Information Markets to Estimate Military Instability

Proposed by Net Exchange, San Diego, CA

2. IDENTIFICATION & SIGNIFICANCE OF THE OPPORTUNITY

In the recent Quadrennial Defense Review, one of the key questions was identified as "What types of small-scale contingency operations are we likely to face, and how many?" Later in that same review, it was stated that "contending with uncertainty must be a centerpiece of U.S. defense planning." This proposal is to study the use of information markets to improve estimates of international instability.

Tens of U.S. troop deployments around the world are made per month in part to promote international stability. Efficient utilization of manpower and equipment in these deployments requires good information and predictions about the likelihood of the timing and location of instability events. There is concern that current estimates are not as good as they could be either because some informed individuals do not participate in the creation of the estimates or because organization incentives may create frictions in the provision of timely and correct information. If one could substantially improve the estimates by bringing in the information of all informed individuals, one might significantly improve the efficiency of deployments and other decisions that depend on instability predictions.

There is a new, and relatively untried, method to do this: information markets. We propose to create and field test the use of information markets to estimate military instability. If the efficacy of information markets can be demonstrated successfully in this area, the Department of Defense (DoD) will have a significant new tool at its disposal that can be used in many venues: one that also has significant commercial applicability in the private sector. The ability to aggregate information into reliable forecasts of, say, the relative success of current R&D projects or future military deployments, is clearly of enormous significance to the DoD and related agencies. The ability to aggregate information into reliable forecasts of, say, future product demand or the likelihood of successful product development, is also of significant commercial interest.

Speculative financial markets, such as futures markets, are widely used to reallocate risk. As a side effect, such markets also typically provide accurate predictions of future prices and future events. The price of an orange juice future can be a better predictor of the probability of a freeze than the very best weather models can provide. (Roll, 1984) Markets do this because they offer powerful incentives to participants to profit by correcting inaccurate prices. After all, contributors must "put their money where their mouth is". This ability of markets to efficiently aggregate information is well known in the finance literature (see Lo, 2000, and Akert and Church, 1998).

But, while speculative financial markets have long been used to identify and reallocate risk, only very recently have such markets been created primarily to make predictions. For example, the *Iowa Political Stock Market* (see R. Forsythe et. al (1999)) seems to predict election outcomes better than opinion polls. Several play-money markets have been found to aggregate information well (Pennock, Giles, & Nielsen , 2001), although they also seem to have problems with biases and limited participation. A few internal corporate real-money markets have also shown promising results (Plott, 2000), although most attempts to create such markets have failed to obtain long-term management support.

To understand how markets can be created to aggregate information into reliable predictions of events of interest, consider the following example. Suppose a decision maker is interested in whether there will be Interstate conflict involving Country X sometime during 2003. They could simply ask everyone, weigh the evidence and guess. Alternatively the decision maker could create two contracts which will be bought and sold. Contract 1 states "I will pay $1 if there is interstate conflict in X during 2003." Contract 2 states "I will pay $1 if there is no interstate conflict in X during 2003." Letting participants trade these contracts among themselves will lead the prices of the contracts to reflect the information of the individuals. A simple story explains this. If only one person knew for sure that there would be an interstate conflict involving country X in 2003 and if the price of contract 1 were less than $1, then that person could make money for sure by buying as many units of contract 1 as possible until its price were driven up to $1. The equilibrium price of contract 1 will be $1 which signals that the probability of that event is 1. It requires a bit more subtle argument when one person's belief is, say, that the probability of an interstate conflict involving X in 2003 is 85%, but the principle is similar. In the end, the market price for each event will indicate an informed aggregation of the probabilities that informed speculators assign to that event. The market "sweeps up" the beliefs of the participants and aggregates them no matter how dispersed or how differentially informed those participants are.

Speculative markets offer several apparent advantages over other prediction institutions, such as surveys, or reports by expert committees or by assigned specialists. Market estimates should be cheap to create, can be frequently updated, are numerically precise, and should offer contributors strong reasons to be careful and honest. Market estimates are also more immune to challenge, as dissenters can always be invited to trade and attempt to profit by correcting the errors they think they see.

We propose therefore to explore the potential of markets for predicting the likelihood of military instability around the world. Current estimates of international stability come from many sources, including statisticians and nation specialists. Unclassified sources seem to be at least as important as classified sources, there are a great many people with apparently relevant expertise, and most of these people do not contribute much to current official estimates. After the fact measures of instability, such as where wars, coups, and riots have been, seem to be relatively uncontroversial, and available from multiple sources, but prior estimates range roughly in accuracy from 60-80%. This seems to be an excellent proving ground for testing the efficacy of information markets in DoD uses.

Why is such an exploration necessary when other information markets, such as the Iowa Political Stock Market have already shown the viability and improved accuracy of such markets? Unfortunately, many potential pitfalls lie in the way of realizing good DoD-relevant information aggregation through speculative markets. It is our judgement that the three main potential problems are: participation, contract design, and market micro-structure design. It will be necessary to create and evaluate means to alleviate or avoid these problems.

Participation can be affected both by market incentives such as how much money is at stake and by non-market issues. For example, desirable participants might be prevented from participation by financial regulations, excessive conceptual or user-interface complexity, or simple disinterest. We will need to find ways to surmount these obstacles and encourage active and accurate participation.

Contract design requires determining what information DoD decision makers really care about, and then creating a structure of contracts whose prices will provide that information. A naïve approach would be to ask the decision maker to list the countries and years of interest. One could then use the simple, paired contracts described earlier – one pair for each country-year one wants predictions for. But this may miss the nuances of most importance to the DoD. For example, the decision maker may really care about the probability of "a conflict involving country X if troops are deployed nearby." This is a conditional probability and it cannot be estimated from a collection of simple paired contracts. It can, however, be estimated if we add some new contracts to the mix. (Hanson, 1999)

Consider the following example. There are four possible basic events, depending on whether country X has an interstate conflict in 2003, and on whether the U.S. deploys troops nearby during 2002.

	Deploy	No Deploy
Conflict	**D&C**	**ND&C**
No Conflict	**D&NC**	**ND&NC**

Imagine creating a contract for each of the four boxes. For example, the D&C asset would pay $1 if there was conflict during 2003, *and* a nearby troop deployment in 2002. Then the market price (i.e., asset amount ratio) of trades between assets D&C and the package D = D&C + D&NC would describe a speculators' estimate of the *conditional* probability of conflict, given deployment. Similarly, the price of trades between ND&C and ND = ND&C + ND&NC would estimate the chance of conflict given no deployment. Thus by increasing the number of contracts, information markets can increase the precision of the information desired by a DoD decision maker.

But there is a potential problem here. The price of "the conditional probability of conflict given deployment" is clearly interrelated with the price of deployment and the price of conflict. Bidding for more conditional estimates increases the inter-relatedness of the information markets. Given these connections, if there are too many contracts and too few participants and if simple bulletin board markets are used, stable and informative market prices may fail to exist. The details of the market micro-structure design are therefore important. We have extensive experience in this area.

It is important to do all of this right. Just saying "let there be markets" is not enough. If the design of the information market is not carefully done, there is a high probability that it will generate data that is either useless or ignored. Decision makers will distrust the market estimates, either because of distrust in the way outcomes are judged, a low evaluation of the market participants, or a general distrust of market approaches to aggregating information. Also, decision makers will have insufficient interest in the outcomes estimated, or have strong concerns about how speculative markets might distort other important DoD institutions.

We believe information markets can be adapted to DoD use and that they will significantly improve predictions of important and relevant future events. We believe the obstacles we have identified can be overcome with the appropriate market design. We propose to create and conduct a field experiment among experts in predicting international stability, and to use Phase I to prepare for that experiment.

3. PHASE I TECHNICAL OBJECTIVES

The primary objective for Phase I of our proposal is to prepare for a field test of the predictive powers of speculative markets regarding of events of interest to the DoD. A secondary objective is to develop forms of speculative markets that are better suited to such information aggregation tasks.

The specific objectives of the program are:

1. Identify a target population of individuals who are knowledgeable about these events, and from whom we will solicit participation.
2. Choose a set of financial and other inducements to participation
3. Select the particular events whose likelihood will be estimated in the field test.
4. Choose one or more non-market institutions, which can provide comparable estimates.
5. Choose several candidate market designs, including the rules of the trading exchange.
6. Develop and integrate an enabling hardware and software platform for operation of the actual field test markets.
7. Create a laboratory testbed that contains the basic relevant features of the field test application and prototypes of the candidate market designs and stress test the candidate prototypes in the laboratory testbed using experimental economic methods.

4. PHASE I - WORK PLAN

The Phase I work plan includes the following seven major tasks for achieving our objectives: identification and recruitment of relevant participants, design of a participation incentive system, definition of contracts to be traded in the market, identification of comparison institutions, design of the micro-market structure, creation of a prototype platform, and experimental testing. The first four require domain expertise, which will be acquired through extensive interviews. We have already had contact with a number of knowledgeable individuals whom we intend to go back to later. These include Bill Tatantino and Shawn O'Brien from the Center for Army Analysis, and Al Goldman of the National Ground Intelligence Center. We also expect to be working with people from the DRI Research Program.

The following table lays out the six-month work plan we intend to follow to accomplish these seven major tasks. The table indicates the use of subcontractors to perform some key functions. These subcontractors include the domain experts that will be interviewed as well as certain experts and resources outside of Net Exchange. However, at least two-thirds of the research effort required to accomplish the tasks will be conducted by Net Exchange internal staff and affiliates. Details on most of the planned subcontracts can be found in sections 9 and 10 of this proposal. Detailed cost breakdowns supporting the expenditures listed in the table can be found in section 12 of this proposal. The balance of this proposal section details how we will go about accomplishing each of the seven major tasks.

Major Task (plus Reporting)	Man Hours per Month (Total/Subcontractor)						Expenditure, $	
	1st	2nd	3rd	4th	5th	6th	Total	Subs
Identify Participants	40/20	20/10					9,000	4,500
Design Participation Incentive System	20/10	40/20					9,000	4,500
Define Contracts to be Traded		20/10	30/10	10/5			9,000	3,750
Identify Comparison Institutions		25/20	10/5				5,250	3,750
Design the Micro-Market Structure			25/5	55/15			15,000	3,000
Creation of Prototype Platform			20/0	40/0	140/20	40/10	22,500	4,500
Experimental Testing					30/0	40/30	25,000	7,000
Reporting	1/0	1/0	1/0	1/0	1/0	15/5	3,000	750
Totals	**61/30**	**106/60**	**86/20**	**106/20**	**171/20**	**95/45**	**$97,750**	**$31,750**

4.1 Task I – Identification of relevant participants

One of the attractions of deploying information markets to estimate military instability as a field test is the large number of experts we can draw on to obtain participants. There are many private individuals whom the DoD recognizes as having relevant expertise. These range from professors of political science to investment analysts who specialize in a particular nation. Many experts within the DoD do not rely on classified sources to construct their estimates, and many of those who do the estimates themselves are not classified. All of these people are potential participants. (Our market estimates will not be classified information, and so should not easily reveal classified information.)

We may also want to cast a wider net and allow participation by many people who the DoD would not be likely to recognize as relevant experts, in order to see whether their contributions on net improve or hurt the market estimates. We might even create two markets for each event, one for everyone and one only recognized experts can trade in.

4.2 Task II – Design an incentive system to encourage participation

Because of the many costs to participants to learn and manage trading, the incentive to participate must be real and significant. One of the reasons we have selected international stability as the domain for our field experiment is that we think we can demonstrate the efficacy of information markets here even without a high hit rate in participation. Nevertheless we intend to test and learn what incentives might work best in the many other areas of potential application. While the specific mix of inducements remains to be determined, some we will consider are the publication of winners and comparable expert prediction track records, and direct payments for participation (e.g., "here's $500 to trade with, or here's $5 per trade"). We will also consider subsidizing markets in ways that reward performance, such as using a subsidized market maker. We may also host a conference at the start of Phase II to introduce potential participants to the markets and each other.

The "color of money" paid may need to vary with the expert institutional context. That is, while private experts might gain cash from successful trading, other more constrained actors might gain only bragging rights from their track record, with cash going to a charity of their choice or perhaps a larger organizational budget. (Sorting out the legal details surrounding participation is an important task for Phase I.)

What we decide here will determine how much money we must allocate in Phase II to pay for these incentives.

4.3 Task III – Define the range of contracts to be traded

This is one of the more crucial tasks in designing a fully functioning information market that improves the predictions of military instability. The choice of which events to include (whether we include all nations or only a selected subset), what temporal resolution to allow (whether we estimate the month of each event or only the year), and which conditional predictions to add will all have an effect on participation and usefulness. The more contracts on relevant events and contingencies, the more participation. But the more contracts, the more there is a likelihood that there will be relatively little trading in each contract. Without the right market micro-structure design, few trades means unreliable prices and, therefore, unreliable probability predictions.

So part of the research and testing in Phase I is to determine the best balance of contracts. At one extreme we could choose twenty nations where instability is a particular concern and, using simple paired contracts, estimate a general probability of instability in each nation during the second year of Phase II. This would give us very limited statistical power. At the opposite extreme, we could create a market with up to a million types of securities (such as all combinations of 100 countries, 10 instability event types, 10 possible interventions to condition estimates on, over 50 weeks over 2 years). Participants could select to view, and bet on, any set of aggregate estimates that they wanted. For example, a participant might ask to see the current market estimate of the probability that any of the first three event types would happen in the Middle East in the next three months given no new deployments. If this participant thought this estimate were off, he or she could try to profit by betting on one side or the other. The decisions here interact with the market design choices, discussed in Section 4.5, and will be informed by the testing discussed in Section 4.7.

Another crucial, but different, choice to be made in the contract design is the condition for knowing which events actually happen. We will identify a particular authority, or a well-defined process, to declare which events happened where at the end of Phase II, in order to pay off on the contracts held by the participants.

4.4 Task IV – Identify alternative comparison institutions

We will of course seek accurate and relevant market estimates, but our primary goal will be to *compare* market predictions to those of other institutions for aggregating information among the *same* group of experts. We need to choose a particular set of alternative institutions to compare market estimates with. Current institutions for forecasting military instability typically rely on an area specialist form of organization. That is, there is a single primary expert on each foreign nation who determines the estimates for that nation, and who takes advice from other sources. We might therefore compare market estimates about a nation to the predictions of the participant in our field experiment who is the most expert in that nation. We can also compare the market predictions with simple surveys, perhaps weighted by expertise. All these approaches require that we obtain statements of opinions from our participants, in addition to inducing them to trade.

4.5 Task V – Design the appropriate market micro-structure

There are many micro-market structure design choices in building an information market. These are captured ultimately in the rules and context for trading the contracts. These rules cover such details as who is allowed to learn what about current offers and previous trades, whether bids and offers can be withdrawn or not, whether bids or offers have to be improving (NYSE rules), and whether trading happens continuously or is limited to special moments, as in a call market.

In our chosen topic area of international instability, there are a great many potential estimates decision makers might like to see. The more markets per person and the more conditional estimates, however, the fewer trades per market, and hence the *thinner* each market is. Thinner markets can be less stable and more easily manipulated. Our team has a special expertise and interest in working to increase the number of markets any given group of people can manage while avoiding thinness. We have experience in designing combined value markets in such situations, and would also like to consider a subsidized market maker approach.

Active speculative markets, such as NASDAQ and CBOT, are most commonly structured as *continuous double auctions*, where buyers and sellers can offer and trade at any time (cite IEM and *Science* article). This has the spirit of an open outcry auction. But in the past we have found that market thinness and inter-relatedness can be better dealt with by *combined value call markets* (Ledyard et. al (2001), which look for matches in a large set of offers to trade. Call markets are similar to sealed bid auctions.

Continuous markets sometimes require participants to monitor markets often to see if prices have changed (this can often be avoided with limit offers), but allow rapid predictable trade execution when one does pay attention and the market is thick enough Also participants need only consider whether their estimate is higher or lower than a current available price in order to decide whether to trade or not. Call markets allow traders to avoid frequent monitoring and allow orders to accumulate giving participants a higher number of contra-side orders when the deals are made. But they require participants to be more precise about their own estimates, a comparative judgement is not enough. Software agents (see Vragov (2001)) can help in both cases, to reduce monitoring costs or to help construct multiple bids.

During Phase I, we will create two basic designs: a continuous double auction market with subsidized "market-makers" and a combined value call market in which the market prices are formed and contracts made at predetermined time intervals or events. In the proposed continuous approach, each fine grain event will have a subsidized market maker, guaranteeing a small bid-ask spread even on very infrequently traded assets. Fine grain offers would then be aggregated to compute bid-ask spreads on events of interest to users (Hanson, 1995). For the call market design, we will use a variation of markets Net Exchange has previously deployed. Net Exchange is a world leader in this area and has created several working combinatorial markets that take a large number of potential bid types and, using combinatorial algorithms, obtain thicker markets and easier participation (Bossaerts, Fine, & Ledyard, 2000).

How the two market designs perform with real humans in dealing with interrelated and thin information markets needs to be studied scientifically. We will do that using experimental economics methods in Task 4.7 below.

4.6 Task VI – Build a prototype Information Market and Platform

Software implementation of successful web-based markets involves more than throwing up a simple bulletin board and asking participants to log in. GUIs need to be customized, crossing and pricing algorithms need to be tuned to the application, and a database needs to be customized. Nevertheless it is straightforward if you have experience. Net Exchange does.

4.7 Task VII – Experimental Testing of alternative designs and prototype

We also propose to design and run numerous laboratory experiments in support of the design process for this field experiment. Lab experiments can "stress" a market design, indicating its robustness to difficult situations, and can help to avoid design mistakes prior to the field experiment. We have long experience in this methodology. Lab experiments can be used to compare mechanisms for motivating participation, and to see how market estimate accuracy depends on the particular participants selected. We can also measure and identify how the non-trading preferences of participants may affect market estimates

Laboratory experiments in economics typically consist of collecting a room full of subjects, often undergraduates, telling them how their monetary payment will depend on the outcome of a "game" they are about to play, and then watching what happens. This sounds like role playing but it is a carefully controlled experimental methodology. Similar in spirit to the engineers "wind tunnel" for testing airplane designs, experimental labs allow us to scale down a market design and then, by carefully controlling what the participants want and know and the social context of their behavior, we can test theories about economic behavior and measure the performance of alternative market designs.

Issues we might explore include general design robustness, ways to deal with market thinness, ways to induce participation, the adequacy of user interfaces, the adequacy of the alternative institutions we will compare market estimates to, and sensitivity of estimates to allowing a broader range of less expert participants. In addition to the information structure and participation, we will also investigate cases where certain known participants have a stake in the outcome and may want to manipulate prices for their private rewards outside the market. We will want to see if the micro-market structure is important in enabling market participants to counteract these incentives to create an unbiased estimate.

If there is not enough time laboratory exploration of some of these issues will have to await Phase II of this project.

4.8 REPORTING

In addition to day-to-day informal contacts with the program monitor, monthly technical progress reports will be submitted with a complete Phase I Final Report being submitted at the end of the six-month effort.

5. RELATED WORK

The founders of Net Exchange, while still at Caltech, designed, built, and operated their first combinatorial market in 1992 to assist NASA in R&D resource allocation for its Cassini Saturn mission (Ledyard, Porter and Rangel, 1994). The Cassini Science Resource Management Plan was an integral part of the technically successful, on schedule, and within budget development of a multi-instrument payload. In essence, the Cassini resource market was an information market, a market wholly internal to a business process in which the management of asymetric information between instrument developers and project management was key.

Net Exchange was spun out of Caltech in 1994 and has since been a pioneer in the development and commercial use of combinatorial markets. Though Net Exchange has never returned to its roots in information markets, the combinatorial markets designed and developed by the firm have significantly advanced the state of the art, so that a return to information markets should yield impressive advances.

From 1993 to 1996, Net Exchange applied combinatorial market processes to the trucking service procurement problem faced by Sears. This was the world's first commercial one-to-many combinatorial procurement market. It operated at a commercially meaningful scale and resulted in market wide gains of over 13%, amounting to more than $80,000,000 that were shared among Sears and the trucking firms doing business with Sears (Ledyard, et al, 2000). Though a one-to-many process is not directly relevant to an information market application, the demonstrated ability of Net Exchange to design a superior market through the application of combinatorial processes is related to the problem of designing information markets. An information market will necessarily represent a substantial change from whatever information management process is in place, Net Exchange's Sears experience demonstrates an ability to tailor the application of combinatorial processes to the commerce, business, or management process in question.

In 1995, Net Exchange designed, developed, and operated the world's first commercial multiple-buyer, multiple-seller combinatorial market (this was also the world's first Internet-based commercial exchange). The application was the trading of air quality emissions permits among major industrial polluters in the Los Angeles area (Ledyard, et al, 2001). The system built by Net Exchange became and continues to be the dominant means of trading these permits. As a many-to-many combinatorial market, this product is directly applicable to the basic technologies required for a combinatorial information market. Further, Net Exchange again demonstrated an ability to design a market for a type of commerce and business process; rather than attempt to foist a standard package of software on a non-standard problem.

In 1997, Net Exchange began modifying and scaling up the many-to-many technologies behind its air quality product. The first application of this more potent capability was a fixed income trading system, Bond Connect, deployed by State Street Bank in 2000 (Polk and Schulman, 2000). Recently, we have deployed our capabilities into a new logistics product that will debut later in 2001 under the operation of a major U.S. logistical services firm. These recent products are based on technologies of direct relevance to information markets and are designed and built to operate at a scale and with a level of dependability that speaks well for eventual operational deployment of the type of information market prototype proposed herein.

The principal outside consultant that Net Exchange proposes to hire as a subcontractor if awarded this Phase I SBIR is Prof. Robin Hanson of George Mason University. Prof. Hanson has since 1989 been writing and speaking widely about the potential for speculative markets to aggregate information on a much wider range of topics than traditionally considered. In 1990, Prof. Hanson created and managed a real-money internal corporate market estimating product delivery dates at Xanadu, Inc., an early web pioneer. Prof. Hanson also then developed and extensively tested (but did not market) a board game wherein players used a market-maker-subsidized betting market to estimate "who done it" in a murder mystery. In 1994, his design for an e-mail-based play-money became the basis for what is now called the "Foresight Exchange" (see ideosphere.com). This was the first play-money web-betting site, and once had 2000+ players and 100+ claims. It is still the only site to allow users to create their own questions to bet on, or to estimate progress in science and technology. This web site won Prof. Hanson the Prix Ars Electronica Golden Nica electronic art prize in 1995. Prof. Hanson helped create internal real money betting markets at the Foresight Institute, which estimate technological change over the next several decades. These markets are still functioning. As a professional economist, Robin has written and published several papers on the fundamentals of information aggregation.

6. RELATIONSHIP WITH FUTURE RESEARCH OR RESEARCH AND DEVELOPMENT

If successful, Phase I of this SBIR will establish the relevance of combinatorial processes for information markets involving interrelated events. Most information markets that are likely to interest the DoD and much of private industry involve interrelated events, and the target application chosen for this SBIR, estimating international military instability, surely involves interrelated events.

Due to the substantial experience Net Exchange has built up designing, developing, and implementing markets based on combinatorial processes, there is a high likelihood that Phase I will yield the conclusion that the full field test of the target application should proceed in Phase II. Additionally, it should become clear as a result of the Phase I design and test bed work that combinatorial information markets offer broad applicability within the DoD as well as throughout private industry. Anticipating this outcome, Net Exchange intends to actively seek a Fast Track partner from the private sector to participate in and strengthen the Phase II effort.

7. COMMERCIALIZATION STRATEGY

Information markets based on combinatorial processes offer promising solutions for problems and concerns within the DoD and the private sector.

Within the DoD, information markets can augment the extensive wargaming activities undertaken by the various services and other DoD functions. In this role, the information market pools the opinions of a broad array of spectators and can be used to compare the actions taken by the wargame participants with the predictions formed from the aggregation of spectator opinions. An information market that can handle conditional probabilities among interrelated and contingent actions provides the level of detail needed in this sort of wargaming application – such functionality is exactly what combinatorial processes bring to an information market.

Also within the DoD, but directly affecting actual military operations, is the potential to apply information markets to allocating operational resources. An operational extension of the international military instability application proposed in this proposal could be used to help direct the strategic positioning of resources. More sophisticated and dynamic combinatorial information markets could be used for increasingly fine tactical situations, including, in the extreme, battlefield management functions.

Within the private sector, combinatorial information markets offer great potential for improving the management of certain key business processes. The management of a portfolio of internal research and development (R&D) efforts would be a high-valued and rather straightforward application of a combinatorial information market. A classic example of the significance of resource allocation across a portfolio of R&D efforts can be found in any major pharmaceuticals company. For every 1,000 efforts begun, perhaps 10 drugs make it to market and only a few of these will make a profit for the firm. Knowing how and when to allocate resources to an R&D effort, and how and when to stop, can mean the difference between commercial failure or success for the entire firm. Drug R&D efforts are often interrelated; so, resource allocation decisions are fundamentally combinatorial. Further, many of the resources of a pharmaceuticals firm are interrelated (critical labor and capital); thus, enhancing the combinatorial nature of the portfolio resource allocation problem. As the critical information required to make the portfolio decisions is held by the researchers involved with each effort while the portfolio decisions must be made by levels of management above these researchers, an information market is motivated. Many industries have similar R&D structures and many business processes in addition to R&D can benefit from combinatorial information markets.

Net Exchange intends to pursue both DoD and private sector routes to commercialization of the information market techniques that will be developed during Phase I of this proposed project. As the Phase I work progresses, Net Exchange will seek out a private sector commercial partner for the purpose of involving them in a Fast Track Phase II SBIR proposal, should DARPA choose to request such a Phase II proposal from Net Exchange.

8. KEY PERSONNEL

Two Net Exchange employees and two Net Exchange affiliates will serve as key personnel for the proposed Phase I efforts, they will be assisted by the balance of the technical staff at the San Diego office of Net Exchange. The two key employees will be Dr. Charles W. Polk, who will serve as the Principal Investigator for the SBIR efforts, and Dr. Takashi Ishikida, who will have principal responsibility for implementing the market design and associate responsibility for that design. The two Net Exchange affiliates who will serve as key Net Exchange personnel are Prof. John O. Ledyard, who will have oversight responsibility for micro-market structure and tradable contract definition, and Prof. David Porter, who will be responsible for the experimental testing. Professors Ledyard and Porter are two of the founders of Net Exchange and have been involved with most of the firm's research and commercial activities. There history of participation with, and equity holdings in, Net Exchange substantiate there being identified as affiliates. Their academic positions as faculty at Caltech (Ledyard) and George Mason (Porter) prevent their being paid as Net Exchange employees; thus, they will be compensated for their Phase I efforts as 1099 contractors. However, both are, in essence, internal Net Exchange personnel. Brief Bios of all four key personnel follow (note that some of their work is referenced at the end of this proposal):

CHARLES W. POLK

President of Net Exchange, San Diego, CA

EDUCATION:

Ph.D., Social Science, California Institute of Technology 1993

MA, Economics, University of California at Los Angeles 1989

BS, Engineering, Harvey Mudd College, Claremont, CA 1983

CURRENT POSITION AND PROFESSIONAL ACTIVITIES:

In addition to his duties as President of a small corporation, Dr. Polk heads the business development efforts of Net Exchange, a role that involves a substantial amount of applied market design – the art of matching a particular commerce or business process to a market mechanism so as to improve that commerce or process. Dr. Polk participates as a panelist or moderator at various e-commerce gatherings and has been invited to write several market design pieces for the business press, as well as the occasional review or commentary.

RELEVANT EXPERIENCE:

While at Caltech, Dr. Polk was involved with many of the activities that led to the application of combinatorial processes to real-world problems. Dr. Polk's direct involvement with Net Exchange began in 1994 and in 1995 he became its President. Since 1995, Dr. Polk has been directly and intimately involved in the practice of applying combinatorial market principles to commercial and business processes. Dr. Polk is one of the few practitioners of commercial combinatorial market design and application.

JOHN O. LEDYARD

Professor of Economics, California Institute of Technology

EDUCATION:

Ph.D, Economics, Purdue University 1967

M.S., Economics, Purdue University 1965

A.B., Mathematics, Wabash College 1963

CURRENT POSITION AND RESEARCH:

Dr. John Ledyard is Professor of Economics and Social Sciences at Caltech. He is also the Chairman of the Division of the Humanities and Social Sciences. Professor Ledyard has been a major contributor to the development of the principles and applications of mechanism design, a new approach to the understanding of the roles of incentives and information in organizations. His more applied work has included the development of computer-assisted markets for trading pollution rights, resources on spacecraft, logistics contracts, and portfolios of financial assets.

RELEVANT EXPERIENCE:

Prior to going to Caltech in 1985, John Ledyard was the Sydney G. Harris Professor of Social Science at Northwestern University where he had been since 1970. He has also held positions at Carnegie-Mellon University and Wabash College.

He is a Fellow of both the American Academy of Arts and Sciences and the Econometric Society. He currently serves on the editorial boards of several economics journals and has been the President of the Public Choice Society. He received an honorary degree from Purdue University in 1993 for his work in public economics.

Professor Ledyard is also the Chairman of Net Exchange, a company which architects online marketplaces. He has served as Net Exchange Chairman for seven years and led its strategic, technical and economic development. His roles at both Caltech and Net Exchange evidence his belief in the necessity of integrating academia and business practices. He was a major contributor to the design of the first combinatorial auction for the procurement of logistics services (for Sears Logistics), the first Internet market which is also the first combinatorial market, (for trading LA basin pollution permits), and the first combinatorial market for trading financial instruments (BondConnect for State Street Bank).

TAKASHI ISHIKIDA

Director of Research and Development, Net Exchange, San Diego, CA

EDUCATION:

Ph.D. in Operations Research from the University of California, Berkeley 1992

B. E. in Chemical Engineering from the Tokyo Institute of Technology 1980

CURRENT POSITION AND PROFESSIONAL ACTIVITIES:

From 1996 to the present Dr. Ishikida has developed and maintained Net Exchange's proprietary combinatorial order matching engine designed for use in a high-volume, high-speed e-Commerce environment. He has also aided in the commercial application of the Company's matching engines into Net Exchange's B2B Marketplaces.

RELEVANT EXPERIENCE:

Prior to joining Net Exchange, Dr. Ishikida was a Research Fellow in Economics at California Institute of Technology from 1993 to 1995 where he aided the design and implementation of various Internet based combinatorial markets including one for emissions credits which is regarded as the first Internet based B2B marketplace. At Caltech, he was a team member of a group that specialized in economics laboratory experiments on various market designs.

DAVID PORTER

Professor of Economics, George Mason University

EDUCATION:

Ph.D, Economics, University of Arizona 1986

M.S., Mathematics, University of Arizona 1984

A.B., Economics, Arizona State University 1979

CURRENT RESEARCH:

Professor Porter is doing research in creating markets to facilitate the scheduling of common resources among a diverse set of users. In addition to designing scheduling markets, Professor Porter is a major contributor to the literature in Experimental Methods in Economics. He has designed, developed and tested a host electronic markets and has pioneered the process of testbedding applications prior to their field implementation.

RELEVANT EXPERIENCE:

Prior to going to George Mason University in 2001, David Porter was a Senior Research Scientist at the Economic Science Laboratory at the University of Arizona (1998-2001) and the Jet Propulsion Laboratory at the California Institute of Technology (1986-1998). He has also held positions at the Caltech, the Arizona Corporation Commission and Arizona State University.

Professor Porter has conducted market design and testing for Net Exchange for the trading of financial instruments, logistic services and pollution trading. Professor Porter was the designer of the Cassini Resource Exchange, the first market on the Internet, is which scientists and instrument builders traded mass, budgets, and other development resources on a spacecraft, now headed for Saturn. Professor Porter has also tested the FCC package bidding system, NASD limit order trading, Matching systems, and electric power systems.

9. FACILITIES/EQUIPMENT

Net Exchange and George Mason University together have world-class facilities to design, develop and test electronic market hardware, software and human interaction. Net Exchange has the engineering support personnel and hardware to design and create algorithms to support combinatorial searches and pricing computations. George Mason University has three experimental laboratories that are dedicated to the development and testing of new electronic trading systems.

9.1 Net Exchange Facilities

Net Exchange maintains an operations research and computer science staff of five professionals, all of whom have experience designing and developing combinatorial market processes. The prototype application used during Phase I will be a modification of a product demonstration package that Net Exchange maintains and routinely modifies for commercial purposes. This product will used by the George Mason Experimental Laboratories in the performance of the prototype application experimental tests. The prototype will likely operate on Net Exchange servers and be offered over the web to the George Mason Lab. No software or equipment will need to be purchased by Net Exchange in the performance of the proposed Phase I efforts.

9.2 Experimental Laboratories

George Mason University will have in place a 30-station laboratory with high-end workstations and displays; a 40-station laboratory with high-speed communication links (T4 line and fiber optic connections); a 24 station testbed laboratory for systems design. The laboratories have will access to several dedicated large servers to control databases and market algorithms. There will be two SUN ultra5 servers with 1 GB of memory each and a quad 1GHz Server with 1.5 GB of memory and a RAD spindle harddisk for up to 5 terabytes of data storage. No software or equipment will need to be purchased by George Mason in the performance of the proposed Phase I efforts.

10. CONSULTANTS

As indicated in the Phase I Work Plan (section 4), external domain consultants will be paid for relatively small amounts of time to assist Net Exchange in the major tasks of Identifying Participants (approximately 20 hours), Designing the Participation Incentive System (20 hours), Defining the Contracts to be Traded (10 hours), and Identifying Comparison Institutions (10 hours).

The principal outside consultant that Net Exchange proposes to hire as a subcontractor if awarded this Phase I SBIR is Prof. Robin Hanson of George Mason University. Prof. Hanson will be involved throughout Phase I as a 1099 contractor. It is expected that Prof. Hanson's involvement will average five hours per week throughout the six months of Phase I efforts. A brief bio of Prof. Hanson follows:

ROBIN HANSON

Assistant Professor of Economics, George Mason University

EDUCATION:

Ph.D., Social Science, California Institute of Technology, 1997.

M.S., Physics, University of Chicago, 1984.

M.A., Conceptual Foundations of Science, University of Chicago, 1984.

B.S., Physics, University of California at Irvine, 1981.

CURRENT POSITION AND RESEARCH:

Dr. Robin D. Hanson has been a professor of economics at George Mason University for the last two years. Professor Hanson has an unusually diverse research agenda. He is primarily an applied game theorist, using game theoretic analysis to illuminate otherwise puzzling phenomena in a variety of political and economic areas. He also has several papers specifically on information aggregation, and on the economic consequences of envisionable future technologies.

RELEVANT EXPERIENCE:

Prior to going to George Mason University, Robin Hanson was a Robert Wood Johnson Foundation Health Policy Scholar at the University of California at Berkeley for two years. As a graduate student at Caltech from 1993 to 1997, he worked closely with both John Ledyard, his primary thesis advisor, and David Porter in the design and testing of market mechanisms. From 1984 to 1993, Robin Hanson was a computer researcher in artificial intelligence and Bayesian statistics, first at Lockheed (now Lockheed-Martin), and then at NASA Ames Research Center. During that period he was also involved with Xanadu, Inc. designing hypertext publishing institutions. He also spoke and wrote on advocating the use of speculative markets to aggregate information in science. This influenced the construction of several web-based pay-money betting markets, one of which won Robin Hanson a Prix Ars Electronica Golden Nica electronic art prize in 1995.

11. PRIOR, CURRENT OR PENDING SUPPORT

Net Exchange has no prior, current or pending support for a similar proposal.

12. COST PROPOSAL (Note, this has been submitted over the DoD Electronic Submission web site and is included here for sake of completeness.)

1. Name of offeror: Net Exchange, a California Corporation
2. Home office address: 12625 High Bluff Dr., Suite 316
San Diego, CA 92130
3. Locations where work will be performed:

   Location 1: Net Exchange home office in San Diego

   Location 2: California Institute of Technology, Pasadena, CA (Prof. Ledyard)

   Location 3: George Mason University, Virginia, (Profs. Porter, Hanson, and the experimental laboratory for the prototype market testbed)
4. Title of proposed effort: Information Markets to Estimate Military Instability
5. Company taxpayer identification number and CAGE code: 95-4480229, 1URU5
6. Topic number and topic title: SB012-012 Electronic Market-Based Decision Support
7. Total dollar amount of proposal: $97,750
8. Direct material costs: There will be no direct material costs incurred.
9. Material overhead rate and dollars: N/A
10. Direct Labor

    Dr. Charles W. Polk, 140 hours @ $80/hour = $11,200

    Dr. Takashi Ishikida, 100 hours @ $70/hour = $7,000

    Computer Programmers, 190 hours averaging $38/hour = $7,220

    Total estimated direct labor cost = $25,420
11. Labor overhead

a. Rate and hour base: 25% applied to all direct labor hours

b. Total estimated labor overhead: $6,355

12. Special Testing: N/A

13. Special Equipment: N/A

14. Travel: No travel will be billed to the government in the performance of the work proposed here. The distribution of locations and the normal communications among these locations and the key personnel should suffice in the place of travel. Should travel between Southern California and the Washington, D.C. area be required, the cost will be covered by Net Exchange

15. Subcontracts

Prof. Robin Hanson, 105 hours @ $150/hour = $15,750

Prof. David Porter, 48 hours @ $250/hour = $12,000

Prof. John Ledyard, 40 hours @ $300/hour = $12,000

Various Domain Experts (see section 10), 60 hours @ $150/hour = $9,000

George Mason Experimental Economics Lab Use = $7,000

Total Estimated Subcontract Costs = $55,750

16. Other Direct Costs: N/A

17. General and administrative expense

Percent rate applied: 20% for direct costs and 5% for subcontracts

Total estimated cost of G&A expense: $5,084 (direct) + $2,787 (subs) = $7,871

18. Royalties: N/A

19. Fee or Profit: Net Exchange requests a 2.5% fee

20. Total estimate cost and fee or profit: $97,781 rounded to $97,750

21. Signature of responsible official:

____________________________ ___August 14, 2001___

Charles W. Polk Date

President, Net Exchange

22. Answers to Required Questions:

    a. No executive agency of the United States Government has performed any review of Net Exchange accounts or records in connection with any other government prime contract or subcontract within the last twelve months.

    b. Net Exchange will not require the use of any government property in the performance of this proposal.

    c. Net Exchange requests to receive monthly progress payments during the conduct of the efforts under this proposal.

23. Net Exchange proposes this SBIR Phase I contract as a firm-fixed price contract.

13. COMPANY COMMERCIALIZATION REPORT ON PRIOR SBIR AWARDS

Net Exchange has never received an SBIR award and this is the first time Net Exchange has submitted a proposal for a Phase I SBIR award; thus, Net Exchange cannot provide a company commercialization report at this time. Attached at the end of this proposal is a signed copy of a blank SBIR Company Commercialization Report that attests to Net Exchange having never been awarded a Phase II SBIR, and, thus, having no standing from which to report any commercialization due to prior SBIR awards.

14. REFERENCES

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