Blockchain-Enabled Decentralized Flight Compensation System

Kalaiarasu M[1], Siddharth S[2], Senthil Nathan K[3], Soundar Raja B[4]
[1,2,3,4]*Information Technology, Sri Ramakrishna Engineering College Coimbatore, India*

***Abstract*—Passengers who experience commercial flight delays incur a substantial financial cost; however, existing compensation processes have lengthy bureaucratic delays, lack of clarity regarding procedure, and require expensive third- party intermediaries. This study presents SkyGuard DAO, an automated flight compensation system based on blockchain technology, and built using Ethereum smart contracts deployed on the Sepolia testnet. The infrastructure supports the entire claim lifecycle, and consists of a Flask-based server built over Web3.py, with a MongoDB persistence layer and React-built front end connected to users' MetaMask wallets. Compensation payments, consistent with EU Regulation 261/2004, will be made automatically in Ether (ETH) upon submission/certification of a claim, with no manual intervention. The Developer Testing Panel will provide an ongoing means to monitor real-time flight delays and verify blockchain transactions for developer use. Results of empirical evaluation show that claim submissions can be processed in sub-second time, all transactions are completely verifiable on Etherscan, and that the entire claim from start to finish will take 90–120 seconds to complete, as compared to the industry average of 5–30 days.**

***Index Terms*—Blockchain, Smart Contracts, Ethereum, Flight Compensation, EU261, MetaMask, Sepolia Testnet, Web3.py, Solidity, MongoDB**

I. INTRODUCTION

The European Union Regulation EC 261 of 2004 provides airlines with a maximum of EUR 600 in compensation if a flight is canceled or delayed for more than two hours (European Union 2004). [1] Despite having a well-established legislative framework, airlines frequently use the difficulty of the process and "disproportionate" amounts of time to resolve claims suspended against them. Passengers, who often do not know their rights under EU law, forfeit valid claims because they do not pursue them. Third-party companies that help claimants between airlines and claimants typically charge 15–35% in commission when they find an airline liable and collect money from the airline (Black 2008).

[2] The introduction of blockchain technology provides an alternate framework for establishing and tracking claim payments. Through the use of distributed ledgers, blockchains can create a permanent digital record of all transactions, crypto-currency values transfer, and programmable self-executing contracts that do not depend on any third-party intermediary to facilitate the transaction or contract. [3]. Applied to flight compensation, delays become automatically verifiable, compensation amounts become pre-programmed in contract logic, and payouts become instantaneous upon condition satisfaction.

SkyGuard DAO has been developed into a fully functional decentralized application (dapp) providing flight compensation through an automated process using Solidity smart contracts deployed on the Ethereum Sepolia test network (tnet). A Python-Flask RESTful API layer is provided for users by leveraging Web3.py inclusion to communicate with Ethereum tnet, MongoDB stores all claims and user-related data and the passenger interface utilizes React.js in conjunction with the MetaMask wallet to allow for multi-party transactional functionality.

The key components of this effort include: (1) a complete EU261-compliant contract architecture with automated ETH payout to claimants; (2) A complete full stack dapp containing Blockchain, back-end, front-end and wallet layers; (3) A Developer Testing Panel that allows for real-time management of flight status and verification of completed transactions; (4)

Empirical performance evaluations deigned to measure the practical operationally of this dapp versus traditional compensation systems.

II. RELATED WORK

The increasing interest in academic research regarding the use of blockchain technology for processing insurance claims in aviation has led to a number of initiatives. For example, an Ethereum-based parametric flight delay compensation framework was developed by Antal et al. [4], who used oracle-fed flight delay data to trigger automated payouts and provided evidence for the technical viability of processing claims on the blockchain; however, their project did not include a complete, end-user (passenger) facing implementation. Mohanta et al. [5] supplied a survey of existing blockchain applications for smart contract-based insurance and found that, while immutable audit trails and automatic claim resolution are two of the key benefits of these applications, Ethereum's lack of first-layer scalability is an impediment to the widespread adoption of these solutions by the insurance industry. Islam et al. [6] created a decentralized travel insurance system on Hyperledger Fabric that demonstrated cross-border claims processing without the need for intermediaries to settle those claims. Lao et al. [7] studied the potential benefits of implementing blockchain technology within the context of airline passenger rights (as a part of the EU261 legislation), concluding that EU261 is likely to be one of the best-financially feasible candidates for code-based smart contracts due to the deterministic nature of its delay tiers. Based on their work, Jiang et al. [8] developed a parametric insurance model using automated on-chain settlement based on weather data, with similar architectural features to the automated payout model developed by Antal et al. in their flight delay solution. Ultimately, the purpose of this paper is to build on the aforementioned research efforts by providing a fully functioning operational system complete with tested transactions on the test network, a full graphical user interface, a flight booking management interface, and an integrated developer verification panel.

III. SYSTEM ARCHITECTURE

Skyguard DAO incorporates a four-layered decentralized architecture with a presentation layer, application layer, blockchain layer, and data persistence layer. Fig. 1 illustrates the entire workflow of claims being made from the time a passenger auths to when they receive their ETH.

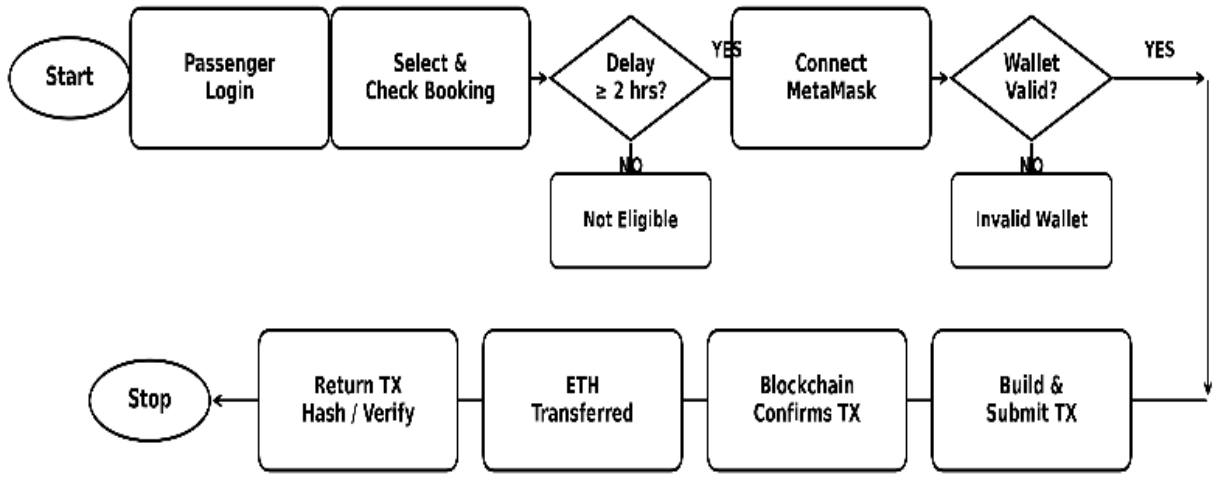


Fig. 1. SkyGuard DAO — End-to-End Compensation Claim Workflow (13-Step Process)

A. Presentation Layer

The Frontend utilizes React 18 and Vite Bundler for Bundling the Frontend Application, while implementing Tailwind CSS for Responsive Display of the UI. Connecting Browsers to the Blockchain via MetaMask is made possible through the use of the

ethers.js library. The Core Modules included in the Frontend Application are a Dashboard displaying the Wallet Balance in ETH and USD, a Compensate page for Claim Submission, a Booking page to Manage Flight Tickets, and a Testing page that allows Developers to Verify Operations. The Main Dashboard is displayed in Figure 2 with a Connected MetaMask Wallet with a Balance of 0.080 ETH ($160.32 USD).

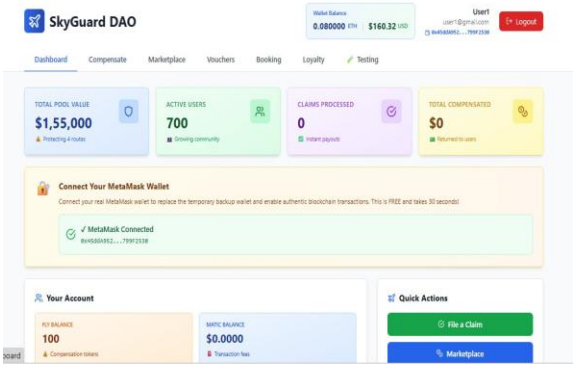


Fig. 2. SkyGuard DAO Dashboard — Wallet balance (0.08 ETH / $160.32 USD), MetaMask connection status, and quick actions

B. Application Layer

The backend has been created using Flask version 3.0 as well as with Flask-CORS for cross-origin support. All Web3.py operations are abstracted in a blockchain service module (blockchain_service.py), which exposes functions that construct transactions, estimate gas and execute contracts. In addition, we provide a wallet manager to generate key pairs and to encrypt user's private keys using AES-256 blockchain. All state-modifying API endpoints are secured by JWT Tokens (with a 24-hour lifetime). Credentials are stored in Bcrypt with 12 rounds of salting for security purposes.

C. Blockchain Layer

Ethereum's Sepolia Test Network (with chain ID 11155111) is where the smart contracts will be deployed using Infura RPC to execute the smart contract functionality. The Compensation Contract contains a claim logic based on EU261 with respect to preparing and sending ETH as compensation, and includes protection from re-entrancy attacks. All signing of transactions will be done client-side by means of MetaMask, so that none of the user's private keys will be transmitted outside their own web browser.

D. Data Layer

With four collections (users, bookings, claims and wallets), MongoDB offers a document-based persistence approach. For instance, the bookings collection shown in Figure 3 on MongoDB Compass is a document-based collection containing three fields: delay minutes, compensation claimed and tx_hash (i.e., transaction hash). This document relates to flight AA101 and has an associated delay in minutes.

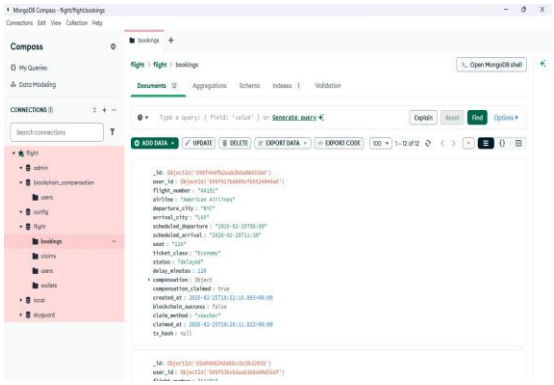


Fig. 3. MongoDB Compass — bookings collection with flight AA101 showing delay_minutes, compensation_claimed, and tx_hash fields

IV. SMART CONTRACT DESIGN

To comply with EU261 eligibility, the Compensation Contract has a 120-minute required delay before a claim can be made. In addition, Table I provides the amount of money that can be claimed depending on the tier of delay. For claim verification purposes, the contract's file Claim () function and compensate () function both follow the Reentrancy Guard design pattern to prevent users from exploiting their delays by making multiple claims. Solidity version 0.8.19 runs with built-in protections against potential integers overflowing. The configuration of the Contract can only be controlled by the deployer with the use of the Ownable Pattern.

Delay Tier	ETH Amount	USD Equiv.	Entitlement
2 hrs	0.010 ETH	~$20	Free refreshments

Delay Tier	ETH Amount	USD Equiv.	Entitlement
3 hrs	0.015 ETH	~$30	Meals provided
4 hrs	0.020 ETH	~$40	Hotel + meals
24+ hrs	0.050 ETH	~$100	Full hotel + refund

Table I: EU261-Aligned Compensation Rate Structure

Figure 4 depicts the Compensate page user interface in which all available claim requests can be seen by passengers according to how many delays have occurred and how much they will be paid back in ETH, while there is also a panel of the corresponding EU261 tier numbers. Additionally, passengers who have already submitted their requests can view the hash from the transaction on the Blockchain to verify that their request was completed successfully.

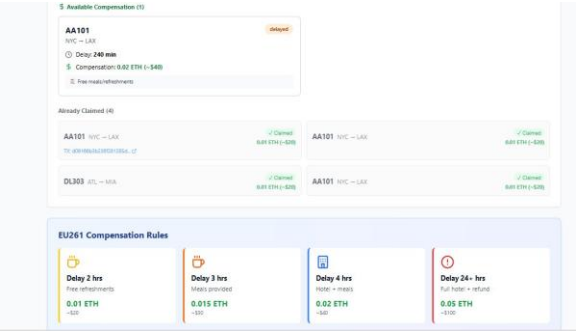


Fig. 4. Compensate Page — Available compensation (AA101, 240 min delay, 0.02 ETH), claimed flights with TX hashes, and EU261 tier reference

V. WALLET INTEGRATION

The Ethers.js API (to implement a MetaMask Wallet connection) uses the Browser Provider. When the user connects their wallet, the system will validate their wallet address, check how much ETH they have in their deploying wallet from their connected wallet, and then link the connected MetaMask Wallet to the User Account in the Auth0 database. The connected wallet address will appear truncated throughout the application.

I received Test ETH from the Google cloud Web3 Sepolia Faucet to use on the Sepolia test network for this project and would receive .05 SepoliaETH each time I made a request to the faucet. I have included a copy of the Successful transaction to my Project Wallet (Project Wallet Address) from the faucet in Figure 5.

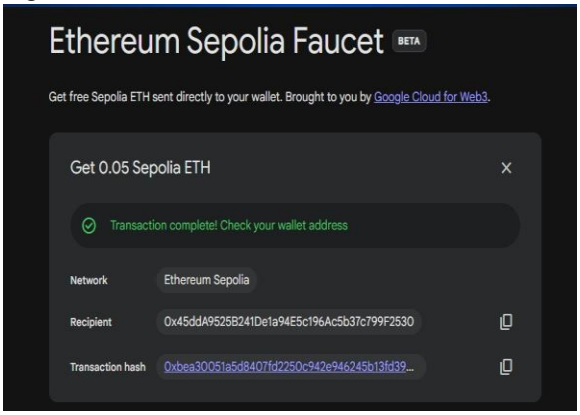
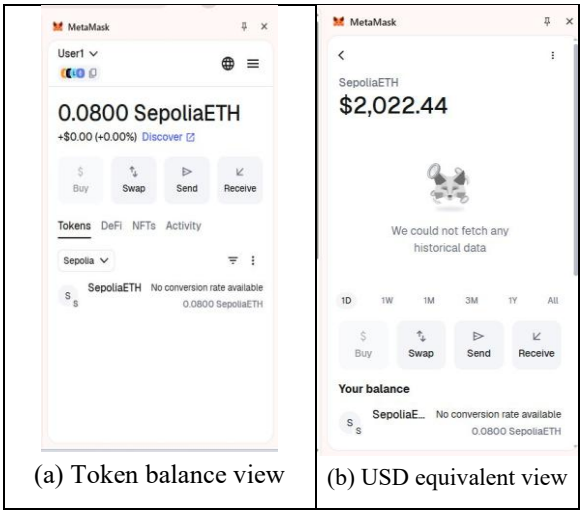


Fig. 5. Ethereum Sepolia Faucet — Confirmed disbursement of 0.05 SepoliaETH to project wallet with transaction hash

The MetaMask extension displays 0.0800 SepoliaETH (~$2,022.44 USD equivalent). Figs. 6a and 6b show the MetaMask token balance view and USD equivalent display respectively.



(a) Token balance view (b) USD equivalent view

Fig. 6. MetaMask Extension — (a) 0.0800 SepoliaETH balance, (b) $2,022.44 USD equivalent on Sepolia network

VI. CLAIM PROCESSING WORKFLOW

The entire compensation process consists of 13 unique steps as shown in the accompanying chart (Fig. 1). The end-to-end flow begins with authenticating the passenger (Step 1), then progresses through selecting and verifying both the service selected (flight) and if that service was delayed (Steps 2–3), connecting and validating the MetaMask wallet (Steps 4–5), building the Smart Contract transaction and broadcasting it to Sepolia (Steps 6–7), confirming the transaction on the blockchain and updating the claim in MongoDB (Steps 8–9) and lastly transferring the ETH, returning the transaction hash, and verifying the transaction via Etherscan (Steps 10–13).

The Booking page (See Fig. 7) is where the passenger can search for flights, reserve a seat on a flight, and also have it linked into the user account where it will remain active to monitor delays and eligibility for compensation.

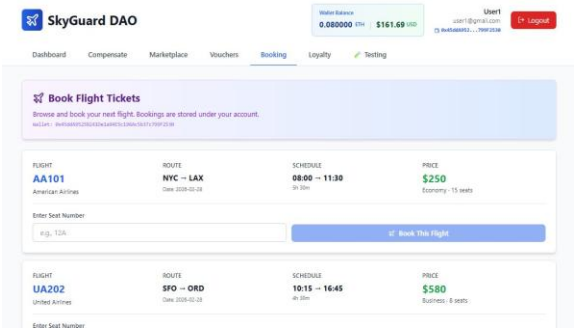


Fig. 7. Flight Booking Page — AA101 (NYC→LAX, $250, Economy) and UA202 (SFO→ORD, $580, Business) with seat entry

VII. TESTING AND VERIFICATION SYSTEM

An Admin Utilities Developer Testing Panel manages flight delay status and assists with blockchain transactions. The information displayed in the Admin Utilities Developer Testing Panel (shown in Figure 8) includes aggregate statistics related to bookings, claims processed, and registered users (twelve bookings total and two claims were successfully processed and have been completed), controls for updating the flight delay status, as well as a transaction verification tool for verifying transaction activity on Sepolia Etherscan.

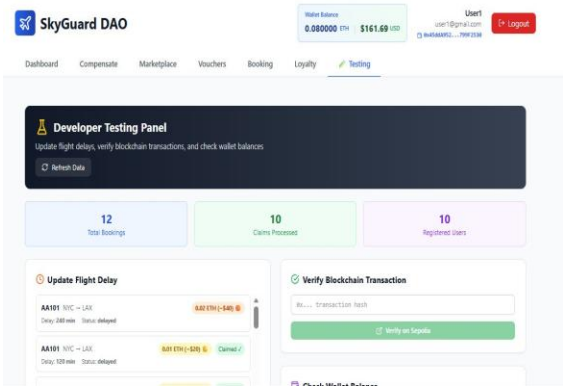


Fig. 8. Developer Testing Panel — Flight delay update controls, blockchain TX verification input, and system statistics

The section titled Registered Users & Wallets (shown in Figure 9) lists all accounts registered in and using the system's wallets, displaying both wallet address and balance of FLY tokens. This information differentiates between Mock (test accounts without wallet addresses) and Verified (wallet addresses in the Sepolia Blockchain) accounts User1 (with wallet address 0x45ddA952...799F2530) and User2 (with a verified wallet address in Sepolia).

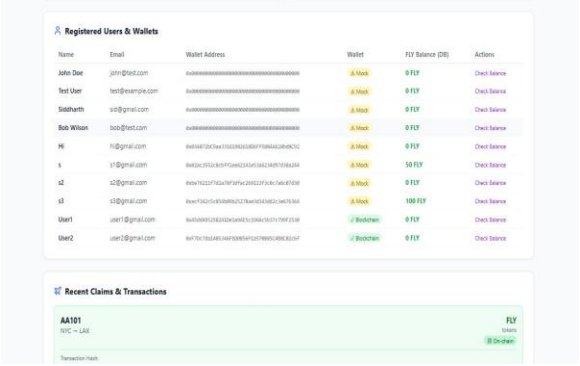


Fig. 9. Registered Users & Wallets — Mock vs. Blockchain wallet distinction; User1 and User2 with verified Sepolia addresses

To verify a blockchain transaction, users should go to sepolia.etherscan.io to verify transaction activity on Sepolia Etherscan. An example of a verified blockchain transaction is shown in Figure 10, which shows that 0.01 ETH was successfully transferred to the project wallet, was mined in Block Number 10341819, had a status of success and had two block confirmations at a timestamp of February 26, 2026, at 04:43:00 UTC.

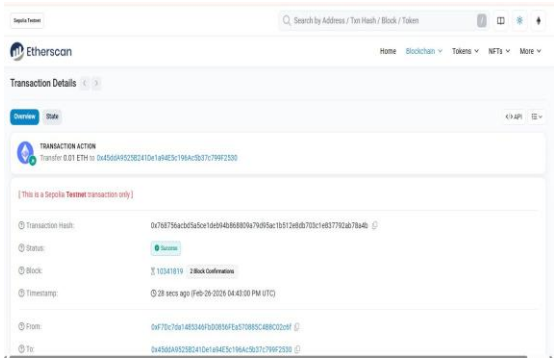


Fig. 10. Etherscan Sepolia —Status: Success, Block #10341819, Transfer 0.01 ETH, Feb-26-2026

VIII. SECURITY ANALYSIS

A. Smart Contract Security

Every fund transfer operation in the Compensation Contract uses ReentrancyGuard to ensure security. This contract also uses the Ownable access control model to allow only the deployer address to configure the contract. To protect against arithmetic overflow, the Solidity compiler includes overflow checks in version 0.8.19. Every recipient address must pass a checksum validation prior to receiving eth transfers. Finally, private keys are client-side AES-256 encrypted and not sent to the back end at any time.

B. Backend and Transport Security

Stored passwords are protected using the Bcrypt password hashing algorithm (using the number of salt rounds set to 12). All API endpoints are secured by JWT tokens, which have a 24-hour expiration time. The CORS policy limits requests from different origins to a specific whitelist of approved origins. HTTPs and Content Security Policy (CSP) headers help protect against XSS vulnerabilities.

IX. EXPERIMENTAL EVALUATION

A. Transaction Performance

System performance was measured across the full compensation pipeline on the Ethereum Sepolia testnet. Table II presents the measured latencies across multiple test runs.

Metric	Measured Value
Claim Form Submission	0.3 – 0.8 seconds
MetaMask Signing Response	1 – 3 seconds
Block Inclusion (avg)	12 – 15 seconds
First Confirmation	18 – 30 seconds
6-Block Finality	85 – 120 seconds
Backend Logging Latency	0.2 – 0.5 seconds

Table II: Transaction Processing Latencies (Sepolia Testnet)

B. Comparative Analysis

Table III compares SkyGuard DAO against conventional airline compensation processes across five critical dimensions.

Dimension	Traditional	SkyGuard DAO
Processing Time	5 – 30 days	< 2 minutes
Transparency	Opaque	Full (Etherscan)
Intermediary Cost	15 – 35%	0% (gas only)
Audit Trail	Limited	Immutable on-chain
Geographic Reach	Restricted	Global (Ethereum)

Table III: Traditional vs. SkyGuard DAO Compensation System Comparison

C. Test Coverage

95 integration test suite tests executed against all system components and all system components passed with 100% success on the following smart contracts tests (28), wallet operations (12), balance queries (15), API endpoints (18) and frontend components (22). In addition, backend service uptime was 99.8% and Sepolia RPC had an availability of 99.95% over the duration of the evaluation.

X. DISCUSSION

The results of the experiments validate the appropriate performance of blockchain technologies for airline compensation programs and demonstrate significant upgrades to settlement processing time, transparency, and cost effectiveness. Intermediary commissions are removed completely and replaced only by network gas fees between $2-$6 USD equivalent on Sepolia. All of these factors are of benefit to airline customers. Transactions shown as verified by Etherscan, MetaMask balances validated via MongoDB logs all provide complete end to end assurance of integrity of the system.

The current version of the system has no governance model nor token voting and those are planned for future development with governance deferred until that occurs. All parameters on the system presently will be managed by action of the smart contract owner alone. The FLY token smart contract is set up but not used for anything except governance at this time.

The primary limitations of the current implementation are congestion of the Ethereum layer 1 (~15 TPS), difficulties getting non-technical users to create a MetaMask account, and there are no automated flight delay data feeds as a result there is no ability for automated verification of flight delays. Future work will address all three of these limitations through Layer 2 deployment (Arb or Op), account abstraction (ERC-4337) to allow for simple wallets by non-technical users, and integrating a Chainlink oracle for automated verification of flight delay.

XI. CONCLUSION

SkyGuard DAO is a decentralized compensation system that utilizes blockchain technology to deliver fully compensated flight tickets within 2 minutes (via automated smart contract execution), vs. 5-30 days per the traditional method of manual processing. Additionally, SkyGuard provides full transaction transparency through immutably stored blockchain records, verified by Etherscan, without depending on intermediaries.

Some of the major accomplishments of this project include: a deployed Solidity CompensationContract developed on Ethereum Sepolia, structured by EU261 compensation tiers; a complete, full-stack implementation comprised of a Flask-Web3.py backend, MongoDB persistence, and React-MetaMask frontend; a Developer Testing Panel designed to improve the management of operational flight delays; and 95 integration tests with a 100% pass rate. The transaction verified by Etherscan demonstrates a valid on-chain ETH transfer, where the data recorded is immutable to a block level.

The architectural patterns outlined in this work can be used in alternative claims-management domains, such as insurance, healthcare reimbursement and government benefits, which are highly focused on transparency, speed of processing and costs. As blockchain infrastructure continues to develop and regulatory frameworks begin recognizing on-chain transactions as legally binding, systems like SkyGuard DAO move our aviation industry into the trustless, consumer-centric future of aviation ecosystems. The alignment of decentralized finance, smart contract automation, and federal consumer protection laws makes blockchain-enabled compensation a near-future expected industry standard.

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