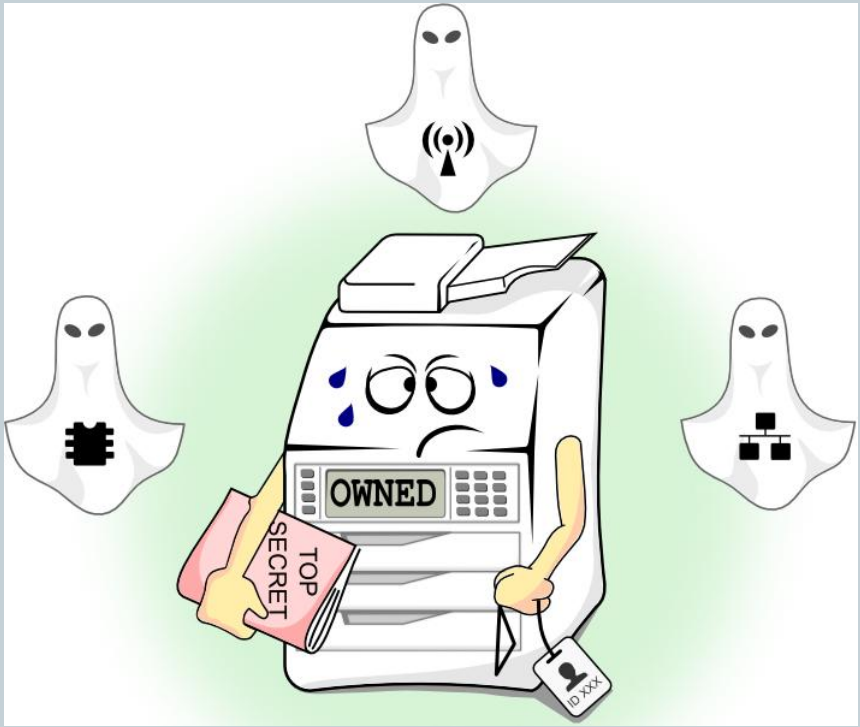
Hacking printers: for fun and profit



Impressum

- Andrei Costin
- Author of MFCUK
  - MiFare Classic Universal toolKit
- Day-time programmer (after-8pm type of hobbyist hacker)
- Generally interested in (but especially in last 2 bullets):
  - Programming/hacking: RFID, GSM, biometrics, embedded
  - Almost everything which:
    - Is connected to networks/communications lines
    - Have smart-cards (contact and contactless)
    - Have crypto involved somewhere down the line
    - Is or should be secure
  - Corporate/Enterprise IT support software & security
  - TEMPEST and ISS

Abstract

- While more and more new devices (routers, smartphones, etc.) are getting connected to our SOHO/enterprise environments, all-colour hats are getting plenty of focus on their security: defend and harden on one side; exploit and develop malware on the other.
- However, a special class of network devices (specifically network printers/scanners/MFPs), which are networked for more than 15 years, are constantly out of the modern security watchful eye.
- And even though we entrust them even the most confidential documents or the most sacred credentials (LDAP, PINs, RFID badges, etc.), we don't realize closely how weak and unsecured they are, despite the few minor security bulletins that started to pop-up here and there in the recent few months.
- In this presentation, we will try to analyze the reasons why hacking network printers/MFPs is a reasonable and accomplishable idea. Also, we will take a look at current state of (weak) affairs in the vulnerability and security research available. Then we will try to envision types of possible exploitation scenarios, backed-up with a printer remote-exploit demo. We will conclude the presentation with possible solutions and what can be done to protect ourselves as well as our network environments.

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- *big fat one – because everybody *loves* fineprints

\H1B%-12345X@PJL JOB "HackingPrinters"

- This presentation is about:
  - Hacking "the PC inside printers/MFPs"
    - Why would someone hack a printer/MFP
    - How would someone hack "the PC inside printers/MFPs"?
    - How easy/feasible is MFP *fir*malware creation and exploitation
    - How to protect yourself and your so-much-loved MFP?
  - Laying foundation for further community security research/development/PoC
- This presentation is NOT about:
  - Printers' display hack (RDYMSG, OPMSG, STMSG)
  - Printers' embedded web-server hacks
  - Printers' SNMP configuration hacks
  - Exhaustive guide to hack every and last MFP (not yet!)

MFPs Exploitation – Why?

- First, my term for MFP = Mfp, Fax, Printer
- Many would ask "Why would you exploit an MFP?" – answer derives from questions below:
  - How many persons would expect their MFP infected?
  - How many users/admins/security-auditors audit and hard-secure their/network MFPs?
    - Even if they do, do MFP vendor pay attention to security?
      - Bottom-line is always "It's just a damn printer/MFP!"
  - How many persons or anti-malware products could clean such a malware?
    - Afaik, 0(zero) antimalware products for (huge) printers/MFPs market
  - Why not (net/port/vuln)scan the network from a printer which is not suspected/cleanable?
  - Why not hide the malware/payload on a network printer and then make your way through the network/data?
  - Etc., etc., etc.

MFPs Exploitation – Why?

- First of all – (most) printers/MFPs are already full-blown computers! (or even space-ships ☺)
- Have goodies to play/own:
  - Some flavor of (RT)OS (VxWorks, LynxOS, Nucleus, Linux)
  - Embedded Java VM (eg.: ChaiServer)
  - Embedded Web Server (eg.: Virata EmWeb)
  - Ethernet/WiFi
    - Not covering TCP/UDP/IP stack attacks, but there are examples
  - Eventually HDD – nice to scan/dump
    - Eg.: recent CBSNews Investigation Case – with much hype
  - Eventually SecureJet-like extensions – sweet thing ☺!
  - Eventually Fax board
  - Eventually Mailboxes

MFPs Exploitation – Why?

- MFPs interact with (hence can get access to):
  - RFID badges
  - Smart/swipe cards
  - Fingerprints
  - PINs
  - LDAP/domain passwords
  - Aren't these some-of **sweet** things we are hunting after all?

MFPs Exploitation – Why?

- Looking for confidential documents?
  - Why taking the trouble for infecting a PC-host on a network (eg. both elements being secured, updated & monitored) just to get a document with strong crypto using long-enough key and then not being able to decrypt it…
  - …when instead wait for it to be in-printer decrypted (eg. SecureDimm) and printed (and I guess secret documents are still being printed on paper occasionally for selected eyes) so you get it decrypted in plain text
- Produce PDFs with 0-day exploits
  - Just infect/replace the PDF output engine
  - Usually, DSS and scanners are trusted internal sources
- Spam inside/outside networks
  - Many devices have emailing capabilities (not all configured though)
- Maybe useful for idle-time processing:
  - computing/hash-cracking/sniffing/scanning

MFPs Exploitation – Why?

- Not so much information in this area (compared to PC or mobile devices)
  - PJL UPGRADE – approx 6 results
  - PJL LPROGRAMENG – 0 results
  - PJL LPROGRAMRIP – 1 result (security paper)
  - PJL DMINFO – approx 300 results
  - PJL DMCMD – approx 75 results
  - Compare with this PDF "/Launch" – approx **55 Mln** results
- Too few known (more or less) public research:
  - slobotron, phenoelit, irongeek, Protek Research Lab's, DSecRG, SEC Consult + few other brave enthusiasts
- Recent disclosures mainly focused on web-admin, snmp, XSS and uncontrolled buffer overflows
  - Not too much detailed analysis on OS, kernel and firmware level
- Anyone remember the psybot story?
  - ~100k MIPS-embed-based DSL router botnet-ed

MFPs Exploitation – Why?

- Big number of devices – according to Gartner:

Worldwide: Page Printer Vendor Shipment Estimates, 2005 (Thousands of Units)

Company	2005 Shipments	2005 Market Share (%)	2004 Shipments	2004 Market Share (%)	2004-2005 Growth (%)
Hewlett-Packard	10,527,966	49.0	8,828,405	48.7	19.3
Samsung Electronics	1,874,820	8.7	1,901,933	10.5	-1.4
Lexmark	1,268,089	5.9	1,131,213	6.2	12.1
Brother	1,178,039	5.5	1,018,642	5.6	15.6
Canon	1,154,203	5.4	909,492	5.0	26.9
Other Vendors	5,468,926	25.5	4,322,420	24.0	26.5
Total	**21,472,043**	**100.0**	**18,112,105**	**100.0**	**18.6**

Source: Gartner Dataquest (February 2006)

- Theoretically, magnitude of 10 x mlns of devices (24 mlns/yr):
  - Perfectly exploitable & non-easy-cleanable
  - Always on, no antivirus & firewall running inside of them

MFPs Exploitation – Why?

- The Holy Grail would be to own "securities printers"
  - Currency/financial assets printing machines
    - Unfortunately limited to very closed circles ☹ - for obvious reasons
    - No updates/patches on internet to poke around
  - Industrial currency check/count machines
    - More or less accessible
    - From BPS 2000/3000 Banknote Processing Systems for Central Bank Applications "*The operating system software and all production data can be authenticated to protect data integrity and guard against tampering (optional)*" – isn't it just sweet ☺
  - Passport/ID printing machines
  - Eg.: Oberthur, Giesecke&Devrient, others
  - These are not part of this presentation ☹… yet ☺!

Current main players

- Canon
- Fujitsu
- HP
- Konica Minolta
- Lexmark
  - Dell is selling Lexmark – "So, Lexmark makes Dell's printers?"
  - Eg.: BRQP205.ffb is for Lexmark E342N/Dell Personal Laser 1710
- Xerox
- Sharp
- Kyocera Mita
- Kodak
- Brother
- Samsung
- Toshiba
- Ricoh, Lanier, Nashuatec, Infotek, OCE, OKI

Current state of vulnerabilities

- Xerox – Total 44
  - XRX04/10, XRX05/9, XRX06/7, XRX07/2, XRX08/10, XRX09/4, XRX10/2
- HP – CVE-HP-printer, CVE-HP-MFP = Total 20
- Lexmark – CVE-Lexmark-printer = Total 7
- Canon – CVE-Canon-printer = Total 2
- Kyocera – CVE-Kyocera-printers = Total 2
- OKI – CVE-OKI = Total 2
- Fuji – CVE-Fuji = Total 2
- Ricoh – SB05-005 = Total 1
- OCE – CVE-OCE = Total 1
- Brother – CVE-Brother-printer = Total 1
- Nashuatec – CVE-Nashuatec = Total 1
- Too few for such a complex, big & old industry!
  - This can't be true - the exploits are there waiting for us ☺

MFPs Exploitation – Real (miss)use scenarios

- PDOS aka bricking
  - Can be at most a teenage prank. Fun first 1-2 times.
  - Citing HDMoore: *"It seems like if you can do a remote update of firmware, it would better to deliver a Trojan'ed firmware image, instead of just a DOS"*
- Port/network/exploits scanner
- Malware/upload storage
- "Stealth"/uncleanable command and control
- Unencrypted data theft
- Corporate/enterprise/intelligence assets data theft
  - Using SecureJet-like extensions

MFPs Exploitation – Real (miss)use scenarios

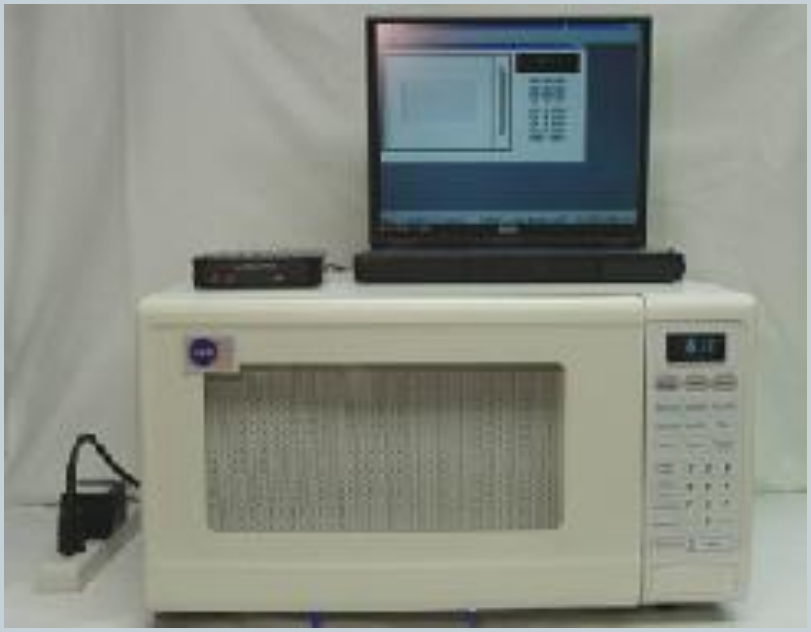
- Ransomware (as it becomes more widespread)
  - Install the ransom-ware, which takes care to overtake the firmware upgrade module
  - So ransomware accepts only secured&signed upgrades/unlocks from it's creators – anything else rejected
  - Store & forward (if external connection detected) documents-to-print to the creator
  - But instead of printing any document, print something like:
    - "This printer is hijacked. Get unlock got from: www.printerhijacker.com using these details: [brand] [model] [serial_number] [ethernet_MAC] [other_bits]"
  - Based on printer model (it's price, year), the ransom amount can be decided (obviously a fraction of the catalog/second-hand cost)
  - If the victim pays, unlock code/firmware is provided (customized for that printer only based on serial#/MAC/etc)
  - Otherwise, victim risks to "loose" his/her device (sometimes quite expensive - $32K)

MFPs Exploitation – *Futuristic/unreal* scenarios

- Espionage/blackmail (high-profile)
  - Very-unlikely, but possible. Target mainly models with HDD in high-profile organizations (those afford HDD models ☺)
  - Store the documents which hit keywords (Eg.: strategic, attack, intelligence, transactions, $$$) – hint: good as MFPs AI research!
  - When storage is full, display [critical_dummy] error , document the error as "ship to 800-fake-service", get data from HDD, ship back ☺
- Compete-ware
  - Want to make trouble to competitors? Increase their OPEX
  - Malware (for printer fuser especially) to run warm-up and high-power non-stop during office-nights
  - Eg.: HP LaserJet 4250dtnsl eats-up 750 watts – sweet bill
- Terror-ware (not realistic today, but can be tomorrow)
  - Malware disables temperature-sensors and blocks paper in fuser assembly, heat-up fuser and ignite fire
  - *"The paper's speed keeps it from burning as it passes through the fuser assembly"*. Temp approx: 185 ° C/ 365 ° F

Terror-ware: off-topic slide

- The appliance **NOT** to connect to internet yet – is your microwave oven ☺!
  - Specs: *"Access Control - Remote Access From Broadband Connected Windows PC Or Macintosh, Or Any Cell Phone, Or Any Telephone Land Line with Touch Tone"*
  - NASA-based tech (small logo)
  - CES-honored
  - BBC news-casted
  - TMIO product details
  - Perfect for world take – over plan



Main printer specs

- Myriad of specs and languages… %)
- UEL – Universal Exit Language
  - Just one command *Ec%-12345X (Ec is 0x1B aka \H1B aka ESCape)*
  - Harmless by itself. Lethal in specific combinations ☺
- PJL – Printer Job Language
  - Developed by HP
  - Job level controls: printer language switching, job separation, environment, status readback, device attendance and file system commands
  - Have essential security design flaws, hence exploitable
- PCL – Printer Control Language
  - Developed by HP
  - Well, actually it's not a control language (PJL is)… name confusion…☺
  - It's more a formatting-control language, like PS
  - Harmless, but parsers and interpreters could be exploited

Main printer specs

- PS – PostScript Language
  - Developed by Adobe
  - Mostly formatting-control language, but has “device control” commands as well ☺
  - On top, it is a programming language as well… (see later)
  - Also, parser and interpreters could be attacked
  - Hence can be exploited
  - …not that Adobe doesn’t have enough exploits lately ☺
- PML – Printer Management Language
  - HP’s object-oriented request-reply protocol to exchange device management information
  - PML can be used to query SNMP values from a printer device
  - So… turning SNMP off doesn’t solve all problems ☺

Main printer specs

- PPD – Adobe PS Printer Description
  - Describe the entire set of features and capabilities available for their PostScript printers
  - Contains the PostScript code (commands) – way to hack
- GPD – Generic Printer Description
  - Windows GDI-based spec, similar to PPD
  - Used for creating unidrv.dll minidrivers for non-PS printers
  - Something like a customization plugin over unidrv.dll (not a bad idea)
  - Usually here: *c:\windows\system32\spool\drivers*
  - Examples of attack later

Specifications holes

- PJL holes:
  - No provisions for authentication
  - No provisions for encryption
    - All usernames, PINs & passwords are in clear-text
      - @PJL SET USERNAME=“HackingPrinters"
      - @PJL SET HOLDKEY="1234“
      - @PJL SET **KM**USERKEY2 = "password"
  - No provisions for standard, secure and vendor/arch/os-independent way for binary/firmware upload/upgrades
    - Everyone reinvented their own wheel
    - Sadly, most did it the wrong "square"-type of way
  - Print job PIN security (@PJL HOLDKEY)
    - We are in 2010 – we get 0-9999 PIN/password range… ☺
    - Specs say nothing about N-tries-and-fails scenario actions
      - Again, the wheel…

Specifications holes

- PS/PPD holes:
  - setdevparams/setsystemparams
    - Can be powerful (and dangerous ☺)
    - Can be helpful, if you trust .PS file or know what you are doing
    - Can also set security/password settings on device – sweet
  - Think this: *.doc attack PC, *.ps attack MFP
  - Also, since PS is an interpreted programming language
    - fuzzck (fuzz stack) with PS recurssion
  - **Password* PS-field in the PPD file is in clear-text
  - PPD have nice **PatchFile* and **JobPatchFile* commands
    - Explained later

MFPs Exploitation – How?

- Remote-initiated printing exploit
  - Java is our best friend here
  - Flash and Silverlight are not too friendly… yet
  - JavaScript is good as well – use CrossSitePrinting
  - Will Google Cloud Printing be as well? Time will show
- Locally-initiated printing exploit
  - MS Word can somewhat help us
  - Adobe LiveCycle XDC files can help us
  - GhostView is not too friendly yet
- Locally-executed applications with rogue firmware
  - Requires social engineering
- Exploiting "test print" access in printers' EWS
  - Not always available
  - Easy to patch – though easy patches are hard to get right for some…
- Printer driver hacks
  - Requires either social engineering or admin-level escalation

Remote-initiated printing exploit

- Printing Payload Exploit (PPE) over Java Applets requires user intervention

- Lure the users to a site and then trick to print
  - Eg: print tickets, print discount coupons, print charity-related stuff, print government/tax related forms/discounts, etc.
- Can be successful using social engineering/nagging
  - Similar to VBScript Help Keypress Vulnerability

Remote-initiated printing exploit

- Demo time!
  - HackingPrinters_RemoteExploit_JavaAppletPPE.mp4

Remote-initiated printing exploit

- Possible exploitation problems
  - User doesn't check the box
    - This can be detectable by subsequent calls to java print services
    - Then annoy user until user checks the box (detectable by time-based analysis between java print services calls)
  - Printer name != precise target name
    - Java print services gives us only printer name ☹
    - Use 1 binary with all known printers exploits
      - Hope one sub-firmalware hits the target, others will be discarded
      - Big data file is not quite invisible
    - Use "magic" detection (eg. like "%HP%") and then fire one or a subset of firmalwares

Locally-initiated printing exploit

- MS Word
  - Work in progress, PoC is almost there ☺
  - Print-and-get-owned type of exploit

- Adobe LiveCycle XDC files (XML files)
  - "Infect"/replace all XDC files with required firmalware payload
    - Doesn't necessarily need admin rights
  - Good example how to do this is here on page 15

```
<xdp:xdp xmlns:xdp="http://ns.adobe.com/xdp/">
<xdc name="ps_plain" xmlns="http://www.xfa.org/schema/xdc/1.0/">
<pdl>
<seq id="preDoc"><ESC/>%-12345X@PJL RDYMSG DISPLAY=""&#13;&#10;
@PJL UPGRADE SIZE = 1024&#13;&#10;[hex_encoded_payload]<ESC/>%-12345X</seq>
</pdl>
</xdc>
</xdp:xdp>
```

Locally-initiated printing exploit

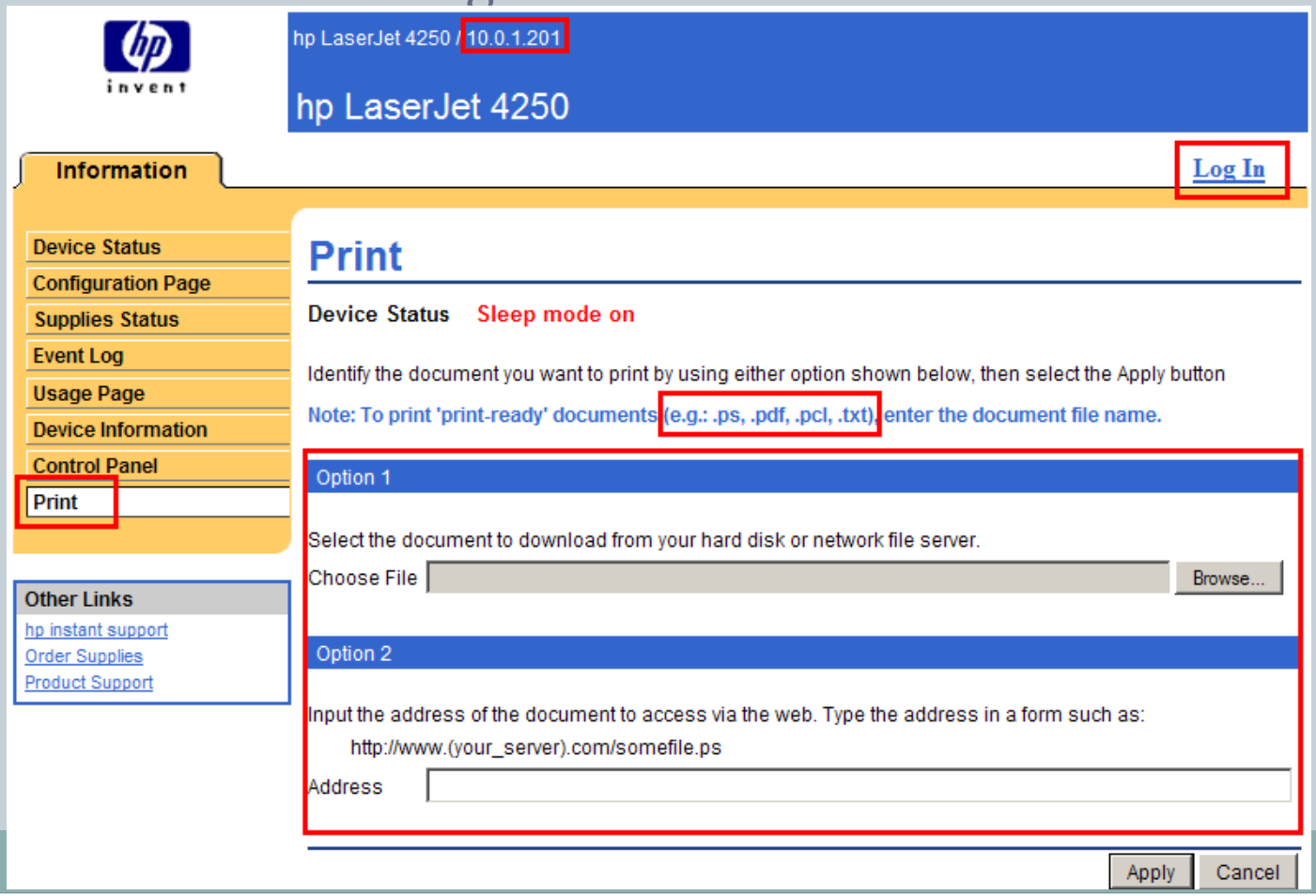
- Demo time!
  - HackingPrinters_LocalExploit.mp4
  - Well, PoC not ready yet… sorry ☹

Solutions for remote+local initiated exploits

- How to fix?
  - **Hard**, since it's PJL design + device vendors' faults
  - Java, Word, LiveCycle have no big blame
    - They act as "channels" for exploitation
    - Rather than fixing channels, better fix specifications and devices
  - Perhaps correct PJL specs + follow standard and safe low-level communication with devices on top of PJL
  - Paranoid solution:
    - Print everything thru a virtual/proxy/filtering printer
    - That will filter out unsafe/suspect payloads (and alert!), producing "safe" docs to print on real devices
      - Unless the virtual printer has bugs/is exploitable itself ☺

Exploiting “test print” access in printers’ EWS

- Print is unprotected! (and leaks internal network IP)
  - Do vendors think diagnostics actions can be harmless?



Exploiting “test print” access in printers’ EWS

- Accepts file as direct upload :
  - Filters based **only** on extension: txt, pdf, pcl, ps
  - Will **not** accept:
    - *print_my_hexor.**rfu*** or
    - *print_my_hexor.**fmw***
  - Will accept:
    - *print_my_hexor.**pcl!***
    - Yes, in PCL we can embed PJL UPGRADE/equivalent commands
  - Also, **extension check doesn’t enforce content check**:
    - Rename *print_my_hexor.pcl* into *print_my_hexor.pdf* and **here we go again ☺**
    - Example: use *HP_LJ5200_restart.pcl.pdf*

Exploiting “test print” access in printers’ EWS

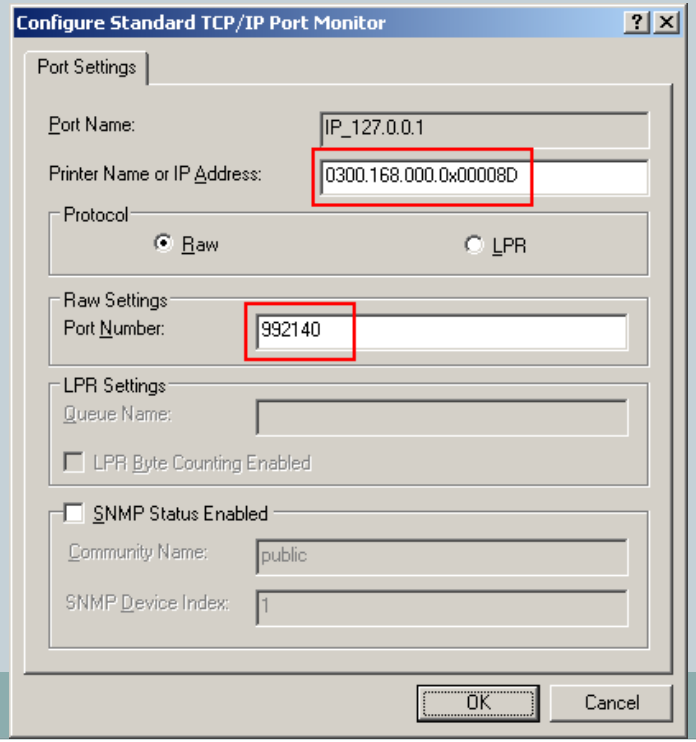
- Accepts file as URL link to a printable document:
  - Exploit as in previous direct local upload
- Other interesting uses:
  - Check if printer can access external addresses (cool for command-and-control type of attacks)
  - Might reveal internal/external topology, as well as proxies along the way
    - If the chain is not properly configured and secured
  - Try to DoS the MFP in two types of slowloris
    - Attacker’s http-client “slowloris”es MFP’s EWS
    - Attacker’s http-server “slowloris”es the MFP’s initiated http-clients to our URL-document
    - Do both from above simultaneously ☺
  - Find race conditions in parsers: direct print, direct URL print, port 9100 print and print-server print; include also PJL/non-PDL cmds

Locally-executed apps with rogue firmware

- If all other fail
  - Eg.: fixes in webserver, script-blockers, etc.
- Social engineer the user to “download and play a nice game” application
- Doesn’t have to be a PC virus, a valid app will do ok:
  - It will be just a printer virus
  - So zero antivirus detection guaranteed still ☺
- Just connect to TCP port 9100 printer job spooler
- Dump the exploit/malware with @PJL UPGRADE style command

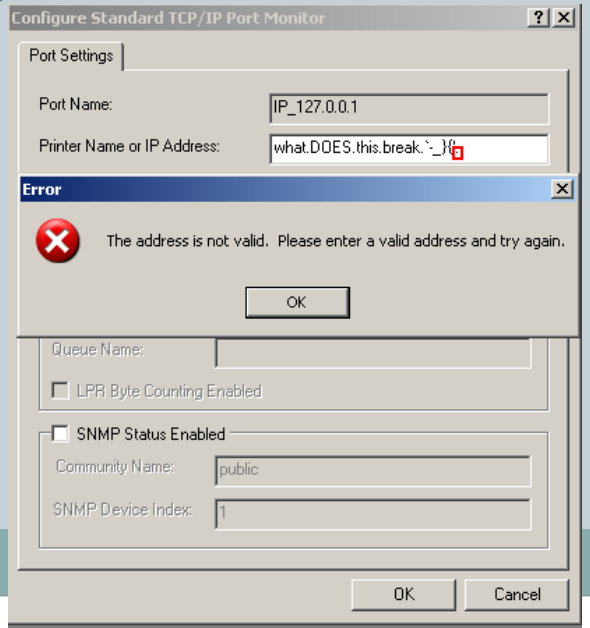
Locally-executed – Windows Printing broken

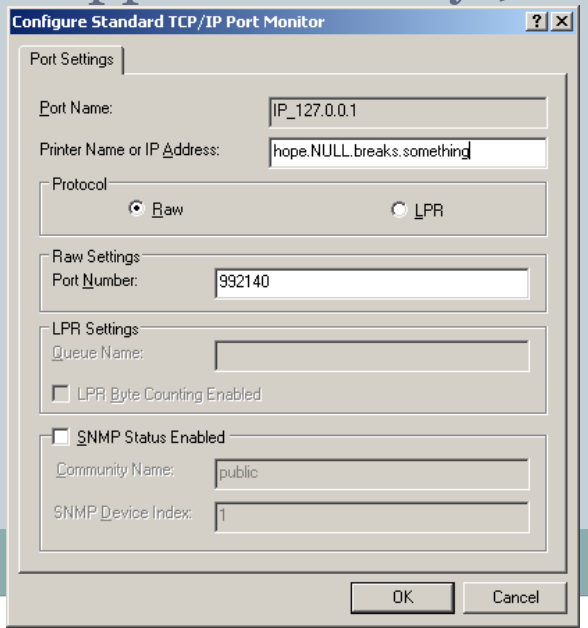
- TCP port integer overflow (corporative-style)
  - Port 9100 is actually: 0 < 9100 + k*0x10000 < 999999
    - Hence: k ∈ [0..15] – will all print OK to 9100 ☺
  - Not found yet a practical exploitation use



Locally-executed – Windows Printing broken

- IPv4 validation fail (it's 2010 dudes! wtf?)
  - Accepts: dec, hex, oct ☺ - not necessarily new/scary.
    - Eg.: 0300.168.000.0x00008D = 192.168.0.141
  - Cares last char not to be "." (dot) – everything else is "just fine"
  - Please tell me where those packets go (eg.: 255.255.255.255 [.255] and this.IP.is.NULL.and.trapped – literally!)





Locally-executed – Printer driver hacks

- Find exploit stream for unidrv.dll/pscript5.dll
  - Possibly get LOCAL SYSTEM privileges (spoolsv.exe)
  - unidrv/pscript5 dlls called from user space, no need for admin
- Other require social engineering+admin level
  - Replace the driver *.dlls
  - Provide an "enhanced" driver, with printer-malware inside
- Infect the GPD files
  - Replace with legitimate **Cmd* containing malware payload

```
*Command: CmdSelect
{
        *Order: DOC_SETUP.4
        *Cmd: "<1B>%%-12345X@PJL SET RESOLUTION=150<0A>@PJL ENTER LANGUAGE=PCL<0A0D1B>E<1B>*t150R"
}

*Command: CmdSelect
{
        *Order: DOC_SETUP.4
        *Cmd: "<1B>%%-12345X@PJL ENTER LANGUAGE=UPGRADE<0A0D1B><DE><AD><BE><EF><13><37>"
}
```

Locally-executed – Printer driver hacks

- Infect the PPD files
- **PatchFile*, **JobPatchFile*
  - *Represents a PS language sequence that is a downloadable patch to ROM code or into initial VM*

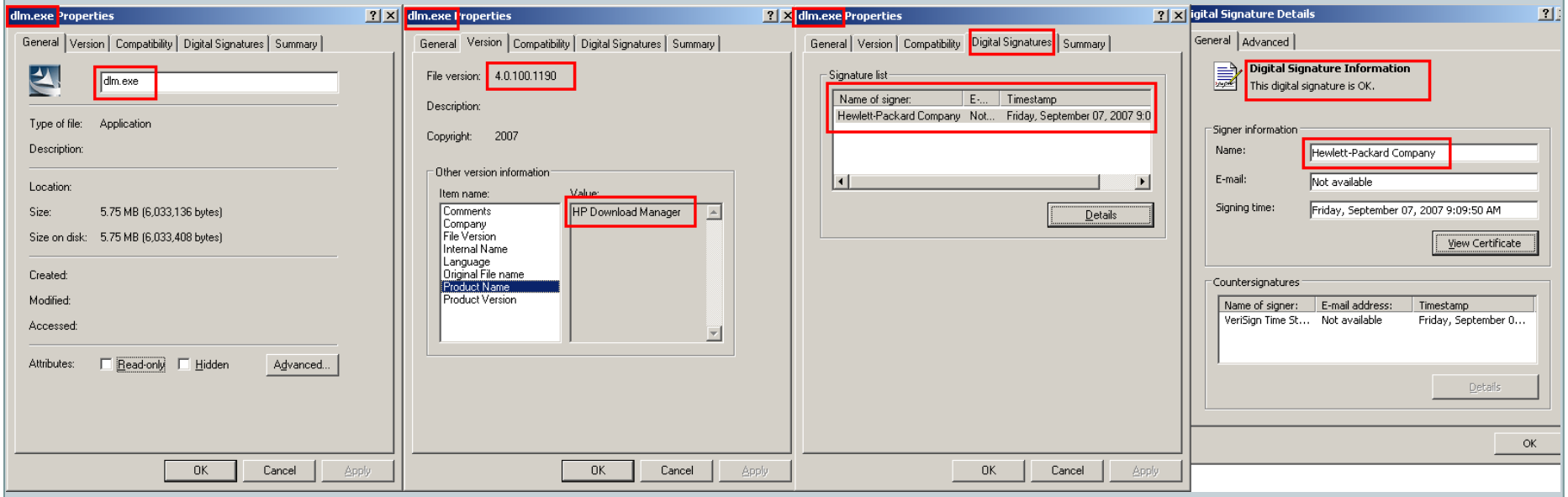
```
*JobPatchFile 1: "
%
%%BeginResource: LH PatchFile
%
false(
800344A251010CD0613719CCA731D08205041C8DC6031190C04032170C61A728
…
```

- **FileSystem*
  - *The *?FileSystem query can be used to dynamically determine whether or not a file system is actually present*

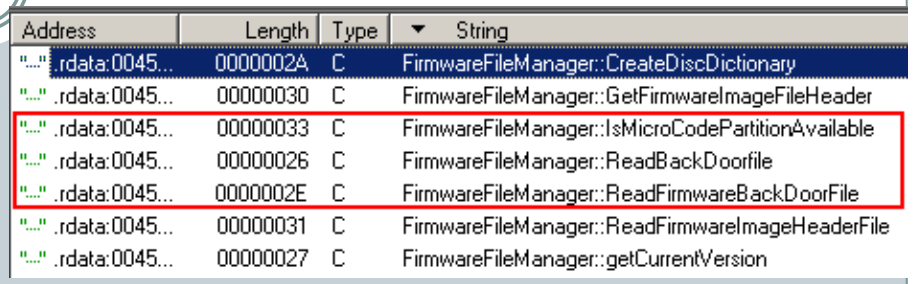
```
*?FileSystem: "
    save false
        (%disk?%)
        { currentdevparams dup /Writeable known
            { /Writeable get {pop true} if }  { pop } ifelse
        } 10 string /IODevice resourceforall
    restore"
*End
```

First public traces of MFP *malware*

- Not satisfied with printer tracking dots?
- Satisfaction guaranteed with:
  - HP Download Manager – a story from backstagedoor
  - Will present analysis of *hpjdwnld.exe*



First public traces of MFP *malware*



Address	Length	Type	String
.rdata:0045...	0000002A	C	FirmwareFileManager::CreateDiscDictionary
.rdata:0045...	00000030	C	FirmwareFileManager::GetFirmwareImageFileHeader
.rdata:0045...	00000033	C	FirmwareFileManager::IsMicroCodePartitionAvailable
.rdata:0045...	00000026	C	FirmwareFileManager::ReadBackDoorfile
.rdata:0045...	0000002E	C	FirmwareFileManager::ReadFirmwareBackDoorFile
.rdata:0045...	00000031	C	FirmwareFileManager::ReadFirmwareImageHeaderFile
.rdata:0045...	00000027	C	FirmwareFileManager::getCurrentVersion

- Important note:
  - It's not managing a PC-backdoor
  - It is managing an MFP-backdoor
  - *strings* utility is enough to spot it
  - Checks for *%HOME%\upgrades\jetdirect\SpecialUpgrades.txt*
  - Checks special firmware files for ShortStack/CodeImage microcodes
  - If you have samples for above 2 items, please share them!
  - Possibly similar to AMD K8 Microcode backdoor update feature
- Most probably HP will down-play this:
  - "Investigation lead this to a miss intended ex-engineer…"
    - Feature too meticulously designed and debug-logged
  - "It is a remote assistance/management/support feature…"
    - Backdoor ≠ remote assistance/management/support
- Are vendors being responsible when including backdoor/call-home features?
  - Well-known PR fiascos: Energizer, Sony

DevEnv – How?

- My vision (yours might be slightly/totally different)
  - Unpack/mount the firmware
    - Need to reverse most important formats out of myriad
    - Crack any crypto + signature is a “desirable option” of course
  - Map it’s arch + OS
    - Wiki, hex-view, specs, IDA, obj* suite
  - Fine-tune IDA, binutils, obj* army for that specific combination
  - Reverse the workings of (each) specific executable
  - Introduce the payload:
    - Byte-patch, if you talk code-machine better than your native lang
    - Compile a binary in an emulated env (if all prerequisites permit)
  - Test payload:
    - Directly on hardware – tricky, may brick it, need **good** HW skills, etc.
    - In an emulated env – very convinient, but again not always possible

DevEnv – Why?

- A DevEnv+Emulator tandem is preferred for:
  - Vendor firmware testing for vulnerabilities (parsers, etc.)
  - Develop malicious payloads/firmware for a device/device-class
  - Allows easier fuzzing
  - Is a more formal approach, rather than trial-and-error
- Unless:
  - You want a BIG net of BIG bricks (not bots) and BIG angry corps on your 455!
  - You own a warehouse of MFPs for tests

DevEnv – What?

- Toolchains:
  - Crosstool-ng, buildroot, scratchbox
- Emulators
  - Qemu, OVP, RTEMS, ARMulator
- OSes on most printers/MFPs:
  - LynxOS
  - VxWorks
  - NucleusOS
  - Linux (for various non-std architectures)
  - pSOS
- Processors on most printers/MFPs:
  - MIPS (PCM-Sierra)
  - RISCs (Toshiba TMPR4955)
  - ARM (Marvell ARMv5TE-compliant, custom HP-ARM)
  - SPARC (Fujitsu MB86830 series)

DevEnv – first things first – Linux

- Lexmark luckily went Linux/GPL
  - But VxWorks and LynxOS are not out-of community potential/knowledge
- Best start for devenv setup & research bootstrap
  - *E23x_E33x_141_C20.FLI* is a good kernel-loading example
  - Interacts with NVRAM and other stuff (good to understand)
  - Have "|*BIN*" wrapped image of Linux kernel
    - Can also be built from sources, though EAN.KA.K009 not released

```
0001fc00h: 00 00 00 00 00 00 00 01 00 00 00 00 58 A7 7C 42 ; ............X§|B
0001fc10h: 49 4E 00 1A BE FE FF AA 00 D7 FF AA 00 C0 FF AA ; IN..¾þÿª.×ÿª.Àÿª
0001fc20h: 00 C1 00 00 00 64 FF AA 00 C5 62 65 61 66 01 00 ; .Á...dÿª.Åbeaf..
0001fc30h: 01 00 00 00 C0 00 00 06 3C CA 4B 65 72 6E 65 6C ; ....À...<ÊKernel
0001fc40h: 00 00 00 00 00 00 00 00 00 00 45 41 4E 2E 4B 41 ; ..........EAN.KA
0001fc50h: 2E 4B 30 30 39 00 00 00 00 00 30 00 00 00 00 00 ; .K009.....0.....
0001fc60h: 00 00 00 00 1B BE 00 00 50 00 00 00 00 00 00 00 ; .....¾..P.......
0001fc70h: 00 00 00 00 00 02 62 6C 64 2D 6C 69 62 00 00 00 ; ......bld-lib...
0001fc80h: 00 00 00 00 00 00 57 65 64 20 4E 6F 76 20 32 39 ; ......Wed Nov 29
0001fc90h: 20 31 35 3A 31 30 3A 35 30 20 32 30 30 36 00 00 ;  15:10:50 2006..
```

DevEnv – Firmware Unpack/Mount

- Firmware image unpackers:
  - Simple script-like C-tools
  - Do not work yet with encrypted firmware package
  - Strip proprietary-PJL wrappers and spit binary raw inside
    - Some have a single ELF file (example: E23X_.fli)
    - Some have a FS-like object with tree-structure and binary content
  - Can adopt and use libPJL from phenoelit
- Ultimate goal:
  - File-based FS drivers
  - To be as simple as:
    - **./mount –t hp-fru HPLJ5200.fru /mount/fw_test**

DevEnv – Firmware Unpack/Mount

- Example: excerpt from a single block of HP simple-FS, many of these found inside a single RFU firmware file:

```
00000600h: 00 00 00 04 00 0C 00 01 2E 00 00 00 00 00 00 03 ; ................
00000610h: 00 0C 00 02 2E 2E 00 00 00 00 00 05 00 0C 00 03 ; ................
00000620h: 6C 69 62 00 00 00 00 06 00 14 00 09 77 65 62 53 ; lib.........webS
00000630h: 65 72 76 65 72 00 00 00 00 00 00 07 00 10 00 06 ; erver...........
00000640h: 69 6D 61 67 65 73 00 00 00 00 00 08 01 B8 00 04 ; images........¸..
00000650h: 64 61 74 61 00 00 00 00 00 00 00 00 00 00 00 00 ; data............
```

```
#define PJL_UPGRADE          "@PJL UPGRADE SIZE="

// small endian architecture
/*
    4 bytes ID/parent of entry,
    2 bytes size of entry (ENTRY_SIZE),
    2 bytes length of entry_name (ENTRY_NAME_LEN),
    ENTRY_NAME_LEN bytes having name,
    (ENTRY_SIZE - 4 - 2 - 2 - ENTRY_NAME_LEN) bytes
*/
typedef struct _fsentry_fix_
{
    unsigned char entry_id[4]; // 4 bytes
    unsigned char entry_size[2]; // 2 bytes
} fsentry_fix;

typedef struct _fsentry_var_
{
    unsigned char entry_name_len[2]; // 2 bytes
    char *entry_name; // variable
} fsentry_var;

typedef struct _fsentry_
{
    fsentry_fix fix;
    fsentry_var var;
} fsentry;
```

Sample firmware under microscope

- BarSTORM barcode printers
  - Btw, violate and persistently ignore GPL-related requests!
    - ~~NOTE: JetMobile's SecureJet Box does as well~~ – not anymore
      - https://www2.jetmobile.com/kb/entry/74/
      - https://www2.jetmobile.com/kb/entry/72/
- Linux FS image with default unsalted passwords
  - root:$1$$I209Z7NcvQAKp7wyCTlia0:10933:0:99999:7:::
  - lp:$1$$RfHkehRv/LWAGZdCEvUU90:10933:0:99999:7:::
  - bcadmin:$1$$YSpLiaVeoDkQidsOLxlm5/:10933:0:99999:7:::
  - engineer:$1$$YSpLiaVeoDkQidsOLxlm5/:10933:0:99999:7:::
  - admin:$1$$I209Z7NcvQAKp7wyCTlia0:10933:0:99999:7:::
  - crypt("password")=$1$$I209Z7NcvQAKp7wyCTlia0

Sample firmware under microscope

- IBM InfoPrint IP 6700
  - 369676.prg
  - pRiNtrOnIx firmware and components
    - Seems like a H4X0R designed the firmwares ☺
- Has RFID from awidasia
  - SDK and samples to play with are here
- Some keywords to get you interested:
  - PaRtITiOn OF RFID, rfidfirm.bin, rfidchip.inf, rfidtag.inf
  - AWID MPR-1510 V2.6h UHF MODULE Firmware Ver4.27
  - Why not spy on RFID tags or KIL all tags?

```
Silicon,TID,EPC Word Length,USR Word Length,TID Word Length,ACS/KIL supported?
Impinj Monza 1,E200104.,6,0,2,No
Impinj Monza 1a,E200105.,6,0,2,Yes
Impinj Monza ID,E200106.|E200108.,6,0,2,No
Impinj Monaco 64,E200106.|E200108.,6,4,2,No
Impinj Monza 2,E200107.,6,0,2,Yes
Impinj Monza 3,E200109.,6,0,2,Yes
Alien Higgs 2,E2003411,6,0,2,Yes
Alien Higgs 3,E2003412,6,0,6,Yes
Phillips Ucode EPC Gen2,E2006001,6,14,2,Yes
Philips Ucode G2XL,E2006004,15,0,4,Yes
Philips Ucode G2XM,E2006003,15,32,4,Yes
ST Micro XRAG2,E2007240,16,0,4,Yes
```

Sample firmware under microscope

- SMS Printers (examples)
  - Eg.: DPSPro, Gatetel, Possio GRETA, Secugis
- Empty paper roll DOS attack (most printers)
  - Avg ~ 62 SMSes (160 new-line chars each SMS) for 50m rolls
- Configuration commands attack
  - Against DPSPro. Others might have hidden conf commands as well!
  - "*#V1: 0=SMS 1=VOICE CALL [0]. This variable chooses whether the Printer will confirm with an SMS or placing a call.*"
  - "*#Y: Programs ACCEPT number to which ACCEPT SMS will be sent. Note1: if the CALL option is enabled, the unit will place a call instead.*"
  - Make it call your/friend's premium number is the answer ☺
- Nice to have – reflash by TPDU-SMS ☺

"Secure Thinking" *in quotes*

- HP Security Solutions
  - "*Q23. Are current HP multifunction printers susceptible to viruses and worms?* **No, since the majority of viruses and worms exploit vulnerabilities in Windows-based computers**. HP MFPs use non-standard operating systems other than Windows. Consequently, they are immune to these viruses and worms. **In practice, there have been no known instances of viruses or worms infecting HP MFPs**"
    - Well, PoC-community or some haxor or some IT-criminals might change that "in practice" then!
  - "*Firmware generally behind software in terms of secure development & deployment*" – more than true
    - Wonder if HP's SecLab PhlashDance ever reached HP's MFP R&D

"Secure Thinking" *in quotes*

- Sharp Security Suite
  - *"Sharp MFP products use unique embedded firmware and are not based on Windows operating systems. Therefore,* ***Sharp MFP's internal systems are not subject to the same Virus vulnerability as Microsoft operating systems****. We believe this approach provides the internal systems of our products with protection against common Windows executable viruses and other similar infectious software programs."*
    - Well, possibly are vulnerable to *other* (i.e. not same) virus vulnerabilities!

"Secure Thinking" *in quotes*

- Lexmark MFP Security, Samsung MFP Security
  - *"In other areas, the security considerations around printers/MFPs are substantially different:* ***they generally don't run conventional operating systems, they don't have network file shares that need to be secured, they probably don't need or support antivirus software****, etc."*
    - Who did copy from who that text? Or they just assumed *the leader* is right and mutually-copy-pasted?
    - "…probably…" ?!
      - Nowadays, if you have an OS, a FS and externally connected execution environment, most likely you need internal antivirus/IDS/IPS

"Secure Thinking" *in quotes*

- Final thought on above "secure thinking" quotes
- Remember psybot?
  - Non-conventional arch – *true* – MIPS
  - Non-conventional OS – *true* - Mipsel Linux
  - Doesn't support antivirus – *true* – "why should we?!"
  - Got owned – *very true* – ~100k devices in a sophisticated command-and-control botnet

---

  - If you need more arguments for securing/cleaning embedded devices, running unconventional OS+arch which do not support secure/antimalware standards/frameworks
    - Perhaps security is your *lowest priority hobby* – my $0.02…

Solutions – Printer Vendors' Side

- First, accept that present day printers (especially network ones) are:
  - Full-blown computers themselves
  - A security target/threat
  - To be considered as part of Secure Development/Testing/Audit Lifecycles
- Fix those damn specs and parsers (PJL, PCL, PML, PDF, PS)
- Fix those damn web/telnet/ftp/snmp/etc. interfaces
- If first random 200 bytes fuzz string crashes/bricks your device…
  - …time to put in practice SDL. we are in 2010, remember?…

Solutions – Printer Vendors' Side

- Authenticate uploader, crypt, sign and verify signature of the uploaded firmware
  - Btw, homebrew or kindergarten crypto is NOT crypto!
  - Or make the implementation FOSS – so open and secure standards are implemented ☺
- Be fair – transparent and backdoor-free systems/software
- Collaborate with antimalware vendors for your platforms
  - Could win you a nice marketing step
- Last but not least – remove default passwords and make mandatory strong-password changes as part of the initial setup procedures/installations

Solutions – Antimalware Vendors' Side

- Collaborate with vendors and security community
  - Make vendors understand those MFPs are real exploitable targets
  - Also, it could be a good marketing step "First antimalware on printers/MFPs"
  - Develop open and secure practices/protocols for in-printer antivirus management and updates
- If above collaboration does not work
  - Sponsor high-profile MFP exploit botnet – volunteers are out there
  - You have your foot in the "MFP antimalware market"`s door
  - This point is more to be joke ☺
  - Though, not that there were no surprising developments
- Setup honey-pots for most-spread MFPs EWS :
  - Similar to renowned /etc/passwd
  - Study blackhats/bots actions to train IDS/IPS for MFPs
  - Get samples of firmalware or exploit payloads (PJL, PS, PCL)

Solutions – Admins' Side

- Develop and **follow** secure periodic practices and checklists for all your MFPs/printers
- Use and analyze extensive logging using MFPs management platforms
- Properly isolate MFPs on appropriate network segments
- Perhaps implement stricter domain-level printing policies
- Well, last but not least – don't leave those default accounts/passwords on

Solutions – Users' Side

- Stay updated to latest firmware of the printer's vendor
  - Make sure you choose a security-aware vendor (but skip the marketing BS between the lines)
- Don't print anything from untrusted sources
  - Well, this is hard… everybody is untrusted today
- Don't open unknown files
  - Not guaranteed that malware detection is triggered for printers-related malware
  - Important point – exploits the MFP, no need for admin rights on PC!
- Log and monitor printers' activity
  - Connects from it's IP
  - Paranoid mode – USB data filter from the printer to host PC
    - You never know what bugs do printer's driver have on the PC
    - Good topic to check ☺
- Use safe virtual printers to produce malware-free docs

RE: Responsible Disclosure

- Well, some pieces of presented materials cannot be considered "responsible disclosure" style
  - This info contains no 0-day, but perhaps can lead to some (PPEs over Java Applets)
- Other important questions to ask&answer:
  - Are vendors being responsible when including backdoor/call-home features?
    - Well-known PR fiascos: Energizer, Sony
  - Are vendors being responsible when they do not inform/document user about **all** features of their products?
  - Are vendors being responsible when they tend not to release patches because they think it's not an issues
    - Yes, not an issue, until 0-day exploited in the wild

Conclusions

- As PoC shown, printers are exploitable
- Specs have holes and are outdated for the new IT security realities:
  - Device and antimalware vendors seem to ignore the issues… yet
- MFPs are than “dummy printers” – are full-blown machines with great power
- MFPs tend to interact with same (or even bigger) number of technologies as computers:
  - Eth
  - WiFi
  - RFID
- MFPs have access to almost same set of secrets as PCs

Recommended reading

- Slobotron on Hacking Printers
- phenoelit's HP resources
- Irongeek's "Hacking Network Printers"
- SANS Auditing and Securing Multifunction/MFP Devices
  - Amuzing note: "Using this port and the right utility you can, among other things, *change what shows up on the LCD display*. Modification of the LCD panel, either causing confusion ("Out of Service") or opening the door for social engineering purposes ("Error. Call 555-5151.")."

Recommended reading

- "Vulnerabilities in Not-So-Embedded Systems"
- "Exploiting Printers by Analyzing Their Firmware" (nowhere to find on the net… censored?!)
- "Juste une imprimante"
- "Network Printing" book
- MFP Security for Enterprise Environments
- cyrtech.de

\H1B%-12345X@PJL EOJ “HackingPrinters”

- Questions?
- Thank you!
- Print to this addresses:
  - zveriu @ gmail.com
  - andrei @ andreicostin.com