

# Project Progress Report: Ensemble Deep Learning for Real-Time Adventure Insurance Fraud Detection Using AWS SageMaker

**Date:** December 24, 2025

**Project Title:** Ensemble Deep Learning for Real-Time Adventure Insurance Fraud Detection Using AWS SageMaker

**Status:** In Progress (Core Models Validated; Integration Pending)

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## 1. Executive Summary

This report details the strategic development and implementation status of a real-time multimodal fraud detection system. Addressing a global fraud crisis projected to exceed **\$80 billion annually by 2025**, this initiative focuses on the unique vulnerabilities of adventure sports insurance. The project utilizes a stacking ensemble of deep learning models to process unstructured narratives, visual evidence, and telemetry data within a **<100ms** inference constraint.

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## 2. Problem Statement & Objectives

### 2.1 The Adventure Insurance Crisis

- **Verification Gap:** Unlike urban accidents, adventure sports incidents (e.g., paragliding crashes or remote trekking evacuations) often lack independent witnesses, forcing insurers to rely on claimant-provided digital evidence.
- **Multimodal Complexity:** Fraud detection requires cross-verifying disparate data streams, including high-value equipment photos, GPS logs, and narrative descriptions.
- **Operational Burden:** Manual audits currently increase processing times by up to **20%**.

## 2.2 Core Objectives

- **Maximize Recall:** Achieve a **>95% detection rate** for "hard fraud" fabrication.
- **Real-Time Processing:** Maintain a system latency of under 100 milliseconds to enable mobile-first claim processing.
- **Regulatory Compliance:** Adhere to **IRDAI 2025 guidelines** by ensuring "Understandable by Design" AI explainability.

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## 3. Current Progress Status

As of late December 2025, significant progress has been achieved in developing the foundational unimodal models.

### 3.1 Completed Milestones (Base Layer Models)

The following four deep learning architectures have been successfully developed and validated individually:

Modality	Model Architecture	Function
Visual	ResNet50	Processes incident images to detect injury patterns and equipment damage.
Textual	DistilBERT	Performs sentiment and deception analysis on claimant narratives.
Telemetry	Bi-LSTM	Analyzes time-series data (GPS/IGC logs) for physical inconsistencies.
Tabular	TabNet	Assesses structured risk

		factors like policy history and premium patterns.
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### 3.2 Methodology & Data Engineering

- **Synthetic Data Generation:** Due to the scarcity of genuine fraud data, high-fidelity synthetic datasets were generated using **Stable Diffusion** for medical imagery, **StyleGAN2-ADA** for equipment damage, and **LLMs (GPT-4)** for narrative synthesis.
- **IGC Validation:** Logic has been integrated to verify **G-Record** security signatures in paragliding flight logs to prevent manual file manipulation.

## 4. Preliminary Results

The prototype multimodal ensemble has been tested on synthetic validation sets:

- **Recall: 0.96 (96%)** — Successfully detects the vast majority of fraudulent cases.
- **Precision: 0.88 (88%)** — Minimizes investigation fatigue for human adjusters.
- **Latency: 92ms** — Currently meets the real-time processing window through quantization and optimized inference pipelines.

## 5. Pending Tasks & Immediate Next Steps

The following critical components are currently under development:

### 5.1 Meta-Learner Integration

The final fusion layer, a Bayesian-Optimized XGBoost classifier, is pending. This component will fuse the 2,988 dimensions of embeddings from the base models into a single fraud probability score. The planned fusion vector follows the structure:

`V_final = [E_visual, E_text, E_telemetry, E_tabular]`

## 5.2 AWS Cloud Deployment

The full **Cloud Native Deployment** architecture is currently being set up, including:

- **Amazon Kinesis:** Real-time data ingestion and streaming.
- **SageMaker Inference Pipelines:** Orchestrating the chain of pre-processing and model containers.
- **Explainability (XAI):** Integration of **SHAP** to provide claims adjusters with local interpretability plots for every rejected claim.

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## 6. Strategic Roadmap & Future Goals

- **Federated Learning:** Transitioning to a privacy-preserving ecosystem using the **Flower framework** to allow collaborative training across multiple insurers without sharing raw claimant data.
- **Adversarial Robustness:** Developing training techniques to harden the model against AI-generated fraud evasions.