Security Signals

A framework to scale web security

Sławomir Goryczka
Information Security & Software Engineer
Google Switzerland
slawek@google.com

Michele Spagnuolo
Staff Software Engineer
Google Switzerland
mikispag@google.com

Agenda

01 Introduction to Web Security

02 Collecting Signals

03 Processing Signals

04 Using Data to Improve Security

05 Use Cases

06 Example: Cross-Site Request Forgery

07 Q&A

01

Introduction to Web Security

Why is Web Security hard, especially at Google?

Possibly the largest number of web application in the world:

- more than 8000 web services,
- services are hosted across almost 1000 registrable domains,
- processing trillions of HTTP requests from billions of web users daily,

… serving web pages created and persisted by a heterogeneous ecosystem with:

- many programing languages, e.g. Java, C++, Python, Go,
- HTML template system engines, sanitizers,
- Billions of line of code, thousands of third-party libraries,

… changing all the time.

Secure-by-Design or Fail to Scale

With a large-scale, rapidly evolving codebase, fixing vulnerabilities one-by-one is neither efficient nor scalable.
To make security an ambient property of the developer infrastructure, the following is needed:

- **Guidelines and recommendations** for developers,
- **Tools, libraries,** and **frameworks**,
- A **“well-lit path”**,
- **Security evaluation and justification of non-recommended approaches**,
- **Fixing regressions**, blind spots, etc.

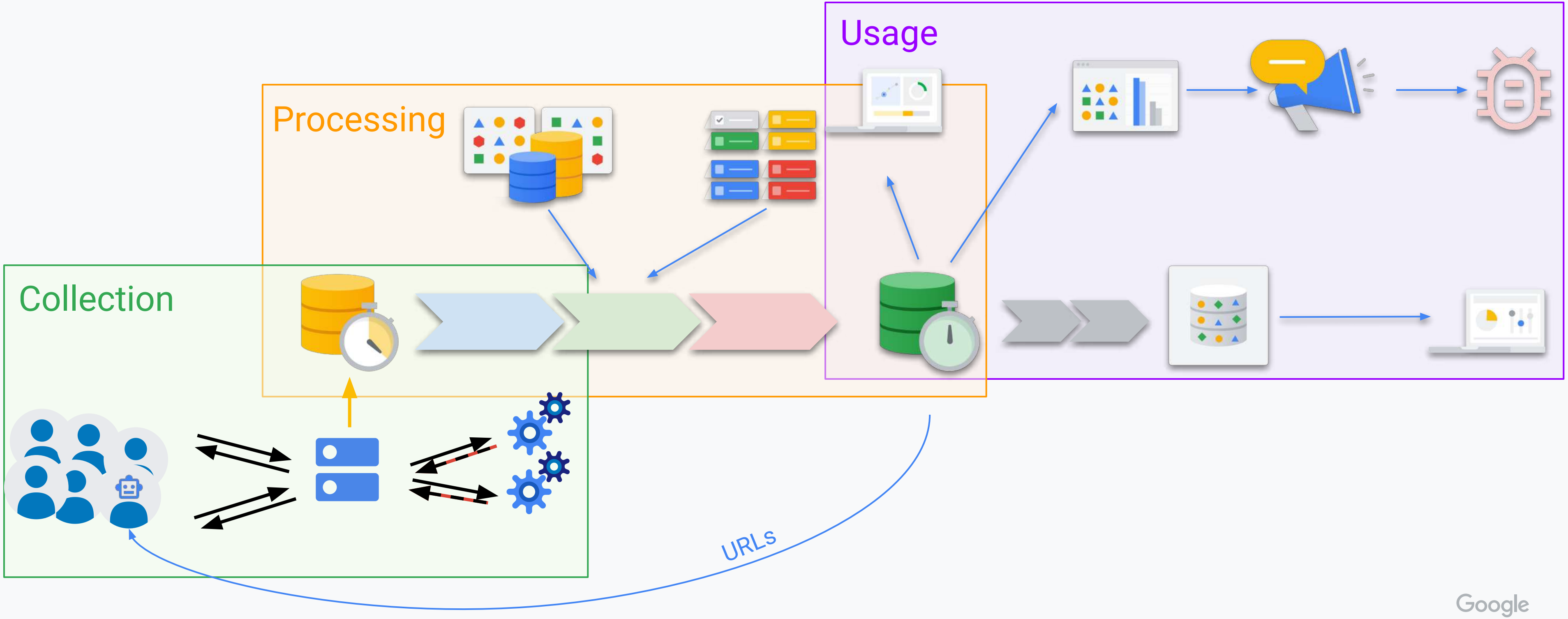
Google

Security Signals Framework

Security Signals is a framework to collect static and security-related usage data (aka signals) about a web ecosystem to generate insights, report bugs, or prioritize work.
It can also provide higher-level interpretations of the data to:

- Provide **visibility** into security stance of the web infrastructure, e.g. to determine if certain applications are inherently "**secure-by-design**"
- **Optimize resource allocation**, by evaluating web application risk,
- Provide **continuous monitoring** of security controls and assurance of the alignment to the "secure-by-design" principles.

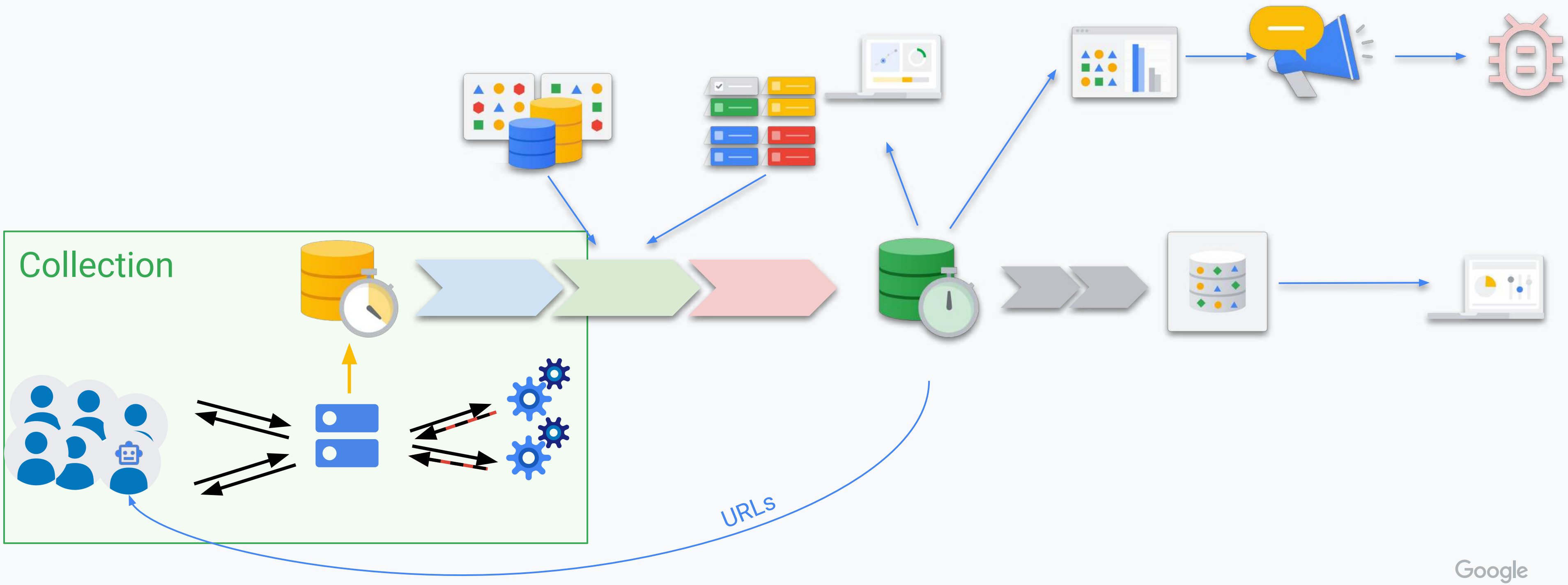
Security Signals Architecture



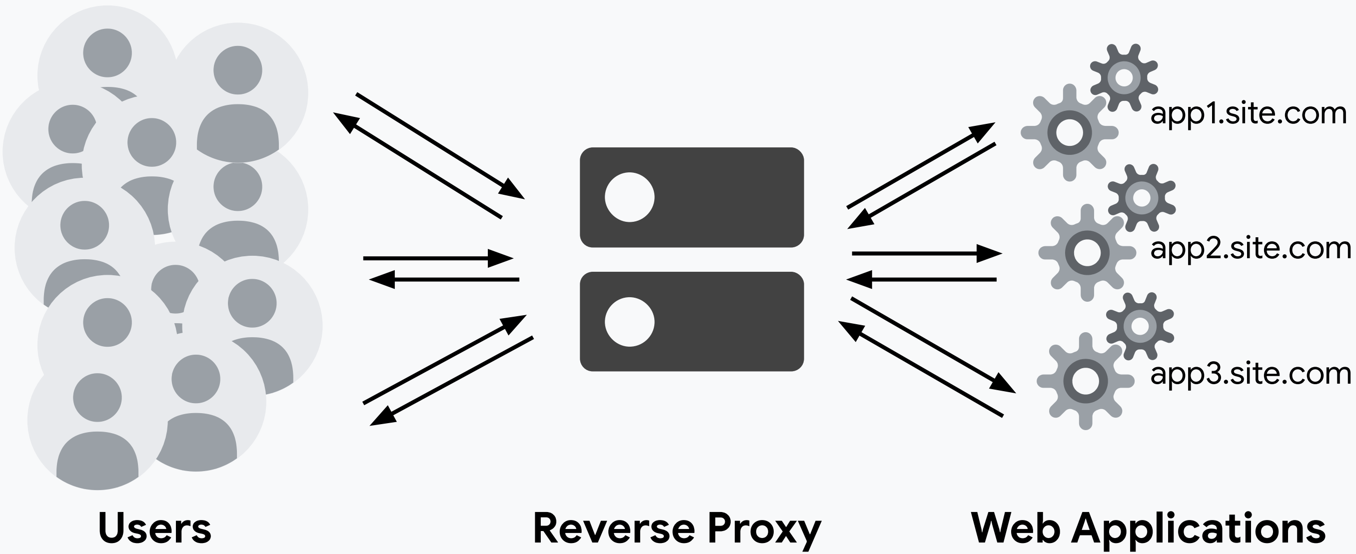
02

Collecting Signals

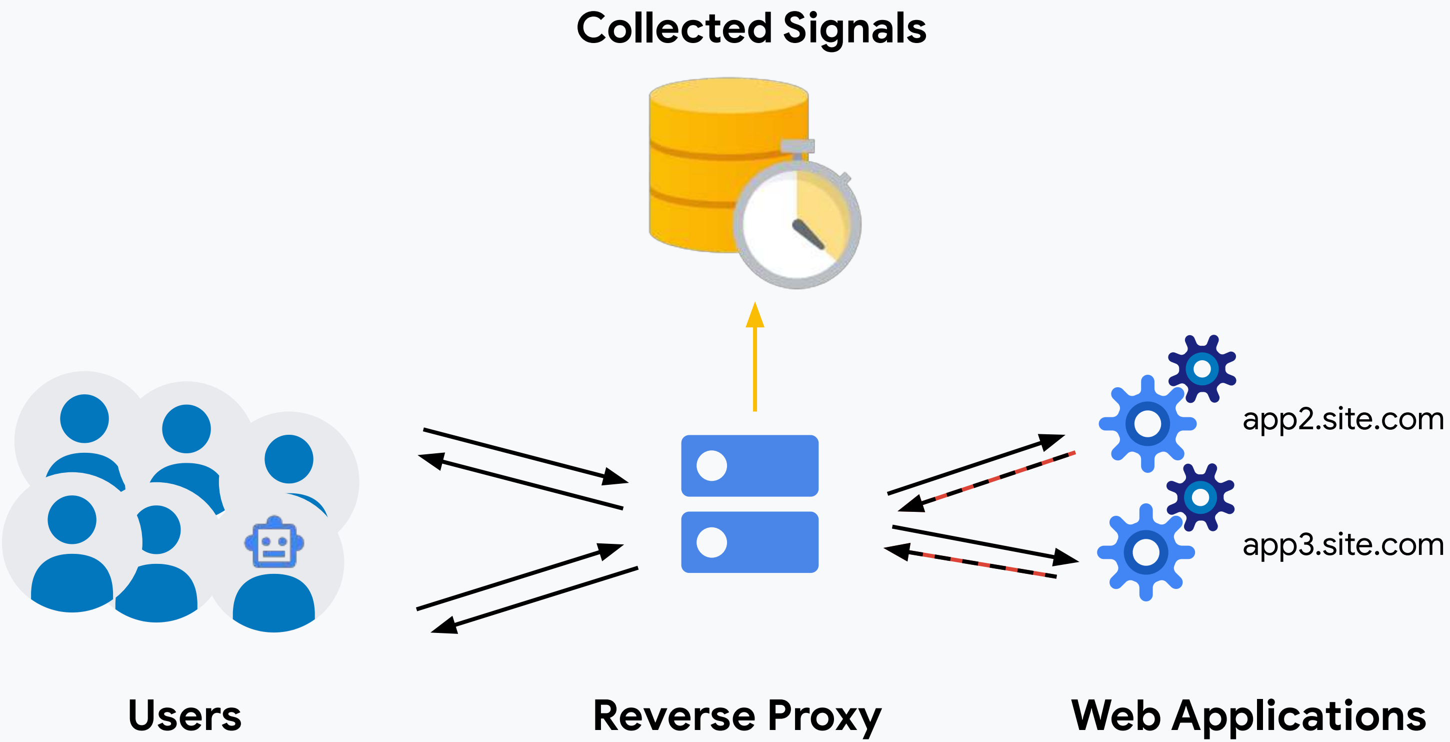
Security Signals Architecture



Web Traffic Flowing Through a Reverse Proxy



Collecting Security Signals



Collecting Data: Challenges

Google processes trillions of HTTP requests from billions of web users daily. To ensure privacy of users, feasibility and quality of generated insights:

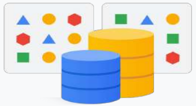
- **Web traffic is sampled** with a rate of usually up to 1%, and 10% for internal traffic,
- **Sensitive data** and request/response **bodies are not collected**,
- Individual HTTP requests/responses are not persisted for a long time – **only aggregated and de-identified data**,
- A very short **retention time**,
- **Isolation** of persistent data with **audited access**, and only **justified human access**,
- **Stability** and **functionality** of the GFE.

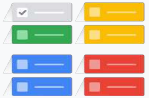
Web Traffic Signals

- Basic HTTP request/response data, e.g. hostname, content type, redacted path,
- Security-related HTTP headers, e.g. `Content-Security-Policy`, `Strict-Transport-Security`, `X-Content-Type-Options`,
- Synthetic Security Signals,
    - Generated by instrumented web frameworks,
    - Using an internal-only `X-Google-Security-Signals` HTTP response header,
    - Collected when passing reverse proxy...
    - ... and dropped before sending outside.

Nothing about and from the HTTP request/response body is collected.

Auxiliary Data and Risk Signals





Auxiliary data are collected from internal databases. They enrich security signals with information about:

- the production environment,
- product and ownership information,
- source-code information, etc.

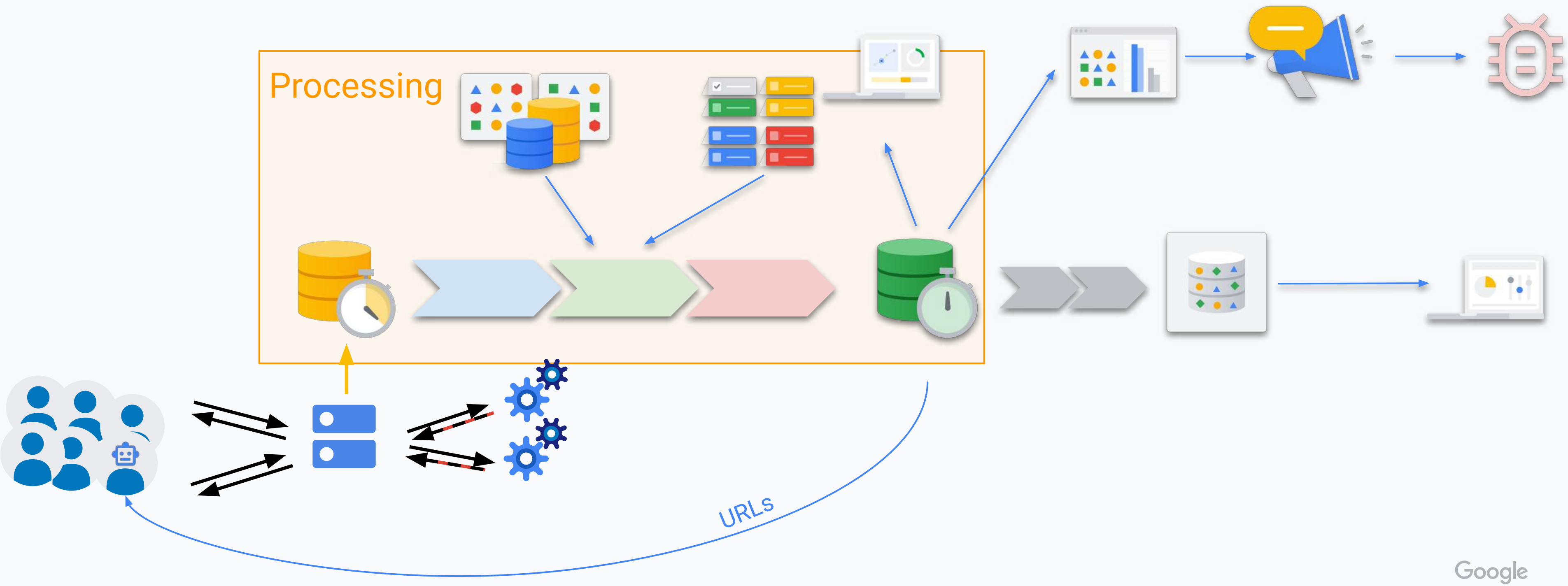
This context is crucial for streamlining **remediation efforts** and **automated bug filing.**

Risk signals provide data necessary to assess risk and prioritize according to it, e.g. sensitivity of the hosting domains based on Domain Tiers, exposure of services, volume of traffic.

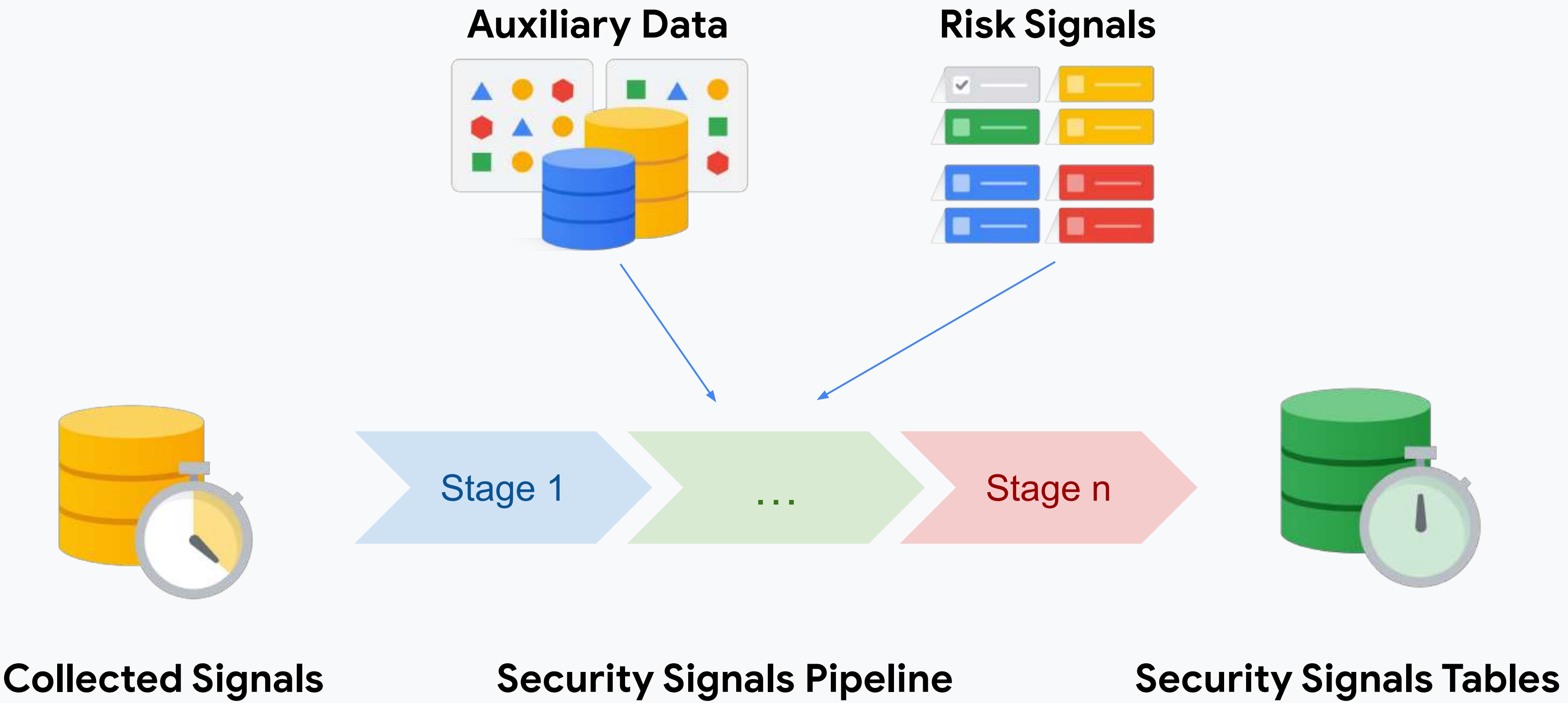
03

Processing Signals

Security Signals Architecture



Security Signals Pipeline



Cardinality Reduction

Collected Security Signals have billions of entries with high-cardinality dimensions, which makes them impractical to query. The pipeline reduces cardinality by aggregating values, while maintaining data usefulness.

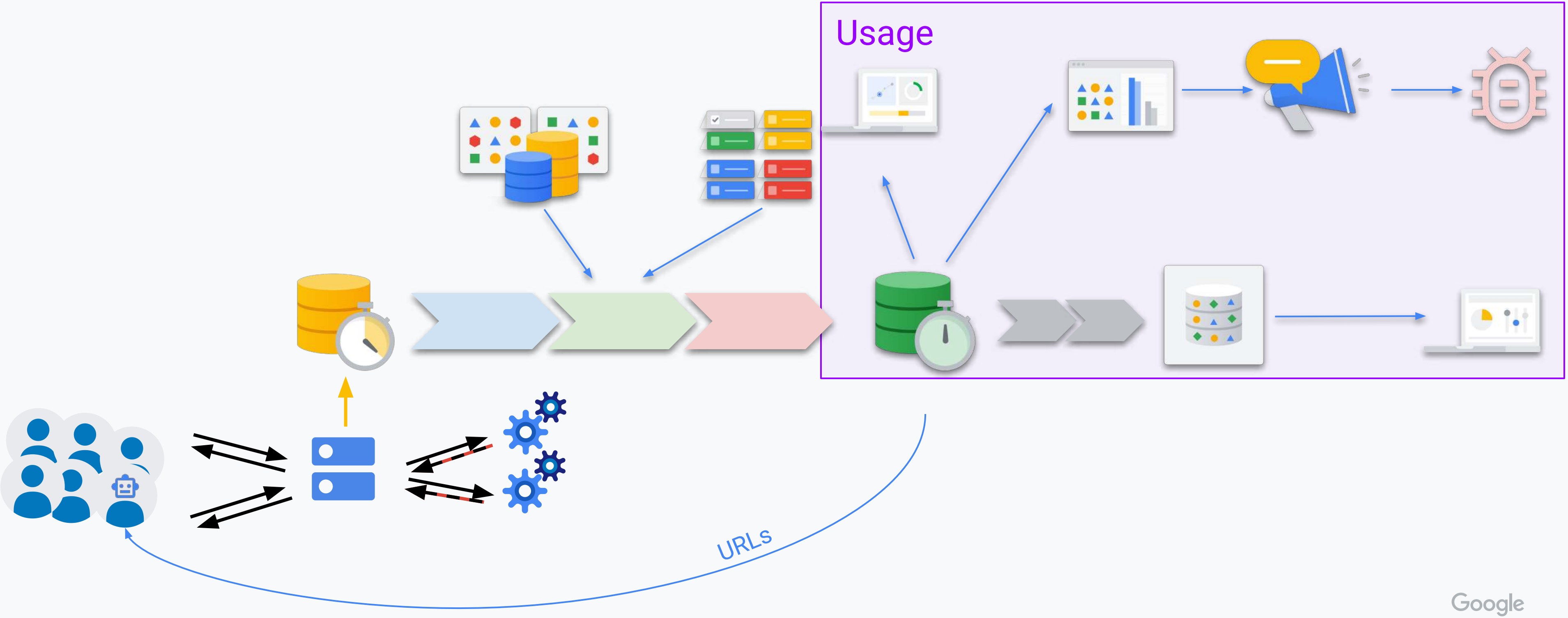
URL paths often contain superfluous information, e.g. capability-bearing tokens, timestamps, user inputs. All URL paths are **redacted** into *path patterns* by:

1. Leveraging path routing information to match and replace variable parts, e.g. from synthetic signals or per-service infrastructure configurations (API definition).
2. On remaining paths, using filtering rules based on a manually curated set of well-known high-entropy paths.
3. On the left-over paths, executing a ML model (random forest of 11 trees with max depth of 5).

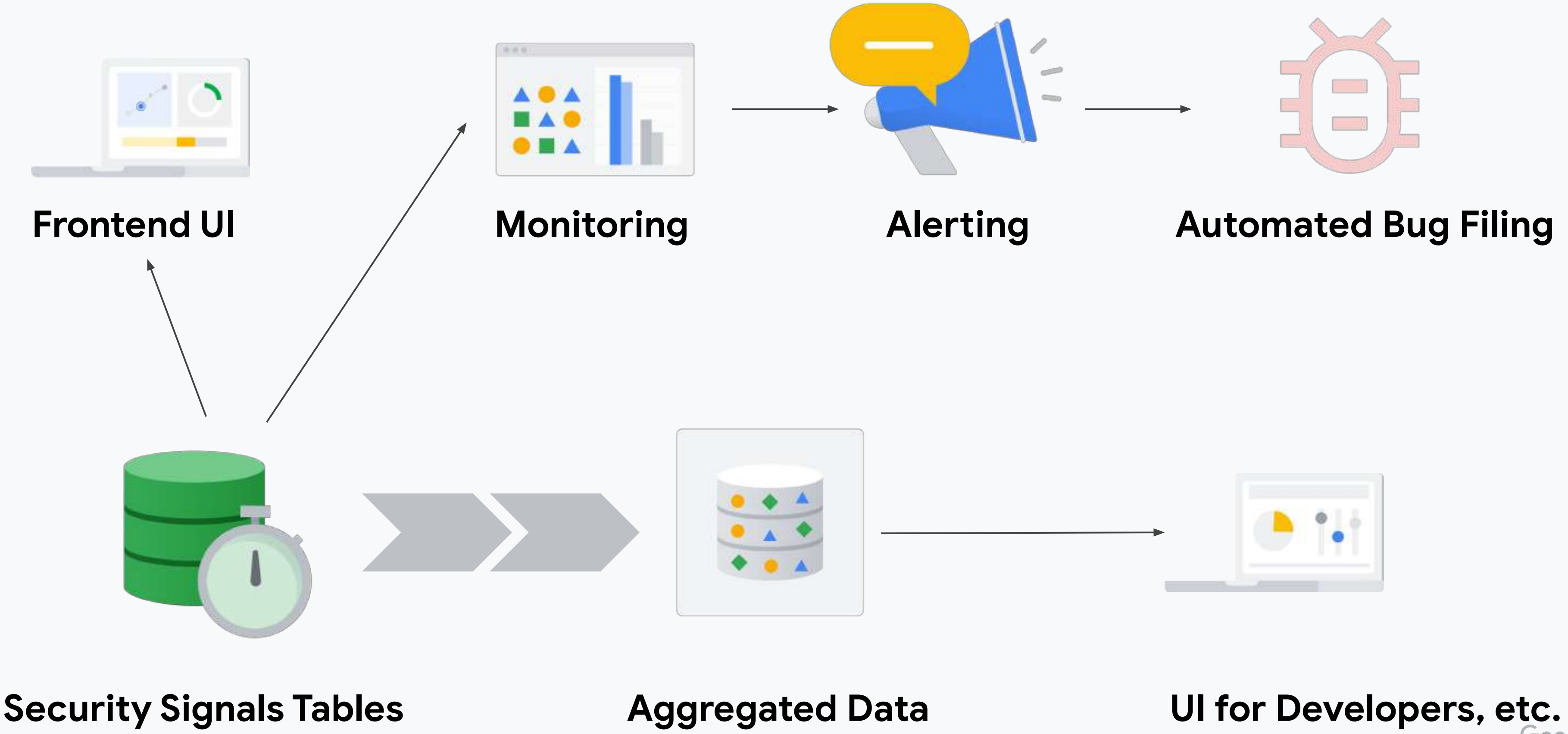
04

Using Data to Improve Security

Security Signals Architecture



Security Signals Tables Users

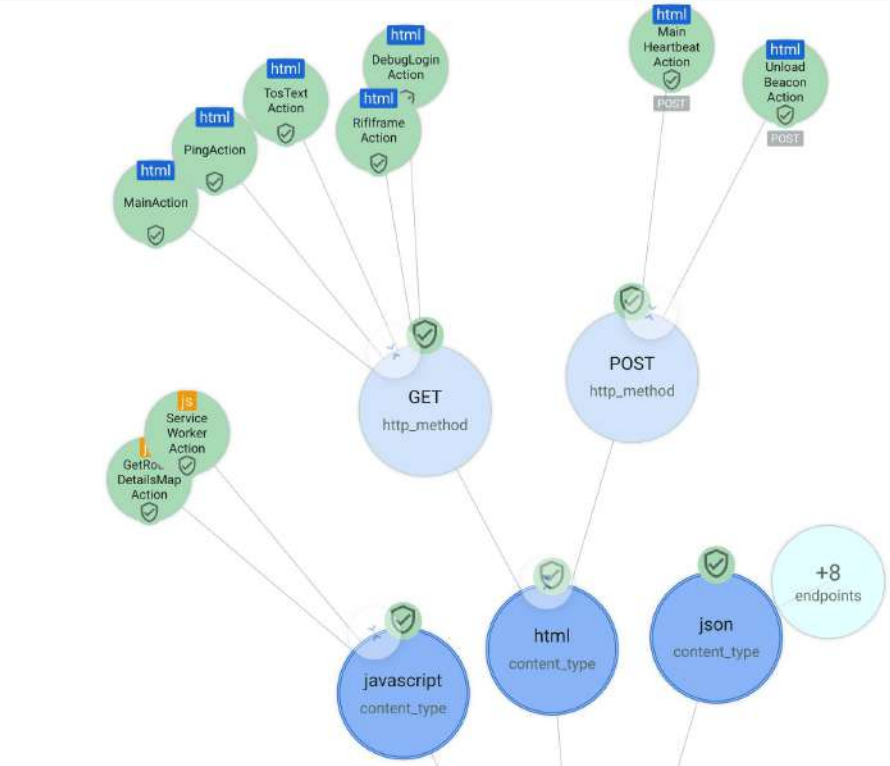


Google

Security Signals UI for Security Engineers

Application endpoints are presented as interactive "bubbles" to:

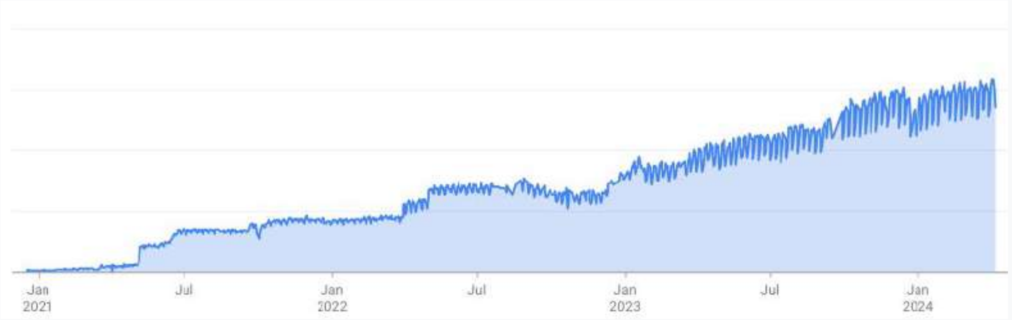
- Identifying security gaps,
- Initiating targeted remediations,
- Filing pre-populated bugs.



Monitoring, Alerting, Bug Filing

Continuous monitoring of Security Signals Tables allows:

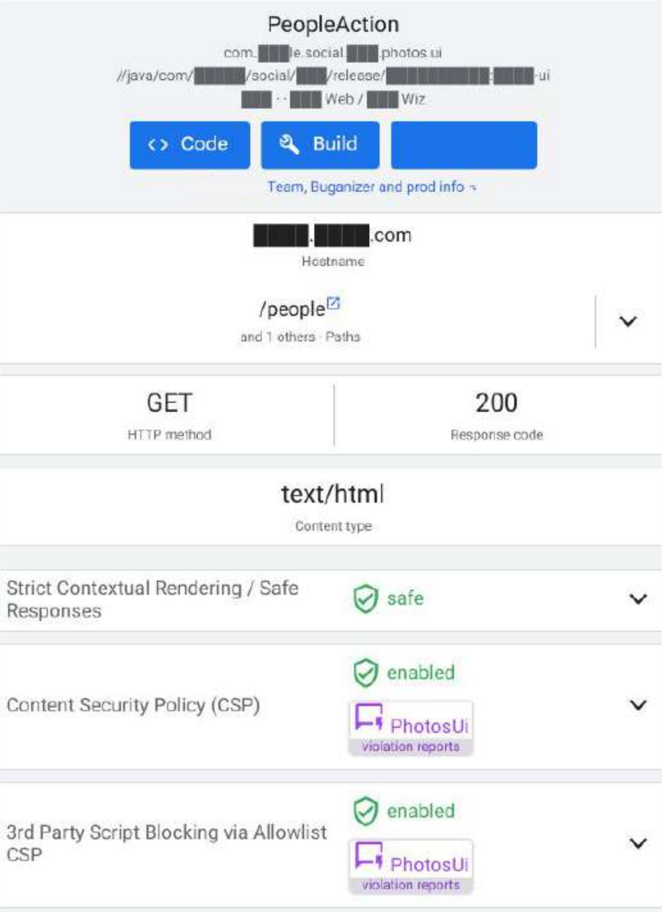
- Monitoring progress regarding coverage of security mitigation measures,
- Identifying violations of predefined security invariants,
- Monitoring regressions,
- Alerting about anomalies, findings and regressions,
- Automatically filing and assigning bugs for high confidence findings by leveraging ownership information within Security Signals.



Web Security Portal for Product Engineers

Web Security Portal provides insights tailored to each team’s application framework. The portal:

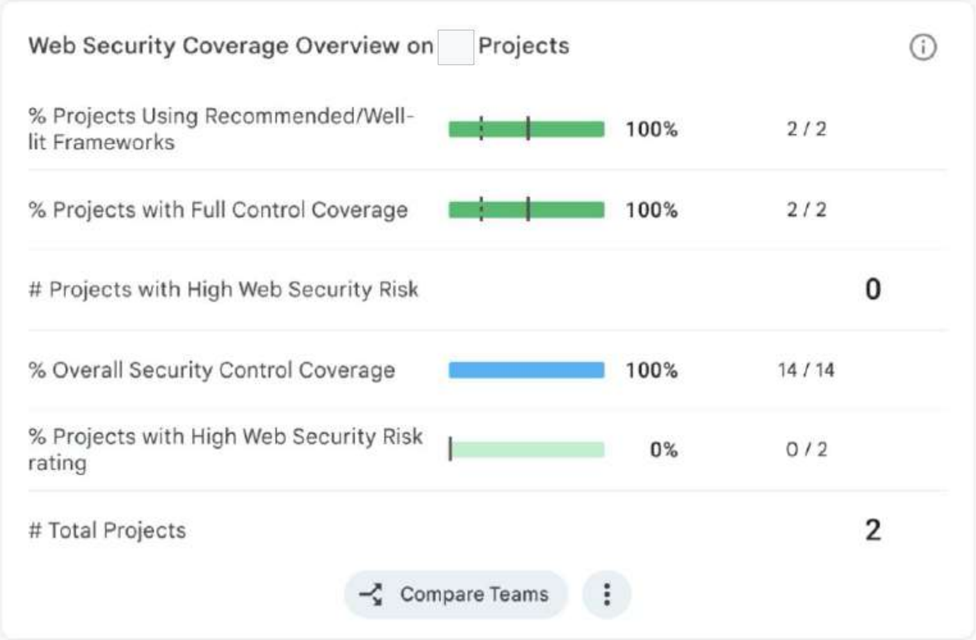
- is dedicated to developers without security expertise,
- shows web security posture of a product,
- highlights areas for improvement,
- offers framework-specific recommendations.



Dashboards for Executives

Security Signals provides high-level visibility and strategic insights to executives to allow:

- Assessing overall web security posture,
- Identifying areas of focus,
- Tracking progress and quantifying impact,
- Risk-based prioritization,
- Optimizing resource allocation decisions.



05

Use Cases

Google

Safe Coding: Security Engineering Use Cases

The responsibility for ensuring security is moved to the developer environment (**Safe Coding environment**) and product design (**secure-by-design**) and includes:

- Hardened and secure-by-design web frameworks,
- Frontend guidelines and recommendations,
- Required web security features.

New web applications adopt this approach seamlessly, but architecture of existing ones need to be adjusted.

Use Case: Security Research & Remediations

Legacy code and systems create the **need to continuously improve the security** state of existing web services.

Security **remediations** are engineering efforts aimed at mitigating systemic sources of vulnerabilities. Each crucial step of remediations is driven by Security Signals:

1. Identifying potential security risks.
2. Designing mitigations.
3. Adopting mitigations.
4. Detecting regressions.

Use Case: Additional Capabilities

< ai>...</ai>

- **JavaScript Signals pipeline** for all executed JavaScript scripts.
- **Improving Security Scanning Coverage**, which is limited by crawling.
- **Non-security Use Cases** to monitor rollouts of web features, debug issues, etc. (~50 teams across Google).
- **Surfacing AI/ML Properties** by Web Endpoints.

06

Example

Example: Cross-Site Request Forgery

Webpages can include resources from other places, e.g.

```
<img src="https://example.com/images/cat.jpg" alt="some cats"/>
```

... or turn off your home router:

```
<img src="http://192.168.0.1/off.php"/>
```

... or transfer money:

```
<form action="https://mybank.com/send?amount=10k&from=thomas&to=eve&do=true"
       method="POST" id="form">
</form>
<script>document.getElementById('form').submit()</script>
```

Example: Cross-Site Request Forgery (Prevention)

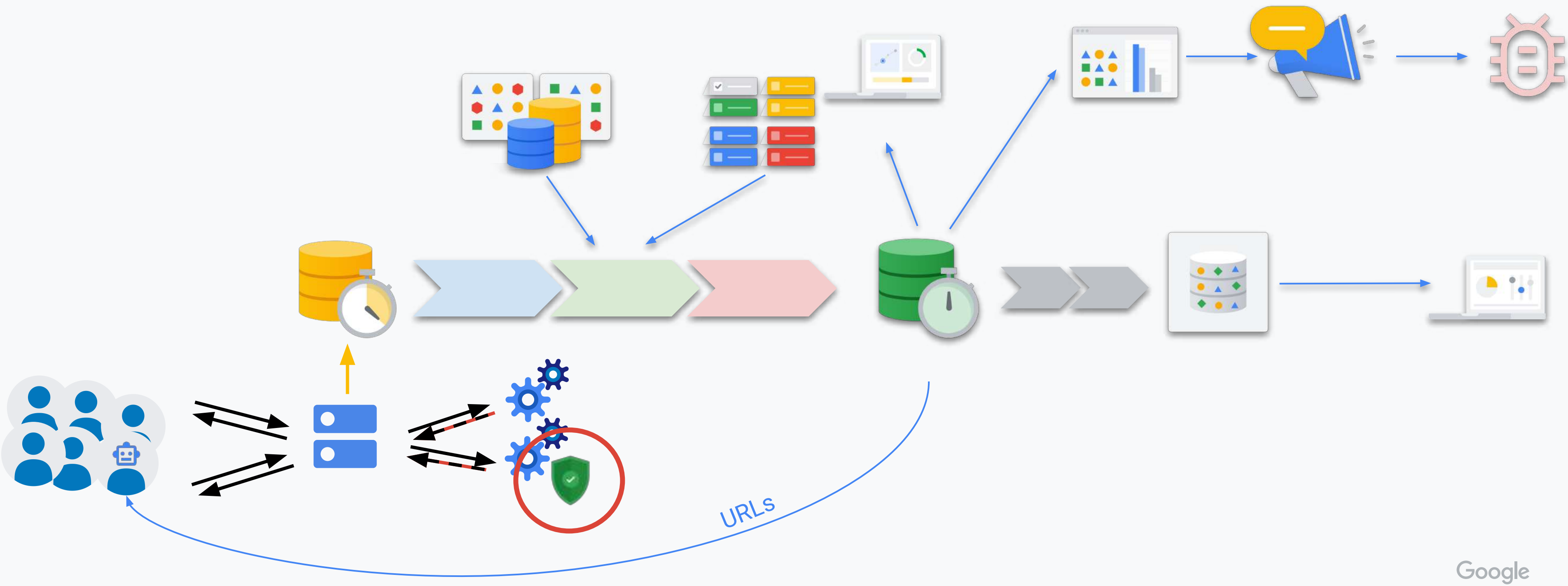
CSRF/XSRF token: a new piece of information that is both **unguessable** and **client-correlated** and send with each request.

```
Xsrf-token=YL9yaTsbfn
```

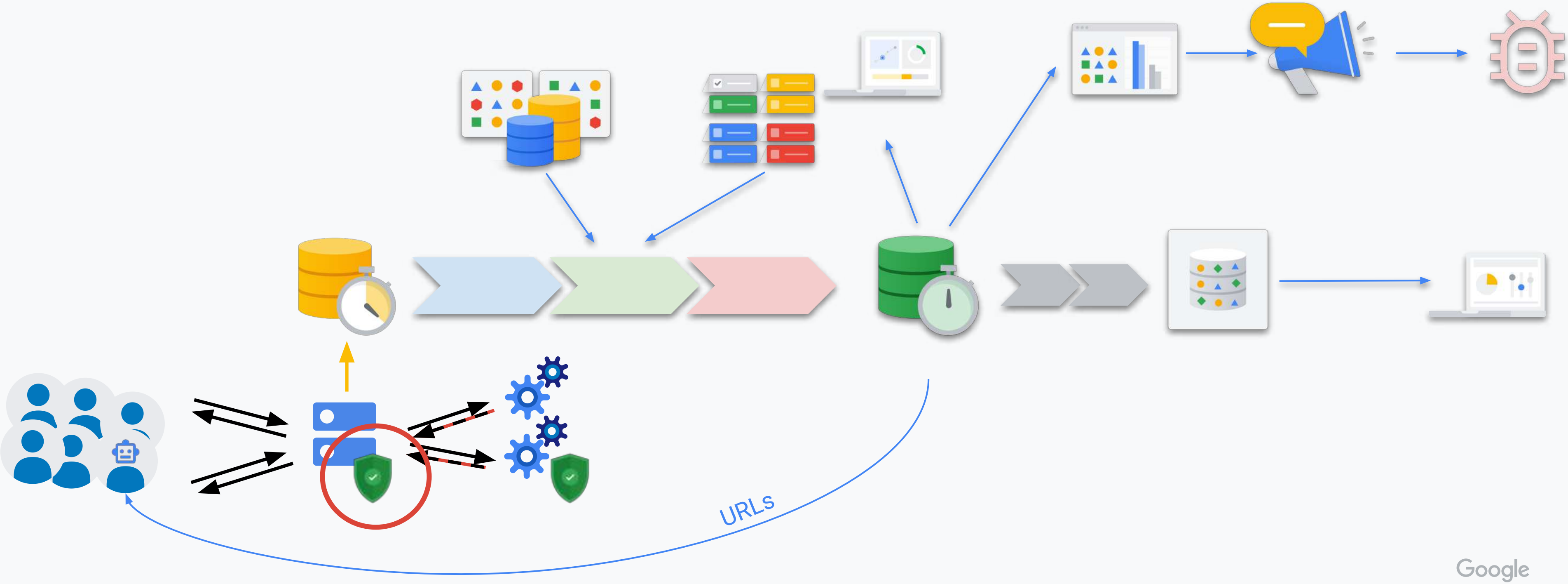
The rollout:

1. Identify URL endpoints implementing state-changing functionality and their XSRF tokens.
2. Introduce a new synthetic security signal: `CSRF`.
3. Refactor web frameworks to populate `CSRF` signal, prioritizing them by Domain Tiers.
4. Handle exceptions/special cases.
5. Go to (3).

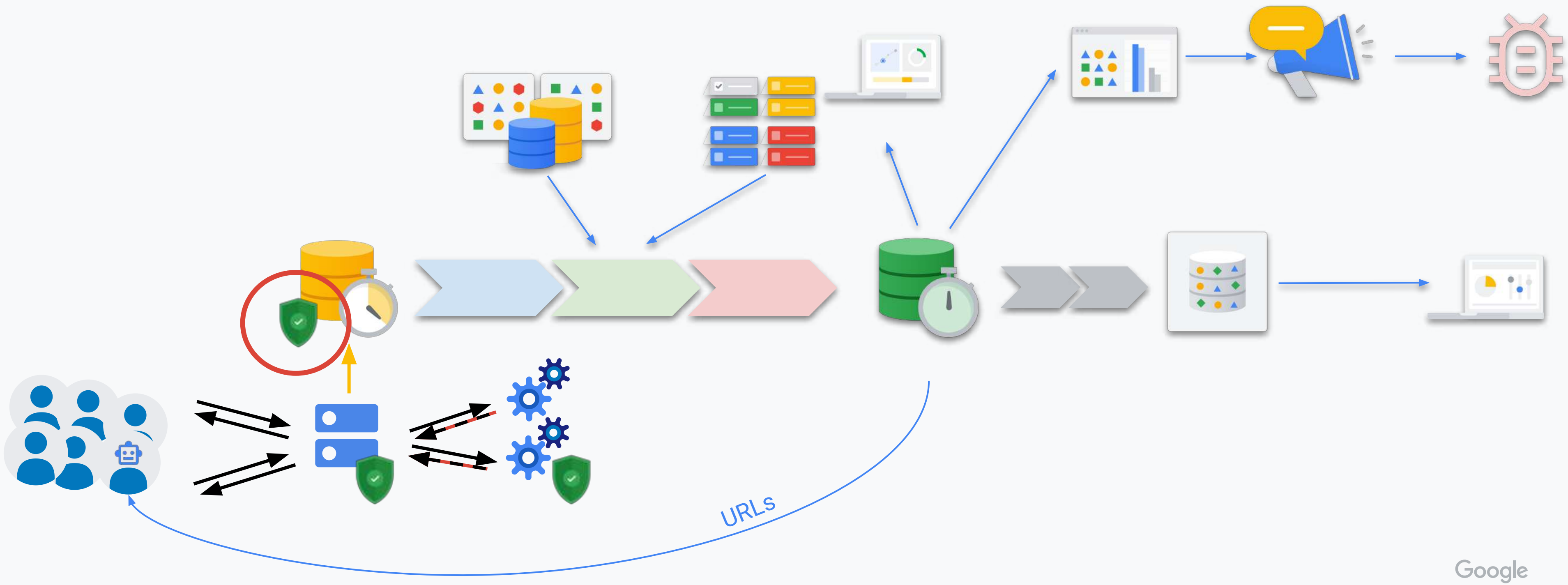
Example: Cross-Site Request Forgery (Data Flow)



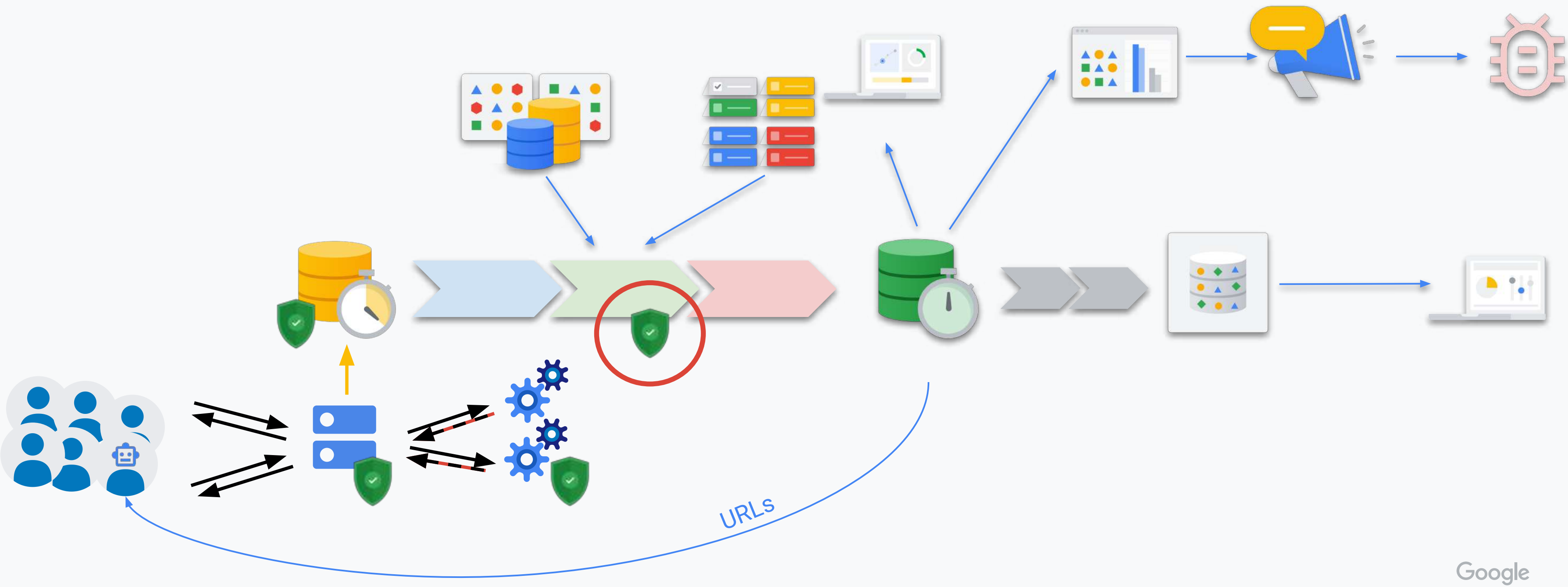
Example: Cross-Site Request Forgery (Data Flow)



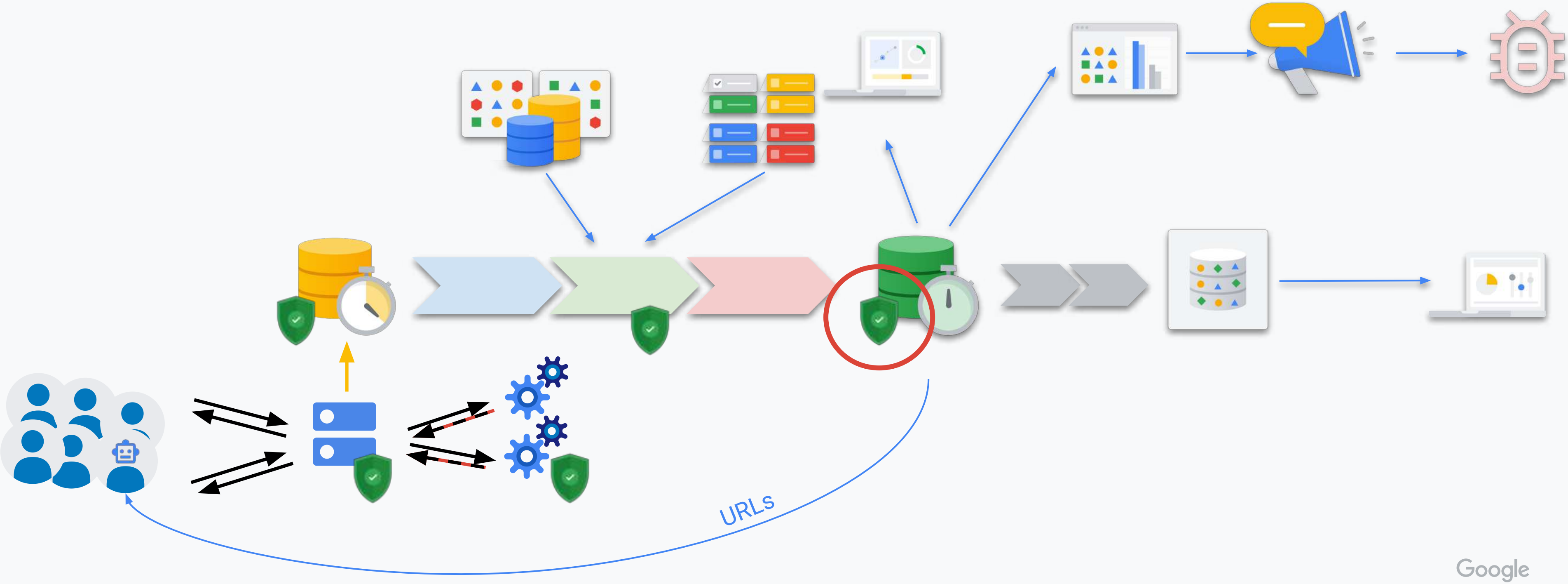
Example: Cross-Site Request Forgery (Data Flow)



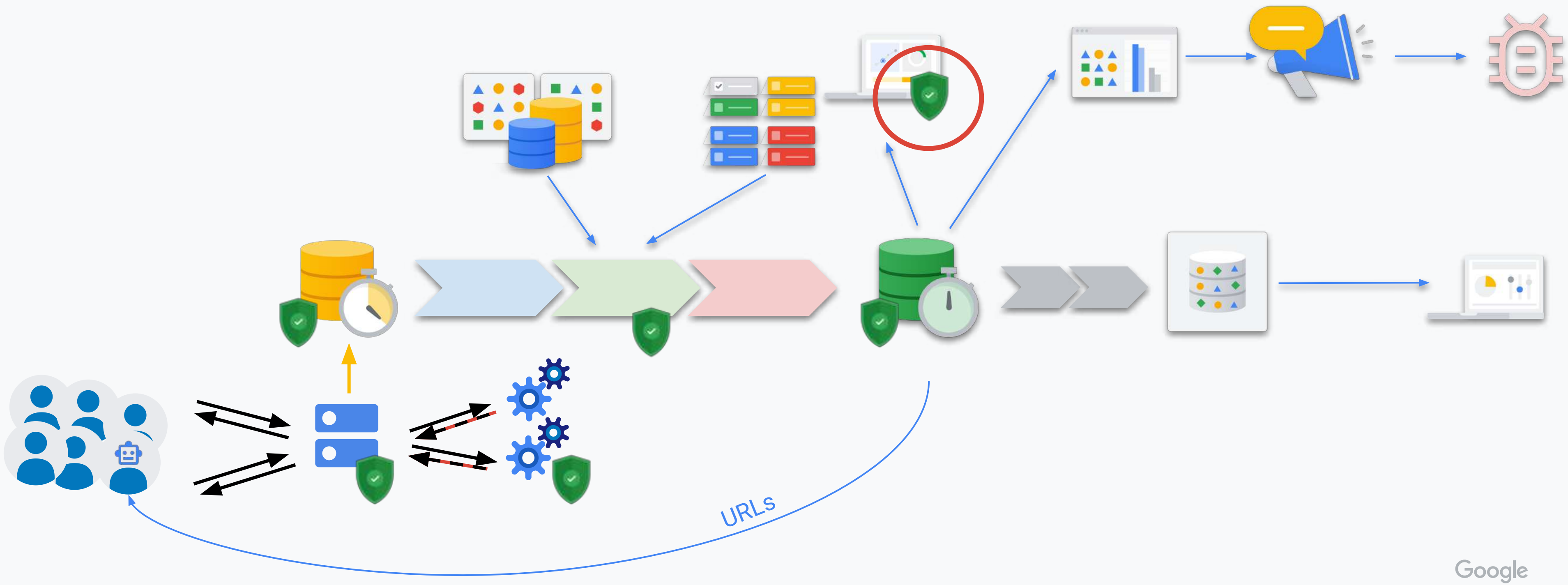
Example: Cross-Site Request Forgery (Data Flow)



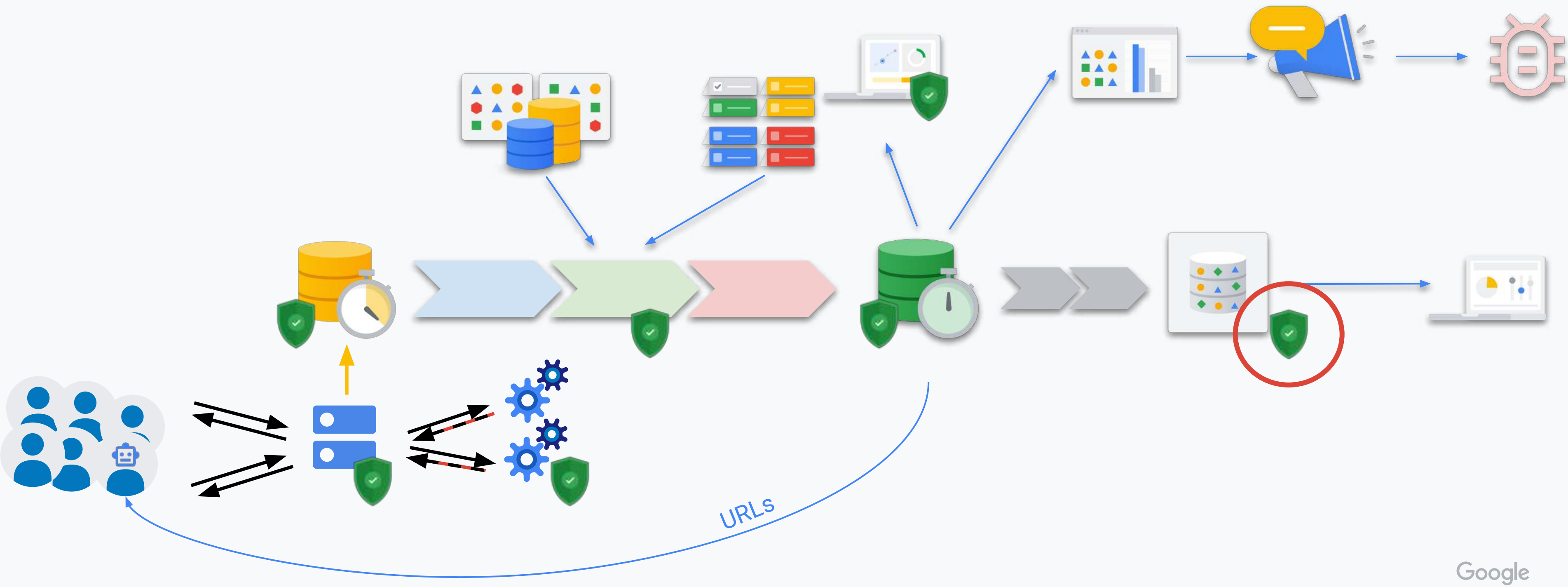
Example: Cross-Site Request Forgery (Data Flow)



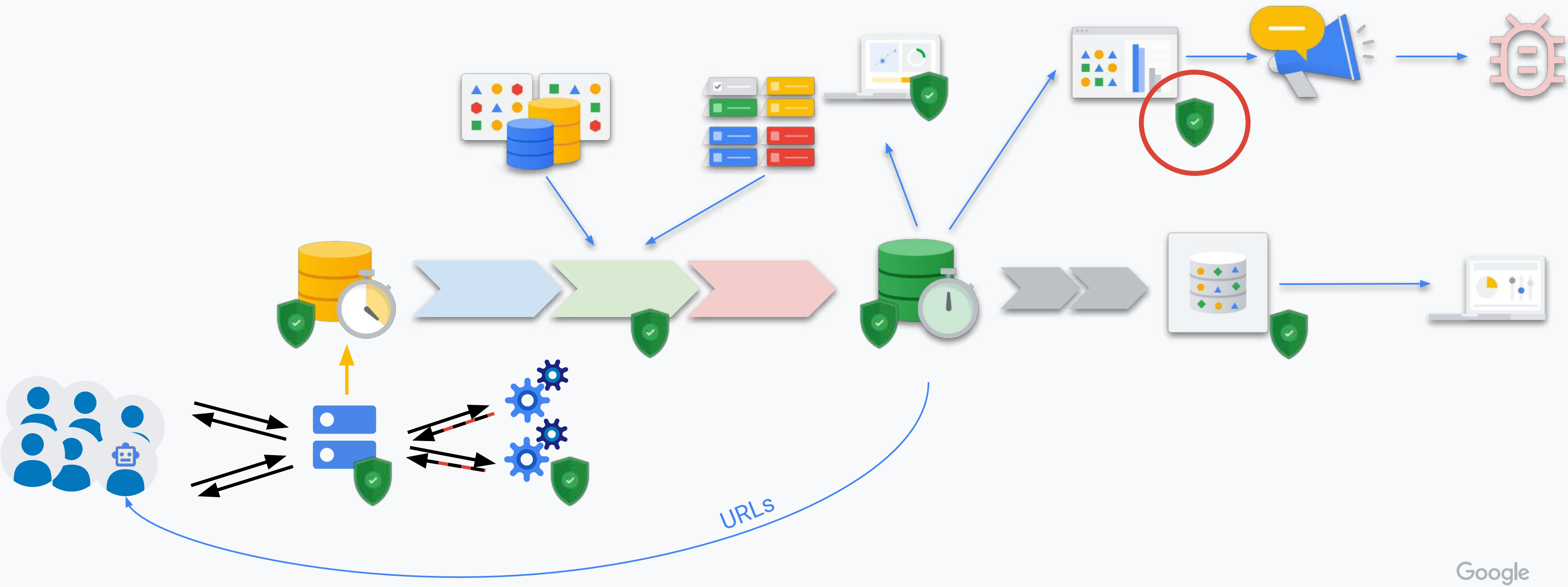
Example: Cross-Site Request Forgery (Data Flow)



Example: Cross-Site Request Forgery (Data Flow)

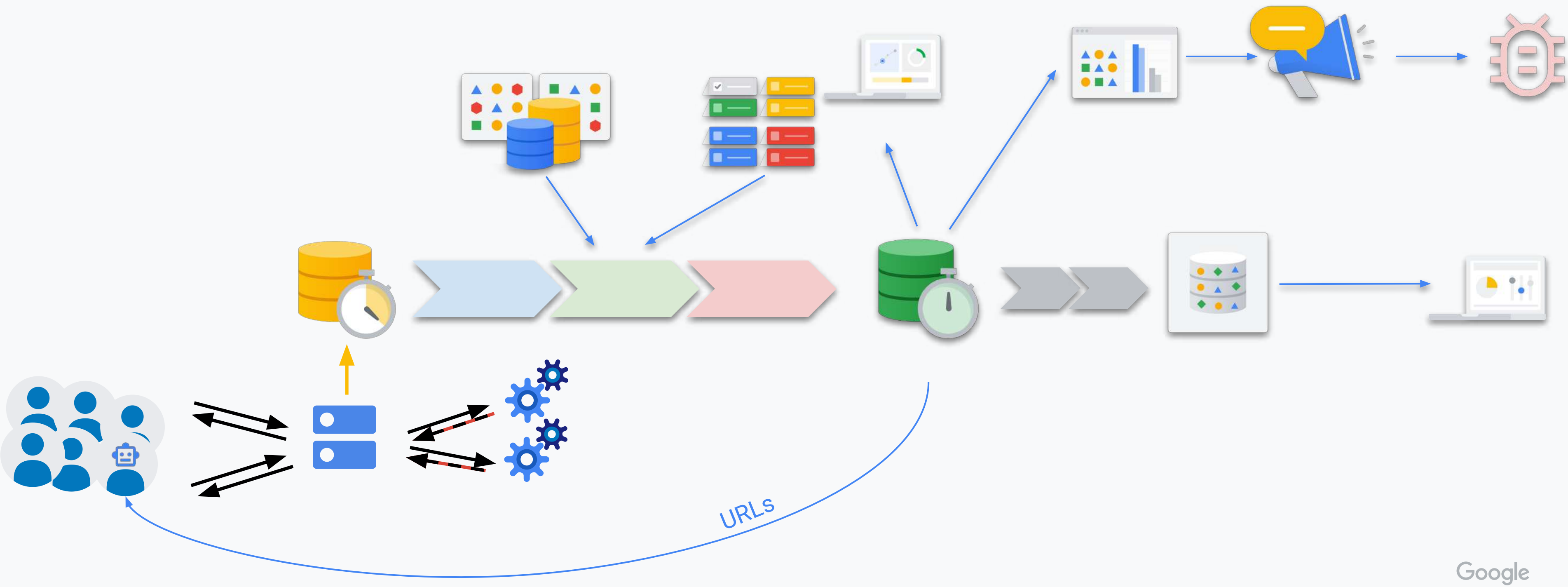


Example: Cross-Site Request Forgery (Data Flow)



Google

Security Signals Infrastructure



Thank you!
Q&A

Google