LLVM Supply Chain Security

From Developer's Desk to User's Device

Tom Stellard
Red Hat

Red Hat

What is Supply Chain Security?

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Example: Lock Company

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Example: Lock Company

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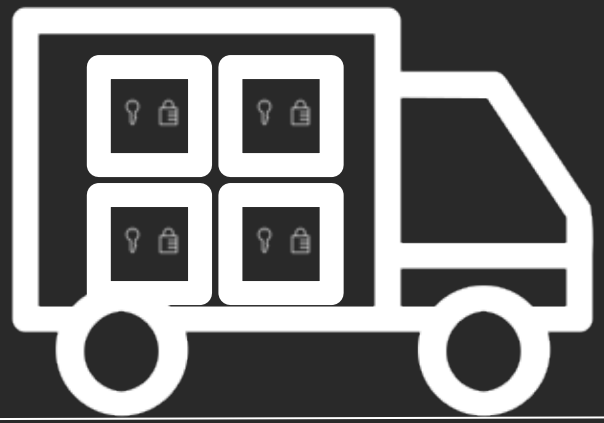
Example: Lock Company



Red Hat

What does our software supply chain look like?

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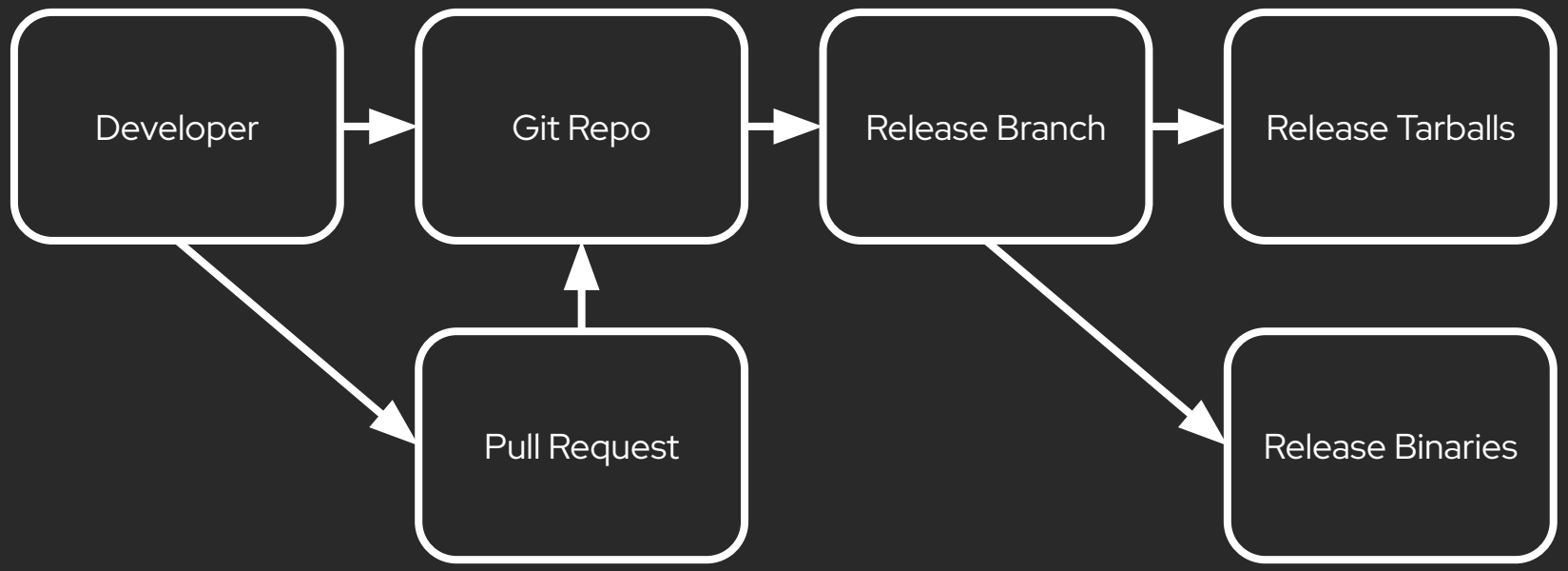
LLVM Supply Chain



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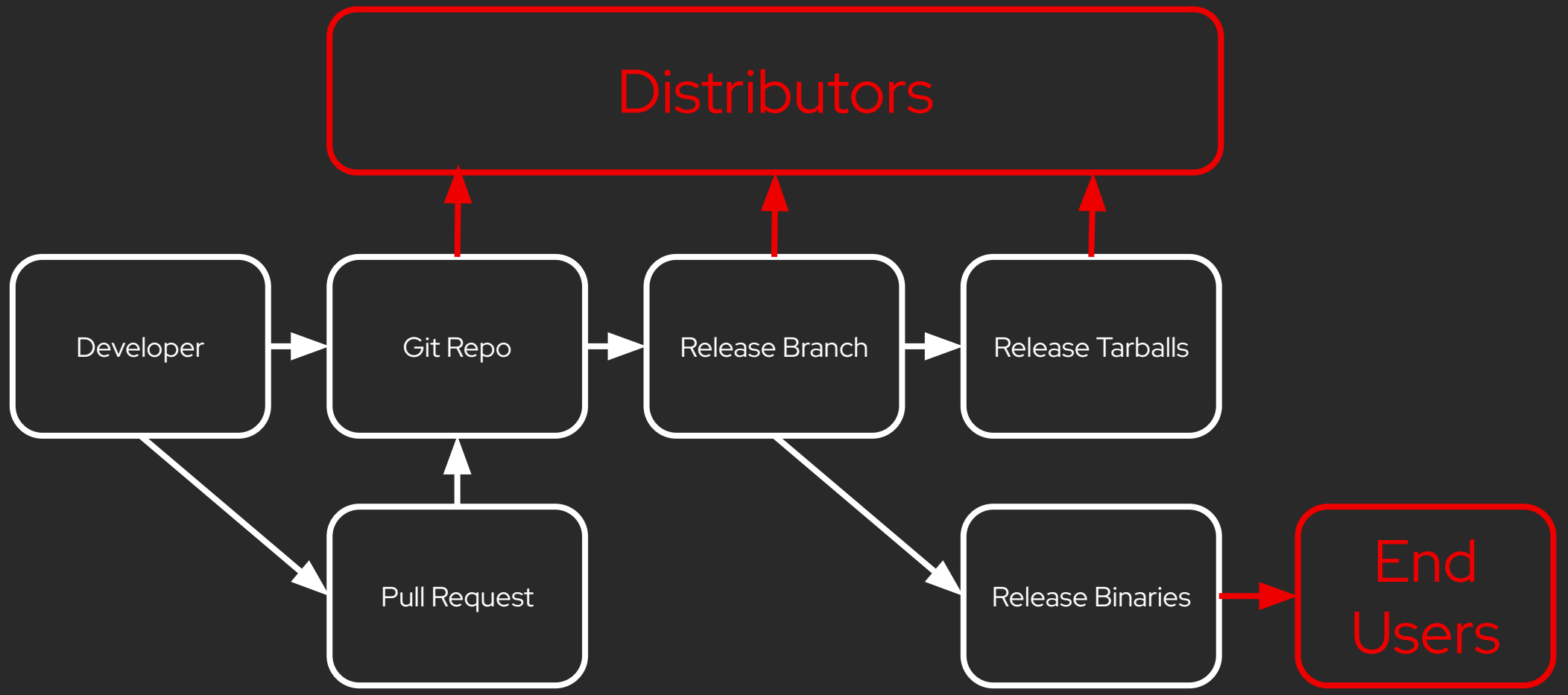
LLVM Supply Chain



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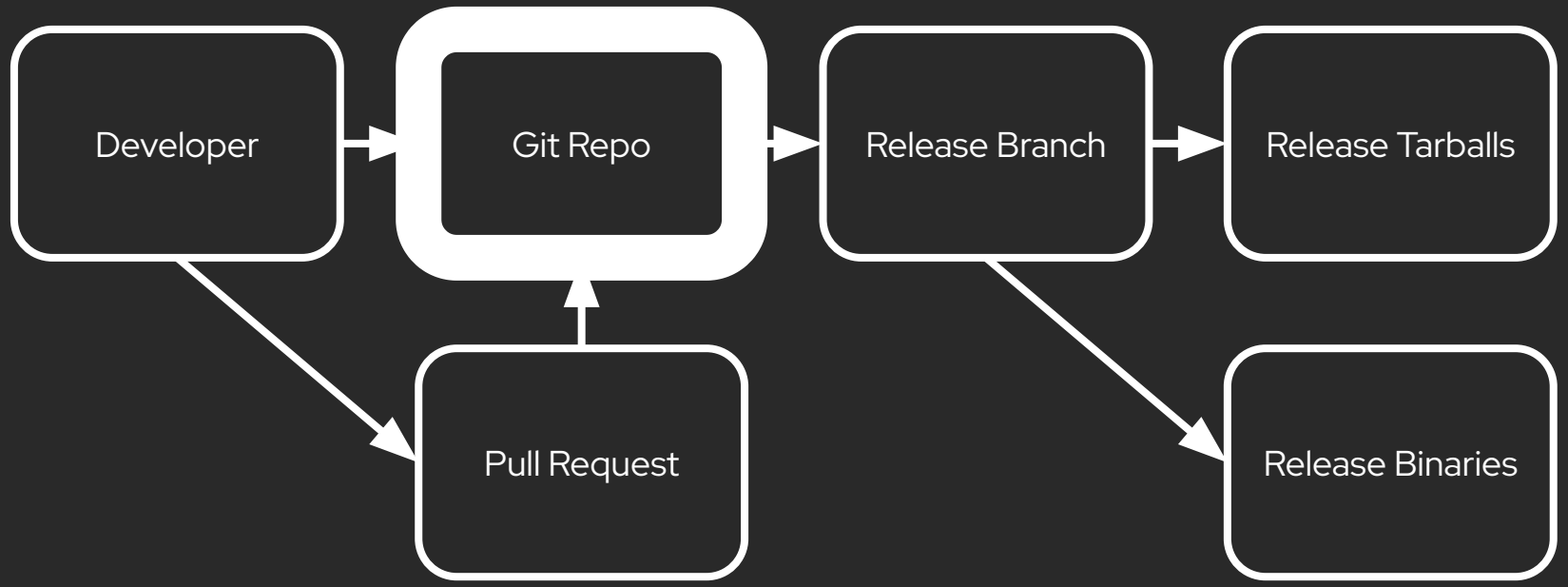
LLVM Supply Chain



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How do we secure the git repository?

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How do we secure the git repository?

- **Restrict Commit Access.**

What are the requirements for commit access?

- Ask!
- Give a Reason.
- No contribution requirements!

Red Hat

How do we secure the git repository?

- Restrict Commit Access.
- **Commit rules.**

What commit rules do we have?

- Major changes require an RFC.
- Pre-commit review with exceptions for ‘Code Owners’ and trivial changes.
- CI Tests must pass.

We have reactive enforcement.

Red Hat

How do we secure the git repository?

- Restrict Commit Access.
- Commit rules.
- **Post-Commit review.**

Post-Commit Review

- Commit lists get 1000 emails per day!
- How many people actually monitor the commit lists?

Red Hat

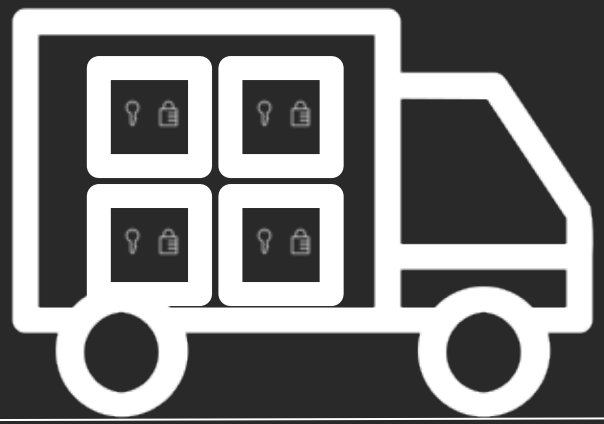
How do we secure the git repository?

- Restrict Commit Access.
- Commit rules.
- Post-Commit review.

Summary: Protecting the git repository.

- Anyone can get commit access!
- Anyone can commit at any time!
- We rely on people, not technology, to catch mistakes or prevent misuse.

Are we leaving our truck unlocked at night?



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Who should be worried about this?

- Everyone!

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Do you build your product from main?

- What would happen if malicious code was pushed to main?
- Is your build pipeline secure against untrusted code?
- Reactive upstream policies won't protect you.

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Do you have internal CI building main?

- Even just testing main can put your systems at risk.

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What are the risks?

- Modified CMake files to execute arbitrary commands on your system.
- Backdoor inserted into compiler.
- Compiler modified to insert backdoors in everything it builds.

How did we get this so wrong?

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We didn’t actually do anything wrong!

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It all comes down to priorities.

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What are the goals of our current policies?

- Make it easy for new contributors.
- Give experienced contributors flexibility to make their own decisions.

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Can we update our policies while still meeting these goals?

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New Contributors.

- In the SVN days being a contributor without commit access was very frustrating!
- GitHub makes this easier: One click merge for pull requests.
- Technology has changed, but our policies haven't!

Experienced Contributors.

- Do we need to explicitly define this group?
- Can we give extra privileges to experienced contributors?

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New policy ideas.

- Require pre-commit review for new contributors.
- Add requirements for obtaining commit access.
- Make CI mandatory.

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How you can help?

- Share your ideas!
- Review and comment on RFCs.
- Review your internal build/test process.

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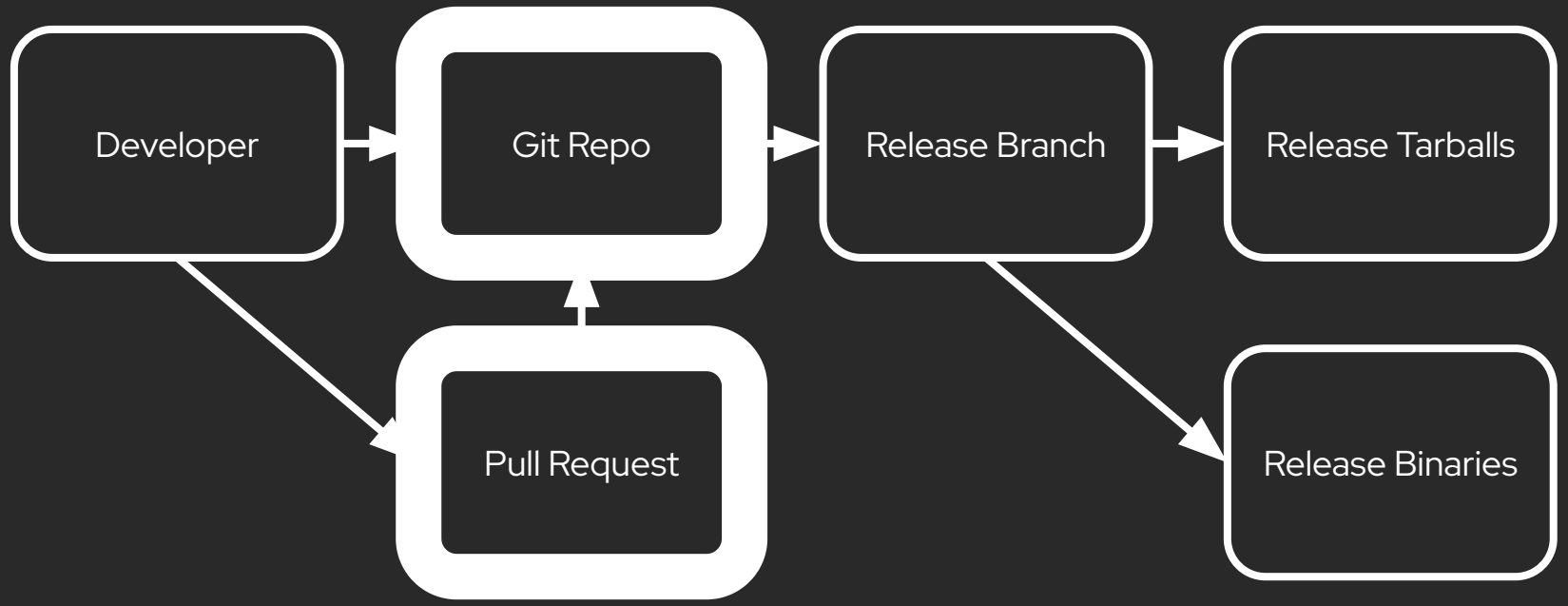
LLVM Supply Chain



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How do we secure our infrastructure?

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GitHub Actions: Overview

- Run automated jobs on GitHub infrastructure or self-hosted runners.
- Uses yaml based workflow definitions.
- One workflow per file, multiple jobs per workflow.

GitHub Actions: Overview

- Jobs started by various events: pull request, issue comment, etc.
- Each job has its own access token: GITHUB_TOKEN
- Can add ‘Secrets’ for enhanced access.

GitHub Actions: Risks

- Token/Secret compromise
- Repository Denial of Service attacks.
- Resource stealing.

GitHub Actions: Tokens

- Allow access to GitHub via REST API.
- Some Examples:
  - Creating comments.
  - Adding labels.
  - Creating Pull Requests.

GitHub Actions: Tokens

- GITHUB_TOKEN permissions configurable for each job.
- Expires when the job finishes.
- Has permissions for current repository only.

Workflows will not start on events initiated by GITHUB_TOKEN!

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workflows/commit-access-review: Use get_collaborators() function #108313

Edit | Code

Merged **tstellar** merged 8 commits into `llvm:main` from `tstellar:access-review-fix` 3 weeks ago

Conversation 3 | Commits 8 | Checks 9 | Files changed 3 | +113 -107

tstellar commented last month • edited — Member

This gets us the full list of users with commit access to llvm/llvm-project rather than the list of people in the llvm-committers team. This will ensure we are able everyone to track everyone with commit access in case they receive access some other way.

tstellar added 2 commits last month

- `workflows/commit-access-review: Use get_collaborators() function` ✗ 2109d17
- `Fix token permissions` ✗ 579ca1f

github-actions bot commented last month • edited

✅ With the latest revision this PR passed the Python code formatter.

Reviewers
boomanaiden154 ✓

Assignees
No one—assign yourself

Labels
github:workflow

Projects
None yet

Milestone
No milestone

Development
Successfully merging this pull request may close these issues.

None yet

Red Hat

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workflow/release-binaries: Checkout sources before downloading artifacts #109349

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Conversation 4 | Commits 1 | Checks 43 | Files changed 1 | +8 -8

tstellar commented 3 weeks ago — Member

The actions/checkout step will clear the current directory, so we need to checkout the sources first so that the downloaded artifacts won't be deleted.

`workflow/release-binaries: Checkout sources before downloading artifacts` ✓ `fde570d`

tstellar requested a review from **tru** 3 weeks ago

llvmbot added the github:workflow label 3 weeks ago

llvmbot commented 3 weeks ago — Member

@llvm/pr-subscribers-github-workflow

Author: Tom Stellard (tstellar)

▸ Changes

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tru ✓

boomanaiden154 ✓

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No one—assign yourself

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github:workflow

Projects

LLVM Release Status

Status: Needs Triage

Milestone

LLVM 19.X Release

Development

Successfully merging this pull request may close these issues.

None yet

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Milestone
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None yet

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GitHub Actions: Secrets

- Used to allow ‘chaining’ of workflows.
- Can grant more permissions than GITHUB_TOKEN.
- Can be anything e.g. pypi token, signing keys, etc.

Anyone with commit access can view secrets.

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GitHub Actions: Real World Exploits

- pytorch
- GItHub Runner Images
- Token leaks affecting many projects

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GitHub Actions: Best Practices

- Use GITHUB_TOKEN when possible.
- Grant GITHUB_TOKEN minimal permissions.
- Use GitHub hosted runners.
- Limit use of secrets.
- Disable workflows for first time contributors.

Workflow file for this run

.github/workflows/new-issues.yml at a4916d2

```yaml
name: Labeling new issues
on:
  issues:
    types: ['opened']

permissions:
  contents: read

jobs:
  automate-issues-labels:
    permissions:
      issues: write
    runs-on: ubuntu-latest
    if: github.repository == 'llvm/llvm-project'
    steps:
      - uses: llvm/actions/issue-labeler@main
        with:
          repo-token: ${{ secrets.GITHUB_TOKEN }}
          configuration-path: .github/new-issues-labeler.yml
          include-title: 1
          include-body: 0
          sync-labels: 0
          enable-versioned-regex: 0
```

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```


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GitHub Actions: Pull Request Events

- Two types: pull_request and pull_request_target
- pull_request has no secret access and read-only repo access.
- pull_request_target has access to secrets and write access to the repo.

Do not use pull_request_target when executing untrusted code (e.g. CI).

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GitHub Actions: Pull Request Events

- We have three workflows using pull_request_target.
- Generally, considered safe since they only use code from main.
- Could be ported over to pull_request event.

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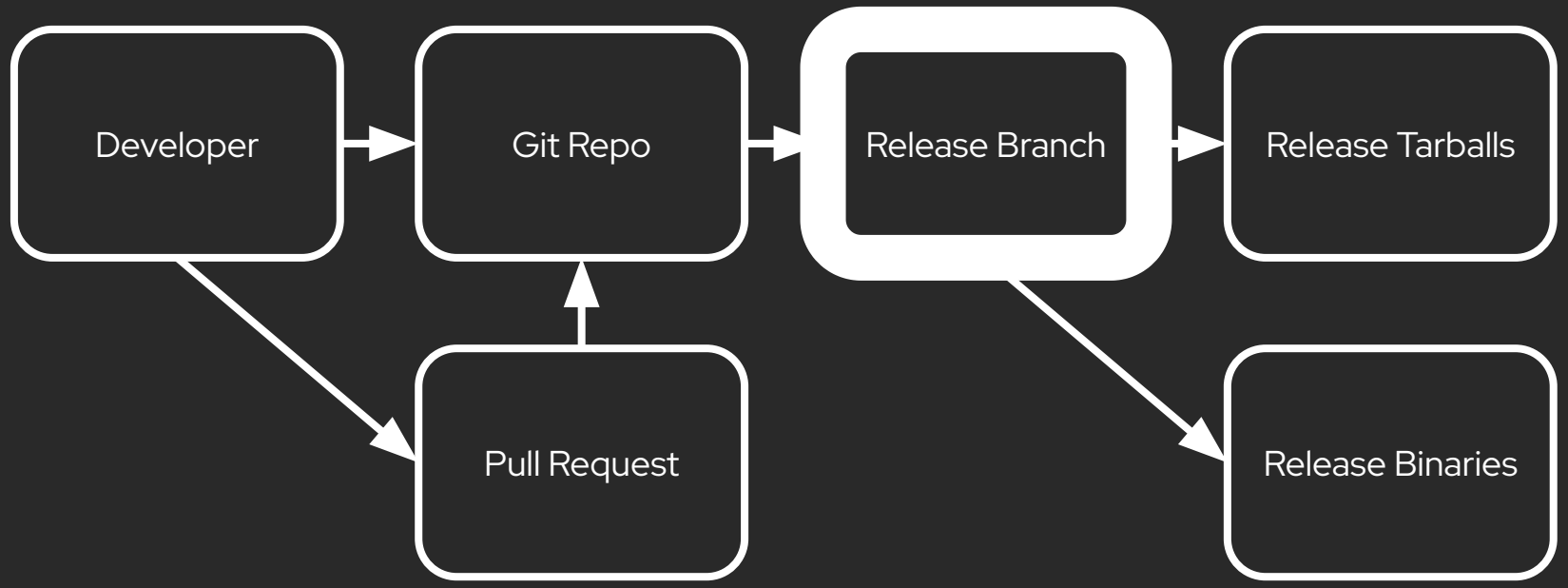
Other Infrastructure: Buildkite, Buildbot.

- Need to be hardened against running untrusted code.
- Using Ephemeral nodes mitigates some kinds of attacks.
- Internal CI systems carry the same risks!

LLVM Supply Chain



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Release Branch

- New release branch created every 6 months.
- Only release managers can commit.

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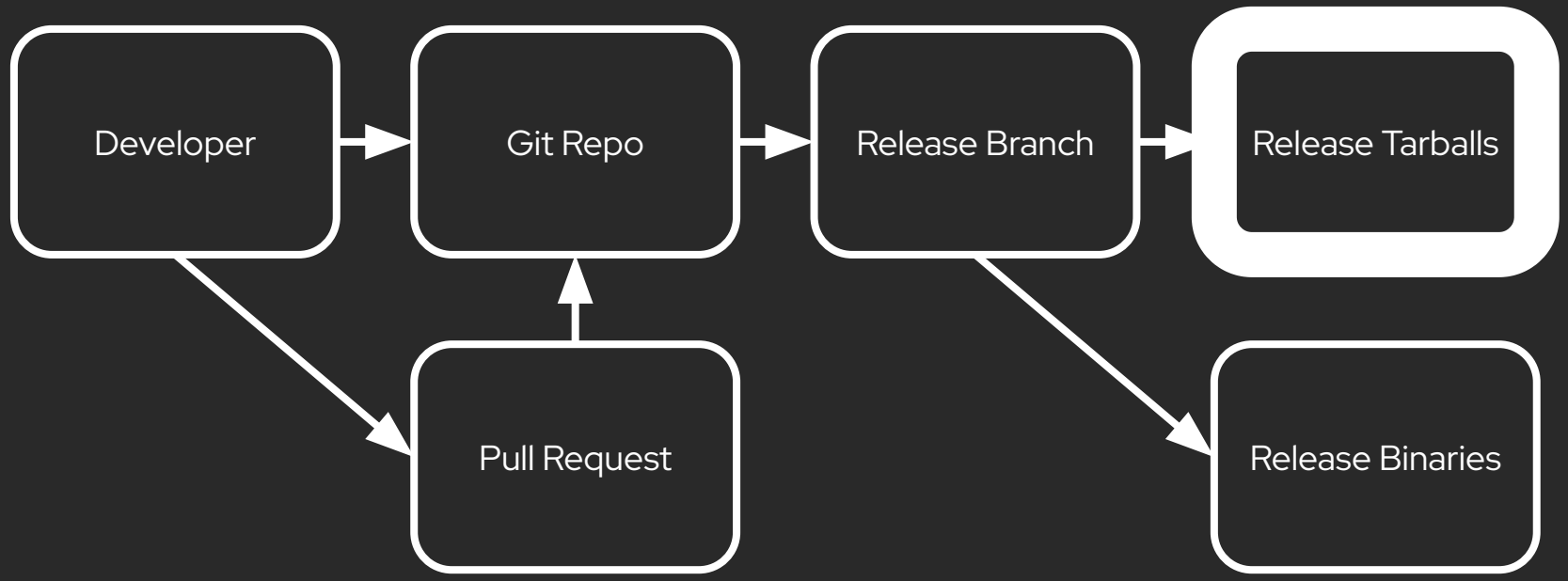
LLVM Supply Chain



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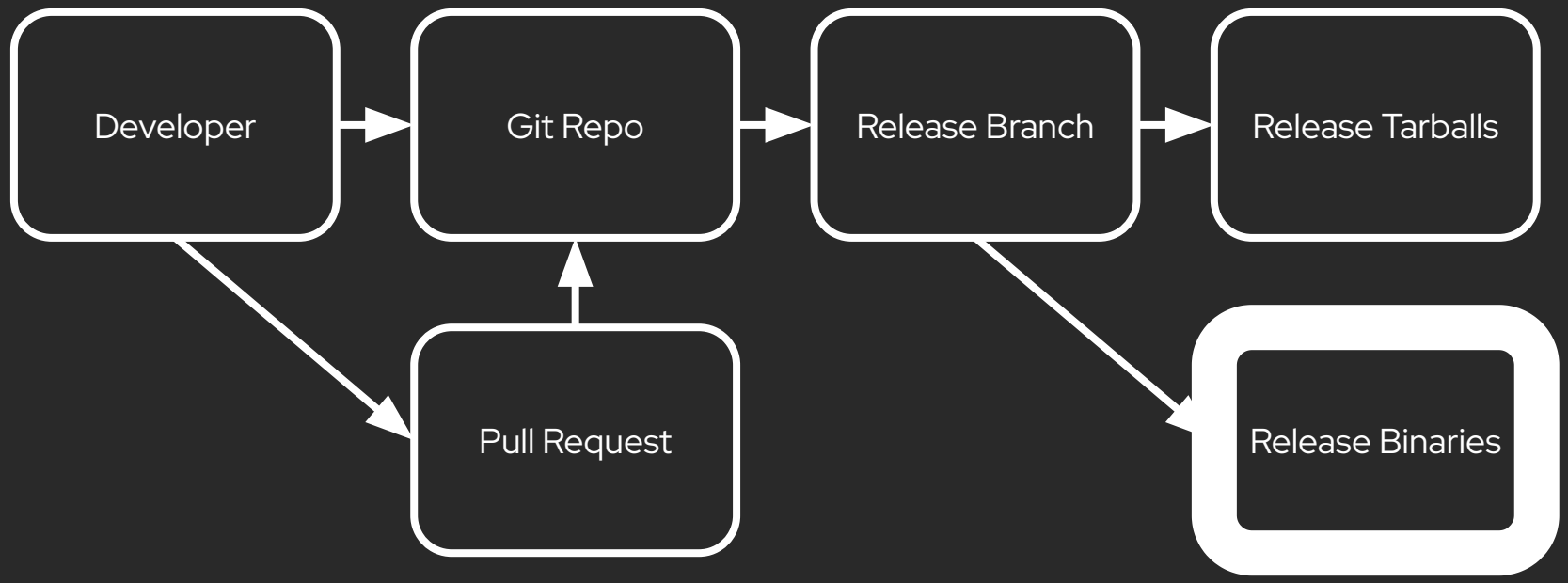
Release Tarballs

- Generated using GitHub Actions.
- Signed by release managers.
- Provenance established using GitHub Artifact Attestations.

LLVM Supply Chain



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Release Binaries

- Official binaries generated using GitHub Actions.
- Signed by release managers
- GitHub Artifact Attestations.

← Attestations

LLVM-19.1.0-Linux-X64.tar.xz #2097234

View build summary | Download

Created	3 weeks ago (Wed, 18 Sep 2024 04:57:41 GMT)
Commit	8e2dbab24276a8521d241463b4161c78bc4d39d2
Subject Digest	sha256:cee77d641690466a193d9b88c89705de1c0…
Predicate Type	https://slsa.dev/provenance/v1
Workflow	.github/workflows/release-binaries-all.yml@refs/heads/main
Verify	gh attestation verify <filename-or-url> --owner llvm --bundle ./llvm-llvm-project-attestation-2097234.sigstore.json

Certificate Summary

Build Config Digest	8e2dbab24276a8521d241463b4161c78bc4d39d2
Build Config URI	https://github.com/llvm/llvm-project/.github/workflows/release-binaries-all.yml@refs/heads/main
Build Signer Digest	8e2dbab24276a8521d241463b4161c78bc4d39d2
Build Signer URI	https://github.com/llvm/llvm-project/.github/workflows/release-binaries.yml@refs/heads/main
Build Trigger	workflow_dispatch
Issuer	https://token.actions.githubusercontent.com
Runner Invocation URI	https://github.com/llvm/llvm-project/actions/runs/10904034079/attempts/1
Runner Environment	github-hosted
Source Repository Digest	8e2dbab24276a8521d241463b4161c78bc4d39d2
Source Repository Identifier	75821432
Source Repository Owner Identifier	17149993
Source Repository Owner URI	https://github.com/llvm
Source Repository Ref	refs/heads/main
Source Repository URI	https://github.com/llvm/llvm-project
Source Repository Visibility	public

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LLVM-19.1.1-Linux-X64.tar.xz	1.54 GB	3 days ago
LLVM-19.1.1-Linux-X64.tar.xz.jsonl	10.2 KB	3 days ago

```
[fedora@tstellar-uploader 19.1.1]$ gh attestation verify -R llvm/llvm-project -b LLVM-19.1.1-Linux-X64.tar.xz.jsonl LLVM-19.1.1-Linux-X64.tar.xz
Loaded digest sha256:8204de000b6a6921f0572e038336601e3225898e9a253c8aaa43b0a5fae8a4ce for file://LLVM-19.1.1-Linux-X64.tar.xz
Loaded 1 attestation from LLVM-19.1.1-Linux-X64.tar.xz.jsonl
✓ Verification succeeded!

sha256:8204de000b6a6921f0572e038336601e3225898e9a253c8aaa43b0a5fae8a4ce was attested by:
REPO                PREDICATE_TYPE                  WORKFLOW
llvm/llvm-project   https://slsa.dev/provenance/v1  .github/workflows/release-binaries.yml@refs/tags/llvmorg-19.1.1
```


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Anyone with commit access can upload assets to the release page!

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Release Assets

- No fine-grained permissions.
- We have an audit job that checks assets once per hour.
- Discussed moving assets to a different repository.

Should you download this file?

https://github.com/llvm/llvm-project/files/13166493/LLVM-19.1.1-Linux-X64.tar.xz

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Should you download this file?

https://github.com/llvm/llvm-project/files/13166493/LLVM-19.1.1-Linux-X64.tar.xz

No!

Red Hat

User Upload (could be malicious):

https://github.com/llvm/llvm-project/files/13166493/LLVM-19.1.1-Linux-X64.tar.xz

Official Upload:

https://github.com/llvm/llvm-project/releases/download/llvmorg-19.1.1/LLVM-19.1.1-Linux-X64.tar.xz

XZ Attack

https://www.openwall.com/lists/oss-security/2024/03/29/4
https://boehs.org/node/everything-i-know-about-the-xz-backdoor

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XZ Attack: Mechanics

- ‘Trusted’ user granted commit access.
- Malicious test binaries pushed to the repo.
- Release tarball hosting moved to github.
- Release tarballs modified to include script that injected malicious code into xz.

XZ Attack: Results

- RSA_public_decrypt calls redirected to malicious code.

LLVM vs XZ: How do we compare?

01 Title of table

	XZ	LLVM
Commit Access Wait Time	8 Months [1]	Days
Test Binaries in Repo	Yes	Yes
Mandatory Code Review	No	No
Maintainers	1	Many

[1] https://boehs.org/node/everything-i-know-about-the-xz-backdoor

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What’s next?

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What's Next? (my opinions)

- Having low bar for commit access is OK.
- Having minimal commit rules is OK.
- Having both at the same time is very risky.
- We should make some changes.

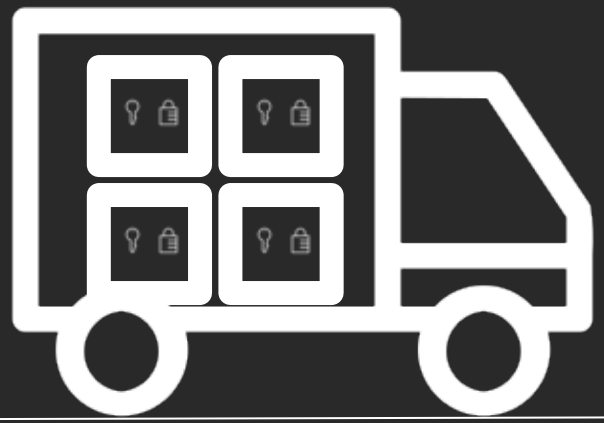
Ideas

- Mandatory pull requests.
- Mandatory review for all changes.
- More strict requirements for commit access.
- We need to balance convenience and security.

Advice for downstream.

- Know your risks.
- Contribute to upstream.
- Hire someone to work on this full time.
- Donate to the LLVM Foundation!

Conclusion: This is important.



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