🔐 Security Analysis with Spans

> **Series:** SPANS | **Notebook:** 6 of 8 | **Created:** December 2025

Protecting Distributed Traces and Ensuring Compliance

This notebook demonstrates how to use span data for security analysis, audit for sensitive data exposure, and ensure compliance with regulations.

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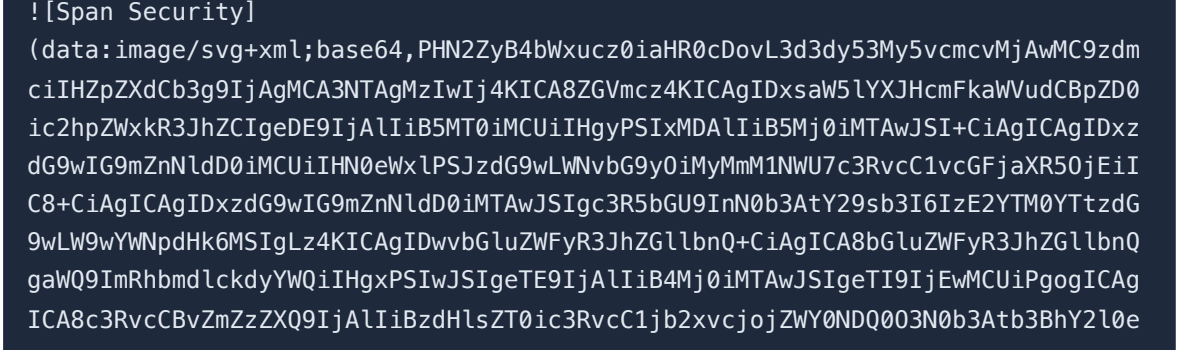
Prerequisites

Before starting this notebook, ensure you have:

- ✅ Completed previous SPANS notebooks (01-05)
- ✅ Understanding of HTTP status codes and security concepts
- ✅ Access to span data containing HTTP attributes
- ✅ Familiarity with OpenPipeline basics

1. Understanding Sensitive Data in Spans

Distributed traces can inadvertently capture sensitive information:



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C90ZXh0Pgo8L3N2Zz4K)

Fields to Consider for Protection

Field	Risk	Recommendation
`url.path`	PII in path/params	Mask or use http.route
`http.request.header.*`	Auth tokens/cookies	Drop sensitive headers
`db.statement`	SQL with user data	Parameterize or mask
`exception.stacktrace`	Variable values	Truncate or filter
`messaging.payload`	Message content	Drop or encrypt
Custom attributes	Business data	Evaluate case by case

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2. PII Audit Queries

Regularly audit your span data for potential PII exposure. These queries help identify data that may need masking or removal.

Step 1: Find URLs with Email Addresses

```dql
// Find URLs that might contain email addresses
// Look for @ symbol or URL-encoded %40
fetch spans
| filter isNotNull(url.path)
| filter contains(url.path, "@") or contains(url.path, "%40")
| fields start_time,
         dt.entity.service,
         http.route,
         url.path
| dedup http.route
| limit 20
```

```

### Step 2: Find URLs with User Identifiers

```dql
// Find URLs with potential user identifiers
fetch spans
| filter isNotNull(url.path)
| filter contains(url.path, "user") or
        contains(url.path, "email") or
        contains(url.path, "customer") or
        contains(url.path, "account")
| fields dt.entity.service,
         http.route,
         url.path
| dedup http.route
| limit 20
```

Step 3: Find Sensitive Query Parameters

```dql
// Find URLs with sensitive query parameters
// These suggest credentials or tokens in URLs
fetch spans
| filter isNotNull(url.path)
| filter contains(url.path, "password") or
        contains(url.path, "token") or
        contains(url.path, "key") or
        contains(url.path, "secret") or
        contains(url.path, "auth")
| fields dt.entity.service,
         http.route,
         url.path
| dedup http.route
| limit 20
```

Step 4: Audit Database Queries for PII

```dql
// Find database queries that might contain sensitive data
fetch spans
| filter isNotNull(db.statement)
| filter contains(db.statement, "password") or
        contains(db.statement, "ssn") or
        contains(db.statement, "credit") or
        contains(db.statement, "email") or
```
```

```
        contains(db.statement, "phone")
| fields dt.entity.service,
         db.system,
         db.name,
         db.statement
| limit 20
```

Step 5: Check Error Messages for Data Leakage

```dql
// Audit error messages for potential data leakage
fetch spans
| filter span.status_code == "error"
| filter isNotNull(span.status_message)
| fields dt.entity.service,
         span.name,
         span.status_message
| limit 20
```

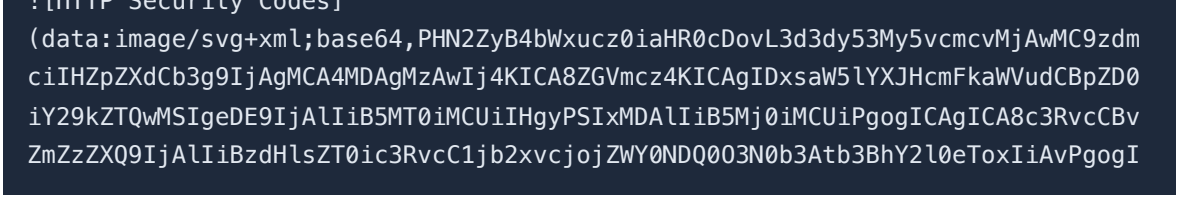
Summary: Which Fields Contain Potentially Sensitive Data?

```dql
// Identify which potentially sensitive fields are present
fetch spans
| summarize {
    total_spans = count(),
    has_url = countIf(isNotNull(url.path)),
    has_db_statement = countIf(isNotNull(db.statement)),
    has_exception = countIf(isNotNull(exception.stacktrace))
  }
| fieldsAdd url_percent = (has_url * 100.0) / total_spans
| fieldsAdd db_percent = (has_db_statement * 100.0) / total_spans
| fieldsAdd exception_percent = (has_exception * 100.0) / total_spans
```

---

3. HTTP Status Code Security Analysis

HTTP status codes can reveal security-relevant patterns:



```
```

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4KPC9zdmc+)

```dql
// Analyze HTTP status code distribution
fetch spans
| filter isNotNull(http.response.status_code)
| summarize {count = count()}, by:{http.response.status_code}
| sort count desc
| limit 20
```

```dql
// Find security-relevant HTTP errors (401, 403, 429)
fetch spans
| filter in(http.response.status_code, {401, 403, 429})
| summarize {
    count = count()
  }, by:{http.response.status_code, dt.entity.service, http.route}
| sort count desc
| limit 50
```

```dql
// Security status codes over time (detect spikes)
fetch spans
```

```
| filter in(http.response.status_code, {401, 403, 429, 500})
| fieldsAdd time_bucket = bin(start_time, 10m)
| fieldsAdd status_category = if(http.response.status_code == 401,
"401_Unauthorized",
                               else: if(http.response.status_code == 403,
"403_Forbidden",
                               else: if(http.response.status_code == 429,
"429_RateLimited",
                               else: "500_ServerError")))
| summarize {count = count()}, by:{time_bucket, status_category}
| sort time_bucket asc, status_category
| limit 200
```

---

4. Authentication Failure Detection

Monitor authentication endpoints for potential brute force or credential stuffing attacks.

```dql
// Find 401 Unauthorized responses (failed authentication)
fetch spans
| filter http.response.status_code == 401
| fields start_time,
         dt.entity.service,
         http.request.method,
         http.route,
         url.path,
         trace.id
| sort start_time desc
| limit 100
```

```dql
// Count authentication failures by endpoint
fetch spans
| filter http.response.status_code == 401
| summarize {
    failure_count = count(),
    unique_traces = countDistinct(trace.id)
  }, by:{dt.entity.service, http.route}
| sort failure_count desc
| limit 30
```

```dql
```

```
// Authentication failure rate over time
fetch spans
| filter isNotNull(http.response.status_code)
| filter contains(http.route, "auth") or contains(http.route, "login") or
contains(span.name, "login")
| fieldsAdd time_bucket = bin(start_time, 10m)
| summarize {
    total_attempts = count(),
    failures = countIf(http.response.status_code == 401)
  }, by:{time_bucket}
| fieldsAdd failure_rate_pct = (failures * 100.0) / total_attempts
| sort time_bucket asc
| limit 50
```

```dql
// High-frequency authentication failures by service
fetch spans
| filter contains(span.name, "auth") or contains(span.name, "login")
| filter span.status_code == "error" or http.response.status_code == 401 or
http.response.status_code == 403
| summarize {
    failure_count = count()
  }, by:{dt.entity.service, span.name, http.response.status_code}
| filter failure_count > 10
| sort failure_count desc
```

---

5. Anomalous Traffic Patterns

Detect unusual patterns that might indicate attacks or misuse.

```dql
// Find endpoints with unusually high error rates
fetch spans
| filter span.kind == "server"
| filter isNotNull(http.response.status_code)
| summarize {
    total_requests = count(),
    error_4xx = countIf(http.response.status_code >= 400 and
http.response.status_code < 500),
    error_5xx = countIf(http.response.status_code >= 500)
  }, by:{dt.entity.service, http.route}
| fieldsAdd error_rate_4xx = (error_4xx * 100.0) / total_requests
| fieldsAdd error_rate_5xx = (error_5xx * 100.0) / total_requests
| filter error_rate_4xx > 20 or error_rate_5xx > 5
```

```
| sort error_rate_4xx desc
| limit 30
```

```dql
// Detect potential enumeration attacks (high 404 rates)
fetch spans
| filter http.response.status_code == 404
| summarize {
    not_found_count = count(),
    unique_paths = countDistinct(url.path)
  }, by:{dt.entity.service}
| filter not_found_count > 100
| sort not_found_count desc
| limit 20
```

```dql
// Find rate limiting events (429 responses)
fetch spans
| filter http.response.status_code == 429
| fields start_time,
         dt.entity.service,
         http.route,
         trace.id
| sort start_time desc
| limit 50
```

```dql
// Unusual access patterns - services with high error rates
fetch spans
| filter span.kind == "server"
| summarize {
    requests = count(),
    unique_operations = countDistinct(span.name),
    error_rate = (countIf(span.status_code == "error") * 100.0) / count()
  }, by:{dt.entity.service}
| filter error_rate > 20
| sort error_rate desc
```

---

6. Sensitive Endpoint Monitoring

Monitor access patterns to sensitive endpoints like admin panels,
configuration APIs, and user data endpoints.

```dql
// Find access to admin or configuration endpoints
fetch spans
| filter span.kind == "server"
| filter contains(url.path, "admin")
      or contains(url.path, "config")
      or contains(url.path, "settings")
      or contains(span.name, "admin")
| fields start_time,
         dt.entity.service,
         http.request.method,
         url.path,
         http.response.status_code,
         trace.id
| sort start_time desc
| limit 100
```

```dql
// Monitor data export or bulk operations
fetch spans
| filter span.kind == "server"
| filter contains(url.path, "export")
      or contains(url.path, "download")
      or contains(url.path, "bulk")
| summarize {
    access_count = count(),
    unique_traces = countDistinct(trace.id)
  }, by:{dt.entity.service, http.route}
| sort access_count desc
| limit 20
```

```dql
// Identify services that might handle regulated data
fetch spans
| filter contains(span.name, "health") or
        contains(span.name, "patient") or
        contains(span.name, "payment") or
        contains(span.name, "card") or
        contains(span.name, "billing")
| summarize {
    span_count = count(),
    unique_operations = countDistinct(span.name)
  }, by:{dt.entity.service}
| sort span_count desc
```

````
---

## 7. OpenPipeline for Data Masking

Use OpenPipeline to mask sensitive data **before** it is stored in Grail.

### Email Masking Configuration

```yaml
# Mask email addresses in URLs and attributes
processing:
  - type: replace
    field: http.url
    pattern: "[a-zA-Z0-9._%+-]+@[a-zA-Z0-9.-]+\\.[a-zA-Z]{2,}"
    replacement: "***@***.***"
```

### Credit Card Masking

```yaml
# Mask credit card numbers (13-16 digits)
processing:
  - type: replace
    field: http.url
    pattern: "\\b[0-9]{13,16}\\b"
    replacement: "****-****-****-****"
```

### Token/API Key Masking

```yaml
# Mask tokens, keys, secrets in query parameters
processing:
  - type: replace
    field: http.url
    pattern: "(token|key|secret|password)=([^&]+)"
    replacement: "$1=***REDACTED***"
```

### Routing Sensitive Data to Restricted Buckets

```yaml
# Route sensitive spans to restricted buckets
routing:
  - condition: contains(service.name, "payment") or contains(service.name,
"auth")
    bucket: spans_sensitive
````
````

````
  - condition: matchesValue(deployment.environment, "production")
    bucket: spans_production

  - condition: true
    bucket: spans_default
```

### Verify Masking Is Working

```dql
// Verify email masking is working
// Result should be empty if masking is effective
fetch spans
| filter isNotNull(url.path)
| filter contains(url.path, "@") and not(contains(url.path, "***@"))
| fields url.path
| limit 10
```

---

## 8. Compliance Considerations

### GDPR Compliance

- **Data minimization**: Only collect necessary data
- **Purpose limitation**: Use data only for stated purposes
- **Storage limitation**: Define retention periods
- **Right to erasure**: Plan for data deletion requests

### PCI DSS Compliance

- **Never store** full credit card numbers
- **Mask** cardholder data in all traces
- **Encrypt** sensitive data at rest
- **Audit** access to payment-related traces

### HIPAA Compliance

- **Protect** PHI (Protected Health Information)
- **Encrypt** health-related span data
- **Restrict** access based on role
- **Audit** all access to healthcare traces

### Secure Query Patterns

**Use aggregations instead of exposing individual records:**
````
````

```dql
// SECURE: Aggregate patterns without exposing individual data
fetch spans
| filter span.kind == "server"
| summarize {
    request_count = count(),
    unique_routes = countDistinct(http.route),
    error_count = countIf(span.status_code == "error")
  }, by:{dt.entity.service}
| sort request_count desc
```

Use `http.route` (pattern) instead of `url.path` (full URL):

```dql
// SECURE: Use http.route (pattern) instead of url.path (full URL)
// http.route: /users/:id (pattern, no PII)
// url.path: /users/john.doe@email.com (actual value, potential PII)

fetch spans
| filter isNotNull(http.route)
| summarize {
    requests = count(),
    avg_ms = avg(duration) / 1000000
  }, by:{dt.entity.service, http.route, http.request.method}
| sort requests desc
| limit 20
```

Limit exposure of trace.id - get just enough to diagnose:

```dql
// For investigation: Get just enough trace.ids to diagnose
fetch spans
| filter span.status_code == "error"
| summarize {
    error_count = count(),
    sample_trace = takeFirst(trace.id)
  }, by:{dt.entity.service, span.name}
| sort error_count desc
| limit 10
```

---

9. Security Audit Queries

Use these queries for regular security audits.

```dql
// Security summary dashboard: Overall security status
fetch spans
| filter isNotNull(http.response.status_code)
| summarize {
    total_requests = count(),
    auth_failures_401 = countIf(http.response.status_code == 401),
    forbidden_403 = countIf(http.response.status_code == 403),
    rate_limited_429 = countIf(http.response.status_code == 429),
    server_errors_5xx = countIf(http.response.status_code >= 500)
  }
| fieldsAdd auth_failure_rate = (auth_failures_401 * 100.0) / total_requests
| fieldsAdd forbidden_rate = (forbidden_403 * 100.0) / total_requests
```

```dql
// Security events timeline
fetch spans
| filter in(http.response.status_code, {401, 403, 429})
| makeTimeseries {
    auth_failures = countIf(http.response.status_code == 401),
    forbidden = countIf(http.response.status_code == 403),
    rate_limited = countIf(http.response.status_code == 429)
  }, interval: 10m
```

```dql
// Services with highest security event rates
fetch spans
| filter isNotNull(http.response.status_code)
| summarize {
    total_requests = count(),
    security_events = countIf(in(http.response.status_code, {401, 403, 429}))
  }, by:{dt.entity.service}
| fieldsAdd security_event_rate = (security_events * 100.0) / total_requests
| filter security_events > 0
| sort security_event_rate desc
| limit 20
```

```dql
// Final audit: Summary of potential security concerns
fetch spans
| summarize {
    total_spans = count(),
    spans_with_url = countIf(isNotNull(url.path)),
```

```
    spans_with_db_query = countIf(isNotNull(db.statement)),
    spans_with_errors = countIf(span.status_code == "error"),
    auth_failures = countIf(
        (contains(span.name, "auth") or contains(span.name, "login")) and
        (span.status_code == "error" or http.response.status_code >= 400))
  }
| fieldsAdd url_percent = (spans_with_url * 100.0) / total_spans
| fieldsAdd db_percent = (spans_with_db_query * 100.0) / total_spans
```

---

10. Security Checklist

Data Protection

- [ ] Audit spans for PII in URLs, headers, query params
- [ ] Configure OpenPipeline to mask sensitive data
- [ ] Use `http.route` instead of `url.path` when possible
- [ ] Drop or mask database query contents
- [ ] Sanitize error messages and stack traces

Access Control

- [ ] Route sensitive spans to restricted buckets
- [ ] Configure IAM policies for span access
- [ ] Limit who can query raw span data
- [ ] Use aggregations instead of exposing individual records

Compliance

- [ ] Define data retention policies per bucket
- [ ] Document data processing for GDPR Article 30
- [ ] Ensure PCI DSS compliance for payment spans
- [ ] Protect PHI for HIPAA compliance

Monitoring

- [ ] Regular audits for new PII exposure
- [ ] Monitor authentication failure patterns
- [ ] Alert on unusual access patterns
- [ ] Review masking effectiveness periodically

Summary

In this notebook, you learned:

✅ **Understanding sensitive data locations** in span attributes
✅ **PII audit queries** to find emails, tokens, and credentials in spans
✅ **HTTP status code analysis** for security-relevant codes (401, 403, 429, 500)
✅ **Authentication failure detection** to identify potential attacks
✅ **Anomalous traffic pattern detection** for enumeration and abuse
✅ **Sensitive endpoint monitoring** for admin and data access
✅ **OpenPipeline masking** configurations for emails, credit cards, tokens
✅ **Compliance considerations** for GDPR, PCI DSS, and HIPAA
✅ **Security audit queries** for compliance and reporting
✅ **Security checklist** for ongoing protection

Next Steps

Continue to **SPANS-07: Grail Buckets & OpenPipeline** to learn:
- Understanding Grail bucket architecture
- Configuring OpenPipeline for span processing
- Data routing and retention strategies
- Access control for span data