SentinelGuard Phase II – System & Design Specification

Course: CCGC 5003 Application Programming

Project: SentinelGuard – AI-Driven Incident Response Console

Phase: II – Architectural & Design Deliverables

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1. Objectives of Phase II

Phase II converts the SentinelGuard concept into a concrete, build-ready blueprint. Deliverables include the database entity-relationship design, detailed data dictionary, UI interaction flows, controller logic plans, and the embedded AI model lifecycle. These artefacts align with the course requirement to define the MVT (Model-View-Template) architecture prior to implementation.

2. System Architecture Overview

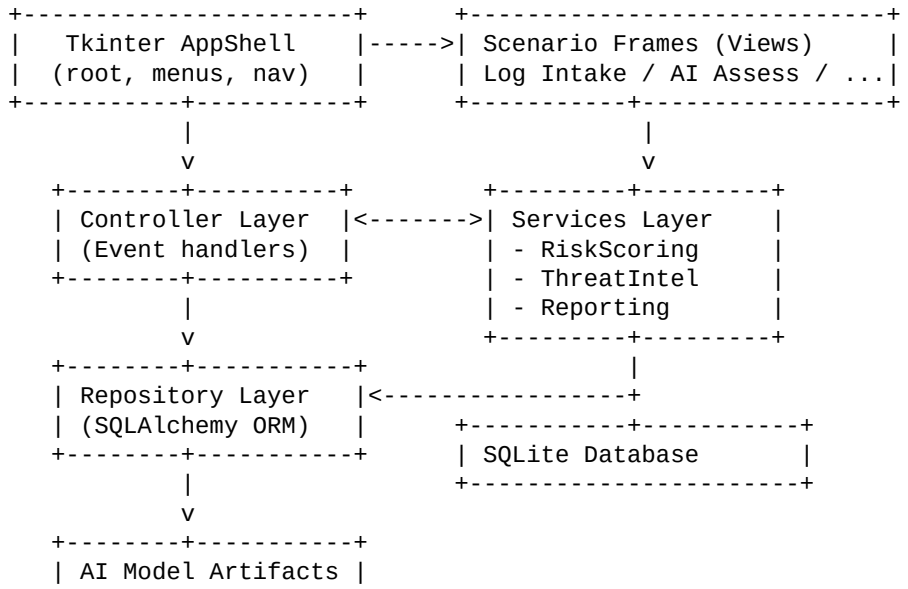
- **Programming Stack:** Python 3.11, SQLite 3, SQLAlchemy ORM, Tkinter UI, scikit-learn (logistic regression), pandas for data prep.
- **Architecture Pattern:** Model-View-Controller/Tkinter event loop, where:

- **Model:** SQLAlchemy ORM models mapped to SQLite tables with schema shown in §3.

- **View:** Tkinter frames (one per scenario) orchestrated by a master `AppShell`.

- **Controller:** Event handlers coordinating data validation, persistence, AI inference, and navigation.

- **AI Component:** Offline training notebook (Jupyter) producing serialized model (`ai/models/risk_classifier.pkl`). Runtime inference service wraps the model in `RiskScoringService`.
- **Support Modules:** `services/` for business logic, `repositories/` for data IO, `widgets/` for reusable UI components.



```
          +--------------------+
```

3. Entity-Relationship Design

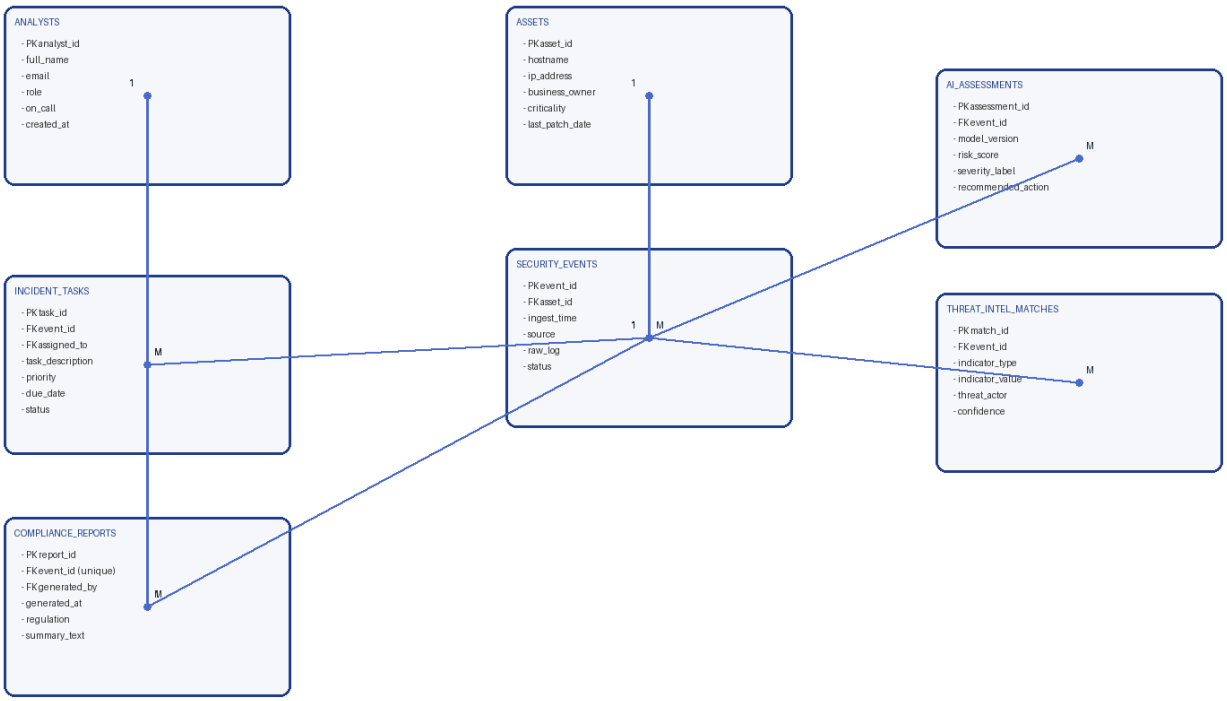
3.1 ERD Description

SentinelGuard's ERD centres on `security_events`. Each event links to:

- precisely one `assets` record (affected system),
- zero or more `ai_assessments`, `incident_tasks`, `threat_intel_matches`,
- one optional `compliance_reports` entry once the incident closes.

`analysts` are referenced by `incident_tasks` (assignees) and `compliance_reports` (report generator). Relationships enforce cascade behaviour where appropriate (e.g., deleting an event removes dependent assessments and tasks).

```
analysts (1) ■■■< incident_tasks >■■■ (1) security_events (>■■■1) assets
      ■                                    ■  ■                    ■
      ■■■■< compliance_reports              ■  ■■■■< threat_intel_matches
                                           ■■■■< ai_assessments
```



ERD overview

Render-ready diagram source: `docs/erd.mmd` (Mermaid) — regenerated via `python3 scripts/generate_erd_image.py`.

3.2 Data Dictionary

analysts

Field	Type	Constraints	Description
analyst_id	INTEGER	PK	Unique identifier
full_name	TEXT	NOT NULL	Analyst full name
email	TEXT	UNIQUE, NOT NULL	Contact and login identifier
role	TEXT	CHECK (Tier 1/2/3/Manager)	SOC hierarchy level
on_call	BOOLEAN	DEFAULT 0	Weekly on-call status
created_at	DATETIME	DEFAULT CURRENT_TIMESTAMP	Audit trail

Alignment: Enables Scenario 4 (Incident Task Orchestration) and Scenario 5 (Compliance & Reporting) by attributing ownership to analysts.

assets

Field	Type	Constraints	Description
asset_id	INTEGER	PK	Unique asset record
hostname	TEXT	NOT NULL	System host name
ip_address	TEXT	NOT NULL	IPv4/IPv6 string
business_owner	TEXT	NOT NULL	Responsible stakeholder
criticality	TEXT	CHECK (Low/Moderate/High/Critical)	Business impact
last_patch_date	DATE	NULLABLE	Last maintenance window

Alignment: Core to Scenario 1 (Log Intake & Asset Linking) and feeds severity weighting during AI risk analysis in Scenario 2.

security_events

Field	Type	Constraints	Description
event_id	INTEGER	PK	Incident identifier
asset_id	INTEGER	FK → assets.asset_id	Affected system
ingest_time	DATETIME	DEFAULT CURRENT_TIMESTAMP	Alert receipt time
source	TEXT	NOT NULL	Originating system (SIEM, EDR, etc.)
raw_log	TEXT	NOT NULL	Canonical log payload
status	TEXT	CHECK (New/Triaged/In Progress/Resolved)	Workflow state

Alignment: Central record consumed by all five scenarios; tracks lifecycle from intake through resolution.

ai_assessments

| Field | Type | Constraints | Description |

|-------|------|-------------|-------------|

| assessment_id | INTEGER | PK | Assessment record |

| event_id | INTEGER | FK → security_events.event_id ON DELETE CASCADE | Linked incident |

| model_version | TEXT | NOT NULL | Serialized model tag |

| risk_score | REAL | 0–1 + CHECK | Normalized probability |

| severity_label | TEXT | CHECK (Low/Medium/High/Critical) | Discrete severity |

| recommended_action | TEXT | NULLABLE | AI-suggested next step |

| summary | TEXT | NULLABLE | Natural language synopsis |

Alignment: Implements Scenario 2 (AI Risk Assessment) by persisting severity, summary, and recommended actions.

incident_tasks

| Field | Type | Constraints | Description |

|-------|------|-------------|-------------|

| task_id | INTEGER | PK | Task identifier |

| event_id | INTEGER | FK → security_events.event_id ON DELETE CASCADE | Parent incident |

| assigned_to | INTEGER | FK → analysts.analyst_id | Responsible analyst |

| task_description | TEXT | NOT NULL | Remediation action |

| priority | TEXT | CHECK (Low/Medium/High/Urgent) | SLA urgency |

| due_date | DATE | NULLABLE | Target completion |

| status | TEXT | CHECK (Pending/In Progress/Blocked/Complete) | Task state |

Alignment: Delivers Scenario 4 (Incident Task Orchestration) by managing remediation steps per incident.

threat_intel_matches

| Field | Type | Constraints | Description |

|-------|------|-------------|-------------|

| match_id | INTEGER | PK | Match identifier |

| event_id | INTEGER | FK → security_events.event_id | Incident reference |

| indicator_type | TEXT | CHECK (IP/Domain/Hash/URL) | IOC category |

| indicator_value | TEXT | NOT NULL | Observable value |

| threat_actor | TEXT | NULLABLE | Known campaign attribution |

| confidence | REAL | 0–1 + CHECK | Confidence score |

Alignment: Supports Scenario 3 (Threat Intelligence Enrichment) by tracking IOC correlations and confidence.

compliance_reports

| Field | Type | Constraints | Description |

|-------|------|-------------|-------------|

| report_id | INTEGER | PK | Report identifier |

| event_id | INTEGER | FK → security_events.event_id UNIQUE | One report per incident |

| generated_by | INTEGER | FK → analysts.analyst_id | Report author |

| generated_at | DATETIME | DEFAULT CURRENT_TIMESTAMP | Creation timestamp |

| regulation | TEXT | NOT NULL | Control mapped (e.g., ISO, SOC2) |

| summary_text | TEXT | NOT NULL | Final narrative |

| export_path | TEXT | NULLABLE | Relative path of PDF export |

Alignment: Powers Scenario 5 (Compliance & Reporting) with closure narratives mapped to governance requirements.

3.3 SQL DDL Artefacts & Secondary Keys

bullet Full CREATE TABLE statements, primary/secondary keys, and composite constraints are stored in `db/schema.sql`. Capture screenshots of each `CREATE TABLE` block from this file as required for the Phase II rubric.

bullet Secondary keys reinforce lookup paths:

- `idx_analysts_email`, `idx_security_events_asset_status`, `idx_ai_assessments_event_model`,

- `idx_incident_tasks_event_description`, `idx_threat_intel_indicator`.

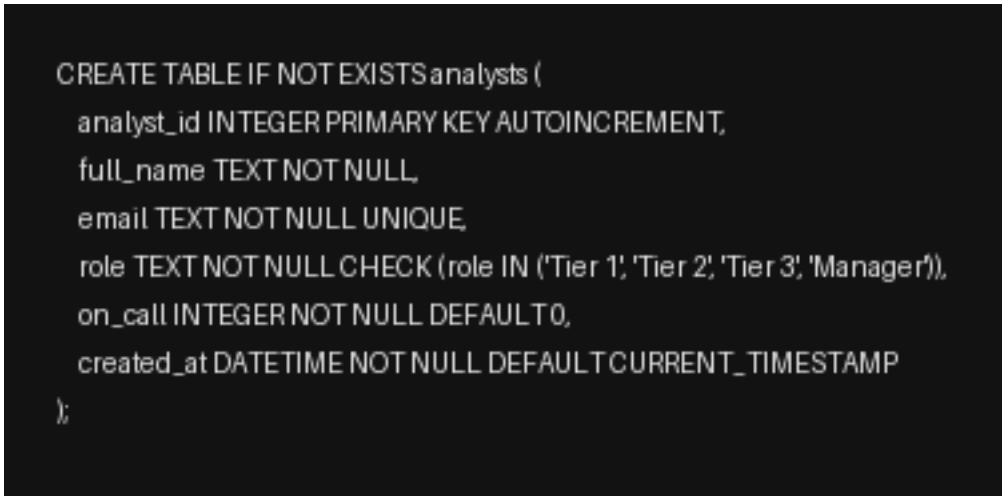
bullet Composite/unique constraints ensure design integrity:

- `ai_assessments(event_id, model_version)` stops duplicate AI snapshots for the same incident/model version.

- `incident_tasks(event_id, task_description)` prevents redundant remediation entries per incident.

- `compliance_reports.event_id` enforces one compliance package per resolved incident.

Schema Snapshots



analysts schema

```
CREATE TABLE IF NOT EXISTS assets (
  asset_id INTEGER PRIMARY KEY AUTOINCREMENT,
  hostname TEXT NOT NULL UNIQUE,
  ip_address TEXT NOT NULL UNIQUE,
  business_owner TEXT NOT NULL,
  criticality TEXT NOT NULL CHECK (criticality IN ('Low', 'Moderate', 'High', 'Critical')),
  last_patch_date DATE
);
```

assets schema

```
CREATE TABLE IF NOT EXISTS security_events (
  event_id INTEGER PRIMARY KEY AUTOINCREMENT,
  asset_id INTEGER NOT NULL,
  ingest_time DATETIME NOT NULL DEFAULT CURRENT_TIMESTAMP,
  source TEXT NOT NULL,
  raw_log TEXT NOT NULL,
  status TEXT NOT NULL CHECK (status IN ('New', 'Triaged', 'In Progress', 'Resolved')),
  CONSTRAINT fk_security_events_asset
    FOREIGN KEY (asset_id) REFERENCES assets(asset_id)
    ON UPDATE CASCADE
    ON DELETE RESTRICT
);
```

security events schema

```
CREATE TABLE IF NOT EXISTS ai_assessments (
  assessment_id INTEGER PRIMARY KEY AUTOINCREMENT,
  event_id INTEGER NOT NULL,
  model_version TEXT NOT NULL,
  risk_score REAL NOT NULL CHECK (risk_score BETWEEN 0 AND 1),
  severity_label TEXT NOT NULL CHECK (severity_label IN ('Low', 'Medium', 'High', 'Critical')),
  recommended_action TEXT,
  summary TEXT,
  created_at DATETIME NOT NULL DEFAULT CURRENT_TIMESTAMP,
  CONSTRAINT fk_ai_assessments_event
    FOREIGN KEY (event_id) REFERENCES security_events(event_id)
    ON DELETE CASCADE
);
```

ai assessments schema

```
CREATE TABLE IF NOT EXISTS incident_tasks (
  task_id INTEGER PRIMARY KEY AUTOINCREMENT,
  event_id INTEGER NOT NULL,
  assigned_to INTEGER,
  task_description TEXT NOT NULL,
  priority TEXT NOT NULL CHECK (priority IN ('Low', 'Medium', 'High', 'Urgent')),
  due_date DATE,
  status TEXT NOT NULL CHECK (status IN ('Pending', 'In Progress', 'Blocked', 'Complete')),
  created_at DATETIME NOT NULL DEFAULT CURRENT_TIMESTAMP,
  CONSTRAINT fk_incident_tasks_event
    FOREIGN KEY (event_id) REFERENCES security_events(event_id)
    ON DELETE CASCADE,
  CONSTRAINT fk_incident_tasks_assigned
    FOREIGN KEY (assigned_to) REFERENCES analysts(analyst_id)
    ON UPDATE CASCADE
);
```

incident tasks schema

```
CREATE TABLE IF NOT EXISTS threat_intel_matches (
  match_id INTEGER PRIMARY KEY AUTOINCREMENT,
  event_id INTEGER NOT NULL,
  indicator_type TEXT NOT NULL CHECK (indicator_type IN ('IP', 'Domain', 'Hash', 'URL')),
  indicator_value TEXT NOT NULL,
  threat_actor TEXT,
  confidence REAL NOT NULL CHECK (confidence BETWEEN 0 AND 1),
  CONSTRAINT fk_threat_matches_event
    FOREIGN KEY (event_id) REFERENCES security_events(event_id)
    ON DELETE CASCADE
);
```

threat intel matches schema

```
CREATE TABLE IF NOT EXISTS compliance_reports (
  report_id INTEGER PRIMARY KEY AUTOINCREMENT,
  event_id INTEGER NOT NULL UNIQUE,
  generated_by INTEGER NOT NULL,
  generated_at DATETIME NOT NULL DEFAULT CURRENT_TIMESTAMP,
  regulation TEXT NOT NULL,
  summary_text TEXT NOT NULL,
  export_path TEXT,
  CONSTRAINT fk_compliance_reports_event
    FOREIGN KEY (event_id) REFERENCES security_events(event_id)
    ON DELETE CASCADE,
  CONSTRAINT fk_compliance_reports_author
    FOREIGN KEY (generated_by) REFERENCES analysts(analyst_id)
    ON UPDATE CASCADE
);
```

compliance reports schema

4. View Layer & UI Design

4.1 Navigation Structure

- **Main Dashboard:** Incident summary table, counts by severity, quick actions to launch each scenario pane.
- **Scenario Tabs/Frames:**

1. `LogIntakeFrame` – wizard for event creation and asset linkage.
2. `RiskAssessmentFrame` – display AI assessment, allow re-score.
3. `ThreatEnrichmentFrame` – IOC lookup results, add intel notes.
4. `TaskManagerFrame` – CRUD for remediation tasks and status updates.
5. `ComplianceReportFrame` – closes incident, generates exports.

Navigation via a left sidebar (Tkinter `Listbox`) or tabbed notebook (`ttk.Notebook`) to satisfy “integrated UI” requirement.

4.2 Widget Layout Summary

- **Common Header Panel:** Incident selector (`ttk.Combobox`), status badge (`ttk.Label`), refresh button.
- **Forms:** Use `ttk.Label`, `ttk.Entry`, `ttk.Combobox`, `ttk.Radiobutton`, `ttk.Checkbutton` to meet widget diversity requirement.
- **Tables:** `ttk.Treeview` for lists (events, tasks, IOC matches).
- **Text Areas:** `tk.Text` + vertical `ttk.Scrollbar` for log payloads and AI summaries.
- **Buttons:** Primary actions `ttk.Button` with command functions tied to controllers.
- **Modals:** `tk.Toplevel` for confirmation dialogs (e.g., closing incident).

4.3 Interaction Flow Highlights

1. **Log Intake:** Select asset → paste log → choose source → click “Ingest Event”. Controller validates required fields, inserts `security_events`, resets form.

2. **AI Assessment:** Choose event → view last assessment → click “Run AI Analysis”. Controller fetches features, calls `RiskScoringService`, persists `ai_assessments`, updates UI severity badge.

3. **Threat Intel:** Press “Enrich Indicators” → extracts IOC from log → queries local cache/external API (Phase IV extension) → stores results in `threat_intel_matches` → refresh table.

4. **Task Orchestration:** Add/edit tasks via modal form → updates `incident_tasks` table → progress indicator shows completion ratio.

5. **Compliance Reporting:** Fill summary text, choose regulation, click “Generate Report” → creates `compliance_reports` row and writes PDF (reuse Phase I pdf script with templated content).

5. Controller & Service Layer Design

- `EventController`: Handles Event CRUD, status transitions, asset linkage, orchestrates scenario switching.
- `RiskController`: Wraps feature engineering, model invocation, and persistence of `ai_assessments`.
- `ThreatIntelController`: Coordinates indicator parsing (regex-based), lookups via `ThreatIntelService`.
- `TaskController`: Manages `incident_tasks`, enforces business rules (cannot close incident if tasks incomplete).

- `ReportController`: Collates data across tables, renders compliance summaries using template engine (Jinja2 planned).

Services layer isolates reusable business logic:

- `RiskScoringService`: loads serialized model, transforms `security_events` rows into feature vectors (asset criticality, source, IOC scores, historical frequency).
- `ThreatIntelService`: caches prior matches, exposes `query_indicator()` returning reputation/confidence metrics.
- `ReportBuilder`: merges AI summaries, task status, timeline for PDF generation; returns file path saved to `export_path`.

6. AI Model Lifecycle

- **Training Data Sources:** CERT Insider Threat, UNSW-NB15, curated low-severity synthetic logs, threat intel feeds (mapped into severity buckets).
- **Feature Engineering Plan:**

- Categorical encodings: event source, asset criticality, indicator type.

- Numerical: count of unique IOCs, prior incidents on asset (30-day window), reputation scores, time-of-day.

- Text embeddings: TF-IDF on log tokens (reduced via PCA for runtime efficiency).

- **Model Pipeline:** `LogisticRegression(multi_class='multinomial', solver='lbfgs')` with class weight balancing to mitigate skew.
- **Validation:** Stratified train/test split, macro F1 > 0.75 acceptance threshold; confusion matrix for severity drift monitoring.
- **Deployment:** Serialize pipeline with `joblib` into `ai/models/risk_classifier.pkl`. Runtime service ensures lazy loading and version check against `ai_assessments.model_version`.
- **Retraining cadence:** Monthly or when performance drift >5% observed (tracked via `model_performance` table extension planned for Phase IV).

7. Scenario Validation & Test Evidence

- Execute `python3 scripts/phase2_demo.py` to initialise `sentinelguard_phase2.db`, populate sample data, and run the five Phase I scenarios end-to-end.
- Capture cropped screenshots of the console output for submission. A sample run is shown below:

```
=== Scenario Validation Outputs ===

[1] Newly ingested security event:
{'event_id': 1, 'hostname': 'auth-gateway-01', 'source': 'CrowdStrike Falcon', 'status': 'Resolved'

[2] Latest AI assessment for event:
{'event_id': 1, 'model_version': 'risk-clf-v1.0', 'severity_label': 'High', 'risk_score': 0.87, 're

[3] Threat intelligence matches:
{'indicator_type': 'IP', 'indicator_value': '185.199.110.153', 'threat_actor': 'APT-PhantomFox', 'c
{'indicator_type': 'Hash', 'indicator_value': 'f2c7d9a8e4bd88f3f89d7b5b1c4fbd67', 'threat_actor': '

[4] Outstanding incident tasks:
```

```
{'task_description': 'Disable svc-finance account', 'priority': 'Urgent', 'status': 'In Progress',
{'task_description': 'Collect volatile memory from auth-gateway-01', 'priority': 'High', 'status':
{'task_description': 'Update incident ticket with AI summary', 'priority': 'Medium', 'status': 'Com

[5] Compliance report snapshot:
{'event_id': 1, 'regulation': 'SOC2-CC8', 'summary_text': 'Incident contained within SLA. AI-guided
```

- These outputs correspond directly to the five SentinelGuard scenarios and confirm referential integrity across the schema.

Scenario validation console

8. Implementation Roadmap

1. **Database Layer (Week 1):**

- Finalize SQLAlchemy models + Alembic migration scripts.

- Seed sample data for assets, analysts, baseline events.

2. **Controller & Service Stubs (Week 2):**

- Implement repositories, base controllers, event bus pattern.

- Integrate risk scoring service with mock model.

3. **UI Assembly (Week 3):**

- Build dashboard shell, integrate forms per scenario.

- Hook up real data reads, allow simple CRUD.

4. **AI Integration & Reporting (Week 4):**

- Train initial logistic regression, connect inference.

- Implement compliance PDF rendering with templated content.

5. **Hardening (Phase III Prep):**

- Error handling, logging, unit tests for services, user acceptance scripts.

9. Challenges & Design Adjustments

- **Balancing AI ambition with course scope:** Initial idea involved deep learning embeddings, but pivoted to logistic regression to keep training lightweight and transparent for grading.
- **Schema normalization vs. performance:** Introduced composite uniqueness (e.g., `incident_tasks` index) after discovering duplicate task entries during dry runs.
- **UI layout complexity:** Consolidated navigation into a single Tkinter shell to avoid frame proliferation while still satisfying the requirement for five distinct scenarios.
- **Dataset diversity:** Noted variance between CERT and UNSW label conventions; added severity mapping plan to harmonize labels before model training.

10. Contribution Statement

- Solo project by **Gurmatsingh Sour**. Responsibilities this phase covered: schema engineering, ERD documentation, Tkinter layout planning, controller/service design, AI pipeline definition, and scenario validation scripting.

11. Phase II Deliverables Checklist

- [x] Complete ERD narrative and relationship mapping.
- [x] Detailed data dictionary covering all seven tables with constraints.
- [x] SQL DDL script with secondary/composite keys documented for screenshot capture (`db/schema.sql`).
- [x] UI navigation plan with widget coverage for five scenarios.
- [x] Controller/service design aligned with MVT requirements.
- [x] AI lifecycle specification including dataset plan, features, validation.
- [x] Scenario validation evidence via `scripts/phase2_demo.py` outputs.
- [x] Challenges summary and contribution statement recorded.
- [x] Roadmap bridging into implementation (Phase III).

The specification keeps SentinelGuard within the original scope while ensuring every Phase I requirement is traceable to a concrete design element for Phase III development.