Write Once, Shell Everywhere: Turning Arbitrary File Writes into RCE

Write Once, Shell Everywhere: Turning Arbitrary File Writes into RCE - André Baptista, Rafael Castilho, Bruno Mendes, Ethiack.

- Published: date not stated
- Original: <https://ethiack.com/info-hub/research/write-once-shell-everywhere-arbitrary-file-writes-into-rce>
- Preserved from: https://ethiack.com/info-hub/research/write-once-shell-everywhere-arbitrary-file-writes-into-rce (stored) on 2026-08-14
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Content

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Write Once, Shell Everywhere: Turning Arbitrary File Writes into RCE

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Two things are in the attacker's hands here. **Path control**, so you choose where the bytes land. And **content control**, so you choose what the bytes are. One request, write anything, anywhere.

And then comes the question that decides whether the report gets triaged as a critical or quietly closed as informative: what is the actual impact? This research was independently conducted and presented by André Baptista (@0xacb), Rafael Castilho (@Castilho) and Bruno Mendes (@s3np41k1r1t0).

Arbitrary file writes (AFW) have a reputation for being awkward to escalate. The write itself is trivial to demonstrate, but the jump from "I can drop a file anywhere" to "I am executing code" is where most reports go to die. The public literature is a pile of individual tricks scattered across blog posts, CTF writeups and cheatsheets, and almost all of it quietly assumes a traditional server: a shell that somebody will eventually log into, a cron daemon, a full init system, an SSH server, a package manager. A lot of what we test today looks nothing like that. It is a distroless container running a couple of processes, with no cron, no SSH, no interactive login, a mostly read-only root filesystem and a userland stripped down to the application and its runtime.

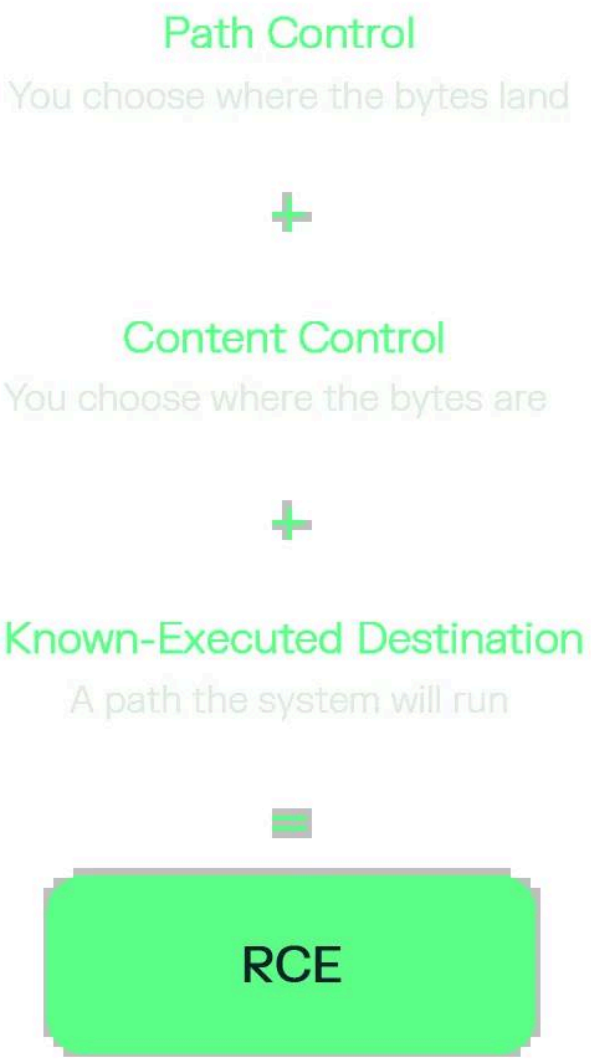
So we decided to do the boring, systematic work: catalog what actually exists, grade how useful each technique really is, and then go looking for what is missing. This blog post is the written version of our **Write Once, Shell Everywhere** talk we gave at Defcon 34's Bug Bounty Village, and it comes in three parts:

- A **catalog** of the current state of the art for turning arbitrary file writes into remote code execution.
- **Environment fingerprinting** - how to turn the write itself into a read primitive, so you stop guessing.
- A couple of specific techniques that need **almost no guessing at all**, which work against exactly the stripped containers where everything else fails.

Let's get started.

The Not So Secret RCE Formula

Every AFW-to-RCE chain we have ever written reduces to the same three ingredients:



The first two terms come free with the bug. The third term is the entire game, and it is the one nobody hands you. Finding a **known-executed destination** means knowing something concrete about the machine on the other end: which operating system, which distro, which language runtime, which version of that runtime, whether it is containerised, and which of those paths are both writable by your process and re-read by something that will run them.

In a white box test you look this up. In a black box test you guess, and every wrong guess is a failed write against a target that is very possibly logging you.

The Shape of a Write Primitive

Before hunting for a destination it is worth grading the primitive you actually have, because "arbitrary file write" covers a very wide range of quality. We found it useful to score every write

along four dimensions:

Destination control

Fully controlled

Forced prefix

Fixed path

Content control

Not verified

Relaxed MIME checks

Strictly verified

Filename control

No constraint

Forced prefix

Forced suffix

Write mode

Overwrite

Append

Create-exclusive

A few of these deserve a comment, because they quietly kill or enable entire technique families:

- **A forced suffix** is usually worse than a forced prefix. A forced /uploads/ prefix still leaves you a whole subtree to traverse out of; a forced .jpg suffix eliminates every technique that depends on the target having a specific name the runtime looks for.
- **Append-only** rules out overwriting binaries and bytecode, but it is perfectly fine for anything line-oriented - shell profiles, authorized_keys, /etc/passwd, cron files, .user.ini. A surprising number of the best targets are plaintext and newline-terminated, which is not a coincidence.
- **Create-exclusive** (the write fails if the path already exists) looks like the worst case, and for exploitation it mostly is. Hold that thought, though - a primitive that reliably fails on existing files is a very clean existence oracle, and we come back to that in the fingerprinting section.

Content control is the one people over-estimate. "Strictly verified" rarely means the file is safe; it usually means the file must be a valid image, or valid JSON, or valid YAML. Plenty of execution sinks are perfectly happy to run a file that also happens to parse as something else, and formats like YAML bring their own deserialisation gadgets to the party.

However, for simplicity sake, during this blog post we assume that we have a file write with the most desirable conditions.

State of the Art: How We Currently Escalate

Before adding anything new, we wanted an honest map of what already exists. The first thing that becomes obvious is that there is no single answer, because the execution context changes everything:

Where does it run?

Linux · Windows · macOS

How is it deployed?

Bare metal · VM · Docker container · Kubernetes pod

What kind of app?

Compiled (Go, Rust) · Interpreted (Python, Ruby, PHP, Node.js)

Behind what?

Flask · Django · Rails · Laravel · Apache · NGINX · Tomcat · IIS

Each row changes which paths are executed, when they are re-read, and which user does the executing. So we split the catalog the same way: first living off the operating system, then living off the language runtime, then living off the framework.

One column in every table below is deliberately subjective. **Usefulness** is our own grade for how often the technique actually pays off on a modern engagement - not how clever it is, and not how well-known it is.

Living Off The OS Land

If you decide to live off the OS rather than the application, you immediately inherit a hard requirement: you need some kind of assurance that you are running as root, because nearly every interesting path is root-owned. Beyond that, the documented techniques split into two disappointing categories. Most of them rely on **user interaction** - a login, a reboot, a crash, an SSH connection - or on **software that has been stripped out** of cloud-native images entirely, like cron, an init system, or sshd.

The only genuinely useful and universal technique we found documented is writing /etc/ld.so.preload.

Scheduled execution

/etc/crontab

Automatic

root-owned, not group/world writable

Plaintext, newline-terminated

Med

/etc/cron.d/*

Automatic

0644, root-owned

Plaintext

Med

/etc/cron.{hourly,daily, weekly,monthly}/

Automatic

+x, root-owned

Plaintext

Med

/var/spool/cron/ crontabs/<user>

Automatic

user-owned, not group/world writable

Plaintext

Med

Cron is the classic answer and it is still a good one on traditional VMs, where a daemon is sitting in the background waiting to run whatever you drop. It is close to worthless on modern container workloads, which do not run a cron daemon at all.

Init mechanisms

/etc/systemd/system/*.service

Reboot or daemon reload

0644, root-owned

Plaintext (INI unit)

Low

~/.config/systemd/user/*.service

User login

user-owned

Plaintext (INI unit)

Low

/etc/init.d/* /etc/rc.local

Reboot

+x, root-owned

Plaintext (shell script)

Med

Systemd units score badly for a practical reason: a unit file alone is not enough, you also need the symlink that systemctl enable would have created, and you need something to reload the daemon

or reboot the server. Same story as cron. It's useful against legacy infrastructure, defeated by anything cloud-native.

Dynamic linker and PAM

/etc/ld.so.preload

Every new process

root-owned

Plaintext list + ELF .so

High

/etc/ld.so.cache

Every new process

root-owned

Binary cache + ELF .so

Med

/etc/pam.d/*

Next authentication

root-owned

Plaintext + ELF .so module

Med

This is the standout of the whole OS section. /etc/ld.so.preload triggers on **every new process**, which means you do not need a login, a reboot, a crash or a daemon. You just need the target to execute anything at all. It does cost you a second write, since you need the shared object on disk too, which can be a problem if you are facing a load balancer that splits traffic between multiple containers.

ld.so.cache is strictly worse for our purposes: it needs the same permissions as ld.so.preload but it is a binary format, while preload is a plaintext list of paths. Given the choice, always take the plaintext one.

Shell and login

~/.bashrc ~/.bash_profile · .bash_login · .profile ~/.bash_logout · ~/.zshenv

User login

user-readable

Plaintext (shell script)

Med

/etc/bash.bashrc /etc/zsh/zshenv

User login

root-readable

Plaintext (shell script)

Med

/etc/profile /etc/profile.d/*.sh

User login

root-owned

Plaintext (shell script)

Med

Every one of these targets a legacy infrastructure assumption: that a human being will eventually log in and give you your shell. Nobody will log in into a Kubernetes pod. Trust us.

SSH and environment

~/.ssh/authorized_keys

No trigger (you connect)

user-owned

Plaintext

Med

~/.ssh/rc

SSH connection

user-owned

Plaintext (shell script)

Med

/etc/ssh/sshrc

SSH connection

root-owned

Plaintext (shell script)

Med

~/.ssh/environment

SSH connection

600, user-owned

Plaintext

Med

/etc/passwd

No trigger (you log in)

root-owned

Plaintext

Med

/etc/environment

Next login

root-owned

Plaintext

Med

authorized_keys is the nicest of the bunch, because it is the rare technique with no trigger. You supply the trigger yourself by connecting. Its weakness is the precondition: sshd has to be installed, running and reachable from where you are. Typical in traditional infrastructure, and once again defeated by cloud-native deployments.

Kernel usermode helpers

/proc/sys/kernel/core_pattern

Any process crash

root-writable knob

Plaintext + executable payload

Med

/proc/sys/kernel/modprobe

Module request by the kernel

root-writable knob

Plaintext + executable payload

Low

/sys/kernel/uevent_helper

Write to /sys/class/mem/null/uevent

root-writable /sys

Plaintext + executable payload

Med

These are elegant and they are also the first thing a container hardening baseline takes away from you. procfs is only writable by root, and inside a container it is a read-only bind mount unless somebody has explicitly configured it otherwise. If core_pattern is writable from inside your container, you have a container escape and suddenly it gets much more interesting than just another RCE report.

Living Off The Language Runtime

Moving up a layer helps, because the language runtime is present by definition. It is code that is running the application you are exploiting. The problems here are different:

- Most techniques involve **some degree of guessing**: which package names get imported, which template names exist, which cache directory is in use, which minor version of the interpreter is installed.
- Several still rely on **crashing the server** and hoping the supervisor restarts it, so the execution environment reloads and picks up your file.
- There are genuinely good gadgets hiding in here, though, and PHP has the best of them.

Python

*.pth

Interpreter start

Writable site directory

Plaintext

Med

sitecustomize.py usercustomize.py

Interpreter start

Writable sys.path or user-site dir

Plaintext (Python)

Med

.pyc in **pycache**

Module import

Writable **pycache** dir

Bytecode (.pyc)

Med

init.py

Package import

Writable package directory

Plaintext (Python)

Med

site-packages/…

Module import

Writable site directory

Plaintext (Python)

Med

<module>.so <module>.abi3.so <module>.cpython-3XX-*.so

Package import

Writable package directory

Binary (native extension)

Med

.pth files are the underappreciated one. Any line in a .pth file inside a site directory that starts with import gets executed at interpreter startup, which makes it a plaintext, no-guessing-required execution sink (as long as you can write into a site directory and something starts a fresh interpreter).

PHP

*.php in the web root

Next request

Writable web root

Plaintext (PHP)

High

.user.ini

Next request

Writable subdirectory under document root

Plaintext (INI + PHP)

High

.htaccess

Next request

Any served dir, AllowOverride

Plaintext (+ PHP)

High

vendor/autoload.php

Next request

Writable vendor directory

Plaintext (PHP)

Med

OPcache file_cache

Next request

Writable file_cache dir

Binary (bytecode .bin)

Low

PHP remains the friendliest target in this entire post, mostly because the trigger is always just the next HTTP request and you never have to wait for anything. The two config gadgets are worth distinguishing: .user.ini only works under PHP-FPM and CGI, while .htaccess needs mod_php.

OPcache scores Low for a very specific reason: to forge a file_cache entry you need to match the build ID exactly. You need an MD5 over the PHP version, the Zend extension ID and the Zend binary ID and you also need to locate the cache directory. That is a lot of guessing for something a plaintext .php file does for free.

**Ruby and Node.js **

config/initializers/*.rb config/boot.rb config/application.rb

Process start

Writable config directory

Plaintext (Ruby)

Med

tmp/cache/bootsnap

Next require

Writable Bootsnap cache

Binary (ISeq bytecode)

High

node_modules/<mod>/index.js

Next require in a fresh process

Writable node_modules

Plaintext (JS)

Med

node_modules/<mod>/package.json

Next require in a fresh process

Writable node_modules

Plaintext (JSON)

Med

The Bootsnap cache technique published by Conviso is the most interesting entry in this table, and. It works, it targets tmp/cache/bootsnap which is commonly writable. But the cache key encodes the Ruby version, so you still need to know or brute-force which Ruby you are talking to, which was the motivation behind dedicating a whole section to explaining an oracle that turns writes into reads.

On the Node.js side, the naive version of the technique needs you to overwrite a module that has not been resolved yet, which limits it badly in a long-lived process.

Living Off The Framework

Frameworks are generous, because a lot of them were designed to pick up changes on disk without a restart. Auto-reload is a feature for developers and a trigger for us.

**Java and the JVM **

<appBase>/<app>/*.jsp

Next request

Writable web-served directory

Plaintext (JSP)

Med

WEB-INF/web.xml

WatchedResource auto-reload (~10s)

Writable WEB-INF directory

Plaintext (XML)

Med

WEB-INF/classes/*.class lib/*.jar

WatchedResource auto-reload (~10s)

Writable WEB-INF directory

Binary (.class / .jar)

Med

.war exploded into webapps/

WatchedResource auto-reload (~10s)

Writable webapps directory

Binary (WAR archive)

Med

conf/context.xml

WatchedResource auto-reload (~10s)

Writable conf directory

Plaintext (XML)

Med

GroovyScriptEngine script dir

Next run()

Writable script directory

Plaintext (Groovy)

Low

The auto-reload behaviour depends on autoDeploy=true, which happens to be the default. The nice consequence is that these combine: overwriting a .class file on its own may not take effect, but pairing it with a touch of web.xml forces a context reload and your class gets picked up.

.NET and IIS

web.config

Next request

Writable app directory

Plaintext (XML)

High

global.asax

Next request

Writable app root

Plaintext

High

bin*.dll

Next request

Writable bin directory

Binary (.NET DLL)

High

*.aspx

Next request

Writable webroot

Plaintext

High

views/*.cshtml

Recompiles on next render

Writable views directory

Plaintext (Razor)

Med

.NET on IIS is the best-scoring block in the catalog: four separate High-usefulness sinks, all triggering on the next request. Dropping a DLL in bin\ triggers an AppDomain restart, but you still have to either guess the name of a DLL that is actually loaded or write a web.config that references yours. This is why web.config and global.asax are the ones you should go for first.

Template engines

Twig cache

Next request

Writable cache directory

Plaintext (PHP)

Med

Jinja2 bytecode bucket

Next request

Writable cache/templates dir

Binary (marshalled bytecode)

Low

Velocity .vm

Next merge()

Writable templates directory

Plaintext

Med

Freemarker .ftl

Next request

Writable templates directory

Plaintext

Med

ERB .erb

Next request

Writable templates directory

Plaintext

Med

Template engines are a great trigger and a frustrating destination. The trigger is free, because the template gets read on the next render. The problem is that most of the time you need to guess both the cache or template directory and the name of a template that will actually be rendered. Twig is the exception worth remembering, because its cache entries are plaintext PHP.

WSGI and app servers

uWSGI .ini

Next reload

Writable .ini

Plaintext (INI)

Med

gunicorn.conf.py

Next reload

Writable CWD

Plaintext (Python)

Med

wsgi.py · manage.py · settings.py

Next restart

Writable app directory

Plaintext (Python)

Med

Apache .htaccess

Next request

Writable served dir + AllowOverride

Plaintext

Med

nginx conf

Next reload

Writable config directory

Plaintext

Low

One historical note that trips people up: AllowOverride has defaulted to None since Apache 2.3.9. The .htaccess trick is still excellent when it is available, but it is no longer something you can assume. And nginx scores Low because a config write is worthless without a reload, and nginx will not reload on its own.

But What About Black Box Scenarios?

Step back and look at the catalog as a whole and we can remember three uncomfortable conclusions:

- Most of the reliable techniques require a **high degree of guessing** - versions, package names, cache directories, template names.
- If you decide to live off the OS you need some kind of assurance that you are **running as root**, which in a container you usually do not have and cannot check.
- There are **not a lot of techniques that work reliably in cloud-native black box environments**, which is precisely where most of today's targets live.

Guessing is expensive and it is loud. Every failed write is a request that may be logged, rate-limited, or that flips a WAF into blocking mode. Which brought us to the observation that motivated the rest of this research.

A Write Is Also a Read

This whole section was built on an absolutely brutal paradox that has allowed us to achieve varying degrees of success: **an arbitrary file write is also an arbitrary path-probe oracle**, provided you can observe differences between a write that succeeded and a write that raised an error.

The reason this works is in the kernel. Path resolution walks the components left to right and **stops at the first component that fails**. The errno you get back leaks the existence, the type, and the writability of exactly that component. Success is not the only option (sorry Eminem). It will actually be most useful if it fails informatively.

One failed write answers three questions about a path:

- Does it exist?
- Is it a file or a directory?
- Can I write into it?

Chain enough of those together and you can profile the target: OS, whether you are in a container, the container runtime, the distro, the distro version, the language and the language version. At which point the "known-executed destination" term in the RCE formula stops being so much of a guess.

Building the Oracle

These are the conditions you can deliberately provoke, and what each one tells you:

Write into a chain that is incomplete

Some component is absent

ENOENT

Write into a directory that exists but is not writable

Directory exists, not writable by you

EACCES

Write to a path that is an existing directory

Name exists and is a directory

EISDIR

Descend through a file (FILE/<rand>)

Mid-path component exists and is a file

ENOTDIR

Exclusive-create over an existing name

Something exists at that exact path

EEXIST

Write below a directory lacking the search (x) bit

Directory exists, not traversable

EACCES

Write through a symlink loop

A symlink cycle exists there

ELOOP

Write onto a read-only mount

Path resolves but the mount blocks writes

EROFS

Write into a file with a large filename

File name exceeds the filesystem limits

ENAMETOOLONG

Collapsed into the only three verdicts that matter most for probing:

ENOENT

A component of PATH is missing

NOT EXISTS

EACCES

PATH exists, you lack write or search permission

EXISTS

EISDIR / EEXIST

The target name exists

EXISTS

ENOTDIR

A mid-path component exists and is a regular file

EXISTS (file)

Success

PATH exists and is writable

WRITABLE

You Will Rarely See errno

A verbose error message is the best case and, unfortunately, the rare one. Production targets wrap the write in a try/catch and hand you a generic error message, or in the worst case nothing at all.

That is far less fatal than it sounds. **The write still executed.** The exception it raised still steered the application down a different code path, and different code paths are observable from the outside. So you can stop looking for the errno directly and start using response metadata as a differential: status code, body length, latency, connection state.

HTTP status code

Success 2xx · Not Found 404 · Permission Error 403 · Other 500

Body length / content

The server may render different error pages depending how the write failed.

Connection state

An unhandled rejection may kill the worker but everything else still returns a response.

Application side effects

An unsuccessful write changes later behaviour in ways you can query.

The Good, the Bad and the Ugly Paths

The workflow is then just calibration. Let's take the simplest example which is the status codes. You send three probes whose outcome you already know, record the signature of each, and from then you can observe the differential between them and decide how they map out.

The Good Path

The Bad Path

*Signature: ENOENT = 404 *(/lolada does not exist.)

The Ugly Path

*Signature: EACCES = 403 *(/root exists but is not writable)

We now have signatures that match our errno and make the oracle possible: 200 means writable, 404 means the path does not exist, 403 means it exists but is locked. Every probe from here on is a lookup against the signatures you just recorded.

Layering the Oracle

With a working oracle, fingerprinting becomes an ordered decision tree. Each layer narrows the search space for the next, so you spend the fewest probes possible.

A

OS family

Linux or Windows?

ENAMETOOLONG

B

Execution context

Container? Runtime? Cloud or PaaS?

/.dockerenv, k8s SA dir, /var/task

C

Distro

Debian, RHEL, Alpine…?

Package-DB dir + legacy release file

D

Language

Python, PHP, Ruby, Node…?

Error dialect + install root

E

Language version

Minor or full patch?

Version-encoding directory

Let’s see this methodology in action below!

OS family and execution context

200-character UTF-16 filename (breaks the 255-byte filename limit on most Linux filesystems)

Linux vs Windows

/.dockerenv

Docker

/run/.containerenv

Podman

/var/run/secrets/kubernetes.io/serviceaccount

Kubernetes pod

/mnt/c

WSL (Windows host underneath)

/var/task (+ /var/runtime + /opt)

WSL (Windows host underneath)

/lib/modules AND /run/systemd/system both absent

Stripped container

The OS-family probe is our favourite, because it needs no knowledge of the filesystem layout whatsoever. Ask for a 200-character UTF-16 filename: Linux filesystems cap a single filename component at 255 bytes, so a name that is comfortably legal on Windows blows past the limit and comes back as ENAMETOOLONG.

The last row is the one that matters most in practice. /lib/modules and /run/systemd/system both being absent tells you that you are inside a stripped container. Which means you can stop wasting

requests on the entire cron, systemd, SSH and login half of the catalog before you have sent a single malicious payload at them.

Distros and Versions

The nicest thing we found while building this out is how many runtimes encode their exact version in a **directory name**. A directory name is exactly what an existence oracle is good at reading.

/var/lib/dpkg/status, /etc/lsb-release

Debian family, Ubuntu

/var/lib/rpm/ + /etc/{rocky,almalinux,centos}-release

RHEL family or clone

/lib/ld-musl-x86_64.so.1

Alpine (musl)

/var/lib/rpm/Packages vs /var/lib/rpm/rpmdb.sqlite

RHEL 8 (BDB) vs RHEL 9 (SQLite)

/usr/lib/python3.12 | 3.11 | 3.10

Ubuntu 24.04 | Debian 12 | Ubuntu 22.04

/usr/lib/php/YYYYMMDD (Zend API date)

Exact PHP minor - the mapping is 1:1 and compiled in

.venv, ~/.pyenv, .nvm, .rbenv, .rustup/versions/X.Y.Z

Full patch version, and decoupled from the distro

Two of these are worth calling out. The /usr/lib/php/YYYYMMDD directory is named after the Zend API date, which maps one-to-one onto a PHP minor version and is compiled into the binary. Therefore, a couple probes gives you the exact PHP minor, which is exactly the input the OPcache technique was missing. And the version manager paths are gold, because ~/.rbenv/versions/X.Y.Z hands you the full patch version of the runtime independently of whatever the base image claims. That is the guess the Bootsnap technique needed.

This list is incomplete but it is rather easy to spin the most default docker images for the different languages and frameworks and start looking for these patterns in there. You go get them!

Learning by Example

Put together, a handful of probes gets you a complete profile:

200-char UTF-16 filename

Exception

/.dockerenv

Exists

/lib/modules, /run/systemd/system

ENOENT

/var/lib/dpkg/status, /etc/lsb-release

Both exist

/usr/lib/python3.12

Exists

/lib/ld-linux-aarch64.so.1

Exists

Profile: Linux · Ubuntu 24.04 · aarch64 · glibc · stripped Docker · Python 3.12.

Six benign probes. No guessing. And crucially, the profile tells you which half of the catalog to throw away: stripped container means cron, systemd, SSH and login triggers are all dead, and Python 3.12 on Ubuntu 24.04 tells you exactly where site-packages lives.

** Minimal Guessing Techniques**

Having Fun with Bash

Fingerprinting removes the guessing. The next question we asked was whether there is a destination that needs no fingerprinting at all.

There is, and it comes from a detail of how shells read their own scripts. **Bash and dash keep the script open and read it lazily**, rather than slurping the whole file into memory. That means the script is held on a file descriptor for the entire lifetime of the process. And because the shell exposes low-numbered descriptors to the script itself, it has to move its own bookkeeping out of the way. Bash's manual is explicit that file descriptors greater than 9 "may conflict with descriptors the shell uses internally", so the interpreter relocates the script descriptor up out of reach:

- bash **fd 255**
- dash / sh **fd 10**

The result is a stable, predictable handle to the running script on the filesystem: /proc/<pid>/fd/255 or /proc/<pid>/fd/10. And for a container entrypoint, **that pid is 1**.

Because the shell re-reads the script on demand, writing through that descriptor rewrites the program that is currently running.

Why It Costs Nearly Zero Guesses

Compare that to everything else in this post. In a typical AFW-to-RCE chain you have to guess:

- the script's path on disk
- what software is even present
- probably need a victim to trigger it for you

A container with a bash or dash entrypoint always gives you one thing for free: **PID 1 is a live shell, and its script is reachable at a fixed descripto**. You never have to learn the script's path, because you never need it.

Bashing the Exploit Together

The mechanism is easiest to see under strace. Watch the shell read one command, run it, then seek back to pick up the next one:

That blocking sleep 30 is the whole exploit window. The shell has already committed to re-reading from offset 36, but it has not read it yet. Whatever bytes are at offset 36 when it comes back are the bytes that get executed.

The preconditions are rather short:

- The container has a bash or dash script as its entrypoint.
- The script is writable.
- You can break out of the currently running command (that is, the write happens while the shell is parked on something - e.g. the server processing your requests).

And the payload:

That newline flood is the true art of the deal. You do not know the exact offset the shell will resume reading from, and you do not need to: pad with enough newlines that wherever the cursor lands it walks harmlessly forward into your command. It is a NOP sled, in bash.

A Useful Example: File Parser in a Kubernetes Job

Here is the shape of a real target, where we found this to be the most desirable target for this gadget. A Kubernetes Job runs a pod whose entrypoint is /app/run.sh, so PID 1 is sh and the script is held on fd 10. Inside that script, a file parser processes untrusted input, and the parser is where the arbitrary file write lives.

The four steps:

- A malicious file is fed to the file parser, giving you the arbitrary file write.
- The write lands on /proc/1/fd/10, which is PID 1's own sh script.
- The parser exits and control returns to the sh entrypoint.
- sh reads fd 10, the next bytes are your payload, and you have RCE.

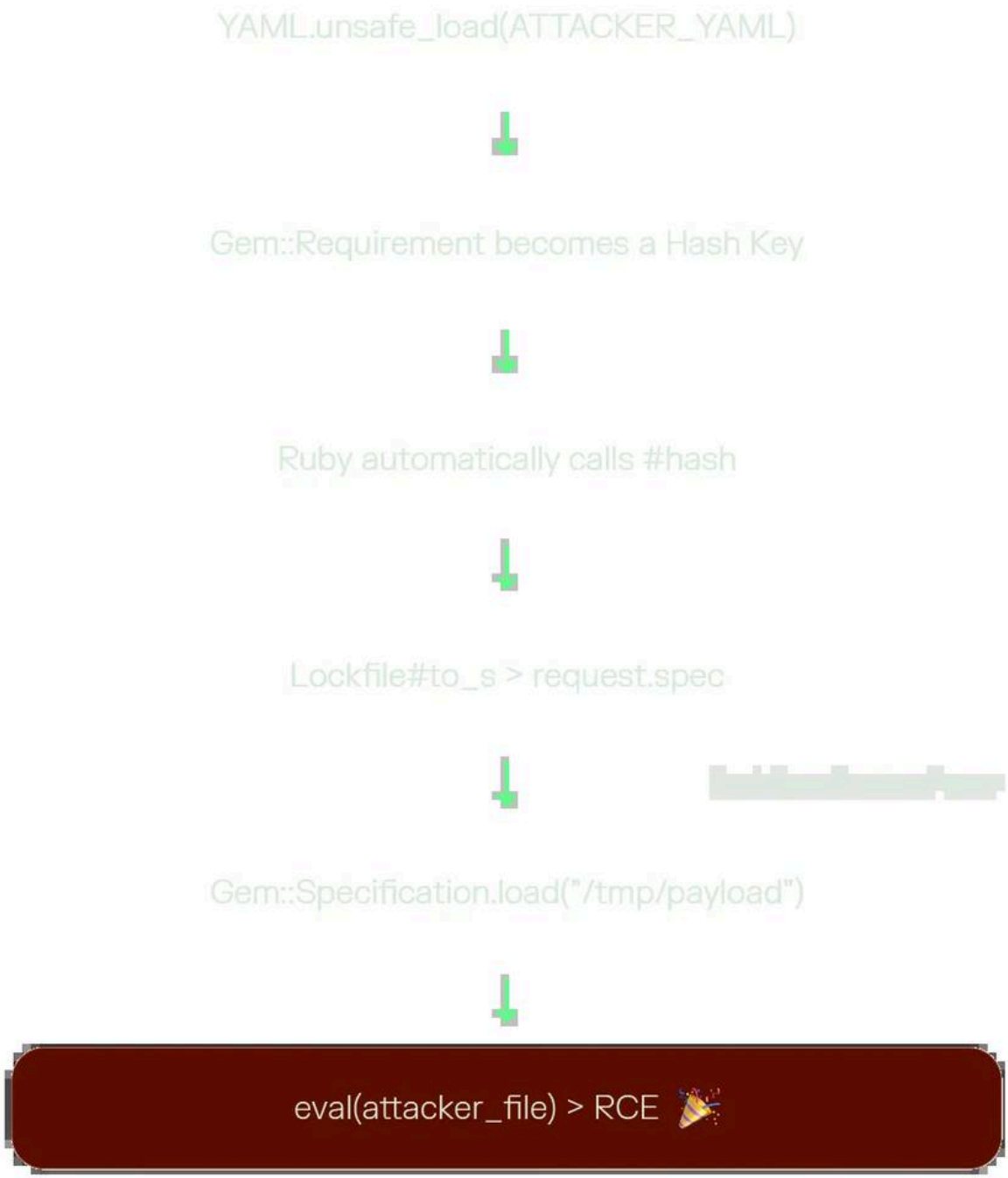
Ruby and schema_cache.yml

The second technique targets Rails, and it is a nice counterpoint because it works through a data file rather than a script.

db/schema_cache.yml is a snapshot of your database structure that Rails loads on boot to eliminate slow, repetitive database metadata queries. It is a performance optimisation, it lives in a

directory that is frequently writable, and Rails loads it with YAML.unsafe_load.

Unsafe YAML loading means the document is not restricted to plain data. It is allowed to construct arbitrary Ruby objects, which turns a file write into a deserialisation gadget hunt. The chain we land on:



Walking that through: the payload declares a Gem::Requirement as a **Hash key**, using YAML's explicit-key syntax. Ruby cannot insert an object into a Hash without hashing it, so it calls Gem::Requirement#hash for us . The attacker-controlled requirement causes Lockfile#to_s to run,

the Lockfile asks a malicious StubSpecification for its specification, and that calls Gem::Specification.load with a path we chose. RubyGems reads that file and evaluates it as Ruby.

Rails does eventually complain, because the result of the load is not a real SchemaCache - but the complaint comes after the eval. Execution has already happened by the time the error surfaces, which is a pattern worth internalising: an application error in the response is not evidence that your payload failed.

Note that this needs two writes: the YAML file and the Ruby file it points at. This is fine, since a write primitive you can use once you can usually use twice.

Make the Node.js Worker Do the Work

Earlier in the catalog we graded the obvious Node.js technique (overwrite node_modules/<module>/index.js) as mid, and the reason is the require cache. Once a module has been resolved and loaded, Node never reads it from disk again, so overwriting it does nothing to a process that is already running.

Workers do not have that problem. Node applications spawn new workers all the time, as a completely normal part of its operation. Each new worker loads its code **from disk**. So the question becomes obvious: what if we overwrite the worker.js?

The Path Is Deterministic

This is what makes it a minimal-guessing technique rather than another entry in the catalog. Worker pool libraries resolve the worker entrypoint relative to their own installation directory. Here is how Piscina is doing exactly that:

```
```

Because the path is anchored to the library's own __dirname, it is fixed by the **library's** layout, not the application's. You do not need to know the app's directory structure, its module names, its entrypoint, or anything else about how it was written. You only need to know which pool library is sitting in node_modules.

These are the ones we mapped:

Piscina

/piscina/dist/worker.js

thread-stream

/thread-stream/lib/worker.js

Tinypool

/tinypool/dist/entry/worker.js /tinypool/dist/entry/process.js

jest-worker

/jest-worker/build/threadChild.js /jest-worker/build/processChild.js

Two of those have two paths each, for the same reason. **Tinypool** supports both worker threads and child processes, and **jest-worker** defaults to child processes but can be configured to use

worker threads. Rather than fingerprint which mode is in play, just overwrite both files and cover either one.

Overwriting worker.js

The exploitation flow is four steps:

- Overwrite node_modules/piscina/dist/worker.js with your payload.
- The pool decides it needs a new worker: load went up, a worker crashed, or a worker hit its recycle limit.
- Piscina spawns one, resolving that same deterministic path.
- Node loads your file from disk and executes it. Boom! RCE

The preconditions are short and, in practice, common:

- The application uses a worker pool library.
- node_modules is writable.
- A new worker gets spawned (which you can simply wait for, or induce by generating enough load to make the pool scale).

That third precondition is the one worth dwelling on. Every other Node technique in this post needs the process to restart, which means you need a crash and a supervisor process to restart the application. Here you need the pool to do the thing it was installed to do. On a busy application you do not have to trigger anything at all. You just overwrite the file and wait for it to run your code for you.

Final Remarks

Arbitrary file write is not a medium severity vulnerability

If there is one thing to take away, it is that the severity of an AFW is a function of how much you know about the target, not of the primitive itself. The same bug is a low-impact file drop against an opaque black box and a root shell against a machine you have profiled. The gap between those two outcomes is reconnaissance, and reconnaissance is something you can automate. We hope that we are unveiling the veal to something much bigger that can be extended to all the execution contexts a reader may imagine.

For defenders

The mitigations that actually move the needle here are unglamorous:

- **Never let user input reach a file write sink.** Generate filenames server-side, resolve the final path and verify it is still inside the intended directory before writing. Canonicalise before you validate, not after.
- **Make the filesystem read-only.** A read-only root filesystem with a small tmpfs for scratch defeats most of this catalog outright, and EROFS is a much better outcome than a successful write.

- **Do not run as root, and do not run as PID 1 with a shell.** Using exec in your entrypoint, or an init shim rather than a long-lived shell script, removes the /proc/1/fd technique entirely. Combined with a non-root user, the OS half of the catalog disappears.
- **Assume error messages are an oracle.** Return one generic response for every filesystem failure. If your responses are distinguishable, you are answering questions about your own filesystem layout.

Hope you enjoyed it, see you next time space cowboy!

References

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