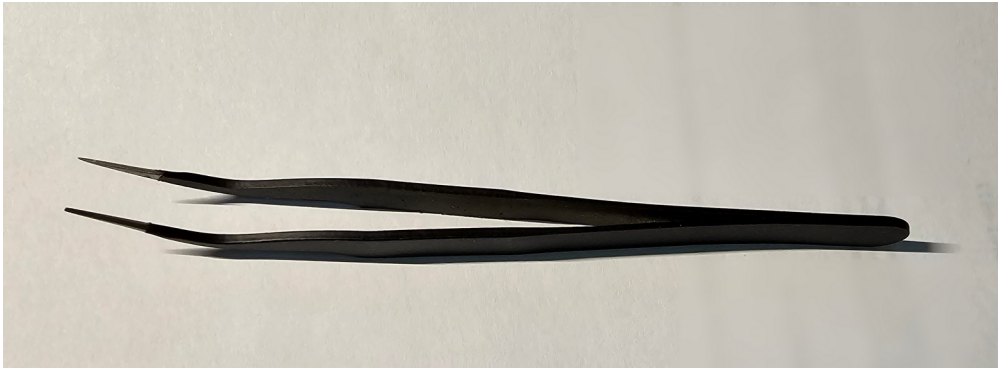
- Total $15

Detailed BOM (Digikey)

Schematic ID	Manufacturer ID	Digikey ID	Description
U1	ESP32-S3-WROOM-1-N16R8	1965-ESP32-S3-WROOM-1-N16R8CT-ND	ESP32S3
U2	SLB9672AU20FW1613XTMA1	448-SLB9672AU 20FW1613XTMA1CT-ND	TPM
D1	TPD2EUSB30ADRTR	296-28153-1-ND	ESD Diode Pair
U4	TLV1117LV33DCYR	296-28778-1-ND	3.3V regulator
Led1, Led2	QTLP601CRTR	1080-1407-1-ND	Led, red
Boot, Reset	RS-282G05A3-SMRT	CKN10384CT-ND	Switch, tactile
R1, R4	RMCF0603JT10K0	RMCF0603JT10K0CT-ND	RES 10K
R2, R3	ERJ-3EKF2001V	P2.00KHCT-ND	RES 2K
C1	CL05A105KP5NNNC	1276-1076-1-ND	CAP CER 1UF 10V
C2, C4, C5	CL05B104KA5NNNC	1276-6720-1-ND	CAP CER 0.1UF 25V
C3	CL10A226MQ8NRNC	1276-1193-1-ND	CAP CER 22UF 6.3V

The High Cost of Assembly

- Precision Placement Device ($2)



- Reflow Station ($49)

Warning

- I used leaded solder paste for assembly.
- Try not to lick the front of the card.

Learn Arduino Programming

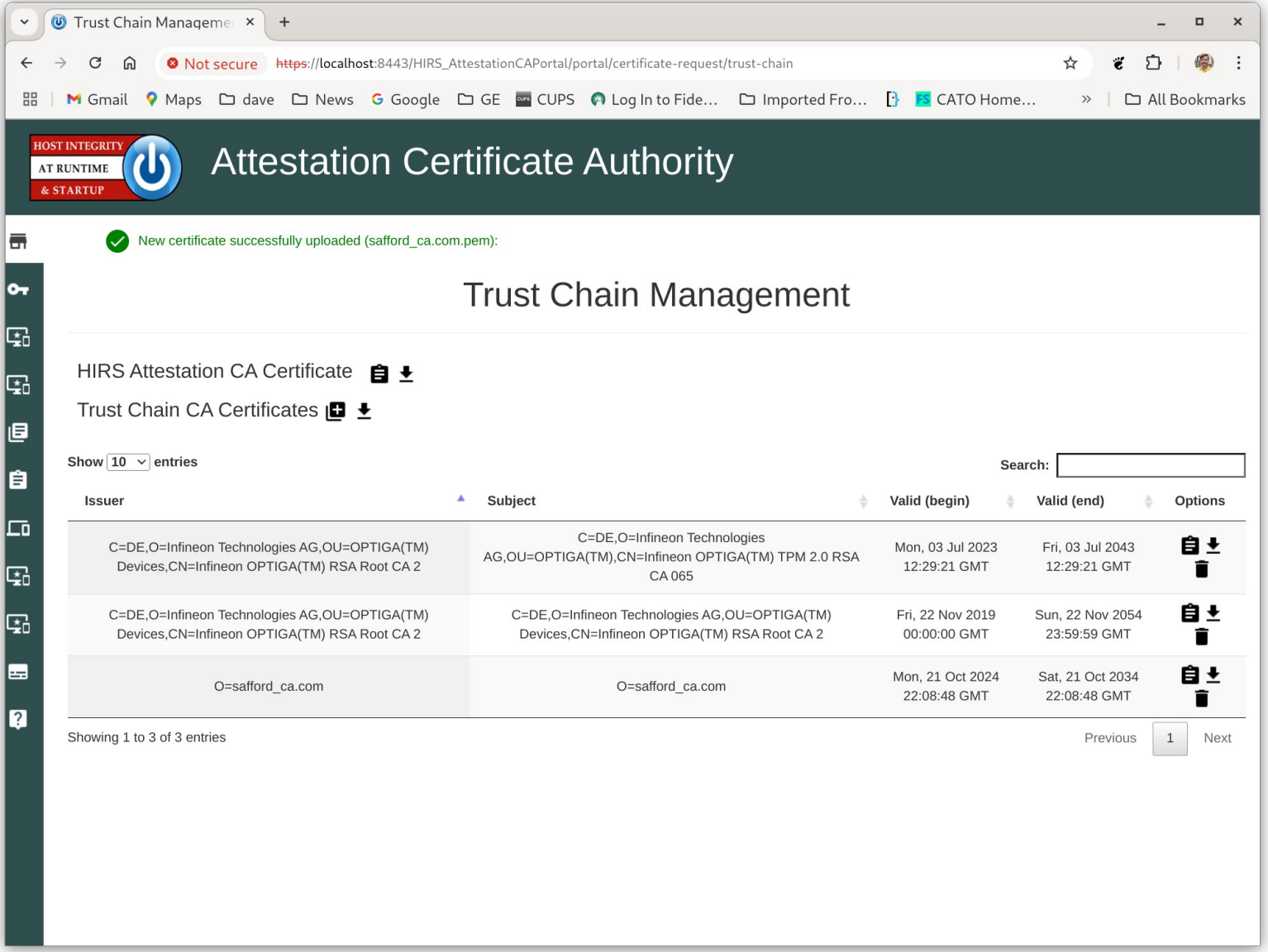
Espressif tools

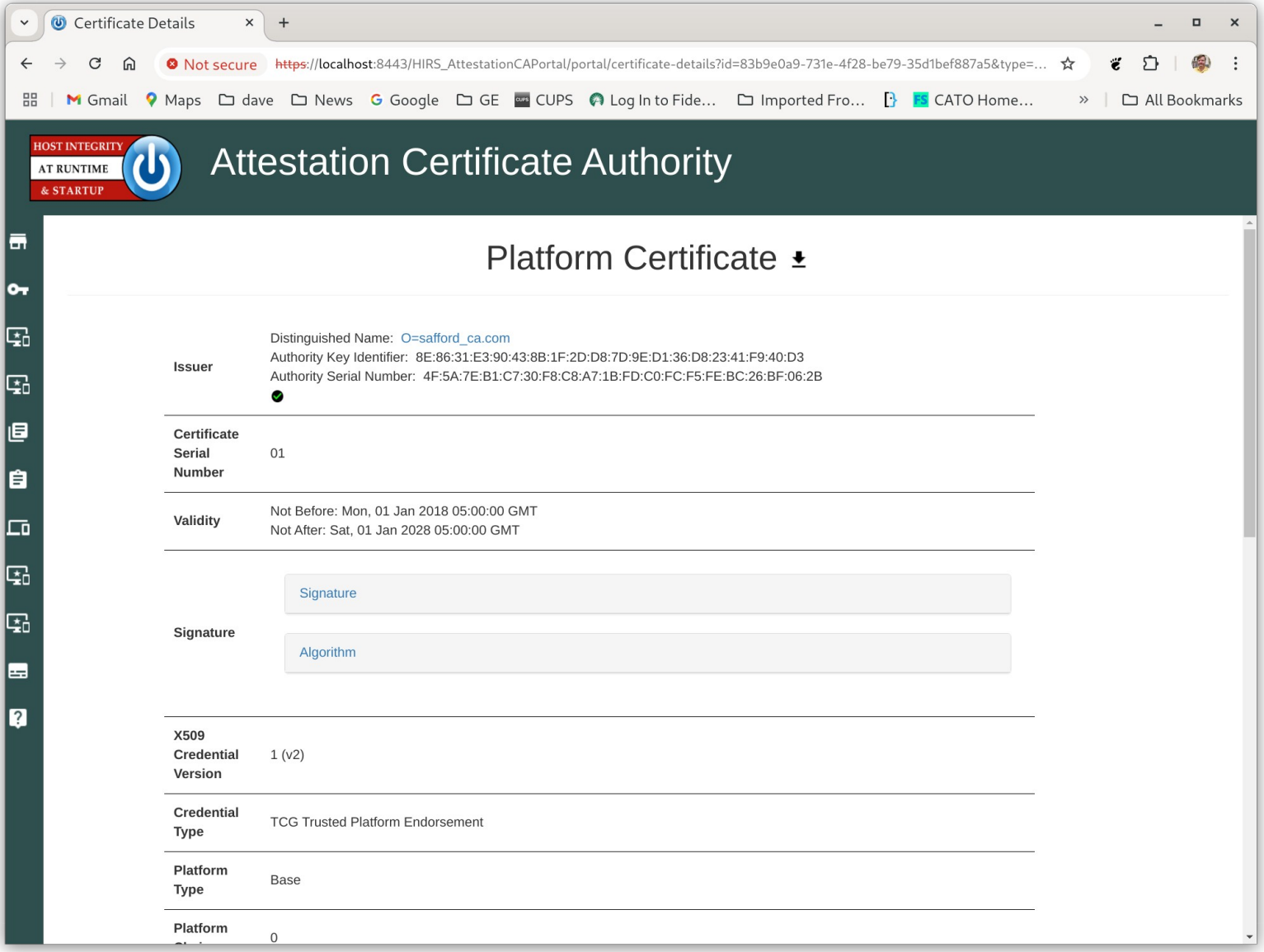
```
idf.py set-target esp32s3
idf.py menuconfig
idf.py build
idf.py -p /dev/ttyACM0 flash monitor
```

Keys and Certificates

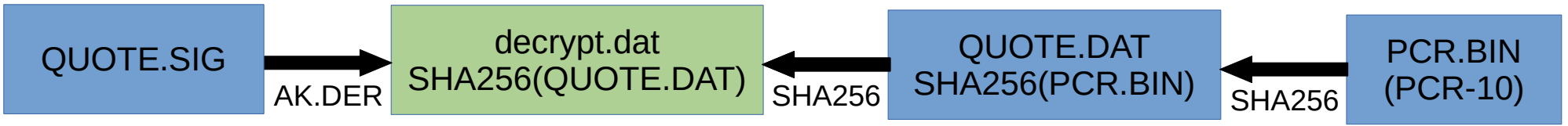
- Infineon OPTIGA(TM) RSA Root CA 2 (Root for EK.CRT)
- Infineon OPTIGA(TM) TPM 2.0 RSA CA 065 (intermediate for EK.CRT)
- safford_ca.com.pem (Self-signed root for AK.CRT and PLATFORM.CRT)
- EK.DER, EK.CRT (signed by Infineon)
- AK.DER, AK.CRT – issued based on verification of EK, signed by Dave
- PLATFORM.CRT binds EK to Platform description, signed by Dave

- Verifying a Quote with AK proves:
  - Talking to Infineon certified TPM
  - Platform characteristics, including EK and AK certified by Dave


Trust Chain Manageme
Not secure
https://localhost:8443/HIRS_AttestationCAPortal/portal/certificate-request/trust-chain
Gmail
Maps
dave
News
Google
GE
CUPS
Log In to Fide...
Imported Fro...
CATO Home...
All Bookmarks
HOST INTEGRITY
AT RUNTIME
& STARTUP
Attestation Certificate Authority
New certificate successfully uploaded (safford_ca.com.pem):
Trust Chain Management
HIRS Attestation CA Certificate
Trust Chain CA Certificates
Show 10 entries
Search:
Issuer
Subject
Valid (begin)
Valid (end)
Options
C=DE,O=Infineon Technologies AG,OU=OPTIGA(TM) Devices,CN=Infineon OPTIGA(TM) RSA Root CA 2
C=DE,O=Infineon Technologies AG,OU=OPTIGA(TM),CN=Infineon OPTIGA(TM) TPM 2.0 RSA CA 065
Mon, 03 Jul 2023 12:29:21 GMT
Fri, 03 Jul 2043 12:29:21 GMT
C=DE,O=Infineon Technologies AG,OU=OPTIGA(TM) Devices,CN=Infineon OPTIGA(TM) RSA Root CA 2
C=DE,O=Infineon Technologies AG,OU=OPTIGA(TM) Devices,CN=Infineon OPTIGA(TM) RSA Root CA 2
Fri, 22 Nov 2019 00:00:00 GMT
Sun, 22 Nov 2054 23:59:59 GMT
O=safford_ca.com
O=safford_ca.com
Mon, 21 Oct 2024 22:08:48 GMT
Sat, 21 Oct 2034 22:08:48 GMT
Showing 1 to 3 of 3 entries
Previous
1
Next


Certificate Details
Not secure
https://localhost:8443/HIRS_AttestationCAPortal/portal/certificate-details?id=83b9e0a9-731e-4f28-be79-35d1bef887a5&type=...
Gmail
Maps
dave
News
Google
GE
CUPS
Log In to Fide...
Imported Fro...
CATO Home...
All Bookmarks
HOST INTEGRITY
AT RUNTIME
& STARTUP
Attestation Certificate Authority
Platform Certificate
Issuer
Distinguished Name: O=safford_ca.com
Authority Key Identifier: 8E:86:31:E3:90:43:8B:1F:2D:D8:7D:9E:D1:36:D8:23:41:F9:40:D3
Authority Serial Number: 4F:5A:7E:B1:C7:30:F8:C8:A7:1B:FD:C0:FC:F5:FE:BC:26:BF:06:2B
Certificate Serial Number
01
Validity
Not Before: Mon, 01 Jan 2018 05:00:00 GMT
Not After: Sat, 01 Jan 2028 05:00:00 GMT
Signature
Signature
Algorithm
X509 Credential Version
1 (v2)
Credential Type
TCG Trusted Platform Endorsement
Platform Type
Base
Platform
0

Verifying the TPM_Quote



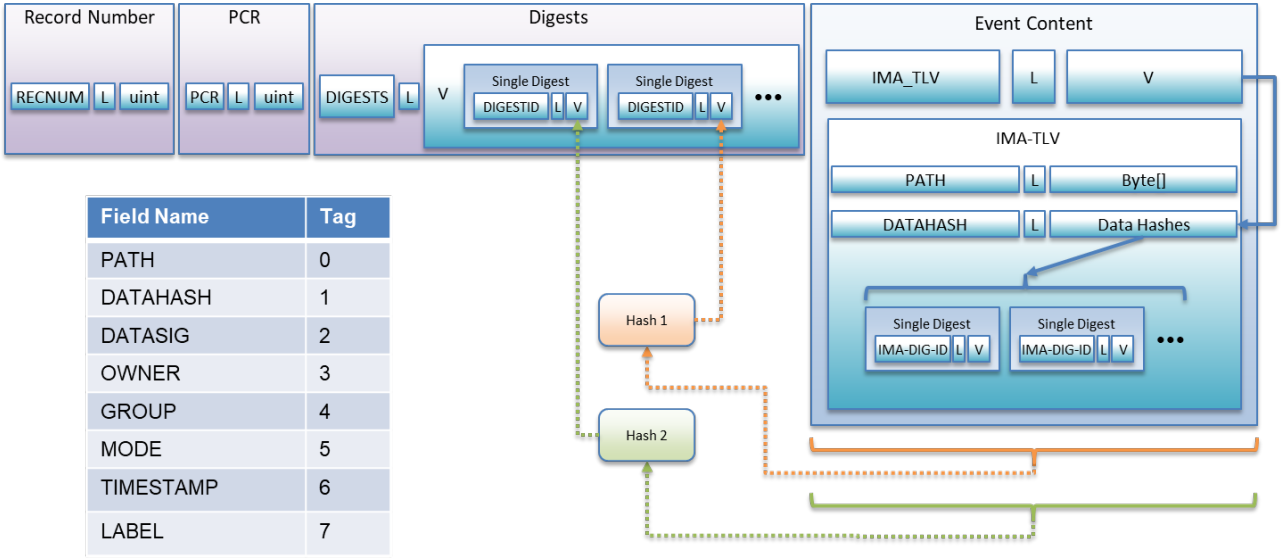
Normally we could do this entire check with tpm2_checkquote utility, but it cannot handle the raw data blobs from WolfTPM, so we have to do these checks manually with openssl.

Example Quote Verification

```
Decrypting QUOTE.SIG with AK

Decrypted data:
00000000  30 31 30 0d 06 09 60 86  48 01 65 03 04 02 01 05  |010...`.H.e.....|
00000010  00 04 20 ea ca a1 c3 4b  d9 9c b3 63 af 60 5f db  |.. ....K...c.`_.|
00000020  2b 0b 99 65 e0 93 2e 55  92 28 70 4f fd 16 e8 57  |+..e...U.(pO...W|
00000030  f1 a0 66                                          |..f|

sha256 of QUOTE.DAT
00000000  ea ca a1 c3 4b d9 9c b3  63 af 60 5f db 2b 0b 99  |....K...c.`_.+..|
00000010  65 e0 93 2e 55 92 28 70  4f fd 16 e8 57 f1 a0 66  |e...U.(pO...W..f|

QUOTE.DAT
00000000  ff 54 43 47 80 18 00 22  00 0b e1 27 0c 17 cb b3  |.TCG..."...'....|
00000010  2f 04 60 27 27 5e 1c 07  be 9b 44 6e 80 76 e4 7d  |/.`''^....Dn.v.}|
00000020  27 32 64 f7 02 a3 59 d9  28 0b 00 00 00 00 00 00  |'2d...Y.(.......|
00000030  17 67 73 9e 27 9f e7 c0  94 6e df a3 01 ad bb dd  |.gs.'....n......|
00000040  1c 87 f7 a5 06 00 00 00  01 00 0b 03 00 04 00 00  |................|
00000050  20 32 d4 a6 27 37 ff 00  e2 90 01 06 26 8f 90 40  | 2..'7......&..@|
00000060  df dc 45 6e 5e 01 85 d3  87 2f 3f 0b 4b 4b e6 bf  |..En^..../?.KK..|
00000070  89                                                |.|

hashed PCR.BIN
00000000  32 d4 a6 27 37 ff 00 e2  90 01 06 26 8f 90 40 df  |2..'7......&..@.|
00000010  dc 45 6e 5e 01 85 d3 87  2f 3f 0b 4b 4b e6 bf 89  |.En^..../?.KK...|

PCR.BIN
00000000  a4 84 07 20 57 9f a9 c1  71 ac b2 26 f8 39 82 db  |... W...q..&.9..|
00000010  9d 9f c1 0f 67 32 ad 08  f6 86 08 4b 33 81 c2 01  |....g2.....K3...|
```

CEL_IMA_TLV

- An example of how to do measurement safely
  - Entire content field, including types and lengths are measured



Field Name	Tag
PATH	0
DATAHASH	1
DATASIG	2
OWNER	3
GROUP	4
MODE	5
TIMESTAMP	6
LABEL	7

Example Attestation Verification

```
Verifying Measurement log from Quote

PCR 10 SHA256: A4840720579FA9C171ACB226F83982DB9D9FC10F6732AD08F686084B3381C201
MATCHES

SEQ 0 PCR 10 CEL_CONTENT_IMA_TLV
    Filename /data/esp/safford.pdf
    Filehash: D0471A5C5E9F00A0A2E761924C6AFF6EB966E8A468822E9016D0DED8751E18F2
    Entire Content TLV Verified by digest
    File Hash Verified by signed RIM

SEQ 1 PCR 10 CEL_CONTENT_IMA_TLV
    Filename /data/esp/card.jpg
    Filehash: 8D5C6DB2635740A84188CDE92D8A8CD56E5F16175F8992C59033B6FBB998AF66
    Entire Content TLV Verified by digest
    File Hash Verified by signed RIM

SEQ 2 PCR 10 CEL_CONTENT_IMA_TLV
    Filename /data/esp/chall.bin
    Filehash: 063F1995CA9EF8471D7F40992E27BD075A04E04F4F6EBA270E1CDBE2FC7CAAF6
    Entire Content TLV Verified by digest
```

Lessons Learned

- Interesting Use Case
  - Goal is to prove authenticity of card
  - No “users” on card
    - No privacy concern
  - Don’t want to set owner auth
  - CA/vendor/Privacy CA can all be one