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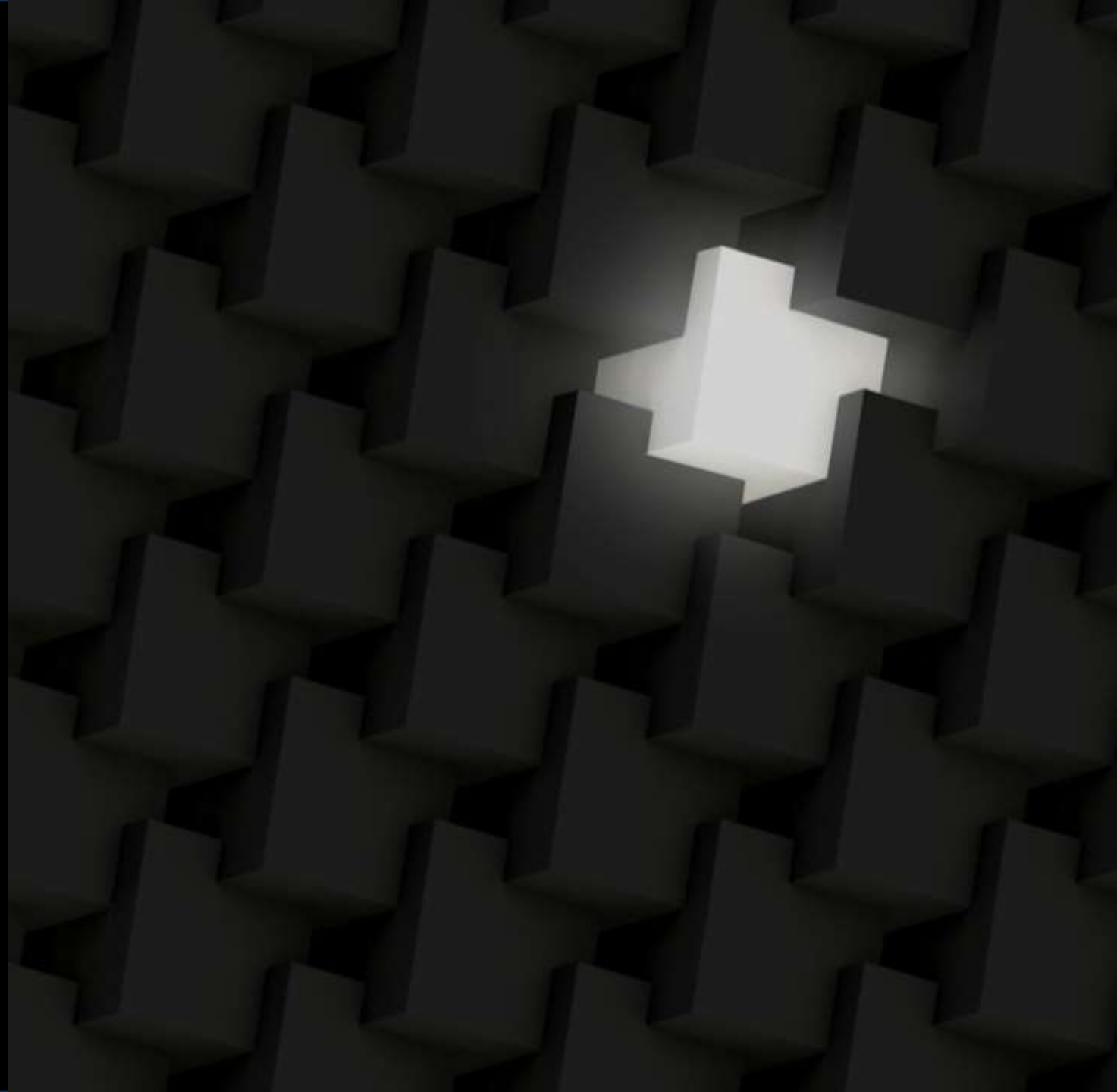
SCAIFE and Static Analysis Classification Research

Presentation for NASA Software
Engineering & Assurance Working
Group

Sept. 25, 2020

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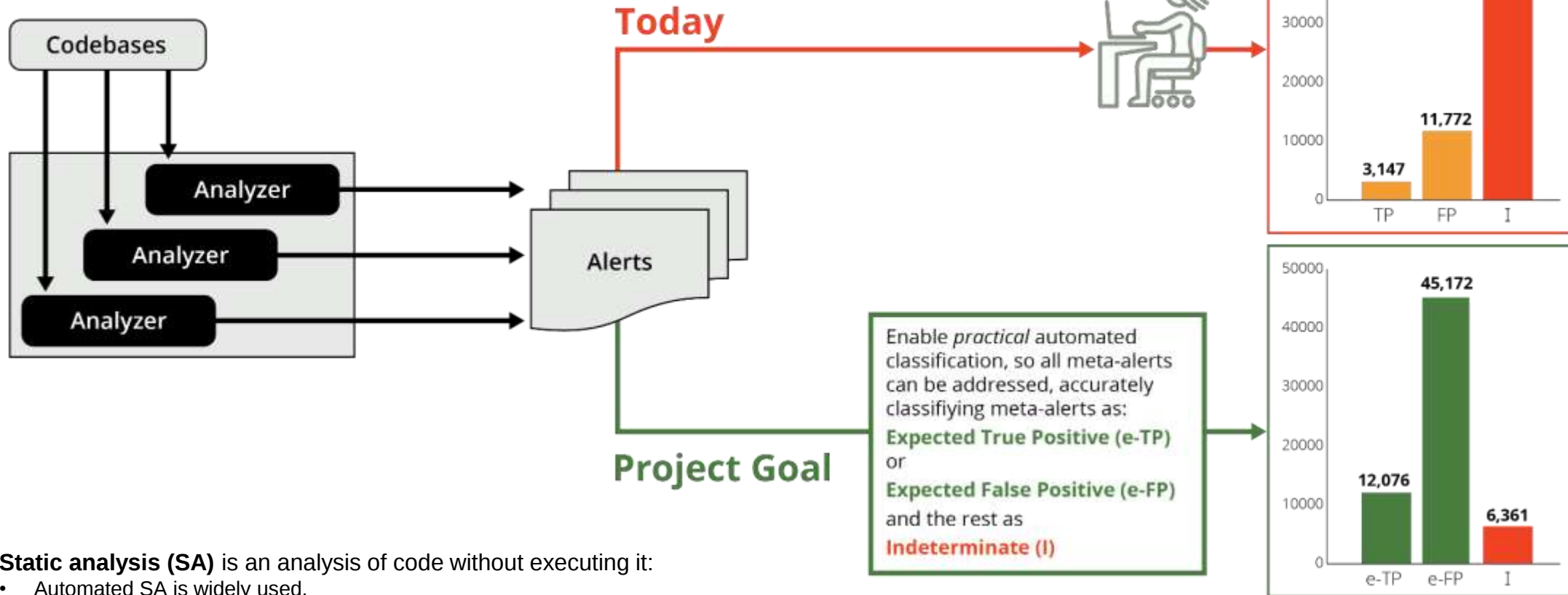
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Overview

Definitions: An *alert* is an SA warning (with a checker ID, line #, filepath, message); an *alertCondition* is an alert mapped to a code flaw taxonomy item (e.g., CWE-190); and a *meta-alert* is mapped to by the set of all alertConditions that differ only by checker ID. We do classification and adjudication at the meta-alert level.

Goal: Enable **practical** automated classification, for more secure software & lower cost/effort

Problem: too many alerts
Solution: automate handling



Static analysis (SA) is an analysis of code without executing it:

- Automated SA is widely used.
- It is a normal part of testing by DoD and commercial organizations.



Static Analysis Classification Research FY16-20

Five Years in Two Slides

FY16-19 Static Analysis Meta-Alert Classification Research

Goal: Enable **practical** automated classification, so all meta-alerts can be addressed.

FY16     

- Issue addressed: classifier accuracy
- Novel approach: use **multiple static analysis tools as features**
- Result: increased accuracy

FY17     

- Issues addressed: **data quality, too little labeled data** for accurate classifiers for some conditions (e.g., CWEs, coding rules)
- Novel approach: **audit rules+lexicon; use test suites to automate the production of labeled (True/False) meta-alert data* for many conditions**
- Result: high precision for more conditions

FY18-19     

- Issue addressed: **little use of automated meta-alert classifier technology** (requires \$\$, data, experts)
- Novel approach: **develop an extensible architecture with a novel test-suite data method**
- Result: **wider use of classifiers (less \$\$, data, experts)** with an extensible architecture, API, software to instantiate architecture, and adaptive heuristic research

* By the end of FY18, ~38K new labeled (T/F) meta-alerts from eight SA tools on the Juliet test suite (vs. ~7K from CERT audit archives over 10 years)

FY20 Static Analysis Meta-Alert Classification Research

Goal: Enable **practical** automated classification, for more secure software & lower cost/effort.

FY20 (of a two-year project, FY20-21)



- Issue addressed: It takes too much time to adjudicate (i.e., audit) static analysis meta-alerts during continuous integration (CI).
- Novel approach: During CI builds, use **classifiers** with **precise cascading** and **CI/CD features**.
- Results
 - Design for CI-SCAIFE system integration
 - SCAIFE System v 1 release (classifier defined, run, and results can be viewed from [G]UI module)
 - Defined cascading API
 - Less-precise cascading using the API
 - Test results for less-precise cascading
 - Significant progress on CI-SCAIFE system integration development
 - Deployment and testing by DoD collaborators (multiple rounds)
 - A published RC_Data open dataset for improved classifier research
 - APIs, technical manuals, and SCALe public publication
- FY21 plan: a precise cascading algorithm, improved classifiers, full integration

Data Quality: Lexicon and Rules

- We developed a **lexicon** and auditing **rule set** for our collaborators.
- It includes a standard set of well-defined **determinations** for static analysis meta-alerts.
- It also includes a set of **auditing rules** to help auditors make consistent decisions in commonly encountered situations.



Improve classifier
precision & recall



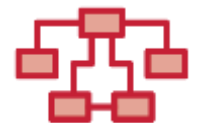
Data quality



Wide variety of
labeled data



Enable classifier use via
modular architecture



Enable classifier use in
CI systems

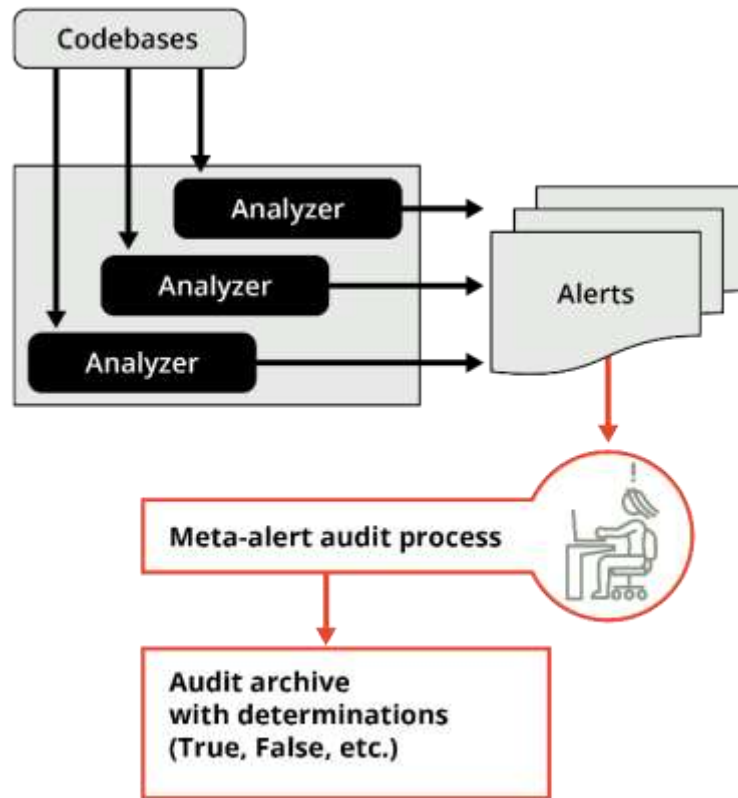
Different auditors should make the **same determination** for a given meta-alert.

Improve the **quality and consistency** of audit data for the purpose of building **machine learning classifiers**.

Help organizations make **better-informed** decisions about **bug fixes, development,** and **future audits**.

Goal: Enable practical automated classification, so all meta-alerts can be addressed

SEI SCALe Framework: Background



Static Analysis Meta-Alert Auditing Framework

Developed by the SEI for ~10 years.

- GUI front end to examine meta-alerts and associated code
- Meta-alert adjudications (true, false) stored in database

Use for Research Projects

- We enhance the framework with features for research.
- Collaborators use it on their codebases.
- Researchers analyze audit data.

After running SA tools, meta-alert adjudication can happen at any point in the software development lifecycle.

Goal: Enable practical automated classification, so all meta-alerts can be addressed



Improve classifier precision & recall



Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

Prioritization Schemes

Prioritization schemes with mathematical formulas user can create and/or use

A screenshot of the 'Create New Scheme' dialog box. It has tabs for 'Instructions', 'CWES', and 'CERT_RULES'. Under 'CWES', there are input fields for 'cert_severity' (2), 'cert_likelihood' (1), 'cert_remediation' (1), 'cert_priority' (0), 'cert_level' (0), and 'confidence' (2). Under 'CERT_RULES', there is a 'Formula for CERT_RULES' section with a calculator interface showing the formula '(cert_severity*2+cert_remediation)*confidence*2'. Below this is a 'Generate The Formula' button. At the bottom, there is a 'Prioritization Formula:' field containing the full formula: 'IF_CWES((confidence*2)+cwe_likelihood)+IF_CERT_RULES((cert_severity*2+cert_remediation)*confidence*2)'. There are 'Save Priority' and 'Priority Scheme Saved' messages, and 'Cancel' and 'Run Priority' buttons at the bottom right.

Practical use of classification



Improve classifier precision & recall



Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

Goal: Enable **practical** automated classification, so all meta-alerts can be addressed

User Field Uploads

User field uploads

- These uploads are for advanced users who can work with SQLite databases and generate values.
- Uploaded fields can be used in priority schemes.
- The CSV uploaded file has the following:
 - One line per project meta-alert ID
 - A left-most field with a meta-alert ID
 - A top row that holds field labels

```
meta_alert_id,safeguard_countermeasure,
vulnerability,residual_risk,impact,
threat,risk,complexity,severity,coupling
112,5,1,4,9,1,1,5,5,1
2,9,3,3,3,1,1,1,9,3
3,3,1,1,1,8,1,5,5,1
4,6,1,1,5,2,1,8,8,1
5,2,1,1,2,3,1,7,7,5
6,5,1,4,4,1,2,4,5,1
7,8,5,3,4,8,2,4,9,9
8,2,1,3,2,8,3,8,8,1
9,6,4,3,6,9,1,4,4,4
10,3,2,2,5,7,1,4,5,9
11,6,1,1,9,6,1,7,7,1
12,2,8,4,1,6,1,4,4,8
```

Practical use of
classification



Improve classifier
precision & recall



Data quality



Wide variety of
labeled data



Enable classifier use via
modular architecture



Enable classifier use in
CI systems

Goal: Enable practical automated classification, so all meta-alerts can be addressed

Archive Sanitizer for Collaborator Data Sharing

We added a data sanitizer to SCALe that has the following functions:

- Anonymizes sensitive fields
- Has an SHA-256 hash with salt
- Enables analysis of features correlated with meta-alert confidence

The audit archive for the project is in a database:

- DB fields may contain sensitive information.
- The sanitizing script anonymizes or discards fields:
 - Diagnostic message
 - Path, including directories and filename
 - Function name
 - Class name
 - Namespace/package
 - Project filename

Practical use of classification



Improve classifier precision & recall



Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

Goal: Enable practical automated classification, so all meta-alerts can be addressed

Analysis of Juliet Test Suite: Initial 2018 Results

Automated Adjudication	Labeled Meta-Alert (counts a fused alertCondition once)
TRUE	13,330
FALSE	24,523

Lots of new data for creating classifiers

(37,853 labeled meta-alerts)

Big savings: a manual audit of 37,853 meta-alerts from non-test-suite programs would take an unrealistic minimum of 1,230 hours (117 seconds per meta-alert audit*).

- The first 37,853 meta-alert audits wouldn't cover many conditions (and sub-conditions) covered by the Juliet test suite.
- We needed true and false labels for classifiers.
- **Realistically**, an enormous amount of manual auditing time is required to develop that much data.

These are initial metrics; we will collect more data as we use more tools and test suites.

*N. Ayewah and W. Pugh. "The Google FindBugs Fixit", *International Symposium on Software Testing and Analysis*, ACM, 2010.

Goal: Enable practical automated classification, so all meta-alerts can be addressed



Improve classifier precision & recall



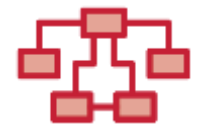
Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

SCAIFE Definitions

SCAIFE is a **modular architecture that enables static analysis meta-alert classification** plus advanced prioritization.

- The **SCAIFE API** defines interfaces between the modular parts.
- **SCAIFE systems** are software systems that instantiate the API.
- Our SCAIFE system releases include a SCALe module plus much more.



Improve classifier precision & recall



Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

SCAIFE = Source Code Analysis Integrated Framework Environment

Goal: Enable practical automated classification, so all meta-alerts can be addressed

SCAIFE Architecture Approach

For efficient development of a robust API to enable widespread classifier use, we need a system architecture that:

- Integrates with existing static analysis tools and aggregators (including SCALe)
- Supports classification and adaptive heuristic functionality
- Demonstrates fast response times for average and worst-case scenarios
- Provides extensibility for future research in static analysis, classification, architecture, and SecDevOps

Swagger/OpenAPI Open-Source Development Toolset

- Quickly develops APIs following the OpenAPI standard
- Auto-generates code for servers and clients in many languages
- Tests server and client controllers with Swagger UI
- Is widely used (10,000 downloads/day)

- Big O analysis was useful.
- Design decisions required balancing goals and analyzing tradeoffs.



Improve classifier precision & recall



Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

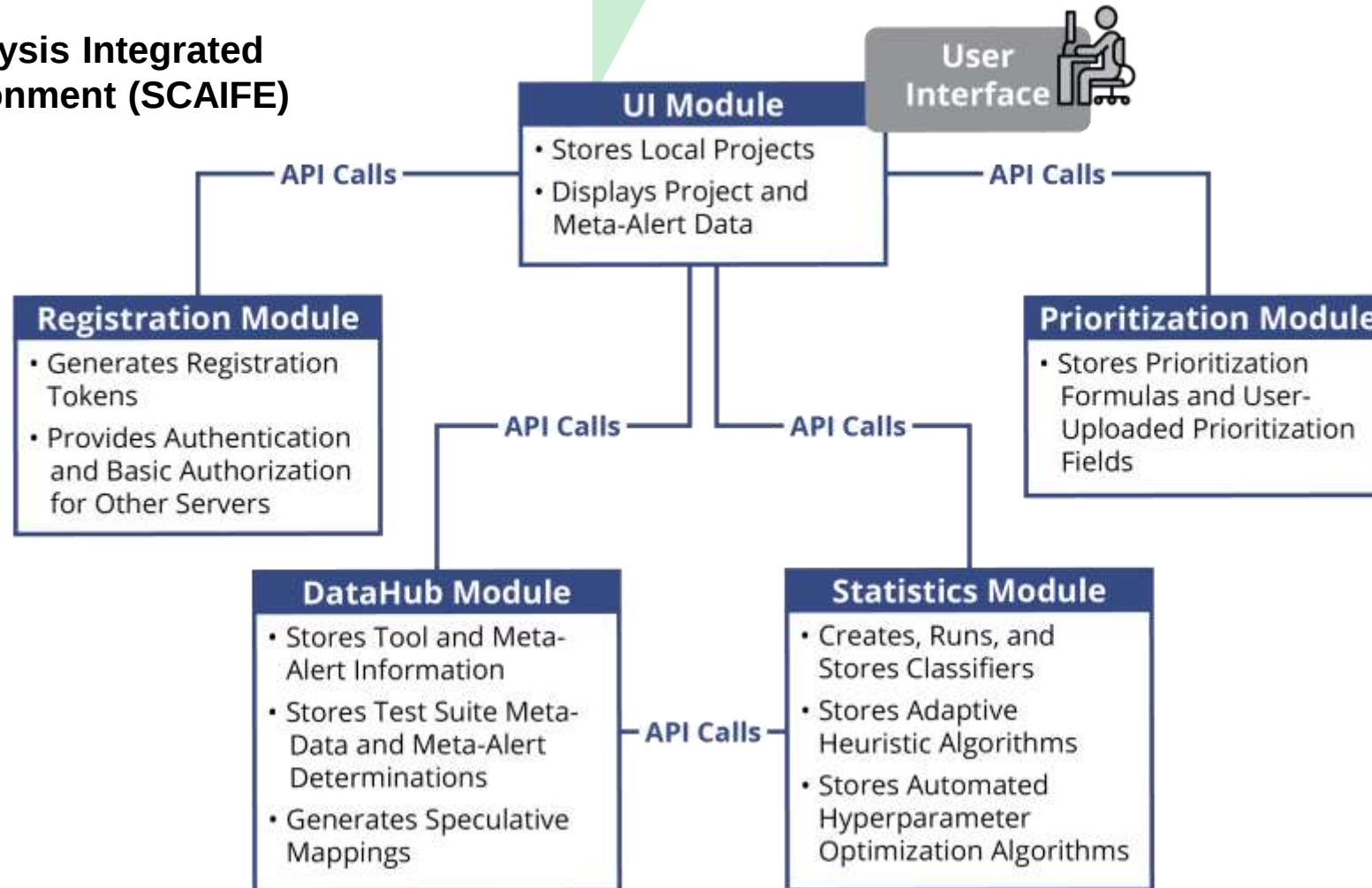
Goal: Enable practical automated classification, so all meta-alerts can be addressed

SCAIFE Architecture

Source Code Analysis Integrated Framework Environment (SCAIFE)

SCAIFE is a modular architecture that **enables users to efficiently start to use classifiers with a wide variety of systems and tools**:

- The formal SCAIFE API definition enables automated code generation to quickly instantiate API calls and generate server stubs in many code languages. This reduces the effort required to integrate existing systems and tools.
- The UI Module instantiation of SCALE is publicly available (GitHub scaife-scale branch).
- Collaborators can get a full SCAIFE instantiation and use it as-is or substitute any module(s) and use the others.



Improve classifier precision & recall

Data quality

Wide variety of labeled data

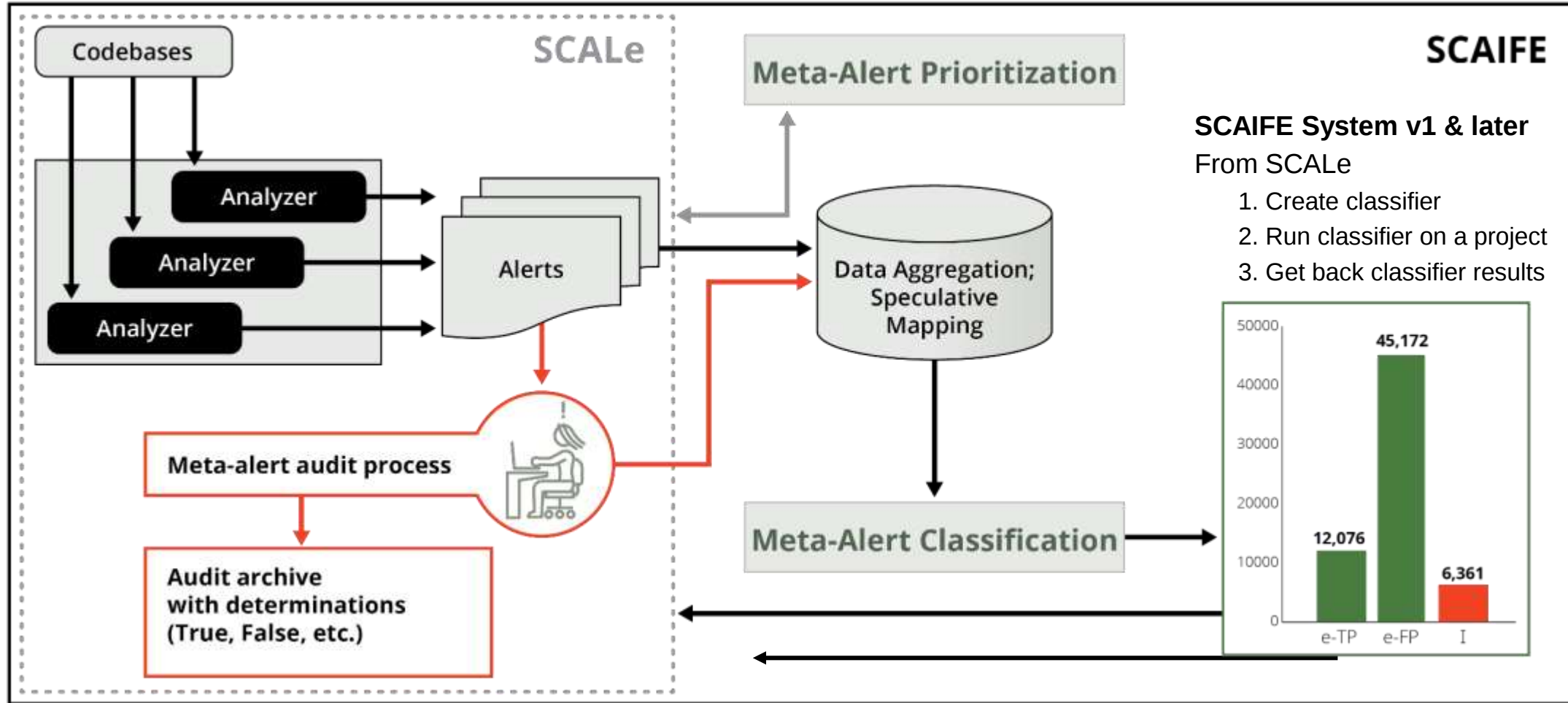
Enable classifier use via modular architecture

Enable classifier use in CI systems

L. Flynn, E. McNeil, and J. Yankel. "[How to Instantiate SCAIFE API Calls: Using SEI SCAIFE Code, the SCAIFE API, Swagger-Editor, and Developing Your Tool with Auto-Generated Code.](#)" SEI Technical Manual. July 2020.

Goal: Enable practical automated classification, so all meta-alerts can be addressed

SCAIFE Meta-Alert Dataflow with SCALE Module



Improve classifier precision & recall

Data quality

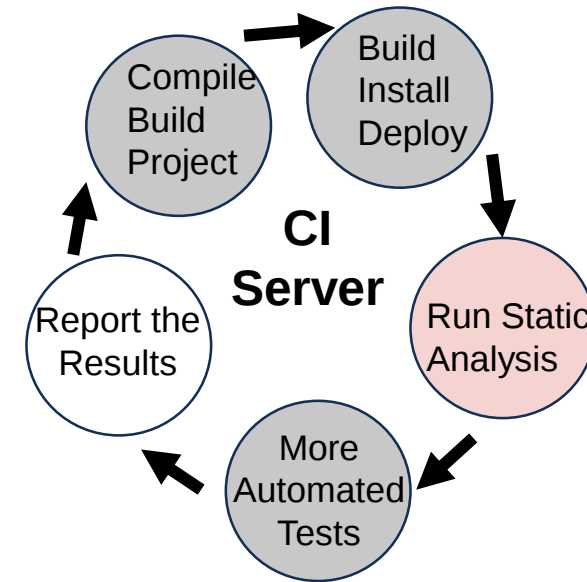
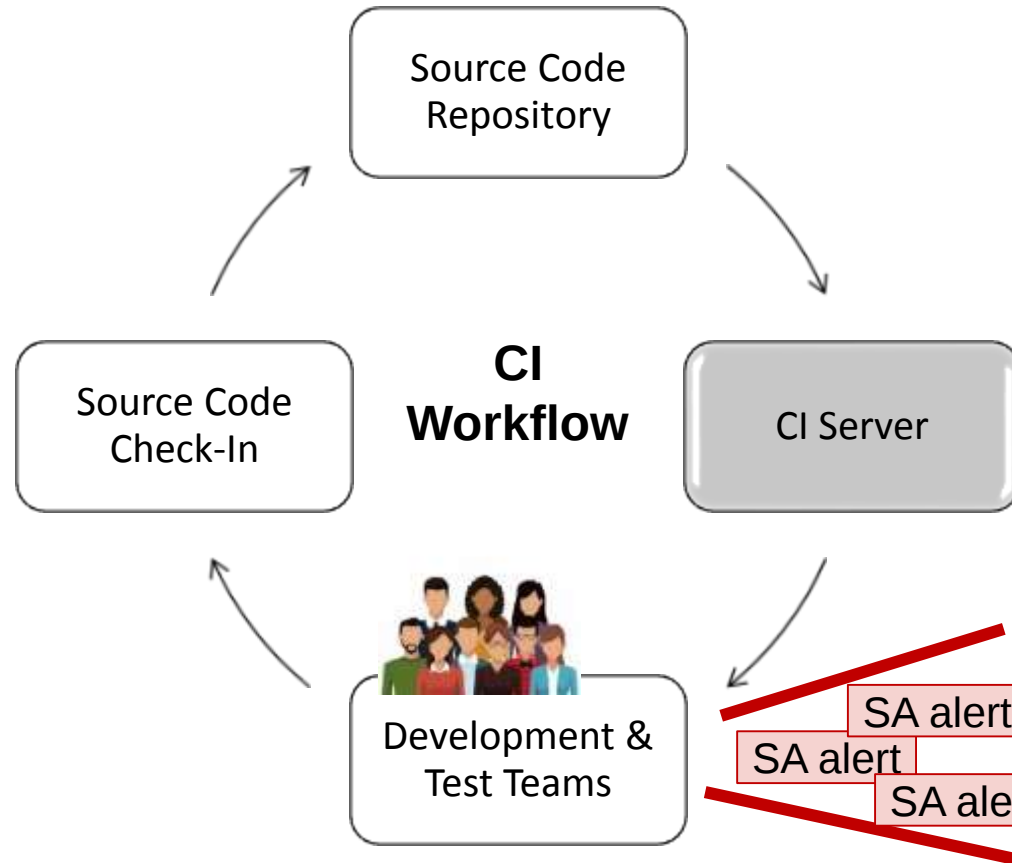
Wide variety of labeled data

Enable classifier use via modular architecture

Enable classifier use in CI systems

Goal: Enable **practical** automated classification, so all meta-alerts can be addressed

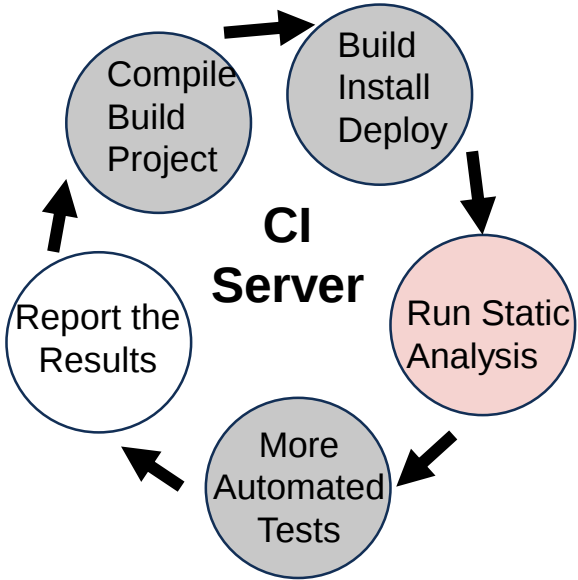
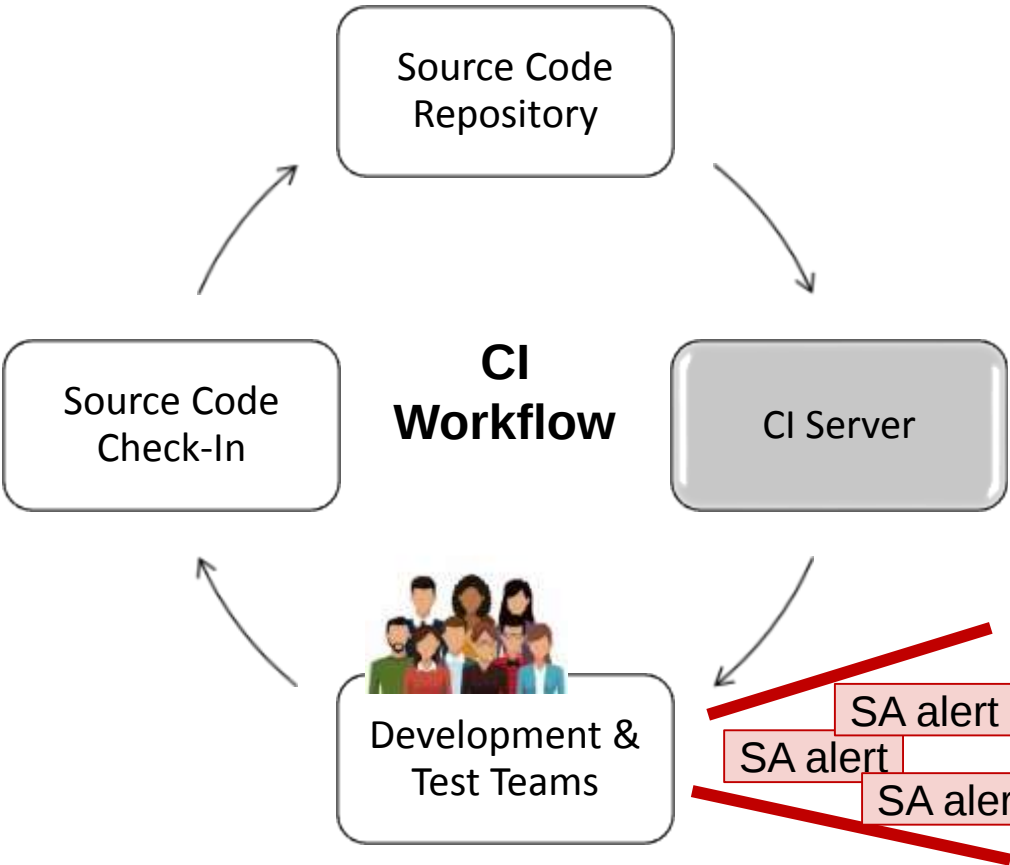
Rapid Adjudication of Static Analysis Alerts During CI



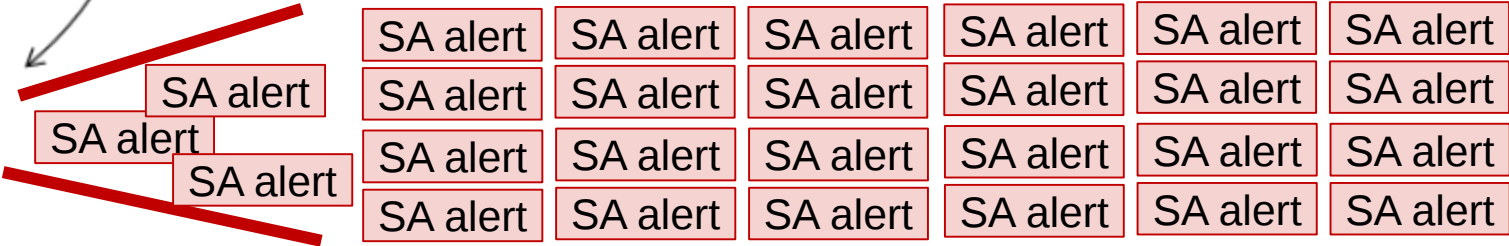
- Improve classifier precision & recall
- Data quality
- Wide variety of labeled data
- Enable classifier use via modular architecture
- Enable classifier use in CI systems

Goal: Enable **practical** automated classification, for more secure software & lower cost/effort

Rapid Adjudication of Static Analysis Alerts During CI

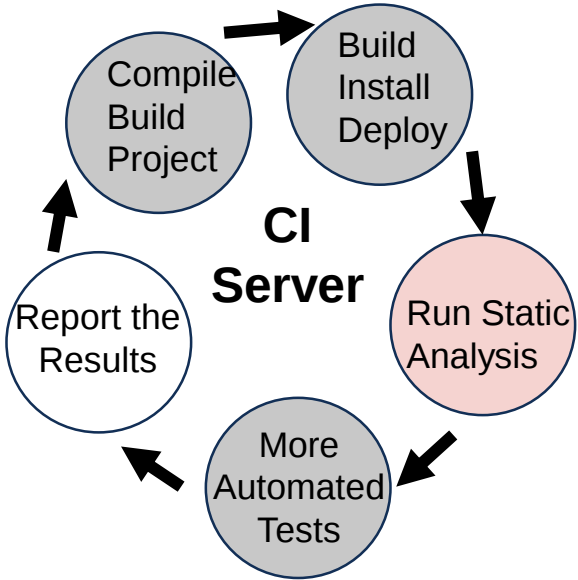
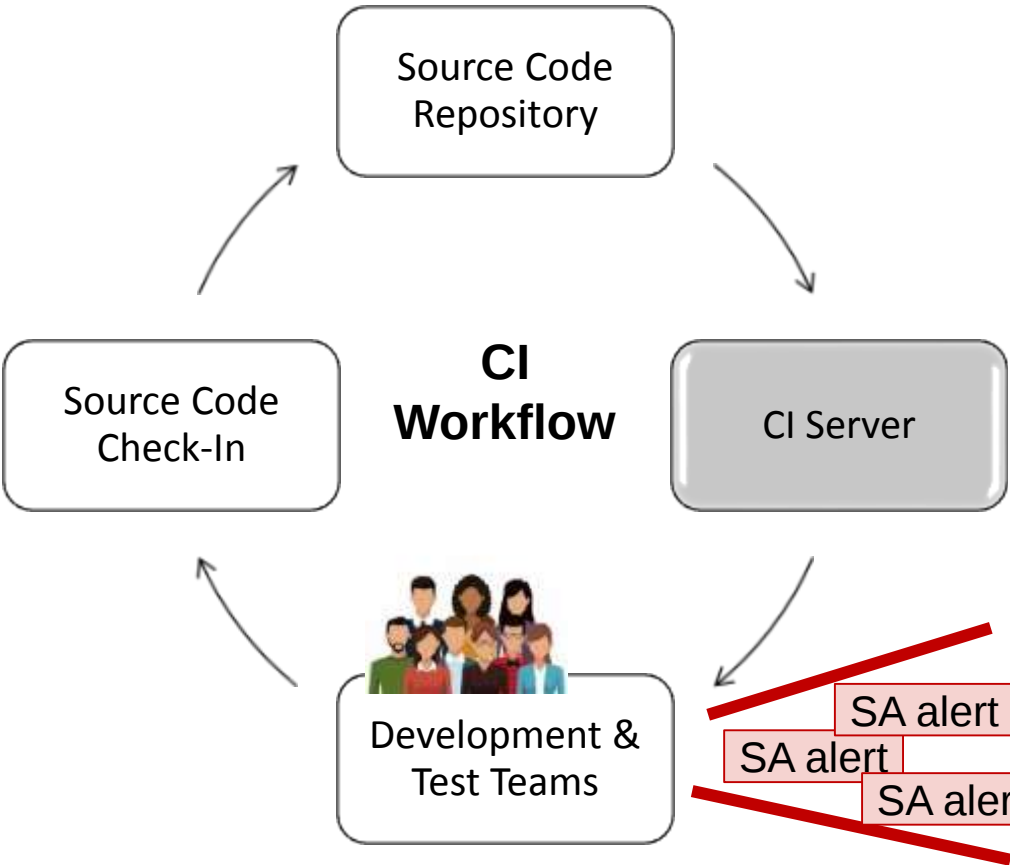


- Improve classifier precision & recall
- Data quality
- Wide variety of labeled data
- Enable classifier use via modular architecture
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Goal: Enable **practical** automated classification, for more secure software & lower cost/effort

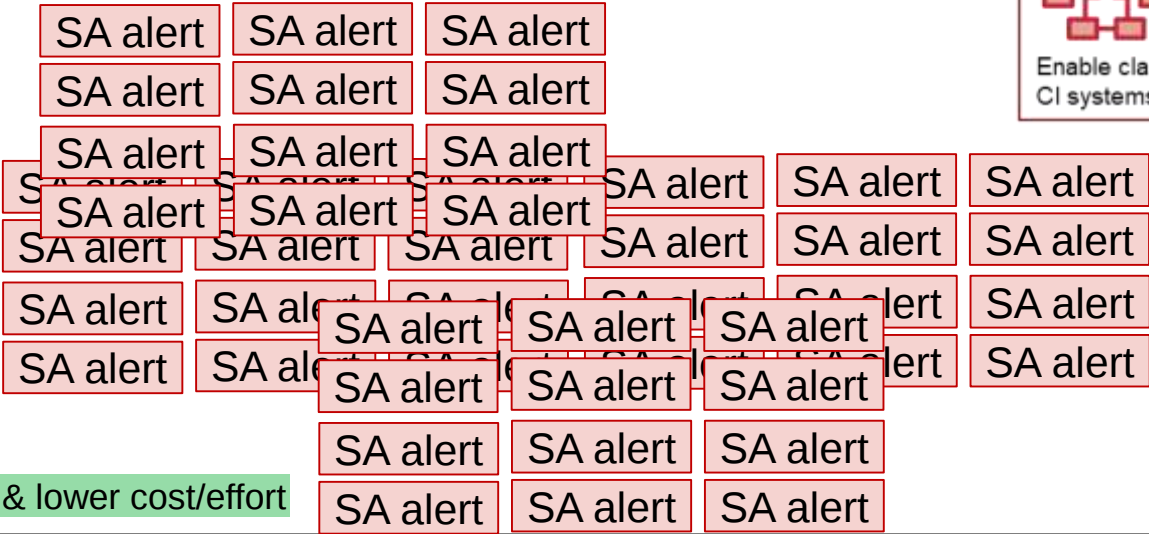
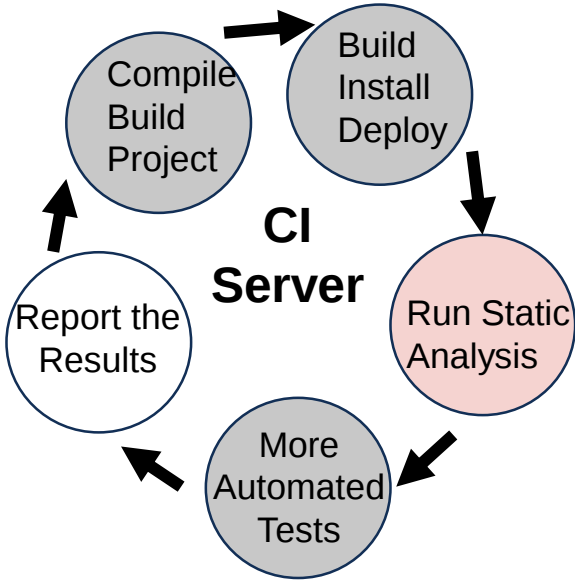
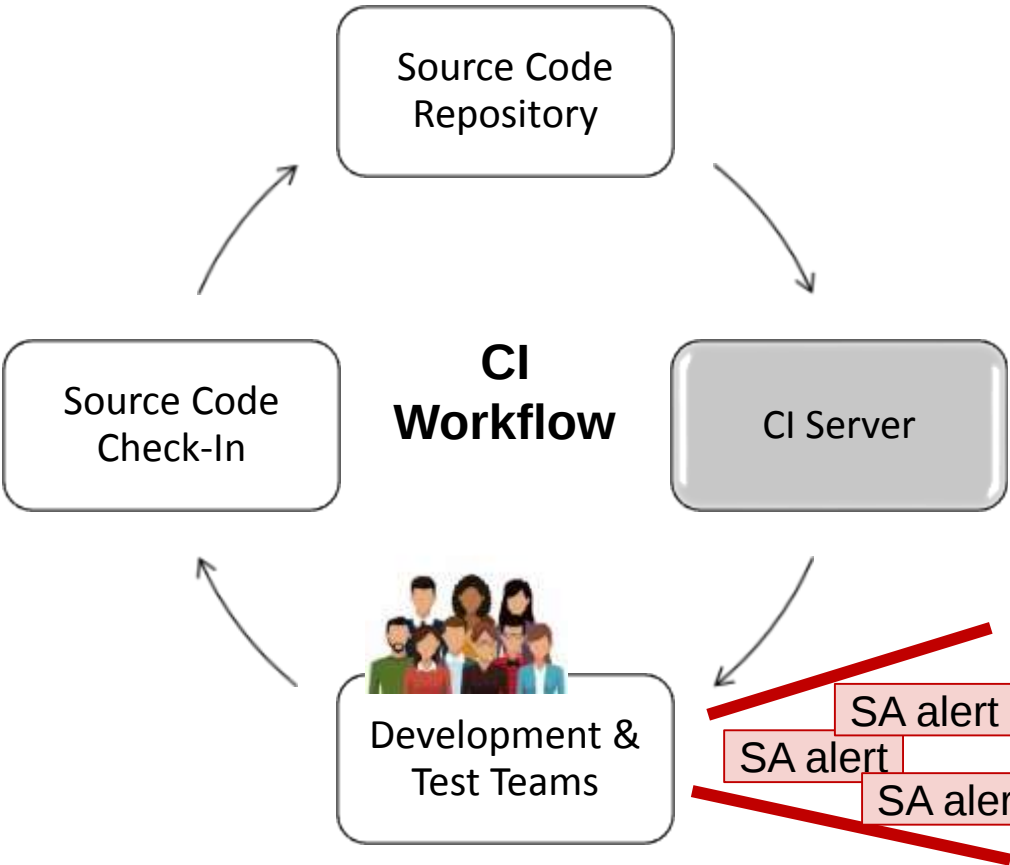
Rapid Adjudication of Static Analysis Alerts During CI



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Goal: Enable **practical** automated classification, for more secure software & lower cost/effort

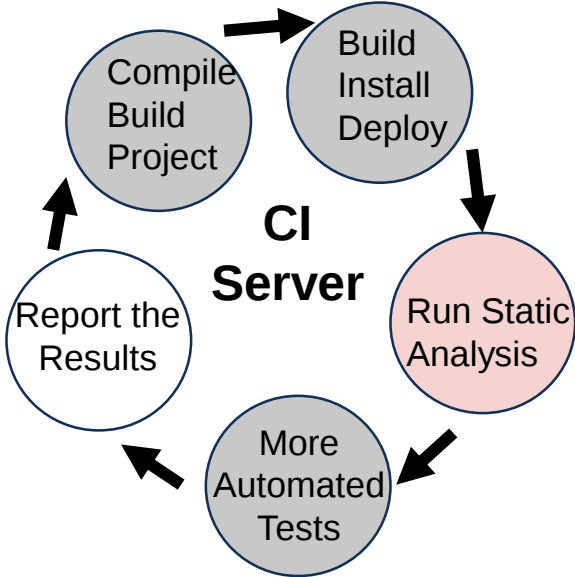
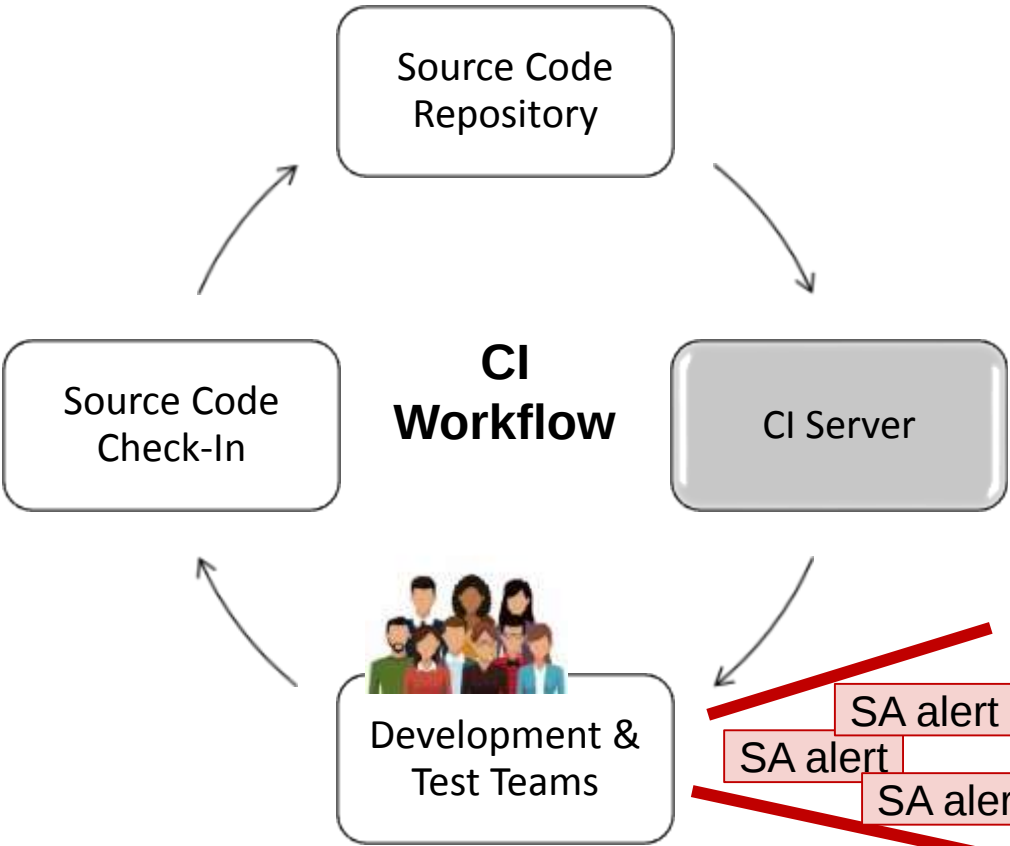
Rapid Adjudication of Static Analysis Alerts During CI



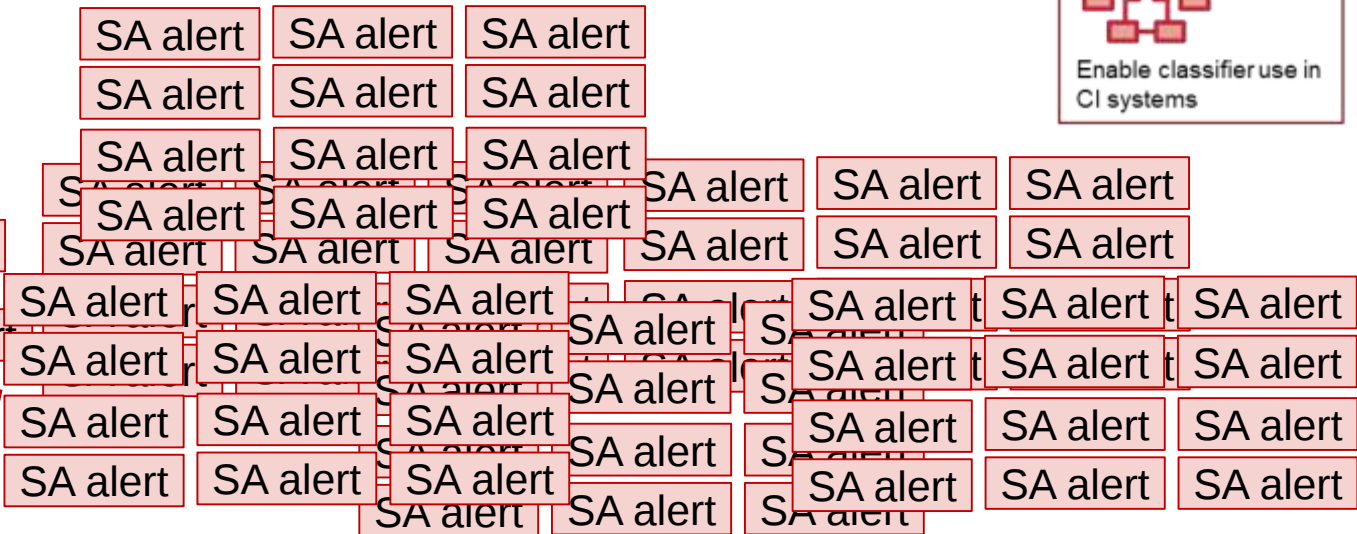
- Improve classifier precision & recall
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Goal: Enable **practical** automated classification, for more secure software & lower cost/effort

Rapid Adjudication of Static Analysis Alerts During CI



- Improve classifier precision & recall
- Data quality
- Wide variety of labeled data
- Enable classifier use via modular architecture
- Enable classifier use in CI systems



Goal: Enable **practical** automated classification, for more secure software & lower cost/effort

Rapid Adjudication of Static Analysis Alerts During CI

DoD is moving to CI/CD but doesn't have a solution to this problem

Problem: It takes too much time to adjudicate alerts from static analysis tools during continuous integration (CI).

Static analysis (SA) is incompletely integrated in CI development projects in the DoD, and the selection of SA tools is limited to those with very few false positives.

Current practice is too labor-intensive. We will automate it.



Improve classifier precision & recall



Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

Two Methods of Alternative Incomplete Approaches

Methods:

1. Adjudicate very few alert types in CI
 - Our method builds on this
2. Run SA automatically in CI but don't adjudicate during CI



Improve classifier
precision & recall



Data quality



Wide variety of
labeled data



Enable classifier use via
modular architecture



Enable classifier use in
CI systems

SCAIFE Architecture

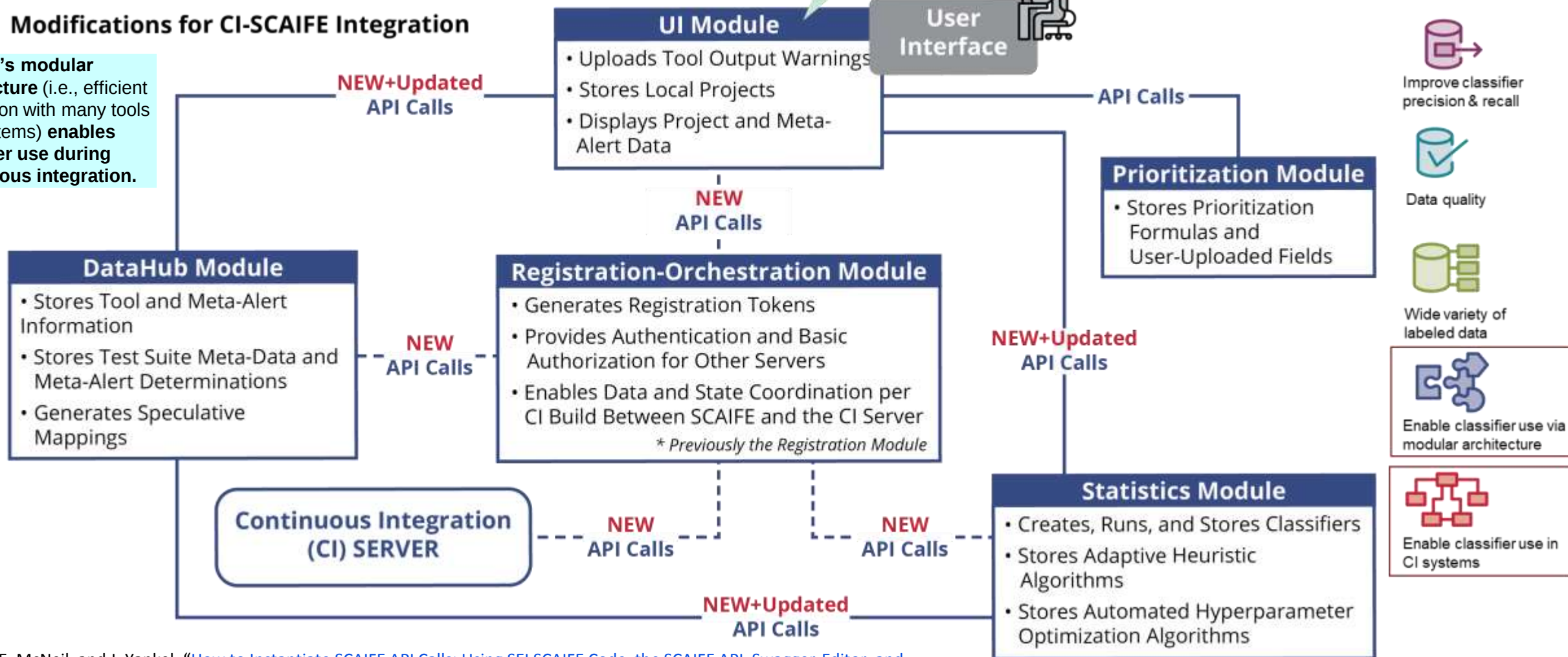
Modifications for CI-SCAIFE Integration

SCAIFE's modular architecture (i.e., efficient integration with many tools and systems) enables classifier use during continuous integration.

Any static analysis tool can instantiate APIs to become a UI Module. For example

- SEI SCALE
- DHS SWAMP
- CCDC C5ISR SwAT

- Other aggregator tools
- Single static analysis tools



L. Flynn, E. McNeil, and J. Yankel. "How to Instantiate SCAIFE API Calls: Using SEI SCAIFE Code, the SCAIFE API, Swagger-Editor, and Developing Your Tool with Auto-Generated Code." SEI Technical Manual. July 2020.

Goal: Enable practical automated classification, so all meta-alerts can be addressed

The diagram illustrates the CI Workflow. It starts with 'Source Code Check-in' leading to 'Source Code Repository'. From there, it goes to 'CI Workflow' and then 'CI Server'. The 'CI Server' triggers a cycle of steps: 'Compile build project', 'Build Install Deploy', 'Run Static Analysis', 'More Automated Tests', and 'Report the Results', which then feeds back into 'CI Server'. Below this, a 'Development & Test Teams' box is shown with multiple red arrows pointing to a grid of 'SA alert' boxes, indicating alerts triggered by the teams.

- Improve classifier precision & recall

Data quality

Wide variety of labeled data

Enable classifier use via modular architecture

Enable classifier use in CI systems

Meta-alert Classification in CI: Impact

If this project is successful:

- Organizations that develop tools and analyze code
 - Cut number of alerts manually adjudicated in half (save \$\$\$), double adjudicated meta-alerts (more security at same cost), or some mix of cost-savings and increased adjudication
 - **By integrating with CI, catch and fix more SA-identified flaws early in development, saving money**
 - Use precise cascader developed in this project to improve code security analyses.
 - Use other code and algorithms developed in this project (e.g., SCAIFE system, API, and classification/active learning) to enable practical meta-alert classification in their systems
- Targeted on-ramps for transition:
 - Research project collaborators
 - Discussions started with SEI engineers on DoD contract projects
 - One project could analyze double the SA meta-alerts with the same effort
 - Another project could integrate SA meta-alert adjudication in their CI



SA Classification in CI: Relevance/Impact for General DoD State of the Practice

Enable the DoD to more efficiently address SA meta-alerts in CI/CD time constraints, by halving time to manually adjudicate meta-alerts for the same level of security.

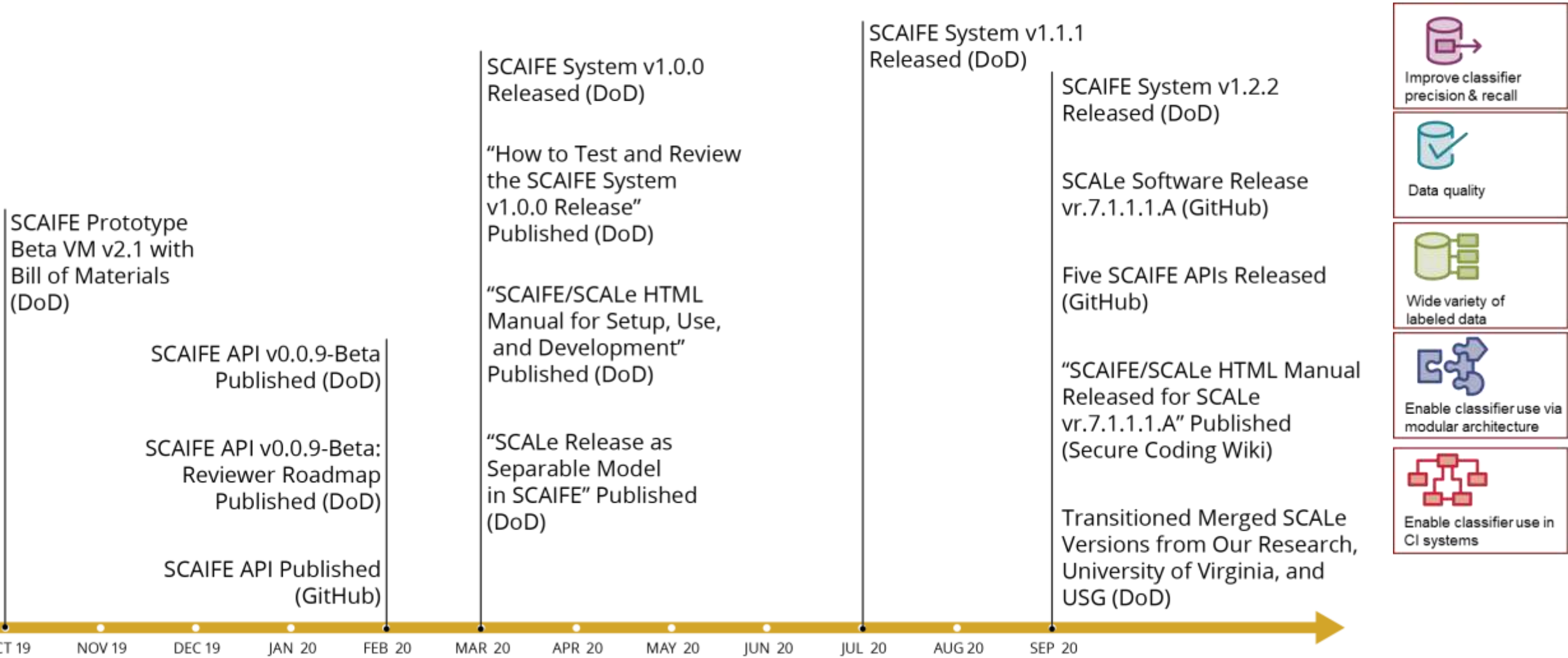
Envisioned classifier-use scenario in Authorization to Operate (ATO):

- DoD Program PMO must provide evidence how software risks managed
 - PMO needs ATO by Authorizing Official
 - How to do this for CI/CD systems is pretty much being developed + experimented, now
 - Possibly CATO (Continuous ATO) option
 - ✓ CWEs and other flaw conditions might be required to adjudicate meta-alerts and fix TPs
- **We envision this classifier-use scenario in CATOs:**
 - CATO covers more code flaw conditions
 - **Meta-alerts classified expected-False would not require manual adjudication**
 - Even if condition not mentioned in a CATO, classifier use frees more adjudication effort



FY20: Select Code/API Artifacts

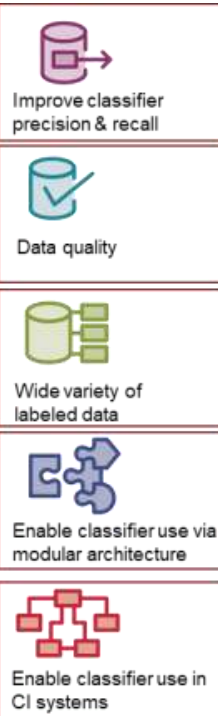
- DoD can get full implementation
- SCALE + SCAIFE API publicly-published (Sept 2020 versions)
- Significant CI integration; to be completed in FY21



Goal: Enable **practical** automated classification, for more secure software & lower cost/effort

FY20 Select Artifacts (New Detail or Item) –1

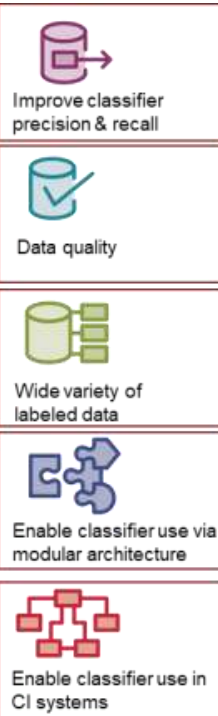
- (Oct 2019 and Feb, April, and Sept 2020) GitHub publication of SCAIFE API versions <https://github.com/cmu-sei/SCAIFE-API>
- (04/2/20) Published the open dataset “RC_Data” for classifier research to the SEI CERT Secure Coding webpage “[Open Dataset RC_Data for Classifier Research](#)”. Database with static analysis alerts from open-source tools, adjudications, code metrics, and more for two codebases.
- (06/18/20) Presentation “Automated Classifiers to Adjudicate Static Analysis Alerts: Challenges, Progress, and Next Steps” (Lori Flynn, Stephen Adams, and Tim Sherburne) to DoD’s DEVCOM Cyber Community of Interest.
- (06/25/20) Presentation “Automated Classifiers to Adjudicate Static Analysis Alerts: Challenges, Progress, and Potential Collaborations with NASA IV&V” (L. Flynn) to leaders of the NASA IV&V Static Code Analysis Working Group (SCAWG).



Goal: Enable practical automated classification, for more secure software & lower cost/effort

FY20 Select Artifacts (New Detail or Item) –2

- (07/8/20) Technical manual “[How to Instantiate SCAIFE API Calls: Using SEI SCAIFE Code, the SCAIFE API, Swagger-Editor, and Developing Your Tool with Auto-Generated Code](#)” (L. Flynn, E. McNeil, and J. Yankel) Instructions for three types of SCAIFE System code access: (1) none, (2) access to [SCALE code](#), or (3) full access.
- (07/13/20) Auto-generated Java client code for the five SCAIFE API modules for a DoD collaborator, to help them quickly start to instantiate SCAIFE API calls from their tool
- (09/14/2020) Blog post “[Managing Static Analysis Alerts with Efficient Instantiation of the SCAIFE API into Code and an Automatically Classifying System](#)” by Lori Flynn
- (09/22/2020) Presentation “Rapid Adjudication of Static Analysis Meta-Alerts During Continuous Integration”, Software Assurance Community of Practice (SwA CoP).
- (Sept. 2020) SCALE code at <https://github.com/cmu-sei/SCALE/tree/scaife-scale>
- (Sept. 2020) Test data generated with ‘diff’ cascading, for comparison to precise cascading



Goal: Enable practical automated classification, for more secure software & lower cost/effort



SCAIFE and Static Analysis Classification Research

Invitation to Collaborate

DoD Orgs that do CI Development: Invitation to Test

I need DoD collaborators that do CI development, to test our tooling

- Current collaborators test but not doing CI
- Full system implementation release currently limited to DoD
- CI testing does *not* have to include data sharing (next slide)
- If interested please contact me lflynn@cert.org

Deployment and testing supported by project

- release system containerized and with configuration files (ports, URLs, names) to ease integration in wide variety of systems
- comes with much documentation, we've extended that a lot in last year per collaborator feedback
- Part of FY21 project specifically is for helping collaborators use the system

All: Might you be able to help us get labeled data?

- Effort to label data on particular open-source codebases
- SCALe (scaife-scale branch) on GitHub can be used to do the adjudication and store results
- Even better, SEI can provide full SCAIFE system to DoD orgs (includes SCALe + classification etc.)
- Auditing self-training support via published materials (next slide)
- Possibly your own stored archives, sanitized before sharing

High-quality manually labeled data would help us improve our DoD sponsored classification research.

If our research succeeds, the improved classification techniques and data will help your orgs to secure your code and save money.

Goal: Enable **practical** automated classification, for more secure software & lower cost/effort



Improve classifier precision & recall



Data quality



Wide variety of labeled data



Enable classifier use via modular architecture



Enable classifier use in CI systems

Self-Training Resources for Auditing Meta-Alerts

- Paper “[Static Analysis Alert Audits: Lexicon & Rules](#)” (D. Svoboda, L. Flynn, W. Snaveley) IEEE SecDev
- Presentation “Hands-On Tutorial: Auditing Static Analysis Alerts Using a Lexicon and Rules” (L. Flynn, D. Svoboda, W. Snaveley) <https://resources.sei.cmu.edu/library/asset-view.cfm?assetid=505451>
- Webcast (1 hour video, hands-on SCALE use): “Improve Your Static Analysis Audits Using CERT SCALE’s New Features” by L. Flynn. (The SCAIFE System includes the SCALE tool, as a separable part of SCAIFE.)
<https://resources.sei.cmu.edu/library/asset-view.cfm?assetid=538843> (video) and
https://resources.sei.cmu.edu/asset_files/Presentation/2018_017_101_532198.pdf (slides)
- Video “Rapid Construction of Accurate Automatic Alert Handling System” Nov. 2019 <https://youtu.be/dwYbhgko3to>
- Slides “Rapid Construction of Accurate Automatic Alert Handling System” Nov. 2019
https://resources.sei.cmu.edu/asset_files/Presentation/2019_017_001_635435.pdf

It will increase the quality of data if your team studies definitions of the code flaw types ("conditions") they will inspect static analysis meta-alerts for, as defined in a formal code flaw taxonomy.

For this classification research, the taxonomies currently of the most interest are:

- MITRE CWE <https://cwe.mitre.org/data/index.html>
- CERT coding rules for C: <https://wiki.sei.cmu.edu/confluence/display/c/SEI+CERT+C+Coding+Standard>
- CERT coding rules for Java:
<https://wiki.sei.cmu.edu/confluence/display/java/SEI+CERT+Oracle+Coding+Standard+for+Java>
- CERT coding rules for C++: <https://wiki.sei.cmu.edu/confluence/pages/viewpage.action?pageId=88046682>

The SCALE (scaife-scale branch) GitHub release includes a SCAIFE/SCALE HTML manual with extensive information about how to use the SCAIFE and SCALE systems to adjudicate (aka ‘audit’) static analysis meta-alerts.

Goal: Enable practical automated classification, for more secure software & lower cost/effort





SCAIFE and Static Analysis Classification Research

Impacts Time Frame

Project Impacts Time Frame

NEAR

Public can use/review SCAIFE API and SCALe* module.

DoD collaborators will further test SCAIFE to

- provide data and feedback
- integrate their tools using the API

The FY20-21 research project incorporates continuous integration (CI) into architecture design.

MID

More collaborators (DoD and non-DoD) to test SCAIFE with CI.

Design improvements for transition include

- classification precision
- latencies
- bandwidth/disk/memory use
- business continuity
- scalability

FAR

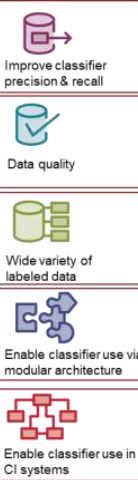
A wide variety of systems will do automated meta-alert classification, using

- SCAIFE System
- SCAIFE API

Goal: Provide better software security, or less time and cost for the same security (DoD and non-DoD).

** Version of SCALe used in SCAIFE System implementation*

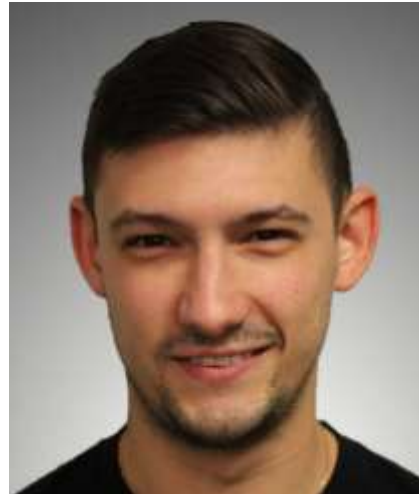
Goal: Enable practical automated classification, for more secure software & lower cost/effort



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Thanks + Contact Info

Thank you for listening!

Questions?

Feedback and potential collaborations
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