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## Game Theoretic Real Option Approach of the Procurement of Department of Defense: Competition or Collaboration

Marc Rabaey, Belgian MoD, University of Hasselt

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ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
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Acquisition Chair
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road, Room 332
Monterey, CA 93943-5103
Tel: (831) 656-2092
Fax: (831) 656-2253
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# Preface & Acknowledgements

During his internship with the Graduate School of Business & Public Policy in June 2010, U.S. Air Force Academy Cadet Chase Lane surveyed the activities of the Naval Postgraduate School's Acquisition Research Program in its first seven years. The sheer volume of research products—almost 600 published papers (e.g., technical reports, journal articles, theses)—indicates the extent to which the depth and breadth of acquisition research has increased during these years. Over 300 authors contributed to these works, which means that the pool of those who have had significant intellectual engagement with acquisition issues has increased substantially. The broad range of research topics includes acquisition reform, defense industry, fielding, contracting, interoperability, organizational behavior, risk management, cost estimating, and many others. Approaches range from conceptual and exploratory studies to develop propositions about various aspects of acquisition, to applied and statistical analyses to test specific hypotheses. Methodologies include case studies, modeling, surveys, and experiments. On the whole, such findings make us both grateful for the ARP's progress to date, and hopeful that this progress in research will lead to substantive improvements in the DoD's acquisition outcomes.

As pragmatists, we of course recognize that such change can only occur to the extent that the potential knowledge wrapped up in these products is put to use and tested to determine its value. We take seriously the pernicious effects of the so-called "theory–practice" gap, which would separate the acquisition scholar from the acquisition practitioner, and relegate the scholar's work to mere academic "shelfware." Some design features of our program that we believe help avoid these effects include the following: connecting researchers with practitioners on specific projects; requiring researchers to brief sponsors on project findings as a condition of funding award; "pushing" potentially high-impact research reports (e.g., via overnight shipping) to selected practitioners and policy-makers; and most notably, sponsoring this symposium, which we craft intentionally as an opportunity for fruitful, lasting connections between scholars and practitioners.

A former Defense Acquisition Executive, responding to a comment that academic research was not generally useful in acquisition practice, opined, "That's not their [the academics'] problem—it's ours [the practitioners']. They can only perform research; it's up to us to use it." While we certainly agree with this sentiment, we also recognize that any research, however theoretical, must point to some termination in action; academics have a responsibility to make their work intelligible to practitioners. Thus we continue to seek projects that both comport with solid standards of scholarship, and address relevant acquisition issues. These years of experience have shown us the difficulty in attempting to balance these two objectives, but we are convinced that the attempt is absolutely essential if any real improvement is to be realized.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the Acquisition Research Program:

- Office of the Under Secretary of Defense (Acquisition, Technology & Logistics)
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- Defense Business Systems Acquisition Executive, Business Transformation Agency
- Office of Procurement and Assistance Management Headquarters, Department of Energy

We also thank the Naval Postgraduate School Foundation and acknowledge its generous contributions in support of this Symposium.

James B. Greene, Jr.
Rear Admiral, U.S. Navy (Ret.)

Keith F. Snider, PhD
Associate Professor

# Panel 21 – Innovative Mechanisms for Improved Acquisition

| Thursday, May 12, 2011 | |
|---|---|
| **1:45 p.m. – 3:15 p.m.** | **Chair: Dr. Fred Thompson,** Professor, Atkinson Graduate School of Management, Willamette University<br><br>***Optimal Cost Avoidance Investment and Pricing Strategies for Performance-Based Post-Production Service Contracts***<br>David Nowicki, Jose Ramirez-Marquez, and Ilona Murynets, Stevens Institute of Technology, and Wesley Randall, University of North Texas<br><br>***Prediction Markets as an Information Aggregation Tool for Effective Project Management in Defense Acquisition Projects***<br>Ricardo Valerdi, Massachusetts Institute of Technology, and Matthew Potoski, Iowa State University<br><br>***Game Theoretic Real Option Approach of the Procurement of Department of Defense: Competition or Collaboration***<br>Marc Rabaey, Belgian MoD, University of Hasselt |

**Fred Thompson—**Grace and Elmer Goudy Professor of Public Management and Policy Analysis at the Atkinson Graduate School of Management, Willamette University. Dr. Thompson is a specialist in the field of tax policy and regulation.

Dr. Thompson is co-editor of the *Handbook of Public Finance*. He was the founding editor of the *International Public Management Journal* and is currently associate editor of the *Journal of Comparative Policy Analysis*. He has been published in numerous scholarly journals, including the *American Political Science Review*, *Public Administration Review*, *Public Choice*, and *Journal of Economic Behavior and Organization*.

In 2000, Dr. Thompson received the Distinguished Research Award of the National Association of Schools of Public Affairs and Administration and the American Society for Public Administration. In 2005 he received the Aaron B. Wildavsky Award for Outstanding Lifetime Scholarly Achievement in the field of public budgeting and financial management of the Association for Budgeting and Financial Management. In 2006 he served on the United Nations Development Program's Blue Ribbon Commission on Macedonia.

Dr. Thompson earned his Bachelor of Arts in Economics and History from Pomona College and his PhD from the Center for Politics and Economics, Claremont Graduate University.

# Game Theoretic Real Option Approach of the Procurement of Department of Defense: Competition or Collaboration

**Marc Rabaey—**marc.rabaey@gmail.com

## Abstract

The real option analysis for investments is well known. In order to make decisions (delay, stop, start up, continue), management is waiting to collect more information, or is waiting for a better environment (market situation, political situation and so on). However this is without taking into account the (inter)actions of the other players in the market. Option games will place the real options into a strategic (game theoretic) context., i.c. DoD for procurement.

In reality, the complexity of real options and the need for the permanent monitoring of the environment make some managers reluctant to introduce it in the enterprise for investment decision-making. A generic framework “Intelligence Base” is being proposed to approach intelligence and game options in a holistic way for the strategy and the investments.

## Introduction

The real option analysis for investments is well known. In order to make decisions (delay, stop, start up, continue), management is waiting to collect more information, or is waiting for a better environment (market situation, political situation and so on). However, this is without taking into account the (inter)actions of the other players in the market. Option games will place the real options into a strategic (game theoretic) context.

As we will show, for the strategic interaction with other parties alone, an organization who wants to gain competitive or collaborative advantage, has to screen permanently its environment and its own functioning.

Weeds (2006) points out that to use real options, the real options valuation (ROV) requires a detailed analysis of the full range of possible developments in the future and the probability of success of each one, not just the expected or average outcome. Furthermore, implementation of ROV requires managers to monitor the business environment to assess what should be done with the options. If they cannot bring up the effort to do so, then they are unlikely to achieves the values calculated using ROV. This and the complexity of ROV makes it difficult to implement ROV.

The attentive reader will certainly remark that the effort to monitor the environment of the organization for strategic reasons, can also be used to collect information to implement and maintain the ROV and even more when both are combined in the option games. Therefore, we will propose a generic intelligence system that every organization can instantiate in function of its culture and capabilities.

In what follows we will start from the art of war to develop a forum in which all decisions for investments and procurement can be made. In the next section the process of decision-making for that forum is discussed. In the Intelligence Base section and the Conceptual View on the Intelligence Base section we will propose a generic intelligence system, called intelligence base. The Investments section handles the combination of real options and game theory. Before we conclude, we will give an overview how a department of defense can use the game-theoretic approach of real options in the cases of collaboration

and competition and how DoD can determine the possible strategy games for the suppliers (procurement).

## From Strategy to Action

### *The Art of War*

To Bernard (1976), there are three principles of the Art of War:

- Balance between Goals and Means,
- Liberty of Action, and
- Economy of Forces.

Regarding the military (Hart, 1991; Bernard, 1976), grand strategy is the art to combine resources of an organization to attain its objectives. This is determined by the first principle of the Art of War, being the balance between objectives and resources. If a company uses too many resources to attain the objectives, then it is not efficient. If too few resources are used, then the company will not be effective and it will not attain its objectives.

As a result of the balance between goals and means, two types of strategy will be derived from the grand strategy: the business strategy and the resources strategy. Examples of resources are human resources, financial resources and ICT.

The business strategy will define strategic objectives that have to be attained by the (core) business units through their processes. Thus, the strategy itself is realized by business processes. These processes may belong to one or more organizations.

The first principle has one rule: the permanent seeking of intelligence, inside and outside the organization. The balance between goals and means is about determination of the right objectives, given the environment and the available and/or possible needed resources related to these objectives. The result is the grand strategy of the entire organization. As a consequence of this balance, two other strategies can be derived: Business and Resources Strategies. The first is focused on the creation and the deployment of the core competences to attain the imposed objectives, while the latter is focused on the means and the processes to support the first (Rabaey et al., 2007a).

The liberty of action is about security: avoiding, preventing as much as possible, hostile actions of other organizations and the assuring of the communication lines (logistics, information; for intelligence). The economy of forces treats the economical and right use of the resources (efficiency and effectiveness).

The deeper in the hierarchy of the organization, the less impact the leaders have on the resources aspects and the scope of their business levels. Therefore, in the ever-faster changing world, the structure becomes less hierarchical, so flexibility is gained. This implies that these leaders (and/or managers) need to have access to more information and have a more extended information system.

### *Interdisciplinary Forum*

Rabaey et al. (2007) define a business process as a logical set of activities that consumes resources to attain its objectives. In the organization of the business processes, we have the second alignment of goals and means. The resource managers and the business unit managers will discuss the operational use of resources (organization) in an interdisciplinary forum—interdisciplinary because of the multitude of functional domains

(Rabaey et al., 2007a). The result is the providing of the resources and their service levels (SLA = Service Level Agreement).

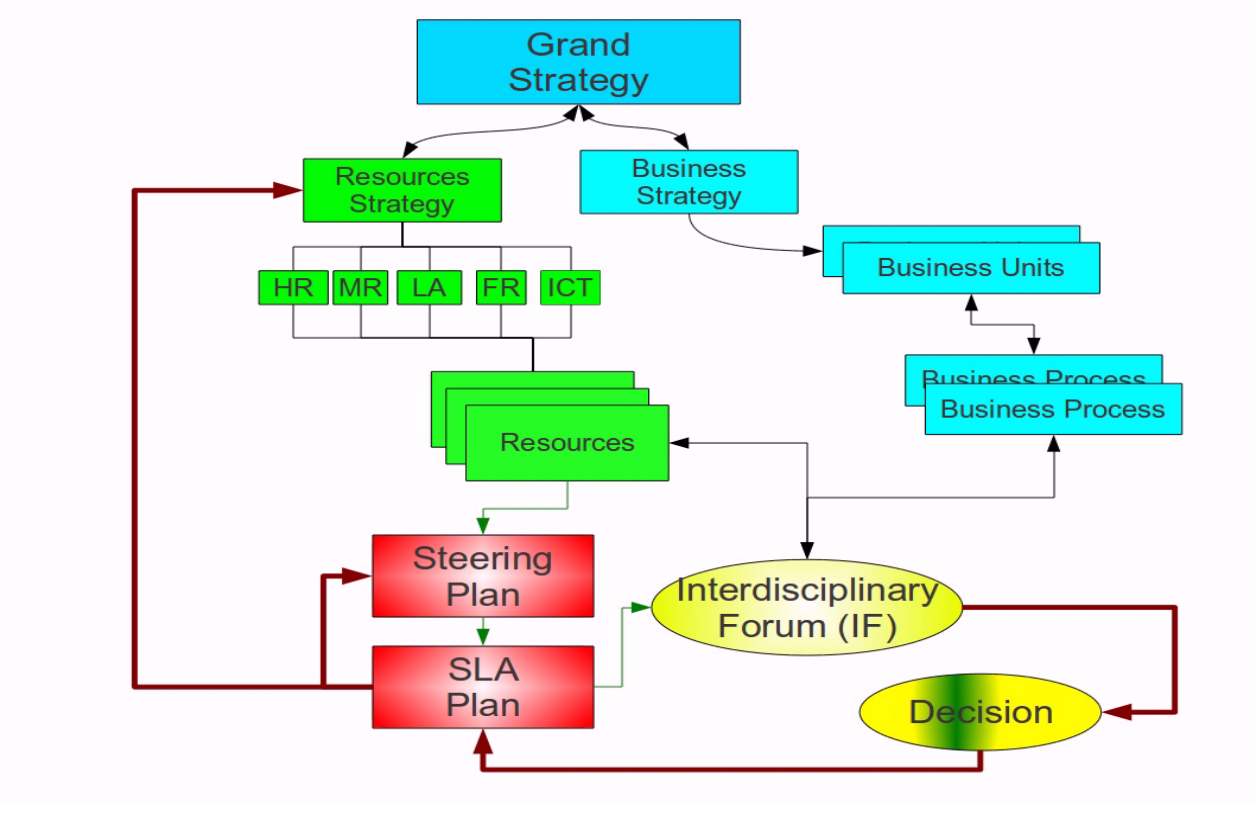


**Figure 1. Interdisciplinary Forum**

From a business perspective, a resource or service provider will be evaluated on the delivery of the service (SLA) and the quality of service (QoS). The deployment of resources in a business process is the result of a decision process (of the interdisciplinary forum). If software must be able to choose and to deploy itself the resources and the modules of its capability, then it must be capable to understand the characteristics and the purposes to attain its imposed objectives.

***Different Games on Different Levels***

If we look at an organization as DoD, the organization can play different games at the same time in different domains. So, there is no such thing as a unique strategic game to play.

Moreover, the underlying organizational elements can themselves play different games regarding the mother organization and regarding each other, even for a same project: IT can collaborate with third parties, while human resources are in competition with these parties. If there is no superstructure (like project management or business unit), then contradictory signals are sent to the market.

Thus for the procurement of goods and services the strategy for that project, the chosen strategic game is that of the superstructure. The strategies (games) for the sub-organizational units will be derived from that game. As such, suboptimal strategies are

avoided in the request for proposal. It is the interdisciplinary forum that determines the strategy and rules for the procurement for that particular project.

### *Enterprise Architecture*

The strategy of the project itself has to be aligned with the higher strategies and the already made investments (because most of them are irreversible, therefore there are sunk costs). The new project may change the investment plan, thus flexibility and adaptability are demanded. For that reason, real options are very useful.

The changes of investment will reflect on the steering plan (see Figure 1). Since IT performs more and more an important role, it is necessary to have a framework in which IT can be situated in the function of the business. Enterprise Architecture (EA) is such a framework. The Enterprise Architecture Research Forum (http://earf.meraka.org.za/earfhome/) defines Enterprise Architecture as "the continuous practice of describing the essential elements of a socio-technical organization, their relationships to each other and to the environment, in order to understand complexity and manage change." Therefore, Enterprise Architecture should consist of distinguished levels. The naming of the distinguished levels may differ, but in general at least EA should consist of Business Architecture, Information Architecture, Application Architecture, and Infrastructure Architecture (Rabaey et al., 2007a).

Rabaey (2012) proposes to add an additional layer, namely Knowledge Architecture, because IT will become a utility (commodity) and competitive/collaborative advantage will become almost fully dependent from the capability of producing intelligence for decision-making and knowledge management (in systems, processes and human resources). Some investment techniques use knowledge units (Housel & Bell, 2001) or Knowledge Value Added (KVA) to assess investment probabilities (Mun & Housel, 2006).

## Decision-Making

### *Uncertainty and Risk*

Real options are used to assess risk (Benaroch, Jeffery, Kauffman, & Shah, 2007) and uncertainty and take the appropriate measures and decisions. Both terms, risk and uncertainty, are interchanged because of the fact that the outcome is the same (expected values; Aven, 2010, p. 55), but semantically they are very different in the approach regarding decision-making.

Organizations have to make important decisions (like investments) without complete information in a complex and fast changing environment. Uncertainty is a state in which the outcomes are unknown and perhaps unknowable; the more distant in time (future), the greater the uncertainty (Funston & Wagner, 2010, p. xxiii).

There is a correlation between the level in the organization and the degree of uncertainty: the higher in the organization, the less explicit information exists, so the more uncertainties exist, and therefore the more intelligence it needs to reduce this uncertainty (see Figure 2).

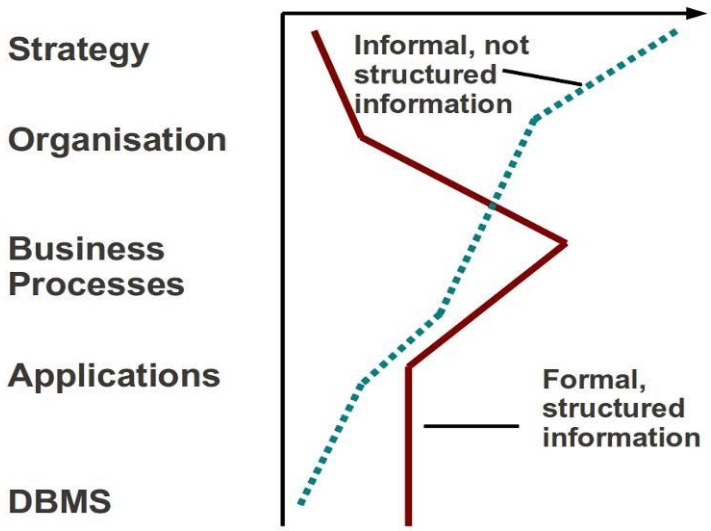


**Figure 2. Lack of Formal Information**
(Rabaey et al., 2007)

The decision horizon is further at the strategic level than at the operational or tactical levels of the organization. For most of the organizations in this ever-faster changing environment, the time line at the strategic level is from the present until the long term (at least a year), while the operational level is from now until short term (a couple of weeks or months at most).

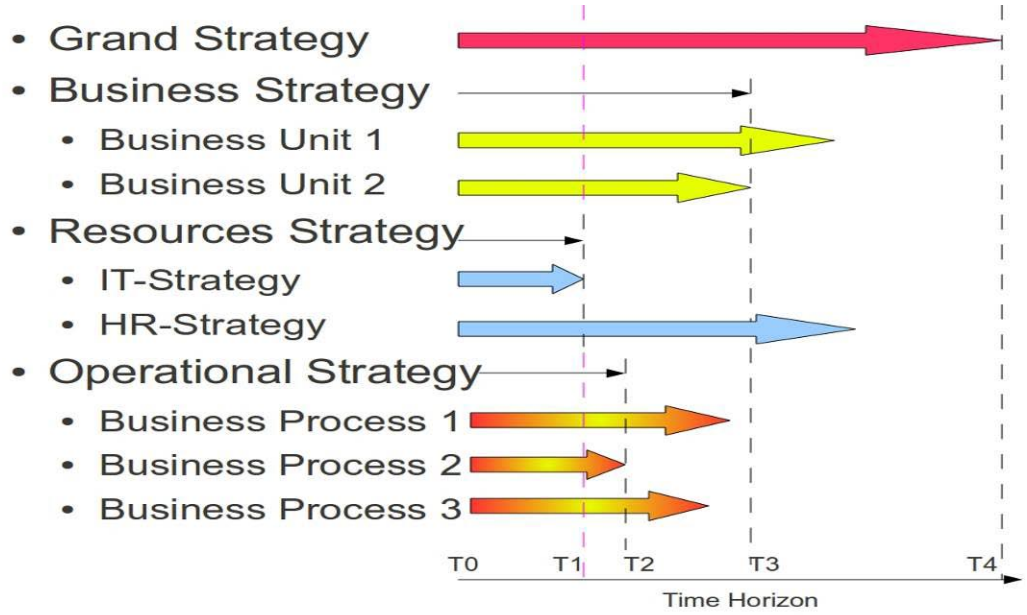


**Figure 3. Time Horizon, Uncertainty and Volatility**

In Figure 3 the grand strategy determines the long term horizon (T4). The other arrows are indicating the quasi-certain period. For the business strategy business unit 2 determines T3, IT causes T1 for Resources strategy, which may explain the shorter period

T2 for the business process 2. The volatility is not a sum of the volatilities of the different units, rather a product. However, as stated above, there are different types of uncertainty, the approach to reduce the uncertainty is in function of the type.

Frank Knight described two types of uncertainty: first, that in which probabilities are known or knowable (so expected), which he called risk. The Open Group defines risk as the probable frequency and probable magnitude of future loss ("Risk," n.d.). The second type is real uncertainty,[1] which is not known or knowable.

So risk is a measurable unknown, while certainty is an unmeasurable unknown. For the former, we can collect information to improve the already existing knowledge, while for the latter, an organization should collect information to "discover" it. The unmeasurable unknown can be divided in the known-unknown (the organization knows that it doesn't know something) and the unknown-unknown (the organization is not aware that something exists).

In any case, be it for risk or uncertainty, an organization should always be collecting intelligence (also the only rule for the first principle of the Art of War). To game theory, unknown-unknown facts can influence the strategy game and strategists are somehow, sometimes aware of it (intuition), while to real options only the known-unknown and risks are taken into account.

***OODA***

USAF Colonel John Boyd has developed an important concept on decision-making at the strategic, operational and tactical level: Observe-Orient-Decide-Act (OODA). OODA is a decision-making process (see Figure 4). However, Osinga (2007) stresses that OODA-loop is more than a decision-making process; it is a model of an organizational learning and adapting in which the element "Orient" plays an important role in the organizational adaptability. The capability to adapt to uncertainties and risks is one of the parameters to determine the volatility of a real option (Piesse & van de Putte, n.d.).

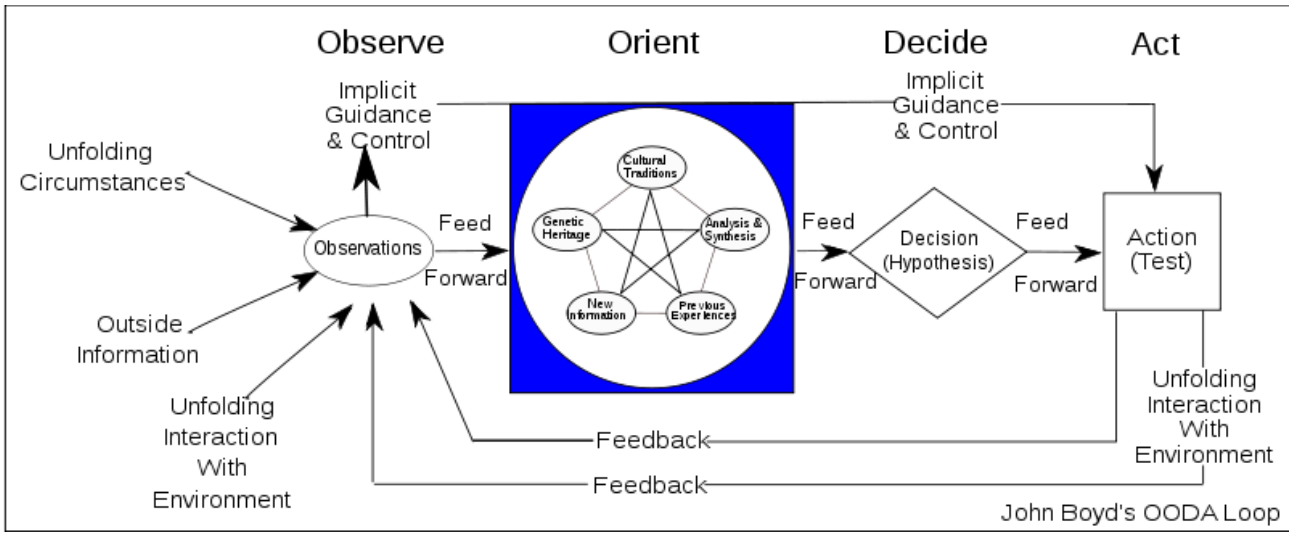


**Figure 4. OODA-Loop**

[1] Lack of certainty.

Dr. Norma Bubier (personal communication, March 30, 2011) refers to OODA as an organic process. The organization is interacting with its environment and has to interpret it to decide what, when, where, and how to act in function of the new information, culture, previous experiences (skill, knowledge) and organizational structure (genetic heritage). This implies that organization should always monitor the environment and itself to detect risks, and therefore also opportunities.

Translated to the interdisciplinary forum, we can represent OODA as follows (see Figure 5): In an interactive and iterative way the interdisciplinary forum will decide with the superstructure what it should do. The superstructure will then communicate the sub-organizational units (business units, and/or resources-units) what to attain as goals (in a coordinated way). The sub-organizational units will perform then their own OODA-loop to determine the best possible actions on their level. A similar interactive and iterative process for the intelligence cycle will below be discussed.

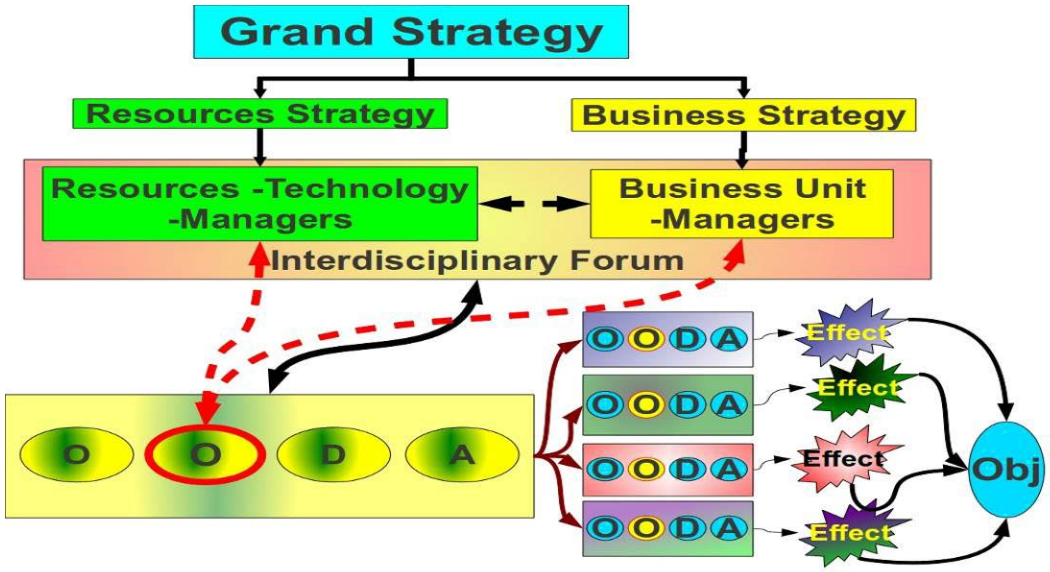


**Figure 5. OODA: Unit and Subunits**

***Predictably Irrational***

Game theory explains with success the behavior of humans when they act rationally. However, it does the same for birds or fish, from which we cannot say that they have brains comparable with human brains. Binmore (2007, p. 5) states that rationality in game theory is about consistent behavior, not reasoning. Therefore we may not automatically assume that by using game theory in the procurement domain, we imply that those decisions are made rationally.[2]

Literature on behavioral economics (Ariely, 2009; Montier, 2010), intuitive management (Burke et al., 1999), psychology (Libet, 2011; Pucket & Purdy, 2011), naturalistic decision-making (NDM; Brooks, 2007; Berryman, 2007; Shattuck & Miller, 2006) proves that the decision-making is not always rational. A lot has to do with how people and their brains are coping with uncertainty and risk. Collecting intelligence can reduce uncertainties and handle better risks, what we will discuss in the next point.

[2] Which, of course, they may be.

## Intelligence Base

### *Need for Intelligence*

At all levels of the organization, uncertainty exists. However, the closer to the strategic level of the organization, the higher the uncertainty. This is because of the decision time horizon. The strategic level of an organization must give the general direction to which the whole organization has to evolve.

It must be noted that uncertainties and risks are not always external the organization but also internal. Techniques such as Baldrige (n.d.) and Common Assessment Framework (CAF, n.d.) are used to assess the internal organization and to improve its working, which comes down to obtaining the right knowledge and information to attain the objectives of the organization and to use, in a rational way, its resources.

In an economical context, rationality has more to do with the ratio of benefits to costs instead of the philosophical meaning of reasoning ("Rationality," n.d.). It is not a surprise that even the first principle of the Art of War is to have the right balance between goals and means to decide which is the best strategic plan to adopt for preserving the best interest of a nation. The only but obligatory rule of this principle is the permanent collection of intelligence (Bernard, 1976). So to reduce its uncertainties to make better decisions, the organization will collect intelligence.

Funston and Wagner (2010, p. xxiii) write the following:

> The risk intelligent enterprise recognizes that risk intelligence and risk management are not ends in themselves but a means toward the ends of creating and preserving value and surviving and thriving in uncertainty. Risk intelligence is an approach to conducting business that improves decision making and judgment in vital areas and initiatives. After all, to be enterprising means to be bold and willing to undertake new initiatives that involve risk.

The Defense Security Service document (DSS, 2005) states,

> Intelligence is the product resulting from the collection, evaluation, analysis, integration, and interpretation of all available information, that concerns one or more aspects of foreign nations or of areas of foreign operations, and that is immediately or potentially significant to military planning and operations.

This is done by the intelligence cycle process. However, not only intelligence is obtained for the decision-making process, also, knowledge can be created with this process. This is not surprising because knowledge is also used to make decisions (Courtney, 2001).

### *Intelligence Cycle*

The intelligence manager has the following resources in the so-called intelligence cycle: the memory (where all acquired information is stored), the network (of sensors) and the analysis capability. The latter analyzes all incoming information and processes it into intelligence that will be stored into the memory. In the scheme of Besson and Possin (2003) in Figure 6, the "unknown" actively drives the intelligence cycle; however, it is the sensors that collect the information, which can be of use to the organization.

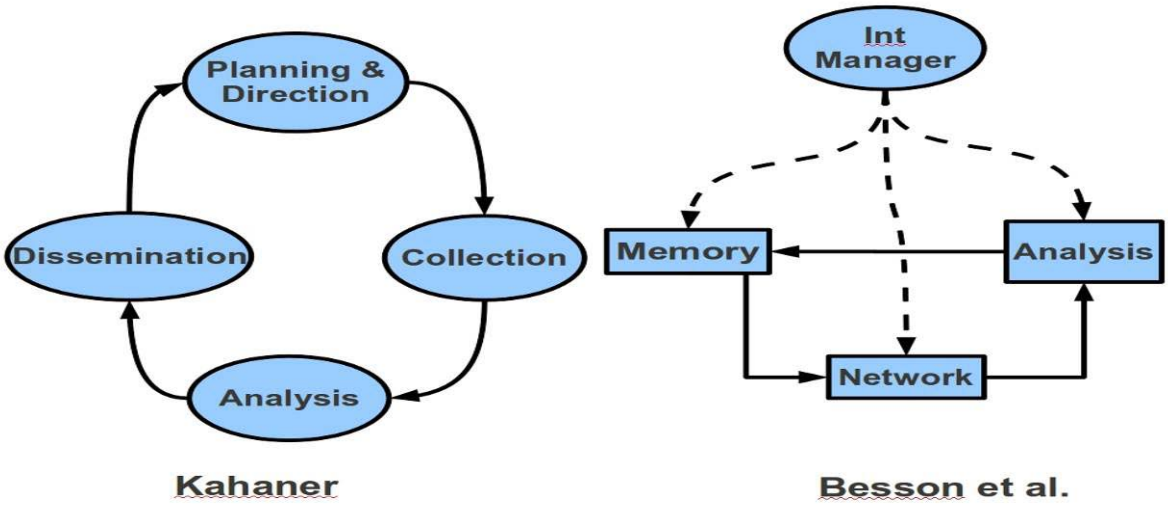


**Figure 6. Intelligence Cycles**

The most difficult task is to formulate and translate the question into a clear language, which would then lead the organization to the pertinent and relevant information. In other words, it conveys knowledge about opportunities and threats, which the organization (Kahaner, 1997) ignores (Besson & Possin, 2003, p. 22).

Larry Kahaner (1997) sees the intelligence cycle as a process instead of a function. "Therefore it should appear in all aspects of your business as one seamless, continuous activity not relegated to one area, division or unit" (Kahaner, 1997, p. 23). This process has four steps: Planning & Direction, Collection, Analysis and Dissemination (Kahaner, 1997, p. 43).

The step "Planning & Direction" starts with a clear understanding of the user's needs and includes his time constraints. Once well understood, further intelligence actions are planned. The step "Collection" involves obtaining raw information that can be turned into usable intelligence for the decision-making of an organization.[3] "Analysis" is the process of taking information and integrating it with other information so that intelligence is created. "Dissemination" is distribution of the intelligence towards the client and other organizations that may also be concerned by this intelligence.

### *Knowledgebase (KnB)*

Guida et al. (1994) defines a knowledge-based system (KBS) as a software system capable of supporting the explicit representation of knowledge in some specific competence domain and of exploiting it through appropriate reasoning mechanisms in order to provide high-level problem-solving performance. The knowledgebase stores available knowledge concerning the domain at hand, represented in appropriate explicit form and ready to be used by the reasoning mechanism.

[3] Mainly two types of information exist: primary and secondary. Primary information comes directly from the information sources. Secondary information is coming from other sources then primary sources, which have altered the "raw facts."

Is intelligence also knowledge? For Peter Drucker (1998) knowledge is information effective in action so information focuses on results. Sanchez and Heene (1997) define "knowledge as the set of beliefs held by an individual about causal relationships among phenomena. Causal relationships in this definition are cause and effect relationships between imaginable events or actions and likely consequences of those events or actions. Organizational knowledge is then defined as the shared set of beliefs about causal relationships held by individuals within a group."

Therefore, both terms (intelligence and knowledge) are supporting the decision-making process and these terms are sometimes interchanged (Kahaner, 1997, p.21) or confused with information. It is, however, clear that interpreted and integrated information becomes intelligence, which enables the person to make a decision using the inference rules of the concerned knowledge domain.

Yet knowledge evolves, facts stay. Therefore, an organization should store the facts (information) in a "Facts Base" for later re-interpreting the same facts but with other knowledge. Besides tracking the intelligence, an organization should place the intelligence on a dedicated storage "Interpreted Information Base" to assess the quality of intelligence (Besson & Possin, 2001).

Using the same logic as intelligence assessment, the decision-making process can be assessed (Yates, 2003) and thus the knowledge. Sanchez and Heene (1997) define three types of knowledge: factual knowledge (entities, relationships), inferential knowledge (reasoning functions) and strategic knowledge (problem-solving strategies).

### *Unknown Base*

If an organization knows what it knows, then it knows what it does not know but would like to know. The Unknown Base supports the management of the unknown. The whole system of detecting, managing and collecting the unknown is very strategic for an organization. If its competitor/enemy knows what the organization does not know, then the competitor/enemy can take advantage of this. Security is of the utmost importance.

In what follows, the conceptual, strategic and operational level of the Intelligence Base will be discussed.

## Conceptual View on the Intelligence Base

### *Components*

The *Dictionary of Military Terms* (DoD, 1999) defines an Intelligence Data Base as "The sum of holdings of intelligence data and finished intelligence products at a given organization." The term "data" is too limited in the context of intelligence (OMB, n.d.); moreover, we have added the management of the Unknown, and therefore we suggest the term "Intelligence Base."[4] The management and the storages of the unknown, the facts and intelligence, and the supporting Intelligence Information system form together the "Intelligence Base" (IntB; see Figure 7).

[4] Section based on Rabaey et al. (2005).

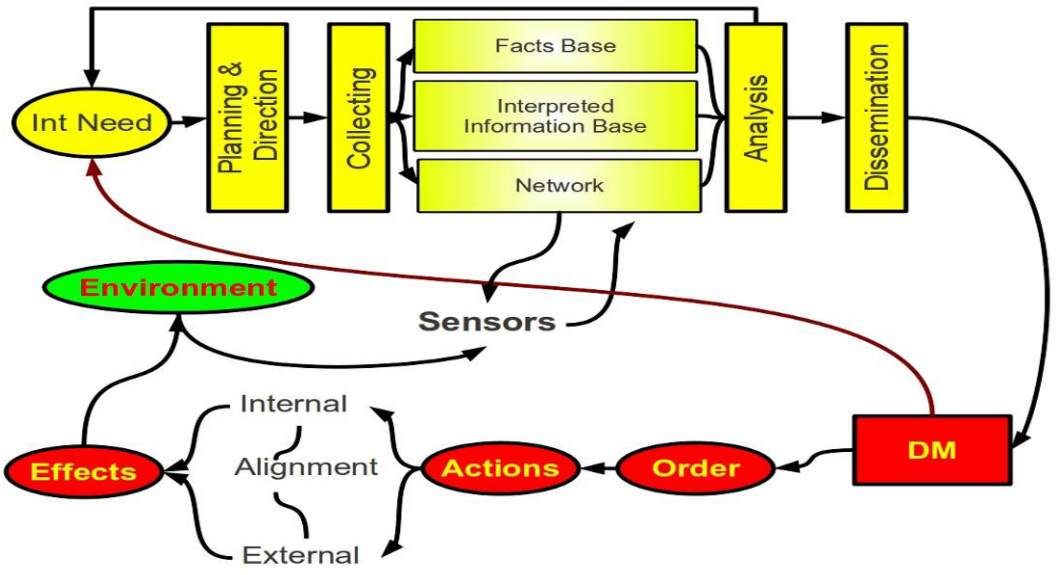


**Figure 7. Intelligence Base Concept**

Every level of the organization, be it strategic, operational or tactical, interacts with its environment, which gives opportunities to collect information (push or pull, see below) about that environment. The collected information should be transferred via a special and dedicated communication system of the intelligence information system (Int IS), which supports the Intelligence Base.

Figure 8 shows similarities with OODA-loop of the interdisciplinary forum (see Figure 5), which is logic because they are intimately interwoven with each other.

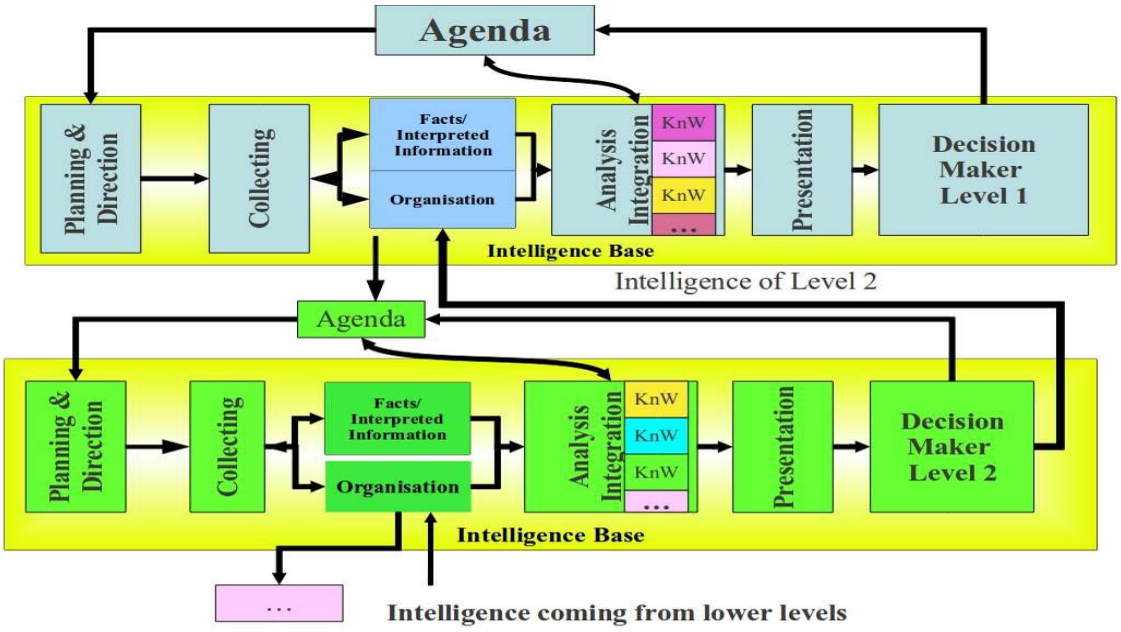


**Figure 8. Cascading Intelligence Processes**

### *Decision Making and Intelligence Process*

Before handling the triggers, "it is important to always link information to the decision making process. Only pertinent information and information that increases the knowledge base need be processed. All other information may remain unprocessed or discarded." (Morua & Bruns, 2002). In our system the processed information becoming intelligence is placed in the Interpreted Information Base, while the facts (processed or not), went to the Facts Base. The knowledge base is composed of the Interpreted Information Base and Facts Base. How does this information come into the system?

Two events can trigger an interaction between the decision-making process and the intelligence process. Firstly, the decision-maker expresses an intelligence need. The second trigger is the transmission of newly detected facts by the sensors. Of course, the intelligence process can also express intelligence needs.

The case of "Information Pull" is when the decision-maker does not find the necessary intelligence (in the Intelligence Base or outside of it), then he expresses his need to the "Planning & Direction." The latter will then define the needed intelligence actions. The needed information may not be in the Intelligence Base in which case the network has to be instructed (push). The planning of the dynamic search-path is established (Besson & Possin, 2001) and the plan of action is managed in the Unknown Base.

The resulting information (if any) is then analyzed. Additional information may be required if there is not enough information to be integrated into intelligence. Once the intelligence is acquired, then it will be disseminated to the intelligence client. The information and intelligence are stored respectively in the Facts Base and the Interpreted Information Base, and the Unknown Base is updated.

In the case of "Information Push" the sensors are injecting information in the network (push). The transmitted information is then analyzed. If the information can be integrated, then the resulting intelligence is pushed to the concerned people and/or organizations. The information and intelligence (if any) are stored respectively in the Facts Base and the Interpreted Information Base.

## Investments

### *Real Options and Game Theory*

The classic investment methodologies like Net Present Value (NPV) and Return of Investment (ROI) are lacking the flexibility that management need to be able to postpone, delay, start, and abandon projects.

Real Option Analysis (ROA) gives management this flexibility, and it tackles the problem of uncertainty and risk related to each investment. Options are the right but not the obligation to execute an action (sell or buy). Translated to real option, it means that management can decide to postpone, stop, start, restart or put on hold a project. The reasons may be because of the lack of relevant information, or to wait for results of some pilot projects.

Although ROA is known in the IT-world, our study of recent literature on Cloud Computing shows that this literature is still referring to ROI and NPV. Besides the reasons mentioned in the introduction, another reason is that most of the books are written by technology people. Therefore, this subject gives the possibility to introduce ROA, also in the philosophy of more technical business environments, like Cloud Computing. ROA, however,

has a common drawback, like the classic investment techniques, being the lack of taking into account the interaction of the organization with its environment (market, government, etc.). The solution is to combine ROA with game theory, which resulted in the theory of option games (Rabaey, 2011).

### *Mono-Game and Multi-Game Options*

Game theory on its own analyzes complexities of the equilibriums and the payoffs into detail by determining players' utility functions without any relation to market values. Real options analysis places these payoff values under uncertainty, considering market values and the flexibility of response by the optimal exercise of the options.

However, because the actual actions (and necessary actual decisions) seem to erode partly the value of waiting. This is the main reproach that we can find in the literature on the option games. Our approach brings both theories together in another way.

Real options are a set of chains of future decisions. In order to make decisions (delay, stop, start up, continue), management is waiting to collect more information, or is waiting for a better environment (market situation, political situation and so on). The situation has to be assessed at that moment in the future, but we will place it in a game theoretic context. Our proposal is not only a chain of possible decisions (as in the non-interactive original version of real options), but also a chain of possible interaction situations represented by games.

Every decision node consists of two phases. The first is to assess the situation in which the decision has to be made, in other words the probable payoff matrix of the game. The second phase is to determine the value of the real option based on this payoff matrix.

If the convention is to always take the same game, then we call this the mono-game chain of options. A more complex version is to consider more than one game, and therefore determine the value of the real option for each game (and its corresponding payoff matrix). As a result, each node with multiple games (in the so called multi-game chain of options) will generate more branches than in the case of a mono-game chain of options.

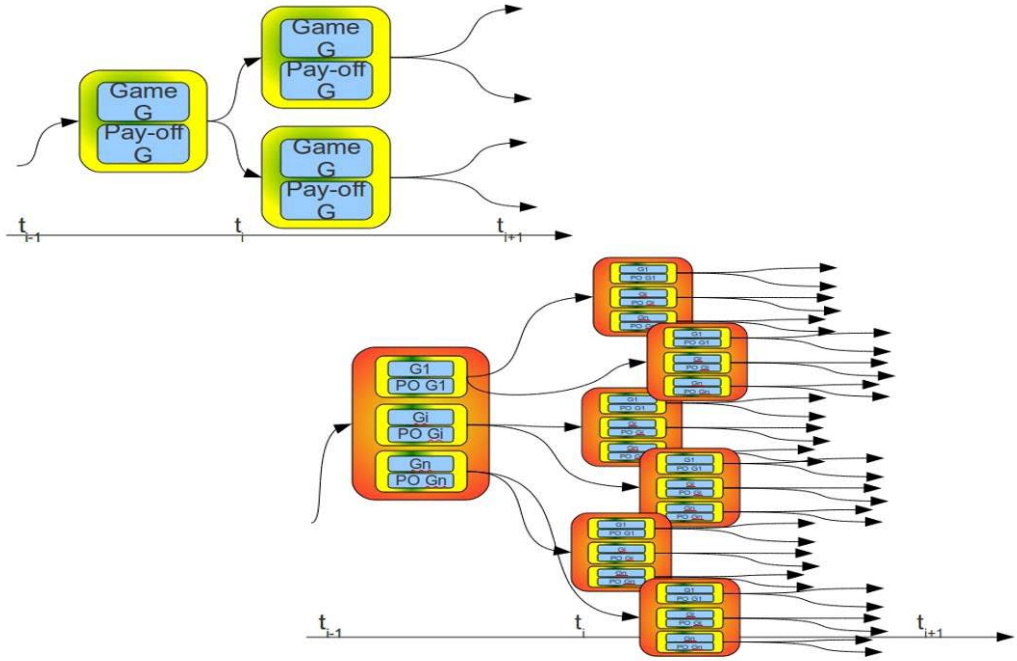


**Figure 9. Mono-Game and Multi-Game Options**

In the upper part of Figure 9 we see the representation of a mono-game option in a decision tree, while the lower part represents a multi-game option. The latter has a tendency to become a chaotic (although deterministic) system after a certain point in the time horizon.[5] To select the more relevant games, meaning reducing the number of possible games, it is necessary that the organization collects intelligence about the possibilities on collaborating or competing with one or more actors in the market. Otherwise the system will overload itself.

## DoD Procurement in Competition and in Collaboration

In general, there are two kinds of situations: competition and collaboration. We will first discuss the competition situation, but before we are referring to Weeds (2006) with the remark that certain urgent events force the organization to act immediately. We will integrate the elements of Weeds (2006) in our discussion. But again it indicates that an organization should permanently screen its environment, and therefore implement an instance of the intelligence base. It must be stressed that even organizations that are not using ROV must implement a similar system, otherwise it will miss opportunities and run more risks.

### *First or Second Mover*

The DoD of a country is in competition with other DoD or government agencies to obtain from the limited number of suppliers, the capabilities to produce goods or to deliver services. In function of the strategic importance, the DoD can chose between a first mover (leader, innovator), or a second mover (follower).

[5] More research will be done on this subject.

The first mover advantage (FMA) is when the DoD invests first, rather than continuing to delay, and the competitor continues to delay. The invested cost can be seen as a basis investment for further options, while the DoD as first mover has as advantage that there will be a strong alignment of the "new" capabilities on its own strategy. A second advantage is that for a limited time the DoD has a monopoly and can create market conditions for the suppliers and, not to forget, also the customers of the suppliers (see the DoD as Regulator in the Market for Its Own Procurement Environment section). However, it is not without any risk. If it fails, then the competitor who has delayed can take advantage of the mistakes of the first mover (this is an example of a Second Mover Benefit, SMB).

To be a second mover can have many causes.[6] First of all, the DoD had not enough information to reduce its uncertainty or to mitigate the risks. Then, with the information coming from the actions (failure or not) of the competitor, the DoD can reevaluate the situation and improve its payoffs.

The DoD can also consider saving the costs of being the first mover, but it will have to adapt to the solution of the first mover, by sacrificing some of the strategic objectives, or part of it, unless the first mover has failed. In the latter case, the second mover can take the lessons learned to determine a better strategy to obtain the necessary capabilities, as already mentioned previously.

It can even be a strategy that the follower wants the other one (pushed in the role of leader) to move as first, so that the latter can come with a better strategy or products or gain better resources (or methodologies) and hope that the follower becomes the leader.

Weeds (2006) states that FMA tends to conflict with real options because there is a threat of preemption of a rival; however, that is more the now-or-never situation (see below). FMA comes from the strategic (competitive) advantage (opportunity) of that moment. By investing (consuming cash flow), the DoD hopes to create more potential for the future (for attaining the objectives of the political governance) and knows that a possible reaction of the follower can come. In the case of now-or-never, the initiative is not exclusively for the leader.

As for the game-theoretic aspect, the DoD as first mover must be aware that the competitors will react. These reactions can undermine the FMA; therefore, the DoD should not only consider its own actions but also the reactions of the competitors and the influence of these reactions on its own payoffs—in the case of leader-follower game. Therefore, from the point of view of the leader, the DoD will establish two payoffs matrix, one for the case that the follower reacts quickly, and one for the case that the follower continues delaying any action. By creating intelligence (collecting and analyzing information), the organization can better determine the utility functions and the probable reaction of the follower and its impact on its own payoffs.

### *Now-or-Never*

There is a third type of competition in which the DoD is obtaining simultaneously the scarce resources. This is the case when it is strategically important to have a specific system (or goods or services) and therefore has to compete with other agencies. In this the competitive pressures to obtain the resources or goods/services are strong and the cost of being preempted is considerably high, then waiting can cause considerable damage by losing the investment opportunities to its competitors.

[6] If the DoD does not have the capabilities to invest (for any kind of reason), then this is obviously not an active strategy, and we can speak of a "mover."

This is a now-or-never opportunity where the option has no value anymore and classic investment techniques can be used. It is not a failure of the system of real options, only strategic (game) considerations oblige DoD to act as soon as possible. Of course, the decision can have significant influence on other projects or investments, of which the option values can change dramatically. Therefore, it is not because of the fact that real options have not been used in an urgent case that the decision nodes along the scenarios tree don't need an ROV anymore.

It must be clear that the DoD has to develop (strategic) scenarios in which not only first and second mover must be taken into consideration but also the now-or-never situations.

### *Unknown-Unknown*

Another situation can be a lack of information on the part of the DoD, resulting in it being unaware of the competition for capabilities of other agencies (silent or secret negotiation phase), so an unknown-unknown situation.

### *Collaboration*

The second situation for DoD procurement is collaboration. It is in a common interest that the DoD of a country collaborates with allies (p.e. NATO). Collaboration does not necessary mean that the DoD is in a less stressful situation. "Missing the boat" to collaborate can be as disastrous as in competition. However, most of the time, the context of collaboration is determined by the higher political bodies of a nation.

In the cases of repeated games, the game theory, linked with the real option analysis, can be used by a DoD of a country to steer the decisions in a best possible way to obtain the strategic objectives. However, this subject is still in the phase of research.[7]

## DoD as Regulator in the Market for Its Own Procurement Environment

### *Regulator*

The strategic objectives determine the functional requirements of the goals, where the resource strategy is determining the technical requirements based on standards, policy or doctrine of use. The request for procurement or proposal is then published to the suppliers (market). As seen previously, when the DoD was itself submitted to the market strategic games, the suppliers can be put in two situations: competition or collaboration (coordination).

In this case we don't use the game theory to position the DoD in the market, but as the organization which creates a particular micro-environment for the suppliers, a market regulator for its own procurement. As a matter of fact, the DoD is creating the game theory framework in which the suppliers will interact with each other. We will focus us more on the procurement of IT-related items.

In the case of competition only, the DoD will enforce its own standards or the market standards. The best possible proposal will be chosen.

[7] The research extends also to drama theory and the theory of Bryant (2003).

Competition followed by collaboration is the particular situation in which the DoD will let different suppliers compete based on the competences (capability), and it creates a short-list for each capability. Afterwards, the DoD creates an environment in which the chosen suppliers are encouraged to chose one or more partners to collaborate so that the main capability can be formed.

This is a more active steering of the formation of collaborative suppliers than the next situation: collaborate and competition. If a project is too big for a single company (supplier) then the interested suppliers will look for themselves to find the best partner to collaborate with. So the market itself will be clustering the different players into ad hoc entities. Once these entities are formed the competition can start.

Collaborate: In the situation in which there are no clear standards for a specific system, this collaboration of interested suppliers will produce and propose standards. Here the DoD can also play an active role to determine the to-be-developed standard(s).

### *Monopolist of Demand*

As a matter of fact, in the "market of (legal) violence" the DoD has the monopoly of demand. The very specific attributes of the defense market of some weapon systems make so that the DoD is confronted on the supply side with a oligopoly (of big players). The subject of oligopoly or duopoly with option games is well documented in the literature. We propose that the DoD use game theory to follow up the "ethical" and "economical" collaborations and competitions (no cartel for instance).

However, because of the globalization of the market, it is possible that in some parts of the market (of "violence") the DoD will lose its monopoly due to the fact that the technology demand has been taken over by commercial companies or other government agents.

## Conclusions

Although for strategic reasons an organization should create intelligence to determine the best way to allocate resources to attain its goals, reality shows that besides the complexity, real options are not easily implemented because of the ongoing effort to collect information to maintain the real option valuation.

Therefore, we are proposing two processes, one to obtain intelligence (intelligence base) and one to decide the investments and to maintain the steering plans and service level agreements (interdisciplinary forum). The organization can instantiate from these generic processes their own systems in function of its culture and capabilities.

Since the intelligence base delivers relevant information for determining the strategies (game theory) and for the interdisciplinary forum (real options, other investment techniques), the combination of both, namely game options, can also be supported. However, to exploit effectively game options, some further research has to be done, especially in the domain of collaboration.

In our discussion we also came to the conclusion that it is the situation in which the strategic games are played that determines if real options (game options) are used or not. Some urgent problems in the business environment of the organization may oblige the organization to choose other investment techniques than real options. The organization has the right but not the obligation to use real options (in certain circumstances).

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