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Prediction Markets: A Review with an Experimentally Based Recommendation for Navy Force-shaping Application

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16 December 2009

by

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Abstract

Prediction markets generally are small-scale electronic markets that tie payoffs to measurable future events. They are similar to stock markets, in which the "stocks" are outcomes or events rather than shares in a company. The growing popularity of prediction markets reflects the notion that markets are an excellent means of efficient information aggregation among a disparate group of people. Trading prices in the prediction markets provide decision-makers with a timely, accurate, and continuously updated picture on the likelihood of future events. This enables decision-makers to better evaluate risk. Based on historical successes in prediction market utilization, it is both logical and important to assess the usefulness of prediction markets as they contribute to critical elements of Navy total force-shaping.

Navy Manpower, Personnel, Training, and Education (N1) regularly forecasts re-enlistment rates, over/under endstrength, and many other force-shaping factors as an input into their resource allocation decision-making process. In an effort to improve upon the force-shaping decision-making process, N1 has shown interest in using prediction markets to complement or replace alternative methods for forecasting various Navy force-shaping elements.

The aim of this thesis is to act as a foundation for ongoing prediction market research within the Department of Defense (DoD).

Keywords: Prediction markets, information markets, information aggregation, forecasting, force-shaping

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Lieutenant Mike Chinn received a Master of Business Administration degree from the Naval Postgraduate School in December of 2009. He enlisted in the United States Navy in 1992 as a nuclear machinist's mate. He separated from the Navy in 1998 to pursue his undergraduate degree. While attending college, LT Chinn joined the Navy Reserves as an Intelligence Specialist. Upon receiving his Bachelor of Science degree in Biological Studies from Old Dominion University, he accepted a commission as an ENS in 2004 in the Navy Reserves as an Intelligence Officer. He served as the Operations Officer in the Fleet Forces Command reserve unit until coming back to active duty in June 2008 to attend NPS. He is currently assigned to Naval Reserve Forces Command, Norfolk, VA.

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List of Acronyms and Abbreviations

ASVAB	Armed Service Vocational Aptitude Battery
CDA	Continuous Double Auction
CDAwMM	Continuous Double Auction with Market Maker
CFTC	Commodity Futures Trading Commission
DARPA	Defense Advanced Research Projects Agency
DEP	Delayed Entry Program
DJIA	Dow Jones Industrial Average
DPM	Dynamic Pari-mutuel System
FDA	Food and Drug Administration
FutureMap	Futures Markets Applied to Prediction
IEM	Iowa Electronic Markets
MSR	Market Scoring Rules
N1	Navy Manpower, Personnel, Training and Education
NFL	National Football League
NPS	Naval Postgraduate School
PAM	Policy Analysis Market

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I. Introduction

A. Background and Purpose

Prediction markets generally are small-scale electronic markets that tie payoffs to measurable future events. They are similar to stock markets, in which the "stocks" are outcomes or events rather than shares in a company. Private firms are using prediction markets to help forecast key events, such as the success of new products, future profitability, or mergers/acquisitions within their industry. Prediction markets also have been popular as an alternative to polls or surveys. The growing popularity of prediction markets reflects the notion that markets are an excellent means of efficient and effective information aggregation among a disparate and diverse group of people. The strength of prediction markets is that they aggregate knowledge in a clever way, allowing people to digest other people's information and make their own decision based upon the new information, vice simply averaging survey responses. The trading prices in the prediction markets provide decision-makers with a timely, accurate, and continuously updated picture on the likelihood of future events. This enables decision-makers to evaluate risk, and it provides an early warning of possible problems and needed policy changes. Based on private and commercial successes in prediction-market utilization, it is both logical and important to assess the usefulness of prediction markets as they contribute to critical elements of Navy total force-shaping.

Navy Manpower, Personnel, Training, and Education (N1) regularly forecasts future attrition rates, re-enlistment rates, over/under strength, and many other force-shaping factors as these factors help determine N1's future resource allocation. N1 relies on historically based econometrics in tandem with quick-poll data to forecast force-shaping estimates. Econometrics models, however, often produce incorrect predictions.

To improve upon the force-shaping decision-making process, N1 has shown interest in using prediction markets to replace or complement quick-polls and econometrics for various aspects of force-shaping forecasting. The significant potential of prediction markets lies in their ability to efficiently and accurately aggregate current information in any economic environment. Furthermore, prediction markets may offer potential cost-savings against methods such as polling.

The objectives of this research paper are: 1) to consolidate previous prediction market literature to provide a thorough description and assessment of prediction market benefits, limitations, and design and implementation; and 2) to consider the feasibility of utilizing prediction markets as alternative forecasting measures for Navy organizational leadership decision-making. As part of these objectives, we address the following issues throughout:

B. Research Questions

1. What are the key benefits and potential limitations of prediction markets?
2. What does the current literature and practical evidence suggest about prediction market use as a forecasting tool?
3. Can prediction markets be an effective tool for Navy force-shaping forecasting?
4. In what areas should the Navy consider using a prediction market?
5. In conducting a pilot prediction market, what lessons learned can we provide to the Navy regarding the design, implementation, and utilization of prediction markets?

C. Methodology

This research provides a thorough review and overview of previous prediction market literature. Furthermore, it underscores the key benefits and limitations of prediction markets, discusses when prediction markets are best utilized, and addresses their critical design and implementation issues. To better

understand the intricacies associated with market design and implementation, the researchers conducted a practical experimental prediction market. Finally, using the research and experimental lessons learned as a basis, this thesis offers recommendations on the potential forecasting usefulness of prediction markets for critical elements of Navy total force-shaping strategy and policies.

D. Limitations

This research project is limited in scope and breadth due to time and participatory constraints associated with designing and conducting an experimental prediction market. Furthermore, the experiment's participant pool perhaps was not as broad and diverse as preferred for a market of such specificity. Finally, due to time and budget constraints, it was not feasible to ensure all participants were trained properly and collectively on the concept and nuances of prediction markets.[1]

[1] Multiple anonymous post-market survey responses indicate that several initial participants ceased participation due to a lack of understanding. This likely is a result of improper participant training.

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II. Prediction Markets Synopsis

This introduction provides an overview of prediction markets and serves as a prediction market primer for future practitioners. Prediction markets (also known as information, electronic or decision markets) are proposed as an alternative forecasting means for predicting future events. The idea is for prediction markets to supplement existing forecasting techniques, such as quantitative and judgmental methods, when these techniques are unsuitable for predicting future events.

Quantitative and judgmental forecasting methods have limitations. Quantitative methods rely on historical data. These statistical methods are invalid either when organizations simply have not collected the historical data needed to predict future events or when the fundamental nature of the operating environment shifts radically and invalidates implicit assumptions. These situations render quantitative forecasts meaningless. Similarly, judgmental methods also have practical limitations. The Delphi and judgmental bootstrapping methods are the most prominent judgmental forecasting methods and combine the opinions of experts. However, identifying experts, garnering their participation, and making sense of conflicting subjective opinions can be a herculean task (Ashton & Ashton, 1985; Batchelor & Dua, 1995). These practical limitations provide an opportunity for an alternative forecasting method.

A. Definition

Prediction markets do not have a universal name or definition. However, an extended literature review of prediction markets by Tziralis & Tatsiopoulos (2007) chose this definition based upon a definition by Berg, Nelson, and Rietz (2003):

> Prediction markets are defined as markets that are designed and run for the primary purpose of mining and aggregating information scattered among traders and subsequently using this information in the form of market values in order to make predictions about specific future events. (p. 1)

B. Theory

Friedrich Hayek's article "The Use of Knowledge in Society" (1945) describes the theoretical superiority of aggregating widely dispersed information versus relying solely on statistical algorithms or experts. Hayek emphasizes the intrinsic value of implicit information, what is now referred to as tacit knowledge. Simply put, it takes time to learn how to perform a job well even after receiving formal, theoretical education. Additionally, he argues from a resource-allocation perspective that a centralized planning office cannot meet the efficiency of an open market because the individuals only know a very small amount compared to the collective knowledge of society. Therefore, a decentralized economic structure complements the dispersed nature of information spread throughout society (p. 520). Additionally, he challenged himself and his peers to find a method of pulling together this knowledge from the disparate sources.

Prediction markets are based upon the notion of collective intelligence. James Surowiecki's book *The Wisdom of Crowds* re-popularized Hayek's ideas in 2004. The book asserts that, under the right circumstances, the collective knowledge of a group can be superior to the smartest individual members of the group. Surowiecki states four criteria are required for groups to demonstrate collective intelligence (2004, pp. XVIII–XIX):

- Diversity of opinion
- Member independence

- Decentralization
- A mechanism to aggregate opinions

Prediction markets are proven information aggregation mechanisms. Moreover, previous empirical evidence supports the position that prediction markets are more accurate than quantitative and judgmental methods at predicting the likelihood of future events. Herein lies the competitive advantage for prediction markets. Subsequent chapters discuss prediction market accuracy in greater depth.

C. Prediction Market Anatomy

This section will provide a brief framework to increase readers' understanding of how prediction markets work. This will serve as a brief introduction to some of the design factors and terminology; however, these concepts will be covered in detail in subsequent chapters.[2]

1. Design Factors

a. Claim Definition

The claim definition is the question or statement posed to the marketplace traders. The claim definition must account for all possible outcomes.

b. Claim Structure

The claim structure is the means of assigning the associated payoff to market traders. There are three main types of claim structures.

[2] A focused discussion on each design topic below is provided in Chapter V.

(1) Winner-take-all

- Pays out $1 if a specific event occurs
- Pays $0 otherwise
- This claim structure is useful for determining the probability of whether an event will or will not occur.

(2) Index

- Contract pays out the value of a specific future event
- This claim structure is useful for determining the mean value of the market's expectation of a continuous number range.

(3) Spread

- Amount of bet is fixed
- Market trades based on cutoffs that determine whether an event will occur
- This claim structure is useful for determining the median expected probability that an event will or will not occur.

c. Trading Mechanisms

The market trading mechanism is what determines market conduct among all participants; it is that which connects buyers and sellers for market trading. There are three common trading mechanisms:

(1) Continuous Double Auction (CDA)

- Person-to-person trading

(2) Market Scoring Rules (MSR)

- Mathematical algorithm to facilitate liquidity by use of an automated market maker[3]
- Maintains a probability distribution across all possible events

(3) Dynamic Pari-mutuel (DPM)

- Mathematical algorithm to facilitate liquidity by use of an automated market maker
- Operates based on a price function that reflects a continuously updated probability for a given event's occurrence

d. Participation

Active and productive participation is an essential element of prediction markets. Wider participation pools generally provide a greater knowledge base than do narrow participation pools. Thin markets exist when there are few participants and/or participants do not actively participate in such a way to ensure continuous trading occurs. Thin markets are a limitation of prediction markets. Prediction market designers hope for thick markets.

e. Real Money, Play Money and Associated Incentives

Incentives can be useful for enticing participants who otherwise would not engage in the prediction market. Cash incentives are most commonly associated with real-money markets. Play-money markets are among the most prevalent for public and professional use. These markets usually provide some initial endowment of play money. Generally, play-money markets rely on the use of other incentives, such as prizes or points, to elicit participation (Chen, 2005).

[3] Automated market makers are explained in subsequent chapters; refer to page 42 for a more thorough discussion, under Trading Mechanisms.

D. How Prediction Markets Work

In finance, the efficient-market hypothesis posits open financial markets efficiently aggregate all available information into market prices. These market prices reflect all known information and quickly respond to new information leading to a change in price. Organizations are applying this concept to aggregate organizational information by using their disparate and diverse stakeholder group as prediction market traders. Thus, prediction markets offer a real-time mechanism to aggregate this fragmented information in order for organizations to use it to their advantage. The commodities traded are claims about future events in which the market prices represent a real-time, consensus probability about the event's likelihood of occurrence. The market also provides a historical context in which one may see how individual and collective opinions have changed over time.

In general, the trading price depends on the joint distribution of the traders' beliefs, budgets and risk preferences (Manski, 2006). Budgets are intuitively less of a consideration when the market uses play money as currency. Similarly, play money traders may be more apt to take risks that they otherwise would not take with real money. Fortunately, some empirical evidence suggests the accuracy of prediction markets using play money is comparable to real-money prediction markets (Servan-Schreiber, Wolfers, Pennock & Galebach, 2004). This same study concludes that the use of real money is not critical but is one of many ways to motivate well-informed people to trade in the market (p. 250).

The evidence is mixed on the issue of market accuracy when using real versus play money. Rosenbloom and Notz (2006) conducted another study in response to the aforementioned study's assertion that play-money market accuracy is comparable to real-money market accuracy. Although they found that both real and play-money markets provide reasonably accurate forecasts, their

major claim is “that real money markets are significantly more accurate than play money markets when forecasting non-sports events” (p. 63).

Trading prices do not simply reflect an average assessment by the group; they also reflect the degree of confidence the different members of the group have in their estimates (Levmore, 2003). These markets provide an estimate of the probability distribution of the event coming true via the range of trader bets. More impressively, markets using market scoring rules[4] aggregate information and provide a joint probability distribution over many variables by allowing bets on the value combinations of each dependent variable (Hanson, 2003). In other words, prediction markets using a market-scoring-rule mechanism can provide probabilities for events with multiple mutually exclusive dependent variables.

Since traders participate on a voluntary basis in a prediction market, those who participate tend to have information relevant to the particular prediction (Abramowicz, 2007). Additionally, traders in the market have an incentive to trade at their earliest opportunity upon the discovery of new information before the market has fully priced the new information (Abramowicz, 2007, p. 17). Confident traders have the ability to speculate and, thus, move the trading price closer to the actual probability of the event coming true. Therefore, informed, confident traders are progressively more likely to determine trading prices (Abramowicz, 2007, p. 7).

The mere mention of market speculation naturally leads to a discussion of manipulation. Subsequent chapters more fully discuss the risk of manipulation. Additionally, those chapters will present concrete evidence that dismisses the effect of manipulation on prediction market accuracy. However, the next paragraph discusses manipulation from a theoretical perspective.

[4] Market scoring rules are discussed further in Chapter V.

Prediction market manipulation is a potential danger, just as it is in financial markets. However, the motivation for traders to manipulate is not nearly as high as it is in financial markets, especially if the prediction market uses play money as currency. The key is that if traders are aware, in advance, that other traders have incentives to manipulate, they will counteract their manipulation attempts by seeking to push prices in the opposite direction. From a market efficiency perspective, a greater incentive exists for higher participation by informed traders in markets in which traders are not trading according to market fundamentals (Abramowicz, 2007, p. 31). The informed traders can take advantage of the uninformed traders for an easy profit. The upside to the market is that the additional insight by the informed market entrants should increase market accuracy. Thus, attempts to manipulate the market may actually increase market accuracy (Hanson & Oprea, 2009, p. 304).

Whereas insider trading is illegal in the financial markets, it is encouraged in prediction markets. Thus, decision-makers are afforded access to information possessed by employees with "hidden profiles"—those who would otherwise not reveal their information because of the nature of their personality or hierarchical constraints (Dye, 2008, p. 89).

In summary, the trading prices provide decision-makers with a continuously updated picture on the likelihood of future events. This enables decision-makers to evaluate risk and make informed resource-allocation decisions. Ultimately, the power of prediction markets is that they provide incentives to the traders who discover new information and truthfully reveal it while the market provides a mechanism for aggregating trader opinions (Wolfers & Zitzewitz, 2004).

E. Applications

1. Past and Current Applications

The first electronic application of prediction markets was the Iowa Presidential Stock Market. In 1988, University of Iowa economists designed this market to predict the outcome of US presidential elections. In 1992, these same economists presented their first academic findings that suggested these markets were a good information aggregation mechanism (Forsythe, Nelson, Neumann & Wright, 1992). These early studies laid the foundation for prediction markets to be used by others as an information aggregation mechanism.

The Defense Advanced Research Projects Agency (DARPA) was involved with perhaps the most publicized government prediction market experiment to date. In July 2003, the Futures Markets Applied to Prediction (FutureMap) program was intended to explore the power of prediction markets to aggregate information to thwart future terrorist attacks. Politicians and journalists opposed the FutureMap program idea in the media. They publicly attacked DARPA on the grounds that it was unethical and in bad taste to place wagers on the fate of foreign leaders and the likelihood of terrorist attacks (Looney, 2003). Thus, DARPA cancelled the FutureMap program on July 29, 2003, the day after it was announced (DARPA, 2003, July 29).

The FutureMap program never got the Policy Analysis Market (PAM) out of the planning phase. Thus, it was never operational. However, at least one analysis has found that it would have been self-defeating (Richey, 2005). The argument is that PAM could be effective if it only attempted to predict terrorist attacks. However, the predictions surely would have been acted upon; world leaders would surely have attempted to prevent the predicted terrorist attacks. This prevention action would subsequently reduce the chance of the event occurring. This would be an excellent collective outcome if it indeed led to the prevention of a terrorist attack; however, it would undermine the self-interested

traders' attempts toward individual profit by reducing the chances of the event occurrence (Richey, 2005). Applied to other prediction markets, this phenomenon can also exist if a decision-maker changes course based upon the prediction market forecast.

Some businesses, especially in the technology and pharmaceutical industries, have had a high degree of success employing prediction markets. These companies have used internal prediction markets to forecast quarterly sales with better accuracy than their forecasting departments. Google has used prediction markets to determine how many people will use their applications, such as Gmail (Dye, 2008, p. 87). They have been able to make resource-allocation decisions such as server capacity to support this number of users. Similarly, pharmaceutical companies have used prediction markets to determine which drugs in their experimental process have the best chance for approval by the Food and Drug Administration (FDA). Thus, they are able to make resource-allocation decisions based on those drugs that have the highest probability of successfully making it to market.

Table 1 details client organizations, the type of prediction market they are using and their purpose from one prediction market provider, namely Spigit. Businesses employ prediction markets to aid their forecasting. Some examples are product delivery dates, product uptake rates, manufacturing capacity needs, product ideas, marketing campaigns and competitive actions. Similarly, the government and its agencies may be able to use prediction markets for public policy and decision-making.

Table 1. Spigit Prediction Market Use Cases
(From Spigit, n.d.)

Company	Market Type	Target Community	Purpose
Top 10 Pharmaceutical Company	Restricted Betting Market	A community of biochemists, managers, and IT professionals	Predict effectiveness of candidate compounds for treatment, likelihood and timing of FDA drug approval, completion date of internal development projects
Major European bank	Continuous Double Auction Idea Market	All bank employees including managers, IT, customer-facing agents	Determine likelihood of an idea succeeding as a financial product or service
Fortune 500 Telecommunication Company	Idea Market with Market Maker Trading	Started with managers and senior technologists; soon to expand to all rank-and-file employees	Decision aid in selecting ideas for immediate "angel" investment
Major Insurance Company	Prediction Market with Market Maker Trading	Invitation only community of thought leaders	Predict business and consumer trends affecting success of ideas proposed in the idea management portal.
Fortune 500 Retail	Restricted Betting Market	Multiple user groups including employees, vendors, customers depending on the usage.	Applied mainly in the product marketing area to gauge product demand, packaging preferences, etc.
Fortune 500 Tech	Prediction Market with Market Maker Trading	International community of employees, partners, vendors, and customers.	Used in conjunction with ideation event to assess potential of selected ideas in terms of commercialization, partner adoption, etc.

2. Future Applicability

Organizations looking to improve their forecasting of contentious issues are likely to benefit from prediction markets. The prediction market acts as not only a mechanism by which many people can state their beliefs, but also shows how strongly people feel about their particular belief(s) in a quantitative fashion. If so inclined, the other participants are able to adjust their opinions based upon the rationale of other traders. As this cycle continues, participants provide a comprehensive rationale for the disparate viewpoints within the group.

Organizations considering using prediction markets should start with pilot programs so they can compare the results with traditional forecasting techniques. A learning curve will occur as organizations determine which circumstances and participants are most likely to result in accurate forecasts.

Prediction markets are unlikely to be useful when:

- Outcomes have a high degree of predictability.
- There is not any dispersed information to aggregate.
- There are only a limited number of knowledgeable traders.

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III. Benefits and Limitations

Prediction markets are powerful and efficient forecasting tools that organizations can use under a multitude of external conditions. Prediction markets carry with them several key benefits and potential limitations, which organizations must fully understand and appreciate to utilize prediction markets effectively. This chapter examines the most critical of those benefits and limitations and provides greater insight and supporting evidence for each in relation to a Navy context.

A. Key Benefits

Prediction markets have a proven record of accomplishment in the corporate context. Such a record comes only from years of effort, challenge, error, perseverance, and insight. The insight resulting from previous experimental and practical applications is, perhaps, most valuable from the list above. It is this insight that develops and reinforces understanding in the ways prediction markets ought to be used. Moreover, it is this insight that develops and reinforces understanding of the various strengths and capabilities of prediction markets. The following three sections examine and reflect upon the key benefits of prediction markets: their dynamic nature, accuracy, and potential for anonymous revelations.[5]

1. Dynamic Nature

A major advantage of a prediction market is its dynamic nature. Prediction markets generally are capable of continually aggregating information, keeping market managers well informed as to the group's fluctuating collective belief on the probability of a given event's occurrence. The prime advantage to a

[5] This is the act of revealing or extracting information while protecting participant identities.

prediction market's dynamic nature lies in that prediction market's ability to reflect participants' collective beliefs in light of external environmental impacts, such as significant fluctuations in the public stock markets, the likelihood of war, key political elections, changes in public or private policy, as well as numerous other possibilities. Tziralis and Tatsiopoulos (2007) captured the spirit of this notion and went further with the following excerpt:

> In contrast to traditional approaches, the operation of the prediction market is not affected at all by possible changes in types and sources of information or even the number of inputs or participants. Prediction markets are by nature able to transform unlimited amounts of timely and locally dispread qualitative information into accurate quantitative forecasts about the future. (p. 257)

The dynamic nature also enhances efficiency. As Tziralis and Tatsiopoulos observe, “Some of the most difficult steps in a typical forecasting application are to mine, namely to collect, merge and clean relevant data from human experts” (2007, p. 256). With that, prediction markets are an excellent mechanism for accomplishing and overcoming such tasks. Moreover, some evidence suggests that because of their dynamic nature, prediction markets can provide increasingly improved forecasts over time. This generally is indicative of the information improving over time; in other words, prediction market participants become better informed and more adept at using the markets and more fully embrace their capabilities. Overall, this leads to improved forecasting over time. In 2008, *McKinsey Quarterly* convened a roundtable to discuss key issues relating to prediction markets and their use in the corporate environment. Among the panelists was Bo Cowgill, Google's product manager, who is a leading individual in implementing and managing prediction markets within Google. Mr. Cowgill offered the following observation that supports the ideas above, “The longer you work at Google and the longer you trade in the prediction markets, [...] the likelier you are to have a successful trading record. [...] The market as a whole got smarter [...], and we could observe a steady improvement over time” (Dye, 2008, p. 88).

2. Accuracy

Accuracy is a principle advantage of prediction markets. Prediction markets can quickly pull together information spread across many people and places, and the accuracy of the results can rival most any alternative forecasting method under optimal conditions. Tziralis and Tatsiopoulos (2007) affirm this belief:

> The forecast accuracy of an efficient prediction market is, under the condition of efficiency, optimum. In practice, prediction markets usually tend to perform at least as well as the single best individual, without requiring knowledge of who that individual is in advance. (p. 256)

Not only can prediction markets match the accuracy of experts and alternate forecasting methods, prediction markets are capable of surpassing these measures under the right conditions. Furthermore, prediction markets have accurately performed across a variety of dynamic event subjects: from political polling to corporate performance goals, and from important Wall Street news to the latest Hollywood releases (Servan-Schreiber et al., 2004, p. 244). In supporting this idea, Robin Hanson (2003) cites several specific examples that illustrate prediction market accuracy: Iowa Electronic Markets (IEM) forecasts repeatedly outperformed opinion polls on various US presidential elections; Hewlett-Packard markets bested traditional printer sales forecasts in 75% of the observances; and prediction markets outperformed four of five expert columnists in selecting the 2000 Oscar winners (p. 107).

Aside from their ability to improve upon alternate forecasting methods, prediction markets also are capable of accurately incorporating information more quickly than other methods. For instance, one might assume that a prediction market on a given presidential election would follow the lead of traditional polls. However, Forsythe, Nelson, Neumann, and Wright (as cited in Abramowicz, 2003, p. 18) contend that analysis of the 1988 IEM highlights that traders conducted trades based on information that was subsequently mirrored in the

polls. In other words, traders accurately predicted changes to the candidates' expected voting returns based on information aside from traditional polls, and the "poll results did not drive market prices" (Abramowicz, 2003, p. 18).[6] This supports the idea that prediction markets are capable of aggregating given information more quickly than some alternative methods, ceteris paribus. Although the IEM case results above are not conclusive, they are intriguing, and they do offer supportive evidence on the performance capability of prediction markets.

All told, the accuracy of prediction markets may not be superior to alternative forecasting methods. However, numerous studies and experiments repeatedly have shown prediction market accuracy at least approximates that of alternate methods. For instance, Wolfers and Zitzewitz (2004) analyzed data from a TradeSports contract that paid out only if Saddam Hussein was removed from power by the end of June 2003; their analysis shows that the market price directly corresponded to both fluctuating oil prices and an expert journalist's estimate of the likelihood of a US-Iraq military conflict (pp. 112–113).

Accuracy can suffer greatly in some cases, such as when participation is minimal, or when information is not readily available or easily interpreted by participants. In such instances, managers should view prediction market results with a skeptical eye. However, under desirable market conditions, prediction market accuracy likely will approximate that of alternative forecasting methods; thus, under such conditions, accuracy may not be the ultimate determinant of whether an organization should utilize prediction markets. Rather, the nature and amount of information desired, as well as organizational objectives, may have a more prominent role in such a decision. Nonetheless, if various forecasting methods are considered for a given objective, an organization should closely

[6] In fairness, Abramowicz (2003) contrasts this point by citing a similar election study in the Netherlands that did not reach the above conclusion (pp. 18–19).

examine the motivation, skill, and efficiency of its current forecasting experts. Generally, these experts will provide accurate and useful information. However, Abramowicz (2003) asserts there are times to believe prediction markets may provide greater efficiency or objectivity than expert forecasters: "It is in governmental decisionmaking [*sic*], however, where there is the greatest reason to be suspicious of experts, either because of external influence or because of ideological agendas" (pp. 20–21). For this reason, and others discussed throughout this thesis, prediction markets can benefit government.

3. Anonymous Revelations

Another key benefit to prediction markets is their ability to aggregate information from perhaps otherwise unwilling participants. Often, employees find themselves choosing to withhold information about various aspects of their work. This withholding of information can be for any number of reasons, such as protecting their reputation, character, or job out of fear of what a superior might do with the information. Moreover, some employees may withhold information to maintain an element of expert power or control. From an organizational behavior standpoint, such control may serve as leverage in maintaining status or exchanging reciprocal benefits among co-workers. Beyond this point, some employees act in a role that keeps them relatively hidden in terms of expressing opinions or beliefs on an organization's operations. Todd Henderson[7] describes this in the following way, "information can reside in […] what academics call 'hidden profiles.' These are people within an organization, who because of their personality or position in the hierarchy, won't have the incentive or wherewithal to reveal information" (Dye, 2008, p. 89).

[7] Todd Henderson served as a panelist on the McKinsey prediction market roundtable. At the time, he was an assistant professor of law at the University of Chicago Law School, with a background in law and economics.

Prediction markets are an excellent means of bringing out sensitive knowledge and opinions. Through anonymity, prediction markets allow any employee to have an equal say by enabling hidden employees and shielding fearful or hesitant employees. Prediction markets can foster a spirit of participation by motivating employees to discover and share information, while breaking down personal or political organizational barriers (Tziralis & Tatsiopoulos, 2007, p. 257).

B. Potential Limitations

Because of years of hard work and research in this field, prediction markets are now better understood, and their use is more reality than possibility. However, prediction markets are not without weaknesses. Just as experimental and practical application led to insights regarding the strong suits of prediction markets, such applications also led to insights regarding the shortcomings of prediction markets. The following four sections identify and expound upon the key potential limitations of prediction markets: issues associated with participation, manipulation, biases, and legal restrictions.

1. Participation

Active and productive participation is an essential element of prediction markets. Without active participation, a prediction market cannot realize its full potential, and organizations cannot tap into the associated benefits of prediction markets. Participation heavily hinges on potential participants' intrinsic interest or desire to participate, incentives used to elicit such participation, and even on participants' understanding of the prediction market and its associated questions of concern. According to James Surowiecki, "One shortcoming is that a lot of people inside organizations don't find the market mechanism intuitive or easily understood. They find it very challenging to use, which limits the pool of people who participate" (Dye, 2008, p. 89). This can lead to a problem with attracting a diverse participant pool, and more specifically, a problem with attracting

uninformed traders.[8] Additionally, prediction markets are susceptible to an irrational participation problem in which rational traders have no further incentive or desire to trade once they already have hedged their bets (Hanson, 2003, p. 108). For these reasons, and others, prediction markets may become thin. The following sections discuss problems associated with thin markets and the inability to attract uninformed traders, as well the importance of participant training.

a. Thin Markets

Prediction markets require a sufficiently large and continuously active participant pool. The greater the number of traders and the more diverse the participant pool, the more likely a given prediction market will efficiently and accurately aggregate information. Moreover, such conditions generally are necessary to incite participants to discover or reveal new information pertinent to the market. Thin markets exist when there are few participants and/or participants do not actively participate in such a way to ensure continuous trading occurs. This does not suggest, however, that a market that reaches equilibrium is a thin market. Rather, a thin market is one that generally stagnates without reaching equilibrium.

Thin markets can occur because of poor planning or minimal management support. Organizations are at risk of dooming any given prediction market from its inception when they implement a market without properly planning for the right number and demographic of respective participants. Thin markets also can result from market managers introducing too many questions into the marketplace, thereby allowing participants to dilute their limited trading resources. Additionally, when market managers introduce questions that require a high degree of specialization for forecasting purposes, such questions may attract a very limited

[8] Uninformed traders are those traders who do not possess legitimate or relevant information with respect to a given market. Uninformed traders are necessary to assure market liquidity. A more thorough discussion follows on page 25.

number of participants. With limited participation, the last trade on a given prediction market likely will not be representative of the participants' collective belief on the probability of a given event's occurrence. This is possible because relevant information may be concentrated in only a few participants or in traders who already have hedged their bets in other markets (Abramowicz, 2003, p. 24).

A thin market generally leads to comparatively large price fluctuations, and it may not reach equilibrium—due to the lack of trading activity within the market. Price fluctuations often occur because of relative information asymmetry that exists among the various traders. In particular, increasing degrees of information asymmetry in double auction markets will lead to increased bid-ask spreads; as a result, participants will conduct trades less frequently (Abramowicz, 2003, p. 24). Robin Hanson (2003) offers the following example, "Consider the case where a single person knows something about an event, and everyone else knows that they know nothing about that event. In this case, standard information markets based on that event simply cannot acquire this person's information" (p. 108). Due to the price fluctuations in thin markets, decision-makers should not blindly trust short-term price spikes. Rather, decision-makers should utilize a price-smoothing method—such as averaging prices of a set number of days prior to the market's closing—to diminish effects of extreme price fluctuations prior to making subsequent decisions on the market's data (Abramowicz, 2003, p. 14).

Although there are no straightforward solutions to thin markets, Hanson (2003) argues that market scoring rules can help correct problems associated with thin markets. Market scoring rules use a mathematical algorithm to avoid dependence upon person-to-person trading—the algorithm updates market prices for a given market based on that market's trade history. Hanson's market scoring rules are discussed more fully in Chapter V. Additionally, Chapter VI

reports observed aspects of Hanson's market scoring rules, as they act as a basis for Inkling's[9] prediction market platform.

b. Attracting Uninformed Traders

As mentioned above, prediction markets require a relatively large and diverse group of active traders. Often, a critical issue with prediction markets is attracting both informed and uninformed traders. Informed traders are those who possess legitimate knowledge—knowledge that is not based purely on speculation or hearsay—with respect to a given prediction market; conversely, uninformed traders are those who do not possess such knowledge. Information can only be relayed and exchanged within a given market when some information gap exists. This existence of an information gap heavily relies on the presence of uninformed marketplace traders. According to Wolfers and Zitzewitz (2006), "the success of the prediction market in generating trade depends critically on attracting uninformed traders" (p. 7). It should be noted that although organizations can attempt to ascertain or predetermine which traders are informed or uninformed, this cannot be simply determined. In fact, it is quite improbable that organizations will know which traders are informed until prediction market results are available. Nevertheless, organizations must make every effort to attract a sizeable and diverse participation pool, specifically to include uninformed traders.

To attract uninformed traders, organizations must understand the underlying motivations of potential participants. Generally, the pure thrill of competition and the side-effect of personal entertainment is enough to pique some potential participants' interests. Competitiveness, overconfidence, and a desire for entertainment are intrinsic values that many humans share;

[9] Our experimental pilot marketplace used Inkling's platform. This is discussed more fully in Chapter VI of this thesis.

organizations will do well to tap into these natural sources of motivation to develop an efficient and liquid market (Wolfers & Zitzewitz, 2006, pp. 7–9).

However, incentives are likely necessary to draw in a fully diverse and sufficiently large body of participants. Prediction market experts support this point widely, and it is highlighted in Chapter VII. Organizations must appropriately match incentives to the participant pool, and they must fully consider the way(s) in which they should incentivize participants. For instance, if organizations only reward the highest earner for a given period or market, many participants may stop trading once they no longer have a chance to contend for the reward. Conversely, some participants may make large investments in unlikely outcomes to have a chance at becoming the highest earner—this of course leads to market inefficiency and affects overall market accuracy. Beyond considering who and when to reward, organizations must also consider the types and nature of rewards. This last aspect can become quite challenging, and it may require a great deal of creativity to keep the marketplace fresh, fun, and interesting. Jeff Severts,[10] Best Buy's prediction market pundit, shared the following regarding the challenges of attracting and incentivizing participants, "You always have to be marketing them [prediction markets], just like everything else. [...] Every quarter, you have to refresh your list of prizes and try to come up with something at least as compelling as the last time" (Dye, 2008, p. 89).

To close, the participation issue cannot be overemphasized here, and it certainly cannot be overlooked upon implementation. Participation is the most critical aspect in the practical application of prediction markets. Regardless of who sponsors a given market or what questions managers ask, a prediction

[10] Jeff Severts served as a panelist on the McKinsey prediction market roundtable. At the time, he was the Vice President and General Manager of Best Buy's Geek Squad, with work involving forecasting models and prediction markets.

market has little chance of aggregating information effectively if appropriate incentives do not exist or the participant pool is not appropriately diversified.

c. Participant Training

Participant training can be an underappreciated element in the market implementation process. If an organization does not properly train participants, providing them with a base understanding of the prediction market concept, then the marketplace may struggle to maintain participants in the pool. Following the experimental prediction market conducted in association with this thesis, an anonymous post-market survey was conducted to poll participants on the implementation, operation, and outcome of the experiment. Multiple survey responses indicated that participants stopped trading because they did not understand the markets. This likely resulted from improper participant training.

Although it is imperative that market managers attract uninformed traders, it also is essential that at least the majority of the traders understand the prediction market concept. Traders must realize that not everyone will be an informed trader in every market. In fact, most traders will not be fully informed in most markets. It is neither realistic nor efficient for the majority of participants to be fully informed, as the market would become stagnant without information asymmetry, which is necessary for trading to occur. However, each participant may have some general and unique information with respect to certain markets. Therefore, participants need to understand that in every market, some uninformed traders must participate to ensure market efficiency, even if this means trading only on inclinations or market trends. It is a matter of knowing, understanding and embracing the various roles within the market's participation pool, as well as understanding that traders can act in various roles at various times.

d. Understanding Trading Strategies: Short Selling

To further enhance market efficiency, the majority of traders must understand the ways in which they can utilize their market currency within a given market. More specifically, traders must understand that they have the ability to trade long or short. In addition, they must know how best to do either, based on given market conditions and their belief that a given event is likely to occur.

Trading long is intuitive and relatively easy for most traders to understand and embrace. The basic gist is to buy low and sell high, or hold for an expected positive payout following the market's close. Market inefficiencies can occur when traders do not understand or embrace their opportunities to sell short. Short selling is the act of bidding against (or selling shares one does not own) an event contract that a trader believes has an over-valued (or too high) probability of occurrence. It effectively is the reverse of trading long. With short selling, one effectively sells high, and later buys low—the twist is the seller does not own any shares at the time of the sale, but rather sells on credit with a promise to purchase the same number of shares at a later time. In other words, if most of the market participants believe an event will occur, and a few traders believe that the event has a low probability, then the few can conduct short-sales with an expectation that prices ultimately will drop or move to zero at market closing. According to Brigitte Yuille, short selling contributes liquidity, efficiency and a voice of reason in bull markets (Yuille, n.d.).

An example can help illustrate the process and its advantages: we can assume a given market price is $ 0.80, with payoffs set at $1.00 if event *y* occurs and $0 if event *y* does not occur—one can infer that the market collectively assesses an 80% probability of event *y* occurring. First, we consider the act of trading long. If trader Joe believes event *y* will occur, he may purchase one share at $ 0.80. If event *y* occurs, trader Joe is paid $1.00; he profits $ 0.20 ($1.00 payout minus his $ .80 purchase price). Now, we assume trader Joe does not

believe event *y* will occur; he may elect to short-sell event *y*. Trader Joe would sell one share at $ .80, with a promise to buyback that one share at a later time. If he holds the share, and the market price decreases to $ .30, he may buy back the one share at $ 0.30. Thus, trader Joe profits $ 0.50 ($ .80 revenue from the initial sale minus $ 0.30 from the buyback). Moreover, if he holds the share until the market closes, and event *y* does not occur, he will buy back the one share at $0. Thus, trader Joe profits $ 0.80 ($ .80 revenue from the initial sale minus $0 from the buyback). However, if trader Joe conducted his short-sale as above and event *y* does occur, he would *lose* $ 0.20 ($ .80 revenue from initial sale minus $1.00 from the buyback).

Buyback can occur at any time prior to market closing; thus, the figures above are purely arbitrary for the sake of illustrating the concept. People often conduct their buyback prior to market closing either to collect profit from a decline in a contract's market price or to cut losses from a subsequent rise in a contract's market price. In a short-sale, the risk of loss is much the same as that associated with trading long, but the risk may be greater in terms of amount per share when one sells-short against low-probability events.

Risk of loss is not the only drawback to short selling. When a trader short-sells, a portion of that trader's marketplace assets are placed into holding until the subsequent buyback occurs, and these funds in holding cannot be used for any other marketplace security until the buyback. The amount held in reserve is equal to the maximum cost of buying back every shorted share under the worst-case scenario—this is roughly equal to the number of shares shorted multiplied by the positive payout price. This means that significant portions of a trader's market assets may be held in reserve for high-volume short-sales, which ties up valuable assets from other marketplace ventures.

Traders must understand the implication of short selling, as it can greatly affect the way in which they choose to conduct trades with their personal

knowledge under given market conditions. Furthermore, if traders do not understand the above implications, the market as a whole cannot function as efficiently as possible. New information may be revealed much more slowly, or not at all.

Proper training can help establish baselines for participants with respect to efficient trading strategy. Good training can minimize much inefficiency before it occurs, and it can prevent traders from becoming frustrated by common but unintuitive marketplace occurrences. This, in turn, helps maintain a reliable participation pool.

2. Manipulation

Manipulation is a common concern when decision-makers are considering prediction market utilization. There are several instances of known attempts to manipulate prediction markets, though these attempts at market manipulation generally have failed. However, it is conceivable that some participants may attempt to manipulate a given market. For instance, some unethical traders may explicitly and intentionally spread false information to drive down the price of a given contract subsequent to short selling within that market (Yuille, n.d.). Furthermore, traders may attempt market manipulation to personally profit or to influence decisions linked to a prediction market. However, profit motives for all participants generally ensure such manipulation attempts are not successful (Wolfers & Zitzewitz, 2004, p. 119). Since all traders have incentives to predict accurately, any erroneous or manipulative trades likely will be counteracted and corrected by other knowledgeable and informed traders.

In terms of manipulation for personal profit, Wolfers and Zitzewitz (2006) highlight several examples in which known manipulation attempts resulted in only short-term price fluctuations, which the markets subsequently corrected within 24 hours (p. 11). However, the examples cited by Wolfers and Zitzewitz involved relatively thick markets. The extent to which a given market can be manipulated

depends on the market's thinness (Wolfers & Zitzewitz, 2004, p. 119). With a thin market, the potential for market manipulation is greater because the ability to fend off manipulation attempts resides with many fewer participants.

With respect to manipulation to influence resultant decisions, such attempts can involve individuals or groups. In particular, Michael Abramowicz discussed the notion of unrepresentative decision-makers that make or influence resultant decisions (Abramowicz, 2003, pp. 46–51). Abramowicz suggested that prediction markets that affect resultant decisions could have a participant pool that lacks diversity or is unrepresentative of the general population that is affected by the resultant decision(s). In such cases, the non-diverse participant pool either may intentionally, or through an unintended social judgment bias,[11] systemically provide unrepresentative inputs into the prediction market leading to a particular resultant decision. Again, this is of particular concern with thin markets. Decision-makers must be aware and consider such possibilities when utilizing prediction markets and establishing associated participation pools.

3. Biases

Biases are important elements for decision-makers to consider when assessing prediction market accuracy and correlating market prices to event probabilities. Biases affect how people interact, perceive, and share information. This strong sense of perception related to critical events and conditions can lead people to conduct trades somewhat irrationally. Moreover, biases may cause participants to repeatedly over- or under-value specific contracts. The following sections briefly discuss four of the most prevalent biases of which decision-makers should be aware: 1) over-optimism, 2) under-pricing of extremes, 3) long shot, and 4) social judgment.

[11] See page 33 for more on social judgment bias.

a. Over-optimism

The over-optimism bias is one in which employees hold an overly optimistic view of their organization and/or its ability to achieve certain goals. Most organizations generally would appreciate having a problem such as this, but this bias can affect prices and associated probabilities among prediction markets related to an organization's goals or performance. Bo Cowgill noticed this bias in Google's prediction markets:

> The cause seems to be new employees, whose trades show that they are highly optimistic about our company. The external Google stock price also seems to play a role. [...] People feel excited about the company when the stock performs well, so they're more likely to bet that good things will happen to Google. (as cited in Dye, 2008, p. 88)

b. Under-pricing Extremes

Under-pricing extremes is a common occurrence in which generally risk-averse participants underestimate the likelihood of low-probability events. This may be especially prevalent when a market has contracts with a relatively high actual probability of occurrence; by default, such markets will have some contracts with relatively low actual probabilities of occurrence. In this case, traders may under-price the low-probability event(s) by trading more heavily in favor of the high-probability event(s). In effect, traders may assume away the possibility of a low-probability event actually occurring. For instance, Google observed this bias when utilizing prediction markets to forecast the number of people who would use a given service: "When we floated contracts with five different outcomes—for example, forecasts about the number of Gmail users—the highest and the lowest outcome happened more often than the market expected" (as cited in Dye, 2008, p. 88).

c. Long Shot

The long-shot bias is nearly the opposite of under-pricing extremes. Many risk-seeking people will overestimate the probability of low-probability events

occurring. This can also lead to price or probability distortion, as high-probability events have prices that reflect lower-than-actual probabilities; conversely, low-probability events have prices that reflect higher-than-actual probabilities. The effects of long-shot bias and under-pricing extremes might counterbalance one another in markets characterized by both biases, although to our knowledge no empirical evidence exists to support this.

d. Social Judgment

Social judgment is based loosely on social judgment theory; to our knowledge, it is not a supported theory or bias among economists or prediction market experts. However, social judgment is used here as a way of categorizing and labeling all personally and professionally held biases that are based on one's prior experiences, current circumstances, and any associated social networks (whether formal or informal in nature). The principle idea is that all people hold biases that are continuously formed and reshaped by socio-psychological experiences over the course of their lives. In general, decision-makers may assume that such biases are universal, unavoidable, and have no net effect on a prediction market. However, we hypothesize that in some instances, this bias could affect a given market.

To understand the way in which social judgment may affect a given market, one first must understand the ways in which such biases are reinforced. People tend to socially network in unique and recurring ways; when people socially network with others who possess common social biases, the social judgments of the group may become reinforced or strengthened. This strengthening of judgments likely depends on the size of the social group involved, as well as the strength of respective individual biases among the group. Depending on a given organization's size and makeup, as well as the nature and amount of information sharing in which it engages, the group strengthening of judgments could potentially skew prediction market probabilities for a given market. In short, the chief concern for this bias arises when a prediction market

operates with a participant pool that, unintentionally or not, is homogeneous. Such a group likely would share subjective opinions and beliefs across a number of topics.

Interestingly, a *benefit* may also be gained from the social judgment bias. Again, depending on a given organization's size and makeup, as well as the nature and amount of information sharing within it, this bias may serve to highlight the ways in which information is gathered and shared within that given organization. This may offer insight to an organization's formal and informal social and communication networks. Google's Bo Cowgill recognized observable network communication patterns among his employees during prediction market trading:

> Our [Google's] markets showed that beliefs are clustered, and these clusters are made up of individuals who physically sit and work close to each other. [...] Clusters also form around working together, socializing outside of work, and speaking a common language, even when this doesn't involve sitting close by. (as cited in Dye, 2008, p. 88)

4. Legal Restrictions

Legal restrictions may present one of the chief limitations of prediction markets. In particular, anti-gambling laws are the principal barrier to real-money prediction markets (Hanson, 2003, p. 107). Moreover, Arrow et al. (2007) claim, "Current laws and regulations affecting the use of prediction markets in the United States are likely to stymie innovation, and thus reduce economic welfare" (p. 2).

However, Arrow et al. (2007) suggest three ways an organization may reduce its legal risk with respect to real-money prediction markets: 1) obtain a no-action letter from the Commodity Futures Trading Commission (CFTC), 2) provide allotments to participants so they do not risk losing their own money, and 3) list the prediction market on a traditional futures exchange (p. 2). Interestingly, Arrow et al. (2007) also observe that while the CFTC oversees several prediction

markets at the federal level, only the Iowa Electronic Markets operates with real money because “its [IEM] researchers were able to obtain a letter from the CFTC that permitted them to do so under certain limited conditions” (p. 2).

This chapter has highlighted the key benefits and limitations associated with prediction markets. The following are the key benefits of prediction markets: their dynamic nature, accuracy, and potential for anonymous revelations. Prediction markets are dynamic in nature; that is, they are capable of efficiently aggregating information in a continuous manner. Additionally, prediction markets are capable of performing their information aggregation with a high degree of accuracy; they can quickly pull together information spread across many people and places, and the accuracy of the results can rival almost any alternative forecasting method under optimal conditions. Moreover, prediction markets allow users to express personal opinions and beliefs on specific topics in an anonymous fashion; this encourages feedback at all organizational levels without any fear of management or peer reprisal.

The chief limitations of prediction markets addressed in this chapter are those associated with participation, manipulation, biases, and legal restrictions. Prediction markets require some minimum level of participation to avoid stagnation; without enough participants in the active pool, active traders may lose interest and/or incentive to share their information with other active traders. Additionally, manipulation can become a viable concern in prediction markets that have little active participation. This chapter also discussed the following biases that can affect trading and, thus, accuracy: over-optimism, under-pricing extremes, long shot, and social judgment. Finally, legal restrictions can limit some organizations’ ability to easily or efficiently implement and manage prediction markets; legal restrictions generally have the greatest impact on those who seek to utilize real-money prediction markets, as government concerns with gambling and ethics move to the forefront.

IV. When to Use Prediction Markets

Prediction markets can supersede geographic boundaries and cultural barriers by quickly aggregating information, and they can do so with high quality. However, there can be considerable cost and effort involved in establishing these markets. According to Tziralis and Tatsiopoulos (2007), it is essential that organizations use prediction markets when the desired forecast importance is relatively high in order to optimize organizational efforts and spending involved in implementing and maintaining market(s) (p. 257). One of the most critical questions to consider is that of when to use prediction markets. Several factors determine the answer to this key question, including time-sensitivity of the desired information, importance of information and forecasts, required quality, and cost or budget constraints. For simplicity, these factors can be grouped into two broad categories: 1) forecast objectives and 2) market feasibility. The following sections discuss various considerations of each category with respect to determining whether an organization should use a prediction market.

A. Forecast Objectives

By forecasting objectives, decision-makers can better determine the importance of forecasting; these objectives can help lead decision-makers to select the proper forecasting means for the organization's desired ends. Organizations should use statistical and econometric methods when there is sufficient historical data and information to support forecasting (Chen, 2005). Such methods carry cost benefits as well as familiarity and ease of utilization. However, such methods generally cannot match the detail, flexibility, and efficiency that prediction markets offer.

Prediction markets are superior to other forecasting methods in their ability to aggregate dispersed information efficiently. The following excerpt from Yiling Chen's doctoral thesis (2005) supports this conclusion, "Information markets are

more suitable when information about future events is dispersed among an organization or society, especially when information only exists as tacit knowledge or those who have information tend to not reveal it" (p. 120).

Additionally, a McKinsey conference roundtable discussion (Dye, 2008) on prediction markets provides an example that illustrates these sentiments. Among the panelists was Jeff Severts of Best Buy. He offered multiple accounts in which ground-level, employee-based prediction markets bested the conventional forecasting techniques used by his professional forecasting experts for predicting holiday gift card sales (Dye, 2008).

The nature of forecast objectives likely will not be the only factor decision-makers use to determine whether to use prediction markets as a primary forecasting tool. Rather, the obstacles presented through market use also will play an important role. In spite of their strong benefits, prediction markets certainly carry unique limitations. They require a useful body of pertinent knowledge, in addition to an assembly of users who continually participate with an accurate perception of their collective knowledge pool. Wolfers and Zitzewitz (2004) offer a strong assessment of these two requirements:

> As such, these markets are unlikely to perform well when there is little useful intelligence to aggregate or when public information is selective, inaccurate or misleading. […] For example, the public information on the probability of weapons of mass destruction in Iraq appears to have been of dubious quality, so it is perhaps unsurprising that [...] the markets were as susceptible as general public opinion to being misled. (pp. 121–122)

B. Market Feasibility

In determining a market's feasibility, an organization first must fully understand its desired market objectives. The desired results should heavily affect the market's format through specific and clear market contracts (posed questions). Broad or unclear questions will attract less meaningful information

inputs to the market. When determining the feasibility of prediction markets, organizations must consider three key issues:

- Nature of available information,
- Cost, and
- Political and Legal Considerations.

An organization must assess the nature of available information. To make a prediction market worthwhile, decision-makers must have information that is relevant and available for aggregation. Additionally, the number of questions can drastically affect a market's performance. Therefore, an organization should not use too few or too many questions to aggregate information from market participants. If there are too few questions, an organization cannot aggregate information effectively for optimal forecasting. If there are too many questions, market liquidity will decrease, and, in addition, the resource or time-cost for managing the overall market will increase. Moreover, cost is generally the deciding factor when organizations assess desirability of taking on new investments, so increased costs may deter or limit organizations from using prediction markets. Finally, certain political or legal restrictions may present challenges or obstacles to organizations implementing certain prediction markets. The following sections more fully discuss each of the aspects in turn.

1. Nature of Available Information

A prediction market's quality is no better than the sum of the available information it seeks to aggregate. Furthermore, a market relies on informed and uninformed participants to sustain market liquidity and accuracy. Therefore, an organization should only use a prediction market when it expects that the dispersed information is relevant and of high quality. Moreover, an organization must ensure it can properly incentivize sufficient participants to aggregate the desired information effectively. "Whether there are people with relevant information, and whether these people can be attracted to participate are

important for better predictions" (Chen, 2005, p. 123). Thus, failing to meet either condition above should dissuade an organization from developing a prediction market as its primary forecasting tool.

2. Cost

Cost is a critical issue associated with a greater number of questions. With more market questions, the total cost will be higher in the form of additional time and resources necessary for operating and maintaining the market. Moreover, significant time and resources are required to plan, design, and implement a prediction market. In general, the upfront financial burden of the prediction market may seem quite low, making it an attractive option for organizational forecasting; however, organizations must understand that prediction markets require a great deal of time and effort for successful development and operation. Furthermore, much of this time burden will likely fall on existing personnel (such as departmental managers or higher) to ensure the most appropriate and useful marketplace questions are selected and to ensure contracts are clear and formed in such a way as to draw out all desired information.

Clearly, cost is of significant importance since every organization must abide by some form of budget constraint. Effectively, there is finite money and resources available for organizations to invest in prediction markets. As with all sound investments, the benefits of the investment should outweigh the cost or risk of the investment. Therefore, an organization's leaders must conduct sufficient analysis and evaluation when they are assessing the feasibility of utilizing a prediction market for organizational gain.

3. Political and Legal Considerations

Political or legal circumstances may affect an organization's decision to use prediction markets. The DARPA prediction market effort to predict and prevent terrorist attacks is one common example used to highlight an unfavorable political condition for market utilization. DARPA's FutureMap

program came under Congressional and media scrutiny on the following bases: 1) the markets were unethical and 2) adversaries could potentially manipulate markets in their favor. As a result, DARPA shut down the FutureMap program (Looney, 2003).

Legal obstacles can prove equally challenging when decision-makers are assessing the overall environment for prediction market utilization. Gambling and trade regulations pose serious challenges to adopting prediction markets for decision-making purposes. As a result, an organization's leaders must thoroughly consider the market's trade format as well as the means of incentivizing participants. According to Chen (2005), "legal issues of gambling make most public information markets in the United States only play money" (p. 121).[12]

[12] This does not imply that play-money markets are not as effective or accurate as real-money markets. Indeed, a number of experiments have proven differences in accuracy can be negligible between real- and play-money markets. A subsequent section pertaining to participatory incentives develops this idea more fully.

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V. Design and Implementation

A. Design

1. Introduction/Overview

According to Wolfers and Zitzewitz (2004), “The success of prediction markets [...] depend[s] on their design and implementation” (p. 120). Furthermore, in designing a prediction market, an organization must consider numerous factors and details. The next five sections discuss critical aspects of market design, to include:

- Claim Definition
- Claim Structure
- Trading Mechanisms
- Participation
- Real money, Play money and Associated Incentives

2. Claim Definition

Claim definition is one of the most critical and challenging aspects of prediction market design and development. Claim definition is the means by which a market designer communicates his desired purpose or claim end-state to market participants. Practically applied, the claim definition is the question or statement posed to the marketplace traders. Even with an abundance of useful knowledge readily available for aggregation, a poorly defined claim can render a market ineffective by nullifying potential market benefits and usefulness. Wolfers and Zitzewitz (2004) succinctly state, “[f]or a prediction market to work well, contracts must be clear, easily understood and easily adjudicated” (p. 120).

To be effective and legitimate, prediction markets must account for all possible event outcomes. In practice, this means that if one is interested in

assessing the probability of a given football team beating another, market designers must also account for the possibility of a tie. This allows traders to fully interact with one another without doubt or uncertainty in the contract's designed end-state. Accordingly, contracts must have a clear and definite end-state that bears no element of doubt or uncertainty, and they should have an associated pre-determined timeframe for which they are active. For example, the following claim "The Cubs will win a championship" does not provide a clear and definite end-state because it does not specify whether it refers to the World Series (the major league baseball championship), the National League Championship, or something else altogether; each are viable options that any given individual could perceive as satisfying the claim. Therefore, the claim in question is unclear and open to interpretation. Additionally, the claim "The Cubs will win the World Series" does not provide a pre-determined timeframe for which the claim is active. A more appropriate claim is "The Cubs will win the World Series before 2012." This claim is clearly defined, and has a definite end-state and a predetermined timeframe. Though the requirement is challenging, organizations using prediction markets must clearly define all claims for the market to remain effective, efficient, and manageable.

3. Claim Structure

Participants make claims about the future through the prediction market securities. These claims have associated prices and are traded in the prediction market in much the same way as stocks are traded in public stock markets. The claim structure is the means of assigning the associated payoff to market traders. It depends on the security's objective as determined by the claim definition. The most common claim structures are winner-take-all, index, and spread. The following paragraphs describe each of these three structures.

a. Winner-take-all

A winner-take-all structure determines the likelihood or probability of a single event's occurrence. A political election is a commonly cited example. Winner-take-all should be the claim structure for determining the probability that a party or candidate will win. As described by Wolfers and Zitzewitz (2004), "The price on a winner-take-all market represents the market's expectation of the probability that an event will occur (assuming risk neutrality)" (p. 109).

b. Index

An index claim is useful in determining the expected value of a continuous random variable (Chen, 2005, p. 9). The payoff for an index claim is variable and depends on the event's outcome (e.g., a payment equal to the percentage of the popular vote received by a political party or candidate). Consistent with the above election example, an index claim has the ability to forecast the percentage of votes for a given party or candidate during a given election. Wolfers and Zitzewitz (2004) define an index's market price as "the mean value that the market assigns to the outcome" (p. 109).

c. Spread

The spread claim forecasts the probability of a future event's occurrence by adjusting the margin from a fixed suggested probability for a given claim's occurrence. To remain consistent with the example above, a spread claim is useful in determining whether a particular political party or candidate is likely to receive more (or less) than a given percentage of votes during a given election. Deferring to Wolfers and Zitzewitz (2004) helps provide a clearer description of this claim, in addition to the meaning of its results:

> In spread betting, the price of the bet is fixed, but the size of the spread can adjust. When spread betting is combined with an even-money bet (that is, winners double their money while losers receive zero), the outcome can yield the market's expectation of the median outcome,

because this is only a fair bet if a payoff is as likely to occur as not. (p. 109)

Although the three security claim types discussed are mutually exclusive, market managers may elect to use more than one of the claim types to evaluate information associated with a given market. For the example used throughout this discussion, each claim type offers a different perspective of the aggregated information (essentially, with respect to the same event). This can be quite useful for assessing and analyzing market results for organizations to make better-informed decisions.

4. Trading Mechanisms

Appropriate mechanism design is essential when decision-makers are developing a successful market. In short, the market trading mechanism is what determines market conduct among all participants; it is that which connects buyers and sellers for market trading. Interestingly, many trading mechanisms, such as those utilizing an automated market maker, can function without requiring multiple traders to directly interact with one another. Instead, such mechanisms utilize a computerized programming device or mathematical algorithm that acts as a universal buyer/seller for any given transaction. The advantage of the automated market maker is that a trader can buy or sell at any time, regardless of whether other traders want to buy or sell.

By far, the most common trading mechanisms are the continuous double auction (CDA) and market scoring rules (MSR). In addition, the dynamic pari-mutuel system (DPM) holds credence with many experts. Each of these mechanisms is a viable candidate for market implementation; however, organizations must understand the benefits and limitations of each to select the most suitable mechanism for a given market. Descriptions of each mechanism follow.

a. CDA

CDA is a widespread prediction-market-trading mechanism. It functions much like common financial stock exchanges, in which buyers make offers or bids on a security via buy orders, and sellers post an asking price via sell orders. When the buyer and seller prices meet, there is agreement for the sale or trade of a given security. The key benefit to CDA is its familiarity for market managers and participants. Additionally, CDA is appropriate when organizations aspire to forecast a specific point within a broad range of numbers. However, the critical drawback of CDA is its inability to maintain liquidity in thin markets.

Some CDA markets use a market maker (CDAwMM) to help maintain liquidity, but they possess a unique and severe drawback in the form of added risk for the auctioneer or market owner (Chen, 2005, p. 127). As Chen points out, "The auctioneer may lose considerable amounts of money depends [*sic*] on what happens in the future. The cost of the auctioneer is not bounded" (p. 127).

Though slightly more complex than traditional CDA's, NewsFutures is perhaps the most well known example of a CDA marketplace. NewsFutures utilizes an automated market maker to improve liquidity within its markets, but traders buy and sell shares directly from one another through an automatic trade-offer queuing process.

b. MSR

To overcome liquidity shortcomings associated with traditional CDAs, Robin Hanson proposed a scoring rules mechanism, commonly referred to as market scoring rules (p. 107). Wolfers and Zitzewitz (2004) explain that Hanson suggests using a set of scoring rules to allow market participants to trade on "simultaneous predictions over many combinations of outcomes" (p. 120). This allows a market owner to combine market events for a more realistic forecasting assessment rather than simplistically isolating individual events. According to Wolfers and Zitzewitz, "instead of requiring separate markets for each

combination of possible outcomes, traders effectively bet that the sum of their errors over all predictions will be lower" (p. 120). Hanson's MSR effectively acts as an automated market maker that rewards participants for improving the overall quality of market forecasts in a stepwise manner. Chen (2005) provides the following description of Hanson's MSR:

> MSR maintains a probability distribution across all events. Anyone who believes that the probability distribution is wrong can change it at any time. The person then receives a payment [...] according to a scoring rule, and in return, agrees to pay the next person who changes the distribution. (p. 127)

MSR is useful in forecasting a broader or more complex set of outcomes. Additionally, MSR guarantees liquidity since no buyer-seller pricing matching is required for trading to occur. However, because of its design, MSR is not appropriate when forecasting figures within a continuous range of numbers.[13] Although there is some risk or cost required for subsidizing the initial market bet(s), MSR limits the market manager's maximum cost to the initial subsidy. Participants assume all other trading risk by paying (receiving) funds to (from) one another via the market maker and according to the market's scoring rules.

Inkling's public marketplace is a good example of MSR. The MSR acts as an automated market maker by which users can conduct trades via the simple web-interface. Participants can always buy or sell shares within a given market, assuming they have sufficient wealth in their portfolios. The Inkling platform is discussed further in Chapter VI of this thesis.[14]

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[13] This often is overcome, to some extent, by offering multiple contract options, each associated with a given smaller range within the entire range of consideration. Collectively, the smaller ranges are continuous, and they encompass the entire desired range of consideration.

[14] The practical experiment associated with this thesis relied upon Inkling's platform.

c. DPM

Seeking to overcome potential liquidity limitations associated with traditional market mechanisms, David Pennock proposed the dynamic pari-mutuel system and its associated differential equations. In effect, DPM acts as an automated market maker since DPM operates based on a price function that reflects a continuously updated probability for a given event's occurrence. Share prices update dynamically according to the price function, which can be fixed in one of two primary ways: money-ratio or share-ratio. The money-ratio price function "defines the ratio of any two stock prices in the same market as always equal to the ratio of money invested in the stocks" (Chen, Pennock & Kasturi, 2008, p. 4). With the share-ratio, the price function sets the share prices "to equate the ratio of prices of any two securities by the ratio of number of shares outstanding for the two securities at any time of the market" (Chen, Pennock & Kasturi, 2008, p. 2). Because of the ways in which the price functions work, market probabilities are not explicitly inferable from given market prices. Rather, other differential equations translate market prices into given event probabilities, if so desired.

Whether real or play, money from the sale of market securities moves to a collective market pot. For market payout, the market manager deducts any maintenance and transaction fees from the pot and then disperses funds to all market winners, with market losers receiving nothing. Chen (2005) offers a good description of the DPM payout process:

> After the true outcome is revealed, all the money that is lost by those who bet on the incorrect outcome is redistributed to those who bet on the correct outcome. […] Unlike a pari-mutual market, where each dollar always buys an equal share of the payoff, each dollar that people wager in a DPM buys a variable share of the payoff depending on the state of the market. (pp. 127–128)

Familiarity and simplicity are benefits of the DPM mechanism. In addition, unlike traditional pari-mutuel systems that incentivize late trading, DPM

incentivizes participants to reveal good information early. This occurs because the amount invested in the market can only increase over time, which means that market probability predictions are more sensitive to a given investment earlier than later. Additionally, the DPM mechanism has infinite liquidity, as there is no requirement for buyer/seller order matching (Chen, 2005, p. 127). Furthermore, DPM generally is desirable when organizations seek to forecast a specific point within a broad range of numbers. Finally, similar to MSR, there is no manager risk or cost beyond the required subsidy for the initial trade(s).

It is unclear whether any current public marketplaces exclusively utilize DPM. However, the Yahoo!-O'Reilly Tech Buzz Game is one of the most notable DPM applications. The Tech Buzz Game operated from 2005 to 2008 with dual purposes: "One [was] to evaluate the power of prediction markets to forecast high-tech trends. [...] The other [...] [was] to field test the dynamic pari-mutuel market" (Mangold et al., 2005, p. 94). Traders conducted on-demand transactions by buying and selling shares from one another and/or from a market maker—the marketplace interface smoothly masked the market mechanism's mechanics. Traders simply placed orders and watched transactions occur instantly, without knowledge of whether a given trade occurred with another trader or with the market maker.

Selecting an appropriate market mechanism is central to the design process. Organizations must fully understand their own objectives, intended scope, and other likely market limitations when selecting the market mechanism for a given marketplace. Additionally, there is no such thing as a "one-size-fits-all" design appropriate for all organizations. For a given organization, determining which trading mechanism is most appropriate depends on two primary considerations:

- How large is the potential participant pool?
- What type of information is the organization attempting to forecast?

If the potential participant pool is small, the resultant design implication is that an automated market maker is necessary to promote liquidity and avoid high person-to-person bid/ask spreads. Additionally, the organization's selection of market mechanism should depend on the type of information the organization seeks to forecast. If an organization is forecasting mutually exclusive or discrete outcomes, MSR is an appropriate mechanism. However, MSR does not allow organizations to forecast continuous organizational metrics. Rather, the CDA or DPM mechanisms are more appropriate when organizations want to pinpoint a continuous number.

Borrowed from Chen (2005), the data Table 2 summarizes the above mechanisms and their relative liquidity and risk.

Table 2. Comparison of Trading Mechanisms
(Chen, 2005, p. 129)

Trading Mechanism	Liquidity	Market Manager Risk/Cost
CDA	Illiquidity when market is thin	No risk, only matching orders.
CDAwMM	Guaranteed liquidity	Market owner has risk, can incur unbounded cost.
MSR	Guaranteed liquidity	Market owner has limited risk, can incur bounded cost.
DPM	Guaranteed liquidity	Market owner needs a predetermined cost to start the market. No risk after the market is started.

5. Participation

In determining which individuals should participate in a given prediction market, organization leaders should look beyond an expert-only participant pool

and should elicit participation from any organizational member with access to pertinent market information. Intuitively, wider participation pools generally provide a greater knowledge base than do narrow participation pools. Moreover, prediction markets can thrive only when liquidity exists from a diverse pool of active participants. Put simply, markets need uninformed participants—those participants whose topical knowledge base provides no further insight into a given market security's potential outcome—in addition to informed participants to ensure market liquidity and ongoing activity. This diversity creates potential for profit and, thus, creates incentive for all participants to engage actively. If only experts are invited to participate, organizations may miss this necessary diversity if expert opinion is relatively uniform, and participants face the motivation challenges discussed below.

Decision-makers must also elicit participation when operating a prediction market. Often, the primary motivation factors driving market participation are entertainment and personal confidence or pride in one's expertise. People generally choose to participate in markets and auctions when there are prizes or when the market is attractive and entertaining. Common examples are sports and movie wagering markets, which are only a step away from gambling in terms of individual motivation for participation. Wolfers and Zitzewitz (2004) appear to support this notion: "the 'play money' exchanges and sports gambling industry both suggest that it may be possible to motivate [...] trading simply through the thrill of pitting one's judgment against others, and being able to win a monetary prize may sharpen this motivation" (p. 121).

Personal pride or confidence in one's expertise can also lead individuals to participate in prediction markets; in other words, people are more motivated to participate if they presume superiority in obtaining or processing available knowledge. If all participants believed they were no better than anyone else at obtaining or processing available information, then there would be no motivation to conduct trades or seek new information. Moreover, the nature of available

information plays a significant role among participants in perceiving their own relative understanding of that information. For instance, people are hesitant to conduct trades when they believe there is a subgroup of participants possessing insider information. Skepticism can affect the group as a whole, preventing would-be participants from conducting trades. In this environment, the market can break down and become completely ineffective. The following passage from Wolfers and Zitzewitz (2004) underscores the importance of these revelations:

> These insights suggest that some prediction markets will work better when they concern events that are widely discussed, since trading on such events will have higher entertainment value and there will be more information on whose interpretation traders can disagree. Ambiguous public information may be better in motivating trade than private information, especially if the private information is concentrated, since a cadre of highly informed traders can easily drive out the partly informed, repressing trade to the point that the market barely exists. (p. 121)

6. Real Money, Play Money and Associated Incentives

As discussed in the previous section, participation is vital for a prediction market's success. However, various motivating forces drive participants to engage actively in a given market. According to Schrieber (2004), "Although many informed individuals are motivated to trade simply out of an intrinsic enjoyment [...] remuneration may be required to extract timely and accurate information from others" (p. 37). When considering participation, one likely thinks of potential participatory incentives. Such incentives can be useful for enticing participants who otherwise would not engage in the prediction market. To this point, successful markets have utilized cash and non-cash incentives to elicit participation. Moreover, these incentives are generally linked to a market's assets. Market assets are defined by two specific market structures: real money and play money. The following paragraphs provide real- and play-money market descriptions, along with discussions on cash and non-cash incentives.

Cash incentives are most commonly associated with real-money markets. Real-money markets require participants to use their own money, though perhaps subsidized by the organization, to conduct trades. This structure may provide strong incentives for some individuals, as it can appeal to their sense of competition and desire for profit. Additionally, this strong incentive for participants to perform well also implies the market itself fares better with frequent and improved forecasting performances. The previous section regarding legal and political constraints has already discussed the major challenge presented by this reward structure. Real-money markets are not acceptable for all markets, environments, or organizations because of their similarity to gambling, concerns over market manipulation, and ethical concerns over requiring employees to provide personal capital for organizational benefit.

Play-money markets are among the most prevalent for public and professional use. These markets usually provide some initial allotment of play money (Chen, 2005, p. 130), which participants are free to use within the market as they see fit. As discussed by Wolfers and Zitzewitz (2004), an added benefit of play-money markets is the flexibility they offer: “Play money contracts [...] offer more freedom to experiment with different kinds of contracts” without participants bearing a monetary risk or penalty (p. 121). Generally, play-money markets use other incentives, such as prizes or points, to elicit participation. Chen (2005) cites one good example, “participants of Newsfutures’ prediction markets can use the play money they earned to buy some items in an online auction shop” (p. 130).

Although non-cash incentives can be associated with real-money markets, they predominate in play-money markets as the primary motivating force(s). The most common non-cash incentives are prizes or points—for use as currency in a marketplace store—that reward the historically most accurate traders or most active traders for their participation. Additionally, intrinsic motivating incentives that drive marketplace traders to continue participating over time include personal pride, natural competition, and a means of anonymously voicing

opinions. These motivators generally factor into most markets, regardless of whether they use real or play money.

When establishing a real or play-money market, decision-makers may find initial endowments useful because they provide a similar feel and motivation to those of real-money markets, but the organization absolves risk from individual participants and removes ethical concerns over participants using their personal money for organizational benefit. Generally, this structure allows participants to profit, in some form, from amounts raised beyond the initial endowment. Although this particular reward structure may address some ethical concerns, Chen (2005) warns that others still exist: "For public information markets, legal and political concerns often prevent markets from using real money" (p. 130).

In evaluating the reward structures above, prediction market experts have posed a common question regarding accuracy: Are play-money markets as accurate as real-money markets? Although insufficient evidence exists for irrefutable confirmation, various studies do support the claim that play-money markets are nearly equally as accurate as real-money markets because play money "wealth" can only be accumulated through a history of accurate predictions (Wolfers & Zitzewitz, 2004, p. 121). In support of this claim, Wolfers and Zitzewitz offer the following:

> In a suggestive experiment, Servan-Schreiber, Wolfers, Pennock and Galebach compared the predictive power of the prices from real money and play money exchanges over the 2003 NFL football season, finding that both yielded predictions that were approximately equally accurate. (p. 121)

Clearly, several options exist for market designers to elicit participant involvement. The choice of which structure to use will not always be clear. Additionally, external forces or pressures such as legal or political issues may drive this choice. In any event, the choice may prove to be one of preference rather than necessity. Tziralis and Tatsiopoulos (2007) state, "The decision of

whether to use monetary […] or non-monetary rewards […] is up to designer and remains more an art than a science" (p. 256).

7. Review

The previous sections covered several aspects of prediction market design, including: 1) claim definition, 2) claim structure, 3) trading mechanisms, 4) participation, and 5) real money, play money and associated incentives. Table 3 provides a summary of the various design aspects discussed above.

Table 3. Summary of Prediction Market Design Aspects and Considerations

Design Aspect	Considerations
Claim Definition	Clear and definite end-state Pre-determined timeframe
Claim Structure	Winner-take-all Index Spread
Trading Mechanisms	CDA DPM MSR
Participation	Diverse body of participants Motivating forces
Market Format	Real money Play money Initial Endowment
Incentives	Cash incentives Non-cash incentives Prizes Competition Pride Ability to voice opinions anonymously

B. Implementation

To introduce market implementation, Chen (2005) offers the following, "Market implementation is the construction of the new [prediction] market and the delivery of the market into operation" (p. 134). In planning to implement a prediction market, an organization should consider three primary phases of implementation: 1) preparation, 2) conduct, and 3) support. The three phases of implementation offer a useful structure for assessing potential prediction market limitations, challenges and risks. Organizations should assess each phase of the implementation process. The following subsections highlight issues of concern for each respective phase.

1. Preparation

The preparation phase encompasses several aspects of prediction market implementation, from feasibility assessment, to budgetary considerations, to establishing a pilot market. Preparing to implement a prediction market is a challenging and meticulous process. Appropriate support systems, such as networks and software packages, must be in place. An organization must determine its target audience, what market framework to use, and what types of questions will best meet market objectives. Additionally, an organization must have a good sense of the type(s) of incentives that are best suited for the target audience to meet market objectives. Cost assessments should provide useful information for determining how to fund the market, as well as for determining market scope limitations. Finally, before introducing a market to the target audience, organizations should conduct at least one pilot market to assess adequacy and monitor for undesirable market issues or attributes. This action will help prevent participants from forming an unfavorable perception of prediction markets because of poor market design or improper market implementation.

2. Conduct

One potential pitfall when opening a market is setting initial contract prices. Contract prices should be set at a reasonable level to ensure there is not an overwhelming arbitrage opportunity when the market opens. Moreover, prices generally are a direct indicator of the marketplace's assessed probability of a given event's occurrence. Therefore, improper initial pricing can give early traders an unfair advantage to trade on a contract that is widely believed to be under- or overpriced. Furthermore, initial prices can affect traders' perceptions of a given event's expected probability. Thus, poorly set initial prices can adversely affect the overall market's initial assessment of a given event's probability of occurrence. In theory, an efficient market will eventually overcome such problems.

Next, when conducting a market, an organization must continually monitor participation rates to assess the effectiveness of incentives. As previously discussed, incentives can significantly affect overall participation. Another factor that can affect participation is the selection of relevant and clear questions. If questions are unclear or irrelevant, participants are generally less inclined to trade.

An additional issue is that organizations must find the right balance of questions that will adequately aggregate information without thinning out the markets. Due to various participatory constraints, such as limited available trading time or personal interest in the marketplace, participants may conduct some fixed number of total trades within the overall marketplace. As the number of questions increases, the average participation rate per question decreases. This leads to adverse market conditions with improper equilibrium prices due to the market's thinning. Therefore, the market may not efficiently aggregate all available information.

A final element to consider for market conduct is timing. The timing of when and how frequently questions are released may affect participation rates—in part reflecting geographic divides among participants. Furthermore, poor or untimely questions can present arbitrage opportunities for those individuals who are first to trade on a given contract.

3. Support

As with any process or service, organizations must provide ongoing support to ensure the market operates as designed and desired. The support phase entails all details and considerations to ensure participants remain involved and that the market operates optimally to aggregate useful information. Chen (2005) highlights potential problems and issues arising in this stage, to include “dispute[s] over market trading rules and traded contracts, database or network problems, and system security issues” (pp. 134–135).

VI. Practical Experiment

A. Experiment Description

The researchers conducted an experiment involved running a pilot market to begin examining whether the Navy should consider applying prediction markets to manpower outcomes, such as recruiting, retention, and re-enlistment bonuses. The experiment was more hastily designed than we would have preferred. We faced a time constraint in designing and conducting a pilot market to meet our Navy sponsor's desires and our graduation timeline. Thus, our goals were to perform due diligence given our time constraints and to document our lessons learned.

The N1 directorate identified 53 potential participants for the pilot, spread across both operational N1 personnel and the research organizations supporting N1. Because many of the N1 members perform similar and interrelated work, our hope was that a natural competitive spirit would create a cycle of market activity, engagement, and participation. The Naval Postgraduate School (NPS) added another five participants consisting of two students and three thesis advisors. Each participant received an initial endowment of $5,000 in play money. Table 4 shows the distribution of potential participants by their location, office code, and functional responsibilities.

Table 4. Potential Participant Distribution by Location and Office Code

Location	Office Code	Office Functional Responsibility	Quantity
Washington, DC	N104	Modeling and Analysis Branch	18
Washington, DC	N1Z	Strategic Affairs Office	3
Washington, DC	N13	Manpower, Personnel, Training and Education Division	2
Washington, DC	N130	Military Pay and Compensation Policy Branch	2
Washington, DC	N133	Nuclear Propulsion Program Policy Branch	1
Washington, DC	OCNR	Research	1
Washington, DC	CNA	Contractor	7
Washington, DC	LMI	Contractor	2
Washington, DC	SAG	Contractor	2
Washington, DC	Lewin	Contractor	1
Washington, DC	SERCO	Contractor	1
Millington, TN	NPRST	Quick Polls	7
Millington, TN	PMO	Management	2
Millington, TN	BUPERS 3	Community Manager/Career Development	4
Monterey, CA	NPS	Research	5
Total			***58***

As described in Chapter V, user anonymity may be important in markets containing potentially controversial questions or in markets whose members are from varying hierarchical levels. Participants initially received a generic username consisting of their first initial followed by their last name. Upon creating their accounts, participants had the option to keep their generic username or modify it for fun or anonymity.

One unfortunate circumstance of beginning the pilot market quickly is that it left little time to discuss incentives. NPS suggested our N1 sponsors incentivize participation with non-monetary rewards to the top-gainer, such as a preferred parking space or lunch with a VIP. However, N1 chose not to offer non-monetary incentives.

B. Design

The limited number of participants was the primary factor in our decision to adopt a platform using an automated market maker. This choice allows participants to trade without using the bid/ask process required in the CDA mechanism. Thus, it promotes market liquidity. The choice to use an automated market maker drove the subsequent choices of securities types and their

associated payoffs. The CEO of Inkling Markets, Adam Siegel, generously provided his time to answer questions, and he offered the Inkling Market platform, pro bono, for the pilot prediction market. The Inkling Market platform uses Robin Hanson's (2003) market scoring rules as the basis for its automated market maker.

As Berg and Proebsting (2009) point out, Hanson's market scoring rules operate under the assumption that a security has mutually exclusive outcomes. Thus, the automated market maker is useful for determining binary (yes/no), interval, or discrete option outcomes. However, the algorithm cannot predict the market equilibrium of a continuous number, which is one function Navy N1 would like to have in their prediction markets. We were able to circumvent this limitation, to some extent, by allowing traders to choose between relatively narrow numerical intervals.

Hanson's market scoring rules calls for subjectively choosing what value to assign an elasticity constant, *b*. Berg and Proebsting (2009) describe the issue in this way:

> The elasticity constant *b* controls how much prices change for a given transaction size (measured in shares or cost). Setting *b* is a vexing problem: set too low, the market prices will swing wildly on any trade, and set too high, the market may not move enough [to] reasonably reflect aggregate opinions. (p. 51)

Inkling Markets chooses to set *b* to .10 per share traded, which means that, the price adjusts up or down by ten cents per share purchased or sold, respectively. Adam Siegel admitted this was an arbitrary number, but he indicated that it has worked for their markets.

The security payoffs were designed as winner-take-all. Thus, the shares representing the correct outcome were worth $100, while the shares representing incorrect outcome(s) were worth $0. The selection of winner-take-all payoffs was required for Inkling's automated market maker using Hanson's market scoring

rules, in which a market involves a set of mutually exclusive outcomes. Because the algorithm assumes only mutually exclusive outcomes are possible, it precludes using an index or spread payoff.

C. Market Management

We tailored and sent out an Inkling, Inc., memo to demonstrate executive sponsorship to participants. Additionally, we tailored an Inkling, Inc., introductory PowerPoint slide show to serve as an introduction to prediction markets and the Inkling Markets platform. We emphasized the explanation of short-sales in this tutorial to ensure participants were aware of what they are and how to execute them.

1. Claim Selection

The overall intent was to ask questions to assess what was actually taking place with respect to Navy active-duty entry and retention. Generally, the United States economy was in relatively poor condition; higher than normal unemployment rates were coupled with declining stock market prices and housing values. These non-normal conditions made it difficult for the Navy to forecast retention rates using historical data because the economic conditions were much different from the past.

Taken together, this seemed to be an ideal time to explore the capability for prediction markets to forecast retention. However, it proved difficult for Navy N1 to identify four appropriate securities for the pilot. The N1 pilot faced two inherently difficult issues. The first was timing. The pilot was scheduled to last just under two months and conclude at the end of the federal government fiscal year on September 30, 2009. This did not seem to be problematic at the outset, yet it turned out to be so. N1 leadership had already implemented policy changes to achieve end-of-fiscal-year goals. For example, N1 initially wanted to determine Nuke Zone A retention rates. Upon further investigation, the Navy had just suspended re-enlistment bonuses for the remainder of the fiscal year due to high

retention rates and budget constraints. Therefore, the Nuke Zone A retention rate security was uninteresting: rational candidates would wait until the following fiscal year to re-enlist when they would be eligible to receive a substantial bonus for re-enlisting. Thus, any change in the retention rate from the current level would only reflect those leaving the Navy. The N1 and NPS consensus was to discard this candidate question.

The other issue was bureaucratic in nature. One candidate question involved the number of people waiting to join the Navy via the Delayed Entry Program (DEP). While attempting to determine the inputs to this calculation, we learned there were at least two different DEP calculations to meet differing organizational purposes. As a result, there would be confusion over the security's definition.

Ultimately, the N1 pilot involved two direct measures for Navy entry and retention. These were markets regarding Navy endstrength and the following year's enlisted accession goal. The pilot also consisted of two indirect economic measures that may affect sailors' decision to stay in or leave the Navy. The two indirect measures were for the national unemployment rate and the Dow Jones Industrial Average (DJIA). We also employed short-term markets, involving primarily sports and entertainment questions, in hopes of keeping participants interested and active in the marketplace. Table 5 shows the questions asked, dates the markets began and ended, contract type, contract choices and initial market prices.

Table 5. N1 Prediction Market Pilot Questions

Question	Date Began	Date Ended	Contract Type	Contracts	Initial Market Price
What will be the Navy's endstrength (for officers and enlisted personnel) for FY2009? (See details in Market Information)	Aug. 10, 2009	Sep. 30, 2009	Multiple-choice	Less than 330,200	16.67%
				330,200-330,350	16.67%
				330,350-330,500	16.67%
				330,500-330,650	16.67%
				330,650-330,800	16.67%
				Greater than 330,800	16.67%
What will be the official Sept. 2009 national seasonally-adjusted unemployment rate (per US DoL)? (9.4% in July; 9.7% in August)	Aug. 10, 2009	Sep. 30, 2009	Multiple-choice	Less than 9.0%	16.67%
				9.1 - 9.3%	16.67%
				9.4 - 9.6%	16.67%
				9.7 - 10.0%	16.67%
				10.1 - 10.5%	16.67%
				Greater than 10.5%	16.67%
Will the Dow Jones Industrial Average (INDU) close above 9,400 by COB on Friday, Aug. 14, 2009? (Closed at 9,370 on Aug. 7, 2009)	Aug. 10, 2009	Aug. 14, 2009	Binary	Yes	50%
				No	50%
On September 30, 2009, what will the Navy's FY10 enlisted accession goal be?	Aug. 17, 2009	Sep. 30, 2009	Multiple-choice	Below 35,750	33.33%
				Exactly 35,750	33.33%
				Above 35,750	33.33%
Which series will receive the "Outstanding Drama Series" award at the 61st Primetime Emmys? (See details in Market Information)	Aug. 17, 2009	Sep. 20, 2009	Multiple-choice	Big Love	14.29%
				Breaking Bad	14.29%
				Damages	14.29%
				Dexter	14.29%
				House	14.29%
				Lost	14.29%
				Mad Men	14.29%
Which series will receive the "Outstanding Comedy Series" award at the 61st Primetime Emmys? (See details in Market Information)	Aug. 17, 2009	Sep. 20, 2009	Multiple-choice	Entourage	14.29%
				Family Guy	14.29%
				Flight Of The Conchords	14.29%
				How I Met Your Mother	14.29%
				The Office	14.29%
				30 Rock	14.29%
				Weeds	14.29%
Who will win the 2009 NFL opening game between the Pittsburgh Steelers and Tennessee Titans? (See details in	Sep. 1, 2009	Sep. 10, 2009	Multiple-choice	Tennessee Titans	40.00%
				Washington Redskins	59.90%
				Tie	0.10%
How many Major League Baseball teams will clinch a playoff spot before October 1st, 2009? (See details in Market Information)	Sep. 8, 2009	Sep. 30, 2009	Multiple-choice	Less than 4	20%
				4	20%
				5	20%
				6	20%
				7-8	20%
Will the FY 2010 Defense Appropriation bill be signed into law before October 1st, 2009?	Sep. 8, 2009	Sep. 30, 2009	Binary	Yes	50%
				No	50%

2. Setting Initial Market Prices

The initial market prices for each security, with one exception, were set at 1/N, where N is the number of possible outcomes on which traders may bid. The initial market price for predicting the winner in the 2009 National Football League (NFL) opening game between Pittsburgh Steelers and the Tennessee Titans was set at $59.90 for Pittsburgh to win, $40.00 for Tennessee to win and $0.10 for a tie. This allowed for the possibility of a tie, though a tie is extremely unlikely. We considered setting the initial prices for predicting both the Navy endstrength and

unemployment rate to reflect a bell-shaped distribution to account for central tendency. However, the Inkling software automatically re-sorts the contracts in an ascending order according to price, which could confuse the initial securities listing. Thus, we decided to set the contract initial prices equally, using 1/N, with the NFL football game as the only exception. This initial pricing policy provided an incentive for traders to make relatively easy gains by participating early to make trades on seemingly over-/under-priced contracts.

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VII. Assessment

A. Trader Participation

Overall, 32 of 58 potential traders registered for their N1 Prediction Market Pilot account. Of those 32, eight participants did not make any trades, resulting in 24 actual traders. Table 6 lists the breakdown of actual and potential pilot participants.

Table 6. N1 Prediction Market Pilot Participants

	Actual	Non-users	Potential
Number of NPS participants	5		5
Number of N104 participants	8		18
Number of Non-NPS and Non-N104 participants	11		35
Number of Potential Participants that did not create their accounts		26	
Number of Potential Participants that created accounts but did not trade		8	
Total	24	34	58

Initially, there appeared to be high organizational interest in the prediction market pilot. However, the total number of traders and trades conducted declined as the prediction market progressed. Figure 1 provides a graphical view of the pilot by question and depicts the respective number of traders and trades.

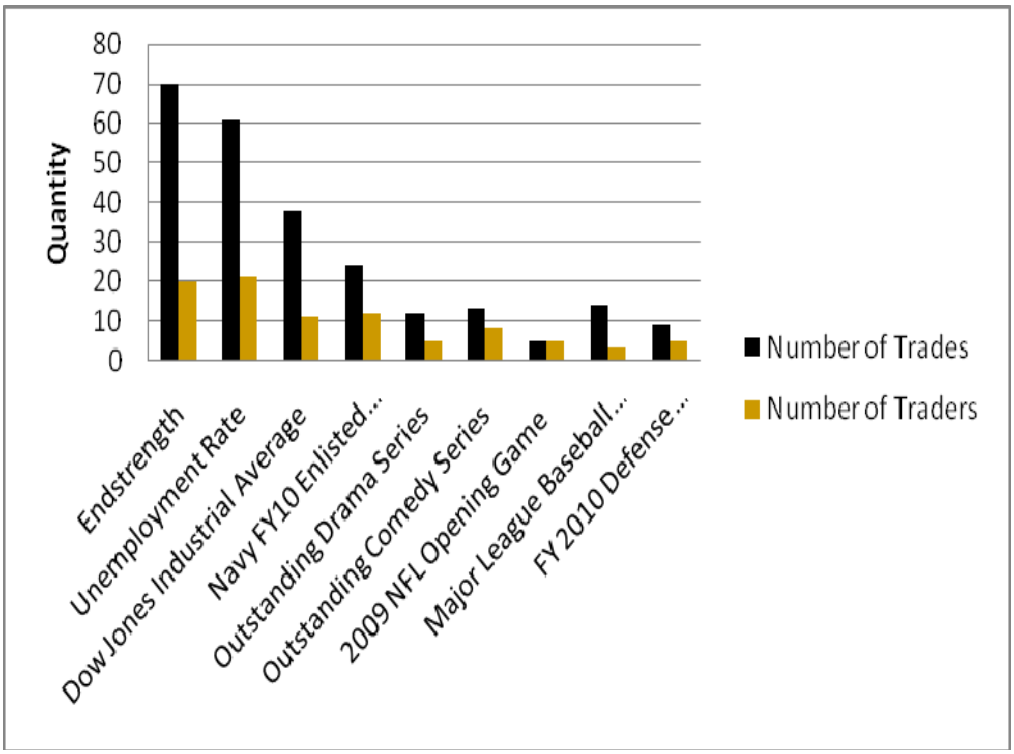

Figure 1. Quantity of Traders and Trades by Question

B. Quantity of Trades

The number of trades also declined rapidly after the first two weeks, as shown in Figure 2. Of all the trades conducted in the 52-day pilot, 56.9% were conducted in the first two weeks. The decrease in trading could reflect traders' belief that the markets were appropriately priced and had reached market equilibrium. This, however, does not seem to be the case because there were many opportunities for a seemingly easy gain as new securities were introduced using the 1/N initial pricing. Thus, some securities simply were not appropriately priced from the outset, and traders did not take advantage of these opportunities. Therefore, we conclude the novelty had worn off for the traders, and their participation waned.

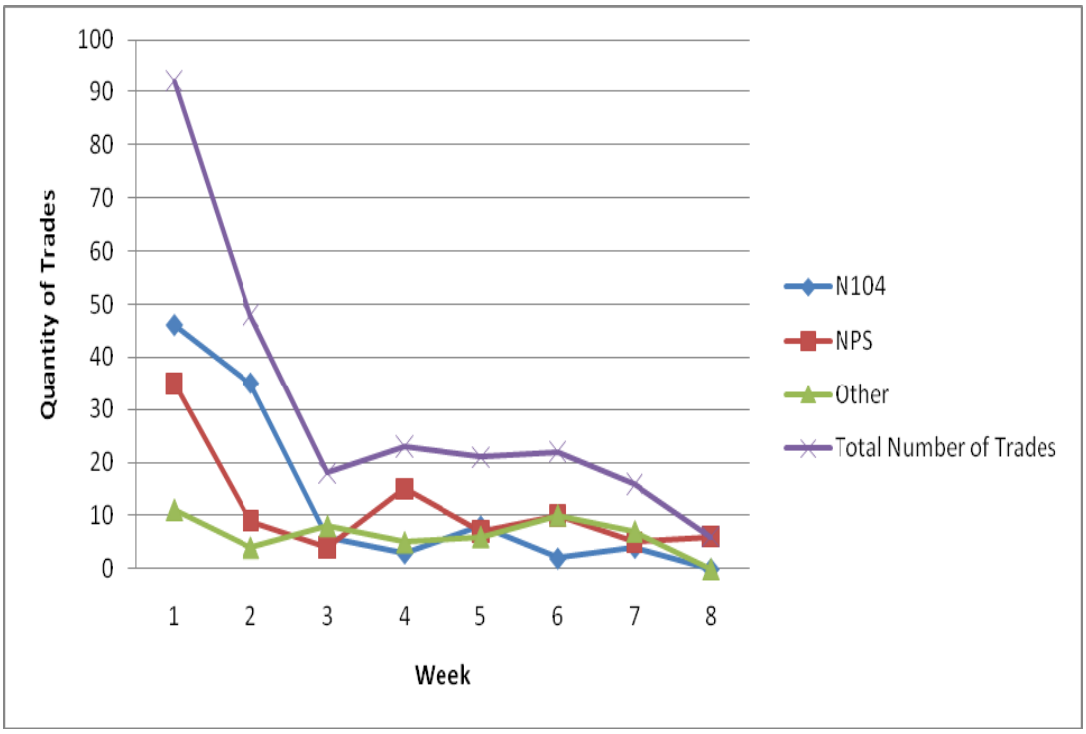

Figure 2. Quantity of Trades by Week and Office Code[15]

Table 7 depicts the quantity of trades per question by organization. The first four questions in the pilot were germane to the N1 organization. The remaining questions, shaded in gray, were added for "fun" and were intended to spur interest and enhance participation. Surprisingly, 78% of the trades were conducted on the N1-relevant questions. There was much less trading on the "fun" questions.

[15] Week 8 consisted of only 3 days since the market concluded at the end of the Fiscal Year.

Table 7. Quantity of Trades per Question by Organization

Question	N104	NPS	Other	Grand Total
What will be the Navy's endstrength (for officers and enlisted personnel) for FY2009? (See details in Market Information)	37	21	12	70
What will be the official Sept. 2009 national seasonally-adjusted unemployment rate (per US DoL)? (9.4% in July; 9.7% in August)	33	14	14	61
Will the Dow Jones Industrial Average (INDU) close above 9,400 by COB on Friday, Aug. 14, 2009? (Closed at 9,370 on Aug. 7, 2009)	16	21	1	38
On September 30, 2009, what will the Navy's FY10 enlisted accession goal be?	9	8	7	24
Which series will receive the "Outstanding Drama Series" award at the 61st Primetime Emmys? (See details in Market Information)	2	5	5	12
Which series will receive the "Outstanding Comedy Series" award at the 61st Primetime Emmys? (See details in Market Information)	3	6	4	13
Who will win the 2009 NFL opening game between the Pittsburgh Steelers and Tennessee Titans? (See details in Market Information)	1	2	2	5
How many Major League Baseball teams will clinch a playoff spot before October 1st, 2009? (See details in Market Information)	1	11	2	14
Will the FY 2010 Defense Appropriation bill be signed into law before October 1st, 2009?	2	3	4	9
Grand Total	**104**	**91**	**51**	**246**

C. Pilot Prediction Market Assessment

The reduction in trading volume may reflect the topics or the timing of their introduction. We predicted the first two “fun” questions, regarding the Primetime Emmy’s for Drama and Comedy series, would have wide appeal and elicit participation. That proved not to be the case. These questions were introduced at the same time as the Navy’s FY10 enlisted accession goal question. The number of trades on the Navy’s enlisted accession goal was nearly equal to the number of trades on the two Emmy questions.

We thought introducing a question about the 2009 NFL opening game between the Tennessee Titans and Pittsburgh Steelers would be an engaging question, considering the general enthusiasm for the beginning of the NFL season and the teams involved. However, this question was the least-traded question in the pilot market. The Pittsburgh Steelers were favored to win by more than five points. Perhaps the traders thought the contract was already appropriately priced. Nonetheless, we suspect that interest in the prediction market had waned by this point, and traders simply were not actively trading anymore.

Furthermore, trading on this question remained open throughout the game and for one hour following the game; by leaving the market open, we provided an opportunity for guaranteed profits, as the price for Pittsburgh remained at $60.44 even though the payoff would be $100 per share for a Pittsburgh victory. Although the football game had four lead changes and ultimately was decided in overtime, no traders conducted in-game trades; moreover, no traders exploited the guaranteed after-game profit potential. In the traders' defense, the game ended around 11:30 pm EDT. Therefore, those traders who watched the game likely went to sleep at the conclusion of the game instead of checking to see how well they did in the pilot prediction market or exploring an opportunity to make an ex-post trade for guaranteed profit.

The other two "fun" questions also had poor trading volume. Taken together, introducing "fun" questions certainly did not elicit a cycle of engagement, participation, and trading as anticipated. Perhaps there was a mismatch in NPS researcher and N1 member interests. N1 participation may have been better if we had predetermined their interests to ask questions they think are entertaining and engaging.

Data shows that participation was low, especially by the Non-NPS and Non-N104 participants, as only 11 of 35 potential participants actually made trades. Because trading decreased significantly after the first two weeks, we

suspect that interest in the prediction market pilot quickly wore off once the novelty was over. Moreover, the traders had no real incentive to participate, and we believe this limited interest. Prediction markets simply will not work without active participation.

D. Lessons Learned with Substantiating Post-prediction Market Survey Results

We conducted two anonymous post-market surveys: a "user" survey for those who registered and conducted at least one trade, and a "non-user" survey for those who did not participate. These surveys featured many multiple-choice questions. Respondents were asked to select all applicable responses. The questions and potential responses for the two surveys are provided in Appendices A and B.

The "user" survey asked active participants about their motivations to initially trade and sustain trading past the first few weeks, as well as their thoughts regarding implementation, operation and outcome of the prediction market experiment. Overall, 12 of 24 potential respondents completed the "user" survey; 3 of these 12 respondents were from NPS. The "non-user" survey was intended for those who were invited to participate in the experiment but chose not to do so. We wanted to find out why they chose not to participate and what incentives would entice them to participate. In total, 6 of 34 potential respondents completed the "non-user" survey. We list the lessons learned from this pilot prediction market below.

1. Participation is Critical for a Prediction Market to be Efficient. Furthermore, Incentives are Necessary for People to Participate.

The active-traders were initially highly motivated to participate due to their intrigue in prediction markets. Additionally, 6 of 12 traders claimed a factor in

their decision to initially participate was that the questions were both relevant and interesting. See Figure 3.

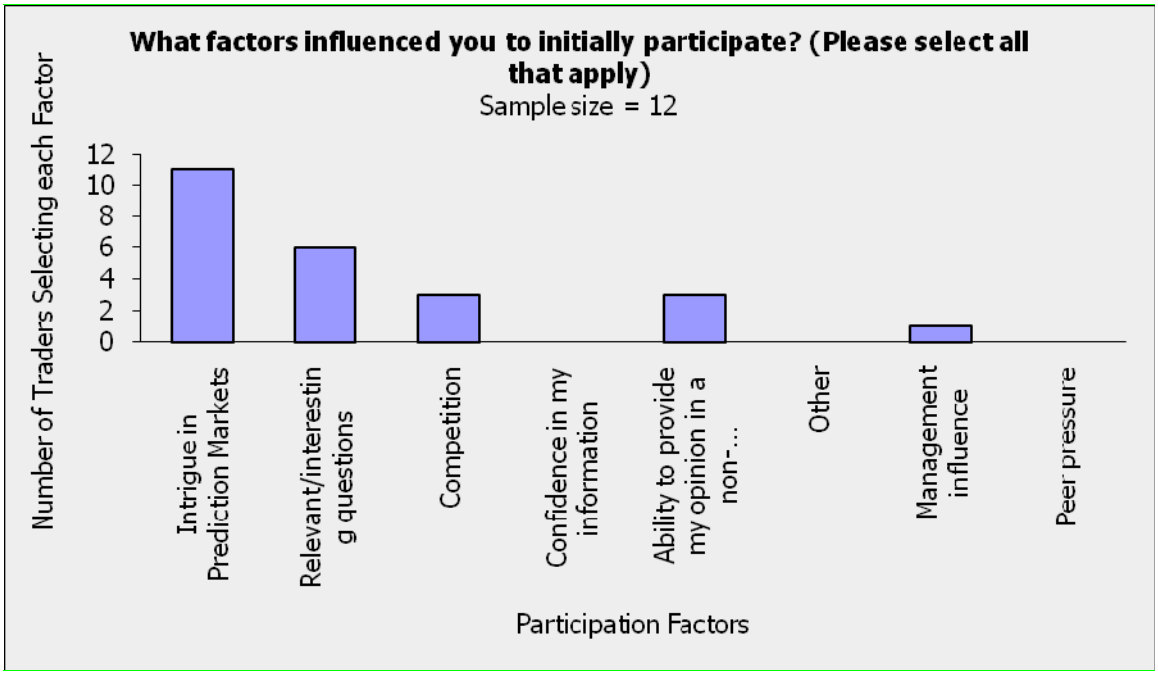

Figure 3. Active-user Initial Participation Factors

The motivations for traders to participate past the first few weeks were slightly different (see Figure 4). The top factors were still intrigue in prediction markets and the draw of relevant and interesting questions. However, the intrigue dropped significantly from 11 of 12 to 7 of 12 traders indicating their intrigue in prediction markets was a factor in participation. Interestingly, 6 of 12 participants viewed the relevant and interesting questions as a factor for their continued participation past the first few weeks. Another item of interest is that participants listed competition as an increased factor for their continued participation. Nevertheless, the precipitous drop in trading volume after the first few weeks suggests that interest in competition waned. One would expect trading volume to increase if a competitive spirit had emerged and the traders did not believe the markets were appropriately priced.

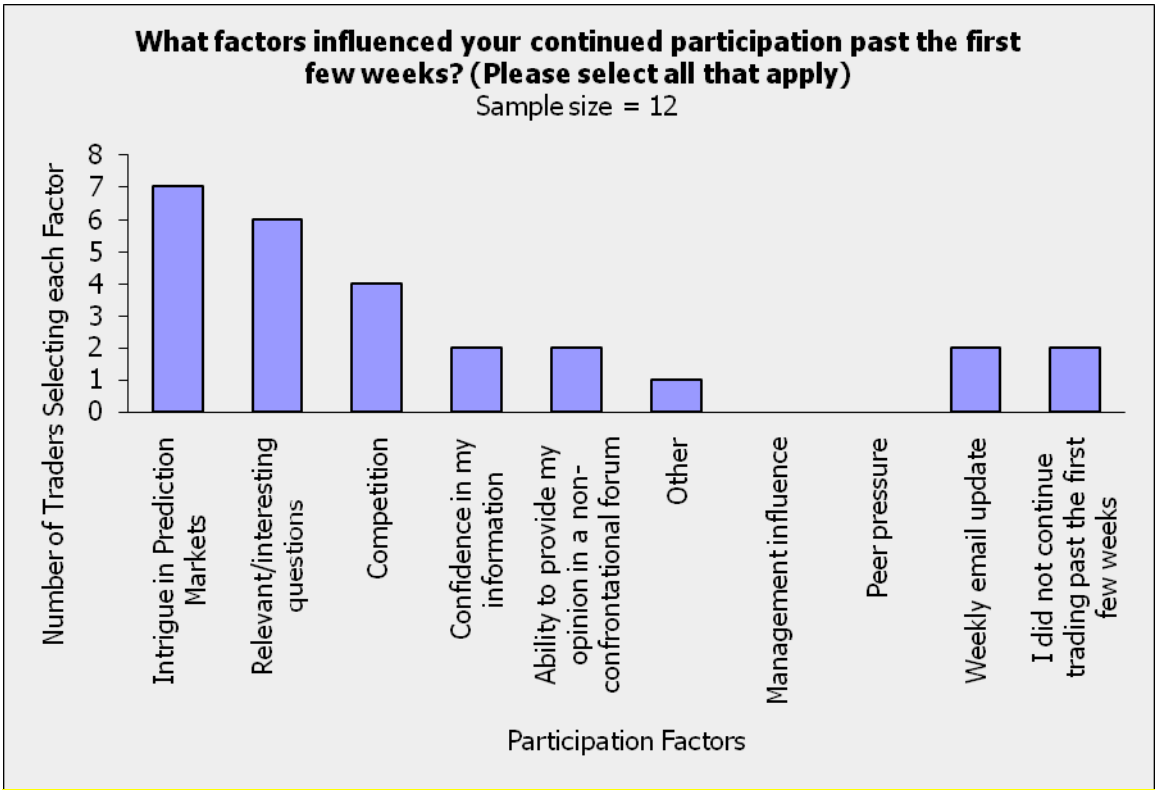

Figure 4. Factors for Active-user Continued Participation

A prediction market would work best if every organizational member were a self-selected participant who would work to discover and share his or her information. If this were the case, incentives would not be necessary. The reality is that most people will not do this. It is obvious that monetary gain provides a natural participatory motivation in real-money markets. In play-money markets, other participation incentives are likely needed to attract and sustain participation.

Figure 5 shows the factors leading to declining participation past the first few weeks of the pilot prediction market. Four of 12 active participants indicated that either lack of incentive or time caused their trading volume to decline after the first few weeks. Furthermore, only 1 of the 12 attributed their trading volume decrease to a belief that market questions were appropriately priced and had reached equilibrium. Thus, evidence suggests that incentives are necessary for traders to overcome time constraints to register and sustain participation.

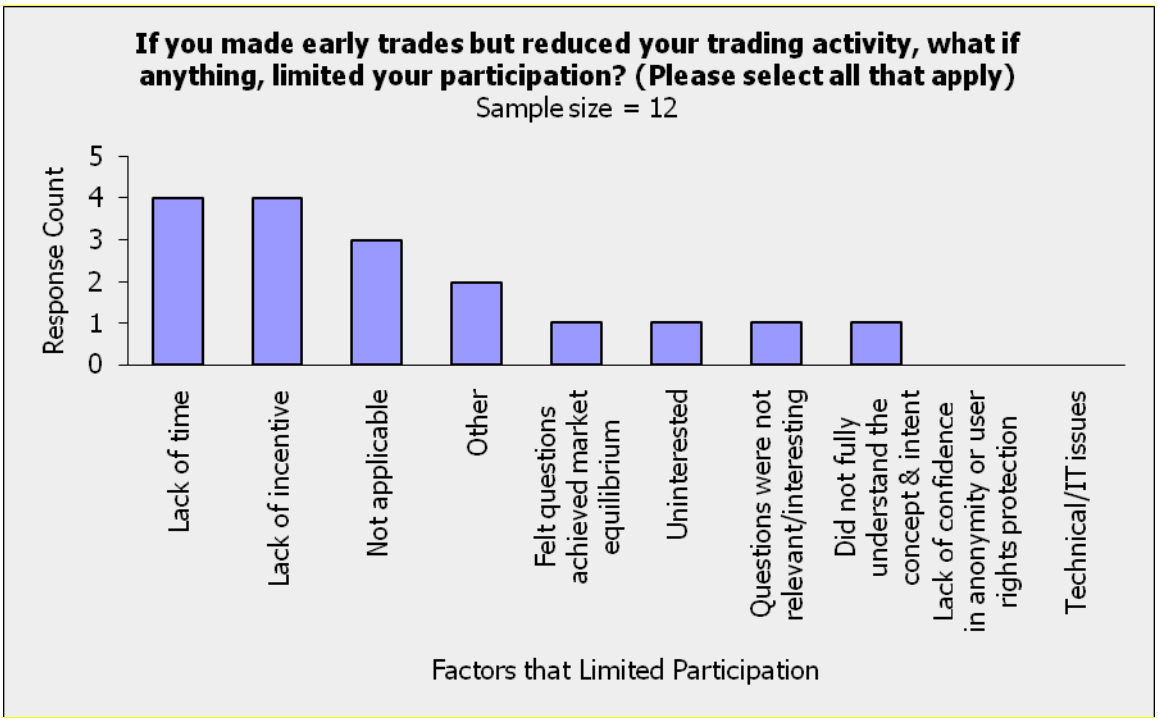

Figure 5. Active-user Reasons for Decline in Trading Volume Past the First few Weeks

Given our pre-survey belief that incentives play a role in participation, we asked a question in both the "user" and "non-user" survey on what incentives would motivate traders to participate in a future Navy-sponsored prediction market. We provided a list of tangible and intangible incentives for respondents to choose from and gave them the opportunity to enter "Other" preferences in a free text area. Figure 6 shows the results for active-users. They displayed an affinity for tangible rewards, such as cash prizes or an iPod. Interestingly, 2 of 12 respondents indicated they would participate with no incentives. In addition, 3 of 6 "Other" responses indicated that the subjects were happy to participate with no incentives but their participation may have increased if a tangible prize were offered. The remaining three textual responses were singular votes for tangible prizes, special liberty and no incentives required.

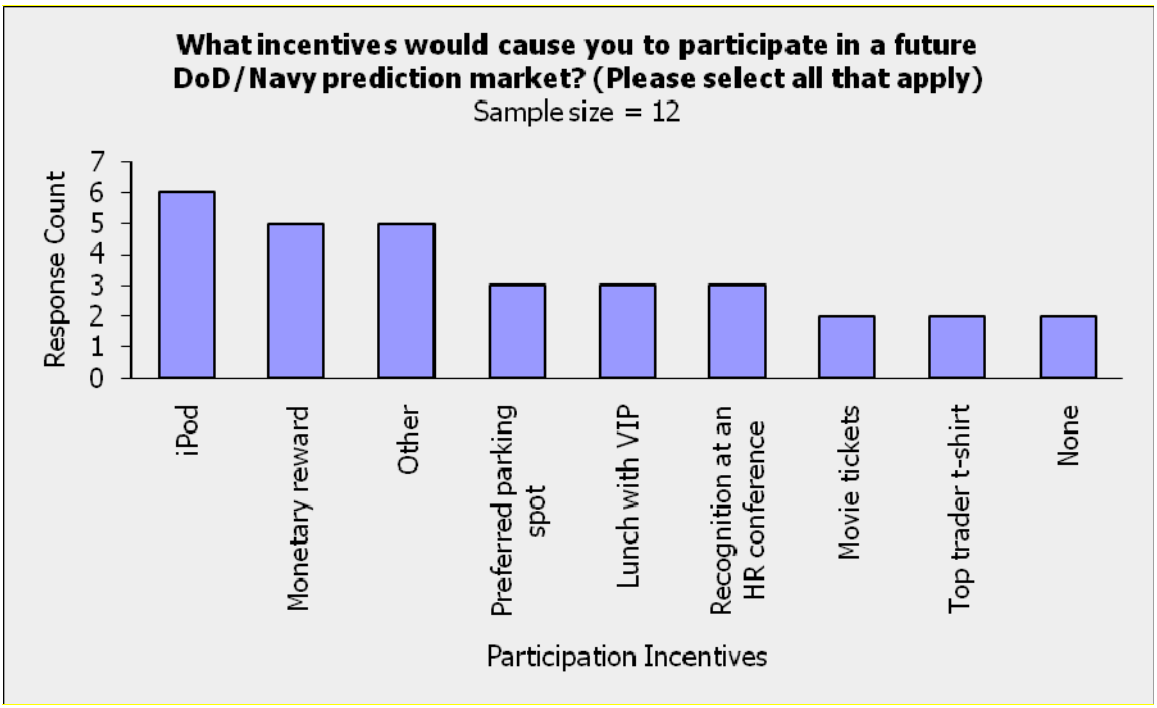

Figure 6. Active-user Incentive Preferences

Figure 7 presents the non-user responses to the same question. One non-user indicated that no incentives would be necessary for him/her to participate in a future Navy prediction market. The non-user responses to the incentive question were dominated by the "Other" response. One non-user indicated he/she would participate if he were given paid time off from work—even just a few hours. The remaining respondents who selected "Other" did not answer the question directly and expressed frustration in the free text area regarding technical issues, account setup, uninteresting questions and ambiguity with the concept. Interestingly though, none of the non-users indicated they would not participate in a future prediction market.

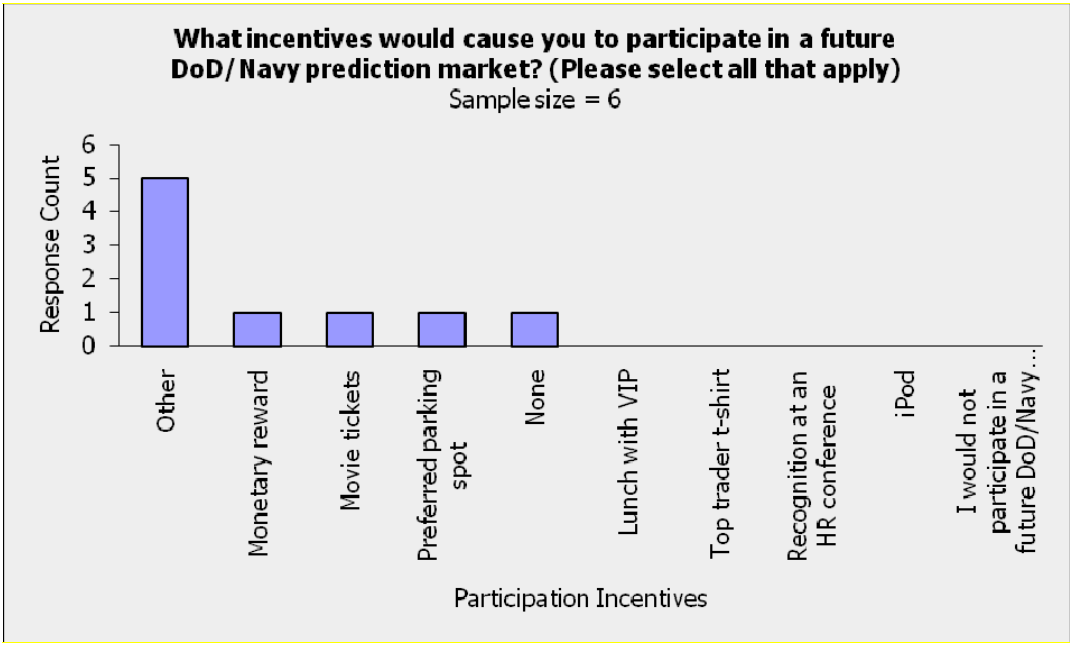

Figure 7. Non-user Incentive Preferences

Despite the explicit preference for tangible prizes from both the active- and non-users, there are several reasons to believe that social rewards may induce participation more effectively. The primary reason is that expected monetary or other rewards have a low relative value compared to the time and energy expended to discover new information and make trades (Cowgill, 2007). Moreover, neither profit-maximizing companies nor thrifty government organizations expend the resources to make these tangible rewards worth their employees' time to fully engage in the prediction market and meet the requirements of their individual jobs. An organization may be able to foster competition between employees or organizational divisions to create a culture that values top individual- and divisional-trader bragging rights. Organizations may be able to curtail tangible incentives once this type of culture is in place. For suggestions on how to foster this type of culture, Bo Cowgill (2007) provides

excellent insight into how Google was able to develop a culture in which employees value their reputation as top traders more than monetary rewards.[16]

2. Participant Selection should be more Inclusive than Exclusive.

A diverse and broad pool of prediction market participants is optimal. As discussed many times in this paper, it is impossible for the organization to determine exactly who has useful knowledge. The active-users were more inclusive than exclusive when expressing their opinion of what groups of people should be included in future Navy N1 prediction markets. When asked, "What group(s) of Navy personnel should be included in future N1 prediction markets to help better aggregate force-structure information," respondents overwhelmingly agreed that recruiters, manpower analysts, and budget analysts should be involved. The single "Other" response was a free text opinion that "any and all people connected with Navy MPT&E" should participate. Figure 8 illustrates these results.

[16] This is a frequent topic for Bo Cowgill. One transcript regarding this subject may be found at: http://www.midasoracle.org/2007/04/11/how-prediction-exchanges-can-best-encourage-participation/#comments.

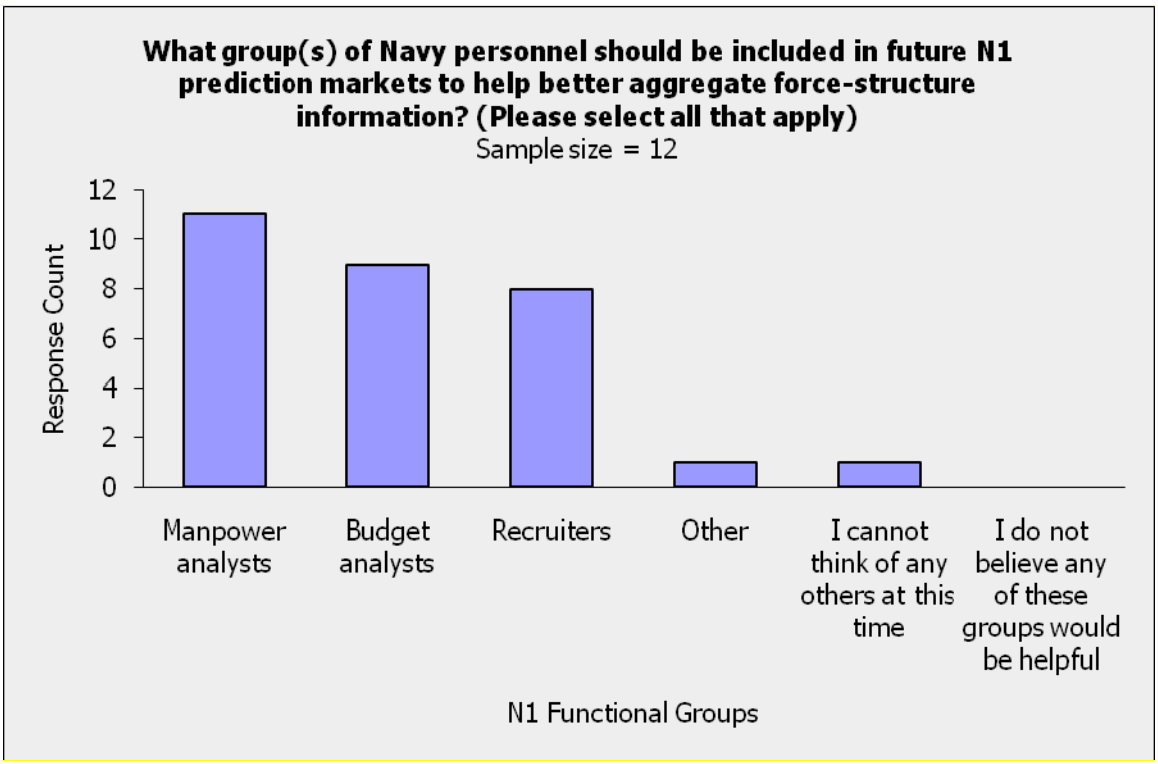

Figure 8. Active-user Opinion Regarding Which Groups of N1 Members Should Be Included in Future Navy N1 Prediction Markets

How does an organization know who or how many people should participate? It is easy to say that an organization should be more inclusive than exclusive. However, as a practical consideration, it is clear that not every individual needs to participate in a prediction market, especially in very large organizations such as the Navy. The location of that dividing line is an open question.

There is not a specific ratio of people who should (or should not) participate. Rather, the organization must weigh the costs and expected benefits of implementing the prediction market. Using this as a guide, the costs should not exceed the expected benefit. The decision of whether to conduct a prediction market and who should participate is driven by these factors:

- Fixed Costs:
  - Management and support costs
  - Cost of tangible incentives
- Variable Costs:
  - Participant's time spent training (this will vary by labor rate and the length of the training program)
  - Participant's time spent trading (this will vary by labor rate and time spent trading)
    - One way to limit this cost is to restrict trading to specific days or times
  - Interface costs if using a commercial service (usually a per-user fee per month)

3. Thorough Group Training Should Be Provided to Potential Prediction Market Participants to Explain the Prediction Market Concept and Its Organizational Purpose and Intent.

In the post-market survey, non-users were asked what factors affected their decision not to participate in the pilot market. Figure 9 presents potential responses and results. Two of 6 respondents indicated they did not understand the concept or intent or did not participate because of technical issues. A group training session could also include the account setup for the chosen prediction market interface. The group training would provide fewer excuses for people not to participate with the participants' accounts setup and any technological hurdles addressed.

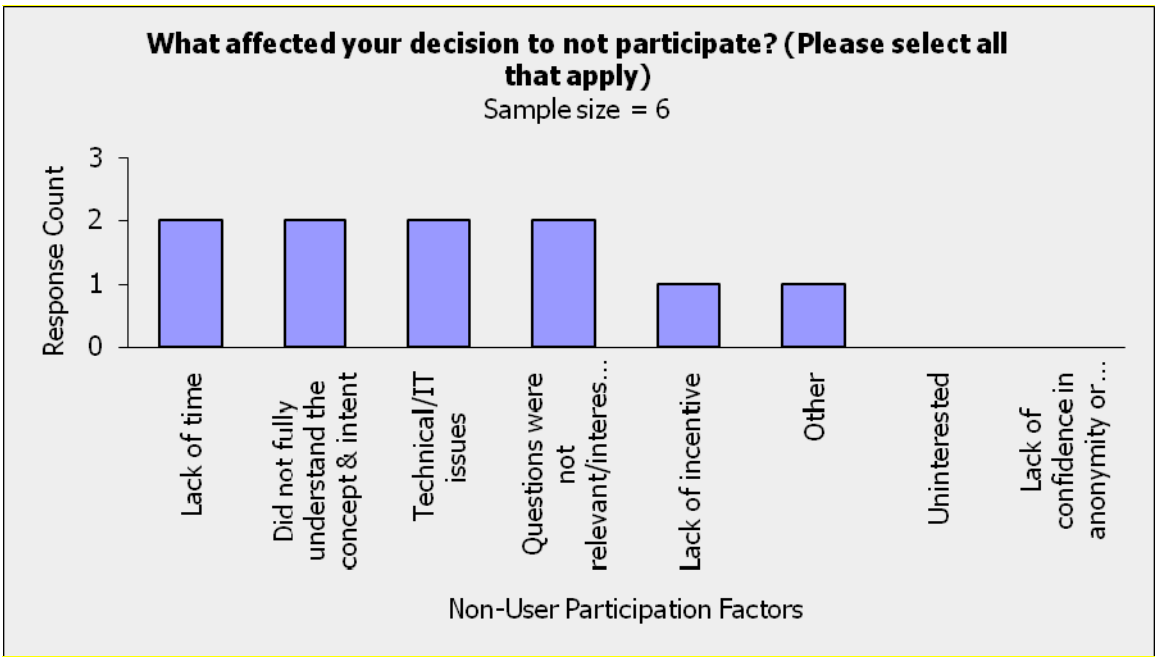

Figure 9. Non-user Participation Factors

The training would also provide an opportunity for senior leaders to sponsor the prediction market concept. The N1 leadership may have inadvertently undermined the prediction market experiment by simply forwarding the introductory e-mails from NPS students vice sending the e-mails as if coming directly from an N1 senior leader. In fact, 3 of 6 non-users indicated they thought the prediction market experiment was simply an NPS student thesis project, whereas none of the active users felt this way. Conversely, 10 of 12 active users thought the experiment was a joint N1 and NPS thesis project; the remaining two perceived the experiment as an N1 initiative. Our surveys showed that executive sponsorship is of the utmost importance to ensure prediction market participation.

The training should also include a tutorial regarding trading strategies. The goal is to educate participants about long- and short-selling strategies, along with their advantages and disadvantages. The Inkling interface made short selling extremely user friendly, such that traders may not have fully understood the concept even though they thought they did. However, 9 of 12 active users

indicated that they understood the concept of short selling. We cannot determine whether they fully understood the concept or if the Inkling interface made short selling so easy that participants thought they understood it.

4. When Attempting to Forecast an Organizational Metric, Develop a Complete Understanding of what Is Being Measured and from Where the Data/Results Come.

As previously discussed, N1 initially wanted to forecast the Nuke Zone A retention rate. With minimal research, we discovered that the candidate question would not be very useful in a prediction market at that time, as the Navy had temporarily suspended re-enlistment bonuses.

5. Properly Phrasing Prediction Market Questions is a Challenging Task that Requires Great Care.

It is very easy to introduce ambiguity in a question with haphazard phrasing. For example, we published a market with the following phrasing: Will the Dow Jones Industrial Average (INDU) close above 9,400 **by** COB on Friday, Aug. 14, 2009? (It had closed at 9,370 on Aug. 7, 2009, when the weeklong market was introduced). Instead, we meant to ask the following: Will the Dow Jones Industrial Average close above 9,400 **on** Friday, August 14, 2009, at COB? The published phrasing provided an opportunity for the Dow Jones Industrial Average to eclipse 9,400 each day up to August 14, 2009. Hence, we were forced to closely monitor the conclusion of the stock market each day in the event the Dow Jones Industrial Average closed above 9,400. If this condition were met, we would have preemptively closed and paid out the market before the intended closing date of August 14, 2009.

We faced two additional challenges with phrasing. One challenge was jargon ambiguity. The N1 jargon was the Nuke Zone A retention rate. We simply did not understand the rules for determining whether a Nuke was in Zone A or another zone. Second, the Inkling interface limited the question length to 140

characters for Twitter integration. This 140 character constraint made it very difficult for us to ask complicated questions. We generally used the Market Information text box to provide supplemental details. Unfortunately, the Market Information text box appeared at the bottom of the webpage and may not have been obvious to participants.

Despite these challenges, we were pleased to find out the drop off in participation was not because of poorly phrased questions. In fact, 11 of 12 active users felt the prediction market questions were somewhat or very clear.

6. Running a Prediction Market Takes Time and Effort.

This may seem an obvious statement, but the point should not be taken lightly. Our recommendation is to outsource the initial market setup. There are many decisions in the initial setup that affect the market's success. After the market is established, one person could easily manage accounts and technical issues as a collateral duty. However, it would be unwise to task one person to generate interesting, yet unambiguous questions.

Perhaps the most difficult task was to generate, formulate, and vet questions for all possible trader interpretations. It would be very difficult for a single person to consider how different participants may interpret the prediction market questions. Even with three to five people reviewing each question before publication, we still ended up with at least one poorly worded question. We recommend that a group of approximately three to five middle-management personnel perform this task. This group should publish questions and monitor trader comments for possible confusion. If necessary, they should suspend trading and refund participants to pre-trade levels. In addition, the members of this group need to ensure they fully understand how the outcome is measured and whether the pay-off is clear.

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VIII. Navy-specific Considerations for Prediction Market Utilization

Navy decision-makers need all available useful information to make informed decisions. An efficient and effective information aggregation tool may prove invaluable to Navy decision-makers considering the gravity of the decisions they must make. It is important, however, to consider both the benefits and the limitations of prediction markets that most directly affect Navy utilization of prediction markets.

A. Benefits

Generally, the prediction market benefits and limitations discussed in Chapter III hold true for Navy prediction markets. The dynamic nature and potential for accessing the collective organizational information are among the most important and desirable benefits of prediction markets.

The dynamic nature of prediction markets can help Navy decision-makers overcome common organizational challenges. For instance, in some Navy commands, decision-makers do not have adequate access to much of the organization's existing knowledge. Moreover, they simply may not know it exists or may not know whom to ask for the information they seek. The Navy is too large an organization and too complex for any single individual to fully grasp the details and inner workings of each level of operation. This adverse characteristic unfortunately translates down to the command level as well. For instance, when tracking progress on an acquisition program, such as the Joint Strike Fighter, no one individual can identify, understand, and maintain every detail associated with that program. Therefore, middle-level managers collect and manage information in a departmentalized way. However, information often is lost in translation and transmission upward through chains-of-command. Prediction markets would

allow Navy decision-makers to easily query the whole organization to aggregate the specific information spread across the entire organization.

Another challenge Navy decision-makers face is that some organizational information is lost over time. Information can be lost because some people do not have the incentive or wherewithal to reveal it to appropriate decision-makers; additionally, tacit knowledge is almost certainly lost as military members continuously rotate in and out of Navy commands. Easily accessible prediction markets can provide a means for retrieving such information that normally would be lost.

Prediction markets may benefit the Navy further because of their ability to aggregate useful information in an anonymous manner. It is always easy for employees to trumpet pleasant information to their superiors, but many employees (especially middle management) find it difficult to share negative information, resulting in uninformed senior leadership. Anonymous prediction markets offer a solution for sharing unpleasant information and removing the middle management bias by giving lower-level individuals a mechanism through which to share their insight and perspective, without fear of middle-management reprisal.

B. Limitations

The Navy also must consider prediction market limitations to make a sound judgment on whether and when to utilize prediction markets. We believe participatory challenges and organizational/cultural barriers are the limitations most likely to affect the success of Navy-sponsored prediction markets. These, in turn, would have implications on the markets that can be used. Each challenge is discussed below.

1. Participatory Challenges

We believe there are three primary reasons the Navy will face participatory challenges when utilizing prediction markets. First, the Navy's prediction market claims will be highly specialized—such as claims on endstrength, re-enlistment bonuses, recruiting goals and other issues that are not common to the layperson—and they will require a degree of Navy-specific knowledge for individuals to trade with any expertise. As a result, most potential participants may feel disadvantaged in a given market since they believe other traders possess either privileged information or greater specialization, while they themselves do not. Second, the Navy is limited in the rewards it may offer traders for their participation. Various legal and ethical barriers may preclude the Navy from using monetary or nonmonetary compensation; yet, incentives are essential for ensuring market participants remain actively engaged. Finally, traders may believe that their participation is futile or irrelevant since market parameters can easily change. Decision-makers can affect prediction markets by changing policies or conditions that are directly associated with a given market; when this occurs, trader positions can be undermined within the affected market.

a. Perceived Disadvantage

As mentioned above, Navy prediction markets often deal with very specific items of concern. As such, traders may need to possess relevant specialized information. Additionally, some traders may have unique access to critical or sensitive information relative to a prediction market, and some may have earlier access than others to market information.

Although the nature of prediction markets requires a degree of insider trading to reveal information, the detriment comes when only a few individuals have insight to the relevant market information. When this occurs, the majority of the participation pool is considered uninformed, and the informed traders can exploit their insider positions. Insider trading is outlawed in public stock markets

to protect non-insiders. Yet, it is difficult to make similar regulations for prediction markets.

Participants believing others have a significant advantage (due to access to information) may avoid trading because of their perceived position of inferiority within a given market. As such, certain Navy markets—such as those pertaining to recruiting goals or endstrength—will likely have a very thin and specific participant pool.

One such case occurred within our prediction market experiment involving the Navy endstrength. Two traders from N104 posted weekly updates of current Navy force strength levels. This led some traders to believe that these individuals, if not others, had early access to critical information. Moreover, one NPS trader explicitly indicated that he felt he was at a significant disadvantage because other people had this early access to the current force numbers. It so happens that this was the most-heavily traded market in terms of total active traders and total trades. This may reflect that this particular market was the first market introduced to all our participants, so it was up and running when traders were still active. Of note, roughly 50 of 70 total trades within the endstrength market occurred after the N104 weekly forecast updates first began. Therefore, had other participants drawn the same conclusion as the NPS trader, this particular market may have experienced significantly less trading activity and participation.

b. The Navy Is Limited in the Incentives It Can Offer

Prediction market participation often hinges directly on participation incentives. Because legal restrictions and concerns over public perception likely preclude the Navy from using real-money prediction markets, it will have to incentivize participation while using play-money markets. In addition, it is unlikely that the Navy could elicit participation via certain hard incentives, such as monetary rewards. Such incentives might raise public concerns on the proper

and ethical use of government money. A secondary concern may be that some cash rewards could shift Navy prediction market participants' loyalties and focus them away from their primary duties and toward their participation and engagement in Navy prediction markets. This last concern is explained more fully below in the section discussing organizational/cultural barriers.

c. Parameters May Change

It is important to note that managerial decisions can drastically affect an open market regardless of whether such decisions depend on that market's current forecasting assessment. Herein lay the dilemma: organizational leaders want to use prediction markets as a forecasting tool to enhance their decision-making process; however, actions taken or decisions made by these leaders can significantly affect open markets and their associated assessments, potentially undermining trader positions. Thus, some traders may be less inclined to participate in markets they believe to be overly susceptible to influence through management decisions. As a result, participation may wane in certain Navy markets.

For instance, imagine the Navy wishes to establish a market to determine if it will meet its recruiting goal in a period when the economy is growing. When the economy is growing, the Navy has a more difficult time reaching its recruiting goals. Nevertheless, the Navy typically meets its recruiting goals by making appropriate management decisions. Some common decisions are to raise enlistment bonuses, lower Armed Forces Vocational Aptitude Battery (ASVAB) score requirements, issue more conduct waivers (allowing those with a criminal history to enlist), or raise the recruit maximum age requirement. If Navy decision-makers perceive they are not reaching recruiting goals, they would make necessary changes to enlistment incentives or standards, changing the parameters for any prediction market.

This may limit participation for two reasons. First, the likelihood that the Navy will do what it takes to meet its goals (for recruiting or retention) could make a market uninteresting to some potential traders. On the other hand, some may invest in the prediction market based on that belief. One case from our prediction market experiment highlights this. Numerous traders participated in the market surrounding the following question: "What will be the Navy's endstrength (for officers and enlisted personnel) for FY2009?" Although only one trader offered a reason for conducting trades in the manner that he/she did, that one trader stated: "Meeting endstrength is a high priority—the Navy makes it happen." In this instance, it is clear that the trader believed the Navy would take action(s) to ensure the established endstrength goal was met and, therefore, conducted a market trade as a result of this belief.

Second, participation may be limited because the changed parameters may undermine traders' positions. For example, a trader may believe that the economy is going to be stronger (and thus the recruiting environment will be more difficult) than most people think, but they may be hesitant to invest in an outcome based on this belief knowing that the Navy may change the parameters (e.g., raise enlistment bonuses) to meet the end-goal. Many individuals in the Navy believe the Navy will act to ensure they meet established goals. Therefore, potential traders may be less likely to participate in a market associated with a goal open to managerial influence. This concern does not apply to all outcomes, but it applies to outcomes such as recruiting and retention.

In markets with outcomes for which the Navy can change the underlying parameters, incorporating specific market rules to accommodate unexpected managerial parameter changes may alleviate traders' concerns. One common rule pays traders at the time of any major policy change that could affect the prediction market outcome. Such a rule must be in place and clearly communicated to all potential participants prior to and during a given market's

open period. This ensures that all participants are aware of the potential for change and that an identifiable contingency is in place for such change.

As a consequence of potentially limited participation from these problems, the Navy is susceptible to thin markets. If the potential participant pool is small, an automated market maker is necessary to promote liquidity and avoid high person-to-person bid/ask spreads.[17] As discussed earlier, thin markets are not a preferred condition for prediction markets. Moreover, automated market makers are not necessarily desirable, as they inject an unwanted element of artificiality into the markets.[18]

To conclude, participatory challenges will affect the Navy's ability to usefully employ some prediction markets. These challenges include each of the following: 1) some traders perceive themselves to be at a disadvantage relative to other traders who may possess privileged information; 2) the Navy is limited in the incentives it can offer, and 3) prediction market parameters may change. Each of these issues could affect a potential trader's desire to participate in a given prediction market, and each can ultimately cause overall participation levels to decrease. Furthermore, each of the participatory challenges can lead to thinner markets. As a result of thin markets, the Navy likely would have to use some market maker to promote liquidity throughout the markets. Unfortunately, market makers can inject artificiality into markets.

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[17] As discussed in Chapter V, automated market makers act as a universal buyer/seller to permit trades to occur without requiring direct trader-to-trader interactions.

[18] As mentioned earlier, the way in market makers conduct their calculations often is based on the market manager's arbitrary assignment of specific values within the market maker's root formulas. As a result, the market maker artificially approximates the market's supply-and-demand equilibrium, resulting in a correlated security price—instead of the new market price simply being set by the lowest asking price.

2. Organizational/Cultural Barriers

In addition to participatory challenges, the Navy may have great barriers to overcome in terms of its organizational structure and culture. Strong-rooted, hierarchical organizations such as the Navy may be less inclined to adopt and embrace prediction markets without skepticism and resistance from many people throughout the chain-of-command; individuals generally oppose change within such organizations because they routinely and frequently experience change with senior leaders rotating in and out of command positions. Furthermore, there stands to be a blemish on senior decision-makers' records if they take actions that oppose fulfilled beliefs of the collective prediction market group. In other words, if the group believes a given event will occur, and its belief is contrary to the opinion of senior Navy leaders, then the senior leaders may appear inept if the event actually occurs according to the group's forecasted belief. Tom Davenport of Babson College elaborates:

> The barriers to adoption of prediction markets are primarily cultural [...]. Let's say that your company runs a prediction market on first-year sales of a new product, and the results come out not so positively. Let's say that the employees who participate predict much lower sales than, say, the product manager for the new product, the division president, and the CEO. […] The crowd has made the hierarchy look bad, and the hierarchy doesn't generally like to look bad. (2008, January 14)

Because of this potential problem, prediction markets likely will be most effective and welcomed in Navy commands that have particularly strong leaders who are open to change and readily acknowledge they are not always capable of making the best decisions without the aid of their subordinates and colleagues.

Aside from the issue of professional image, other organizational barriers may exist. Some employees may work in a position that affords them an opportunity to affect a given prediction market. Worse yet, some employees may work in a position that allows them to affect organizational operations because of personal interest in a given prediction market. Individuals in this sort of position

likely have excellent insight to offer the market as a whole. However, the potential consequences of participation by these people raise more questions that Navy decision-makers must consider prior to implementing prediction markets:

- Should individuals (or teams) with such positions be permitted to participate in the market?
- Should their participation in the market be limited or controlled?
- Is there another way to work their knowledge into the market without risking a conflict of interest?

These questions and challenges create a serious quandary for any organization, but the nature of the Navy's work makes them ever more important and challenging.

C. When Not to Use Prediction Markets

There are several conditions for which prediction markets probably would not add any value to current forecasting techniques. The first condition is when outcomes have a high degree of predictability. There is little advantage to using a prediction market to predict events that are highly predictable. The organization should simply rely on historical data and patterns to forecast these events. In our market, one trader commented on the enlisted accession goal question that the Navy would do what it takes to meet their retention goal. He intuitively knew that they would make a management decision to change parameters to meet the enlisted accession goal.

Prediction markets may offer a benefit to the Navy when historical data is limited, erratic, or unreliable—under such conditions, statistical and econometric forecasting methods generally cannot provide accurate forecasts.

The second condition rendering prediction markets less useful exists when there is limited dispersed information to aggregate or market participants cannot

retrieve existing information. The point of a prediction market is to aggregate available information from among its participants. If information does not exist, participants do not possess relevant information or participants cannot retrieve existing information, then the prediction market cannot function. Furthermore, if traders attempted to participate in a market that is incapable of aggregating information because of the condition above, the collective market assessment is uncertain, making the assessment unfit for use by organizational decision-makers.

The third condition exists when there are only a limited number of knowledgeable traders. There is no need to use a prediction market to forecast an event if an organization can reliably turn to one or a few members for the information. One trader in our prediction market experiment had early access to Navy endstrength numbers. This trader shared that information with the rest of the traders and updated the market with weekly numbers. As previously mentioned, other people may have opted not to participate in the market surrounding this question because they perceived this individual to have insider knowledge.

Prediction markets seem to be a natural fit for determining Navy project management and acquisition outcomes, such as determining how a given project's progress is tracking with respect to all departments, divisions, and subprojects. For example, "When will the Joint Strike Fighter program receive milestone decision authority approval to begin full-rate production?" There appear to be fewer instances in which prediction markets are appropriate for determining outcomes in the Navy N1 domain. It seems N1 should have the technology to collect, aggregate and access quantifiable information on-demand.

D. The Way Forward for Navy Prediction Market Application

Prediction markets can be a positive and powerful decision-making resource, and they can have a place in Navy forecasting—with strong leadership and a positive organizational culture that embraces change and opportunity. However, what we have seen to this point is that the challenges and limitations of prediction markets are extremely significant, and they may be difficult to overcome.

Should Navy leadership use prediction markets in a formal and official manner, the top levels of the chain-of-command must accept, embrace, and encourage the markets. Moreover, leadership must establish a full training initiative to ensure all members of the organization understand the purpose of markets, as well as their roles within the market. Finally, Navy leadership must fully understand the intricacies of prediction markets to employ them properly. Lessons learned from this thesis highlight the fact that it is an extremely difficult task to understand what organizational issues or concerns are best assessed by prediction markets. For instance, an organization may forecast specific sensitive metrics, such as endstrength, but prediction markets can be complicated when forecasting these metrics because of the following additional problems:

- Inconsistencies in organizational or cross-organizational terminology,
- Misunderstandings or misperceptions among organizational leadership or members on what truly is or should be forecasted, and
- Difficulty in pinpointing the means by which organizations officially measure a given metric; it is essential to ensure markets are appropriately closed, and contract payouts are noncontroversial.

Based on post-market survey results and lessons learned during this thesis research, the following are some manpower outcomes (that we did not

previously consider in our discussions with N1) that could potentially work in a prediction market:

- Advancement opportunities;
- Attrition rates—unlike recruiting and retention outcomes, attrition would not likely be subject to policy changes;
- Whether the Navy will change certain recruiting and retention incentives, for example:
  - Increase (or decrease) an enlistment bonus,
  - Increase (or decrease) SRB's for particular ratings, or
  - Increase (or decrease) the limit on enlistees without a high school diploma.

Note that all of these would avoid the problem of management changing policy levers, which could undermine traders' positions in certain outcomes.

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IX. Conclusion and Recommendations

Navy N1 regularly forecasts re-enlistment rates, endstrength, and many other force-shaping factors as an input into its resource-allocation decision-making process. In an effort to improve upon the force-shaping decision-making process, N1 has shown interest in using prediction markets to complement or replace alternative methods for forecasting various Navy force-shaping elements. We conducted a pilot prediction market with N1 personnel as the participants. We subsequently conducted two anonymous post-prediction market surveys: a "user" survey for those who registered and had at least one trade and a "non-user" survey for those who did not participate.

The aim of this thesis is to act as a foundation for ongoing prediction market research within the Department of Defense (DoD). To this end, we answer our research questions.

A. Research Questions

1. What are the Key Benefits and Potential Limitations of Prediction Markets?

Prediction markets have a proven record in the corporate context. The key benefits of prediction markets include their dynamic nature, accuracy, and potential for anonymous revelations. Prediction markets are dynamic; that is, they are capable of efficiently aggregating information in a continuous or ongoing manner. Additionally, prediction markets are capable of aggregating information with a high degree of accuracy; they can quickly pull together information spread across many people and places, and the accuracy of the results can rival almost any alternative forecasting method under optimal conditions. Moreover, prediction markets allow users to express anonymous personal opinions and beliefs on specific topics; this encourages feedback at all organizational levels without any fear of management or peer reprisal.

The chief limitations addressed in this thesis are those associated with participation, manipulation, biases, and legal restrictions. Prediction markets require some minimum level of participation to avoid stagnation. Without enough active participants, some traders may lose interest and/or incentive to share their information with others. Furthermore, manipulation can become a viable concern in prediction markets that have little active participation. Additionally, several biases can affect trading and, thus, accuracy, including: over-optimism, under-pricing extremes, long shot, and social judgment. Finally, legal restrictions can limit some organizations' ability to easily or efficiently implement and manage prediction markets; legal restrictions generally have the greatest impact on real-money prediction markets, as government concerns with gambling and ethics move to the forefront.

2. What Does the Current Literature and Practical Evidence Suggest about Prediction Market Use as a Forecasting Tool?

The current literature highlights practical evidence of prediction market use in various industries. Furthermore, it discusses prediction market potential and the arenas within which markets should be considered. Some businesses have had notable success employing prediction markets. These companies have used internal prediction markets to help forecast key events, such as the success of new products, future profitability, or mergers/acquisitions within their industry.

One previously noted example is that of Hewlett-Packard's prediction markets outperforming traditional printer sales forecasts in 75% of the observances (Hanson, 2003, p. 107). Additionally, Google has enhanced its management's decision-making process by using prediction markets to forecast how many consumers will use their applications, such as Gmail (Dye, 2008, p. 87). Google has been able to make resource-allocation decisions, such as server capacity, to support its projected number of users. Similarly, pharmaceutical companies have used prediction markets to determine which drugs in their experimental process have the best chance for FDA approval. Thus, they are

able to make resource-allocation decisions based on those drugs that have the highest probability of successfully making it to market. Finally, Abramowicz (2003) asserts there are times to believe prediction markets may provide greater efficiency or objectivity than expert forecasters: "It is in governmental decisionmaking [*sic*], however, where there is the greatest reason to be suspicious of experts, either because of external influence or because of ideological agendas" (pp. 20–21).

3. Can Prediction Markets Be an Effective Tool for Navy Force-shaping Forecasting?

The current literature, corporate successes, past and present lessons learned, and the growth of the prediction market field all indicate that prediction markets could be an effective tool for Navy force-shaping forecasting and decision-making. However, results of this project's experimental prediction market are inconclusive. Several constraints and issues caused us to design and implement the experimental market in a less-than-ideal manner. As a result, we can speak very little regarding the accuracy or efficiency of our markets. Moreover, issues associated with participant selection, ongoing participation, and perceptions of ownership reinforced the researchers' preconceived belief that certain cultural and organizational hurdles may adversely affect the development and implementation of an official Navy prediction market.

The researchers still believe that prediction markets can be a positive and powerful decision-making resource, and they can have a place in Navy forecasting—with a positive organizational culture that embraces change and opportunity. However, what we have seen to this point (as indicated by post-market survey results) is that several individuals elected not to participate because they did not understand the markets' purpose and intent, lacked time or incentives to participate, were uninterested, or did not believe the markets were spearheaded by Navy organizational leadership. To be sure, these issues are not a negative reflection upon prediction markets or upon any members associated

with the design, implementation, or conduct of the markets. Rather, such issues are an expected byproduct of the research and experimental process.

The aforementioned issues, highlighted by the post-market survey, speak more directly to underlying issues of organizational culture and proper training. More effective training might have curbed some of the sentiments expressed in the post-market survey. Additionally, the Navy, as well as most governmental organizations, is known for having a strong and unique culture steeped in tradition and heritage. There are, however, some commonly known and experienced negative effects associated with such a culture, and the inability to easily accept and embrace change is one.

Should Navy leadership choose to use prediction markets in a formal and official manner, the top levels of the chain-of-command must accept, embrace, and encourage the markets. Moreover, leadership must emplace a full training initiative to ensure all members of the organization understand the markets' purpose, as well as their role(s) within the market. Finally, Navy leadership must fully understand the intricacies of prediction markets to employ them properly. Lessons learned from this thesis highlight the extreme difficulty to understand what organizational issues or concerns are best assessed by prediction markets. More specifically, an organization may forecast specific sensitive metrics, such as endstrength, but prediction markets can be complicated when attempting to forecast these metrics because of several problems:

- Inconsistencies in organizational or cross-organizational terminology,
- Misunderstandings or misperceptions among organizational leadership or members on what truly is or should be forecasted, and
- Difficulties in pinpointing the means by which organizations officially measure a given metric, while ensuring markets are appropriately closed and that contract payouts are noncontroversial.

4. In what Areas Should the Navy Consider Using a Prediction Market?

Since the results of the experimental prediction market are inconclusive, one cannot say with certainty how the Navy should use prediction markets. Moreover, this thesis is the first of several to examine the potential for Navy prediction markets. Subsequent theses will focus more on practical applications and developments to meet the Navy's real-world needs. Thus, the results of those theses should be more conclusive and offer greater insight in this respect than did this one.

In addition, it is worth reiterating major participatory challenges the Navy will face in using prediction markets, as discussed in Chapter VIII. First, the Navy's prediction market claims will be highly specialized—such as claims on endstrength, re-enlistment bonuses, recruiting goals and other issues that are not common to the layperson—and they will require a degree of expertise for individuals to trade with any certainty within a given Navy market. As a result, potential participants may perceive that they are at a disadvantage in a market because other traders possess either privileged information or the necessary degree of specialization, while they themselves do not. Second, traders may believe that their participation is futile or irrelevant since market parameters can easily change. Decision-makers can affect prediction markets by changing policies or conditions that are directly associated with a given market; when this occurs, trader positions are undermined within the affected market. Therefore, the Navy should avoid using prediction markets for predicting outcomes that have parameters that are likely to change.

In light of the major challenges facing prediction market utilization, the Navy can utilize prediction markets to forecast many issues of concern. The key to successfully employing the markets lies in designing effective and measurable market contracts pertaining to the issue(s) of concern, developing a useful participation pool, and eliciting ongoing participation. Employed properly,

prediction markets should be able to assist decision-makers in most issues of concern.

Post-market survey results offer some specific examples of key forecasting issues for which the Navy might consider utilizing prediction markets. In addition to endstrength and annual enlisted accession goals (as covered by this thesis's experiment), survey respondents cited the following specific Navy issues for future prediction markets: advancement opportunity, retention rates, and attrition rates. The following are some manpower outcomes we believe could potentially work in a prediction market:

- Advancement opportunities;
- Attrition rates—unlike recruiting and retention outcomes, attrition would not likely be subject to policy changes;
- Whether the Navy will change certain recruiting and retention incentives, for example:
  - Increase (or decrease) an enlistment bonus,
  - Increase (or decrease) SRB's for particular ratings, or
  - Increase (or decrease) the limit on enlistees without a high school diploma.

5. In Conducting a Pilot Prediction Market, What Lessons Learned Can We Provide to the Navy Regarding the Design, Implementation, and Utilization of Prediction Markets?

Participation is, perhaps, the most critical and challenging aspect of prediction market implementation and conduct. Traders need to be induced into participating in a prediction market, especially when the participant pool is small. With a large potential participant pool, a low participation rate is not necessarily bad. An efficient market, rather, depends upon a critical mass of active traders. If an organization with limited potential participants introduces a prediction market, a higher participation rate is more critical than in an organization with a larger potential participant pool. In any case, participant selection should be more

inclusive than exclusive. It is important to include people from varying organizational levels and departments so the prediction market may incorporate the information afforded them by their unique perspectives.

Additionally, there is no such thing as a “one-size-fits-all” design for all organizations. As described in Chapter V, decision-makers must consider many issues when determining what type of market is most useful, given organizational preferences and parameters. The primary considerations are:

- How large is the potential participant pool?
- What type of information is the organization forecasting?

If the potential participant pool is small, an automated market maker is necessary to promote liquidity and avoid high person-to-person bid/ask spreads. Additionally, the organization’s selection of a market mechanism should depend on the type of information the organization desires to forecast. If an organization is forecasting mutually exclusive or discrete outcomes, MSR is an appropriate mechanism. However, MSR does not allow organizations to forecast continuous organizational metrics; the CDA or DPM mechanisms are more appropriate when organizations want to pinpoint a continuous number.

Group training is necessary, as it can preclude or mitigate confusion or doubt among potential participants. Specifically, organizations should use group training for the following reasons: to introduce potential participants to the prediction market interface and demonstrate its site navigation, to inform participants of various trading strategies (such as short selling), and to display executive sponsorship. If the training includes account setup and interface introduction, participants will have fewer reasons for not participating. Furthermore, group training may provide an opportunity to preemptively boost participation by challenging people to compete against one another.

Prediction market administration requires a great deal of time and effort, and it is complicated by subtleties such as question phrasing. It is difficult to develop useful and measurable organizational questions. Additionally, the prediction market experiment proved it challenging to phrase questions unambiguously so people with varied backgrounds clearly understand the true intent of the question asked. It is equally challenging to derive comparative forecasts to measure the relative accuracy of the prediction market forecasts. Each of these challenges translates into additional administrator time and effort to manage a market. Moreover, marketplace administration should not be tasked to one, or even two people. Ideally, organizations should designate a small group of people to manage and administer the marketplace—the size of the group will depend on the questions involved, as well as the nature of information sought.

Appendix A. Active-user Survey

Question number	Questions to Ask	Suggested Question Type	Responses
1	Do you feel the Prediction Market questions were clear?	Rate one item on a scale Comments optional	Rating scale:
			Very clear
			Somewhat clear
			Neutral
			Somewhat unclear
			Very unclear
2	Did you feel you had expertise in the Navy-specific market questions?	Yes/No/Uncertain	
3	What group(s) of Navy personnel should be included in future N1 prediction markets to help better aggregate force-structure information?	Multiple select multiple choice	Select all that apply:
		Comments optional	Recruiters
			Manpower analysts
			Budget analysts
			Other
4	What factors influenced you to initially participate?	Multiple-select multiple choice	Select all that apply:
			Management influence
			Peer pressure
		Comments optional	Relevant/interesting questions
			Intrigue in Prediction Markets
			Confidence in my information
			Ability to provide my opinion in a non-confrontational forum
			Competition
			Other

5	What factors influenced your continued participation past the first few weeks?	Multiple-select multiple choice	Select all that apply:
			Weekly email update
			Management influence
			Peer pressure
		Comments optional	Relevant/interesting questions
			Intrigue in Prediction Markets
			Confidence in my information
			Ability to provide my opinion in a non-confrontational forum
			Competition
			Other
6	If you made early trades but reduced your trading activity, what if anything, limited your participation?	Multiple-choice multiple select	Select all that apply:
			Not applicable
			Felt questions achieved market equilibrium
			Lack of time
		Comments optional	Lack of incentive
			Uninterested
			Questions were not relevant/interesting
			Lack of confidence in anonymity or user rights protection
			Did not fully understand the concept or intent
			Technical/IT issues
			Other
7	What incentives would cause you to participate in a future DoD/Navy prediction market?	Multiple-select multiple choice	Select all that apply:
			None
			Preferred parking spot
			Lunch with VIP
		Comments optional	Movie tickets
			Top trader t-shirt
			Recognition at an HR conference
			Monetary reward
			iPod
			Other

8	What other Navy topics would you find interesting to try to predict using a prediction market?	Free text	
9	Do you believe you understand the concept of short-selling (selling shares you don't have, believing that a category is priced too high)?	Yes/No/Uncertain	
10	Based upon your experience with your prediction market, would you participate in a future prediction market?	Yes/No/Uncertain Why or why not? Comment required	
11	What was your understanding for the motivation of this Prediction Market pilot?	Single-select multiple choice Comments optional	Select one: NPS Thesis Project N1 Initiative Neither Both

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Appendix B. Non-user Survey

Question number	Questions to Ask	Question Type	Responses
1	What affected your decision to not participate?	Multple-choice multiple select	Select all that apply:
			Lack of time
			Lack of incentive
			Uninterested
		Comments optional	Questions were not relevant/interesting
			Lack of confidence in anonymity or user rights protection
			Did not fully understand the concept & intent
			Technical/IT issues
			Other
2	What incentives would cause you to participate in a future DoD/Navy prediction market?	Multple-choice multiple select	Select all that apply:
			None
			Preferred parking spot
			Lunch with VIP
			Movie tickets
		Comments optional	Top trader t-shirt
			Recognition at an HR conference
			Monetary reward
			iPod
			Other
3	What was your understanding for the motivation of this Prediction Market pilot?	Single-choice multiple select	Select one:
			NPS Thesis Project
			N1 Initiative
		Comments optional	Neither
			Both

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2003 - 2009 Sponsored Research Topics

Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-tem Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
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