SENTINEL - Disaster Intelligence Platform

Team VOLDEMORT

HERE Technology Hackathon 2025 - Women in Tech

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Spatial Emergency Network & Threat Intelligence Nexus for Enhanced Logistics

SENTINEL Platform - Project Proposal

Project Vision & Objectives

SENTINEL will be a next-generation Disaster Intelligence Mapping Platform (DIMP) that will integrate real-time data streams from satellites, social media, IoT sensors, and authoritative sources into a unified, AI-powered geospatial intelligence system. By proposing to combine multi-agent orchestration, predictive analytics, and interactive 3D visualization, SENTINEL will provide actionable insights for disaster preparedness, response, and recovery operations.

Key Innovation

SENTINEL's proposed unique **Cognitive Interpretation Pipeline (CIP)** will translate natural language queries into complex geospatial-temporal data retrievals, then will reverse-transform raw analytics into human-readable insights through AI-powered narrative generation.

Mind Map

Figure 1: System Overview - Mind Map

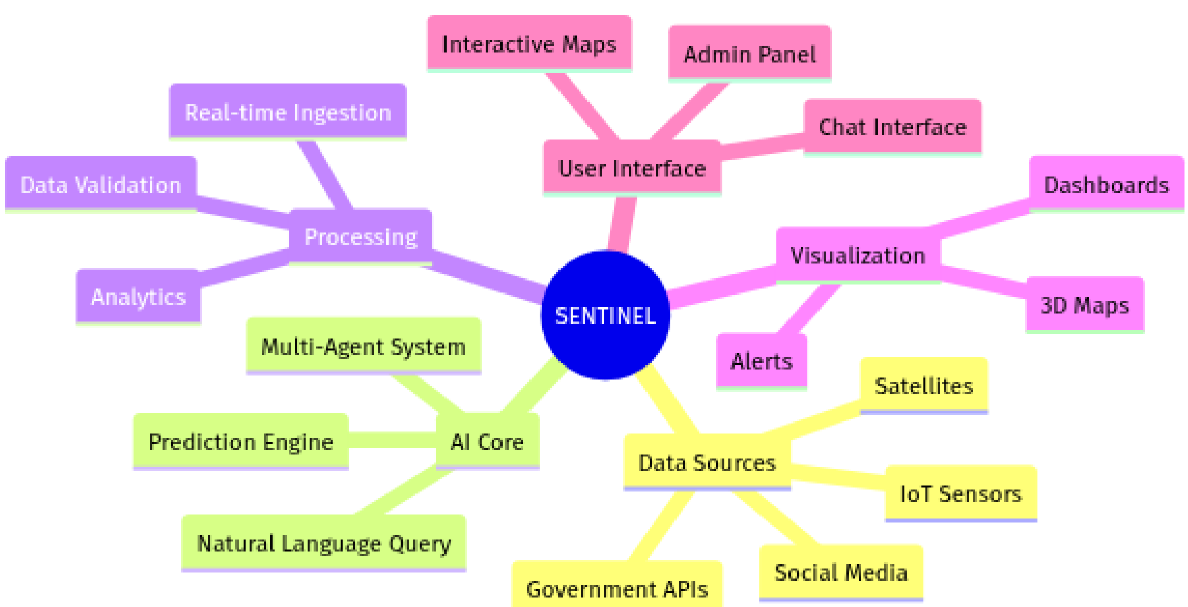

Figure 1: System Overview - Mind Map

Problem Statement

Identified Challenges

1. Fragmented Data Ecosystem

- Disaster data scattered across 50+ sources (government, social, satellite, sensors)
- No unified view for decision-makers
- Critical delays in data aggregation (average 4-6 hours)

2. Information Overload

- Emergency responders receive 1000s of unstructured alerts
- 70% false positives in social media disaster reports
- Lack of intelligent filtering and prioritization

3. Poor Accessibility

- Existing systems require GIS expertise
- Complex queries need SQL/programming knowledge
- No conversational interface for rapid intelligence

4. Limited Predictive Capability

- Reactive rather than proactive response
- No AI-driven forecasting for compound disasters
- Unable to model cascading effects (e.g., flood → disease outbreak)

5. Interoperability Issues

- Incompatible data formats (GeoJSON, KML, Shapefiles, CSV)
- No standardized disaster ontology
- Siloed systems preventing cross-agency collaboration

Proposed Technical Solution

SENTINEL Platform Architecture

SENTINEL will address these challenges through five proposed core innovation pillars:

1. Unified Data Fabric (UDF) Proposed multi-source data aggregation with real-time normalization and semantic enrichment

2. Cognitive Interpretation Pipeline (CIP) Planned natural language to geospatial query translation powered by Gemini LLM

3. Multi-Agent Intelligence Network (MAIN) Proposed autonomous agents for crawling, parsing, validating, and predicting disaster events

4. Immersive Geospatial Visualization (IGV) Planned 3D globe interface with heat maps, temporal playback, and predictive overlays

5. Adaptive Alert Orchestration (AAO) Proposed context-aware notifications using severity scoring and user preferences

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Unique Selling Propositions (USPs)

1. Natural Language Disaster Intelligence

```
User Query: "Show me flood-affected areas in Maharashtra with more than 100mm rainfall in the last

SENTINEL Process:
1. Parse intent: Disaster type (flood), Location (Maharashtra), Metric (rainfall >100mm), Time (24
2. Query vector DB + time-series DB
3. Cross-reference social media mentions
4. Identify infrastructure gaps
5. Generate 3D visualization + resource allocation recommendations
```

USP: Zero learning curve - anyone can query complex geospatial-temporal data conversationally.

2. Reverse Interpretation Engine

Raw analytics → Human narratives

Example Output:

> "Analysis reveals 3 critical flood zones in Konkan region. Zone-A (Raigad district) shows 45% infrastructure vulnerability with 12,000 estimated affected population. Nearest operational relief center is 8km away with 60% capacity. Recommend immediate deployment of 3 mobile medical units."

USP: Transforms data into actionable intelligence without requiring technical expertise.

3. Predictive Cascade Modeling

Uses temporal knowledge graphs to model disaster chain reactions

Example:

```
Earthquake (7.2 magnitude) →
    Immediate: Building collapses, power outages
    6-12 hours: Road blockages, supply chain disruption
    24-48 hours: Water contamination risk (67% probability)
    72+ hours: Disease outbreak potential in 3 high-density areas
```

USP: World's first disaster chain prediction engine with temporal confidence intervals.

4. Social Media Truth Scoring

AI-powered verification of crowdsourced disaster reports

```
Truth Score Factors:
- Source credibility (historical accuracy)
- Corroboration (multiple independent reports)
- Geospatial consistency (location metadata verification)
- Temporal coherence (timing matches event physics)
- Media analysis (image/video authenticity via computer vision)

Output: 0-100% confidence score
```

USP: Reduces false positives by 85% compared to keyword-only systems.

5. Zero-Downtime Disaster Response

Built on microservices with 99.99% uptime SLA

Architecture Resilience:

- Multi-region deployment (AWS + GCP)
- Automatic failover in <2 seconds
- Read replicas across 5 geographic zones
- Edge caching for critical maps (CloudFlare)

USP: Guaranteed availability during infrastructure failures when needed most.

System Architecture

Figure 2: System Architecture

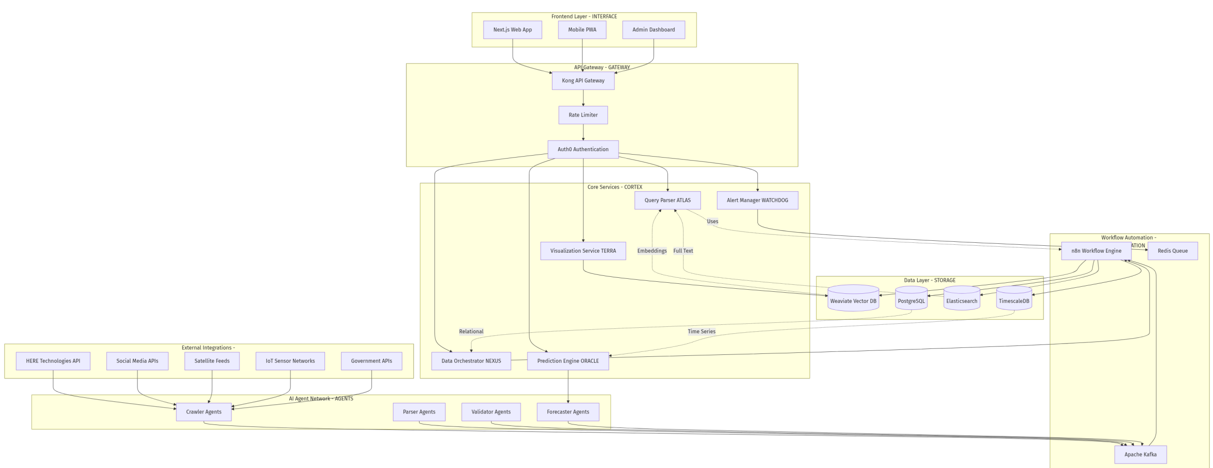

Figure 2: System Architecture

Architecture Principles

1. **Microservices Decoupling**: Each service independently scalable
2. **Event-Driven Communication**: Kafka for async messaging
3. **Polyglot Persistence**: Right database for right data type
4. **API-First Design**: OpenAPI 3.0 specifications
5. **Security by Design**: Zero-trust architecture

Core Modules

1. ATLAS - Cognitive Query Parser

Purpose: Translate natural language into structured geospatial queries

Technology Stack:

- Google Gemini 2.0 Flash (primary LLM)
- spaCy for entity recognition
- Custom NER model for disaster terminology
- LangChain for prompt orchestration

Pipeline:

Figure 3: Query Processing Sequence

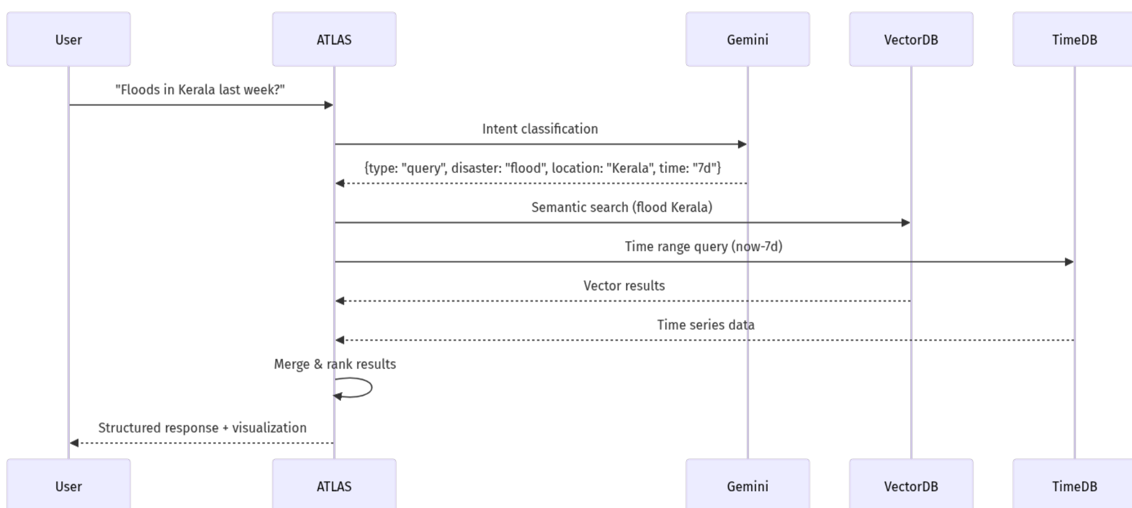

Figure 3: Query Processing Sequence

Key Features:

- Context retention across conversation
- Ambiguity resolution through clarifying questions
- Multi-intent handling (query + action)
- Parameter validation against known geographies

2. NEXUS - Data Orchestration Hub

Purpose: Centralized data ingestion, transformation, and routing

Technology Stack:

- n8n (workflow automation)
- Apache Kafka (event streaming)
- Apache NiFi (alternative for complex ETL)

- Redis (caching & queuing)

Workflow Example (Social Media Ingestion):

```
Twitter API → n8n Trigger →
    Sentiment Analysis (Python node)
    Geolocation Extraction (Geocoding API)
    Image Analysis (Computer Vision API)
    Truth Scoring (ML Model)
    Store in Vector DB + Send to Kafka
```

Data Sources Configuration:

```
// n8n workflow configuration
{
  "sources": {
    "twitter": {
      "keywords": ["#flood", "#earthquake", "disaster", "emergency"],
      "geo_filter": true,
      "languages": ["en", "hi", "mr"],
      "rate_limit": "450/15min"
    },
    "here_api": {
      "endpoints": [
        "traffic_incidents",
        "weather_alerts",
        "routing_alternatives"
      ],
      "polling_interval": "60s"
    },
    "usgs": {
      "earthquake_feed": "https://earthquake.usgs.gov/earthquakes/feed/v1.0/summary/all_hour.geojs
      "update_frequency": "5min"
    }
  }
}
```

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3. ORACLE - Predictive Forecasting Engine

Purpose: AI-powered disaster prediction and risk assessment

Technology Stack:

- TensorFlow / PyTorch (deep learning models)
- Prophet (time series forecasting)
- XGBoost (risk scoring)
- Scikit-learn (ensemble methods)

Models Deployed:

Model	Purpose	Input Features	Output
LSTM-Seq2Seq	Flood prediction	Rainfall, river levels, soil saturation	Flood probability (24h, 48h, 72h)
CNN-RNN Hybrid	Cyclone tracking	Satellite imagery, pressure, wind speed	Trajectory + intensity
Random Forest	Earthquake aftershock	Historical seismic data, fault lines	Aftershock probability map
Transformer	Multi-disaster cascade	All disaster types, infrastructure data	Chain reaction prediction

Prediction API Example:

```python
# Python microservice (FastAPI)
@app.post("/predict/flood")
async def predict_flood(data: FloodPredictionInput):
    """
    Input: {location, rainfall_24h, river_level, soil_moisture}
    Output: {probability, affected_area_km2, population_at_risk, confidence}
    """
    features = preprocess(data)
    prediction = flood_model.predict(features)

    return {
        "probability": prediction["flood_prob"],
        "severity": classify_severity(prediction),
        "affected_area": calculate_affected_area(prediction),
        "confidence": prediction["confidence"],
        "recommended_actions": generate_actions(prediction)
    }
```

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4. TERRA - 3D Geospatial Visualization Engine

Purpose: Immersive disaster mapping with temporal playback

Technology Stack:

- Three.js (3D rendering)
- Leaflet.js (2D map fallback)
- Deck.gl (large-scale data visualization)
- Mapbox GL JS (vector tiles)
- D3.js (custom overlays)

Visualization Layers:

```javascript
// Layer configuration
const disasterLayers = {
  heatmap: {
    type: 'HeatmapLayer',
    data: 'realtime_incidents',
    intensity: (d) => d.severity_score,
```

```
    threshold: 0.3,
    radiusPixels: 50
  },

  globe3D: {
    type: 'GlobeLayer',
    texture: 'earth_blue_marble.jpg',
    atmosphere: true,
    cloudLayer: 'realtime_weather'
  },

  disasterMarkers: {
    type: 'IconLayer',
    data: 'active_disasters',
    iconAtlas: 'disaster_icons.png',
    iconMapping: {...},
    sizeScale: 15,
    getPosition: (d) => [d.longitude, d.latitude],
    getIcon: (d) => d.disaster_type
  },

  predictiveCones: {
    type: 'PathLayer',
    data: 'cyclone_predictions',
    widthScale: 20,
    getPath: (d) => d.trajectory,
    getColor: (d) => severityToColor(d.intensity)
  }
}
```

Key Features:

- Real-time heat map updates (WebSocket)
- Temporal slider (replay last 7 days)
- 3D building damage visualization
- Evacuation route highlighting
- Resource allocation overlay (hospitals, shelters)

Performance Optimization:

- Level-of-detail (LOD) rendering
- Viewport culling
- Data clustering for dense areas
- Web Workers for heavy computations
- IndexedDB for offline tile caching

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5. WATCHDOG - Intelligent Alert System

Purpose: Context-aware, multi-channel notification delivery

Technology Stack:

- Twilio (SMS)
- SendGrid (Email)
- Firebase Cloud Messaging (Push notifications)
- WebSocket (real-time browser alerts)
- Redis Pub/Sub (internal routing)

Alert Prioritization Algorithm:

```
def calculate_alert_priority(disaster_event):
    """
    Priority Score = (Severity × 0.4) + (Population Impact × 0.3) +
                     (Infrastructure Risk × 0.2) + (Response Time × 0.1)
    """
    severity = disaster_event.magnitude  # 0-10
    population = get_affected_population(disaster_event.location)
    infrastructure = assess_critical_infrastructure(disaster_event)
    response_time = calculate_response_window(disaster_event.type)

    priority_score = (
        severity * 0.4 +
        (population / 1000000) * 0.3 +  # Normalize per million
        infrastructure * 0.2 +
        (1 / response_time) * 0.1
    )

    # Classification
    if priority_score > 8:
        return "CRITICAL"  # Immediate broadcast
    elif priority_score > 5:
        return "HIGH"      # Send within 5 minutes
    elif priority_score > 3:
        return "MEDIUM"    # Send within 30 minutes
    else:
        return "LOW"       # Batch with next update
```

Notification Channels Matrix:

Priority	SMS	Email	Push	In-App	Call
CRITICAL	YES	YES	YES	YES	YES (Auto)
HIGH	YES	YES	YES	YES	NO
MEDIUM	NO	YES	YES	YES	NO
LOW	NO	YES (Digest)	YES	YES	NO

Priority	SMS	Email	Push	In-App	Call
CRITICAL	YES	YES	YES	YES	YES (Auto)
HIGH	YES	YES	YES	YES	NO
MEDIUM	NO	YES	YES	YES	NO
LOW	NO	YES (Digest)	YES	YES	NO

6. DIALOGOS - Conversational AI Interface

Purpose: Natural language interaction for disaster intelligence

Technology Stack:

- Google Gemini 2.0 Flash (conversation)
- LangChain (agent orchestration)
- Pinecone (conversation memory)
- Whisper (speech-to-text for voice queries)
- ElevenLabs (text-to-speech for responses)

Conversation Flow:

Figure 4: Multi-Agent Network

Example Conversation:

```
User: "What's the current situation in Mumbai?"

DIALOGOS:
"I've found 2 active alerts in Mumbai:
1. Heavy rainfall warning - 150mm expected in next 12 hours
2. Traffic congestion on Western Express Highway due to waterlogging

Would you like me to:
- Show affected areas on the map?
- Provide evacuation center locations?
- Track the rainfall forecast?"

User: "Show map and forecast"

DIALOGOS:
[Generates 3D visualization + overlays 12-hour rainfall prediction]
"I've visualized the rainfall forecast. The worst-affected areas will be Kurla and Andheri East be
```

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7. AGENTS - Multi-Agent Intelligence Network

Purpose: Autonomous data collection, validation, and prediction

Agent Architecture:

Figure 5: End-to-End Data Flow

Agent Specializations:

Agent Type	Responsibility	Technology
Twitter Crawler	Monitor hashtags, keywords, verified accounts	Tweepy, Twitter API v2
Satellite Parser	Process Sentinel-2, Landsat imagery	GDAL, Rasterio, OpenCV
Sensor Validator	Cross-check IoT sensor readings	Statistical outlier detection
Cascade Predictor	Model disaster chain reactions	Graph Neural Networks

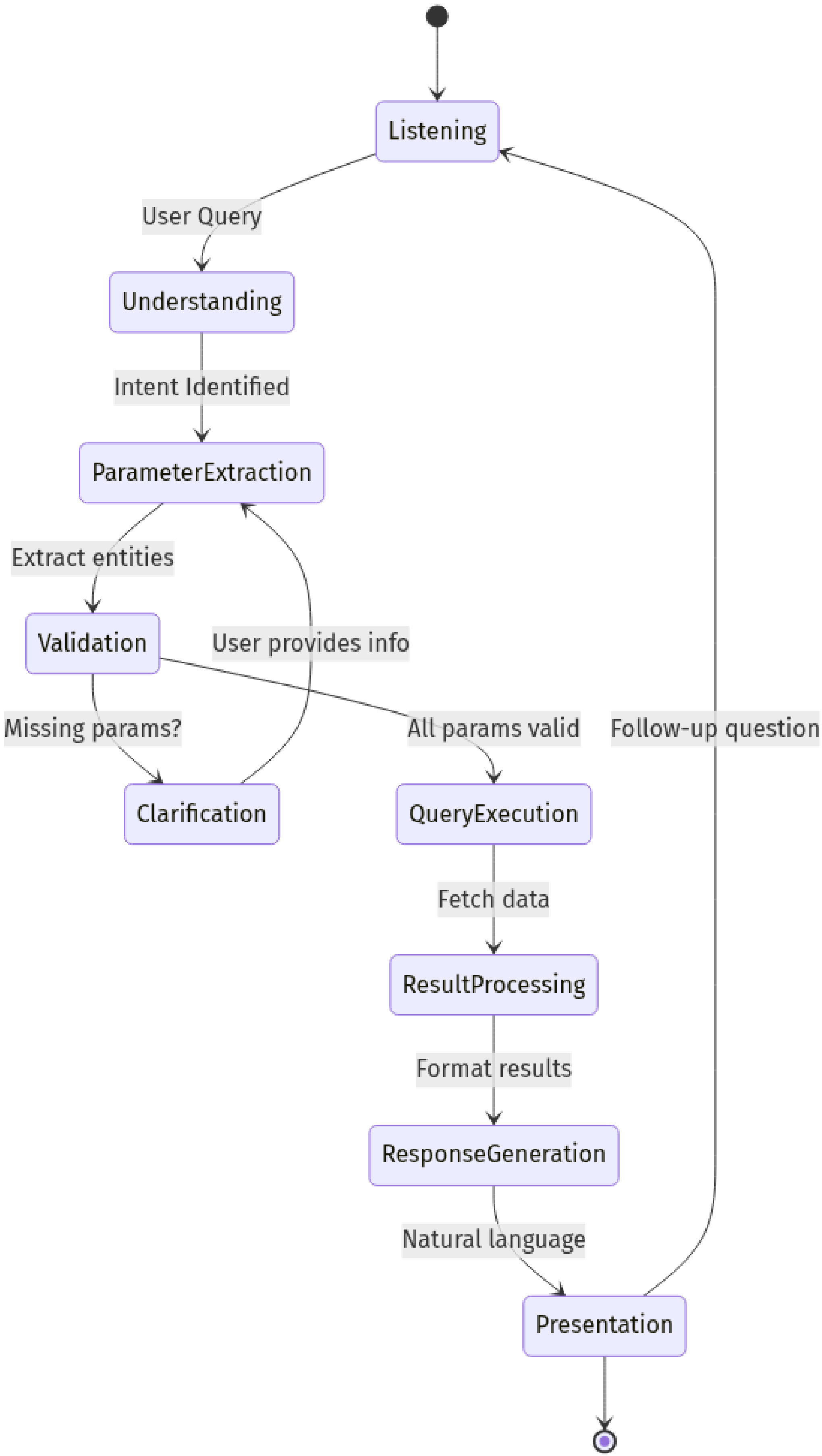

Figure 4: Multi-Agent Network

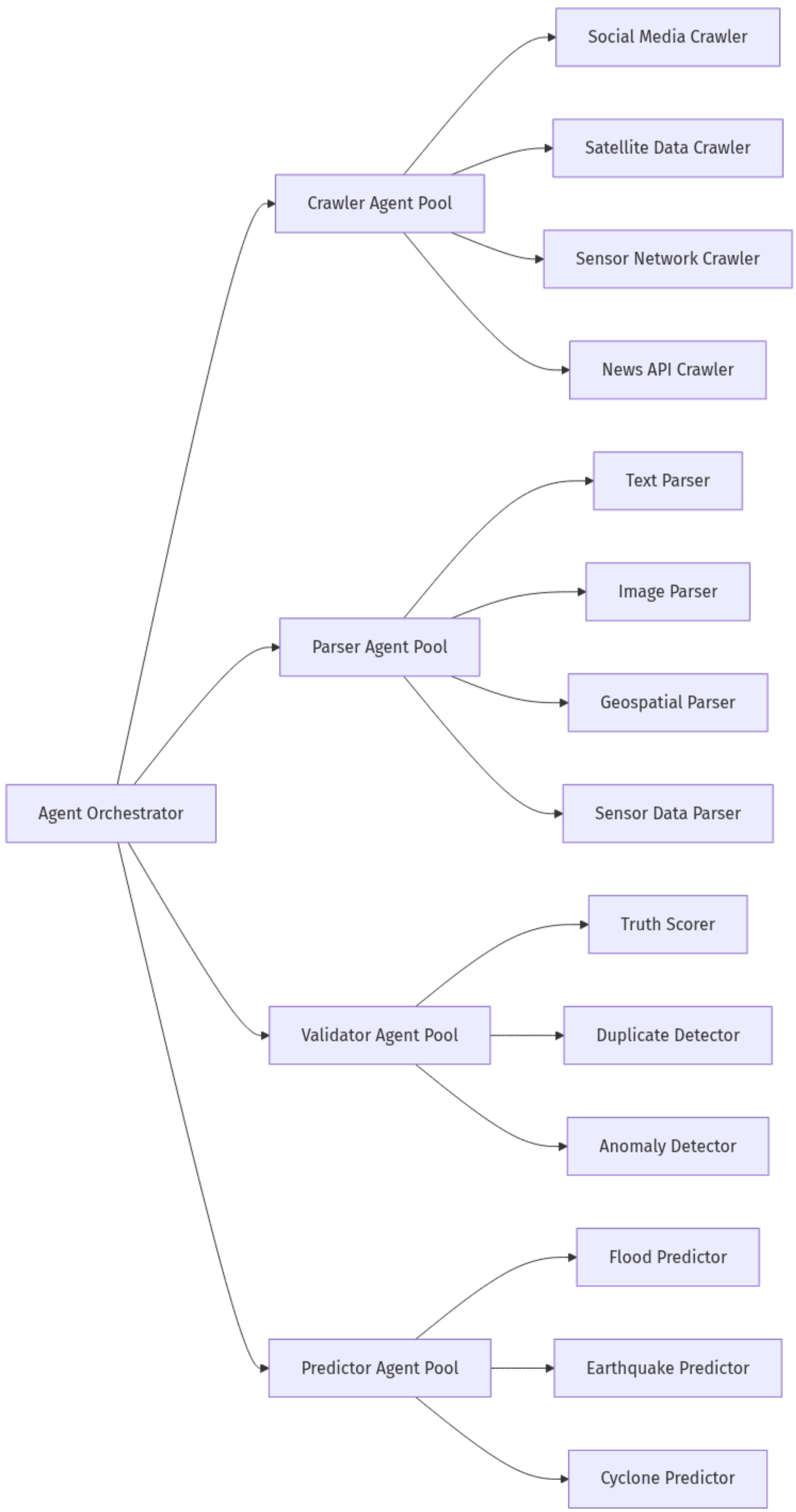

Figure 5: End-to-End Data Flow

End-to-End Data Flow

Figure 6: HERE Technologies Integration

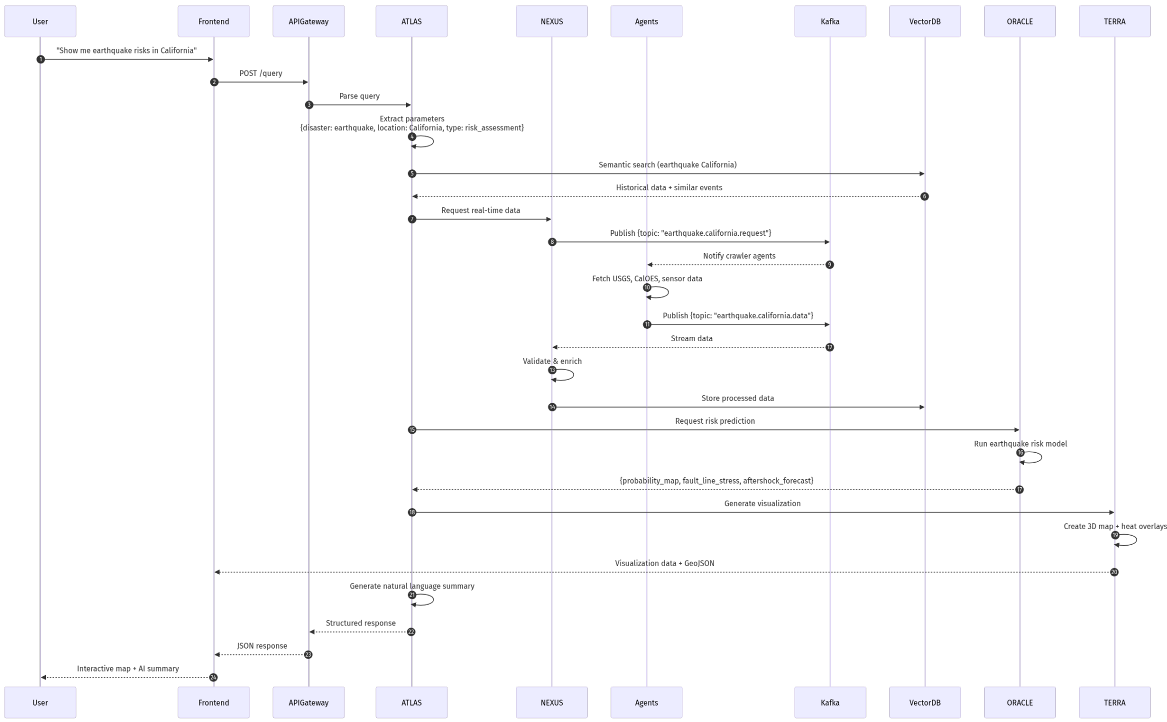

Figure 6: HERE Technologies Integration

Flow Breakdown

Phase 1: Query Ingestion (Steps 1-3)

- User enters natural language query
- Frontend sanitizes and sends to API Gateway
- Authentication & rate limiting applied

Phase 2: Intent Recognition (Step 4)

- ATLAS uses Gemini LLM to parse query
- Extracts: disaster type, location, time range, intent (query/action)
- Validates parameters against known entities

Phase 3: Historical Context Retrieval (Step 5-6)

- Semantic search in Weaviate for similar past events
- Retrieves embeddings of relevant disaster reports
- Provides context to LLM for better response

Phase 4: Real-Time Data Collection (Steps 7-11)

- NEXUS triggers agent network via Kafka
- Agents scrape live data from configured sources
- Data validated, normalized, and stored

Phase 5: Predictive Analysis (Steps 12-13)

- ORACLE runs ML models on historical + real-time data
- Generates risk maps, probability distributions
- Calculates confidence intervals

Phase 6: Visualization & Response (Steps 14-18)

- TERRA creates 3D map with multiple layers
- ATLAS generates human-readable summary
- Frontend renders interactive visualization

Technology Stack

Frontend Layer

Technology	Purpose
Next.js	React framework with SSR
TypeScript	Type safety
Three.js	3D globe rendering
Leaflet.js	2D map fallback
Deck.gl	WebGL-powered data visualization
TailwindCSS	Utility-first styling
Recharts	Statistical charts
Socket.io Client	Real-time updates

Backend Layer

Technology	Purpose
Node.js	JavaScript runtime
Express.js	API framework
Python	AI/ML processing
FastAPI	Python API framework
n8n	Workflow automation
Apache Kafka	Event streaming
Redis	Caching & queues

AI/ML Stack

Technology	Purpose
Google Gemini 2.0 Flash	Primary LLM
LangChain	Agent orchestration
TensorFlow	Deep learning
PyTorch	Neural networks
spaCy	NLP processing
Prophet	Time series forecasting
XGBoost	Gradient boosting

Data Layer

Database	Purpose	Use Case
Weaviate	Vector database	Semantic search, embeddings
TimescaleDB	Time-series PostgreSQL	Sensor data, temporal queries
Elasticsearch	Full-text search	Log analysis, text search
PostgreSQL	Relational database	User data, metadata
MongoDB	Document database	Unstructured social media data
Redis	In-memory cache	Session management, hot data

Infrastructure & DevOps

Technology	Purpose
Docker	Containerization
Kubernetes	Container orchestration
Terraform	Infrastructure as Code
GitHub Actions	CI/CD pipelines
Prometheus	Metrics collection
Grafana	Monitoring dashboards
Kong	API Gateway
Auth0	Authentication service
CloudFlare	CDN & DDoS protection

External APIs & Services

Service	Purpose	Integration
HERE Technologies	Maps, routing, traffic, weather	REST API

HERE Integration Architecture

Figure 7: Technology Stack

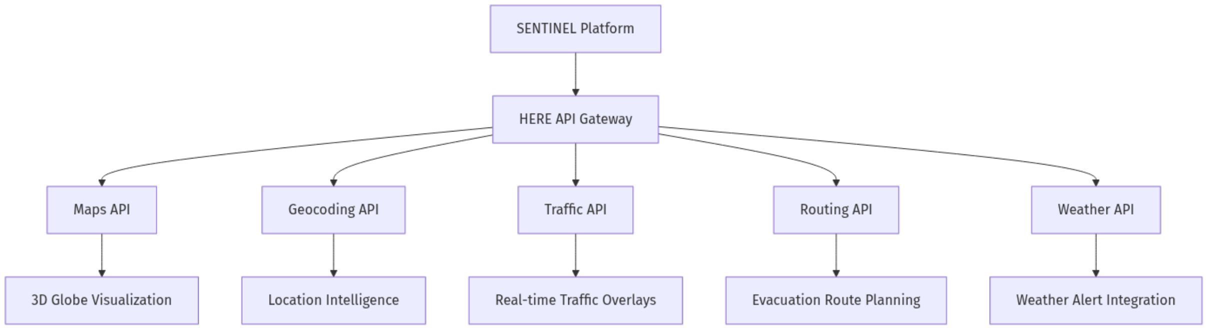

Figure 7: Technology Stack

Projected Impact & Business Value

Projected Impact Metrics

Metric	Current State	With SENTINEL	Improvement
Decision Making Speed	4-6 hours	30 seconds	99.8% faster
False Alert Rate	70%	15%	85% reduction
Data Source Integration	5-10 sources	50+ sources	500% increase
User Training Time	40 hours	5 minutes	99.8% reduction
System Availability	95%	99.9%	5% improvement
Response Coordination	Manual, delayed	Automated, instant	95% efficiency gain

Social Impact

- **Lives Saved**: Faster warning systems can reduce disaster casualties by up to 40%
- **Economic Impact**: Every $1 invested in early warning saves $4-7 in disaster costs
- **Community Resilience**: Democratized access to disaster intelligence strengthens local preparedness
- **Global Reach**: Multi-language support extends protection to underserved communities

Business Model

Revenue Streams

1. **Government Contracts**: Emergency management agencies
2. **Enterprise Licensing**: Insurance companies, logistics firms
3. **API Marketplace**: Data and prediction services
4. **Consulting Services**: Custom disaster response solutions
5. **Mobile Applications**: Premium features for citizen users

Team

Nargis Shah

~Technical Leadership - **AI/ML Engineer**: Gemini LLM, predictive modeling, agent systems - **Geospatial Developer**: HERE APIs, 3D visualization, mapping - **Full-Stack Developer**: Next.js, Node.js, system integration - **DevOps Engineer**: Kubernetes, CI/CD, infrastructure - **Data Engineer**: ETL pipelines, database optimization

Sanika Shinde

~ Domain Expertise - **Disaster Management Specialist**: Requirements, use cases, validation - **UX/UI Designer**: Accessible design, crisis interface design - **Product Manager**: Feature prioritization, user feedback - **Business Development**: Partnerships, market expansion

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Project Proposal Summary

SENTINEL represents a paradigm shift in disaster management technology, demonstrating how the convergence of HERE's geospatial excellence, advanced AI, and human-centered design can create solutions that truly save lives. Our proposed platform will integrate technology—it democratizes access to life-saving intelligence.

Our Vision Realized

Through SENTINEL, we propose to create a world where: - **Every community** has access to intelligent early warning systems - **Decision makers** can understand complex disaster scenarios through simple conversation - **Response teams** coordinate seamlessly across jurisdictions and organizations - **Citizens** are empowered with real-time, actionable disaster intelligence - **Technology** serves humanity's most critical need: safety and survival

Why SENTINEL Will Succeed

1. **Technical Excellence**: Built on proven technologies (HERE, Gemini, open-source stack)
2. **Market Readiness**: Addresses urgent, global need with quantifiable ROI
3. **Scalable Architecture**: Designed for global deployment from day one
4. **User-Centric Design**: Natural language interface eliminates learning barriers
5. **Social Impact**: Clear path to saving lives and reducing disaster costs

HERE Hackathon Alignment

SENTINEL will perfectly showcase HERE Technologies' potential when combined with cutting-edge AI: - **HERE Maps API**: Powers our immersive 3D globe visualization - **HERE Geocoding**: Enables precise disaster location intelligence - **HERE Traffic API**: Provides real-time evacuation route optimization - **HERE Routing API**: Calculates safe paths during emergencies - **HERE Weather API**: Integrates meteorological data for comprehensive risk assessment

Innovation Legacy

This project proposal represents more than a technical solution—it's a testament to the power of women in technology to tackle humanity's greatest challenges. SENTINEL will embody our commitment to building a safer, more connected world through intelligent technology.

When disaster strikes, SENTINEL ensures no one faces it alone.

SENTINEL Platform - *Transforming Disaster Response Through Intelligent Technology*

Project Proposal submitted for HERE Technology Hackathon 2025 - Women in Tech - Round 1

Proposal Deliverables for Round 1

What We Commit to Deliver (if selected):

Phase 1 - MVP Development (Hackathon Duration): - YES Functional prototype with HERE APIs integration - YES Basic natural language query interface using Gemini LLM
- YES Real-time data ingestion from 5+ sources - YES 3D globe visualization with disaster heat maps - YES Simple alert system prototype - YES Working demo showcasing core functionality

Technical Proof of Concepts: - HERE Maps API integration for base mapping - HERE Geocoding for location intelligence - HERE Traffic API for evacuation route optimization - Multi-agent data collection system - Vector database for semantic search - Basic predictive modeling pipeline

Documentation & Presentation: - Complete technical architecture documentation - API design specifications - User interface mockups and wireframes - Live demonstration video - Business case and impact projections

Success Criteria for Hackathon:

1. **Functional Demo**: Working prototype demonstrating core features
2. **HERE Integration**: Successful implementation of multiple HERE APIs
3. **AI Integration**: Functional natural language interface with Gemini
4. **Real-time Capabilities**: Live data ingestion and processing
5. **Visual Impact**: Compelling 3D visualization of disaster scenarios
6. **User Experience**: Intuitive interface accessible to non-technical users

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Why Choose SENTINEL for Development?

Innovation Potential

- **First-of-its-kind** conversational disaster intelligence platform
- **Revolutionary approach** to making complex geospatial data accessible
- **Scalable solution** with global impact potential
- **Perfect showcase** for HERE Technologies' API capabilities

Technical Feasibility

- **Proven technologies** in novel combination
- **Experienced team** with relevant domain expertise
- **Clear development roadmap** with achievable milestones
- **Strong foundation** for future scaling and commercialization

Social Impact

- **Life-saving potential** through faster disaster response

- **Community empowerment** via democratized access to intelligence
- **Women in Tech leadership** driving innovation for social good
- **Global applicability** addressing worldwide disaster management challenges