swimming with the kubectl fish

the why, the how, the what of the CNCF Kubernetes Assessment

git blame

```
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WARNING: DEAF
WARNING: Noo Yawk
```

outline

1. intro
2. outline
3. takeaways
4. the why: audit objectives
5. the how: modeling & assessing large FLOSS
6. the what: selected vulns

takeaways

1. large, heterogeneous codebase (~3.7m SLoC)
2. developers have different threat model than yours
3. lurking assumptions, threats, and vulnerabilities

github.com/trailofbits/audit-kubernetes

the why

- Cloud Native Computing Foundation (CNCF)
- Linux Foundation project
- "owns" k8s
- promotes containers
- first *code level* public audit
    - & TM, whitepaper, reference impl...

the why: audit objectives

- meant to find new bugs
- desired result?
  - low hanging fruit
  - threat model
  - relatively secure base configuration

the why: anti-objectives

- "red team" (adversary) lateral movement w/o novel bug
- Helm/Brigade/kops/Whatever bugs
- cloud-provider specific bugs
- previously-known issues
- that means
  - novel bugs
  - open source system
  - with many eyes & users
  - within base k8s

the why: results

- a security review: 37 findings
- a threat model: 17 findings + control analysis
- a white paper: ergonomics of k8s

the why: empower other researchers

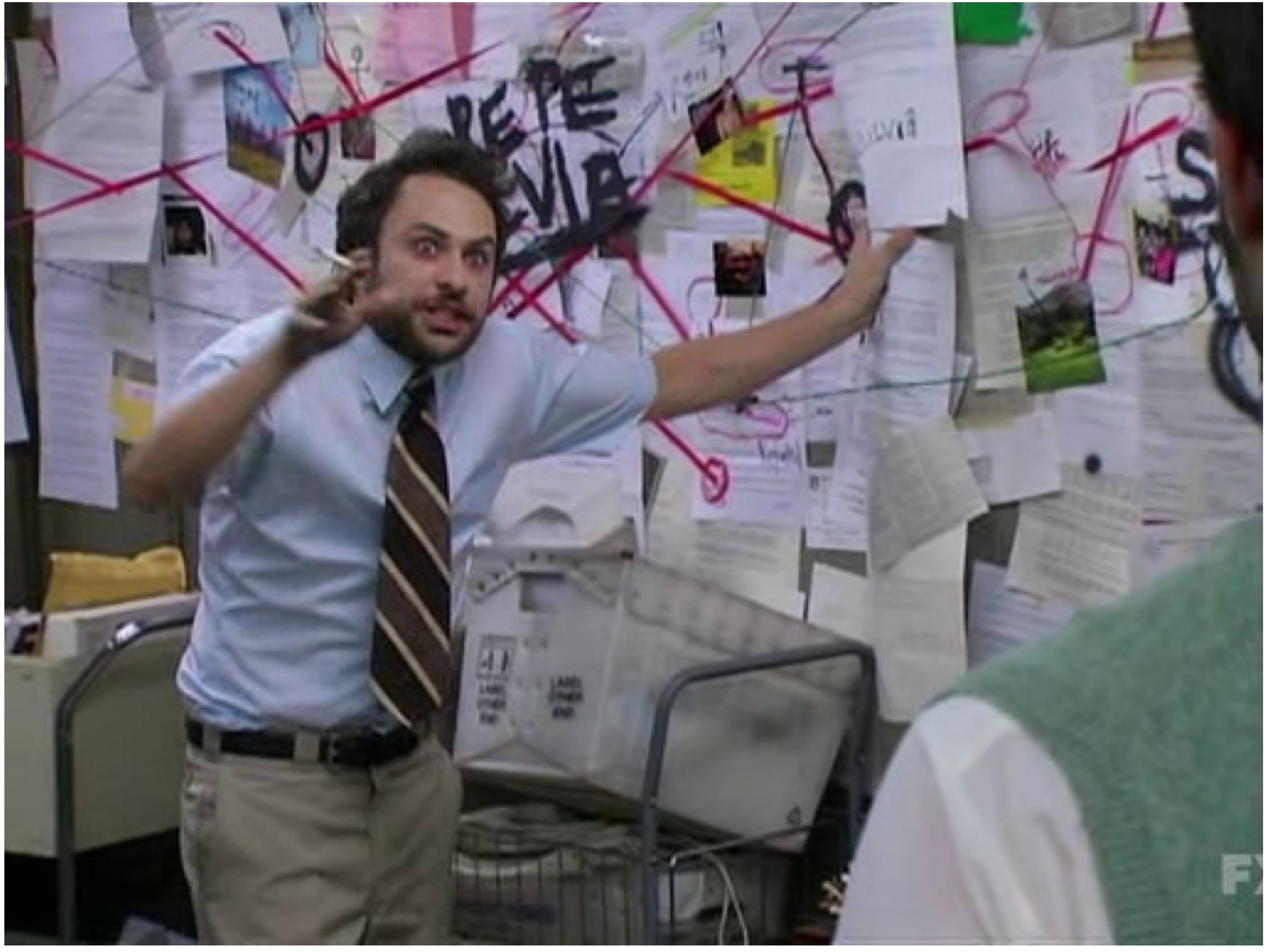
- more-complete data flow, control analysis, & threats
  - CNCF's SIGSEC
- areas where more bugs lurk
  - Nico Waisman's integer-width bug hunt with Semmle
- direction for k8s devs
  - Craig Ingram mapping all findings to GH issues
  - GKE mapping the findings to GKE's own controls
- future audits

the how

- easily a more interesting part
- unique tooling & ideas
- lots and lots of ~~RipIt~~ Code Reading

the how: interesting stats

- subcomponents: kube-apiserver, etcd, KCM/CCM, kube-scheduler, kubelet, kube-proxy, CRI
- control families: authentication, authorization, cryptography, secrets management, networking, "multi-tenancy"
    - last one was a hard one
- against k8s 1.13.4
- All told? 2.7+ mSLoC Go, 126+ kSLoC C, &c.



the how: the problems

- go static analysis tools are a mixed bag
- minimal tooling specifically for k8s at a code level
- enormous code base
- with lots of components, styles, companies...
- minimal dataflow, connection analysis, &c.

the how: top level approach

1. Kubernetes in Action + Running Clusters
2. container sec class
3. "Kubernetes Clusters I have Known and Loved"
4. prep the code into `audit-kubernetes`
    i. https://github.com/trailofbits/audit-kubernetes

the how: code

- mainly manual: lots of `ack` (me) or Goland (normal people), some code indexing
- internal checklist of golang problems
- minimal: govet, gosec, errcheck (actually did help to kickstart)
- `hypothesis => stare at code => ... => profit`

the how: code (part deux)

sidebar if I had to again:

- ~~use signal, use tor~~ use Semmle, use Custom Golang tooling
- Nico has found 24 more instances of bugs with simple searches in Semmle
- More kernel faulting via krf

the how: threat modeling

- I use a slightly-different approach
  - Brian Glas (@infosecdad) & I have worked on for ~10 years
- Controls, Data, Gaps, Inherited Controls... all par for the course
- NEW Mozilla Rapid Risk Assessment (RRA) docs

the how: threat modeling FLOSS?

- what do we need in threat modeling?
  - ~~defined users~~ distributed user base
  - ~~responsible devs~~ distributed, unpaid dev base
  - ~~business direction~~ minimal overarching purpose

the how: threat modeling FLOSS

1. design rough dataflow
    i. k8s docs aren't fun
    ii. k8s in Action, but slightly out of date
2. talk with developers
3. write up notes (lives on GitHub)
4. report threats, control analysis, &c.

the how: talk with developers

1. Pre-fill RRAs
2. Email SIGs for meetings
3. Meeting with Devs
4. Send RRA documents back to SIGs for PR
5. Iterate
6. Write Report

https://github.com/trailofbits/audit-kubernetes/commits/master/notes/stefan.edwards/rra

the what: 3 things

1. devs have widely varied skill-levels & backgrounds
2. Linux interfaces are non-trivial to code against
3. preponderance of (policy) choice

the what: devs

- devs come from a wide background
- what does this do?

```
        v, err := strconv.Atoi("4294967377")
        g := int32(v)
        fmt.Printf("v: %v, g: %v\n", v, g);
```

the what: devs

- Issues?
  - Unsigned to Signed
  - Wrong Width: `$GO_ARCH` -specific width to 16/32/64 bits
  - Both: many flows of `strconv.Atoi` => `int16`
- devs may not have background on machine-width ints
- TOB-K8S-015 & Appendix B

the what: devs

- We found a number of flows from Incorrect Widths/Sign
- Nico Waisman (of Semmle) found *many*

```
if len(s) > 1 && (s[0] == 'E' || s[0] == 'e') {
parsed, err := strconv.ParseInt(string(s[1:]), 10, 64)
        if err != nil {
                return 0, 0, DecimalExponent, false
        }
        return 10, int32(parsed), DecimalExponent, true
}
```

the what: devs

- a wide range of audit/logging backgrounds
- high security vs standard applications
- end result?
  - TOB-K8S-001: Bearer tokens are revealed in logs
  - TOB-K8S-026: Directory traversal of host logs running kube-apiserver and kubelet
  - TOB-K8S-007: Log rotation is not atomic
  - TOB-K8S-TM05: Credentials exposed in environment variables and command-line
  - TOB-K8S-TM06: Names of secrets are leaked in logs

the what: devs

- devs often do not have context between items
- diff components have diff devs
- innocuous code leads to problems

```
if rt.levels[debugCurlCommand] {
   klog.Infof("%s", regInfo.toCurl())
}

if rt.levels[debugRequestHeaders] {
   // ...
}
```

the what: devs

- we need logs!
- logs are hard coded to go to "/var/log"
- we need to see & display logs
- what else lives in /var/log?

the what: devs

- innocuous code:

```
func logFileListHandler(req *restful.Request,
resp *restful.Response) {
        logdir := "/var/log"
        http.ServeFile(resp.ResponseWriter,
        req.Request, logdir)
   }
```

```
# curl -k -H "Authorization: Bearer $MY_TOKEN" "https://172.31.28.169:10250/logs/"
<pre>
<a href="alternatives.log">alternatives.log</a>
<a href="amazon/">amazon/</a>
<a href="apt/">apt/</a>
<a href="auth.log">auth.log</a>
<a href="auth.log.1">auth.log.1</a>
<a href="btmp">btmp</a>
<a href="cloud-init-output.log">cloud-init-output.log</a>
<a href="cloud-init.log">cloud-init.log</a>
<a href="containers/">containers/</a>
<a href="dist-upgrade/">dist-upgrade/</a>
<a href="dpkg.log">dpkg.log</a>
<a href="journal/">journal/</a>
<a href="kern.log">kern.log</a>
<a href="kern.log.1">kern.log.1</a>
<a href="landscape/">landscape/</a>
<a href="lastlog">lastlog</a>
<a href="lxd/">lxd/</a>
<a href="pods/">pods/</a>
<a href="syslog">syslog</a>
<a href="syslog.1">syslog.1</a>
<a href="syslog.2.gz">syslog.2.gz</a>
<a href="syslog.3.gz">syslog.3.gz</a>
<a href="syslog.4.gz">syslog.4.gz</a>
<a href="syslog.5.gz">syslog.5.gz</a>
<a href="syslog.6.gz">syslog.6.gz</a>
<a href="syslog.7.gz">syslog.7.gz</a>
<a href="tallylog">tallylog</a>
<a href="unattended-upgrades/">unattended-upgrades/</a>
<a href="wtmp">wtmp</a>
</pre>
```

the what: devs

- k8s uses many files
- k8s does not have standard routines for permissions nor a model
- TOB-K8S-004: Pervasive world-accessible file permissions

the what: devs

```
cluster/images/etcd/migrate/data_dir.go:49:
err := os.MkdirAll(path, 0777)
cluster/images/etcd/migrate/data_dir.go:87:
err := os.MkdirAll(backupDir, 0777)
```

the what: devs

- not picking on etcd
  - logs
  - credentials
  - other info
- you must pay attention to operational concerns
  - no on is coming, it's up to us

the what: linux

- k8s runs "pods"
- containers are a lie
- theory: containers are separation boundaries
- reality: namespaces + cgroups + ... = same kernel
- let's look at cgroups

the what: linux

- resource allocation/specification
- hierarchical model of groupings
- sometimes moved
- Issues?
  - TOB-K8S-022: TOCTOU when moving PID to manager's cgroup via kubelet
  - TOB-K8S-021: Improper fetching of PIDs allows incorrect cgroup movement

the what: linux

- TOB-K8S-022 allows privesc
- Attacker can now read/write host devices
  - ... limited by AppArmor now

the what: linux

- PIDs are also hard, ala TOB-K8S-022
- But so is `procfs` in general
- What does this code do?

```
func isKernelPid(pid int) bool {
        _, err := os.Readlink(fmt.Sprintf("/proc/%d/exe",
        pid))
        return err != nil
}
```

the what: linux

- kernel threads not expected to have a `/proc/$PID/exe`
- We can cause `os.Readlink` to fail
- Now you're a kernel PID...

the what: linux

- seccomp?
- limits syscalls (or filters with bpf)
- used by docker, &c for security
- use of `unconfined` generally a vuln
    - TOB-K8S-002: Seccomp is disabled by default

the what: linux

- Linux APIs are hard
- misconfigured or unapplied

the what: policy

- Kubernetes allows us to apply policies
  - Think PSP & NetworkPolicy
- two main issues:
  - application silently fails
  - can have complex failure modes

the what: policy

- PodSecurityPolicy (PSP)
- restricts service accounts
- validation error
- good... right?

the what: policy

- was disabled
- no warning
- result?
  - I've created a strong policy...
  - with no application

the what: policy

- NetworkPolicy too
- restricts ingress/egress
- sets up inter-pod comms
- oops! chose a CNI that doesn't apply NetworkPolicy
- TOB-K8S-TM01: Policies may not be applied

the what: policy

- besides silent failure...
- complex failure mode
- Many, many components
- they manage & interact in odd ways
- for example

the what: policy

- where do we restrict? complex interactions
  - AuthN? AuthZ? AC? PSP? WebHook?
- mo Scope, mo problems
- PSP includes validation for `hostPath` BUT
- PSP's inclusion leads to `hostPath` validation bypass
- So, add security, get a vuln (TOB-K8S-038)

Thanks!

- wild ride, thanks for joining
- Questions?