AI-Powered EV Battery Fire Prevention System

Ensuring a Fire-Free, Secure & Sustainable EV Future

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The Problem

EV Battery Fires are a Major Concern

- Frequent **thermal runaway incidents** leading to fire hazards.
- Lack of **real-time battery health monitoring** & **risk alerts.**
- **Fleet operators & EV owners** suffer from unexpected breakdowns and expensive battery replacements.
- **Regulatory pressure** (AIS-156) for stricter safety measures.

Example : Bangalore has seen a **300% increase in EV fire incidents in 2023-24.**

Project / Module Details

AI-Powered EV Battery Fire Prevention System

- Battery Temperature Monitoring System
- Battery Voltage & Current Analysis
- State of Charge (SOC) Estimation
- EV Battery Health Prediction
- Real-Time Battery Monitoring with IoT
- Intrusion Detection in Battery Management System (BMS)

The Solution

Leverages AI & Machine Learning to predict battery failures before thermal runaway.

Real-Time Monitoring of critical parameters:

- Temperature fluctuations
- Voltage imbalances
- Cell inconsistencies

AI-Driven Predictive Analytics for early detection of anomalies.

Automated Preventive Actions:

- Controlled discharge to prevent overheating
- Active cooling mechanisms (liquid/air cooling)
- Emergency shutdown & alerts

Seamless BMS Integration:

- Works with existing Battery Management Systems
- Adds AI-powered safety layer

Cloud-Based Analytics & OTA Updates:

- Continuous learning from real-world battery failures
- Over-the-Air (OTA) updates for AI model improvements

Access devices / sensors from connected EV / Software Defined Vehicles

CONNECT	Connect to the Vehicle from Mobile device and Authenticate.
DETECT	Detect Devices & Sensors (Battery Details, Telematics Information.. etc)
READ	Read the status of the Devices & Sensors
WRITE	Change the device / sensor status
DISPLAY	Display Device / Sensor's info on Dashboard
COLLECT	Collect and upload device details to Cloud for Analysis
ANALYSE	Device analysis using Machine Learning
CONTROL	Control vehicle using mobile (Lock, Unlock, Start, Stop | CAN Bus)

Intrusion detection in connected EV / Software Defined Vehicles

SCAN	Scan the Devices | Sensors | Battery | Telematics | WiFi in the Vehicle (On demand basis)
MONITOR	Monitor the vehicle system for accidental attack
DETECT	Detect Intrusion of attack from Network | Internet | Other IoT | Apps
ALERT	Alert the user about the issues / problems
COLLECT	Collect and upload Intrusion details to Cloud for Analysis
ANALYSE	Intrusion analysis using Machine Learning
REPORT	Generate the report (Detected Issues and other analysis information)
RECOMMEND	Recommendation | Recovery | Protection

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Intrusion detection in Battery Management System

Collect Battery Data Logs (or Use Sample Data)

Analyse Normal vs. Anomalous Data

Implement an Anomaly Detection Model

Real-Time Intrusion Detection Simulation

Secure Battery Data with Encryption

Potential Cyber Threats:

Spoofing Attack: Fake voltage readings injected

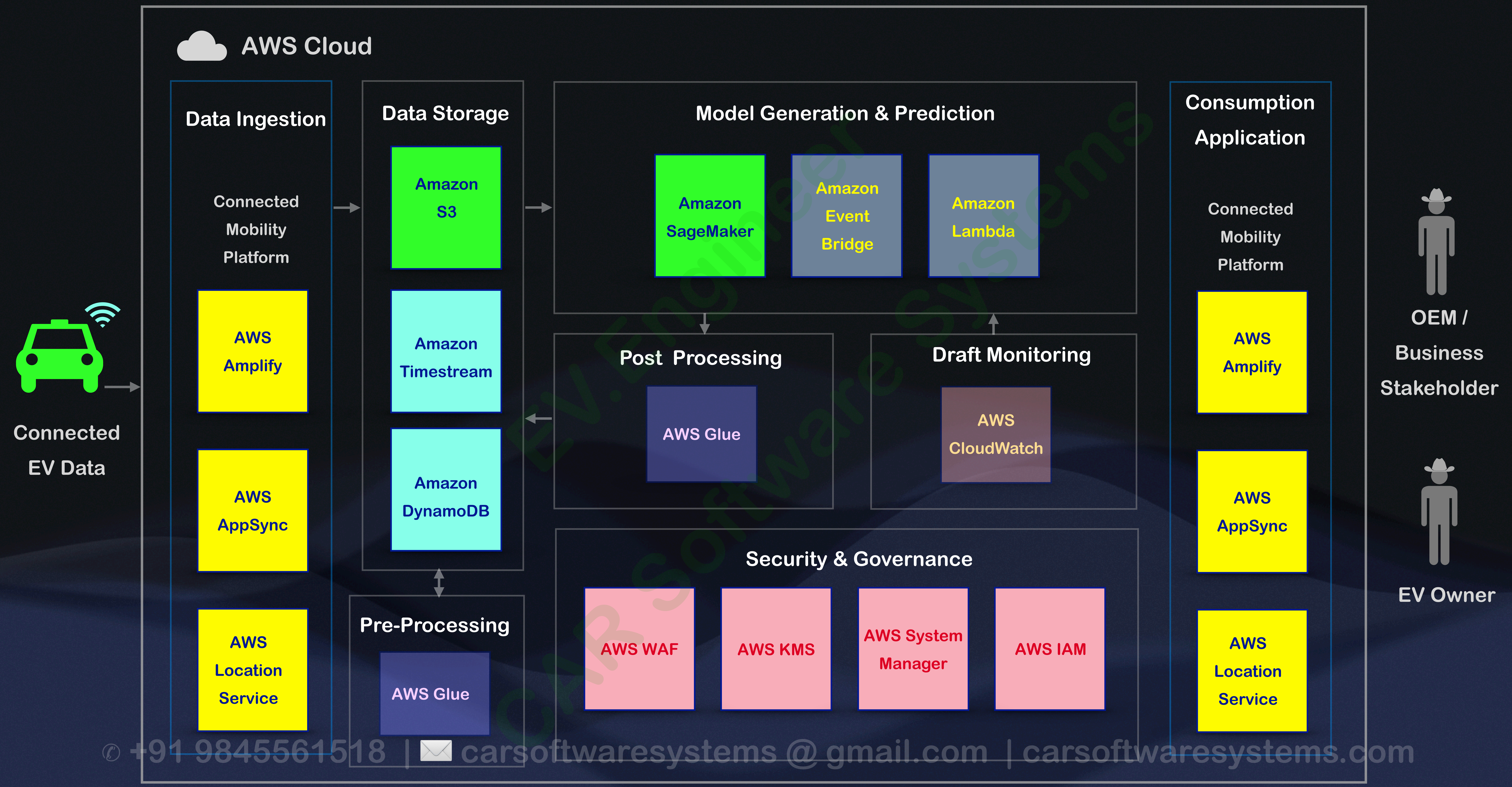
Man-in-the-Middle Attack: SOC data modified

Malware in BMS: Unauthorised data manipulation

Battery Diagnostics Reports / Fault Status

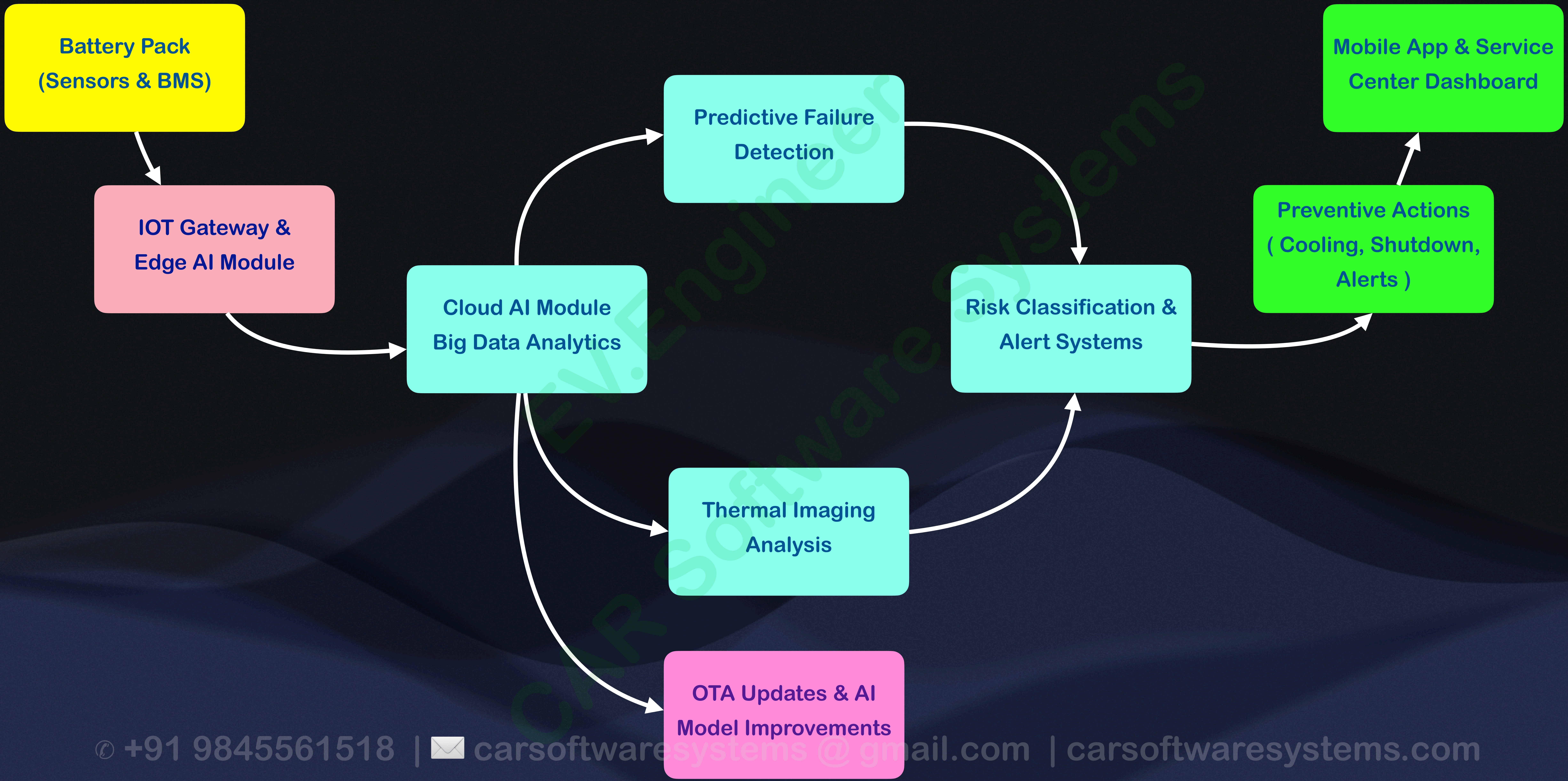
Short Circuit	Deep Discharge	Health
Imbalance	Over Heating	Safety Level
BMS Fault	Reserve Current	Energy Level
Charger Fault	Voltage Drop	SOC
Aging	Water Damage	SOH

Cloud Architectural Design



Architecture of EV Battery Management Systems

AI-Powered EV Battery Fire Prevention System



AI & Quantum Computing - Layered Architecture

Cloud & Edge Quantum Computing Infrastructure
(Top-Level Control & Computation)

Secure Quantum Cryptography Layer
(Ensures Data Integrity & Security)

AI-Powered Anomaly Detection & Prediction Layer
(Early Warning System - Classical AI Approach)

Quantum Computing Optimisation & Decision Making
(Advanced AI with Quantum Computing)

EV Battery Data Collection & Monitoring Layer
(Real-Time Execution & Sensor Data Processing)

Hybrid Quantum - Classical AI System :

- Uses IBM Qiskit, Microsoft Azure Quantum, Google Cirq for cloud-based quantum simulations.
- Supports real-time Quantum AI execution for battery analytics.
- Balances computational workload between Classical AI and Quantum AI for optimised processing.

Quantum Edge Computing for Real-Time Battery Monitoring

- Processes data locally for fast response and battery failure prevention.
- Reduces latency by executing Quantum AI models at the edge.

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Quantum Key Distribution (QKD) for Secure Over-the-Air (OTA) Updates

- Ensures BMS firmware updates remain protected against cyber threats.
- Integrates with AI-driven cybersecurity to detect and mitigate potential breaches.

Post-Quantum Cryptography (PQC) for Secure EV Data Storage

- Encrypts battery logs, BMS firmware, and user data to prevent hacking.
- Provides resilience against classical and quantum cyber threats.

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Classical AI/ML for Initial Anomaly Detection

- AI models trained on historical EV battery failure incidents.
- Identifies early warning signs of thermal runaway.
- Uses probabilistic models and deep learning for failure prediction.

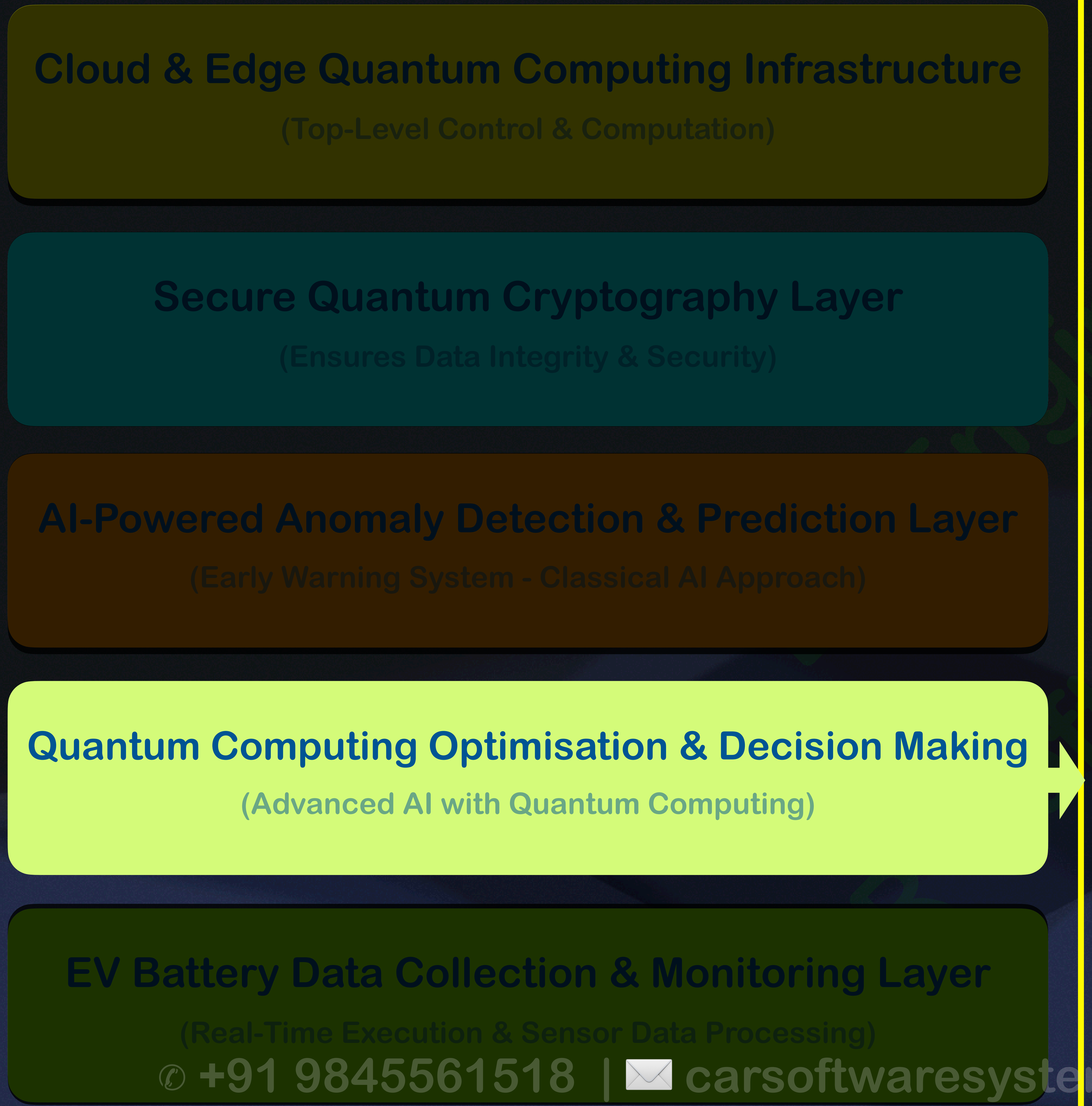
Deep Learning for Fire Risk Estimation

- Neural Networks classify battery safety levels and generate alerts.
- Implements explainable AI (XAI) to interpret failure causes.

Classical Optimisation Algorithms for Battery Management

- Uses Reinforcement Learning & Heuristic Search to optimize battery efficiency.
- Enhances battery longevity and optimal energy usage.

AI & Quantum Computing - Layered Architecture



Quantum Machine Learning (QML) for Battery Health Prediction

- Uses Variational Quantum Circuits (VQC) for complex pattern recognition.
- Enhances AI's ability to process non-linear battery degradation patterns.

Quantum Neural Networks (QNNs) for Thermal Runaway Risk Assessment

- Quantum-enhanced deep learning models predict potential failures.
- Simulates high-dimensional battery behaviour for precise anomaly detection.

Quantum Approximate Optimisation Algorithm (QAOA) for Energy Management

- Optimises battery charging, discharging, and thermal management.
- Uses quantum annealing techniques for highly efficient decision-making.

Quantum Annealing for Battery Safety Optimisation

- Uses D-Wave's quantum annealers for efficient battery performance tuning.
- Applies quantum-enhanced combinatorial optimisation for fire prevention strategies.

AI & Quantum Computing - Layered Architecture

Real-time Sensor Data Acquisition

- Captures data from EV battery sensors (temperature, voltage, current, SOC, SOH).
- Uses IoT & Edge Computing at the Battery Management System (BMS) for real-time processing.
- Implements self-healing AI models that adapt to sensor noise and environmental variations.

Edge Computing at BMS

- Low-latency, real-time analysis to detect early battery anomalies.
- Integrates AI-driven edge computing for preemptive failure response.

Secure Data Transmission:

- Utilises Quantum Cryptography (QKD) for secure communication between EV and cloud servers.
- Ensures tamper-proof data logging for compliance and traceability.

1. Battery Temperature Monitoring System

Goal: Read temperature data, analyse trends, and detect overheating.

Concepts: File handling, NumPy, Pandas, Matplotlib

Tasks:

- Read a CSV file containing battery temperature data
- Calculate average, max, and min temperatures
- Plot a temperature trend graph using Matplotlib
- Detect overheating conditions (e.g., alert if temp > 60°C)

Outcome: Basic battery monitoring using Python

2. Battery Voltage & Current Analysis

Goal: Analyse voltage & current data to detect anomalies..

Concepts: Pandas, Data Visualisation, Time-Series Analysis

Tasks:

- Load battery voltage & current datasets
- Identify voltage drops and current spikes
- Plot Voltage vs. Time & Current vs. Time
- Set a rule: Alert if voltage drops below a threshold

Outcome: Detect battery performance issues

3. State of Charge (SOC) Estimation

Goal: Estimate battery SOC using voltage and current data.

Concepts: Numerical computing, Basic Machine Learning

Tasks:

- Load historical battery data (Voltage, Current, SOC)
- Train a simple regression model to predict SOC
- Validate results using test data
- Display real-time SOC values for a given input

Outcome: SOC estimation using Python

4. EV Battery Health Prediction

Goal: Use AI to predict battery degradation over time.

Concepts: Machine Learning, Data Science

Tasks:

- Load battery charge-discharge cycle data
- Identify patterns in battery degradation
- Train an ML model (Scikit-learn) to predict Remaining Useful Life
- Visualise predictions with graphs

Outcome: AI-based battery health prediction

5. Intrusion Detection in Battery Management System

Goal : Detect anomalous activities in an EV Battery Management System using Python. (Hacking attempts, data tampering, or unauthorised access)

Concepts Used:

- Log Analysis & Data Forensics
- Anomaly Detection (Machine Learning)
- Cybersecurity Threat Detection

Project Overview

The Battery Management System (BMS) logs critical parameters:

- Voltage, Current, Temperature
- State of Charge (SOC), State of Health (SOH)
- Communication logs (CAN messages)

Potential Cyber Threats:

- **Spoofing Attack**: Fake voltage readings injected
- **Man-in-the-Middle Attack:** SOC data modified
- **Malware in BMS:** Unauthorised data manipulation

Expected Outcomes

- Build a Battery Intrusion Detection System (IDS)
- Detect cyber attacks on BMS data
- Train an ML model to differentiate between normal and attack conditions
- Secure BMS communication with encryption (Advanced)

STEP 1 : Collect Battery Data Logs (or Use Sample Data)

- Use a CSV file containing battery logs with timestamps
- Add a column for intrusion detection labels (Normal / Attack)

STEP 2 : Analyse Normal vs. Anomalous Data

- Load the dataset using Pandas
- Visualise voltage/current variations using Matplotlib
- Identify unexpected spikes, drops, or inconsistent SOC values

STEP 3 : Implement an Anomaly Detection Model

- Use Scikit-Learn to train an ML model for intrusion detection
- Algorithms: Isolation Forest, Random Forest, or Logistic Regression
- Train model on normal vs. attack data samples
- Detect real-time anomalies from live battery logs

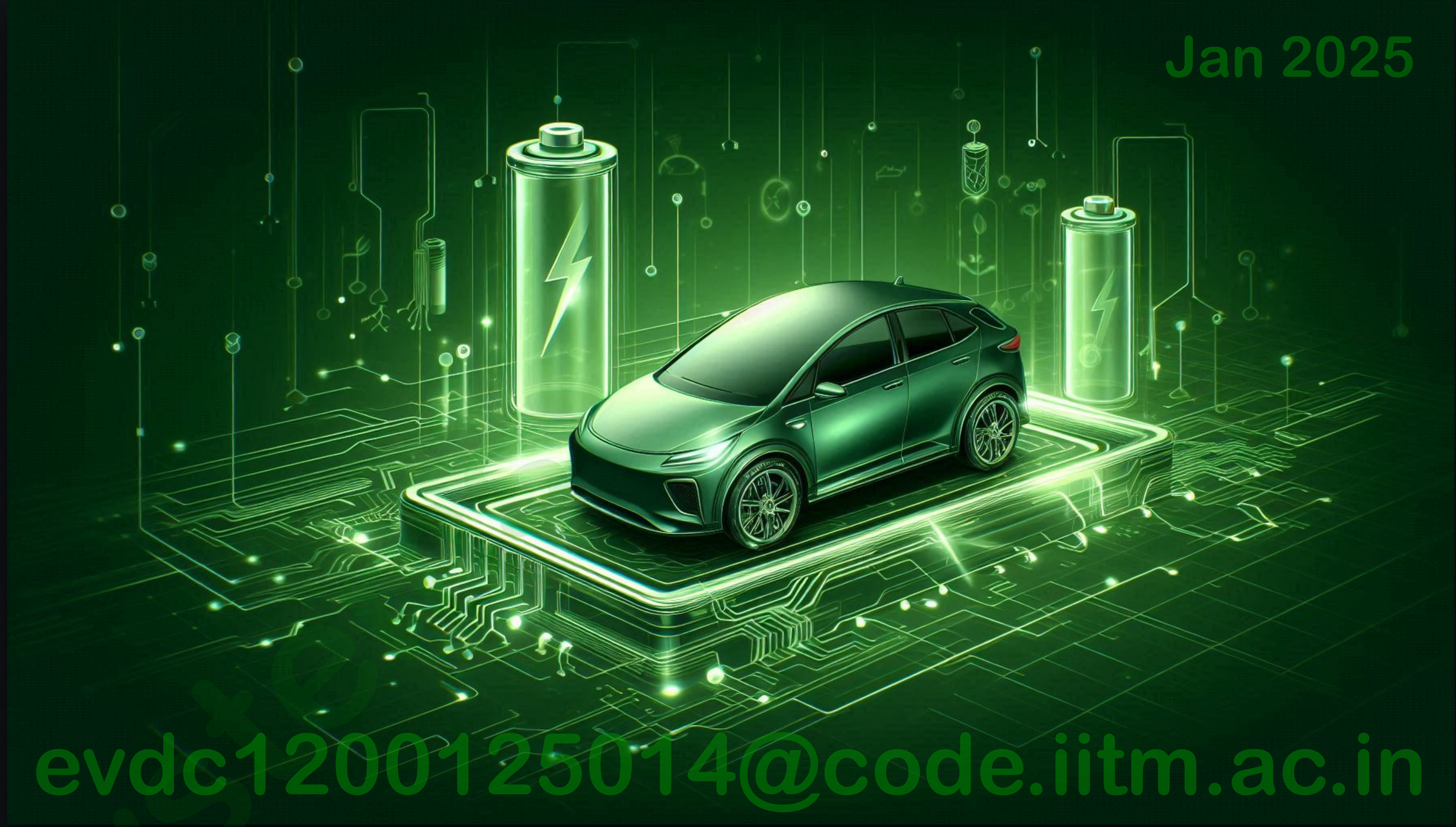
STEP 4 : Real-Time Intrusion Detection Simulation

- Simulate incoming battery data (live stream using Python)
- Detect unauthorised activities and trigger alerts
- Implement logging system to save security breach attempts

STEP 5 : Secure Battery Data with Encryption

- Use AES Encryption (Python pycryptodome module)
- Encrypt critical BMS data before transmission \
- Ensure only authorised systems can decrypt it

Business Plan



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- Lack of **real-time battery health monitoring** & **risk alerts.**
- **Fleet operators & EV owners** suffer from unexpected breakdowns and expensive battery replacements.
- **Regulatory pressure** (AIS-156) for stricter safety measures.

Example : Bangalore has seen a **300% increase in EV fire incidents in 2023-24.**

The Solution

AI - Powered Thermal Runaway Early Warning System (TREWS)

- **Predicts & prevents battery overheating** & **fire risks** using real-time analytics.
- **AI-driven thermal modelling** detects early failure patterns.
- **Smart charging optimisation** prevents excessive heat buildup.
- **Instant alerts via SMS, WhatsApp, Fleet Dashboards** for preemptive action.
- **Cybersecurity integration** to prevent data tampering & enhance safety.

Vision Statement

"To revolutionise EV Battery safety with AI-powered predictive technology, ensuring a fire-free, secure, and sustainable electric mobility future."

Mission Statement

"We are building AI-driven early warning systems that predict and prevent EV Battery Thermal runaway, ensuring a fire-free and secure electric mobility future.

Our solution reduces risks, enhances battery longevity, and provides real-time safety insights for fleet operators, service centers, and manufacturers—creating a scalable, high-impact business model in the growing EV industry."

Core Values

- **Innovation** – We push boundaries in AI and predictive analytics to enhance EV safety.
- **Quality** – Delivering accurate, reliable, and high-performance safety solutions.
- **Safety & Security** – Protecting lives and assets by preventing battery failures before they happen.
- **Customer-Centricity** – Focused on solving real-world EV battery safety challenges for fleet operators, service centers, and manufacturers.
- **Team Empowerment** – Fostering a culture of excellence, collaboration, and continuous learning.
- **Sustainability** – Promoting a cleaner, greener future by improving EV battery efficiency and longevity.

Market Opportunity

EV Market Growth in India (2024-2030):

- **4M+ EVs on Indian roads by 2025** → Rising demand for predictive safety solutions.
- **$2B+ TAM** in EV battery analytics & predictive safety by 2027
- **EV Two-Wheeler Market CAGR 49%** → 90% of growth from fleet & delivery startups.
- **Battery Fire Incidents Increased by 300% (2023-24)** → Regulatory compliance & safety demands.
- **Total Addressable Market** : $2B+ EV Battery Analytics Industry by 2027.

Primary Target

- **Bangalore's EV Battery Service Centers & Fleets** → Rapid Expansion to Other Cities.

Target Customers & Business Model

Target Customers

- **EV Battery Service Centres** – Main focus for early adoption & pilot testing.
- **Fleet Operators** – Require predictive battery health insights.
- **Battery Swapping Networks** – Need real-time monitoring for multiple batteries.
- **EV OEMs & Dealerships** – Long-term partnerships for factory-level integration.

Business Model

- **Service Center Subscription** : ₹2,999 - ₹9,999 per month (for battery analytics & fire prevention insights)
- **Add-on Services for EV Owners** (via Service Centres) : Freemium model (basic free, premium ₹499/year)
- **API Licensing for EV OEMs & Battery Swapping Companies.**

Goal

- **Secure 3-5 pilot customers in Bangalore → Scale Nationwide.**

Competitive Landscape

Competitor	Solution	Weakness
Ola Electric	Internal battery monitoring	No AI-based thermal runaway prediction
Ather Energy	BMS safety system	No external predictive analytics
ION Energy	AI analytics for OEMs	Not available for individual EV owners
Log9 Materials	Battery R&D & safety focus	No real-time user alerts
EV Doctor	AI-powered battery diagnostics & monitoring	Primarily targets service centres; limited end-user focus
Our Solution	AI-powered real-time battery fire prevention system	First with proactive early warning & smart alert system
	Key Differentiators : Predictive AI | Smart Alerts | Cybersecurity | Scalable SaaS.	

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Roadmap & Execution Plan

Short-Term (0-1 Year):

- Secure partnerships with 3+ major battery service centers in Bangalore for pilot testing.
- Deploy AI-based predictive analytics as a service for EV battery inspections.
- Collect real-world data & refine AI model accuracy.

Medium-Term (1-3 Years):

- Scale to 50+ service centers across major Indian cities.
- Expand to battery swapping companies & fleet operators.
- Integrate with OEMs for factory-level safety compliance.

Long-Term (3-5 Years):

- Become India's #1 AI-driven EV battery safety platform.
- Expand beyond 2-wheelers to 4-wheelers & public transport.
- Standardise AI-driven battery diagnostics across all EV service centers

Risk Management

- **Dependence on Data Availability** – AI accuracy depends on access to high-quality battery telemetry data from service centers & fleets.
- **Service Center Adoption Barrier** – Some traditional service centers may resist adopting AI-based predictive solutions due to a lack of familiarity.
- **Integration with Existing BMS Systems** – Many EVs have built-in BMS; we need to demonstrate the added value of our AI analytics.
- **Cybersecurity Risks** – Handling critical battery safety data makes the system a potential target for hacking or tampering.
- **Real-Time Processing Costs** – Running AI-driven analytics at scale requires cloud infrastructure, balancing costs while keeping subscriptions affordable.

Mitigation Strategies

- Partner with **leading fleet operators & service centers** to improve data collection.
- Provide **training & easy-to-use interfaces** for service centers.
- Highlight **differentiation from BMS** by offering **early risk detection & alerts.**
- Implement **strong encryption & cybersecurity protocols** to protect data.
- Optimise **cloud-based architecture** to balance cost efficiency & performance.

Investment & Funding Requirements

- Develop & test AI models with real-world data
- Build the web platform & API integrations.
- Launch pilot programs with fleet operators & service centers.
- Scale cybersecurity & cloud infrastructure.

Potential Investors & Grants

- Micelio Fund, Blume Ventures, Indian Angel Network.
- Government Grants: FAME India, Startup India, NITI Aayog.
- Corporate Collaborations: EV battery makers, fleet operators, OEMs.

Goal

- Secure first funding → Build MVP → Achieve Product-Market Fit → Scale Nationwide.

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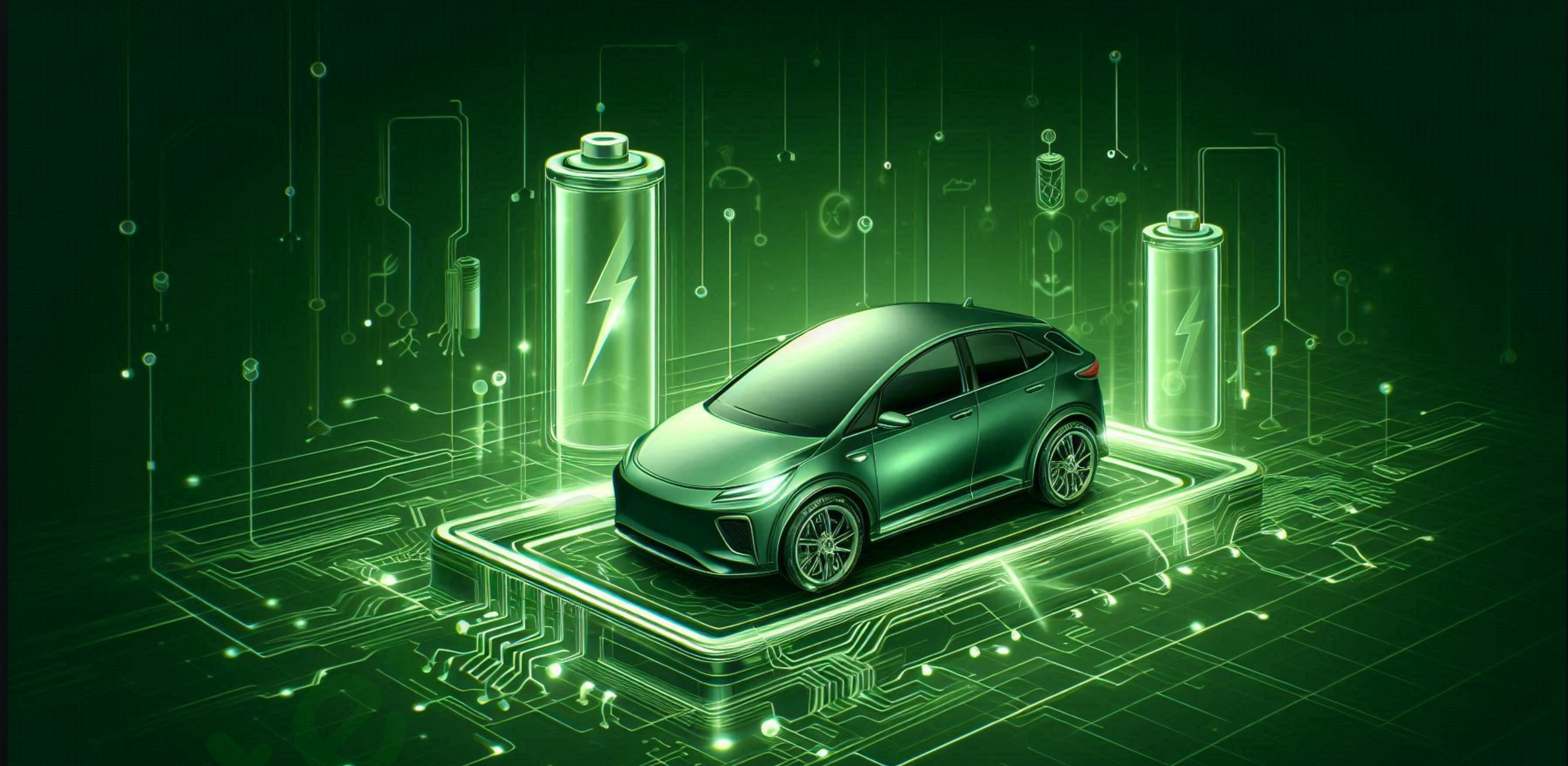

Join Us in Creating a Fire-Free EV Future!

Looking for Strategic Partners, Pilot Customers & Investors.

Thank you

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