Security Implications of Malicious G-Codes in 3D Printing

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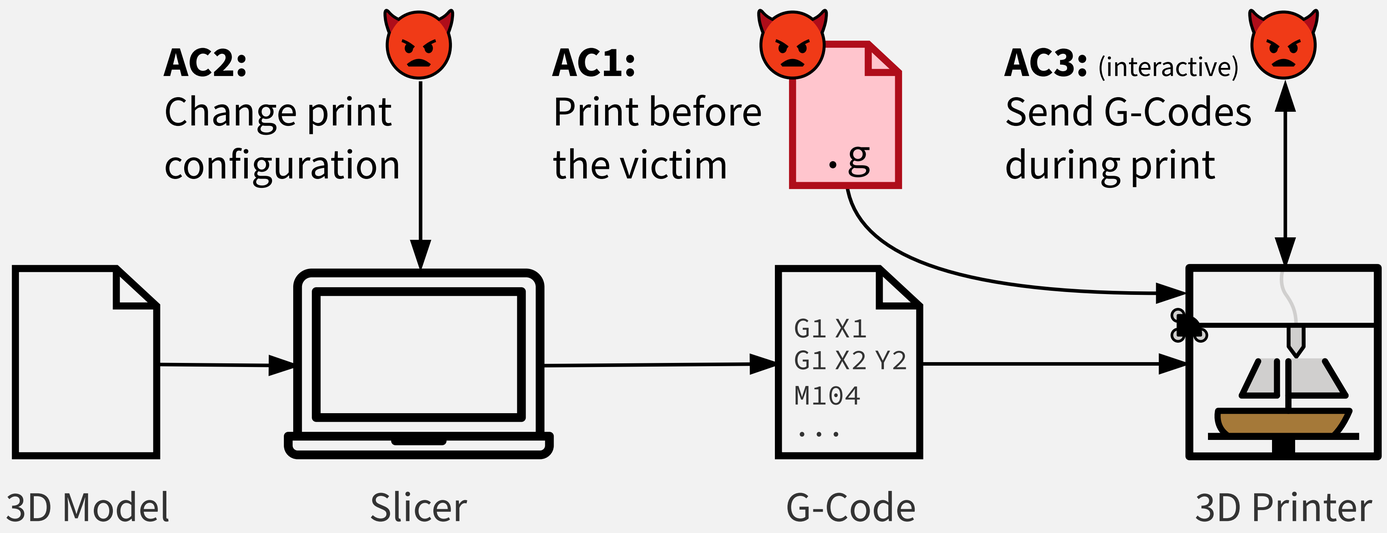
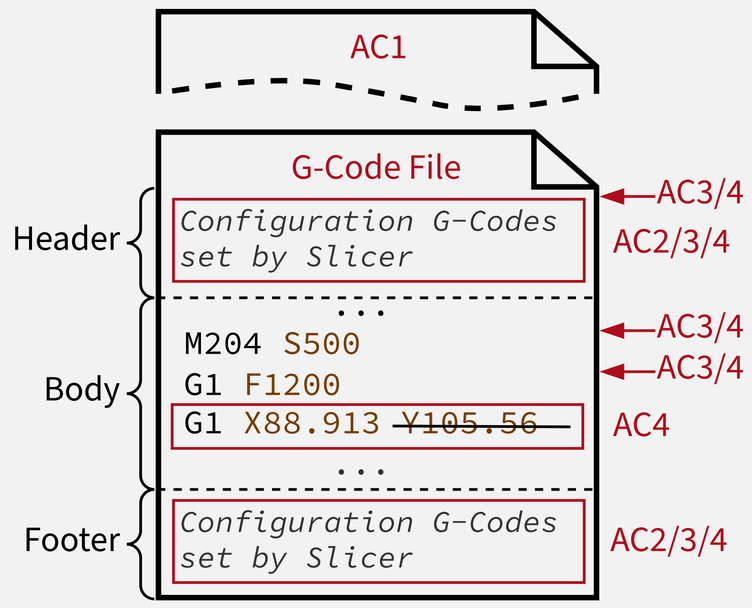
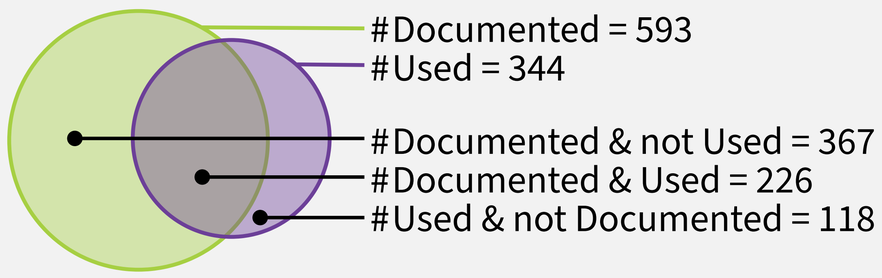
Attacker Capabilities



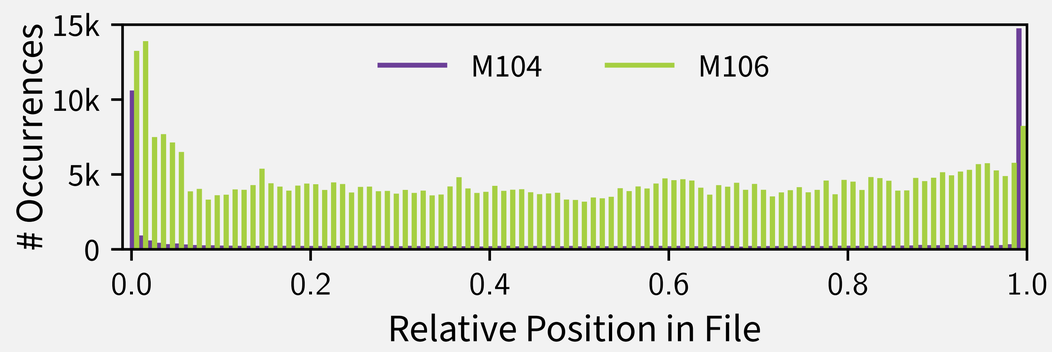


Understanding G-Code Usage

1) Extracting **documented** G-Codes from firmware documentation and scraping **used** G-Codes from Thingiverse.



3) Analyzing usage patterns determining which AC can be assigned.



2) Manual analysis of **documented** G-Codes and their potential security impact.

Example Attacks

```
1 M928 file.g ; write log to file
```

```
1 M808 L0 ; set marker to repeat forever
2 ; execute arbitrary commands (or do nothing)
3 M808 ; jump to last marker
```

```
1 G20 ; set units to inches
```

```
1 G1 X1 Y2 E1
2
3 G1 X2 Y3 E1
4 G1 X3 Y4 E1
5
```
Original

```
G1 X1 Y2 E1

~~G1 X2 Y3 E1~~
~~G1 X3 Y4 E1~~
```
“all-powerful” (AC4)

```
G1 X1 Y2 E1
M28 file.g
G1 X2 Y3 E1
G1 X3 Y4 E1
M29
```
via injection (AC3)

```
1 M200 D1.75 ; change extrusion mode
```

```
1 M220 S50 ; 50% speed
```

```
1 M143 S30 ; 30 deg C
```

Attack Category	# Malicious Codes	% Vulnerable Devices AC1	AC2	AC3
Information Disclosure	92			
Intellectual Property Theft	3	◔	◔	◕
Metadata Leakage	90	◕	◕	◕
Denial of Service	140			
Interrupt Printing	123			
Infinite Loop	14		◔	◔
Delay Commands	56			◕
Ignore Commands / Stop Print	27		◕	◕
Destroy Model / Make Unusable	40		◔	◕
Disable Access / Bricking	30			
Software	18	○	○	○
Hardware	12	○	○	◔
Model Manipulation	80			
Toolpath Manipulation	17			
Voids	8			◑
Surface Anomaly (X/Y Shift)	13			◕
Layer Height Anomaly (Z Shift)	11			◕
Faulty Extrusion	44			
Under Extrusion	21	◕	◕	●
Over Extrusion	19	◕	◕	●
Material Relocation	6			◕
Filament Retraction	19			◕
Printing Speed	18			◑
Temperature Changes	30			
Bed Temperature	15	○	●	●
Nozzle Temperature	19	○	●	●
Fan Speed	7			◕

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