NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Prediction Markets as a Way to Manage Acquisition Programs

By: Joshua M. Dishmon

June 2011

Advisors: Pete Coughlan
William R. Gates

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** June 2011	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report	
4. TITLE AND SUBTITLE Prediction Markets as a Way to Manage Acquisition Programs			**5. FUNDING NUMBERS**
6. AUTHOR(S) Joshua M. Dishmon			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol Number ____N/A_____			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE** A
13. ABSTRACT (maximum 200 words) Prediction markets generally are small-scale electronic markets that tie payoffs to measurable future events. They are similar to stock markets, where 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 in acquisition programs. This thesis evaluates the usefulness of prediction markets in the Department of Defense (DoD) acquisition field.			
14. SUBJECT TERMS Prediction markets, information markets, information aggregation, forecasting, acquisition			**15. NUMBER OF PAGES** 49
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

PREDICTION MARKETS AS A WAY TO MANAGE ACQUISITION PROGRAMS

Joshua M. Dishmon, Lieutenant Commander, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
June 2011

Author: _____
Joshua M. Dishmon

Approved by: _____
Pete Coughlan, Lead Advisor

_____
William R. Gates, Support Advisor

_____
William R. Gates, Dean
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

PREDICTION MARKETS AS A WAY TO MANAGE ACQUISITION PROGRAMS

ABSTRACT

Prediction markets generally are small-scale electronic markets that tie payoffs to measurable future events. They are similar to stock markets, where 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 in acquisition programs. This thesis evaluates the usefulness of prediction markets in the Department of Defense (DoD) acquisition field.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I. INTRODUCTION....1
- A. BACKGROUND....1
- B. BENEFIT OF THESIS....2
- C. THESIS SCOPE....2
- D. METHODOLOGY....3
- E. ORGANIZATION OF THESIS....3

II. PREDICTION MARKETS: WHAT THEY ARE AND WHY THEY ARE (POTENTIALLY) VALUABLE....5

III. DESIGN ISSUES/DECISION VARIABLES OF PREDICTION MARKETS....7
- A. MARKET DESIGN....7
- B. CONTRACT TYPE....7
- C. PAYOFF TYPE....9
- D. PARTICIPANT QUALITY....10

IV. MEASURING PERFORMANCE OR SUCCESS....11
- A. ANONYMITY....11
- B. INCENTIVES....11
- C. RANGE OF OUTCOMES....11
- D. REAL-TIME UPDATES....11

V. PRIVATE SECTOR APPLICATIONS AND RESULTS....13
- A. HEWLETT-PACKARD....14
- B. SIEMENS....15
- C. MICROSOFT....17

VI. OTHER "REAL WORLD" APPLICATIONS AND RESULTS....19
- A. IOWA ELECTRONIC MARKET....19
- B. GOLDMAN SACHS AND DEUTSCHE BANK "ECONOMIC DERIVATIVES" MARKET....20

VII. APPLICATION TO DEPARTMENT OF DEFENSE ACQUISITION PROCESS....23
- A. CONTRACT....24
- B. END POINT....24
- C. PARTICIPANTS....25
- D. MANAGEMENT INVOLVEMENT....25

VIII. CONCLUSIONS....27
- A. CONCLUSIONS....27

LIST OF REFERENCES....29

INITIAL DISTRIBUTION LIST....31

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

Figure 1. Multiple Contract Results (Illustrative Example) 8
Figure 2. Pay-off Structure at Siemens (From Ortner, 1998).....16
Figure 3. Information Revelation Over Time (From Wolfers & Zitzewitz, 2004) 20
Figure 4. Forecasting Economic Outcomes (From Gürkaynak & Wolfers, 2005) 21

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

Table 1. Contract Types (From Wolfers & Zitzewitz, 2004).....9
Table 2. Experiences of Early Adopters (From Malone, 2004 & Kiviat, 2004).....13
Table 3. Summary of Private Sector Applications.....18
Table 4. Popular Prediction Markets.....22

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
HP	Hewlett-Packard
PAM	Policy Analysis Market
R&D	Research and Development

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

I would like to thank the following people for their roles in this project:

- Dean Bill Gates–Thank you for pushing me to complete this, and for the guidance you have provided along the way
- Professor Jeremy Arkes
- Professor Pete Coughlan
- I would especially like to thank my beautiful wife, Amanda, and precious daughter, Adah, for their love, patience, and encouragement.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. BACKGROUND

Prediction markets—also known as information markets, internal markets, decision markets, or futures markets—collect and gather information from a number of people to make a prediction about a future event. Information is gathered by buying and selling shares in alternative outcomes for some future event. The idea is that every person in the market has a small piece of information about the future event, and the most likely outcome will be identified when information is aggregated via a prediction market. Traders use their best information when buying and selling contracts because incentives are tied to accurate predictions, not biased expectations. "In a truly efficient prediction market, the market price will be the best predictor of the event, and no combination of available polls or other information can be used to improve on the market-generated forecasts" (Wolfers & Zitzewitz, 2004, p. 108). From the prediction market outcome, management can make strategic decisions about future sales or products.

The range of current applications includes political elections, entertainment, sports, science and technology developments, commodities futures, current events, and economic data. "[Prediction markets] are practical for corporate strategists given that internal markets can stream decentralized intelligence into accurate predictions about future events" (Corporate Executive Board, 2006, p. 2). A number of companies currently use prediction markets, including Hewlett-Packard (HP), Microsoft, Google, Yahoo, Siemens, Eli Lilly, and others.

The Department of Defense (DoD) attempted to use prediction markets in the past but was met with political pressure to discontinue their use. After the intelligence community's failure to efficiently aggregate intelligence information prior to the September 11, 2001 terrorist attacks, the Defense Advanced Research Projects Agency (DARPA) created a Policy Analysis Market (PAM) to predict terror attacks and other political events around the world. PAM was subsequently cancelled in 2003, one day after it was announced. The controversy with PAM arose from the concern that

individuals could manipulate and profit from this market, including potential terrorists. The goal of this thesis is not to predict political or terror events, but to provide management with an additional forecasting tool to make informed decisions about programs and projects.

B. BENEFIT OF THESIS

With the current and future pressures on the Defense budget, this thesis will investigate the benefits and limitations of prediction markets as an additional (complementary) tool to manage a portfolio of acquisition programs. The potential role of prediction markets in portfolio management would be to help forecast which programs are most likely to succeed, where success means that the program is on or under budget, on or ahead of schedule, and meeting technical performance requirements or objectives. In addition, success means viability in the real world (i.e., would the end product be effective for the end user). Prediction markets have been extensively investigated in controlled settings, and private sector companies have used prediction markets in the past to help forecast the potential market success of products in their research and development (R&D) portfolios. This thesis will review the applications and results of prediction markets in such environments, and deduce if and how the DoD can best implement prediction markets as a management tool.

C. THESIS SCOPE

Private sector companies have used prediction markets to help manage research and development portfolios, employing these prediction markets to forecast which products will achieve technical objectives, be successful at market, as well as avoid cost and schedule overruns. Current and future budget constraints have led to much discussion on cutting certain acquisition programs in the DoD. Prediction markets could potentially be used to assist with decisions regarding which programs to cut based on potential success, and cost and schedule overruns. This thesis explores the feasibility of using prediction markets as a management tool in the DoD. By reviewing past prediction market applications and results, the research will analyze if and how prediction markets can best be used in the DoD acquisition process.

D. METHODOLOGY

The approach to this thesis will primarily focus on reviewing information currently available on prediction markets. The literature review will investigate:

- How and why prediction markets work in principle
- How the performance or "success" of prediction markets is measured
- The market design elements that must be chosen and calibrated in developing and implementing prediction markets
- How prediction markets are applied in private sector companies
- How prediction markets are applied to forecast the outcome of other "real world" events (elections, sporting contests, motion picture success)

The thesis will then make a connection between these previous prediction market applications and results to the DoD. Specifically, the primary objective is to determine how DoD can use prediction markets to manage a portfolio of acquisition programs.

E. ORGANIZATION OF THESIS

The thesis begins with an overview of prediction markets; specifically, what they are and why they are valuable. Next, the market elements and decision variables in prediction market design are investigated. The decision variables play a key role in prediction market success or failure. Then, the thesis discusses measures of performance or success of a prediction market. This can prove difficult in real world environments. Prediction markets measure probabilities of different outcomes. If a prediction market indicates one outcome has a higher probability than another alternative outcome, but the lower probability event occurs, it does not mean that the prediction market misjudged the probabilities; low probability events do occur.

Furthermore, prediction markets can only be as accurate as the information available to the market participants. The fact that the market gets it wrong may simply indicate the information available was low quality. Similarly, accurate prediction market outcomes may simply indicate such an abundance of accurate information that any

forecast could be correct. The most relevant test for prediction market performance is whether repeated prediction market outcomes more accurately reflect the probabilities of actual outcomes than alternative forecasting techniques.

Private sector applications and results are evaluated, along with other "real world" applications and results. Finally, the thesis connects prediction market applications to the DoD. Specifically, how might the DoD use prediction markets to aid in controlling acquisition costs and schedule overruns.

II. PREDICTION MARKETS: WHAT THEY ARE AND WHY THEY ARE (POTENTIALLY) VALUABLE

Prediction markets, in their simplest form, collect and gather information from a number of people to make a prediction about a future event. The idea is that each person has a small piece of information, and by collecting and aggregating all the information, each can make the most accurate possible prediction. Predicting the outcome of uncertain events like political or sporting events, sales forecasts, or macroeconomic indicators clearly requires that we have relevant and sufficient information with which to make our predictions as accurate as possible. Information that is typically relevant is not concentrated in the hands of one person, or even a few people. Instead, it is distributed between many people, each of whom is likely to have a small bit of pertinent knowledge. An optimal solution would be to ask all these people to share what they know and to aggregate all the information they have. To "poll" every individual would require a lot of time, effort, and money, so this method is not feasible. A prediction market is a relatively low cost and efficient means of "polling" a large number of individuals.

The following is a simple example of how information aggregation is beneficial (Kalovcova, 2007): Let us assume there are six possible states A, B, …, F, all with the same initial probability of occurring. Five individuals receive a private signal. The signal is drawn from an urn where the true state (for this example, we assume it is 'A') is represented by five balls and the remaining five states (B through F) are represented by two balls each. The probability of drawing the correct signal is therefore one third (five out of fifteen), and the probability of drawing the wrong signal is two thirds (ten out of fifteen). Each individual draws three balls, with the following results:

AAB	AEE	ABF	ACD	CDF
↓	↓	↓	↓	↓
A	E	?	?	?

The first individual thinks the true state is 'A' and is right, the second thinks the true state is 'E' and is wrong, and the remaining three individuals have no ability to predict the true state based on the signal they received, but think any of three possible states are equally

likely. The aggregated information (AAAAA, BB, CC, DD, EE, and FF) provides a much stronger signal about the true state compared to the private signal of any single individual. The problem is the difficulty in finding all the individuals who possess some relevant information, and encouraging individuals to reveal their signals truthfully. For both reasons, prediction markets are used as a mechanism for individuals to truthfully reveal their information.

Prediction markets usually provide quite accurate forecasts, and have typically outperformed alternative prediction tools. One key benefit of markets is that they motivate traders to re-evaluate the quality of their information on an ongoing basis because trading continues as new information is revealed.

> The power of prediction markets derives from the fact that they provide incentives for truthful revelation, they provide incentives for research and information discovery, and the market provides an algorithm for aggregating opinions. (Wolfers & Zitzewitz, 2004, p. 121)

III. DESIGN ISSUES/DECISION VARIABLES OF PREDICTION MARKETS

The success of prediction markets, like any market, depends on their design and implementation. Some design issues include how buyers are matched to sellers (market design), the specification of the contract (contract type), whether real money is used (payoff type), and whether enough information exists within the participant pool to provide a basis for trading and support accurate predictions (participant quality).

A. MARKET DESIGN

Most prediction markets match buyers and sellers through a continuous double auction mechanism. Buyers submit bids and sellers submit asking prices, and the mechanism executes a trade whenever the two sides reach a mutually agreeable price; this market design requires a large bidder pool so that buyers and sellers can be readily matched. Another method is the pari-mutual system, where all of the money that is bet goes into a common pot and is then divided among the winners. This system is common in horse race betting. Lastly, markets may also use a market maker who announces willingness to buy and sell at a certain range of prices. The market maker determines price using a pricing algorithm and executes trades regardless of whether there are buyers and sellers on both sides of the market. This mechanism is beneficial when liquidity in the market is limited and places a great deal of risk on the market maker.

B. CONTRACT TYPE

A prediction market motivates people to make predictions based on their best information. For the markets to work well, the contracts must be well defined, easily understandable, and tied to a specific event occurring at some fixed point in time.

Table 1 summarizes the three main types of contracts in prediction markets. First, in a "winner-take-all" contract, the contract costs $\$p$, where $\$p < 1$, and pays off \$1, if and only if a specific event occurs. The price of a winner-take-all market represents the market's expectation of the probability that the event will occur. Second, an "index" contract price provides payoffs that vary continuously based on an index number, like the

number of units sold or percent of the total votes received. Bidders purchase contracts if they expect the final outcome to exceed the level indicated by the current price, and sell shares if they expect the fixed outcome to fall short of the currently predicted level. The price of an index contract represents the market's mean expected value of the outcome. Finally, in "spread" betting, traders differentiate themselves by bidding on the cutoff that determines whether an event occurs, like whether sales volume will exceed a certain threshold. The outcome of a spread market can yield the market's expectation of the median outcome.

Additionally, a family of prediction markets can be used to evaluate uncertainty of the expectations of the event. For instance, a family of winner-take-all contracts that pay off only if the sales volume is either less than 10 units, greater than 10 but less than 20 units, greater than 20 but less than 30 units, and so on, reveals almost the entire probability distribution of the market's expectation. Experience at Microsoft has shown that using multiple contracts, and revealing the market's probability distribution, results in the most accurate prediction (Corporate Executive Board, 2006). Figure 1 illustrates that a market using multiple contracts results in a probability distribution of the most likely range of outcomes.

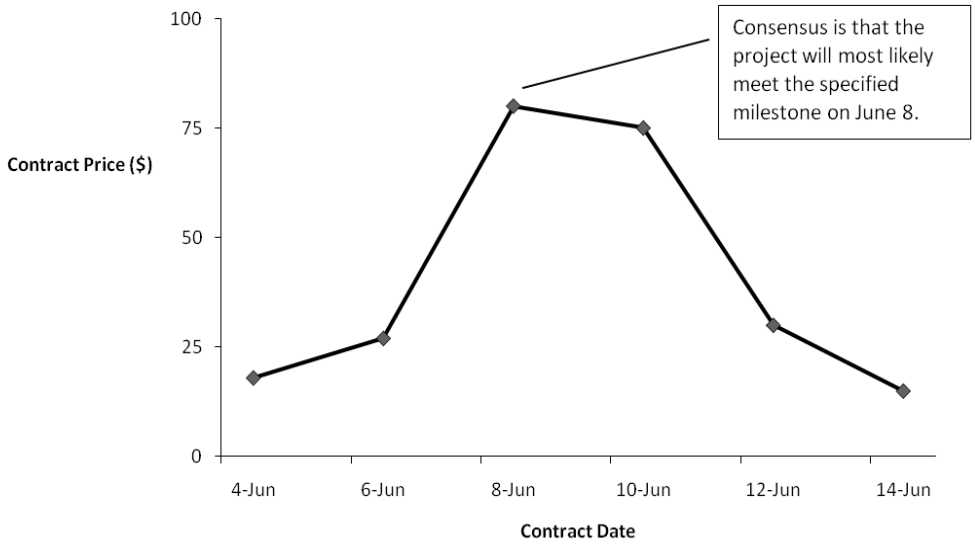

Figure 1. Multiple Contract Results (Illustrative Example)

Table 1. Contract Types (From Wolfers & Zitzewitz, 2004)

Contract	**Example**	**Details**	**Reveals market expectation of…**
Winner-take-all	Event: Sales volume is greater than X units.	Contract pays $1 if event occurs.	Probability that event will occur.
Index	Contract pays $1 for every unit sold.	If 51 units are sold, the contract pays $51.	Mean value of expected outcome.
Spread	Contract pays additional money if sales volume is more than a given threshold.	Contract costs $1. If spread is fixed at 45 units and sales are >45 units, contract pays $2. If not, contract pays nothing.	Median value of expected outcome.

C. PAYOFF TYPE

The appropriate incentive structure must also exist. The market may be designed well with appropriate trading mechanisms and contract types, but may fail if there is no motivation to trade. This raises the question of whether to use real money or play money markets. With play money, participants are provided an initial endowment and are presumed to be motivated to maximize the final value of this endowment after a predetermined trading window. With real money, participants may be given an initial endowment of real money, or they may be expected to invest their personal funds; they are presumably motivated to earn as much money as possible over the trading window. According to Wolfers and Zitzewitz (2004), there has been no difference in the performance of real versus play money markets. Some early adopters indicated employee resistance to prediction markets because they disagreed with the idea of market incentives. Critics argue that prediction markets generate predictions that a company presumes its employees are supposed to provide anyway (Corporate Executive Board, 2006). For instance, at Beta the toughest thing was getting agreement on the incentive structure. An IT Research Manager at Beta states it best:

> A group of people will think that monetary incentives are worthwhile given the potential uses and benefits of market predictions. But, on the flipside, another group believes that incentives are inappropriate, taking issue with paying people for their knowledge when forecasting is a part of the job they do.

The goal of the incentive structure is to encourage market participation to achieve the most accurate result possible. To aggregate all the information available, participation by those with the knowledge is necessary, and the participants must be motivated to trade.

D. PARTICIPANT QUALITY

Another decision factor is selecting the traders. Participants need to be selected carefully to ensure no one with relevant information is overlooked. The mix of traders needs to be diverse, so that people bring different pieces of information to the table. Additionally, one must decide whether to include uninformed traders in the market or to allow only informed participants. Uninformed traders are market participants who have little or no information regarding the future event on which the market focuses. Uninformed traders expand the participant pool and generate liquidity. The downside to uninformed traders is their potential lack of interest in participating. Designers at Beta and Siemens strived for a diverse group of participants in their markets, including employees from all divisions of the company.

Along with trader selection, educating participants is just as important. It is important for traders to re-evaluate their information often. "Inexperienced traders tend to make one trade in the early stages of the market and then not participate for the remainder of the time. Veteran traders participate actively by gathering new information from the market, monitoring the trading behavior of others, and re-evaluating their own information" (Corporate Executive Board, 2006). The most practical way to train participants is to set up experimental markets so traders can figure out how the market works and gain the experience necessary to be better participants. Research has also shown that market prediction accuracy increases through additional repetitions as participants gain experience in how prediction markets work.

IV. MEASURING PERFORMANCE OR SUCCESS

The following features make markets more effective compared to traditional tools.

A. ANONYMITY

When a manager asks a direct report to predict a business outcome or whether a project will be successful, the response is invariably impacted by what the manager wants to hear. Anonymity frees traders from this constraint.

B. INCENTIVES

Market incentives mean that participants trade on their best information and what they truly believe will happen. This greatly reduces the effects of bias found in traditional forecast methods.

C. RANGE OF OUTCOMES

A well-run prediction market includes contracts tied to both positive and negative outcomes. This forces the recognition that failure is possible, and if the market indicates that failure is likely, the organization can adjust accordingly.

D. REAL-TIME UPDATES

Contract prices update in real-time and reflect traders' shifting beliefs as they obtain new information. This is in contrast to other tools, such as surveys, which produce static data and must be rerun to obtain new information.

For these reasons, markets are generally more accurate than traditional forecasts, and even inaccurate markets provide valuable information. Markets are as useful for what they reveal about employee beliefs as for their predictions. The fact that employees are irrationally optimistic or pessimistic is useful in and of itself.

It is important to realize that the markets will always tell you something, whether they are accurate or not. You may learn about the perceptions of employees, or simply that there was not enough information to garner an accurate forecast. Regardless, the outcomes of a market prediction should not be thrown to the wayside. Markets gauge the sentiment of traders, and whether employees support official plans and forecasts. "Even when market predictions are inaccurate, executives can use trader behavior to understand organizational alignment and employee engagement" (Corporate Executive Board, 2006). This allows executives the opportunity to make necessary changes to strategic and operational plans.

> For Microsoft, the biggest surprise was how little some people cared about the accuracy of internal markets. What actually sold most on these markets was their ability to aggregate opinions quickly into an easily decipherable set of predictions. Even if the predictions were wrong, the point was that this was the outcome that traders believed, and knowing that was very useful. (Todd Proebsting, Microsoft)

It is important to look at the results to determine what they are providing, and whether the predictions are accurate.

V. PRIVATE SECTOR APPLICATIONS AND RESULTS

The current corporate applications for internal prediction markets include sales forecasting, project execution, product design, trend forecasting, and resource allocation. Sales forecasting predicts the likely volume of sales in dollars or units. Project execution predicts when projects will reach their planned milestones. Product design forecasts which product features or enhancements customers will prefer. Trend forecasting reveals new or existing market, technology, or customer trends. Resource allocation enables business units to trade resources according to their needs, and can be used to support objectives such as corporate social responsibility (Corporate Executive Board, 2006).

Table 2. Experiences of Early Adopters (From Malone, 2004 & Kiviat, 2004)

Application	Practitioner	Description
Sales Forecasting	Hewlett-Packard	Hewlett-Packard used an internal market system to forecast printer sales with considerable accuracy. Front line sales employees exchanged contracts representing the future sales volume based on their predictions of future printer sales. When trading ended, the contract valued most highly represented the most likely sales range. HP's official forecast erred by 13%, while the market erred by 6%. In further trials, the market performance exceeded the accuracy of official forecasts 75% of the time.
Product Development	Eli Lilly	Eli Lilly applied internal markets to predict correctly which of six potential new drugs would have the greatest success in passing product development hurdles. Employees involved in different stages of drug development traded market contracts based on their information. The market aggregated information with accuracy and opinion detail that would not have emerged had traders responded to a poll.
General Forecasting	Google	Google uses internal markets to forecast events such as new product launch dates and new office openings. The company applies market predictions to determine the likelihood that an event will occur and on a specific date.

Social Responsibility	BP	BP set up an internal market to reduce the oil company's greenhouse gas emissions. Each business unit was granted the right to generate a certain amount of emissions and given access to an electronic trading system that allowed it to buy more emissions capacity or sell excess capacity to other units. The market approach enabled BP to achieve its targeted reductions nine years ahead of schedule.
Project Milestones	Siemens	Siemens used internal prediction markets to predict software project milestones. On one occasion, traditional methods suggested a software project would be delivered on time, but the prediction market suggested it would be 2–3 weeks delayed. The project turned out to be 11 workdays late.
Project Milestones	Microsoft	Microsoft uses internal markets to predict whether projects will meet milestones articulated in their project plans.

A. HEWLETT-PACKARD

An internal market at HP produced more accurate forecasts of printer sales than the firm's internal processes (Chen & Plott, 2002). A total of 12 predictions were performed over a period of three years. The prediction markets at HP included predictions for eight products. In some cases, dollar sales were predicted, and in other cases, the number of units sold was predicted. The market design employed at HP was the web-based double auction market of Marketscape software, developed at the Laboratory of Economics and Political Science at Caltech (Chen & Plott, 2002). From the web interface, participants could enter a buy offer, a sell offer, or acceptance of an offer. If a trade was possible, it was executed; if not, the order was placed in an order book. According to Plott and Sunder (1988), experiments involving single compound securities can have difficulty with information aggregation. As such, HP decided to use a complete set of state contingent contracts (Chen & Plott, 2002). For example, if HP wanted to predict future sales of a product, they would establish a prediction market with multiple securities with each having an interval of say 100 units. Therefore, there would be a security for 0–100 units sold, 101–200 units sold, and so on. Depending on the

interval in which the final outcome falls, the corresponding security pays one dollar per share; all other securities pay nothing. The payoff for HP markets involved real money in which the "winning" security paid off a fixed amount; all other securities paid nothing. HP had issues engaging employees to participate in an activity in which they may lose money (Chen & Plott, 2002). Thus, HP supplemented participants with money at the beginning of the market sessions to ensure participation and minimize the potential employee loss. The markets at HP typically included 20–30 people, mostly from the marketing and finance divisions (Chen & Plott, 2002). Additionally, about five participants were from HP Labs, who had little or no information about the predicted event, but provided additional liquidity to the market.

The results were that the internal market predictions were closer to the actual outcome than the official forecast in six out of eight events (Chen & Plott, 2002). These results are very promising for using prediction markets to predict future sales, compared to traditional forecasting.

B. SIEMENS

Siemens has used prediction markets for software projects. Ortner (1998) describes an experiment at Siemens in which an internal market predicted the firm would fail to deliver a software project on time even when traditional planning tools suggested the deadline could be met. The Siemens market, like HP, used a fully computerized double auction market with a software product called FX developed by Kumo, Inc. (Ortner, 1998). For this software project, Siemens created two separate prediction markets. One asked a simple question: "Can the project be finished in the planned time horizon?" The payoff rule was a simple winner-take-all design. The current market price for this security predicts the probability of meeting the planning time horizon. The second market was designed to predict the length of the possible delay. This market included two shares called "Early" (or YES) and "Late" (or NO). The payoff structure for this market was set up in a linear fashion. The YES share paid the maximum of (1–0.2*weeks late) or zero. The NO share paid the minimum of (0.2*weeks late) or one. For example if the price of the YES share was trading at 0.8, the market believes there

will be a one-week delay. Conversely, if the NO share was trading at 0.2, the market believes there will be a one-week delay. This payoff structure is illustrated in Figure 2.

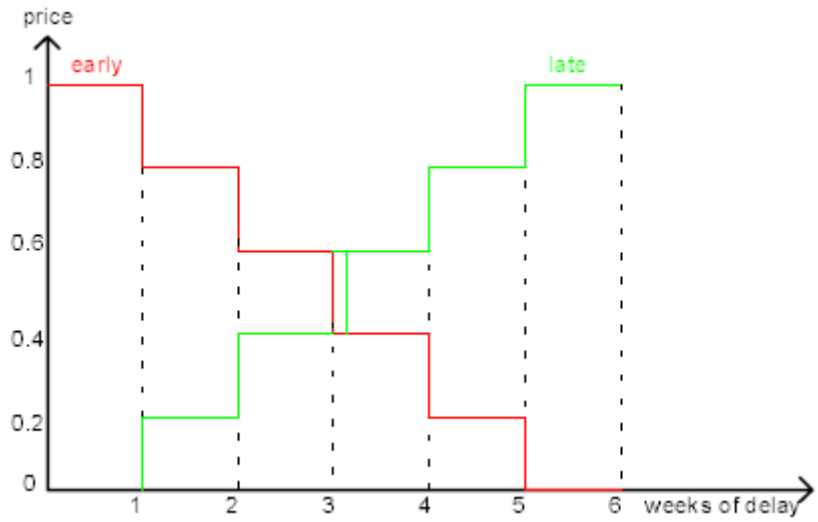

Figure 2. Pay-off Structure at Siemens (From Ortner, 1998)

Siemens opened the market to all people working in the project except upper level management. Sixty-three traders joined the market and about 50 became active traders. Of the participant pool, 67% were developers, 31% group managers, and 2% project managers (second level–first level managers were not allowed to join the experiment, because of their manipulating power) (Ortner, 1998). The Siemens market did not use any uninformed traders.

Results: Initially, after opening the two markets, the winner-take-all market YES shares approached a price of 0.43 and fluctuated between 0.43 and 0.40 for approximately six weeks. About one month prior to the deadline, the YES shares for the winner-take-all market plummeted indicating the market did not believe the project would reach its planned milestone, although it was still possible according to the traditional project plan used by the management team (Ortner, 1998). In the end, the market was closed when the project manager announced the milestone time limit was not reached. Therefore, each YES share paid zero and the NO shares paid one. In the second

market, used to predict the time delay, after only one month of trading and more than three months before the scheduled deadline, the market predicted a delay of two to three weeks. In the end, the actual delay turned out to be 11 workdays.

HP and Siemens' experiences suggest that motivating employees to trade is a major challenge. Both firms ran real money exchanges, with a relatively small trading population (20–60 people), and subsidized market participation by either providing traders with a portfolio or matching initial deposits. Even with the subsidies and small trading population, the predictive performance of these markets was remarkable.

C. MICROSOFT

Microsoft uses internal markets to predict whether projects will meet milestones articulated in their project plans. Microsoft's market relies on an automated market maker that enables traders to access the market at their convenience to buy and sell contracts. By using a market maker, traders can exchange contracts without relying on others' willingness to buy or sell. Microsoft uses multiple contracts, each representing a different predicted date on which a project will reach a certain milestone. Microsoft also has run experimental markets in the past involving naïve and informed traders. "Naïve traders did not impact the accuracy of market predictions because informed traders corrected market price fluctuations caused by naïve participants" (Corporate Executive Board, 2006). However, Microsoft currently limits participation to informed traders because uninformed traders are less likely to participate. Microsoft selects its traders by targeting employees who have enough information to make educated trades, and selecting traders from different corporate functions to aggregate different types of information, giving more accurate results (Corporate Executive Board, 2006). The only concern is leaving out someone who has information, but management is unaware of their having sufficient information. Microsoft encourages participants to trade when they think they can contribute to the market.

Table 3. Summary of Private Sector Applications

Application	**Practitioner**	**Market Design**	**Contract Type**	**Payoff Type**	**Participant Quality**	**Measure of Success**
Sales Forecasting	Hewlett-Packard	Double Auction	Multiple Contracts	Real money	20–30 from marketing and finance divisions	six of eight events were closer to actual outcome than official forecast.
Product Development	Eli Lilly	NA	NA	NA	NA	NA
General Forecasting	Google	NA	NA	NA	NA	NA
Social Responsibility	BP	NA	NA	NA	NA	NA
Project Milestones	Siemens	Double Auction	Winner-take-all	Real money	50–60 from all aspects of a project except upper level management	Predicted time delay of 2–3 weeks. Actual delay was 11 workdays.
Project Milestones	Microsoft	Automated Market Maker	Multiple Contracts	NA	Limits participation to informed traders.	NA

VI. OTHER "REAL WORLD" APPLICATIONS AND RESULTS

A. IOWA ELECTRONIC MARKET

The Iowa Electronic Market, run by the University of Iowa, is probably the best-known prediction market among economists. The Iowa Electronic Market uses a double auction market with winner-take-all and index contract types. It is a real money market with no endowment, and participation is open to anyone interested, but likely only attracts those particularly interested and aware of the market's existence. In 1988, the original Iowa experiment allowed trades in a contract that paid 2½ cents for each percentage point of the popular vote in the presidential election received by Bush, Dukakis, and others. More recently, it has run prediction markets based on the 2008 presidential election, the 2008 congressional elections, and the 2008 Minnesota senate election. The Iowa Electronic Markets has yielded both very accurate predictions and also outperformed large-scale polling organizations (Berg, et al., 2001). Figure 3 shows data from the four U.S. presidential elections between 1988 and 2000. The horizontal axis shows the number of days until the election, and the vertical axis displays the average absolute error between the prediction market price (linked to the two-party share of the popular vote) and the actual popular vote percentage earned in the election. In the last week before the election, the prediction markets have predicted vote shares with an average absolute error of approximately 1.5 percentage points, compared to the final Gallup poll forecasts that differed by 2.1 percentage points (Wolfers & Zitzewitz, 2004).

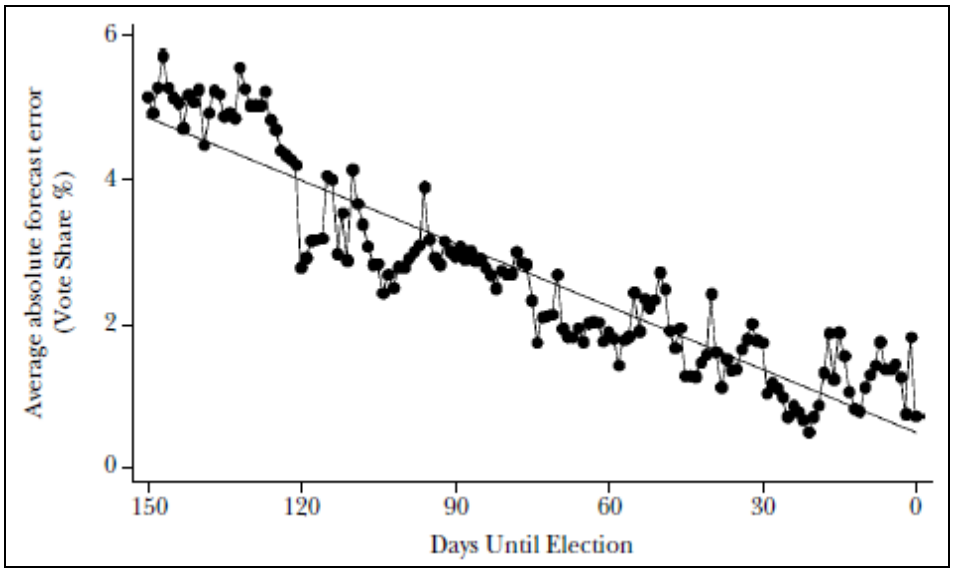

Figure 3. Information Revelation Over Time (From Wolfers & Zitzewitz, 2004)

The superior performance of the Iowa markets may be attributable to the fact that "traders are self-selected with a clear interest in predicting what will actually happen, rather than what they hope will happen" (Corporate Executive Board, 2006). In a poll, respondents predict events without any context of others' beliefs. In a prediction market, each participant knows the current consensus and factors this information into decision-making.

B. GOLDMAN SACHS AND DEUTSCHE BANK "ECONOMIC DERIVATIVES" MARKET

Another example of the relative performance of a prediction market comes from the "Economic Derivatives" market established by Goldman Sachs and Deutsche Bank. This market is tied to macroeconomic outcomes, such as non-farm payrolls, retail sales, levels of the Institute for Supply Management's manufacturing diffusion index, and initial unemployment claims (Gürkaynak & Wolfers, 2005). The market mechanism is a pari-mutuel system where for a given strike price all bets that the specified outcome either will or will not occur are pooled; this pool is then distributed to the winners in proportion to the number of options purchased. The Economic Derivatives market uses multiple contracts, allowing traders to take a position on specified ranges the data will fall in. The outcome results in a probability density function, which prior to this market

was unavailable. Figure 4 compares the performance of the Economic Derivatives market with a survey of economists in predicting economic outcomes based on data gathered by Gürkaynak and Wolfers (2005). They show that the market-based forecast encompasses the information in the survey-based forecasts. Additionally, the markets' response to data releases are better captured in the market-based expectations than survey-based expectations, suggesting the markets perform and react better than survey-based forecasting (Gürkaynak & Wolfers, 2005).

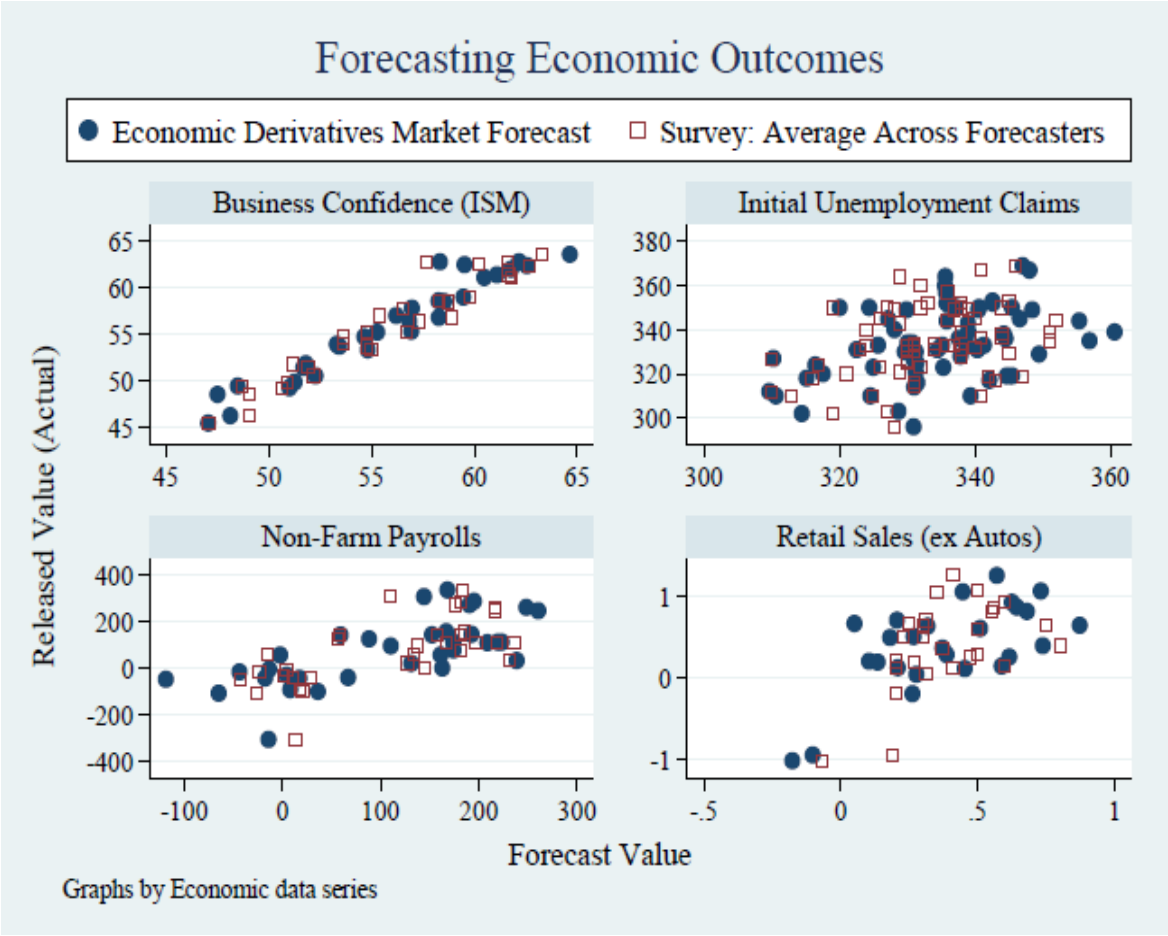

Figure 4. Forecasting Economic Outcomes (From Gürkaynak & Wolfers, 2005)

Table 4 summarizes some of the more popular prediction markets available for public trade.

Table 4. Popular Prediction Markets

Market	Focus
Iowa Electronic Markets <www.biz.iowa.edu/iem> Run by University of Iowa	Small-scale election markets.
Centrebet <www.centrebet.com> For profit company	Northern Territory bookmaker, offering odds on election outcomes, current events, sports, and entertainment.
Economic Derivatives <www.economicderivatives.com> Run by Goldman Sachs and Deutsche Bank	Large-scale financial market trading in the likely outcome of future economic data releases.
Newsfutures <www.newsfutures.com> For profit company	Political, finance, current events and sports markets. Also technology and pharmaceutical futures for specific clients.
Foresight Exchange <www.ideosphere.com> Nonprofit research group	Political, financial, current events, science, and technology events suggested by clients.
Hollywood Stock Exchange <www.hsx.com> Owned by Cantor Fitzgerald	Success of movies, movie stars, and awards. Data used for market research.
Intrade <www.intrade.com> For profit company	Political, financial, current, and similar event futures.

VII. APPLICATION TO DEPARTMENT OF DEFENSE ACQUISITION PROCESS

The main DoD application presented here is in performance management of acquisition programs. Specifically, markets provide insight on whether the organization will meet performance targets (e.g., schedule, budget, and specifications). If the market predicts a performance gap, resources can be quickly re-deployed in response, or kill the project to save time and money.

One of the key problems in project management is controlling projects already started and responding to issues that may arise unintentionally (Ortner, 1998). It is very important to receive as much up-to-date information as possible on the progress of the project from within the group of people working on that project. Project management techniques, like milestone trend analysis, should help recognize delays and other problems that might occur as soon as possible, but significant bad news, like delays, technical problems, or budgetary problems are not often voluntarily passed along due to the fear of negative feedback. Prediction markets provide a way for individuals to pass information anonymously, which enables management to receive timely information as to the status of a project. Management can then react as necessary to correct any deficiencies that may exist. Management involvement will be discussed later.

In order to achieve organizational buy-in, the DoD should initially position prediction markets as an experimental tool. This approach proves less threatening than immediately using markets as a replacement tool for traditional forecasting. The markets can supplement traditional forecasts and indicate if the traditional forecasts should be revised (Corporate Executive Board, 2006). If the markets are successful, they may be used in other areas where traditional methods do not exist to provide more information to management.

There are several criteria that should be examined to determine if a prediction market would be beneficial in a given application. In determining whether to use a prediction market or not, management should examine if a contract can be easily

defined, if there is a known end point or date, if there are enough participants, and the markets should not include issues where management decisions will affect the market outcome before it closes.

A. CONTRACT

Defining the contract is key to the market's success. The contract should be defined in such a way that it is easy to understand, so that all participants know what they are purchasing and what the pay-off structure is. It may be better initially to limit the outcomes to a YES or NO; for example, will a project be completed on time or not? Once traders are familiar with how markets work, then more complicated markets can be devised with outcomes such as how many weeks early or late will the project be completed?

B. END POINT

Knowing when to end a market is important so that traders know there is a deadline. Knowing there is an endpoint will also provide incentives for traders to trade. An endpoint should be selected such that management has time to take corrective actions if the results are not acceptable. For example, the military would not want a market indicating that a project is going to be late to end two days before the project's deadline. It is more beneficial for the market to end sooner so that management can take action to correct deficiencies where needed, or divert resources to the project. The difficulty in choosing the endpoint is that the market must have a well-defined outcome for the event covered by the stock when it ends. If you directly predict an event in which DoD is interested, either the market must end before the event, in which case you don't have the result, or the market close is too late to be useful. One way markets have avoided this is to predict something that is not of direct management interest (e.g., projected orders for Google so they could plan production quantities; the management decision was production plans not hitting a sales target).

C. PARTICIPANTS

The selection of traders is also key to the success in the DoD. As discussed earlier, the group should be diverse, so that different information is brought to the prediction market. The traders need to be decentralized, so that they are not overtly influenced by upper-level management. In addition, the selected individuals need to be independent, so that they pay attention mostly to their own information and do not worry about what everyone around them thinks.

D. MANAGEMENT INVOLVEMENT

As mentioned above, a prediction market's results allow management to receive timely information, and react to correct any deficiencies revealed by the prediction market. However, management reaction to what the prediction market is predicting prior to the market closing can, and will, change the outcome of the prediction. This would undermine the results of the market, and discourage users to participate in the market. This is where selection of the end date becomes important, so that management can react to the market without adversely affecting the market's results while still open. The securities cannot be issues in which management will intervene as prices predict outcomes or the markets lose integrity. Predicting sales volume helps management set production levels, but if management increases advertising it will undermine the market. This becomes critical for the DoD. The DoD is an organization that likes to react to current information available. As discussed, reacting too early to information revealed by the prediction market will affect the outcome of the market. There has to be a conscientious effort not to react immediately to the information provided until the market ends.

THIS PAGE INTENTIONALLY LEFT BLANK

VIII. CONCLUSIONS

A. CONCLUSIONS

Prediction markets may prove to be a successful way to manage acquisition programs. The most notable success documented in this thesis is HP. HP ran markets of similar types that could be used by the DoD. HP also showed that relatively small markets (approximately 20 people) were successful and provided accurate predictions.

The important elements for DoD market design include defining the contract, determining the end point, selecting participants, and management involvement. Define the contract in such a way that it is easy to understand, so that all participants know what they are purchasing and what the pay-off structure is. An endpoint should be selected such that management has time to take corrective actions if the results are not acceptable. Knowing there is an endpoint will also provide incentives for traders to trade. The participation pool should be diverse, so that different information throughout the organization is brought to the prediction market. The traders need to be decentralized, so that they are not overtly influenced by upper-level management. If the DoD can design a prediction market with these elements in mind, and successfully employ the prediction market, market outcomes will provide valuable information to stake holders in the DoD.

Additional research should be conducted to evaluate (in an experiment setting) the effectiveness of these elements in determining the accuracy of the prediction market outcome.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Berg, J., Forsythe, R., Nelson, F., & Rietz, T. (2001). "Results from a dozen years of election futures market research." In *Handbook of Experimental Economic Results*, edited by Charles Plott and Vernon Smith. Amsterdam.

Chen, K., & Plott, C. (2002). *Information aggregation mechanisms: Concept, design and implementation for a aales forecasting problem.* Social Science Working Paper No. 1131, California Institute of Technology.

Corporate Executive Board. (2006, June). "Using internal markets to improve corporate decision-making: Lessons learned by early adopters." *Corporate Strategy Board.*

Gaspoz, C. (2008). "Prediction markets as an innovative way to manage R&D portfolios." *CAiSE Doctoral Consortium.* Montpellier, 62–73.

Gürkaynak, R., & Wolfers, J. (2005). "Macroeconomic derivatives: An initial analysis of market-based macro forecasts, uncertainty, and risk." In *NBER International Seminar on Macroeconomics*, edited by Christopher Pissarides and Jeffrey Frankel. NBER.

Kalovcova, K. (2007). "Why betting and prediction markets work (not) well: An inventory of open questions." Discussion Paper, Center for Economics Research and Graduate Education, Charles University.

Kiviat, B. (2004, July). "The end of management?" *TIME Magazine, Inside Business.*

Malone, T. (2004, April). "Bringing the market inside." *Harvard Business Review*.

Ortner, G. (1998). *Forecasting markets: An industrial application.* Mimeo, Technical University of Vienna.

Plott, C. (2000, July). "Markets as information gathering yools." *Southern Economic Journal*: 2–15.

Plott, C., & Sunder, S. (1988). "Rational expectations and the aggregation of diverse Information in laboratory security markets." In *Econometrica 56*, 1085–1118.

Wolfers, J., & Zitzewitz, E. (2004). "Prediction markets." *Journal of Economic Perspectives*: 107–126.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California