Buckle Up, Buttercup: Our Experience Competing in the AI Cyber Challenge

9 August 2025

Our Team

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Lead Designer of Buttercup

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Co-Designer of Buttercup

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Our Team

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(Semi-Finals)

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Our Team

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Contextualization Lead

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System Developer

Our Team

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Challenge Creator
(Internal Red Team)

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Challenge Creator
(Internal Red Team)

Our Team

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Challenge Creation
(Semi-finals)

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Systems Developer
(Semi-finals)

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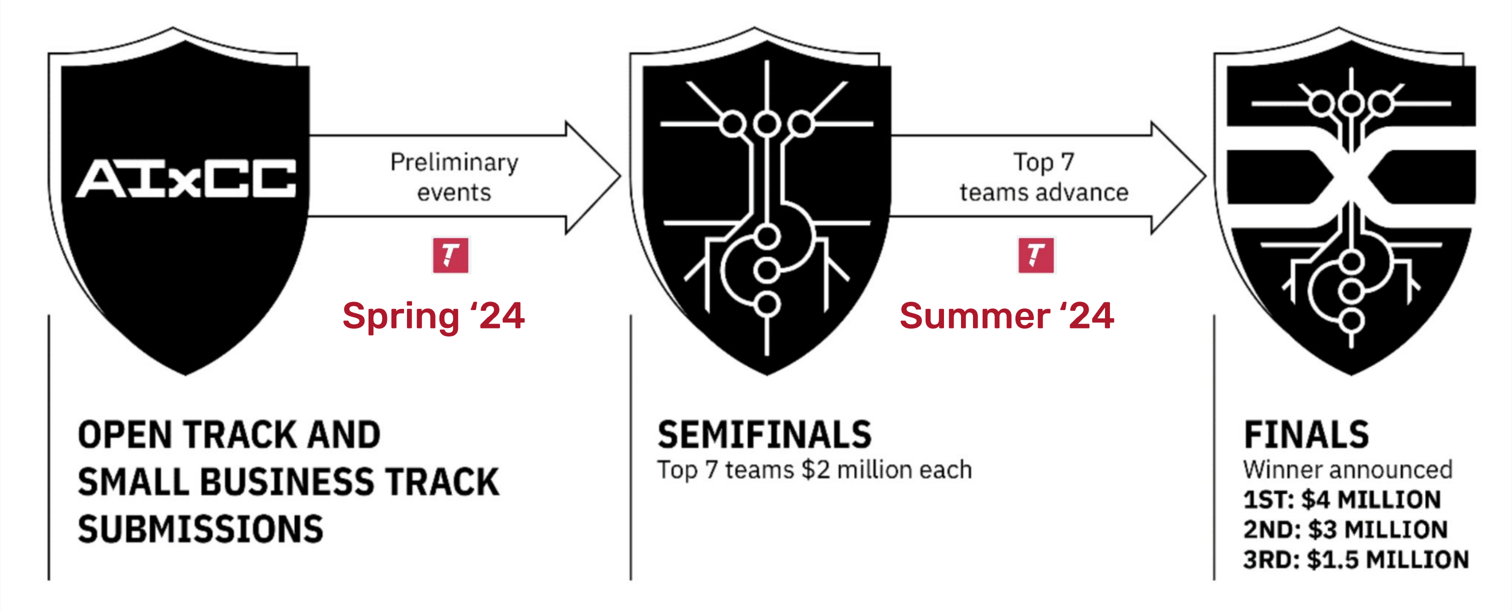
Systems Developer
(Semi-finals)

A Brief Origin Story

AI Cyber Challenge (AIxCC)

AIxCC is a competition to design a novel automated AI system (CRS) that can find and patch bugs in real-world open-source software.



Spring '24

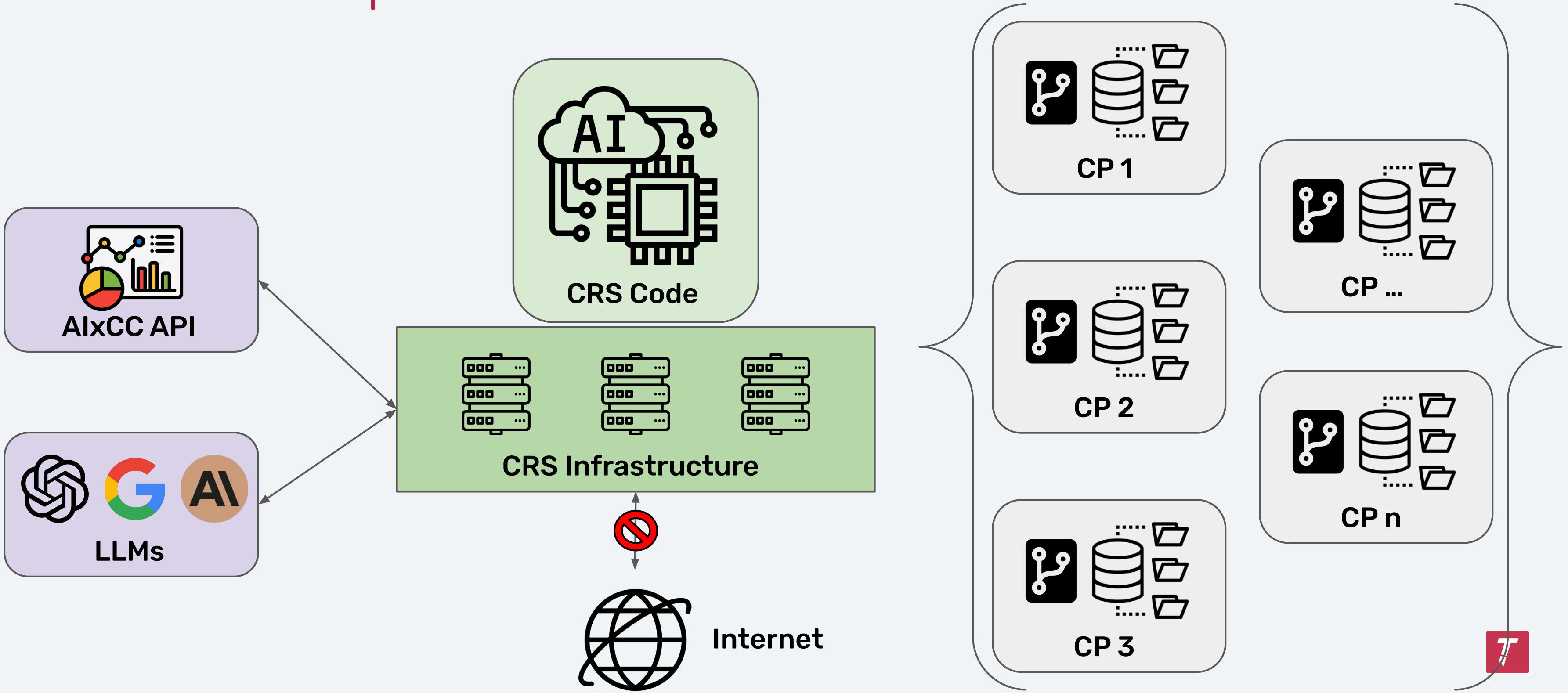
Summer '24

OPEN TRACK AND SMALL BUSINESS TRACK SUBMISSIONS

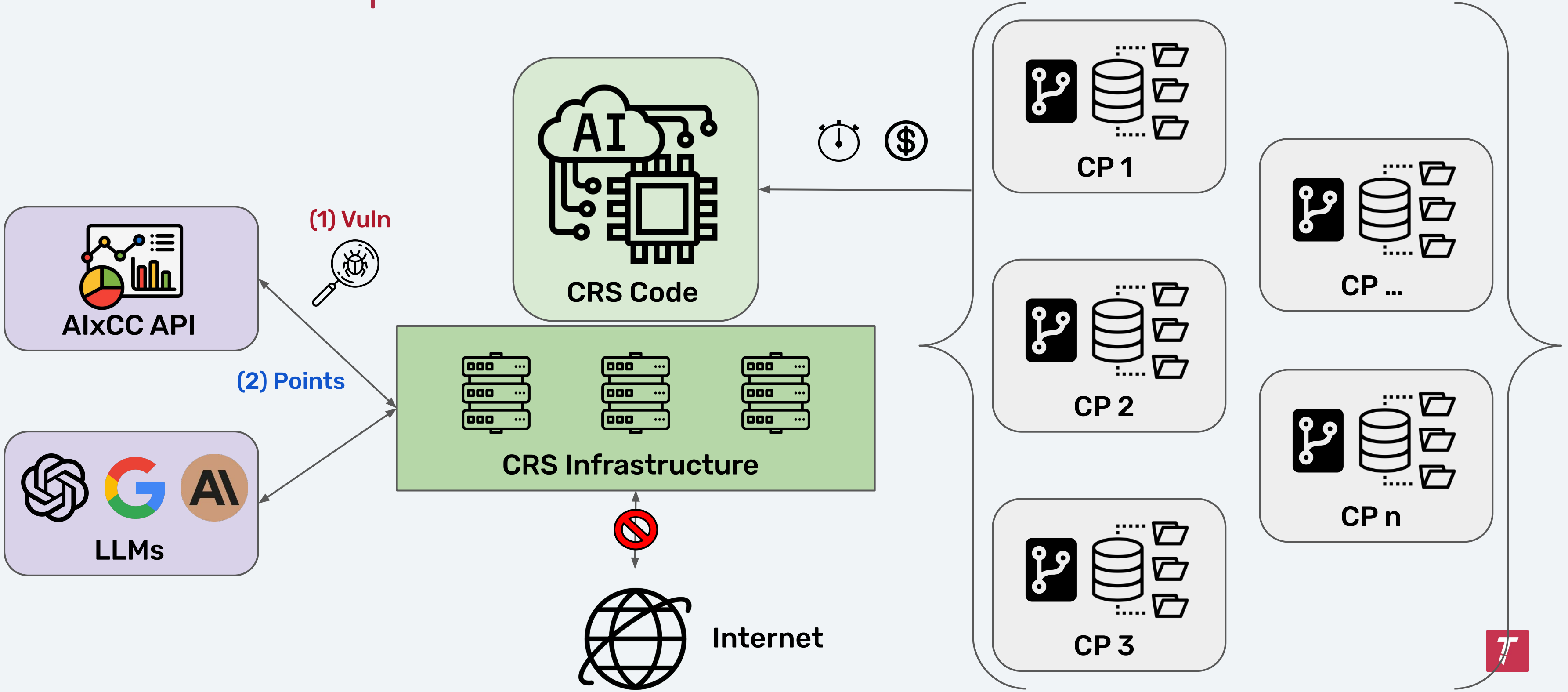
SEMIFINALS
Top 7 teams $2 million each

FINALS
Winner announced
1ST: $4 MILLION
2ND: $3 MILLION
3RD: $1.5 MILLION

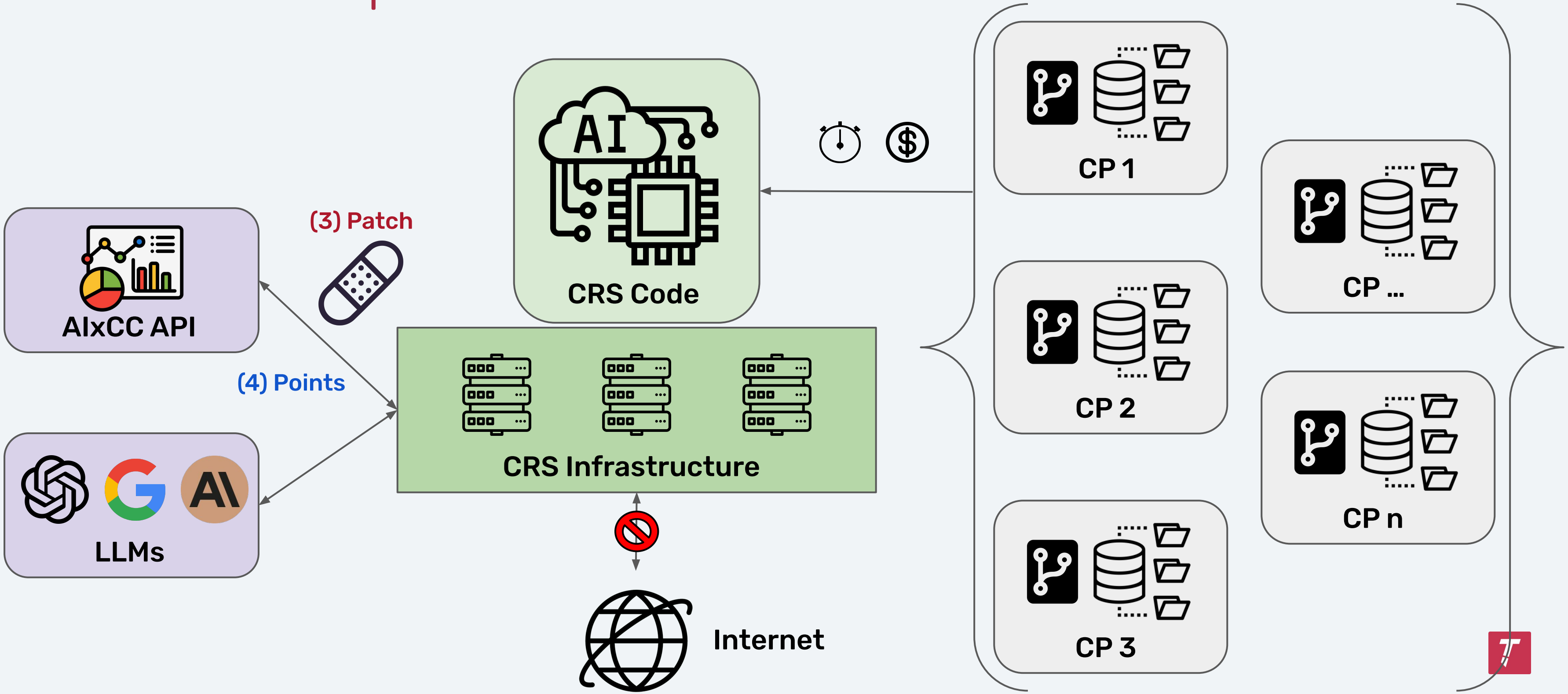
AIxCC Competition Structure



AIxCC Competition Structure



AIxCC Competition Structure



Buttercup’s Design

Our Approach

Guiding Principles

- Conventional software analysis works really well for certain problems.
- AI/ML-based analysis works really well for certain problems.
- Often, one approach works well where the other does not.

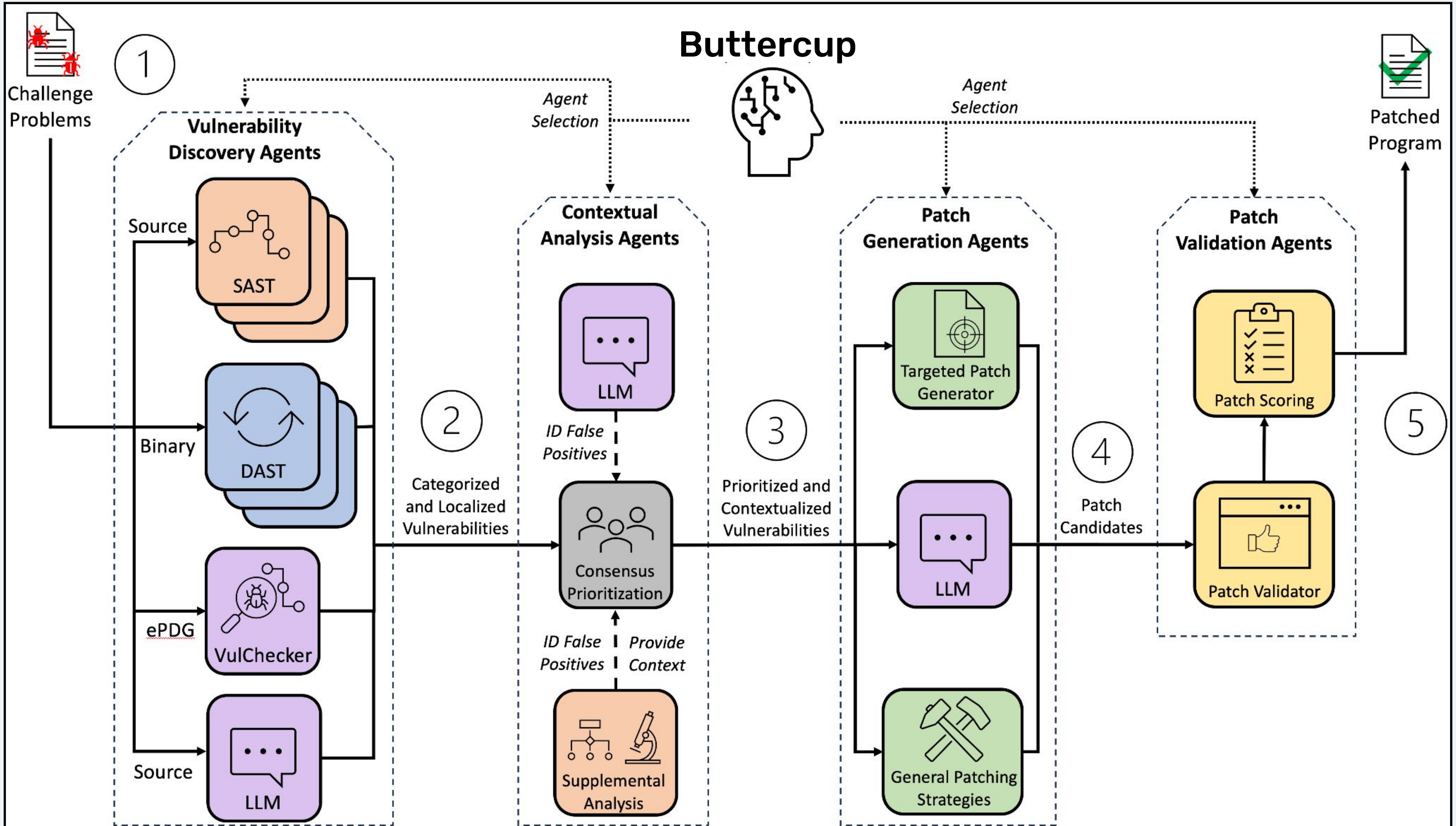
Break the problem down, use the best technique to solve each sub-problem.

Don’t expect LLMs to do things they aren’t good at!

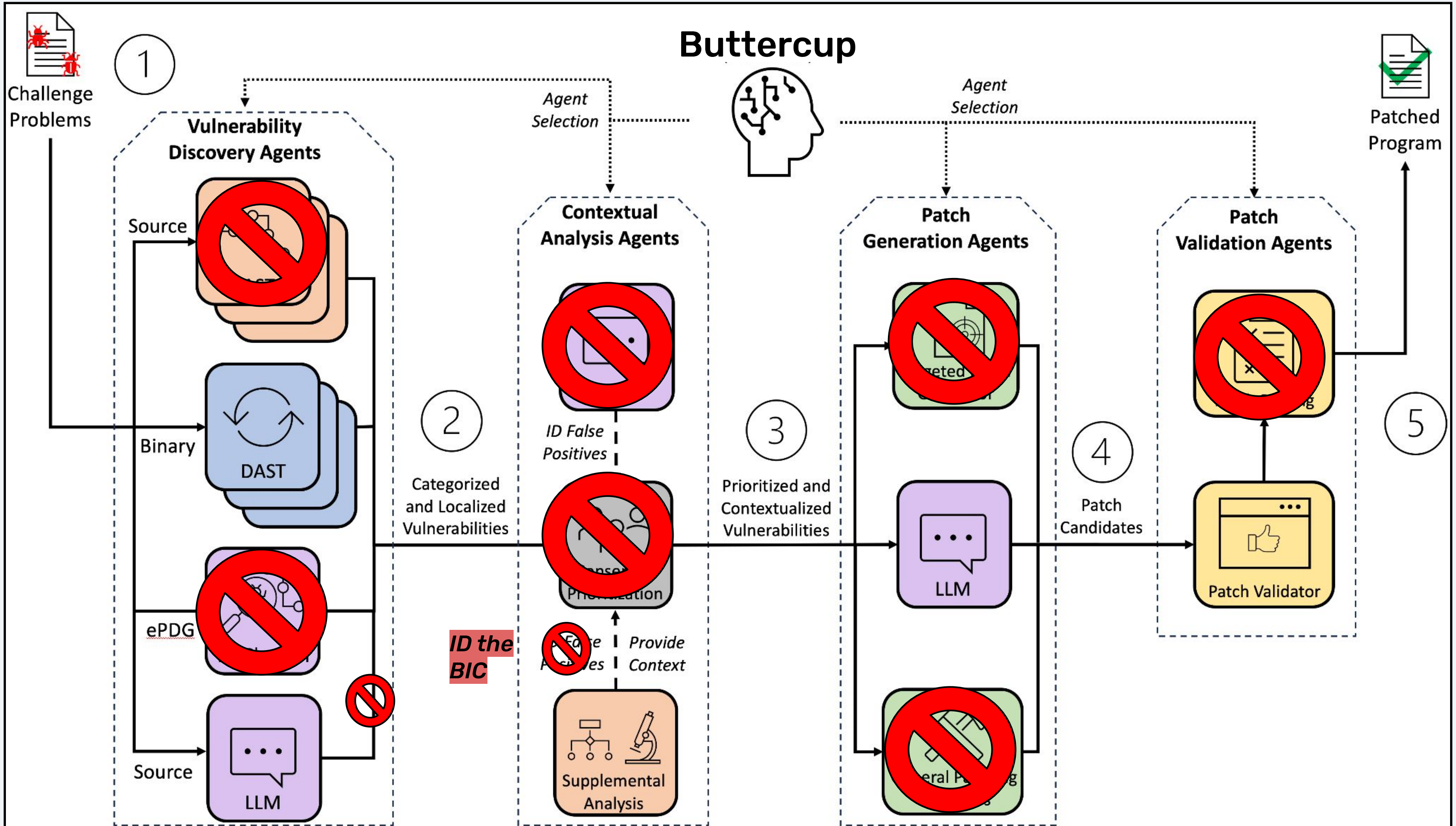
Problem Breakdown

1) Discover / prove existence of vulnerabilities
2) Contextualize vulnerabilities
3) Create and Validate patches
4) Orchestrate these tasks to:
   a) Effectively allocate resources
   b) Maximize score

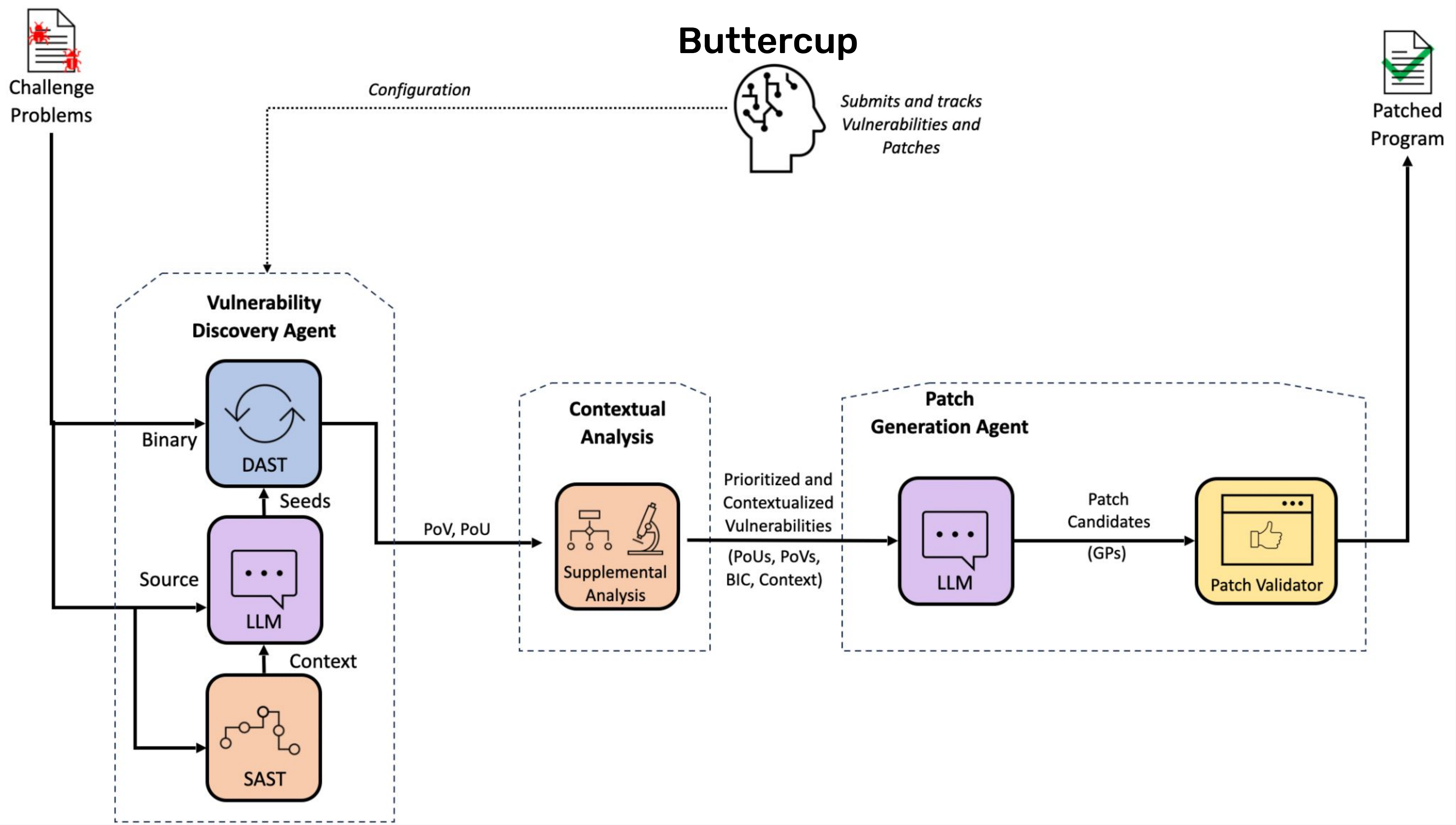
CRS Architecture (Concept Paper)



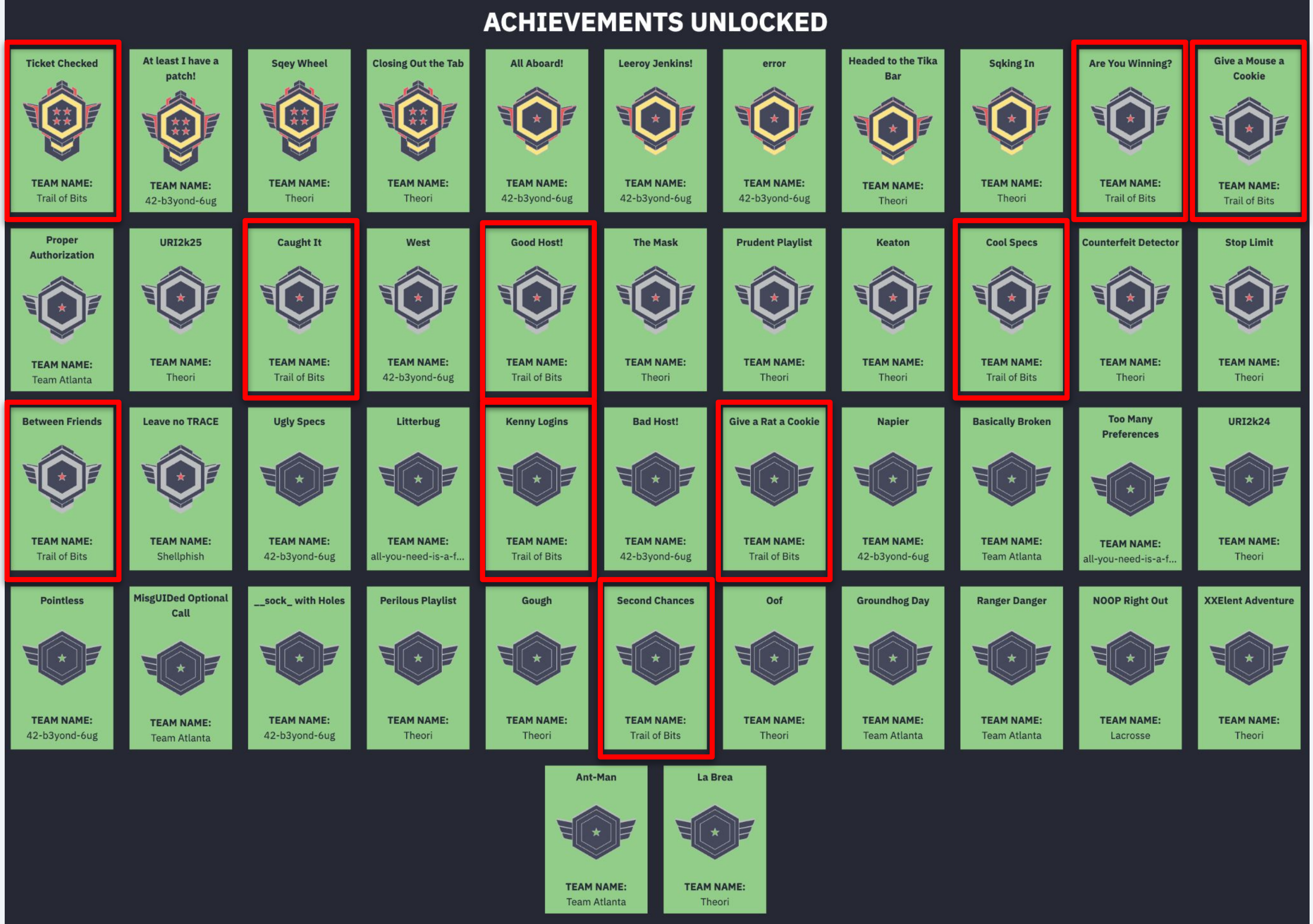
CRS Architecture



CRS Architecture (Competition)



Buttercup in the Semifinals



ACHIEVEMENTS UNLOCKED

Ticket Checked
TEAM NAME:
Trail of Bits

At least I have a patch!
TEAM NAME:
42-b3yond-6ug

Sqey Wheel
TEAM NAME:
Theori

Closing Out the Tab
TEAM NAME:
Theori

All Aboard!
TEAM NAME:
42-b3yond-6ug

Leeroy Jenkins!
TEAM NAME:
42-b3yond-6ug

error
TEAM NAME:
42-b3yond-6ug

Headed to the Tika Bar
TEAM NAME:
Theori

Sqking In
TEAM NAME:
Theori

Are You Winning?
TEAM NAME:
Trail of Bits

Give a Mouse a Cookie
TEAM NAME:
Trail of Bits

Proper Authorization
TEAM NAME:
Team Atlanta

URI2k25
TEAM NAME:
Theori

Caught It
TEAM NAME:
Trail of Bits

West
TEAM NAME:
42-b3yond-6ug

Good Host!
TEAM NAME:
Trail of Bits

The Mask
TEAM NAME:
Theori

Prudent Playlist
TEAM NAME:
Theori

Keaton
TEAM NAME:
Theori

Cool Specs
TEAM NAME:
Trail of Bits

Counterfeit Detector
TEAM NAME:
Theori

Stop Limit
TEAM NAME:
Theori

Between Friends
TEAM NAME:
Trail of Bits

Leave no TRACE
TEAM NAME:
Shellphish

Ugly Specs
TEAM NAME:
42-b3yond-6ug

Litterbug
TEAM NAME:
all-you-need-is-a-f...

Kenny Logins
TEAM NAME:
Trail of Bits

Bad Host!
TEAM NAME:
42-b3yond-6ug

Give a Rat a Cookie
TEAM NAME:
Trail of Bits

Napier
TEAM NAME:
42-b3yond-6ug

Basically Broken
TEAM NAME:
Team Atlanta

Too Many Preferences
TEAM NAME:
all-you-need-is-a-f...

URI2k24
TEAM NAME:
Theori

Pointless
TEAM NAME:
42-b3yond-6ug

MisgUIDed Optional Call
TEAM NAME:
Team Atlanta

__sock_ with Holes
TEAM NAME:
42-b3yond-6ug

Perilous Playlist
TEAM NAME:
Theori

Gough
TEAM NAME:
Theori

Second Chances
TEAM NAME:
Trail of Bits

Oof
TEAM NAME:
Theori

Groundhog Day
TEAM NAME:
Team Atlanta

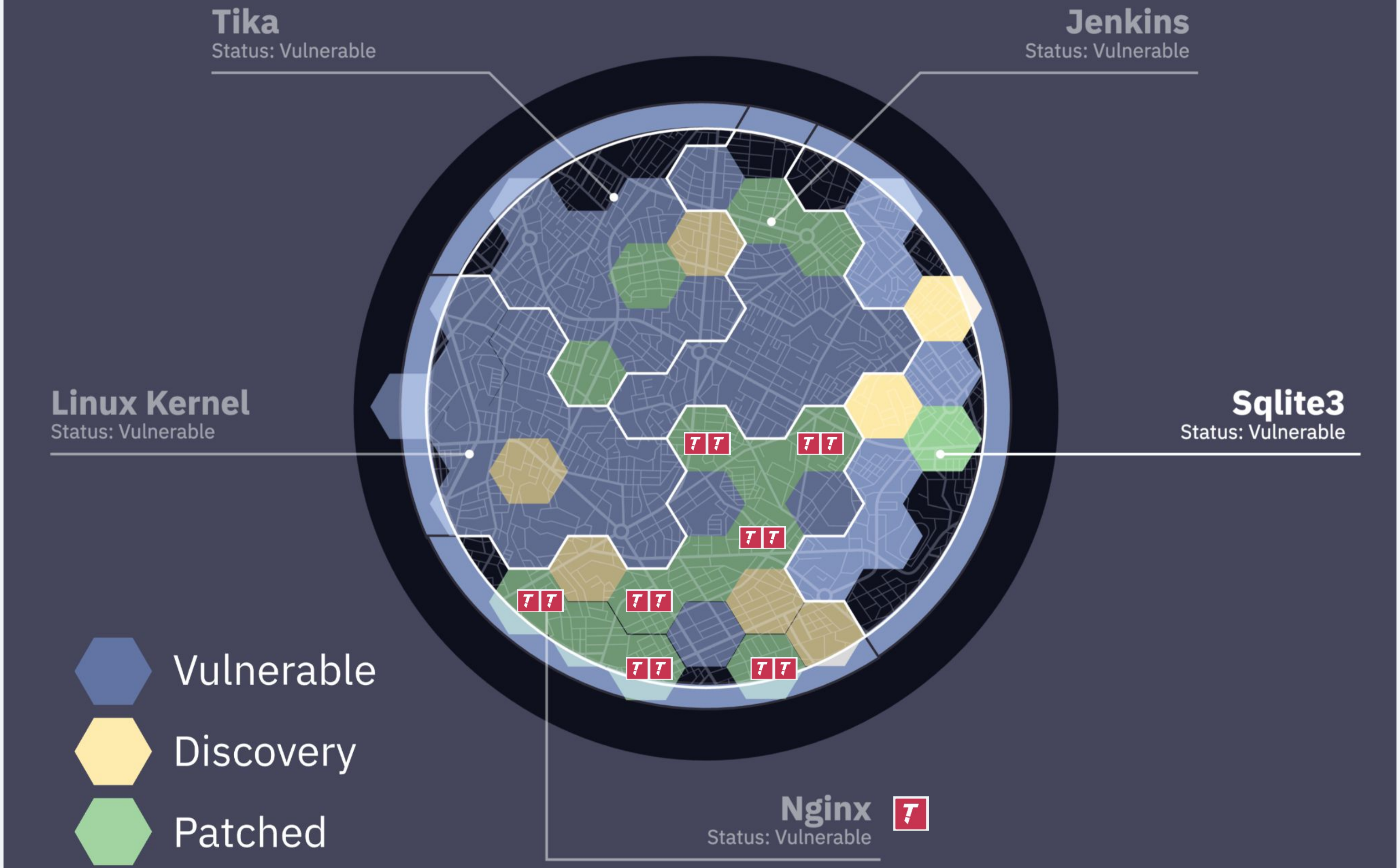
Ranger Danger
TEAM NAME:
Team Atlanta

NOOP Right Out
TEAM NAME:
Lacrosse

XXElent Adventure
TEAM NAME:
Theori

Ant-Man
TEAM NAME:
Team Atlanta

La Brea
TEAM NAME:
Theori



Tika
Status: Vulnerable

Jenkins
Status: Vulnerable

Linux Kernel
Status: Vulnerable

Sqlite3
Status: Vulnerable

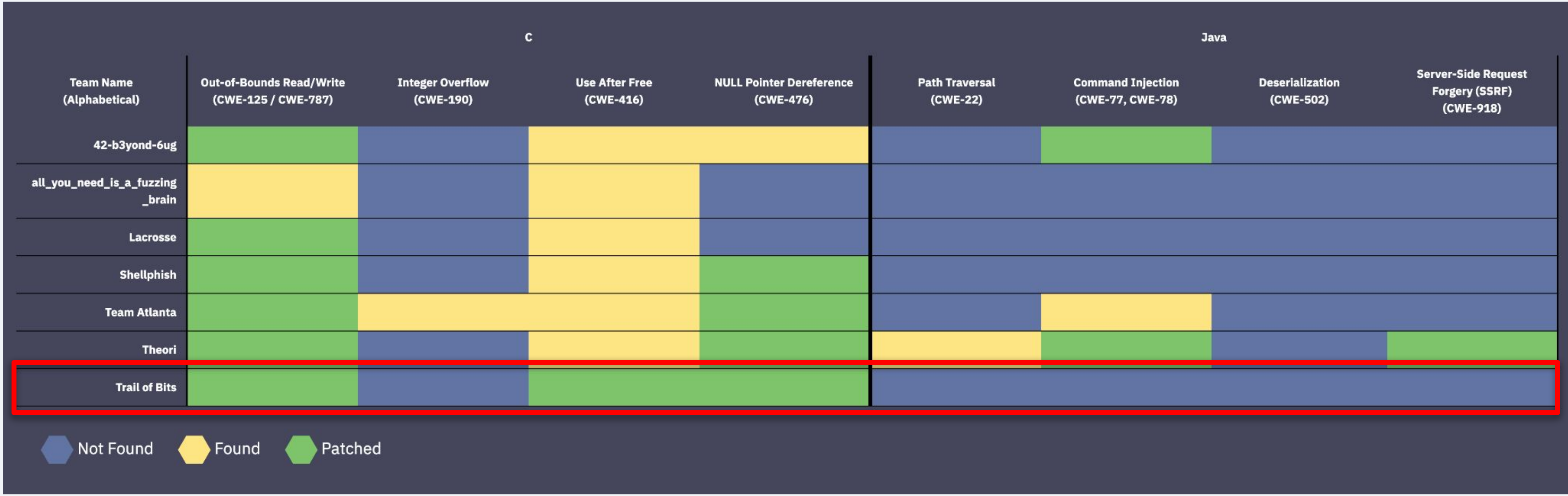
Nginx
Status: Vulnerable

Vulnerable

Discovery

Patched

Performance by CWE type



	C				Java			
Team Name (Alphabetical)	Out-of-Bounds Read/Write (CWE-125 / CWE-787)	Integer Overflow (CWE-190)	Use After Free (CWE-416)	NULL Pointer Dereference (CWE-476)	Path Traversal (CWE-22)	Command Injection (CWE-77, CWE-78)	Deserialization (CWE-502)	Server-Side Request Forgery (SSRF) (CWE-918)
42-b3yond-6ug	🟩	🟦	🟨	🟨	🟦	🟩	🟦	🟦
all_you_need_is_a_fuzzing_brain	🟨	🟦	🟨	🟦	🟦	🟦	🟦	🟦
Lacrosse	🟩	🟦	🟨	🟦	🟦	🟦	🟦	🟦
Shellphish	🟩	🟦	🟨	🟩	🟦	🟦	🟦	🟦
Team Atlanta	🟩	🟨	🟨	🟩	🟦	🟨	🟦	🟦
Theori	🟩	🟦	🟨	🟩	🟨	🟩	🟦	🟩
Trail of Bits	🟩	🟦	🟩	🟩	🟦	🟦	🟦	🟦

🟦 Not Found 🟨 Found 🟩 Patched

Buttercup 2.0

How did Buttercup evolve for the finals?

Lessons Learned from semi-finals:

- Validated our overall approach
- Need better testing / handling of Java challenges
- CWE-type specific seed-generation may have helped

Rule changes for finals:

- Massive scale and budget (time, compute, and AI) increases
- Several exhibition rounds
- More complex scoring (SARIFs, bundles, duplication penalties)
- Custom AI/ML models allowed

Building Buttercup 2.0

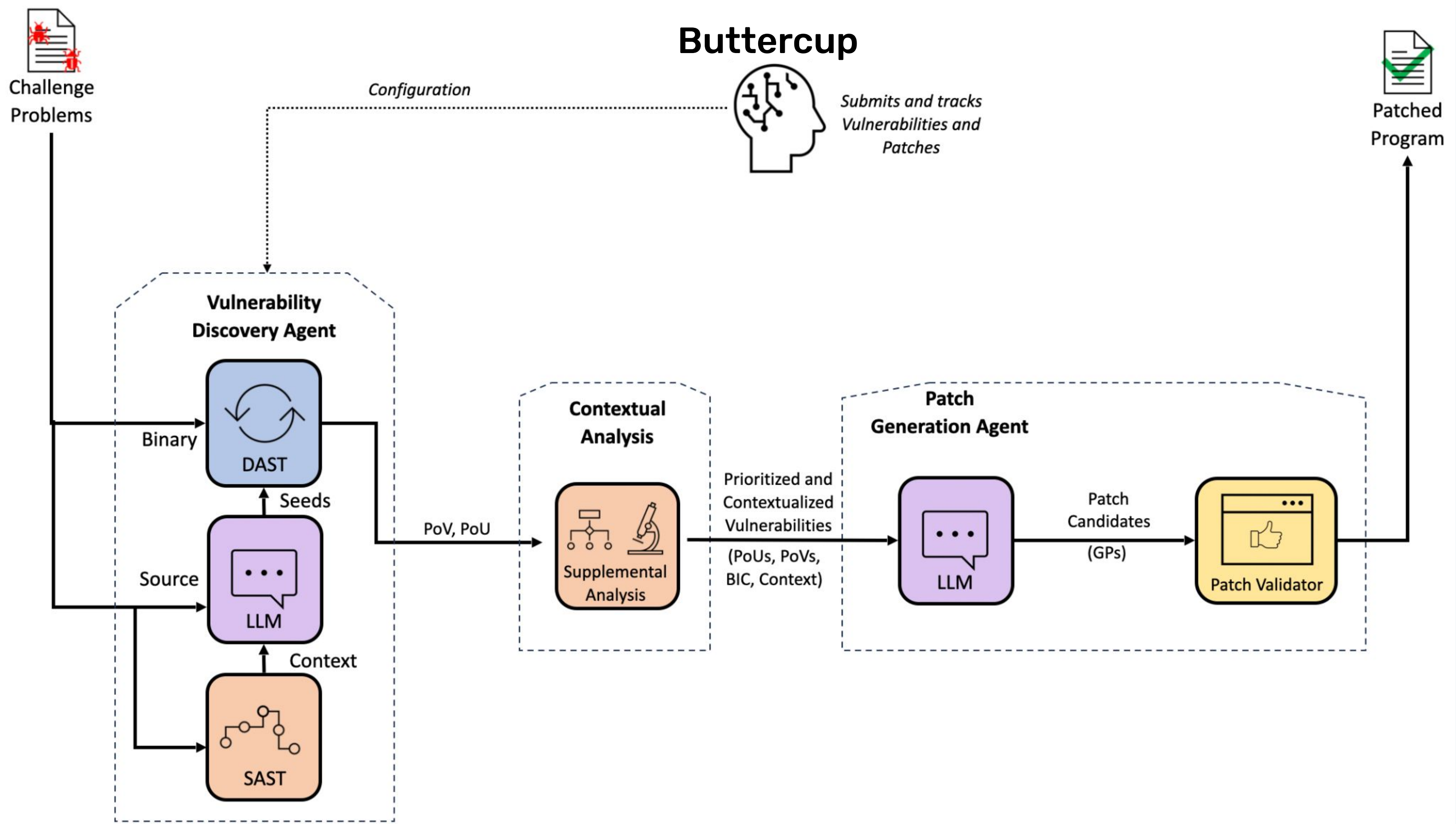
Buttercup 2.0 is essentially a from-scratch rebuild.

Driven by need for:

- more technically complex analysis components
- ability to easily change scale / cost of deployment for various rounds
- high degree of reliability and robustness to errors

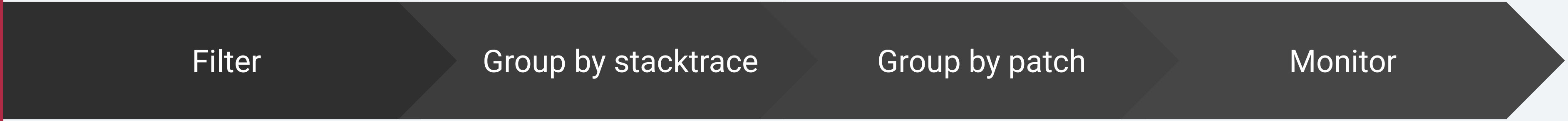
Still, our high-level Buttercup remained the same as the semi-finals

CRS Architecture (Competition)



Buttercup 2.0 Technical Details

Orchestration - Submission Processing



Filter

Group by stacktrace

Group by patch

Monitor

Vulnerability discovery produces many PoVs - filter stack traces already seen

Group PoVs with similar stack traces - examples of the same underlying vulnerability.

Group PoVs remediated by the same patch - same underlying vulnerability

As new PoVs come in merge by fuzzy stack match and patches. Rebuild bundles as needed.

PoV - Proof of Vulnerability

Vulnerability Discovery

- **Strategy: Combine fuzzing and LLM input generation**
- Use standard OSS-Fuzz fuzzers:
  - LibFuzzer for C/C++
  - Jazzer for Java
- Fuzzer bots sample active harnesses to run short fuzz campaigns
- Fuzzing corpus:
  - Merger bots merge a fuzzer bot’s local corpus to the shared corpus
  - LLM input generation also submits to the corpus

Vulnerability Discovery: LLM “seed-gen”

Design

- Several tasks that use LLMs to create seeds and/or PoVs
- All tasks use tools to collect context from the codebase before generating inputs

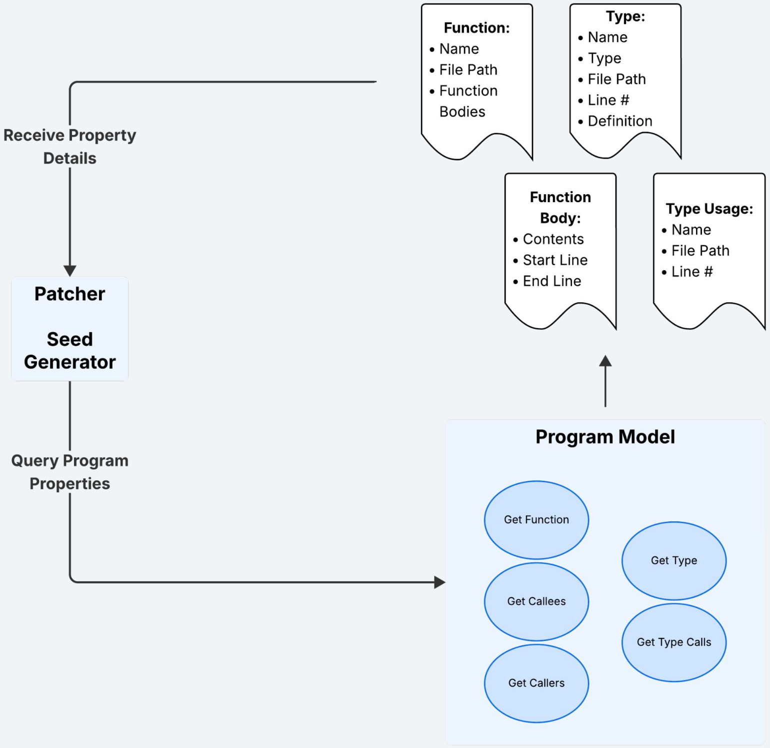
Goal 1: Support Fuzzing

- **Init task**: Bootstrap fuzzer with initial seed inputs that exercise harness
- **Explore task**: Increase coverage for a target function

Goal 2: Independently Find Bugs

- **Vuln discovery task**: Identify and validate vulnerabilities in target to create PoVs
    - Most expensive task to thoroughly explore code and test hypotheses

Contextualization



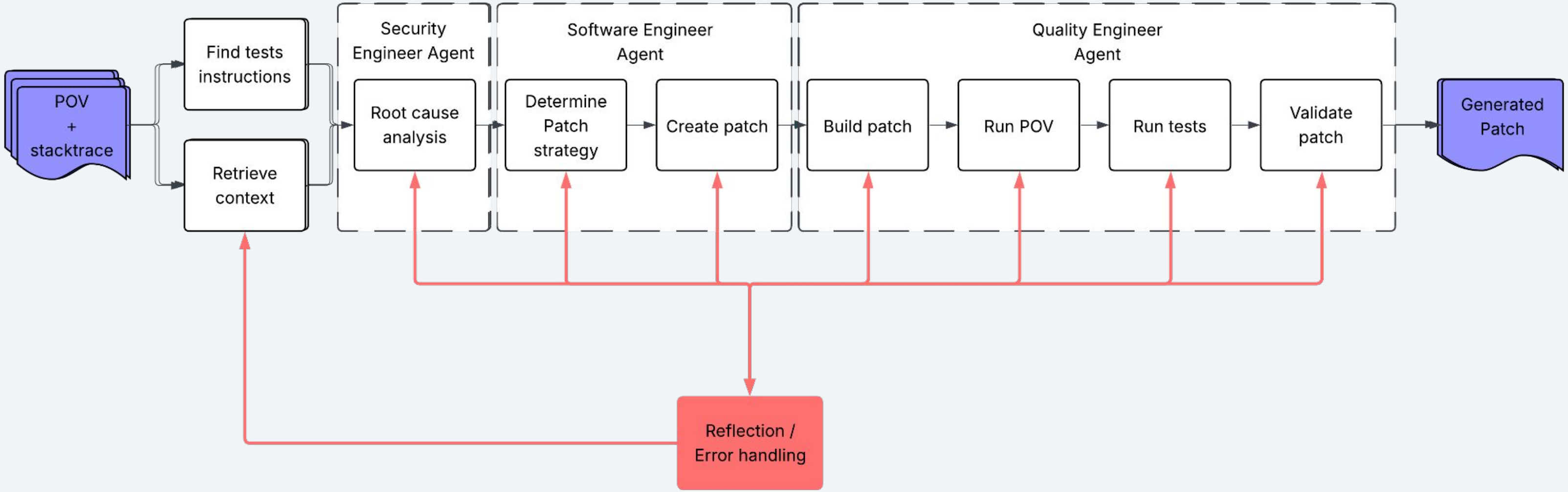
- Constructs program model using CodeQuery + Tree-sitter
- Supports querying program properties (functions & types)
- Called by LLMs from **Seed Generator** and **Patcher** using LangGraph's Tool library

Patcher

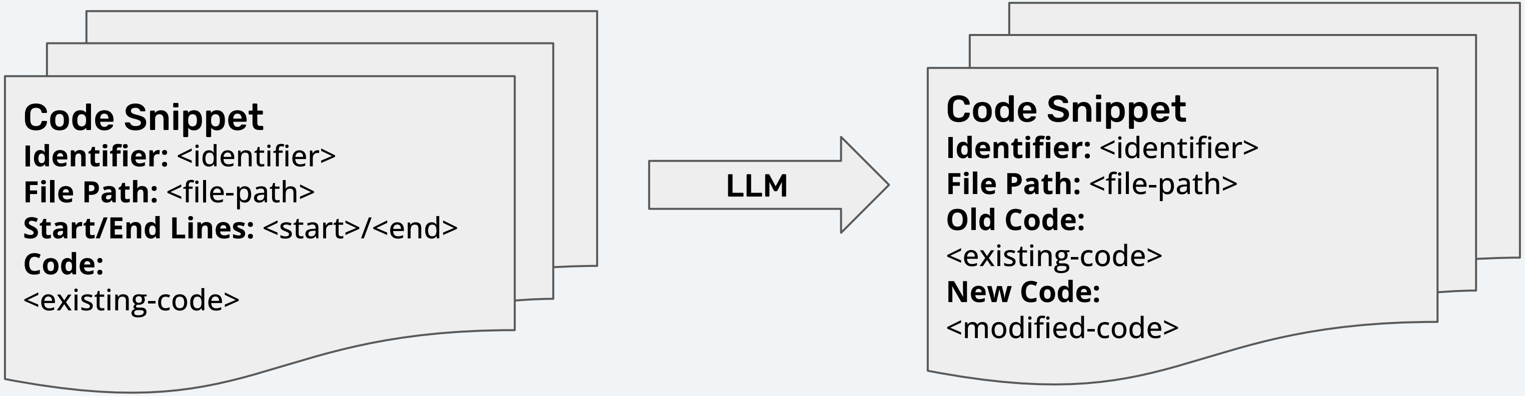
- LLM-based multi-agent system
  - Software, Security, and Quality Engineer Agents working together
- Programmatic agents hand-off
  - Data flow between agent is (mostly) deterministic
  - More control over the process
  - Error handling relies on LLMs to determine resolution steps

- **Implementation**
  - Less than 6K LOC, Python
  - LangChain/LangGraph
  - Preferred model: OpenAI/GPT-4.1

Patcher: flow



Patcher: patch creation



Buttercup in the Finals

How did Buttercup do in Exhibition Rounds?

Buttercup was the best performing CRS in Round 1:

- Found and patched a vulnerability in both challenges with 100% accuracy
- Used only ~$1000 of available $30,000 budget

But we crashed hard in Round 2:

- Issue with filename length in vulnerability discovery component
- Caused a hard failure after only 3/18 challenges were processed
- We later reproduced Round 2 and Buttercup was successful on all challenges

And bounced back in Round 3:

- Buttercup found and/or patched vulnerabilities in 20/26 challenges!

How did Buttercup do in the scored round?

Buttercup came in second place, winning $3 million!

- Found 28 vulnerabilities, patched 19
- Used only ~$40,000 of available budget
- ~90% Accuracy
- Found at least one PoV no one else did
- Found at least one non-synthetic vulnerability

Keys to success:

- Accuracy
- Scoring well across all tasks

I want to try Buttercup!

You’re in Luck….

Buttercup is Open Source!

The exact code we submitted for the semi-finals and finals code is available on our company github organization!

- Buttercup 1.0 https://github.com/trailofbits/asc-buttercup
- Buttercup 2.0 https://github.com/trailofbits/afc-buttercup

Fair warning: Buttercup was designed to run on competition infrastructure and at massive scale, so this version of Buttercup isn’t terribly user friendly…

And we'll do you one better!

A standalone variant of Buttercup is also available!

We've also created a version of Buttercup that runs on commodity (laptop) and typical server-grade hardware. You can check it out at:

- Buttercup standalone https://github.com/trailofbits/buttercup

Enjoy!

Thanks for Coming!