Attacking Xerox multi function printers

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AIRBUS

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Intro

Context

Who am I?

- Reverser since more than 20 years
- Security evaluation expert in Airbus

Airbus security lab missions include:

- Evaluating products that Airbus uses or sells to increase the company's overall security
- Red Teaming (Blue Team sparring partner)
- Check `https://airbus-seclab.github.io`, `@AirbusSecLab`

This presentation:

- Deep dive into Xerox VersaLink, WorkCentre and AltaLink models
- How I found previously unknown vulnerabilities in all models
- Tips for both the Red and Blue teams

Why target multi function printers (MFP)?

Easy target:

- Big companies have thousands of them
- Connected to the LAN, often not firewalled from the clients
- Most probably managed by a contractor (security policies?)
- Probably overlooked by the IT security team

Big MFP: AltaLink C8070

Why target multi function printers (MFP)?

Interesting for an attacker:

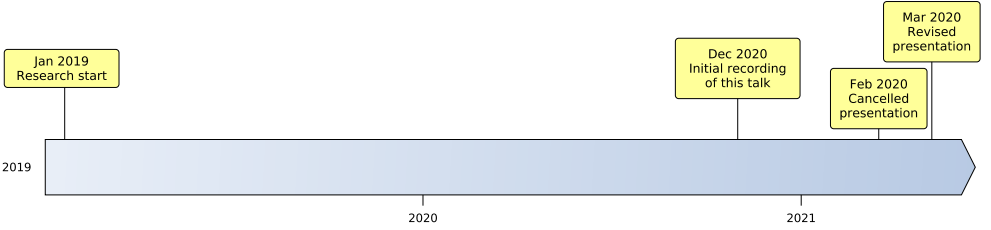
- Handle confidential documents (prints, scans)
- Active Directory (LDAP) credentials (nobody would use a *domain admin*, *right?*)
- Sometimes SMB access to some server (templates, scan to folder)
- Good place for persistence:
  - Often Linux based (tools work)
  - Rarely (if ever?) monitored by the SOC

Previous research

- O'Connor: Vulnerabilities in Not-So Embedded Systems (BHUSA 06)
- Heiland: From printer to pwnd (DEF CON 19)
- Weidenbach, Ernst: PWN Xerox Printers (. . . again)
- Müller: Printer Exploitation Toolkit (PRET)
- Romero, Rivas: Why you should fear your "mundane" office equipment (DEF CON 27)
- Probably others I'm missing, sorry

My story

- Read about the “Printer Exploitation Toolkit” on the week-end
- Tested it on the office’s printer on Monday morning. . .
- . . . Saw it doesn’t work
- Downloaded firmware from Xerox website for a “quick” look
- Got trapped in a reversing loop!
- . . .
- Then I discovered we had other models
- Trapped again!



Our attacker model

Prerequisites:

- Network access to admin interface
- No credentials

Objectives (descending):

- Steal all documents (printed, scanned)
- Establish persistence and relays
- Recover infrastructure creds (AD, email, etc.)
- Recover printer credentials

So the research will look for ways to move from anonymous to root.

Xerox WorkCentre and AltaLink

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Overview

Big machines (high-end models):

- WorkCentre 7835 (~2011): CPU: E500v2 PPC, 1.5GB RAM, 160GB HDD
- AltaLink 8030 (~2016): CPU: Intel Atom, 8GB RAM, 250GB HDD. WorkCentre evolution.

EAL2+ certified: doc gives a good overview of functionalities and attack surface

WorkCentre 7835 , 151 kg, >15k USD

AltaLink 8030, 151 kg, >15k USD

Attacker's view

Network attack surface:

- Xerox's *Information Assurance Disclosure Document* lists up to 24 open ports (!)
- In practice:
  - SNMP
  - HTTP: Web UI, Web Services and endpoints for centralized management
  - Printing protocols (LPR, IPP, 9100)

Functional attack surface:

- File format parsers (PDF, PS, PCL, XPS)
- Image parsers (embedded in PDF, etc)

Local physical attack surface:

- USB ports
- HDD access
- Maintenance access (serial, USB)

First step: extracting firmware updates

DLM File format:

- `tar.gz` with text header:
  - RSA signature
  - RSA-encrypted AES key in AltaLink case

Finding the AltaLink firmware RSA private key:

- Remove hard drive from printer
- Mount filesystem
- Find all private keys on disk

Decrypting the AltaLink firmware:

- Use RSA private key to recover AES-256 key
- Decrypt using AES-256-CBC and null IV

Note: research was done on firmwares released from 2017 to 2020, for both AltaLink and WorkCentre.

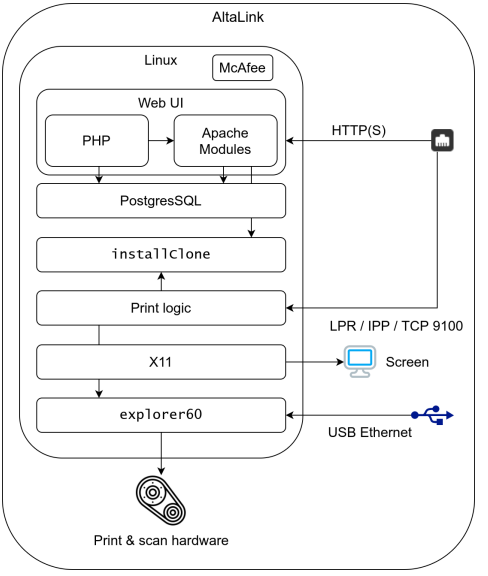
System architecture

Major components, split in firmware:

- OS: main Linux OS
- NC: network controller
- XUI: Xerox User Interface
- CCS_ACD: anti counterfeit detector
- CCS: copy control system

`exp55/explorer60`, 47MB ELF binary:

- Old code in charge of all the HW printing processing (scanning, paper path, printer, etc.)
- Old OS ported inside a Linux process?
- Supports TFTP connections: using Ethernet-over-USB port at the back



AltaLink components

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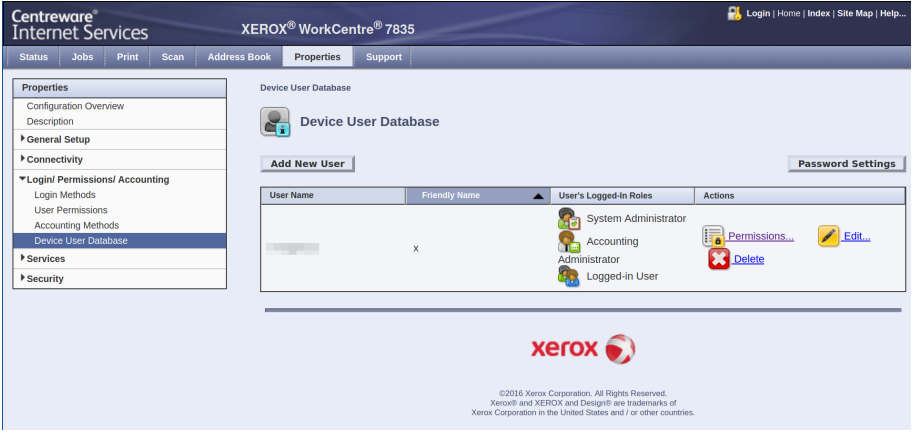
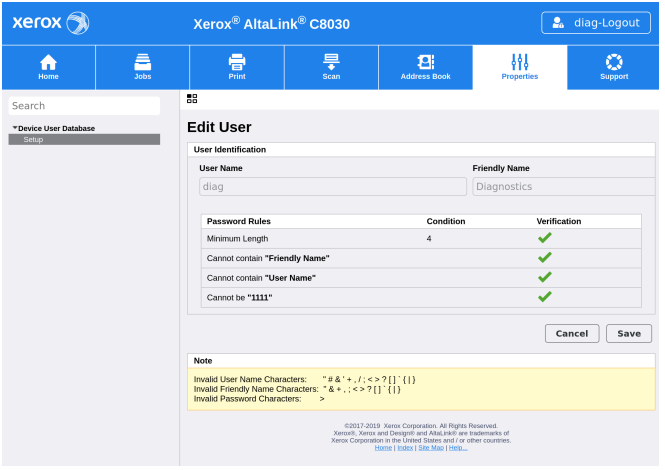
Web UI: WorkCentre



WorkCentre

Web UI: AltaLink



AltaLink

Web UI: authentication

Basics:

- Auth is mandatory on AltaLink to access the Web UI
- Users authentication options:
  - Local: on device DB
  - Network: Kerberos, SMB, LDAP

Roles:

- Normal user
- Accounting administrator: accounting features only
- System administrator: full admin

System security model:

- Everything that runs is signed by Xerox
- No shell access
- Having `admin` should *not* imply code execution on the device

But having `admin` *definitely* increases the attack surface :)

Local accounts: defaults, encryption

User list is stored in PostgreSQL:

- Running as `postgres` user, not accessible from `nobody` user
- `ess` database, `xsa.accounts` table
- Default content (simplified):

```
admin           Admin          0x0D9D2F4DB1E2510D510851487331104EAA    SA
!$ecivreS       CSE Account    0xF399C25961A4A27F8FB0EE2FAA430DBCAA    CSE
diag            Diagnostics    0x9FA43E24372828D55A033E3CDF0D3957AA    CSE
forceonboxlogin Force[...]     0x8FAE69757CEBCEC23B8FE1E75CA948EAAA    CopyOnly
guest           Guest          0xCE617F371AE3817983F214EB7F41C6B9AA    GUEST
```

`esscrypto_encryptString`

Used a *lot* in various places to:

- Hide encryption keys
- Encrypt users passwords

Default and hardcoded accounts (2019 picture)

Decrypting passwords:

- Recover passphrase from call to `esscrypto_encryptString`
- Decrypt using AES-256-CBC and null IV

Five default accounts:

- `admin` / `1111`: default admin password
- `diag` / `3424`: hidden “service” account, documented in service manuals (Remote UI access)
- `!$ecivreS` / `2732`: hidden “service” account, documented in service manuals (local only)
- `forceonboxlogin` / `password`: hidden “technical” account, introduced in 2018
- `guest` / `2222`: hidden “technical” account, introduced in 2018

“Service” accounts?

- Explicitly hidden by UI code
- Password is impossible to change

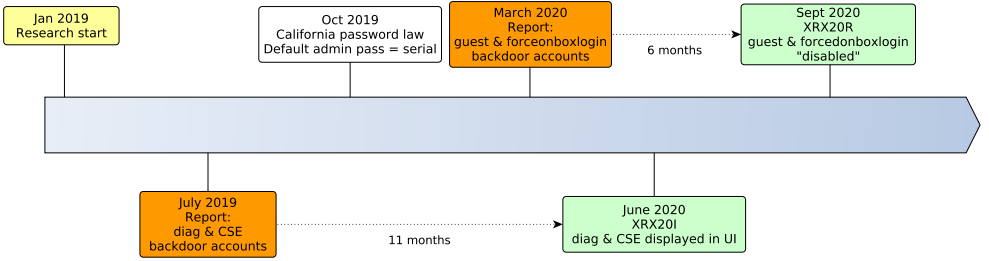
Security improvements as of XRX20-R (Sept 2020)

Account privileges and passwords:

- Some accounts are now only valid for physical access (local UI):
  - `!$ecivreS`, `forceonboxlogin` and `guest`
- Some accounts are now *really* unprivileged:
  - `diag`: can access remote UI (with diagnostics access) if enabled
  - `forceonboxlogin`
- Newer firmware comply with 2020 California Password law (SB-327) and use the serial number by default for `admin` and `diag`.
  - `snmpget -v 1 -c public HOST 1.3.6.1.4.1.253.8.53.3.2.1.3.1`
  - `curl https://HOST/diagnostics/SESStatus.txt | grep Serial`
- Future releases should:
  - randomize the passwords of `guest` and `forceonboxlogin` which are “internal” accounts
  - allow the password for `diag` to be changed

Passwords remain stored without hashing because `WS-Security` needs the password itself.

Accounts and backdoors progress



Web interface “internals”

High level overview:

- Runs as `nobody`
- UI in PHP (completely reworked in AltaLink):
  - (mostly) out of scope for this presentation/research
- A lot of the logic is actually implemented in C/C++:
  - `POST` to `/userpost/xerox.set` and `/dummypost/xerox.set`
  - → Apache modules `mod_loapost.so`, `mod_loaget.so`, `mod_upload.so`, etc.
- see O’Connor’s talk at BHUSA 06 for more info

`mod_loapost.so` extract:

```
Add_HTML_Set_fn("HTTP_Set_Http_Settings_fn", &HTTP_Set_Http_Settings_fn, 1);
Add_HTML_Set_fn("HTTP_Set_Diag_Log_Levels_fn", &HTTP_Set_Diag_Log_Levels_fn, 1);
Add_HTML_Set_fn("HTTP_Retrieve_Diag_Data_fn", &HTTP_Retrieve_Diag_Data_fn, 1);
Add_HTML_Set_fn("HTTP_WS_Reset_IP_Lockout", &HTTP_WS_Reset_IP_Lockout, 1);
```

Past vulnerabilities in PHP code:

```
https://HOST/diagnostics/diagnosticsAjaxHandler.php?command=viewLog&logName=;CMD_TO_EXEC;#
https://HOST/properties/accounting/download_csv.php?generated=../../TARGETFILE
https://HOST/ajax/fileDistributionRequestHandler.php?[...]&urlHeader=http://localhost;CMD_TO_EXEC;"
```

Finding vulnerabilities in the Apache modules

Classic/trivial methodology:

- Look for `.so` importing `system`, `popen`, `execve`, etc.
- Open in IDA
- Find vulnerable code

Remote command injection vulnerability:

```
curl -c cookie.jar -k
     -H 'Content-Type: application/x-www-form-urlencoded'
     --data "_fun_function=HTTP_Set_Diag_Log_Levels_fn"
     --data "&NextPage=%2F&CSRFToken=$csrf"
     --data-urlencode "http;$cmd;.lp" "https://$host/dummypost/xerox.set"
```

Assigned CVE-2019-10880:

- Xerox bulletins XRX19C, XRX19E, XRX19G, XRX19I, XRX19J, XRX19K, XRX19L and XRX19M.
- Fix: removed `HTTP_Set_Diag_Log_Levels_fn`

More Web vulnerabilities: privesc

Privilege escalation in AJAX handlers:

- `/ajax/cfgSetAjaxHandler.php?command=configServerSet` did not check the user's rights before setting conf entries
- Exploit:
  - Use `diag` account
  - Set `deviceAdmin.cloneDlmDownload.DLMPolicy=3` to allow unencrypted clone files submission
  - Submit clone file with new administrator password

Found while diffing XRX19-AQ (Unauthenticated RCE).

More Web vulnerabilities: SQLi

Story time:

- Xerox sent me a pre-release firmware to check some fixes
- Would not give me the admin password of the test printer
- . . . I decided I'd find a way to recover it

SQL injection in account management page:

- Found by looking for non-parametrized queries
- Exploit using `forceonboxlogin` and leak the admin password

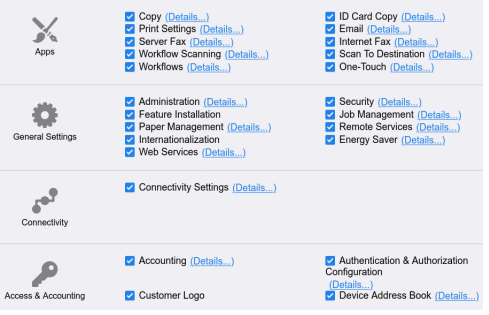
Fixes:

- Both were fixed in XRX20-R, Sept 2020

Clone files

Config backup you can apply to another printer (directly on TCP/9100!). Contains:

- Users configuration (including passwords)
- Network configuration (including passwords)
- Filtering configuration (`iptables`)
- ...



Clone options

Clone files: format

On WorkCentre:

- The clone file is an unencrypted `.tar.gz`
- The files are not encrypted

On AltaLink: `tgz` is encrypted using RSA+AES:

- Random AES key
- Encrypted with a public key. The private key is shared by all AltaLink.
- Sensitive data such as user accounts are also encrypted *inside* the clone file:
  - `.encrypted` extension
  - AES-256-CBC
  - Hardcoded hex key (`ess_crypto_get_hex_string_from_string`)

Network clients credentials

Various passwords are stored in configuration / clone files

- LDAP
- POP3
- SMTP
- SMB
- etc.

Example in `LDAPConfigAttributes.1.1.0`: `ldap.password=0xD7...AA`

Decrypting passwords:

- `esscrypto_encryptString` is used too, but with a different key
- hopefully interesting Active Directory accounts can be found here

Clone files RCE

Clone files restoration workflow (`installClone`):

- `tgz` is decrypted then extracted
- “Regular” configuration entries are applied
- Specific helpers are used in some cases (as root)

`iptables` command injection:

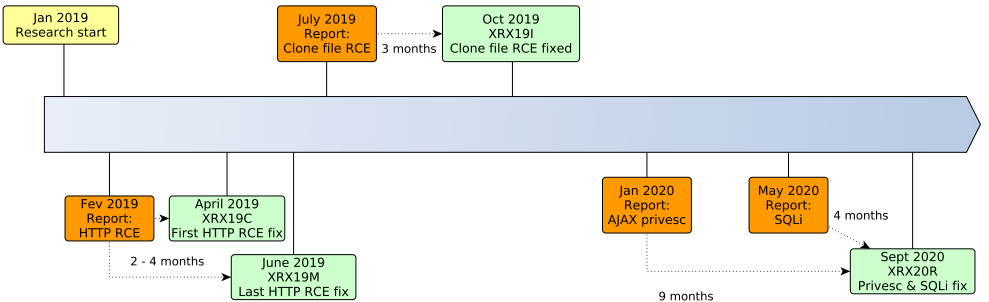
- Add an `iptable` rule in the right file, which passes the basic format check, such as:

`bash path_to_script -p all -j DROP -A INPUT -i eth0 -s 64.64.64.64/32`.

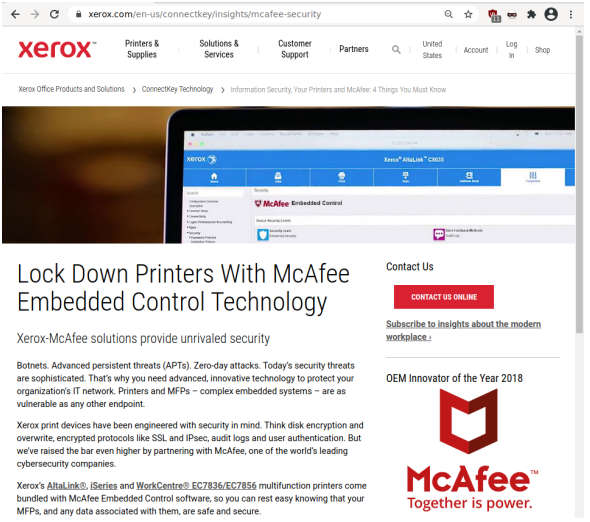
- A script can be embedded in the `AAP/fdi_card_access.png` file in the `tar.gz`. So the following will be executed as `root` when the clone file is loaded:

```
bash /path/to/AAP/fdi\_card\_access.png
 -p all -j DROP -A INPUT \
 -i eth0 -s 64.64.64.64/32
```

Xerox coordinated disclosure timeline



“Defense in depth”: McAfee Embedded Control



“Defense in depth”: McAfee Embedded Control

Host Intrusion Prevention System:

- Logs access to some files
- Prevents read access to some files, including the printer’s config
- Prevents write access to most important paths

Getting around it:

- Disable it through the WebUI (removed in XRX20L)
- Don’t care about it, it’s useless, as seen in `solidcore.conf`

```
CapabilityRules = {
    "0x16\"UPDATER: AUTO_105\"\"/etc/rc.d/init.d/cc_system\""
[...]
```

`cc_system` launches everything, including the web server. So all exposed binaries are authorized.

“Defense in depth”: Hardening

Applications were not compiled with basic exploit mitigations:

RELRO	STACK CANARY	NX	PIE	RPATH	RUNPATH	Symbols	FORTIFY
No RELRO	No canary found	NX enabled	No PIE	No RPATH	No RUNPATH	No Symbols	No

Linux kernel versions:

- WorkCentre: 2.6.34
- AltaLink: 3.10.62

Xerox said they backport security fixes.

AltaLink: Wrap-up

I *currently* do not have a way to remotely compromise an up-to-date AltaLink configured with a strong admin password.

All bulletins with Airbus acknowledgment for AltaLink and WorkCentre:

- XRX21F.
- XRX20G, XRX20I, XRX20R, XRX20X.
- XRX20L, XRX20M, XRX20V.
- XRX19AI, XRX19AP.
- XRX19C, XRX19E, XRX19G, XRX19I, XRX19J, XRX19K, XRX19L, XRX19M, XRX19Q.

Xerox VersaLink

Overview

Info:

- HW: 1 GHz dual-core ARM, 2GB RAM, optional HDD
- C405: 33 kg, ~700USD
- Linux 3.10.62

Xerox, really? Actually *Fuji* Xerox:

- Japanese comments
- Software architecture is completely different from other Xerox printers

System architecture

Software components:

- VxWorks:
  - Could not dig into it, handles the “Marking Engine” (Xerox’s *IAD* states v6.8.2)
- Linux:
  - User-facing OS: handles the network, printing, Web, etc.
  - “Special boot mode” OS (maintenance mode)

Exposed attack surface:

- Network: up to 16 listening ports in TCP/UDP (cf. *IAD*)
  - In practice: SNMP, HTTP, printing protocols
- Local: USB, maintenance access

Some positive security points:

- HW Root of trust
- Disk encryption

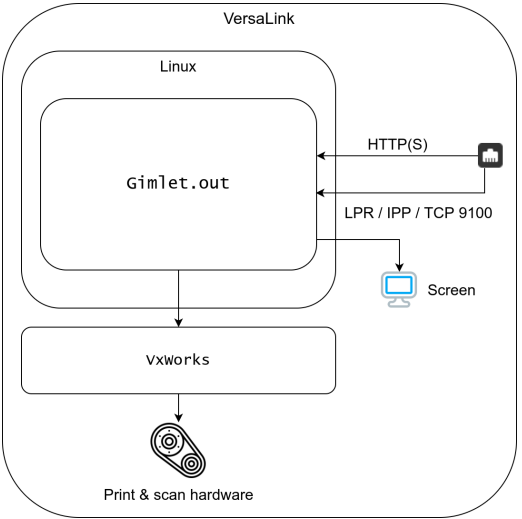
Main binary: `GimLet.out`

Some statistics:

- ~120MB (depending on model)
- 250k functions
- Biggest function is 150KB

Functionalities:

- Handles *everything*:
  - Scanning, printing
  - SMB client
  - Web Server
  - etc.
- Runs as `root`



VersaLink components

Reverse engineering

IDA struggles a bit:

- Partly written in C++
- “no” Xrefs because IDA does not handle this pattern:

```
.text:041384CC          MOV             R0, #0xF310
.text:041384D0          MOV             R1, #0xF740
.text:041384D4          MOVT            R0, #0x7A3
.text:041384D8          MOVT            R1, #0x7A3
```

- Ask Hex-Rays support -> will not be implemented (it was in 7.5)
- Must use the decompiler to have meaningful info

Methodology:

- Look at strings
- Produce full C file
- `grep`
- Look at decompiled code

Backdoor URLs

`https://HOST/backdoor.cmd`:

- Recover information on printing jobs
- Get job memory dump: lot of info leaking
- Get job file:
  - directory traversal allows anyone to recover small files (up to ~200KB) on the filesystem

`https://HOST/nananana/nananana.cmd`:

- Generate and recover diagnostic logs
- LOTS of information:
  - Internal OS info
  - Crashes, including registers and stack traces
  - etc.

Both require authentication, with an hardcoded account

Buffer overflows in HTTP server

Vulnerabilities:

- Several classical stack based buffer overflows in the backdoor argument parsing:

```
if (get_arg_value(v2, "TYPE", &arg) != -1 &&
    atoi(&arg.value, &type_val) == -1) {
    http_res_code = 400;
    strncpy(s, arg.value, arg.len); /* <-- overflow here */
...
```

- Small problem for the attacker: the overflowing data *must* be valid UTF-8

Exploitation:

- No stack cookies
- No ASLR
- Huge binary
- It's possible to find UTF-8 valid addresses to do a `ret2libc` attack:
  - `bash` connect-back

Clone files

Characteristics:

- Must be submitted through the web UI, after authentication
- AES encrypted Zip, with a hardcoded key and a random IV
- Configuration is stored in AES-256-CBC encrypted JSON files (hardcoded key and IV)

Once decrypted:

- passwords are in plain text

Command injection vulnerability:

- Some file names present in JSON files are handled without sanitization
- Shell command injection as root
- A big payload can be included in the Zip file

Xerox coordinated disclosure

Disclosure status:

- Reported all vulns (backdoor, BOF, Clone files RCE) in July 2019
- Pre-release sent in April 2020:
  - *Disables* the backdoor by default
  - Fixes the buffer overflows
  - Invalid fix for the clone files RCE
  - Adds firmware encryption
- Final release XRX20-K in June 2020 (a year later)

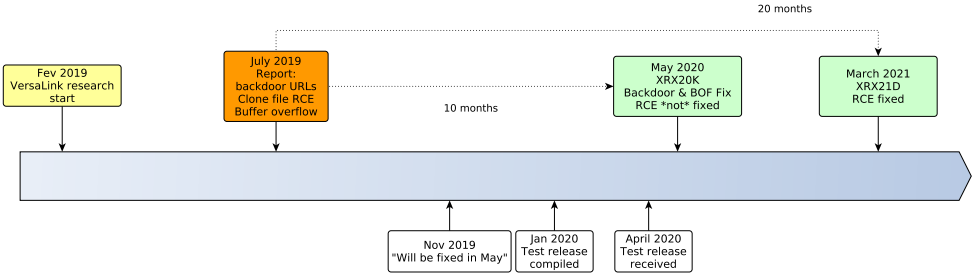
Clone file RCE:

- Finally fixed on March 5 2021 (XRX21D).
- Insecure `system` call to `unzip` replaced by a full *embedded* copy of `unzip`

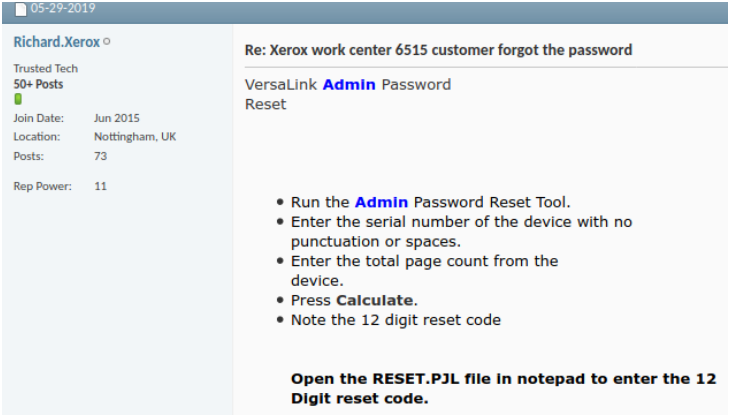
Fixing woes:

- All the development is done by Fuji
- Xerox is just a proxy

VersaLink timeline



Oh, one last thing: one more backdoor!



Forum post on VersaLink reset

RESET.PJL? admin password reset.zip?

`Admin Password Reset Tool.exe`:

- Checks if some Xerox software is present
- Coded in Visual Basic 6

`RESET.PJL`:
`@PJL SET JOBATTR="@RSAP=XXXXXXXXXXXX"`:

- Reverse `RSAP` handler in `GimLet.out`
- Trivial arithmetic to compute unlock code

→ Python script which uses SNMP to get printer counter and serial and resets the admin password to `1111`

Post exploitation

Documents exfiltration

Increased challenge: *secure erase* function

- Two modes: scheduled or right after document print/scan
- Actual file data is overwritten several times in as soon as the job is complete

Stealing docs on the fly:

- Need to win the race against secure deletion:
  - File is overwritten, not just deleted
  - Actual data copy is needed
- How?
  - `inotify` to watch for creation
  - Multi-threaded file copy
  - Use SMTP to send documents
- On-disk file formats:
  - Mostly PDF/PS
  - Proprietary compressed format for VersaLink scans (not RE'd yet)

Tips for the Blue Team

Securing them

Basic stuff:

- Restrict access to administration ports (Web, SNMP) from the LAN
- Disable “installing clone files through printing”
- Disable “Remote control panel” access or restrict it to admins only
- Change the default password, use network auth if possible (Kerberos)
- Use secure protocols: SNMPv3, TLS, etc.
- Keep them up to date!
- Collect logs (SFTP cron, or through fleet management) and check for:
  - backdoor accounts logins
  - password resets (VersaLink)
  - clone events
- Read and apply the security guide

Wait for Xerox to improve security:

- Security improvement planned in future products:
  - Password hashing
  - Hardware root of trust
- Tell them you care about (actual) security!

Last words

Time spent:

- Initial research: 40 person-days
- Diffing of updates and exchanges with Xerox: ~15 days
  - Check out diffware for a really useful tool by Jean-Romain Garnier

But there is still a *lot* to look at.

Big thanks to my colleagues for their contributions to the research:

- Benoît Camredon
- Xavier Mehrenberger
- Julien Lenoir
- Jean-Romain Garnier

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- Twitter: `_trou_` (personal account)

References

- Xerox security bulletins: `https://security.business.xerox.com/en-us/documents/bulletins/`
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- AltaLink B8090 service manual: `https://yadi.sk/i/ckgNGb78d94Cxg`
- Security information for VersaLink C405: `https://security.business.xerox.com/en-us/products/versalink-c405/`
- VersaLink C405 service manual: `http://files.xdigital.com.br/Manuais/Xerox/C400/VersaLink%20C400_C405%20Service%20Manual.pdf`