**AvaxSportsBook**

Decentralized Sports Betting

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**Abstract.** AvaxSportsBook is a blockchain smart contract for straight-up betting on weekend sporting events. Users can be bettors or the house. Cross-margining allows a small number of liquidity providers to support unlimited betting and diversify across events. Its exclusive oracle and liquidity providers equally share the standard sports betting vig. A contract targeting a limited but large portion of a multibillion-dollar market is small enough to manage and big enough to matter.

# Introduction

Sports betting is ideally suited for a completely on-chain smart contract. Consensus odds for straight bets on major events are statistically accurate and stable. The peculiar nature of sports odds—their stability and implicit bid-ask spread—avoids the adverse selection problem in standard asset swapping markets with stale quotes.[[1]](#footnote-2) Bettors do not need *better* odds so much as easy access to ubiquitous conventional odds. If standard odds and event outcomes are recorded on a blockchain smart contract, it is straightforward to apply escrow accounting logic where all bets are permissionless and secure. There is no ‘wisdom of the crowd’ that *adds* efficiency to any big sportsbooks odds.[[2]](#footnote-3)

For American football and mixed martial arts, the absense of intraweek matches makes it easier to assess the odds on weekend events. This creates a predictable repeated game for the oracle. The contract is completely self-contained, with all relevant data on the blockchain, which combined with its pseudonymous administration, and absense of governance issues related to upgrades and extensions makes it uncensorable.

There are three types of *AvaxSportsBook* (hereafter, **ASB**) contract users: bettors, liquidity providers, and the oracle collective. Bettors can take either side of any regular bet offered, subject to a size constraint based on the amount of free liquidity provider (LP) capital. An oracle token holder submits a slate of matches, odds, and start times on Tuesday morning, and betting will be available by that evening until individual gametimes. The weekend’s event outcomes are sent to the contract the following Monday, which then loops through up to 32 events and settles that week’s outstanding bets. Redemptions by bettors are available immiately after settlement, while LPs cannot withdraw for 3 settlements after deposit (i.e., at least 17 days).[[3]](#footnote-4)

Bets are automatically cross margined so that the capital required is minimized. For example, 10 AVAX collateralizes a single bet paying out 10 AVAX, and a contest where the winning payout is 510 AVAX if a team wins and 500 AVAX if its opponent wins.[[4]](#footnote-5) LP capital of *X* supports a book of infinite size when bets of size *X* are made sequentially. The required LP capital on any single event is a function of the maximum *net* payout, which is the payoff on a team *minus* the amount bet on its opponent. An adjustable parameter limits how much of this capital can be applied to any one event so that LPs are not subject to extreme concentrated risk (eg, if there are 100 AVAX, a parameter of 10 restricts the net LP liability for any one contest to 10 avax).

An exclusive ASB oracle provides and validates data sent to the betting contract. ASB fees are split evenly between the oracle and the LPs.[[5]](#footnote-6) Submissions are sent by a single token holder and the collective has at least 11 hours to vote before it can be sent to the betting contract. Token holder fee revenue is a function of how often they vote on data submissions. For example, if a token holder votes on 50% of the data proposals, she would receive half of her potential revenue. The forsaken oracle revenue is reallocated to the other token holders in the oracle contract.

Sports betting is a competitive market, so the standard 4.5% vig reflects an equilibrium balancing the demands of bettors and bookies as opposed to monopoly power. By taking the standard vig as a given we remove naive schemes that in theory are less costly but in practice create failed markets (e.g., Augur). The hassle-free ability to bet or be the house should be sufficient to make it a dominant alternative for many sports bettors.

# Oracle Incentive Compatibility

Creating a game where honesty is an oracle's best strategy is straightforward; the keys are simplicity and a repeated game, which leads to easy monitoring and credible punishment anticipation for a fraudulent oracle data submission. Additional parties, tokens, or scope increases cost, complexity, and delay. Defecting/defaulting implies the loss of the benefit of future interactions, the present value of which acts like over-collateralization on a loan. The potential cheat gain is less than the present value of future revenue foregone even if the oracle were centralized. Incentive compatibility is critical to low-cost enforcement of contracts, and historically this centered on reputation, not contract law administered by the state.

Consider the following cost-benefit analysis for ASB's oracle. Assume a betting contract has 100 in net exposure, which we will conservatively assume is the book’s gross betting exposure (no offsetting bets that generate reward but no risk to the LPs). As the oracle's fee is about half of the vig, this would average about 2.5 AVAX in weekly revenue. Given 50 settlement events over the year, this annualizes to 125 AVAX. Given a conservative 10 price/earnings ratio, this values the oracle collective at 1,250 AVAX. The maximum potential cheating revenue in this example is 100 AVAX, so the LPs have net and gross exposure to the wrong side of every bet made by the cheating oracle’s sock puppet bettor.

Such a scam would be conspicuous in the readable event logs, and no rational person would use this contract again, making the value of the oracle token zero. The data submission is pass/fail, and failure is conspicuous given the binary outcomes, and that odds at major books are always within 3% of each other (in probability of win). This caps a cheater’s ability to slant odds.

Unlike oracles that service many contracts, or there is no plausible deniability by ASB’s oracle collective. Each week they are tasked with producing a singular slate of data, where a single bad data point—one beyond the standard variance in odds across sportsbooks, a late start time, an incorrect outcome—taints the entire slate, and the entire oracle collective as 51% consciously let it happen.

; it would be like a shard of glass in a big bowl of ice cream. It’s like asking someone saying one plus one is three, The oracle collective is ‘all in’ on the betting contract alone.[[6]](#footnote-7)

There is no reason for allowing incorrect data to get voted to the betting contract outside of a conscious intent or radical incompetence. Such data would include start times more than 15 minutes ahead of the actual start time, marking the outcome incorrectly (who won), or odds that are outside the standard beyond the standard variance in odds across sportsbooks given the low verification costs generated by the restrictions on timing and event coverage, and how all oracle voters will have significant token stakes that justify the cost of carefully evaluating data submissions. A voting majority's oracle tokens have a present value of 625 AVAX in the above example, significantly more than the 100 AVAX in a cheat.[[7]](#footnote-8) Honest reporting is the dominant strategy in the improbable worst-case scenario described above (P/E of 10, gross exposure equals net exposure).

The oracle voters have, literally, all day to evaluate a data submission. They should all create algorithms that automate a data download of the necessary information, that makes evaluating the data take no more than a few minutes. A majority 'no' vote among token holders rejects the data so it cannot affect bets, and a fixed amount of the proposer’s tokens are burned. The limited focus of events, timing of oracle submissions remove any plausible deniability for the oracle cheat action in any single event each week. The website generates event log data in readable form, so one does not need specialized knowledge of hash functions to evaluate the oracle’s behavior.

While it is simple enough to incent the oracle properly, this only protects the contract against insiders. In contrast, decentralization defends this contract against outsiders. Powerful institutions have always used centralized power to prevent competition, often using disingenuous rationales emphasizing safety. Such an attack needs a choke point, prevented if a collective of pseudonymous accounts worldwide administers the oracle and provides liquidity.

# Contract Outline

Event data, including start times and odds, are sent to the contract on Tuesday, allowing people to bet on weekend events from Tuesday night to game time. The subsequent Monday, the oracle sends the results to the betting contract, settling that week's bets, and the contract then repeats the process.

Bettors and LPs need only interact only with the betting contract, while the token holders need only interact with the oracle contract. All transactions with the betting contract are denominated in AVAX.

LP capital backstops residual imbalances in the book. The LP's total capital is available equally to all contests that week, but there is a limiting mechanism on how much AVAX can be allocated to any single contest. This diversifies the LPs, reducing the chance that a single contest outcome could extinguish LP capital. The betting contract contains all the methods for bettors and LPs: betting and redemption for bettors, investing, and withdrawal for LPs.

A singular oracle token holder, with at least 10% of the oracle tokens outstanding, proposes the relevant data: the upcoming schedule (who plays whom, when), odds, results, and some technical parameters (e.g., paused matches, the diversification parameter). Each submission is then subject to an evaluation period subject to a majority vote: yes or no. A successful data submission is sent to the betting contract after a voting period of 11 hours, giving the oracle collective sufficient time to veto a fraudulent or incompetent submission.

odds, results, etc

avax fees

Oracle Contract

Betting Contract

avax

avax

data, votes

avax

tokens

Token Holders

LPs

Bettors

The data submitter automatically votes for his submission, so if no one votes, it will succeed, as it is a simple majority vote that determines success or fail. Posting data can only occur in the 60-minute window where the hour is between 12:00:00 and 13:00:00 GMT, which is 8 PM New York time in the summer and 7 PM in the winter. Voting takes place between the noon posting and processing the vote 11 hours later. The processing function can be executed by anyone, as 11 hours is more than enough time for a thorough evalution by the oracle.

If a settlement or initial post are rejected, then a settlement or initial post, must be posted again. This effectively delays the contract by a day. Odds updates cannot occur Saturday or Sunday, and settlement can only be posted the following Monday, so the oracle token holders have no duties until Monday’s settlement.

Each week, aka ‘epoch,’ the MMA, boxing and US football games that weekend are sent to the oracle contract. The data are sent to the betting contract if most oracle token holders vote yes. When the betting contract has data for the next weekend, bettors can bet up to the time of the various games that weekend, as each game is given a starting time that must be between Friday 8PM ET and Sunday 9PM ET. Odds can be updated, but only once a day, or up to three times in a week.

After the weekend, the outcomes are sent to the betting contract, which settles all the week's bets. Once the settlement is sent to the betting contract bettors can redeem their bets. The contract has no ability to seize neglected funds, so as long as the blockchain exists, users will be able to safely let unredeemed money sit in the contract. LPs cannot withdraw or deposit from Friday 7 PM ET through settlement Monday evenining, as otherwise, they could game the contract by anticipating unusual losses or winnings that acrue over the weekend’s events.

## Betting Capacity and Cross Margining

The contract’s logic makes sure all bets are fully collateralized. Unlike in futures markets, the margin is not derived from a probabilistic risk, such as an instant 20% price movement. Such a rule exposes a contract to insolvency, as there is a possibility of price movements greater than 20%, which becomes increasingly probable over time. In betting on binary outcomes, the worst-case scenario for the house is assumed, which is like assuming each LP net position loses. The contract will always be fully collateralized on all bets, as this is enforced at the time of each bet. There is no insolvency risk for LPs, oracle, or bettors.

As bettors take the opposite side of a contest, it is a waste of capital to require the LPs to collateralize both sides independently. The solution involves netting exposure.

**Cross margining example:** Assume two teams are given even odds so that for either team, a 1 AVAX bet pays the winner 2 AVAX. If there is 10 AVAX on team A, and 10 AVAX on its opponent, team B, it would be a 'flat' book in that the LPs have no exposure to this game; payoffs are funded by betting counterparties, not the LPs. A new bet that pushes the book to have a net exposure would necessitate LP funds as collateral, so a bet of 2 AVAX on team A would add 2 AVAX to the LP's locked margin. Given a total of 12 on team A, and 10 on team B, a bet of 2 AVAX on team B would move 2 AVAX *out* of the locked margin because the resulting book would be flat again.

Adjusting the net required LP margin involves 'linear programming' where the LP's net game exposure is the maximum liability of either team winning. The margin adjustment is applied at the time of a bet, so there must be sufficient free LP collateral to accommodate a bet adding to LP exposure.

A contract parameter prevents an overconcentration of LP capital on one event. For example, 123 AVAX in total LP capital and a concentration parameter of 10 implies a maximum of 12.3 AVAX LP exposure for any event. Thus, if the current LP liability for team 0 winning was 10.0 AVAX, it could only accommodate an additional payout of up to 2.3 AVAX on team 0. In contrast, a bet on team 1 could accommodate a bet payoff of 22.3 AVAX. This concentration parameter can be adjusted over time by large oracle holders.

## Betting and Redeeming

All ties and 'no contest' games give bettors their initial bet back. Winners receive their bet amount plus the payoff implied by their bet odds. When the weekend's results are sent to the betting contract, all bets are settled, and the oracle payment is sent to the oracle contract. Settlement creates a mapping from a unique epoch-match-team, which determines which bets credit a user’s balance when looping through a bettors bets. Settlements should happen Monday evening.

Bettors redeem all of their outstanding bets in batch. The redeem function loops through up to 10 bets in a user’s account, and sends the winnings to the bettor’s account. Redemption can only be processed if there are no active bets in the account, so bettors must wait until the next settlement to redeem if they have any active bets. If an account has 16 unredeemed bets, it must redeem them before it can place another bet.

All bets are fully collateralized, and so are the accruals for the oracle. so if one has access to the account used for sending the bet or LP investment, a user's funds are safe in the contract. Unclaimed bets or tokens can reside in the contract and retain their value as long as the AVAX C-Chain exists, as there is no mechanism to sweep neglected funds to LPs, bettors, or token holders.

## Liquidity Providers (LPs)

Sportsbook odds are efficient, in that statistically the house makes a profit, but week-to-week the book can lose money due to small sample variation. The LP’s main risk, however, is the black swan risk in a hack, something not detectible from its historical return. Thus, LPs have an incentive to become oracle token holders to align their incentives, as the most likely cheat would involve a conspiracy between the oracle and a bettor, defrauding the passive LPs. The token rewards allocation to the initial LPs encourages an LP/oracle overlap.

As LP capital is used to collateralize residual bet exposure, the ratio of the net to gross betting volume will be key in determining the return on LP capital. The amount of LP capital relative to the betting volume will equilibrate the market. If the return is too low, capital will leave, raising the expected LP returns; if the return is too high, capital will enter.

To become an LP, one sends AVAX to the betting contract, which then credits the LP with shares representing their pro-rata ownership of the LP pool. For example, if there is 10 AVAX in the LP book, and 10 shares, adding 1 AVAX would give a new LP a 1/11th share of the new pool of 11 AVAX, keeping the AVAX/share the same. This LP claim exists only within the betting contract and is tied to the initial LP AVAX account address. It is not transferable to other AVAX addresses, and so is not represented by a token. LP shares are like a stock at its net asset value; tokens are like a stocks market value.

The size of the LP capital should adjust to the volume and degree of cross-margined betting, the more of which increases the LP’s expected return. For example, a book with 10 bet on team A, and zero on its opponent, will generate an expected return for the LP, statistically, in that over time the vig in the odds spread implies bettors need a 2.2% edge in predicting winners to beat the house, which is difficult (as proven by the nice casinos). If a book had 110 bet on team A and 100 on its opponent, the required LP capital would be the same, but here the LP would make a certain return on the offsetting bets. That is, the gross betting exposure in the latter case is 21 times large than the net exposure. The greater the ratio of gross to net exposure, the greater the return. The expected ratio will be revealed over time, and will greatly affect the return for a given level of LP capital.

LPs can only withdraw during the inactive period if margin is available. A bet backed by LP margin locks this margin until settlement, or bettors take the other side, freeing the LP capital. Since there is at least a 24-hour window each week after settlement (~Monday 8 PM ET) before new bets are offered (~ Tuesday 8PM ET), LPs are sure to be able to withdraw at least once each week. More practically, there will be free margin available for marginal LPs to withdraw over much of every week, as bettors will probably not max out the bookie's free margin in the first days of the week.

LPs must also have their AVAX in the contract for at least three settlements. If LPs could withdraw after only one settlement, people could add large amounts of capital just before the weekend when the pool has little net betting exposure, and then take their money out right after settlement. For example, if all bets were fully collateralized by offsetting bettors one week, the LPs would receive a certain profit given the vig built into the odds. Outsiders could provide superfluous liquidity just before the weekend and withdraw immediately after settlement, generating a certain profit with no risk. This would dilute the profits of LPs providing 'real' liquidity. Mandating the LPs stay for at least three settlements makes this strategy significantly less attractive.

Sportsbook odds are efficient, in that statistically the house makes a profit, but week-to-week the book can lose money due to small sample variation. The LP’s main risk, however, is the black swan risk in an oracle hack, something not detectible from its historical return. The most likely cheat would involve a conspiracy between the oracle and a bettor, as they could target positions actively against the passive LPs. Thus, LPs have an incentive to become oracle token holders to align their incentives. For example, if the LP and the oracle were the same singular agent, he would have no incentive to cheat, as it would be a net zero change to his wealth.

As LP capital is used to collateralize residual bet exposure, the ratio of the net to gross betting volume will be key in determining the return on LP capital. The amount of LP capital relative to the betting volume will equilibrate the market. If the return is too low, capital will leave, raising the expected LP returns; if the return is too high, capital will enter.

# Avalanche

Snowball is Avalanche’s Proof-of-Stake (PoS) consensus mechanism. It’s understandible that second generation consensus mechanisms—outside of PoS—would be an improvement, and this one is really big. Ethereum is stuck with an inefficient mainchain, because all of the development there is on their L2s, so making the mainchain as quick and cheap as an L2 will be much harder than their move to PoS. The bottom line is that it as cheap and fast as an Ethereum Layer 2 blockchains like Optimism. Unlike Ethereum’s Layer 2 blockchains, however, it is already decentralized.

In May 2023 Ethereum saw transaction costs spike 6-fold. The cost was transferred to L2s like zkSync, which would have made the costs of depositing, betting, redeeming, and withdrawing greater than $15, making a standard $40 bet unattractive. To the extent some L2s gas costs did not mirror the mainnet, that just highlights these blockchains are subsidizing users, an understandible strategy for gaining traction. To be sustainable, however, these L2s will have to charge more, and it is uncertain whether or not that will work. Avalanche’s gas price has been much more stable over the past year, with gas prices rarely moving more than 30%.

Thus, I put the contract on the Avalanche C-chain because of its combination of cost, stability, and decentralization. Avalanche uses the same Ethereum Virtual Machine as Ethereum, so it took no extra work. Avalanche has the same address structure as Ethereum, so users can use their MetaMask wallets to store and transact with Avax. Their Core Wallet, however, makes bridging assets from Ethereum or Bitcoin safer and easier than Ethereum’s L2s.

# Oracle Incentives

## Oracle Token Owners

I created this dapp but I have no control or financial interest; I cannot disable or administer the contracts in any way.[[8]](#footnote-9) Contract users—token holders, LPs, bettors—are responsible for obeying their local laws and regulations. The fact that the only way for me to publish this contract is to give it away is likely a major reason why no one else has created such a contract. With 8 billion people on the planet and such a big market, there should be a niche for a quick and easy way to bet.

Initially there will be little visibility so it is essential to have people prudently administering the contract, and people need economic incentives. I gifted the tokens to three people I have no control over, and chose them in part because I do not know them well, as that would make it easier for them to be identified. In that vein, my contact with them going forward will be exclusively through public writings like this. I tried to make their job as easy as possible by giving them tools for their role. The excel spreadsheet in the GitHub repo provides a simple tool for taking the data in the proper form acceptable to the contract, and there are python programs for token depositors to send the various required transactions. These are explained in videos available on the website.

They each received a 13.3% of the immutable supply of tokens, as 10% are required for submitting data (smaller token holding collectives can and should vote on those submissions, via vaults). I chose three because one of them could become incapacitated. Also, if one decided to cheat the contract out of spite or irrationality, it is highly improbable that the other two token holders would allow this would be small, as they do not know each other, and it would destroy a potentially valuable gift.

The other 60% of the maximum oracle token supply, 600k, was sent to the betting contract as rewards for initial LPs. This encourages the LP/oracle overlap for reasons mentioned above. Each week 30k tokens are available for reward distribution, and each week LPs can send a function to receive their pro-rata share (eg, an LP with 10% of the shares would receive 3k tokens). Rewards do not start until epoch 5, to avoid the initial oracle token holders accumulating most of the tokens while the contract has little visibility.The incentive program will last until all the tokens are distributed. There is no ability to mint more than the initial one million tokens minted.

## Oracle Vaults

Smaller governance token holders rarely participate in votes. This is rational because there is a minimum fixed cost to evaluating data, say 20 minutes of time. Assuming 4 votes a week, the implicit hourly wage for this service would be below the minimum wage for someone with less than $1000 worth of tokens. This creates an attack surface for hackers.

To mitigate the standard public choice voter information problem, the minimum deposit in the oracle contract is 40 million tokens, 4% of the total supply. Tokens must vote to receive fee income, and to vote they need to be deposited in the oracle contract. This creates an incentive for small token holders to pool their tokens and designate a voter who would have an incentive to seriously monitor and discipline oracle data submissions.[[9]](#footnote-10) There will be mutual gains of trade for both sides: the small oracle token holders and the administrators of vaults. It should be like representative versus direct democracy, a consequence of Robert Michel’s *Iron Law of Oligarchy*.[[10]](#footnote-11)

The vaults should not be too big, as this would present an attack surface for censors and hackers. Thus each token account within the oracle contract is capped at 140 million tokens (14.0% of the total supply). The vaults should be independent, in that this would make the contract more robust, making the present value of their tokens greater.[[11]](#footnote-12)

## Sending and Validating Oracle Data

The oracle token holders get paid for performing a specific purpose, enforcing honesty. Other than the singular data submitter, evaluating the data and clicking a button to vote on it imposes an insignificant cost on the oracle. In an ideal world, one should not have to pay someone to simply *not* be evil, but that is not the world we live in; crypto has shown that anything pseudonymous based on trust will be exploiting by amoral hackers to the fullest extent. Thus we make sure honesty is the oracle’s profit maximizing action at all times. They can then spend that money on whatever they like, wholesome or debased.

A token holder needs at least 10% of the outstanding tokens to submit data to the oracle contract. While submitting data takes some effort, the cost is relatively low given the ease at which relevant data is available and the limited scope and frequency of data submissions.

Tokens must be deposited within the Oracle contract to submit or vote on submissions. This prevents double-voting and forces the token holders to attend to the contract they should be monitoring. The tokens are meant for governance, not speculation, and generate dividends directly proportional to the bet volume. Token holders cannot vote more than once on any data submission, which requires that token holders cannot withdraw tokens while a vote is active.

The data submission process will look like this, assuming the data pass):



\*optional

The data can then be processed once the GMT hour is before 12. Anyone can execute the function that processes the vote, so I suspect it occur quickly once possible, around 8PM ET. A yes vote sends the data to the betting contract, while a no vote burns a fraction of the proposer's bond and resets the state for the next data proposal.[[12]](#footnote-13) For rejected initial and settlement data submissions, these must be resubmitted; for a rejected odds update, they can be resubmitted or not.

No data can be submitted on Saturday or Sunday. If there are data submission failures, the data submission is either pushed back a day, or if an odds update, omitted.

Token holders submitting failed data submissions are charged a fee of 2k tokens. Rejections should be rare, but they should also be expected due to unintentional mistakes. The penalty is meant to be painful but tolerable. Those rejecting data do not get a bonus, as we do not want to incent users to reject data submissions to acquire more tokens.

## How Oracle Token Holders Claim Oracle's Revenue

The primary way the oracle acrues fee revenue is at settlement. The epoch increments each settlement, which is why this number is recorded in a token depositor’s account. The other way the oracle acrues revenue is when negligent token depositors claim revenue, as if they do not vote each time their accrued revenue is slashed by the percentage of votes they missed, and the lost amount is reallocated to the other token holders. The unearned AVAX is then immediately reallocated to the other token holders by treating it like a settlement dividend.

Each week the oracle receives 5% of the bettor winnings as a fee for their service. This is consistent with the Oracle receiving 2.5% of bet amounts and the LPs receiving the other 2.5%. While the oracle could receive nothing if all bettors lose, the oracle can never lose money. Token holders must vote on data submissions to get their revenue, which requires they keep their tokens in the oracle contract. For example, if their tokens were in the contract for three settlements and eight data submissions, and they voted four times, they would receive one-half of their payment. The other half would be added back to the pool to go to the other token holders, incenting the token holders to actively monitor the the data submitted.

# Conclusion

Most sports betting sites touting their crypto functionality are conventional ones accepting crypto. A truly blockchain-based betting dapp upholds Satoshi's vision of *pseudonymity*, *confiscation-proofness*, and *permissionless access*, which requires it to have no off-chain presence. I hope that a focused dapp with good incentives can provide an example of what blockchain smart contracts can do. The purpose of the contract is to facilitate betting, not create a new token for people to pump. Unlike most dapps, where tokens have a vague governance role and hypothetical revenue, ASB’s token holders have a straightforward but essential job that generates instant revenue.

One should expect players to always act in their selfish best interest. A sustainable contract creates a repeated game where honesty is always the dominant strategy for every player. Simplicity is crucial in generating the cooperative equilibrium because the state space grows exponentially in the number of players and actions they can take. ASB’s simplicity enables an incentive-compatible contract that avoids costly and redundant adjudication procedures, allowing bettors to easily access conventional odds on big games, and cash out in timely fashion.

The trust one puts into the ASB Oracle is fundamentally the same as why investors trust miners: the rational self-interested assessment that honesty dominates dishonesty for a hypothetical individual.

ASB is a straightforward application of escrow logic to a common use case, a digital vending machine. ASB presents a quick and efficient way to get asset exposure without the many hassles in standard contracts. Sports betting is ubiquitous, but it should be easier. This contract provides a simple way to do that.

# Appendix

## Odds Translation

To convert moneyline odds into Decimal odds, we have the following.

For positive moneyline odds: (Moneyline odds/100) + 1 = Decimal odds

For negative moneyline odds: (100/Moneyline odds) + 1 = Decimal odds

To translate decimal odds into moneyline odds that are prominent on NFL betting sites, we have the following adjustment mechanism:

If decimal odds are greater than 2.0: 100 × (decimal odds – 1) = Moneyline odds

If decimal odds are less than 2.0: -100/(decimal odds -1) = Moneyline odds

To translate moneyline odds to fractional odds:

For positive moneyline odds: Moneyline odds/100 = Fractional odds

For negative moneyline odds: -100/Moneyline odds = Fractional odds

To convert decimal odds into winning probability.

prob(win) = 1 / Decimal odds

Decimal odds = 1 / prob(win)

The most common odds offered for the NFL are presented in moneyline form as ‑110 for both teams. A flat book on such a wager would receive 220 and payout 210. In this way, the 'house' makes money used to pay for various costs and a profit from the house. The implicit profit ('vig') in this case would be 4.55%, 10/220. The general formula for estimating the vig is given by the following formula, where *p* and *q* are decimal payouts (e.g., 1.909 for a standard even money bet) for opposing teams.



The spreadsheet 'ASB.xlsx' presents a page where people can see how these transformations are applied. Those interested in sending odds to the contract will find it a helpful template.

## Schedule and Start Times in Contract

Each betting period will contain up to 32 events and target a weekend (e.g., Friday night through Sunday night). Each contest is slotted into an array that can be unambiguously linked to its outcome via event logs that expose what events odds were on the contract. The schedule array contains a string with the sport (NFL, MMA, etc.), the two opponents, and the starting time. The initial favorite will be listed first and the underdog second, though the odds can change over the week while the ordering of the contestants cannot.[[13]](#footnote-14)

The start time is important because if it is wrong, bettors will be able to bet on games that have either started or completed. Websites with event start times are tricky because sometimes these are listed as ET (ie, New York City time), sometimes they are automatically converted into one’s regional time zone. It is best to buy an ‘live odds’ API, and these generally provide the start time in UTC. This time is also called GMT, Greenwich Mean Time, which is often presented in ISO8601 date/time format, where the “Z” suffix means Zulu time, which is another word for GMT/UTC.

## Odds in the contract

Odds are available on many betting websites, and arbitrage limits how far these odds can differ. On average, a team's implied probability of winning will change by only 2% over the week, rarely over 5%. All odd postings and updates are recorded in event logs, observable in online queries at sportAVAX.co.

A contest will have a single odds number posted for a contest. These odds are supplied only for the initial favorite using a truncation of preliminary decimal odds. For example, 1.909 would be stored as 909, 2.50 as 1500, etc. This number, however, is just relevant to the team in slot 0, the initial favorite. Further, it needs to be adjusted to reflect the oracle fee that would be assessed to the winner payout. Thus, the betting odds for a favorite where the match odds were 957 would be 909, via

Net Odds (favorite) = (contractMatchOdds \* 0.95)/1000 + 1

= 957\*0.95/1000+1=1.909

The gross odds for its opponent are generated within the contract by the following formula:



Then to account for the oracle take, the all-in odds for team 1 would be

Net Bettor Odds (underdog) = (underdogOdds \* 0.95)/1000 + 1

With this method, we can ensure that the set of odds for a contest generates a positive vig, removing a potential attack vector.[[14]](#footnote-15) This formula generates a vig of 2.5% for the LPs via parameter 45 in the above equation, and the 5% take of winnings generates an approximate 2.5% vig for the oracle.

The standard odds presented by most casinos embody the standard vig of 4.5%. For example, -110 on an even-money bet, which is 1.909 in decimal odds. ASB applies the vig to each contest via an algorithm that works well, though it is simply a hack as opposed to something derived from axioms. The approach is to put the LP’s take into the ‘spread’ between the odds offered for the favorite and the underdog, but leave the Oracle’s take out of the spread. The Oracle fee is then taken out of the winnings.

Initial odds presented must be between 1.999 and 1.125. The cap at 2.000 reflects the fact the initial odds apply to the initial favorite, while the 1.125 minimum removes events where the initial odds are greater than 8:1, lopsided contests. Eliminating high payout contests mitigates risk, as such events would invite hacker attention.

The excel spreadsheet is provided that generates the data in the necessary format. The basic algorithm is this

1. Take an initial set of odds
   * Home team: +135
   * Away team: -150
2. rearrange so that the favorite team is first
   1. team[0]: -150, team[1]: +135
3. Translate into win probability
   1. team[0]: 59.8%, team[1]: 42.4%
4. calculate probability spread
   1. spread = 0.598 – 0.424 = 0.174
5. Calculate new favorite, team[0], prob(win)
   1. prob(team[0] win) = 51.1% + spread/2
   2. prob(team[0] win) = 51.1% + 8.7% = 59.8%
6. Translate prob(team[0] win) into decimal odds.
   1. decOdds(team[0]) = 1 / 0.598 = 1.6716
7. Translate decimal into the payoff of the bet. This number will represent the match odds in the contract.
   1. contractOdds = 1000 \* (decOdds – 1)
   2. contractOdds = 671
8. Translate into netDecimalOdds(team[0]) presented to bettor
   1. 0.95\*671/1000 + 1 = 1.637
   2. The oracle fee reduces the actual decimal odds returns presented within the contract
9. Translate into team[1] payoff
   1. contractOdds(team[1])= 1e6 / (671 + 45) - 45 = 1359
   2. net decOdds (team[1]) = 0.95\*1359/1000 + 1 = 2.291

In this example, the vig is 4.5%: 1.637 \* 2.291 / (2.291 + 1.637). The above algorithm generates a vig near 4.5% across the range of odds covered in this contract.

The website avaxsportsbook.com displays the decimal odds users receive if they win. For example, a user seeing odds of 1.900 will receive back 1.900 times their bet amount.

## Redeeming a Bet

Bets are stored in a mapping within a better’s struct, and after 10 bets, no further bets can be made until they are redeemed. Redemptions can only occur when a bettor has no active bets, so a bettor should redeem his bets after settlement if he anticipates a problem. All bets in the array are settled for the bettor. Each bet is represented by the unique combination of epoch, match, and pick. At settlement, a bets hash refers to a struct containing this information, and a mapping generated at settlement allows redemption. Users to redeem bets by clicking a single button (it is one transaction).

## Oracle submission Restrictions

The reviewStatus variable in the oracle contract is a control mechanism to prevent illogical oracle submissions given history. Such submissions would either be a hack or a just incompetence, or carelessness.

reviewStatus by oracle function

required if vote succeeds if vote fails

initPost 0 10 0

updatePost 2 20 2

settlePost 2 30 2

voteProcess (init) 10 2 0

voteProcess (update) 20 2 2

voteProcess (settle) 30 0 2

withdrawTokens <10

## LP Revenue

LPs own a pro-rata portion of the contract's revenue based on their percentage of LP capital before that week's events. Statistically, the LP capital will grow each settlement due to the vig; this is how LPs make money. As the relevant LP credit/debit occurs at settlement, the LP's AVAX/share value is fixed each week when users can withdraw or invest.

An initial investment generates the following shares:

LPshares = AVAX invested × TotalLpShares / TotalLpAvax

For example, assume the contract has 123 AVAX owned by its LPs, who have 100 shares. This AVAX may be sitting free or locked up as collateral for upcoming contests. This implies each LP share is worth 1.23 AVAX.

LP AVAX LP TotalShares avax/Share

123 100 1.23

Suppose Alice wishes to invest 10 AVAX into this pool. The above formula implies she would receive 8.13 shares (10/1.23). This would change the pool's balance sheet to

LP AVAX LP TotalShares avax/Share

133 108.13 1.23

Note the ratio of AVAX/share is the same after Alice's investment, so existing shareholders do not lose or gain money via Alice's new investment.

If we assume the LP collective gained 2 AVAX that week, the new balance sheet after a settlement will look like this:

LP AVAX LP TotalShares avax/Share

135 108.13 1.25

The increase from 133 to 135 reflects a 1.5% profit from that epoch's games. If Alice then sold her shares, she would receive AVAX using a transformation of the above formula:

avax Withdrawal = TotalLpAvax × SharesSold / TotalLpShares

Selling 8.13 shares would generate 10.15 AVAX, a 1.5% return on their investment, identical to how much the AVAX LP pool rose over that period.

In this way, any LP investment or withdrawal reflects the percent change in the size of the LP pool’s avax/share over the investment period.

## Oracle Revenue

Oracle token holders must deposit their tokens in the oracle contract to vote, and they must vote to receive revenue. When a weekly settlement transaction is executed, the oracle's 5% fee is applied to the winnings and sent to the oracle contract. The '*feePool'* state variable reflects the lifetime amount of AVAX per token paid to the oracle contract.



When an oracle token holder deposits into the contract, their account notes the current value of *feePool*. When that oracle token holder withdraws or adds to their account, the token holder is sent their entire accrued AVAX using the formula



Having tokens in the oracle is a necessary but insufficient condition for being paid. The contract then takes the total number of tokens





This account's *OraclePoughback* is sent to the Oracle *feePool* as if it were revenue from a settlement.

There is no scenario where the token holders can lose accrued revenue, either due to a lucky win streak by bettors or an oracle hack. Token holders can be sure the contract is in balance, where accounts payable are equal to AVAX in the contract at all times.

## Margin Adjustment for New Bet

There are three types of margin tracked by the contract, all held in the array variable' margin.'

**LP Capital:** This is AVAX owned by the LPs, both free and locked up as collateral.

**LP Locked Capital:** This is AVAX owned by the LPs that are unavailable for bookie withdrawal. It represents the gross worst-case scenario loss for the LPs.

**Bettor Capital**: These are bettor funds applied to outstanding, taken, bets. Bettors do not receive cross margining.

LP capital is available for new bets that increase the contract’s net exposure. New bets that increase the contract's net exposure will increment their LP locked capital account, margin[1]. Bets that decrease the LPs net position will will decrease their LP locked capital account.

For a team with decimal odds of 1.957. the total payoff for a win can be separated into two components: 1 + 0.957, the latter term representing the bettor’s net profit, and the former term representing the bettor's bet amount.

Odds are stored such that



LP Required Margin is the sum of the maximum liability for all the events in an epoch. Each event is independent, so the book is correctly margined by correctly margining all the individual bets. Thus we need merely describe how margining occurs for a single event, knowing these are then summed for determining the overall Required Margin.

The total amount owed if team 0 wins equal the sum of the bet amount and its payoff for all the bets taken on team 0. Let us define two types of capital used to pay bettors, the payout or profit, with must come from someone other than the bettor, and the bettor's initial bet amount, which is returned with his profit:



**betSum0** is the total amount bet on team 0, summing over all the bets on 0. Bettor funds are available for payout but not part of the LP's Required margin (which is in Margin [0] and Margin [1]). **paySum0** is the sum of the bettor's profit if team 0 wins, which requires AVAX from the LPs or bettors taking the other side. As the betSum of team 0's opponent, team 1, is available for paySum0, the trick is monitoring the ability to cover the LP's liability given the amount bet on its opponent. This generates the following maximum liability for the LP (*aka* required capital) for a contest in that it is the maximum liability to either team in a contest:



We add the zero term because the house will have only non-negative liability on every contest. For a new bet long on team 0 playing, the new bet and payout are added to the above max() equation and compared to the extant maximum liability. The difference is the change in the LP's required margin (margin[1]), which is offset by a change in the LP's free Margin (Margin [0]).



This is calculated at the bet time, and the LP's capital is moved into or out of locked LPcapital depending on whether the bet increases or decreases the LP collective’s net exposure. For example, an initial bet will increase the required margin, but a subsequent small bet on the opposing team would lower the required margin. A bet could move the book so that the net LP liability switches from team 1 to team 0 or consists of the decrease in the net liability on team 1. In any case, the above function captures the difference in the worst-case scenarios for contract liability.

In this way, the LP's total book exposure is cross-margined so that 1.0 AVAX capital can support many bets via incremental bets on both contestants. At settlement, the locked LP capital, minus the acrued bettor payouts, is returned to the bookie's total capital and the LP’s locked capital account is set to zero.

Within the GUI, the maximum bet size is displayed when a user toggles the radio button. It is calculated using the following logic. We use the superscript *i* for the pick, and *-i* for the opponent. The potential liability for pick *i* is



The global maximum exposure for any one match is a function of the amount of LP capital and the concentration factor. This number is applied to each new bet, capping the LPs exposure to any one event.



The amount of available LP capital is



With these data, and the odds offered on the bettor’s pick, we can calculate the change in LP locked capital on a new bet:

maximum exposure for a pick:



To translate this into a betsize, we divide by the payoff odds. For example, if the odds were 1.500, this pays out 50% on each dollar bet (decimal odds -1). Thus with 1.0 in LP exposure available for the pick, that would allow a bet for 1/0.5 or 2.0.



LP exposure across matches is independent. The assumption for LP exposure is the worst-case scenario, so there will be no chance of an insolvency, as a bet cannot be taken without capital available.

## Gas for transactions

**contract function gas (x1000)**

oracle initialPost 410

oracle inital voteProcess 129

oracle update Post 112

oracle update voteProcess 72

oracle settle Post 99

oracle settle voteProcess w/ 32 matches 867

oracle settle voteProcess w/ 16 matches 535

oracle settle voteProcess w/ 1 match 191

oracle vote 37

oracle deposit Tokens 52

oracle wd Tokens 84

bet bet 110

bet deposit as LP 54

bet deposit as bettor 48

bet wd as LP 44

bet wd as bettor 33

bet LP claims token Rewards 62

bet bettor redeems bets 55

## Settlement Detail

Settlement records which bets won and then allocates bettor and LP capital to accounts that ensure accrued accounts are fully collateralized. Each bet creates a struct that contains the team and week of the bet. These two inputs create a hash mapped to a number representing its game outcome: 0 for a loss, 1 for a tie, and 2 for a win. When the array of 32 results is sent to the settlement method, the mapping is created (the mapping is zero for uninitialized hashes, so unless updated, the mapping is 0). This mapping is then used for redemptions, in that a bettor claiming his winnings will need the {epoch, match, team} hash to map to a 1 or 2 to generate a payout.

In addition to creating non-zero hash mappings for non-losing teams, the total payments to all bettors were generated using the results and the paySum and betSum arrays:



Here 1*x* is an indicator function that is 1 if true, 0 else. The *WeeklyWinnings* represents the bettor profit, while the WeeklyPayBack represents the initial bettor funding. The oracle fee of 5% is applied to the bettor winnings, representing about 2.5% of the total bet amount. As individual payouts are less than or equal to the total payouts in any week, this rounding truncations on individual redemptions will not compromise contract solvency; rounding will not prevent redemptions.

At settlement, accounts are adjusted as follows:

Redemption capital = WeeklyPayBack

PayoffPot = WeeklyWinnings \* 95 /100

Oracle fee revenue = WeeklyWinnings \* 5 /100

The bookie's capital then adds the money bet that week minus the payouts for wins and ties.

bookiePool = bookiePool + bettorLocked – redemptionPot – payoffPot

The oracle revenues are then just 5% of the WeeklyWinnings, and are transferred to the oracle contract in the settlement function.

The bettor's money exists in the residual and must be claimed via redemption. At redemption, their bet and its winnings are credited to the bettor's user balance, available for withdrawal or future bets.

After settlement, the bookieLocked margin is set to zero, so all LP funds are available for withdrawal. LPs need to pass 3 settlements before they can withdraw.

## Simplicity from Restrictions

### One odds number for each match

Standard odds are presented as a pair, with a spread so that simultaneous bets on both teams loses money for the bettor and makes money for the house. An obvious attack surface for a smart contract would be for the odds to imply an arbitrage as the offsetting bets would minimize the LP capital requirement, enabling the hacker to drain virtually all of the LPs capital at settlement. By using a single number that attack is eliminated. The 4.5% vig creates a competitive two-sided offer, a standard requirement for market makers on centralized exchanges.

### Only odds on (initial) favorite are submitted

The odds for the opponent are calculated via an algorithm. By restricting the odds to apply to the favorite, we can restrict the range of allowable odds, as no favorite has decimal odds greater than 2.000. This makes it easier to exclude bogus odds, as otherwise a hack might be to move odds from 1.500 to 4.00, which would enable a large payout. Updates are allowed to drift outside of the initial restnriction from (1.150, 2.000), to (1.075, 2.200), but that is still much less than if odds were submitted on both favorites and underdogs.

### Weekend straight-up events

Standard centralized sportsbooks cover diverse events on most days of the week, including exotic bets that are are not straightforward to validate. This demands a great amount of attention and competence by the oracle, and increases the probability that a minority of token holders take advantage of inattentive oracle token holders. The weekly reporting also makes the oracle easier to validate historically, in that the event logs refer to who won weekend events, which is easier to verify.

One could use a point spread, but that would not translate to MMA. Football, boxing and MMA will be the primary focus. The matches and odds are well-publicized early in the week. If there were a high profile events other than football and MMA can be accomodated on a case by case basis (for example, a World Cup soccer match).

### There are only 3 contracts

This dapp consists of three solidity contracts: betting, oracle, and token. In contrast, Uniswap’s V3 ‘contract’ contains 31 contracts, which makes it difficult to audit. One can evaluate functions piecemeal, but with tens of interacting files, many upgradeable, it is difficult to span the state space configuration that may make an otherwise innocuous argument a problem. Users must take security on faith. With ASB, one can download the three contracts, and test different different scenarios to find a hacking surface. I provide a dozen hardhat tests as templates to build upon in my GitHub repo.

### The contracts are all non-upgradeable

Static contracts remove any need for governance to vote on upgrades. Most importantly, it means there is no group of developers managing, promoting and proposing changes. Such developers would need to be paid, and generally this requires a corporate structure. Such corporations are attack surfaces for censors. This also removes the risk from bugs often found in upgrades.

### Weekly settlement

Settlement can only occur the Monday following the next Friday.

### Maximum of one daily data submission

The oracle processes at most one submission per day, which must be submitted during the 12th hour GMT. This makes it easier for the oracle to keep track of the data it must evaluate. Odds movement within a week is generally within the effective bid-ask spread implied by the standard sportsbook vig applied in ASB, so a daily update should provide the LPs with sufficient protection against the adverse selection risk created by stale odds..

### No data submissions on Saturday and Sunday

This allows the oracle token collective to take time off without worry about a hack.

### No settlement submission until subsequent Monday

A settlement submitted prior to this would obviously be fraudulent.

### At least 11 hours for data vetting

As no healthy adult sleeps more than 10 hours a day, all token holders will be able to vote before the data submission is processed. The objective is to make it feasible for a single person to do this manually without an extreme investment. The basic functions can be automated to a great degree, and python programs for processing and submitting oracle data are provide in the GitHub repo. The crucial issue is time, giving the oracle collective time to soberly evaluate the data on submission and evaluation.

### Maximum 32 events per weekend

The settlement function loops through the events, and 32 is big enough to capture most weekend events. Gas is a constraint, but this has the added value of making the contract easier to monitor and validate, as obscure contests would be more difficult to asses.

### No ex-post disputes requiring adjudication

A protocol for disputing data validated by the oracle generates considerable delay. The oracle incentives are based on the present value of the oracle token, which should be sufficient. Redundant mechanisms lessen the incentive for the oracle token holders to monitor and discipline data submittors.

### Stay in native AVAX

By using native AVAX for all bets we eliminate unnecessary costly swapping into and out of stablecoins. As stablecoins are generally centralized, we eliminate an attack surface as well. Users will have to bear avax price risk, but this is a minor inconvenience relative to the extra costs created by requiring users to buy a stablecoin.

### LPs and token holders cannot withdraw within an epoch

Flash transactions enable efficient arbitrage, but the benefits here are low, and the costs are high. Many hacks have been predicated on flash loan transactions. token holders have to wait one epoch, but LPs have to wait three epochs. The LP restriction is longer because otherwise there would be an opportunity to make a riskless profit depositing just before and after settlement when the book is flat, which would generate a riskless return for the LPs; that tactic would parasitize the good LPs supplying real liquidity.

### All relevant data are on the Avalanche C-chain.

There is no way to censor a contract that is completely on a single blockchain.

### No extreme odds

Matches with extreme underdogs (eg, 10-1) are attractive for hackers, as the generate the most revenue for the smallest amount of capital. Initial decimal odds on favorites greater than 7:1 are not accepted. Initial decimal odds for favorites must be greater than 1.150, or less than an 88% probability of a win, or a 7-1 probability of winning. Such matches will simply not be covered. This would eliminate about 5% of NFL games historically, but is common among college football and MMA.

## Odds Stability

The relative stability of straight-up sporting event odds compared to the vig allows for a super high-latency oracle that would never work for swapping tokens. Consider that your average daily stock price volatility of 2.5% is 16 times greater than the average bid-ask spread of 0.15%. A market maker who adjusted their bid-ask prices once daily would be exposed as a 'money pump' by arbitrageurs, in that if the price moves up 2.5%, the market maker will almost certainly have sold on the way up, generating real-time losses.

In contrast, the implicit spread on money line bets is 2.5% in terms of a win probability. This means one needs a 2.5% edge in predicting which team wins to beat the house. The weekly volatility of these odds, when translated into a win probability, is less than 1.0%, implying the book would make money even if it used early-week odds. In practice, the closing line and opening lines for NFL betting are statistically identical.

## Incidence Response Suggestions

There is no outside adjudicator to rectify problems, as this would delay payments and complicate the contract—how to incent the adjudicator? All problems must be solved on-chain within these contracts. As I do not and cannot control the contract, this is advice rather than an official protocol or something automatically enforced within the contract code.

Off-chain odds can change quickly and significantly, exposing the LPs to bets with an objectively negative expected value position. In that case, oracle token holders can immediately pause up to two bets. This action does not require the usual 12-hour vetting period to allow oracle token voting. It does not expose LPs or bettors to more risk, as it just prevents new bets on those matches. Such an action has no upside if this is not true for the oracle.

A more extreme solution to bad data on the betting contract would be to adjust the concentration factor. Remember that the maximum exposure on any one match is the total LP capital divided by the concentration factor. If one sets this to a large number, the maximum bet can bet set to a number below the minimum bet size and so would prevent *any* bets increasing LP exposure. Such an action simply prevents more risk (and potential revenue), and can be rescinded when new odds are pushed to the betting contract.

Lastly, if a hacker could sneak in bad data that enabled an odds cheat, the oracle collective could nullify this action by posting a result of a tie regardless of the outcome. This allows the LPs and bettors to get their money back as if nothing happened, and the ‘incorrect’ but fair tie result should be explainable by the event logs showing the earlier hack. This would be an extreme scenario, like a fork in a blockchain, but it is always good to anticipate a worst-case scenario.

1. Adverse selection for LPs would be when they offer odds and get filled only when it’s an objectively bad deal, as with arbitrage.. [↑](#footnote-ref-2)
2. The wisdom of experts, and the masses, or already in a sportsbook’s odd. [↑](#footnote-ref-3)
3. three Mondays span 14 days [↑](#footnote-ref-4)
4. A flat book does not mean the bet amounts for both teams are equal. For example, a contest could have 5 avax bet on a 5:1 favorite, and 1 avax bet on the underdog, leaving the LPs with zero risk. [↑](#footnote-ref-5)
5. It is equal statistically, that is, over time. Both the oracle and LPs are subject to small sample variation from different sources. If there are no winners, the oracle gets nothing; the LP’s could lose all of the bets where they have net exposure and thus lose money. [↑](#footnote-ref-6)
6. Augur was plagued by bad-faith actors like Poyo-Poyo, whose intentionally deceptive bets were dismissed as the actions of a rogue agent. If the implications of his actions were immediately fatal for Augur he would have been disciplined by those with an equity interest in the dapp. [↑](#footnote-ref-7)
7. 625 = 50.001% of 1250 [↑](#footnote-ref-8)
8. I created something that fills a real niche as opposed to the Ponzi scams that dominate dapps. Online betting, let alone providing liquidity or administering a betting contract, is not legal in my state. [↑](#footnote-ref-9)
9. I did not create such a vault but it should be straightforward, though there are several ways to do this. [↑](#footnote-ref-10)
10. In *Political Parties* (1911), he noted that that rule by an elite, or oligarchy, is inevitable within any democratic organization as part of the tactical necessities of the organization. [↑](#footnote-ref-11)
11. vault independence is not enforced in thi dapp. I am just telling the vault creators it is in their best interest to be independent. They would be worth more, collectively. [↑](#footnote-ref-12)
12. The initial data provider’s tokens are credited as a yes vote, and votes are decided on a simple majority of votes cast. Thus if no one else votes, the data submission will pass. [↑](#footnote-ref-13)
13. The favorite/underdog refers to the opening line, and so over the week the initial favorite may become the underdog. Nonetheless, the ordering is fixed in the initial event posting. [↑](#footnote-ref-14)
14. A negative vig would allow someone to create positions that would generate arbitrage profits. [↑](#footnote-ref-15)