AKUA: A Novel Approach to Prediction Markets for Risk Management

Technical Whitepaper

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Abstract

This whitepaper introduces AKUA, a novel approach to prediction markets focused on natural disaster risk management. By moving beyond both traditional insurance models and one-off, unstructured text based prediction markets to recurring, structured, domain-specific predictions, AKUA creates a new paradigm for risk management and knowledge monetization. The protocol begins by applying this thinking to a simple, but valuable and applicable problem domain: earthquakes. By beginning with this simple domain (an earthquake is just a magnitude latitude, longitude and timestamp), AKUA establishes a framework for expansion into other phenomena, creating an ecosystem where expertise directly translates to economic value, while simultaneously providing an innovative solution for risk management.

Contents

1 Vision

AKUA's mission is to create an engine that monetizes humanity's ability to create useful models of the universe, while providing a novel approach to risk management. By leveraging prediction markets and the efficient market hypothesis, AKUA aims to transform how knowledge is valued, traded, and used to manage risk. The protocol serves as a bridge between human understanding and market mechanics, creating a comprehensive ecosystem for both knowledge monetization and risk mitigation.

At its core, AKUA runs on raw event data which users convert into quantifiable market predictions. By creating a market for these predictions, according to efficient market hypothesis, AKUA will be a global dashboard that represents humanity's aggregate understanding of any phenomena for which there is a market available. Through carefully designed incentive structures, the protocol encourages better prediction and understanding of the world around us, while simultaneously providing innovative tools for risk management. This market-driven approach enables the discovery of patterns in measurable event streams, creating an environment where knowledge creators (those who create useful models of the universe) can directly monetize their insights and expertise, and where individuals and organizations can effectively manage their exposure to associated risks.

Success for AKUA is measured by the slope of the curve of knowledge creation, in effect pulling the future closer to the present.

2 Problem: The Limitations of Current Prediction Markets

Prediction markets (even within any given protocol such as Polymarket) suffer from dispersed liquidity. Each "market" (e.g. "Will Trump be re-elected?") exists in isolation, preventing the natural formation of deep, efficient markets. Similar predictions become fragmented across different formats and protocols, leading to thin markets where price discovery is impaired. This liquidity dispersion significantly impacts market efficiency and reduces the overall value of the prediction market ecosystem.

AKUA believes this is due to a fundamental design flaw: their one-off, unstructured, text-based approach to predictions. Each prediction pool is essentially a single event, represented by a string (programming speak for text) description and a set of oracles that validate the outcome. This design leads to several critical limitations that hamper market efficiency and expert participation.

The first major limitation is the lack of recurring structure in these markets. Traditional financial markets thrive on recurring meeting points where buyers and sellers can reliably connect and conduct transactions. Think of a local farmer's market, the value comes from buyers knowing that every Sunday, from 9A.M. to 2P.M., there will be a high quality source of local produce available, and sellers know there will be a crowd of buyers to purchase their goods. In that sense, current prediction markets can hardly be called markets, as they lack this essential reccurring property. This absence of structure prevents the formation of efficient, repeatable market patterns that are crucial for sustained trading activity.

Subject matter experts face significant barriers to participation due to the high friction inherent in cryptocurrency prediction markets: the hassle involved in making acquiring cryptocurrencies, creating a wallet and figuring out how to use the protocol cannot be justified for a single prediction. The inconsistent formats (each prediction is just a question phrased in English) and unique parameters (each prediction has its own parameters, making it difficult to apply expertise systematically) of each prediction require constant relearning and re-evaluation, making it difficult for experts to apply their knowledge systematically. This lack of standardization effectively lowers the value of the market by not capturing these valuable participants. Small differences in prediction formats require reformulating models to fit the new prediction, which is a waste of time and resources.

3 Solution: Recurring, Structured Prediction Markets

AKUA addresses these limitations by creating recurring, structured, domain-specific prediction markets. This innovative approach brings several key advantages that fundamentally transform how prediction markets operate by allowing a model (whether that be an individual's understanding or a computational model) to be re-applied to the same prediction over and over again. The daily volume of predictions in any given market provides some assurance to overcome the frictions of cryptocurrency adoption, and incentivizes participants with such models to use the recurring structure of the market to apply their models in a systematic manner.

AKUA's focused domain strategy ensures that each market type ("Where will the largest earthquake be in the next 24 hours?", "Where will the next 4.0 or greater earthquake occur?") has a specific, well-defined structure that serves its unique requirements, and crucially to market participants, that structure is consistent and repeats. Beginning with earthquake predictions provides an ideal proof of concept, this natural phenomena offers clean, verifiable data that can be consistently measured and validated by multiple independent sources. The repeating nature of the market allows participants (and potential participants) to apply their understanding of the domain with a better idea of what the market volume is both now, and what it will be in the future.

The protocol establishes recurring markets that create familiar and efficient trading environments. By implementing standardized prediction formats (asking the same question over and over again) and regular market cycles, AKUA enables strategic planning and systematic trading approaches. AKUA's consistent market structure builds trust among participants, while predictable daily volume encourages potential participants with "alpha" (better than average models/understanding) to apply their knowledge to the market, improving overall market efficiency and price discovery.

The expert-friendly design (the same question is asked every day, with the same format, and the same parameters) of the protocol enables domain experts to fully leverage their knowledge and capabilities in an automated manner. Subject matter experts who have state of the art predictive models can monetize their predictions in two ways:

- Becoming proprietary trading firms that can make predictions using their own capital
- Licensing their models to other participants in the market

In both cases, experts can develop systematic trading strategies based on familiar data structures, significantly reducing the cognitive overhead typically associated with prediction markets. The standardized formats AKUA employs enable automation and allow expertise to be consistently applied across multiple predictions, maximizing the value of specialized knowledge.

4 Why Earthquakes? (and Ethics)

4.1 Technical Simplicity

Earthquakes represent an ideal starting point for AKUA's structured prediction markets due to their inherent simplicity in validation and scoring. An earthquake can be fully described by a single point in space-time: latitude, longitude, depth, and timestamp. This simplicity stands in stark contrast to other natural phenomena:

- **Hurricanes**: Require tracking a vector field of intensities along a trajectory path, with varying wind speeds and pressure gradients at each point
- **Floods**: Need continuous monitoring of water levels across multiple geographic points and time periods
- **Wildfires**: Involve complex boundaries that change over time, with varying intensities and multiple fronts

This simplicity in scoring is crucial for market efficiency. When participants know exactly how their predictions will be evaluated, they can focus on improving their models rather than dealing with scoring ambiguities.

4.2 From Simple to Complex: A Proven Approach

Building on this technical simplicity, AKUA's approach follows a proven model of strategic incrementalism, similar to Tesla's journey in revolutionizing the automotive industry. Tesla's initial vehicle, the Roadster, provides an instructive parallel:

- **Simplified First Problem**: Tesla began with "glider" Lotus Elise chassis (cars without engines or fuel tanks), focusing solely on electric powertrain and energy storage rather than full vehicle engineering. Similarly, AKUA starts with earthquakes - a phenomenon that can be fully described by a single point in space-time, rather than tackling more complex natural phenomena immediately.
- **Product Market Fit**: The Roadster, as a two-seat convertible, represented a high-margin, low-volume product well-suited to an emerging technology. Similarly, earthquake prediction markets offer a focused, manageable starting point with clear validation criteria to find Product Market Fit.
- **Staged Evolution**: Tesla's progression from Roadster (high margin, very low volume) to Model S (high margin, higher volume) to Model 3 (medium margin, high volume) provides a blueprint for AKUA's expansion:
  - **Phase 1/Launch**: Single Earthquake prediction market ("Where will the largest earthquake be tomorrow?")
  - **Phase 2**: Earthquake prediction with additional parameters/alternative formulations (e.g.,"Where will the next 4.0 or larger earthquake occur?")
  - **Phase 3**: Weather events with simple geometries (e.g., temperature predictions)
  - **Phase 4**: Complex phenomena (e.g., hurricane paths with intensity fields)

This strategic sequencing ensures that each step:

- Generates sustainable revenue
- Develops necessary infrastructure
- Builds upon proven capabilities
- Creates market confidence

The key insight is that having a lofty end goal (Tesla: sustainable transport; AKUA: knowledge monetization and universal risk markets) is insufficient - success requires carefully sequencing each step to build from the current position toward that eventual goal. Each phase must be both ambitious enough to matter and modest enough to achieve.

4.3 Ethical Considerations

A common ethical concern raised about earthquake prediction markets is the question: "How can you bet on events that cause human suffering?" This perspective, while understandable, misses several crucial points:

- **Inevitability**: Earthquakes will occur whether or not people predict them. The existence of a prediction market neither increases nor decreases their frequency or intensity.
- **Knowledge Aggregation**: A well-capitalized earthquake prediction market effectively creates a "model of models" - aggregating the sum of human knowledge about seismic activity. According to the efficient market hypothesis, the market price of predictions in any given location represents humanity's best estimate of seismic risk in that area.
- **Societal Benefit**: Better prediction capabilities, even by a matter of hours, can save lives by:
  - Enabling faster emergency response preparation
  - Creating economic incentives for the development of better prediction models
- **Risk Management**: The market enables individuals and organizations in earthquake-prone areas to hedge against seismic risks, providing a new tool for financial protection against natural disasters.

In essence, AKUA's earthquake prediction markets serve to incentivize the development and deployment of better prediction models while providing risk management tools. The protocol creates economic alignment between prediction accuracy and societal benefit - the better the predictions, the more lives and property can potentially be saved.

5 Economic Design & Incentives

5.1 Market Incentive Design

The protocol's incentive mechanism uses an exponential decay model that rewards accuracy while maintaining a zero-sum game between participants (minus protocol fees). The system separates winners from losers based on prediction accuracy, with rewards and penalties calculated using exponential functions.

All individual bets are standardized to a fixed size (e.g., 10 USDC) for gas efficiency and simplified calculations. When a user places a larger bet, it is automatically split into multiple standard-sized bets at the same prediction point. This standardization offers several advantages:

- **Gas Optimization**: Processing identical-sized bets is more gas-efficient
- **Simplified Calculations**: The reward mechanism processes all bets uniformly
- **Scalable Architecture**: Consistent bet sizes enable efficient smart contract execution

The core mechanics involve:

- **Threshold-Based Classification**: Using the median distance error to separate winners from losers
- **Exponential Scoring**: Both winners and losers receive exponentially scaled rewards/penalties based on their accuracy
- **Fair Distribution**: The pool of lost funds is distributed to winners proportionally to their accuracy scores
- **Zero-Sum Mechanics**: The system ensures that funds are redistributed among participants, maintaining a true zero-sum game (minus protocol fees)

Unlike traditional gambling or prediction markets that often rely on the allure of massive wins or "all or nothing" bets, AKUA's incentive curve is specifically designed to encourage sustained participation and iterative learning. This design is based on well-established psychological principles:

- **Learning-Oriented Feedback**: The median-based threshold creates a clear winner/loser distinction, with exponential penalty curves that increase in severity as predictions move away from the median. This creates a strong psychological incentive to be accurate.
- **Skill Development Incentive**: The exponential reward curve means that consistently achieving even slightly better-than-average predictions can lead to meaningful returns over time. This incentivizes participants to develop and refine their prediction strategies rather than relying on luck.

This reward structure creates a "try again" effect where participants are encouraged to make another prediction and apply learnings from previous rounds. This contrasts with traditional gambling's "one more try to win it all back" or "quit while ahead" dynamics that often lead to problematic behavior or permanent disengagement.

The full mathematical formulation of the incentive mechanism is provided in Appendix D for reference.

5.2 Protocol Fee Structure & Value Accrual

AKUA charges a protocol fee of 2% on all bets placed in the system. Unlike many protocols that direct fees primarily to passive investors or development teams, AKUA's fee structure is specifically designed to strengthen the protocol's infrastructure and create value for active participants.

Protocol fees are allocated to two primary purposes:

- **Oracle Data Provider Compensation (50%)**: The majority of fee revenue is directed to oracle data providers who submit and validate earthquake data. These providers stake AKUA tokens as collateral against accurate reporting and receive fee-based compensation proportional to their contribution to the consensus process.
- **Automated Token Buybacks (50%)**: The remaining fee revenue is used for programmatic token buybacks on decentralized exchanges (DEXs). Smart contracts automatically purchase AKUA tokens at market rates and burn them, reducing total supply and creating buy pressure.

This dual-purpose fee model creates a virtuous cycle that benefits the ecosystem in multiple ways:

- **Value Accrual to Active Participants**: Fees flow primarily to those who actively contribute to the protocol's operation, particularly oracle data providers who secure the system.
- **Enhanced Security**: By rewarding oracle providers with fee revenue, the model encourages more robust oracle participation, increasing the security and reliability of the prediction markets.
- **Sustainable Economics**: The fee-based model creates sustainable, usage-based compensation that scales with protocol adoption, rather than relying solely on token inflation.
- **Aligned Incentives**: The buyback mechanism creates a direct link between protocol usage and token value, benefiting all stakeholders while maintaining economic sustainability.

This fee structure intentionally favors active participants who contribute to the protocol's security and operation, rather than passive holders. By becoming an oracle data provider and staking AKUA tokens, participants can earn a share of ongoing fee revenue, creating long-term alignment between active participation and economic rewards.

5.3 Tokenomics: Distribution and Acquisition

The AKUA token model is designed to maximize decentralization, reward active participation, and ensure sustainable long-term value accrual. The model consists of a carefully designed supply distribution and a unique acquisition mechanism that directly ties token distribution to protocol usage.

The total supply of AKUA tokens is fixed at 1 billion, with the following distribution:

Allocation	**Percentage**	**Purpose**
Team	10%	Core development and long-term alignment
Friends & Family Presale	5%	Initial development funding
Liquidity Provisioning	10%	DEX liquidity and price stability
Protocol Emissions	75%	Rewards for protocol participants

- **Team Allocation (10%)**: Intentionally minimal compared to industry standards, with a 2-year vesting schedule to ensure long-term alignment.
- **Friends & Family Presale (5%)**: A small allocation to fund initial development without relying on venture capital, subject to a 1-year vesting schedule.
- **Liquidity Provisioning (10%)**: Dedicated to ensuring sufficient trading depth and price stability on decentralized exchanges from day one.
- **Protocol Emissions (75%)**: The majority of the supply is reserved for protocol emissions, ensuring that tokens flow primarily to active participants rather than speculators.

AKUA takes a radically different approach to token distribution. Rather than conducting a traditional ICO, AKUA has designed a mechanism where users can intentionally place suboptimal bets (high-altitude predictions) to acquire tokens. This innovative approach converts "bad bets" into protocol incentives, creating a unique token distribution mechanism that aligns incentives from day one.

The "Bad Bet" token acquisition mechanism works as follows:

- Users signal token acquisition intent by placing high-altitude predictions (beyond 4*R)
- These predictions are guaranteed to lose, as valid earthquake locations are at most 2*R apart
- The lost funds increase the reward pool for accurate predictions
- In return, "bad bet" placers receive AKUA tokens based on the conversion rate

The conversion rate is designed to incentivize protocol participation:

- **Conversion Rate**: AKUA tokens are distributed at a 3-5% discount to the current DEX market price
- **Vesting Period**: Tokens acquired through "bad bets" are subject to a short vesting period (e.g. 30 days), to disincentivize immediate arbitrage
- **Automatic Adjustment**: The conversion rate adjusts based on market conditions to maintain sustainable distribution
- **Emission Schedule**: Token emissions follow a decay curve over a 4-year period

This model creates compelling incentives for participants to acquire tokens through protocol participation rather than market purchases, as the discount makes "bad bets" an attractive acquisition strategy despite the vesting period. The mechanism also ensures that token acquisition directly contributes to the protocol's core functionality by enhancing the reward pool for accurate predictions.

Disclaimer: The token distribution model and mechanisms described above reflect the current intent of the development team. All percentages, allocations, and mechanisms are subject to change until the actual commencement of any token distribution, based on various factors including regulatory requirements, technical considerations, and market conditions.

6 Technical Architecture

The AKUA protocol is built on a robust technical foundation that combines blockchain technology with modern web architecture. At its core, the protocol follows a precise, time-bound process for managing prediction pools, supported by carefully designed smart contracts, spatial data structures, and a modern frontend interface.

6.1 Process Flow

The protocol follows a precise, time-bound process for each prediction pool that ensures fairness, transparency, and efficient market operation:

1. **Pool Creation (00:00 UTC)**
   - New prediction pool automatically created for the next 24-hour period
   - Pool parameters initialized (pool ID, timestamp bounds, etc)
   - Smart contract validates pool creation and emits Pool Created event
2. **Betting Period (00:00–23:59 UTC)**
   - Users submit predictions with stakes in USDC
   - Each prediction includes latitude, longitude, and depth
   - Protocol fee (2%) collected on stake submission
   - High-altitude predictions (>4R) flagged for token distribution
3. **Waiting Period (24h)**
   - Pool enters locked state at 23:59 UTC
   - No new predictions accepted
   - 24-hour waiting period ensures all relevant seismic data is recorded
4. **Oracle Submission (24h after pool close)**
   - Oracle providers submit earthquake data
   - Each submission is an X, Y, Z Cartesian coordinate
   - Frontend assists by presenting USGS, EMSC, and other data feeds
   - Minimum number and amount of AKUA staked by submittersrequired for consensus
5. **Consensus Evaluation**
   - Smart contract evaluates oracle submissions for consensus
   - Submissions evaluated using weighted median approach in X, Y, Z
   - Oracle providers stake token, rewarded for being close to consensus, slashed based on distance from consensus
6. **Reward Calculation**
   - Distance calculated for each prediction using Cartesian coordinates
   - Median distance determined as winner/loser threshold

    - Exponential decay applied to normalized distances
    - High-altitude predictions processed for token distribution

7. **Reward Distribution**
    - Winners receive proportional share based on accuracy
    - Loser penalties calculated and distributed
    - Protocol fees transferred to Oracle Providers
    - AKUA Token distribution processed for high-altitude predictions

This structured process ensures:

- Predictable market cycles aligned with UTC time
- Fair oracle consensus through multiple providers
- Efficient reward distribution through batched processing
- Transparent token distribution via high-altitude predictions
- Gas-optimized operations at each stage

6.2 Smart Contract Architecture

The blockchain layer of AKUA implements several sophisticated design patterns to ensure security, efficiency, and upgradeability:

AKUA uses the Singleton Pattern (a design pattern where a class has only one instance and provides a global point of access to it) to manage its prediction market, providing a unified and gas-efficient approach to pool management. All prediction pools are managed within a single contract instance, using unique pool IDs for organization and access. This design choice offers several key advantages:

- **Lower Deployment Costs**: Only one contract needs to be deployed, significantly reducing gas costs compared to deploying individual pool contracts
- **Simpler State Management**: All pools are managed in a single contract, simplifying state tracking and updates
- **Easier Upgrades**: Single point of upgrade if needed, reducing complexity and potential security risks
- **Gas Efficiency**: Shared code and storage structures reduce redundancy and gas costs
- **Simplified Integration**: Frontend and other contracts only need to interact with a single contract address

Our Oracle System implements a robust staking mechanism with consensus calculation and slashing conditions. This design incorporates frontend-assisted presentation of independent data sources (USGS, EMEA, etc) assisting user-driven submissions while maintaining an automated validation processes. The system ensures reliable data feeds while protecting against manipulation through economic incentives.

The Governance module manages system parameters, protocol upgrades, and emergency procedures through a token-based voting system with carefully designed parameter bounds and upgrade controls. This ensures that the protocol can evolve while maintaining stability and security.

The core functionality of AKUA is implemented through carefully designed data structures and state management that ensure precise and efficient operation of the prediction markets:

- **Pool Management**: Unique pool IDs with timestamp-based lifecycle management
- **Prediction Storage**: Efficient mapping structures for user predictions and stakes
- **Participant Tracking**: Arrays and mappings optimized for gas-efficient access
- **Reward Distribution**: Batch processing capabilities for scalable reward calculations

6.3 Smart Contract Dependencies

The AKUA ecosystem consists of several interconnected smart contracts, each with specific responsibilities and dependencies. Understanding the relationships between these contracts is essential for comprehending the system's architecture and operational flow.

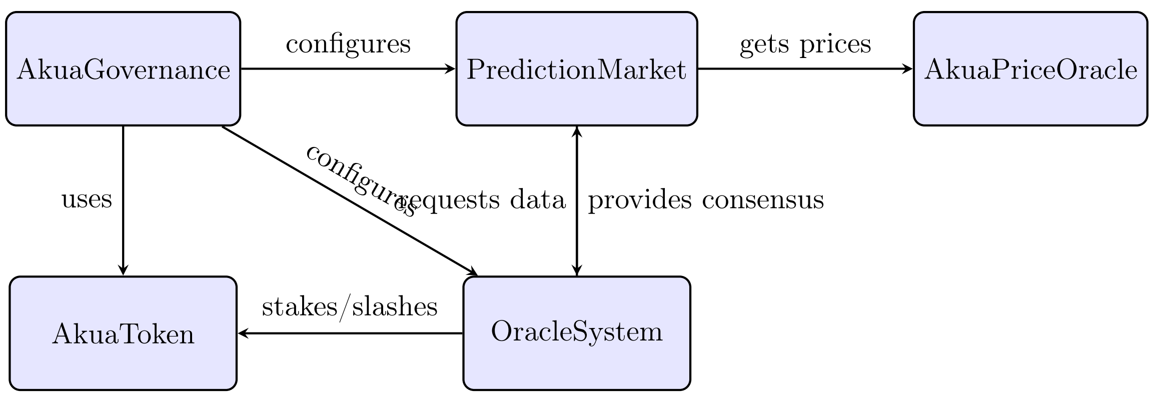

Figure 1: AKUA Smart Contract Dependencies

The contract interdependencies in the AKUA ecosystem are designed to provide clear separation of concerns while enabling secure communication between components:

- **AkuaGovernance**: Central control point of the protocol, manages the Oracle System and Prediction Market. It uses the AkuaToken for staking and voting mechanisms. This contract serves as the owner of other protocol contracts, enabling decentralized management over time.
- **AkuaToken**: Implements the protocol's native token as an ERC1155 token with supply tracking and pausable functionality. Used for governance voting, oracle staking, and protocol incentives. While it operates somewhat independently, key parameters can be adjusted through governance.
- **OracleSystem**: Manages oracle providers who submit earthquake data. Depends on the AkuaToken for staking and the Governance contract for provider eligibility verification. It interacts with the Prediction Market to verify earthquake data for resolving prediction pools.

- **PredictionMarket**: Core contract that manages all prediction pools. It depends on the Oracle System for verified earthquake data and the Price Oracle for token pricing during "bad bet" token acquisitions. Its parameters are controlled by the Governance contract.

- **AkuaPriceOracle**: Provides price information for the AKUA token, used by the Prediction Market for token distribution calculations. While shown as depending only on the Prediction Market, in a production environment it would integrate with external price sources.

Each contract exposes well-defined interfaces, ensuring that dependencies are clearly established and enabling modular upgrades as the protocol evolves. The system's design follows the principle of least privilege, with each contract having access only to the functionality it requires from its dependencies.

For security reasons, critical functions across all contracts implement appropriate access controls, with many functions restricted to the governance contract or the contract owner. This ensures that parameter changes and system upgrades follow the established governance process.

6.4 Spatial Data Structures

For earthquake predictions, AKUA implements precise spatial calculations using Cartesian coordinate systems, while user input is done in spherical coordinates. Spherical coordinates are used for human interface and data input, as they are more intuitive for most users:

- Latitude: -90° to 90°
- Longitude: -180° to 180°
- Depth/Altitude: measured in kilometers from surface

Cartesian coordinates are used for internal calculations, as they are more precise and easier to work with for the computer:

- X, Y, Z coordinates from Earth's center
- All measurements use 18 decimal fixed-point precision
- Automated conversion between coordinate systems

6.5 Frontend Architecture

The user interface is built with performance and usability in mind, leveraging modern web technologies:

- A 3D globe interface built with three.js provides intuitive geographical interaction
- Dedicated betting and oracle interfaces streamline user participation
- A comprehensive user dashboard provides portfolio and activity monitoring

State management is carefully designed to handle contract state, user state, and application state, with particular attention to real-time updates, transaction management, and error handling.

7 Risk Management and Insurance Innovation

7.1 Reimagining Insurance

Insurance represents one of the fundamental primitives of modern finance, traditionally structured as a bet against adverse events affecting the policyholder. However, traditional insurance faces significant challenges in blockchain implementation due to the costly and complex nature of claim verification. AKUA introduces a revolutionary refactoring of the insurance concept, streamlining the process while maintaining its essential function.

7.2 Refactoring the Insurance Stack

Traditional insurance follows a complex chain of events:

$$\text{disaster occurrence} \rightarrow \text{property damage} \rightarrow \text{financial impact} \rightarrow$$

$$\text{claim filing} \rightarrow \text{claim verification} \rightarrow \text{payout}$$

This process introduces multiple points of friction and verification challenges. AKUA refactors this stack by eliminating intermediary steps while preserving the core input-output relationship:

$$\text{event prediction} \rightarrow \text{event occurrence} \rightarrow \text{automatic payout}$$

This refactoring adheres to software engineering principles by maintaining the essential function of insurance (risk mitigation) while dramatically simplifying the implementation. The result is a system that provides the same fundamental value as traditional insurance but operates with the efficiency and transparency inherent to blockchain technology.

7.3 Dual-Purpose Protocol Design

AKUA's innovative approach recognizes the dual nature of its protocol:

- For risk-seeking participants ("degens"), the protocol functions as a sophisticated betting mechanism where knowledge and analysis can lead to profitable predictions
- For risk-averse participants, the same mechanism serves as an insurance substitute, where users can hedge against adverse events by placing predictions on their own location

This dual functionality creates a natural market balance, where risk-seeking and risk-averse participants contribute to market liquidity and price discovery. For example, a property owner can effectively insure against earthquake damage by placing predictions on seismic events in their area, creating a direct hedge against their physical risk exposure.

Our go-to-market strategy deliberately prioritizes the risk-seeking segment through a sophisticated yet playful 3D globe-based betting interface that appeals to "degens." While the underlying liquidity deployed in these betting pools will ultimately be accessible through multiple interfaces—including more traditional interfaces designed specifically for TradFi and insurance-seeking participants—AKUA recognizes that significant protocol liquidity is a prerequisite for meaningful TradFi engagement. Approaching TradFi participants without substantial liquidity would generate minimal interest, as these participants require deep, efficient markets to execute their risk management strategies. By first building deep liquidity pools through engagement with risk-seeking participants, AKUA creates the necessary foundation for broader market adoption and future TradFi integration.

7.4 TradFi Trojan Horse

AKUA's dual-purpose design makes it a natural fit for TradFi integration. By providing a transparent and efficient prediction market framework, AKUA can be used to create new insurance products and financial instruments that are not possible with traditional insurance models. Additionally, it is particularly well suited to providing a "pressure release valve" for traditional insurance products, allowing participants to hedge against adverse events which are difficult to predict and price, and pose a systemic risk to the global financial system. Insurance is one of the base primitives in the global financial system, and AKUA provides a new way to manage and price these risks while also providing access to distributed capital that lowers the chance of systemic cascading failures. AKUA intends to make TradFi players obsolete by providing them a service that they can not provide themselves, and at a fraction of the cost.

8 Future Directions

Mike Tyson famously said, "Everyone has a plan until they get punched in the face." This quote perfectly encapsulates AKUA's philosophy towards future development. AKUA explicitly rejects the common practice in blockchain projects of presenting detailed multi-year roadmaps, recognizing that such long-term planning often amounts to little more than wishful thinking. Markets are dynamic, technology evolves rapidly, and user needs shift in unexpected ways. Instead of pretending to predict the future with precision, this section outlines potential directions for AKUA's evolution. These are not promises or commitments, but rather a framework for understanding how the protocol could develop in response to real market demands and technological opportunities.

8.1 Expansion Strategy

While AKUA begins with earthquake predictions, AKUA's structured approach can be expanded to any event stream data that can be brought on chain. The protocol's architecture is designed to accommodate a diverse range of predictive markets, each built on the same principles of structured data and systematic validation.

In the realm of weather events, AKUA envisions markets for hurricane path and intensity predictions, comprehensive severe weather forecasting, and long-term climate pattern analysis. For solar activity, the protocol will support predictions of solar flares, space weather conditions, and geomagnetic storm anticipation. Volcanic activity presents another promising domain, encompassing eruption likelihood assessment, intensity predictions, and impact radius forecasting.

8.2 Selection Criteria

The expansion into new market types follows a rigorous evaluation framework based on three key criteria: data structure clarity, validation reliability, and market viability.

Data structure clarity is fundamental to AKUA's approach. AKUA requires well-defined parameters that can be precisely measured, along with standardized units and clear boundaries for all predictions. Each market must have objective outcome criteria and consistent measurement methodologies that enable reliable validation and comparison of predictions.

Validation reliability ensures the integrity of AKUA's markets. AKUA requires multiple independent data sources for each market type, supported by objective measurement systems and automated verification capabilities. Strong consensus mechanisms must be in place to resolve any discrepancies and maintain market trust.

Market viability is essential for sustainable growth. AKUA focuses on phenomena with regular, predictable events that generate sufficient expert and public interest. Each market must demonstrate clear economic impact and the potential for meaningful price discovery. This ensures that the markets AKUA creates serve a valuable purpose and can maintain active participation over time.

To prevent fragmentation of attention and liquidity, it is important to note that AKUA will not be a single market, but a protocol that can support multiple markets. Each market will have its own unique characteristics and requirements, and will be subject to the selection criteria - likely this will be achieved by a staking threshold of AKUA tokens to create a new market.

9 Conclusion

AKUA represents a fundamental shift in how prediction markets operate, moving from unstructured, text-based predictions to structured, domain-specific markets. By starting with earthquake predictions and establishing a clear framework for expansion, AKUA creates a protocol where expertise can be directly monetized and where market forces drive better understanding of natural phenomena. More importantly, by refactoring traditional insurance concepts into a streamlined prediction market framework, AKUA provides an innovative solution for risk management that eliminates the friction of traditional insurance while maintaining its essential function. This dual-purpose design creates a unique ecosystem where both knowledge monetization and risk management can thrive, supported by the efficiency and transparency of blockchain technology.

10 Appendix A: Regular Depth Predictions

This example demonstrates the regular depth prediction pool with 25 participants predicting an earthquake that occurred at (35.654°N, 139.841°E) at a depth of 31km.

The prediction pool demonstrates the protocol's reward mechanism across a diverse set of predictions. With 25 participants each staking 100 USDC, the total pool size is 2,500 USDC. The protocol fee of 2% (50.0 USDC) is charged in addition to each stake, meaning participants pay 102 USDC to place a 100 USDC stake, for a total user cost of 2,550 USDC.

Key statistics:

- **Median Distance**: 4,560.8 km (used as winner/loser threshold)
- **Winners**: 13 participants (closer than median)
- **Losers**: 12 participants (further than median)
- **Best Prediction**: 0.51 km error (Alice)
- **Best Reward**: 219.67 USDC (+120% return)

Predictor	Distance (km)	Norm. Dist.	Payout	Return	Status
Alice	0.51	0.000	219.67	+120%	Winner
Bob	890.16	0.195	161.05	+61%	Winner
Carol	1,166.80	0.256	149.52	+50%	Winner
David	1,399.89	0.307	141.52	+42%	Winner
Eve	1,781.72	0.391	131.10	+31%	Winner
Frank	2,629.66	0.577	116.37	+16%	Winner
Grace	2,741.85	0.601	115.04	+15%	Winner
Henry	2,892.13	0.634	113.43	+13%	Winner
Iris	3,063.96	0.672	111.79	+12%	Winner
Jack	3,662.89	0.803	107.49	+7%	Winner
Karen	4,001.20	0.877	105.80	+6%	Winner
Lucy	4,178.67	0.916	105.07	+5%	Winner
Mike	4,560.80	1.000	103.80	+4%	Winner
Nina	5,213.07	0.080	93.67	-6%	Loser
Oscar	5,654.52	0.134	92.55	-7%	Loser
Paul	6,489.38	0.237	89.87	-10%	Loser
Quinn	7,155.55	0.319	87.05	-13%	Loser
Rachel	7,396.46	0.348	85.85	-14%	Loser
Sam	7,737.51	0.390	83.95	-16%	Loser
Tom	8,790.07	0.519	76.35	-24%	Loser
Uma	8,920.61	0.535	75.18	-25%	Loser
Victor	9,693.35	0.630	67.01	-33%	Loser
Walter	9,801.16	0.644	65.67	-34%	Loser
Xavier	12,669.87	0.996	1.20	-99%	Loser
Yuki	12,702.64	1.000	0.00	-100%	Loser

The results demonstrate several key aspects of the protocol's reward mechanism:

- **Accuracy Rewards**: The most accurate prediction (Alice, 0.51 km error) received a +120% return

- **Median Threshold**: Predictions better than the median (4,560.80 km) received positive returns
- **Distance Penalty**: Returns decrease exponentially with distance from the actual location
- **Complete Losses**: The three worst predictions (Walter, Xavier, Yuki) lost their entire stake

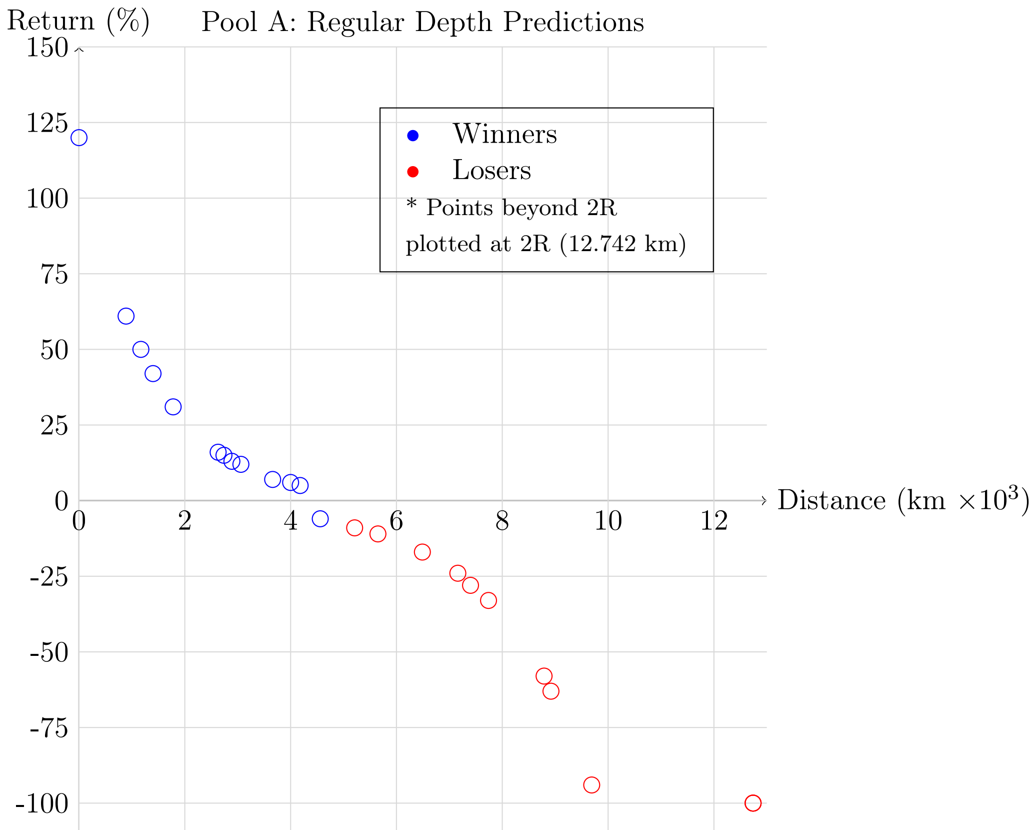

Figure 2: Distance-Reward relationship for Pool A. Blue points represent positive returns (winners), red points represent negative returns (losers). Points beyond 2R are clipped and marked with *.

11 Appendix B: High-Altitude Predictions

This example demonstrates the impact of high-altitude predictions on the reward distribution. The same earthquake location (35.654°N, 139.841°E, 31km depth) is used, but five participants (Uma through Yuki) make predictions at 18,000km altitude, effectively forfeiting their stakes to enhance rewards for accurate predictions in exchange for AKUA tokens.

The prediction pool maintains the same total size of 2,500 USDC (25 participants × 100 USDC stakes). The protocol fee of 2% (50.0 USDC) is charged in addition to each stake, meaning participants pay 102 USDC to place a 100 USDC stake, for a total user cost of 2,550 USDC. The presence of high-altitude predictions significantly impacts the reward distribution.

Key statistics:

- **Median Distance**: 4,560.8 km (used as winner/loser threshold)
- **Winners**: 10 participants (closer than median)
- **Regular Losers**: 7 participants (further than median, regular depth)
- **High-Altitude**: 5 participants (18,000km altitude)
- **Best Prediction**: 0.51 km error (Alice)
- **Best Reward**: 404.91 USDC (+305% return)

Predictor	Distance (km)	Norm. Dist.	Payout	Return	Status
Alice	0.51	0.000	404.91	+305%	Winner
Bob	890.16	0.232	236.86	+137%	Winner
Carol	1,166.80	0.304	206.68	+107%	Winner
David	1,399.89	0.365	186.49	+86%	Winner
Eve	1,781.72	0.465	161.33	+61%	Winner
Frank	2,629.66	0.686	128.58	+29%	Winner
Grace	2,741.85	0.715	125.83	+26%	Winner
Henry	2,892.13	0.755	122.56	+23%	Winner
Iris	3,063.96	0.800	119.33	+19%	Winner
Jack	3,662.89	0.956	111.27	+11%	Winner
Karen	4,001.20	0.034	94.48	-6%	Loser
Lucy	4,178.67	0.070	93.86	-6%	Loser
Mike	4,560.80	0.147	92.26	-8%	Loser
Nina	5,213.07	0.279	88.52	-11%	Loser
Oscar	5,654.52	0.368	85.00	-15%	Loser
Paul	6,489.38	0.536	75.14	-25%	Loser
Quinn	7,155.55	0.670	62.83	-37%	Loser
Rachel	7,396.46	0.719	57.01	-43%	Loser
Sam	7,737.51	0.788	47.10	-53%	Loser
Tom	8,790.07	1.000	0.00	-100%	Loser
Uma*	24,767.08	1.000	0.00	-100%	High-Alt
Victor*	24,918.56	1.000	0.00	-100%	High-Alt
Walter*	25,998.37	1.000	0.00	-100%	High-Alt
Xavier*	30,601.63	1.000	0.00	-100%	High-Alt
Yuki*	30,642.50	1.000	0.00	-100%	High-Alt

The results demonstrate several key aspects of the high-altitude prediction mechanism:

- **Enhanced Rewards**: The most accurate prediction (Alice) received a significantly higher return (+305% vs +120% in Pool A)
- **Capital Redistribution**: Stakes from high-altitude predictions are redistributed to accurate predictors
- **Regular Losers**: Regular-depth predictions beyond 8,790km lost their entire stake
- **High-Altitude Impact**: Five participants intentionally placed high-altitude predictions, forfeiting their stakes

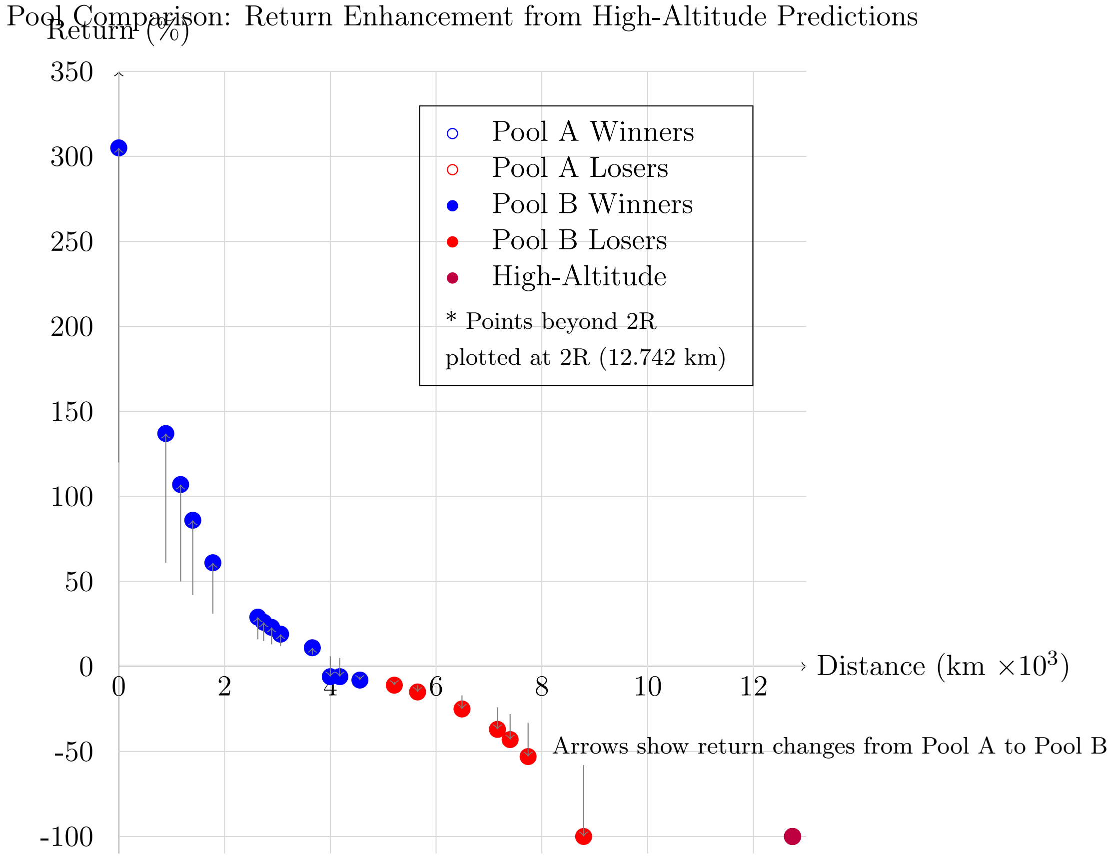

Figure 3: Comparison of return distributions between Pool A (hollow points) and Pool B (filled points). Gray arrows show how returns changed for each prediction when high-altitude predictions were introduced. Note the significant increase in returns for the most accurate predictions.

12 Appendix C: Pool Comparison Analysis

This appendix provides a detailed comparative analysis of the regular-depth prediction pool (Pool A) and the high-altitude prediction pool (Pool B). Both pools predict the same earthquake at (35.654°N, 139.841°E, 31km depth).

Metric	Pool A	Pool B	Difference
Total Pool Size (USDC)	2,500	2,500	0
Total User Cost (USDC)	2,550	2,550	0
Protocol Fee (USDC)	50.0	50.0	0
Median Distance (km)	4,560.8	4,560.8	0
Winner Count	13	10	-3
Regular Loser Count	12	10	-2
High-Altitude Count	0	5	+5
Best Prediction (km)	0.51	0.51	0
Best Return (%)	+120%	+305%	+185%
Worst Regular Return (%)	-100%	-100%	0

Return Band	Pool A	Pool B	Difference
$>$ +200%	0	2	+2
+100% to +200%	1	1	0
+50% to +100%	2	2	0
+20% to +50%	2	4	+2
0% to +20%	8	4	-4
-20% to 0%	6	3	-3
-50% to -20%	3	3	0
-100% to -50%	3	6	+3
High-Altitude (-100%)	0	5	+5

Distance Range	Pool A Return	Pool B Return	Difference
$<$ 50 km	+120%	+305%	+185%
50-500 km	+61%	+137%	+76%
500-2,000 km	+31%	+85%	+54%
2,000-4,000 km	+19%	+22%	+3%
4,000-6,000 km	-8%	-10%	-2%
6,000-8,000 km	-13%	-39%	-26%
$>$ 8,000 km	-100%	-100%	0%

The comparison reveals several key impacts of high-altitude predictions:

- **Enhanced Winner Returns**: The best return increased from +120% to +305% (+185% improvement)
- **Reward Amplification**: Returns improved across all distance bands up to 4,000km
- **Risk-Return Profile**: Higher potential returns compensate for the increased competition
- **Capital Redistribution**: Five high-altitude predictions redirected 500 USDC to accurate predictors

13 Appendix D: Mathematical Formulation of the Incentive Mechanism

This appendix provides the complete mathematical formulation of AKUA's incentive mechanism, including all formulas and parameters that govern reward calculation and distribution.

For each prediction pool, the protocol follows these steps in sequence:

All user bets are converted into standardized units:

$$n_i = \left\lfloor \frac{bet_i}{unit_{size}} \right\rfloor \tag{1}$$

where n_i is the number of standardized units for user i, bet_i is their total bet amount, and $unit_{size}$ is the standard bet size (e.g., 10 USDC).

Protocol fee is applied as an additional 2% on top of each standardized unit:

$$unit_{cost} = unit_{size} \cdot 1.02 \tag{2}$$

where $unit_{cost}$ is what the user pays per unit. For example, to place a 100 USDC bet (10 units of 10 USDC), a user pays 102 USDC.

The protocol calculates the distance d_i between each prediction and the actual earthquake location:

$$d_i = \|\vec{p_i} - \vec{a}\| \tag{3}$$

where $\vec{p_i}$ is the predicted location and $\vec{a}$ is the actual location.

The protocol applies the fundamental distance threshold:

$$d_{max} = 2R \tag{4}$$

where R is Earth's radius (6,371 km). Any prediction with $d_i > 2R$ automatically loses 100% of their stake.

Among remaining valid predictions (those within 2R), the protocol finds:

- The median distance d_{med} which serves as the threshold between winners and losers
- The maximum distance d_{max_valid} which is used for loser normalization
- The minimum distance d_{min} used for winner normalization

The protocol calculates normalized distances:

- For winners (predictions closer than median):

$$\hat{d}_w = \frac{d_i - d_{min}}{d_{med} - d_{min}} \tag{5}$$

- For losers (predictions between median and 2R):

$$\hat{d}_l = \frac{d_i - d_{med}}{d_{max\_valid} - d_{med}} \tag{6}$$

The protocol calculates penalties using the exponential model:

$$penalty_{unit} = \begin{cases} -1 & \text{if } d_i > 2R \\ -e^{-\alpha_l(1-\hat{d}_l)} & \text{otherwise} \end{cases} \tag{7}$$

where α_l is 3.0 (steep penalty curve ensuring complete loss at maximum valid distance)

The protocol calculates total penalty per prediction:

$$totalPenalty_i = n_i \cdot unit_{size} \cdot penalty_{unit} \tag{8}$$

The protocol calculates winner points:

$$points_i = n_i \cdot e^{-\alpha_w \hat{d}_w} \tag{9}$$

where α_w is 3.45 (steep curve that rewards high accuracy)

The protocol distributes final rewards:

- For losers:

$$reward_i = \begin{cases} 0 & \text{if } d_i > 2R \\ n_i \cdot unit_{size} + totalPenalty_i & \text{otherwise} \end{cases} \tag{10}$$

- For winners:

$$reward_i = n_i \cdot unit_{size} + \frac{points_i}{\sum_w points_w} \cdot totalLosses \tag{11}$$

  where $totalLosses$ is the sum of all penalties across all standardized units: $\sum_l |totalPenalty_l|$

The exponential decay rates are carefully calibrated to create the desired reward distribution:

- **Winner Decay** (α_w): 3.45
  - Steep curve that rewards high accuracy
  - Formula: $e^{-3.45 \cdot \hat{d}_w}$
- **Loser Decay** (α_l): 3.0
  - Steep penalty curve ensuring complete loss at maximum valid distance
  - Formula: $-e^{-3.0 \cdot (1-\hat{d}_l)}$

The mathematical formulation ensures the following system properties:

- All bets are processed as collections of identical standardized units
- Protocol fee is charged as an additional cost per unit
- Penalties are calculated uniformly per unit
- Points and rewards scale with the number of standardized units
- Predictions beyond Earth's diameter (2R) automatically lose their entire stake
- Losers between median and maximum valid distance receive exponentially higher penalties
- Winners share the pool of losses proportionally to their exponential scores
- Better predictions receive exponentially higher rewards
- The system maintains true zero-sum between participants (minus protocol fees)
- Normalization using only valid predictions creates a dynamic and responsive reward curve